Scientific Paper

Effect of covers on some soil properties. La Morrocoya farm, Barinas, Venezuela

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Abstract

The study was conducted on an Inceptisol soil of the livestock production farm "La Morrocoya", Sosa municipality, Barinas state, in order to evaluate the effect of covers on some soil properties, as basis to establish sustainable production strategies. Four areas were selected: area 1. Cutting pasture: king grass (*Cenchrus purpureus* L.), three years after establishment in a total area of 2 ha; area 2. Introduced pasture: star grass *Cynodon plectostachyus* L.) 6 years after being established in a 4-ha area; area 3. Introduced forest: mahogany *Swietenia mahagani* L.) with 15 years of establishment and 1,8 ha; area 4. Natural forest, with a total area of 3 ha. Nine samples were taken from each study area at different depths. The analyses performed were texture, organic matter, apparent density, pH, assimilable calcium, potassium and phosphorus. Correlation matrix and principal component analysis were applied. The use of different covers proved that the Introduced pasture and its adequate management improved and stabilized the studied physical and chemical properties after 6 years of establishment, compared with the other covers. Close relationships were determined between organic matter and apparent density and clay + silt, with values of r > 0,80. These soil properties were the ones with better response to the effect of the different covers.

Keywords: nutrient availability, soil management, soil physical-chemical properties

Introduction

The ecological problems of the current world, the depletion of natural resources and the need to preserve soil fertility, in order to feed an increasingly higher population, have originated the need to establish sustainable or organic alternatives to increase yields (Ikemefuna, 2015; Chen and Tang, 2016). The degradation of soils and water resources are the main factors that threaten the sustainability of the agricultural utilization of lands in Latin America and the rest of the world; this leads to serious difficulties to produce the food requirements for its growing population (Abate and Lemenih, 2014; Tesfaye *et al*., 2014; Binyam, 2015). In the Barinas region there are very few results about the diagnosis and monitoring of livestock production soil properties in order to utilize them sustainably. The western plains of Venezuela potentially constitute one of the most important agricultural and livestock production regions of the country and represent more than 25 % of the value of agricultural production (López *et al*., 2015). This is about finding sustainable alternatives of soil management that guarantee stable productions in the development of livestock rearing and agriculture. A change in the soil cover of an area can negatively affect the potential characteristics of the zone, and ultimately, lead to degradation and productivity loss (Lozano *et al*., 2010; Tesfaye *et al*., 2014). Soil degradation is the product of the complex interaction of many chemical, physical and biological variables that reduce its potential capacity to produce (Ikemefuna, 2015). The objective of this work was to evaluate the effect of covers on some soil properties of La Morrocoya farm which serve as basis to establish sustainable production strategies.

Materials and Methods

Description of the study area. The study was conducted on an Inceptisol soil of the livestock production farm "La Morrocoya", located in the La Salera sector, Sosa municipality, Barinas state (120 masl). The temperature varies from 22,6 to 30,5 ºC; it shows a marked seasonal distribution, with well-defined rainfall and drought periods and an annual average rainfall of 1 390 mm (data supplied by INIA-Mantecal, average of 25 years).

Design and treatments. A randomized block design was used with 4 treatments and three replications. For developing the research four areas were selected considering the crop type and use, which constituted the treatments described below:

Area 1. Cutting pasture: king grass (*Cenchrus purpureus* L.) with three years after being established in a total area of 2 ha. The planting distance was 1 m x 1 m (10 000 plants ha^{-1}). It was manually planted by cuttings in the rainy season. The first cut was made since seven months after planting and then the intervals were every 45 days, until cut number 15.

Area 2. Introduced pasture: star grass [*Cynodon plectostachyus* (K. Schum.) Pilg.] with six years of establishment in a 4-ha area. It was manually planted by drilling in the rainy season. Paddock rotation was free and the stocking rate was 1,5 ha^{-1}.

Area 3. Introduced forest: mahogany [*Swietenia mahagoni* (L.) Jacq.] 15 years after being established and at a planting distance of 3 m x 3 m (1 111 plants.ha^{-1}). The total area was 1,8 ha. The trees were transplanted after remaining in nursery for 6 months. This area had the presence of cattle and sheep in its first growth stage.

Area 4. Natural forest: represented by the presence of *Spondias mombin* L., *Inga* sp. L., *Citronella mucronata* (Ruiz and Pavón) D.Don, *Cochlospermum vitifolium* (Willd.) Spreng., *Pithecellobium saman* L., *Guazuma ulmifolia* Lam. in a total area of 3 ha. This area was considered in the trial as the control treatment.

Sampling methodology for the physical and chemical analysis of the soil. The sampling was performed in October, 2013, in the rainy season. In each study area a sample of each depth was taken (0-10; 10-20; 20-40), for a total of 9 samples per area and 36 samples in the experiment. For sampling the methodology proposed by Cairo and Reyes (2016) was used. The physical variables studied were: texture and apparent density. The chemical variables were: assimilable phosphorus, potassium and calcium, pH and organic matter. In this study not only the changes in absolute values of the variables due to the effect of the covers with regards to a referent pattern (natural forest) are evaluated, but also their impact on the category change (low, moderate, high), due to its practical implication.

Description of the analysis methods. The physical and chemical analyses performed were the following: texture (%) by the Bouyucos hydrometer method (Cairo and Reyes, 2016); apparent density (g cm^{-3}) through the cylinder method (Cairo and Reyes, 2016); assimilable phosphorus and potassium (mg kg^{-1}) by the modified Olsen's method (1954); extraction with NaHCO 0,5M, pH 8,5; calcium (mg kg^{-1}) by the modified Morgan's method (1999), extraction with CH_3COONa 0,125M; pH 4.2. pH in water: by the potentiometric method, soil: water ratio 1:2,5; organic matter (%): through the combustion method (Walkley and Black, 1934).

Statistical analysis. The package of the professional program Statgraphics plus version 4.1 on Windows was used for the correlation matrix and the principal component analysis.

Results and Discussion

Effect of the covers on organic matter and apparent density in the different depths

The effect of the covers on organic matter in the different depths when compared with the natural forest, as well as their evaluation category, is shown in figs. 1, 2 and 3. The natural forest tended to accumulate higher OM content in the deepest layers, because of its root system and the transport of surface residues. King grass incorporated OM in the first 20 cm in the category of moderate values, although the biomass was cut for animal feeding. At the depth of 20-40 cm the OM went to the low value category, unlike the values close to high in the natural forest. Studies conducted by Emiru and Gebrekidan (2013), Tesfaye *et al.* (2014), Chen and Tang (2016) showed the importance of cover management for soil protection, where reference is made to the forms of carbon, nitrogen and assimilable nutrient gain.

The introduced pasture and the stocking rate during the six years of management, contributed to the increase of OM with high values (4 % average) in the 0-20 cm depth (fig. 2), unlike a sudden fall from 20 cm, also because grasses concentrate their root system in the soil surface layer (Cairo and Fundora, 2005). This management system achieved a positive response in organic matter and its repercussion on other properties such as apparent density (figs. 4, 5 and 6). Not only the impact of the grass is present, but also that of the animal with the incorporation of solid manure and urine during grazing. These results coincide with the ones obtained by Vargas (2008) who conducted studies in this soil type and with the same pasture.

Organic carbon has been identified as an important soil fertility factor; it has also been proven to be closely related to productivity, soil

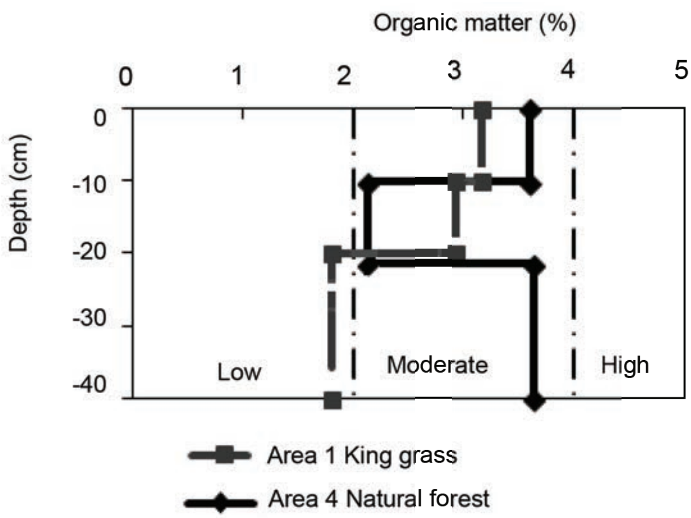

Figure 1. OM distribution. Comparison of area 4 with area 1

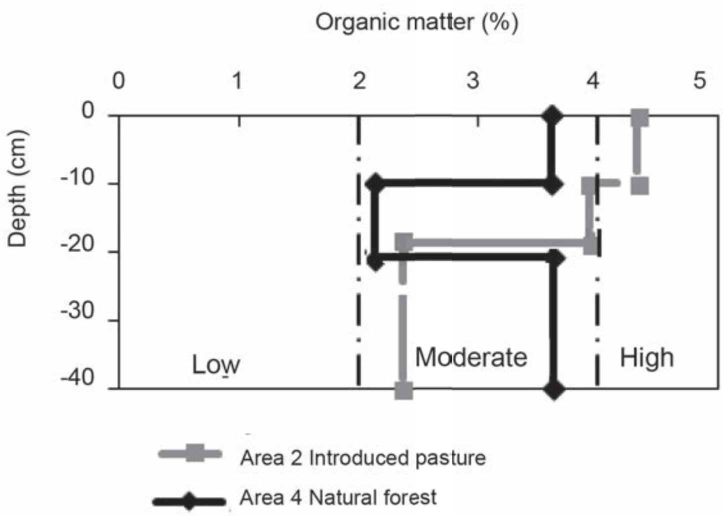

Figure 2. OM distribution. Comparison of area 4 with area 2.

water holding capacity, and long-term yield stability (Liang *et al*., 2012; Pikuła and Rutkowska, 2014; Binyam, 2015). Thus it can be considered as a soil quality indicator. The Introduced forest functioned as a silvopastoral system in the first stage of its development, which proves that it contributed not only the litter biomass, but also the incorporation of cattle and goat manure with organic matter values close to 4 % in the 0-10 cm depth (fig. 3).

The results of the different covers on apparent density were more evident in the 0-10 cm depth (figs. 4, 5 and 6). The effect of king grass was determined, mainly, by the quantity of biomass accumulated on the soil after being cut for animal feeding. For such reason, apparent density was higher in the natural forest at the 0-10 cm depth.

The introduced pasture as well as the introduced forest showed lower apparent density values compared with the natural forest in the 0-20 cm depth, in correspondence with the increases of organic matter. Binyam (2015) obtained positive results in the recovery of degraded soils by using different cover techniques. It should be stated that in the introduced pasture the apparent density value

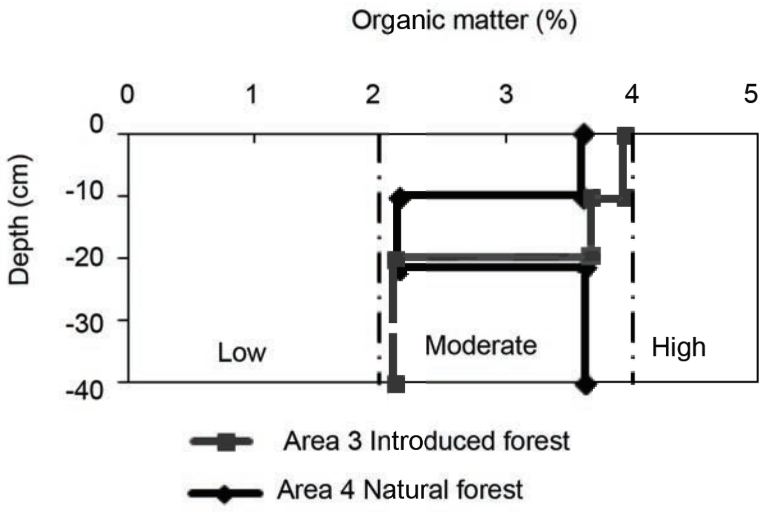

Figure 3. OM distribution. Comparison of area 4 with area 3.

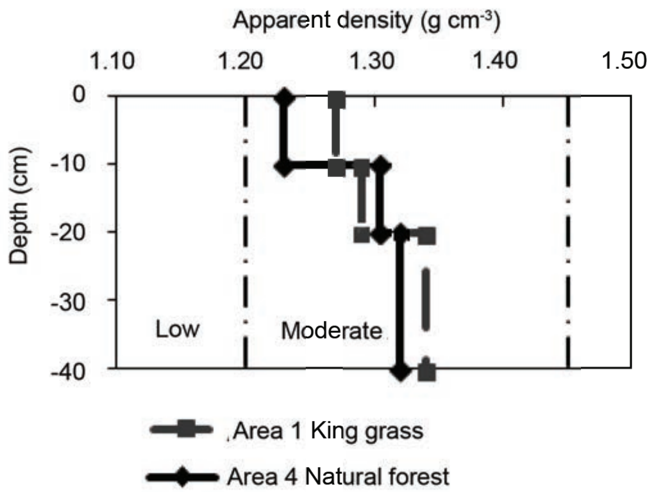

Figure 4. Distribution of apparent density. Comparison of area 4 with area 1.

went from the category moderate to low (1,19 g cm^{-3}) in correspondence with the inverse performance of OM. This could have caused the development of a more favorable structure in the soil (Cairo and Fundora, 2005). According to Vargas (2008) star grass is a species that can adapt well to different edaphoclimatic conditions and to grazing rotation techniques.

Relationships among some soil physical and chemical properties

In this study a strong interrelation was shown between organic matter and apparent density (fig. 7). The correlation showed highly significant values of r = 0,8024 **. When OM increased its values to the high category (higher than 4 %), apparent density did inversely (from moderate to low). Thus more favorable conditions are created, from the soil physical, chemical and biological point of view. In this sense, Ikemefuna (2015) alerted about the need to maintain an integrated plant cover system that guarantees an adequate organic matter content.

This result showed how decisive it is to monitor these two indicators, in order to guarantee adequate

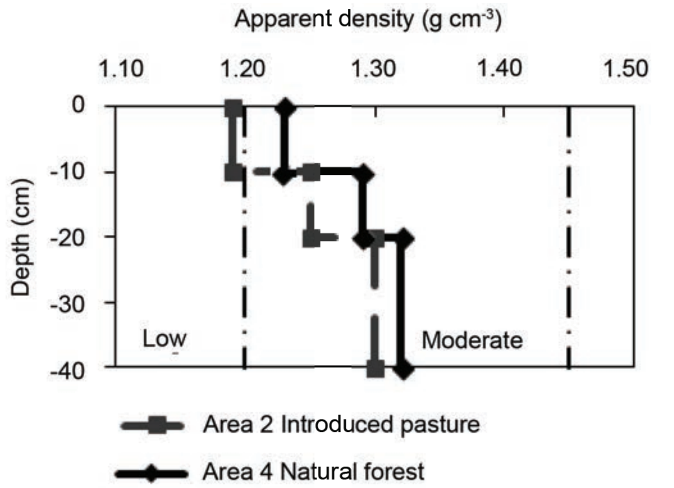

Figure 5. Distribution of apparent density. Comparison of area 4 with area 2.

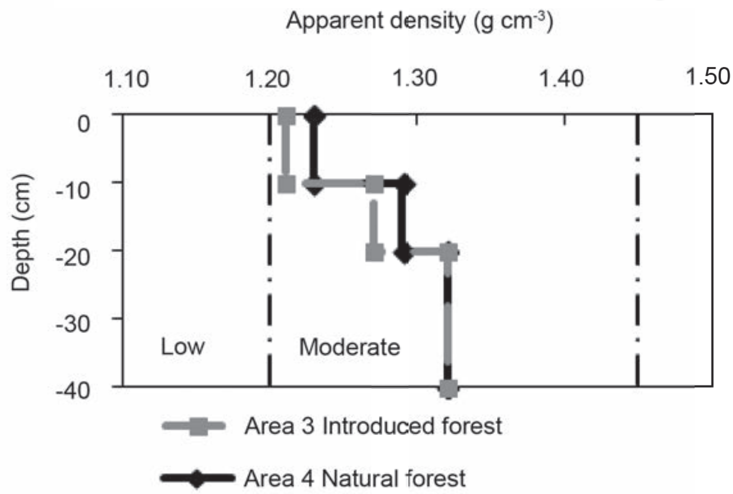

Figure 6. Distribution of apparent density. Comparison of area 4 with area 3.

biomass production and balance in the soil quality (Lopes *et al*., 2016).

Chen and Tang (2016) found significant and highly significant relations between the OM content and the biomass of different covers. On the other hand a close relation of OM with clay + silt was shown, which enhances even more the role of organic matter in soil conservation and fine matters are prevented from being lost by lixiviation and erosion. In this study as organic matter increased there was an increase of clay + silt (fig. 8).

Principal components of the soil properties under different covers

Principal components, from the statistical point of view, are a highly valuable tool to be able to select those properties (physical or chemical) which are indicators of sustainability and soil quality (Ghaemi *et al*., 2014).

The total variance explained (table 1) showed that the properties that were placed in component 1 reached 47,638 % of variance, while those that were placed in the second and third component only reached 26,152 and 17,529 %, respectively, for a total cumulative of 91,309 %.

The soil properties that best responded to the matrix were organic matter, apparent density and granulometry components, in this case clay + silt, which were found in the first component. The role played by organic matter as indicator of soil qual-

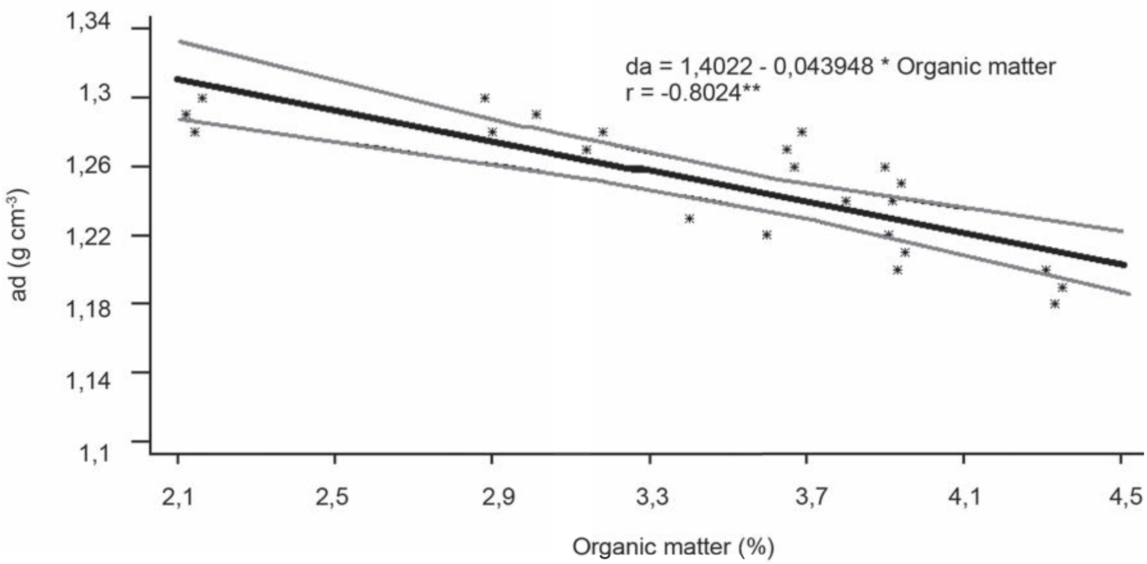

Figure 7. Relation between organic matter and apparent density

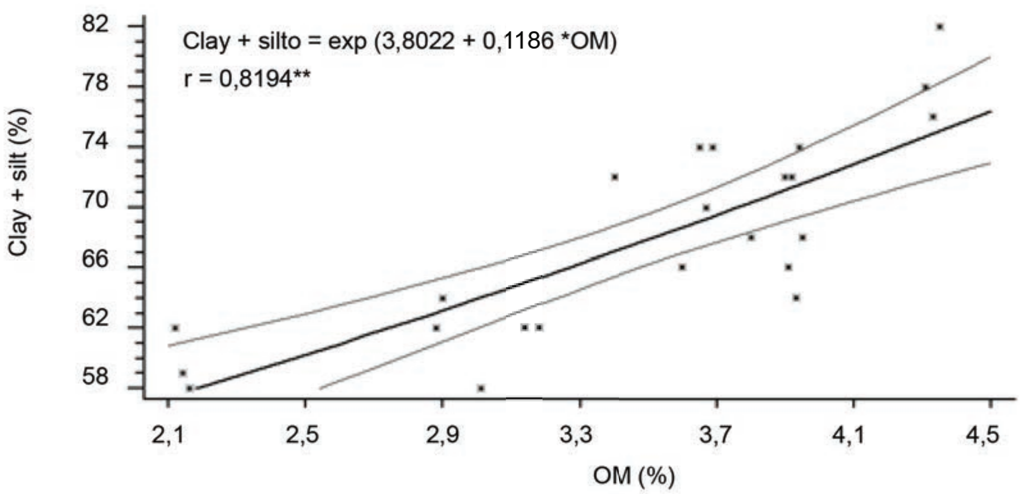

Figure 8. Relation between organic matter and clay + silt.

ity associated to other properties was confirmed (Lópes *et al*., 2016).

According to the results it is concluded that the use of different covers in the farm proved that the introduced pasture and its adequate management improved and stabilized the studied physical and chemical properties, after six years of becoming established, compared with the other covers. A close relation was found of organic matter with apparent density and clay + silt. These soil properties were the ones that best responded to the effect of the different covers.

Bibliographic References

Abate, A. & Lemenih, M. Detecting and quantifying land use/land cover dynamics in Nadda Asendabo Watershed, South Western Ethiopia. *Int. J. Environ. Sci*. 3 (1):45-50, 2014.

Binyam, A. The effect of land use. land cover change on land degradation in the highlands of Ethiopia. *J. Environ. Earth Sci*. 5 (1):1-12. http://www.iiste.org/Journals/index.php/JEES/ article/view/18912/19505, 2015.

Cairo, P. & Fundora, O. *Edafología*. La Habana: Editorial Pueblo y Educación, 2005.

Table 1. Matrix of principal components and total variance

Matrix of components				
Properties		Components		
		1	2	3
ad (g.cm^{-3})		-0,880		
OM (%)		0,879		
Clay + silt		0,866		
Sand (%)		-0,866		
pH (water)		0,754		
Ca (mg kg^{-1})			0,832	
K (mg kg^{-1})			0,754	
P (mg kg^{-1})			0,703	
Silt (%)			-0,652	
Silt/clay				0,841
Clay (%)				-0,740
Additions of the square saturations of the extraction	Total	5,240	2,876	1,928
	% of variance	47,638	26,142	17,529
	Accumulated **%**	47,638	73,780	91,309

Cairo, P. & Reyes, A. *Edafología práctica*. Chile: Universidad de Atacama. (en prensa), 2016.

Chen, J. & Tang, H. Effect of grazing exclusion on vegetation characteristics and soil organic carbon of *Leymus chinensis* grassland in northern China. *Sustainability*. 8 (1). http://www.mdpi.com/2071-1050/8/1/56, 2016.

Emiru, N. & Gebrekidan, H. Effect of land use changes and soil depth on organic matter, total nitrogen and available phosphorus contents of soils in Senbat watershed, Western Ethiopia. *ARPN J. Agric. Biol. Sci*. 8 (3):206-212, 2013.

Ghaemi, M.; Astaraei, A. R.; Emami, H.; Nassiri-Mahallati, M. & Sanaeinejad, S. Determining soil indicators for soil sustainability assessment using principal component analysis of Astan Quds- east of Mashhad- Iran. *J. Soil Sci. Plant Nut*. 14 (4):987-1004, 2014.

Ikemefuna, P. Evaluation of agro-ecological approach to soil quality assessment for sustainable land use and management systems. *Sci. Res. Essays*. 10 (15):501-512, 2015.

Lopes, Ercilia; Cairo, P.; Colás, A. & Rodríguez, A. Relaciones entre las propiedades indicadoras de calidad, en dos subtipos de suelo pardos, en la provincia de Villa Clara. *Centro Agrícola*. 43 (1):21-28, 2016.

López, R.; Hétier, J. M.; López, D.; Schargel, R. & Zinck, A., Eds. *Tierras llaneras de Venezuela: tierras de buena esperanza*. Mérida, Venezuela: Consejo de Publicaciones de la Universidad de Los Andes, 2015.

Lozano, Zenaida; Romero, H. & Bravo, C. Influencia de los cultivos de cobertura y el pastoreo sobre las propiedades físicas de un suelo de sabana. *Agrociencia*. 44 (2):135-146, 2010.

Pikuła, D. & Rutkowska, A. Effect of leguminous crop and fertilization on soil organic carbon in 30-years field experiment. *Plant Soil Environ*. 60:507-511, 2014.

Tesfaye, S.; Guyassa, E.; Raj, A. J.; Birhane, E. & Taye, G. Land use and land cover change, and woody vegetation diversity in human driven landscape of Gilgel Tekeze catchment, Northern Ethiopia. *Int. J. Forest. Res.* http://dx.doi.org/10.1155/2014/614249, 2014.

Vargas, S. *Rediseño, manejo y evaluación de un agroecosistema de pastizal con enfoque integrado para la producción de leche bovina*. Tesis en opción al grado científico de Doctor en Ciencias Veterinarias. San José de las Lajas, Cuba: Instituto de Ciencia Animal, 2008.

Walkley, A. & Black, I. A. An examination of Degtjareff method for determining soil organic matter and a proposed modification of the chromic acid titration method. *Soil Sci*. 37:29-38, 1934.

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