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METHODOLOGY TO PROMOTE SUSTAINABLE USE OF SOIL RESOURCES IN THE TATACOA DESERT ECOREGION

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ABSTRACT

This paper presents three methodologies to perform an applied research that permits enlarging the cultivable areas of the arid zones, improving productivity and biological diversity La Tatacoa Desert ecoregion. For this purpose, it is needed to select the type of crop to be implemented so it can be applied in the pilot methodologies for comparative analysis of the efficiency in each one of them based upon productivity output and maintenance of soil's health. Once the plots of land have been chosen, the following step consists of measuring physicochemical and biological properties of the soils under study. This is achieved before the research starts and three months after its beginning. Then, a statistical analysis of the information is carried out using ANOVA and Tukey test with a significance level of 5%. With this proposal, nutrients degradation behavior found in these zones can be investigated. This helps to decision making for the best option to optimize the soil resources in the Tatacoa Desert.

Keywords: arid zones, tropical dry forest, soil improvers, bioremediation, soil recovery.

1. INTRODUCTION

A tropical dry forest (bs-T) is defined as a vegetal formation with continuous wooded cover, having bio-temperatures higher than 24ºC and rainfall oscillating between 1000 and 2000 mm per year Holdridge (1967). They also have one or two remarkable dry periods during the year, Instituto Alexander von Humboldt IAVH, (1998). According to Espinal & Montenegro (1977), enclaves with own vegetation as bs-T are found in San Andrés y Providencia island, in the north region of the peninsula of Guajira, Santa Marta (Magdalena), in Gamarra (Cesar state), Chicamocha river cannon (Santander), Convención and Ocaña, sorroundings of Cúcuta (Norte de Santander state), Dagua cannon (Valle del Cauca state), Villavieja (Huila state) and Patía valley river (Cauca).

The Tatacoa desert is located 291 km from Bogotá and 38 km from Neiva (Huila state), which is the capital of Huila state in Colombia, South America. This territory is also located in the warm thermal floor with a discontinuous altitude between 386 m and 486 m, an average temperature of 28.6 °C with oscillations that can reach 40 °C, humid, sub-humid and semiarid levels, a predominant vegetation like those in both dry tropical forest and very dry tropical ecosystems (Rodríguez, 2016) and associated to dry sterile soil.

Researches undertaken by Llanos (2001) consider Cactaceae as the more typical species of the ecoregion, in the obtain results are found (80) species or more of plants presenting common adaptations of the environmental conditions. The given description indicates that the major part of the plants exhibit reduced bearing, scarce ramification, either reduced size leaves or converted into spines and some other present rolling caused by dry environment and photosynthetic activities in their stems. By the same token, he affirms the roots of these plants are fibrous and superficial type, deep pivoting or extensively enlarged and some plants are characterized by latex presence.

Given the poor conditions of the Colombian dry tropical forest is important to consider that regenerating zones can be a relevant and unique opportunity of preserving a representative sample of this ecosystem. Moreover, restoration programs must be considered to seek for continuity of the existing remaining with other habitats (IAVH, 1998).

Fensholt *et al.* (2012) pointed out that biological production is imprescidible for the survival means in the major part of semiarid zones, a better understanding of their performance focused on monitoring, modeling and projecting the vegetation changes and productivity. Provide the fundamental knowledge for the preparation of the adaptation means or needed regreening.

The absence of assessment of soil resources can lead to over exploitation or misuse of the soils; therefore, reducing the flow benefits needed to maintain the social welfare. Among the most used methods to assess desertification can be named: zone monitoring, economical assessment due to changes in soil productivity, sample study based upon land criteria, judgement surveys on soil use, report from experts, remote sensing and modeling and simulation (Ortiz, 2013).

Rubio & Brochet (1998) cited by por Flores et al. (2010), have provided a series of indexes for the mentioned assessment, taking both natural and socio-economical particular aspects. These researchers consider desertification as a complex process requiring adequate indicators representing the higher interrelation number of the components under different climate, soil and soil use scenarios.

The predominant soils in the Tatacoa desert are superficial, eroded, rocky outcrops, and having plenty of channels (Olaya & Sánchez, 2001). Hori, Stuhlberger & Simonett (2015) affirm desertification is not land loss by its transformation into desert by sand dunes' movement but the soil degradation into arid, semiarid and sub-humid zones due to several factors including climate changes and human activities. When land degradation occurs in dry

lands in the world, similar desert conditions can be often created. Therefore, soil degradation takes place in any place, but it is defined as desertification when occurring in dry terrains.

Plan cover increasing is not only due to climate conditions but also rainfall increase and soil management (Olsson, Eklundh, & Ardö, 2005). According to Martínez, Fuentes & Acevedo (2008) organic carbon found in soils are related to the sustainability of agriculture systems affecting soil properties related themselves to sustainable output of the crop. Likewise, it is associated to amount and availability of soil nutrients since they provide such elements as Nitrogen which is normally deficient. In arid environment soils, the decomposition process of organic matter are very slow since weather conditions do not promote microbial activity (Bucher, Torres & Abril, 2003; Torres, Abril & Bucher, 2005).

Different researches in this strategic Colombian ecosystem have been carried out. Vargas (2001) studied the Geology of the Tatacoa desert and Malagón (2003) studied the typologies of those soils region by region in Colombia; Calvachi (2012); Mendoza (1999); Rangel & Franco (1985) and Llanos (2001) have prepared vegetable species inventory of the Tatacoa desert, and also, have performed several phytoecological observations in several life regions in the central mountain chain.

Ortiz & Polanía (2013) described the advance of the desertification process in this ecoregion, and Delgado, Hernández & Castaño (2012) led a computational study of radiation in the desert's atmosphere. By the same token, Guerrero, Sarmiento & Navarrete (2000) analyzed the cretaceous series of the Magdalena river; Setoguchi, Shigehara, Rosenberger & Cadena (1985) found primate fossils dating the middle miocene; Villaroel, Brieva& Cadena (2012) found mammal fossils from the late Pleistocene and Sánchez (2001) found fossils of invertebrate, fish, reptiles and birds.

Olaya& Sánchez (2001) have documented the interaction of the Tatacoa desert with hydric resources in the high Magdalena river valley, and as far as fauna is concerned, Losada& Molina (2011) prepare an inventory of the bird species existing in the life zone of the tropical dry forest; Acosta-Galvis (2012) found amphibious in the dry enclaves of the Tatacoa desert and its influential area in the high Magdalena river valley and Sánchez &Olaya (2001) mentioned zoological groups being predominant in the larger extension environments and the ecological roll of them, of course, in the Tatacoa desert.

Although several knowledge areas in the Tatacoa desert have been researched, it is needed to establish strategies on the use of natural resources for the significant contribution to guide the social and economic development of soil use to have more agreement with its potential use. Based on this, this work collects some researches that have led to solve vegetable production problems in arid and semiarid zones, by proposing applied research that can be used in the Tatacoa desert so soil resource management can be optimized.

2. METHODOLOGY PROPOSAL

2.1. Soil Restoration mechanisms and increase of vegetal cover in arid and semiarid zones

In some countries, the integral analysis of biology, ecology and physiology of native species have permitted promoting rational utilization of resources and proposed not only crops as productive alternative systems for the dry tropic but also a contribution to sustainable development of arid and semiarid zones (Díaz, 2001).

There are researches suggesting including commercial attention crops like Aloe Vera and Pineapple, keeping the bushy stratum with native plants. Gutiérrez (1999) and García (1999) conducted experiments adopting a model to permit the interaction of simultaneous crops in agroforest systems, with the assessment of growing and Eco physiological behavior of succulent species like *A. vera* y *A. cocui* associated to *Sorghum bicolour* and with *P. juliflora*, establishing that mesquite-aloe vera-sorghum systems, the productivity, especially Aloe vera, was very favourable and contributed also to increase the protein content in sorghum plants. This confirms the possibility of starting commercial crops to increase the income of the region productivity units. To achieve this goal, it is necessary to take into account any management recommendation, either for agriculture production, industrial exploitation or touristic purposes. Also, having a Deep knowledge of the system, its performance, its interaction and load capacity is important. This attempts avoiding serious risks resulting from the application of inadequate solutions on arid and semiarid lands.

One of the more implemented solutions in soils suffering organic matter losses, absence of fertility reduction or evident pollution is the application organic fertilizers. Its use is flashy for growers since it has low production and application cost and also allows the utilization of solid residue generated as part of the input for elaborating the fertilizers. This takes place in countries where the majority of food production is obtained by traditional agriculture with absence of technology (Roe, 1998).

Composting forms part of one of the more studied techniques for fertilizer production. Studies have demonstrated that it improves a great amount of soil characteristics such as fertility, water storage capacity, nitrogen mineralization, phosphorous and potassium, keep pH levels for agriculture, avoids extreme temperature changes, promotes microbial activity and controls erosion. Todos estos efectos benéficos permiten mejorar los suelos, incluyendo los de zonas áridas y semiáridas, que en general presentan pobreza de fertilidad, materia orgánica, nutrimentos, capacidad de retención de agua y pH alto.– FAO (1991; Trueba (1996); Ruíz (1996), citedby Nieto*et al*.(2002)-.

Combining between compost use to achieve an improvement of soils' characteristics in arid zone and commercial interest crop inclusion, keeping the native vegetal cover will result in an interesting proposal from the social-economic point of view which will impact positively both people and strategic ecosystem. However,

to be able to resolve the nitrogen needs in these arid zones, there will be a need of high amount of fertilizers which leads to increase production costs.A proposed strategy to solve this issue consists of establishing legumes for biological setting, FAO (1993), but it is limited by low irrigation water availability and the commercial interest cropping dates, López-Aguilar (2012).

Among the nitrogen compounds commonly used in organic agriculture are found: fish flour, blood flour, semiliquid manure or purines, and in spite these fertilizers are rich in nitrogen, Hartz y Johnstone (2006) and allow high output in soils of arid and semiarid zones also contain high sodium concentration, Abdurrahman *et al.*(2004) destroying soil structure and generating compaction and reducing infiltration rate of irrigation water, Halliwell*et al.*(2001; Misra y Sivongxay (2009). Zúñiga-Escobar *et al.*(2011) found gypsum ($CaSO_4$ $2H_2O$) prevents and corrects problems of sodium presence in the soils and also contributes to an efficient nutrition since its application brings higher exploitation of other essential nutrients, for instance, nitrogen and phosphorous are absorbed more efficiently where the soil has enough amount of sulphur and calcium.

Based upon the above issue, we propose to develop methodologies to generate cultivable terrains in arid and semiarid zones of the Tatacoa desert, under principles of sustainable agriculture.

2.2. Proposal for the soil resource development in the Tatacoa desert ecoregion

We present three pilot methodologies to perform an applied research to allow enlarging cultivable areas of arid zones, improving both productivity and biological diversity in this ecoregion. We must choose the crop type to implement, for instance Aloe Vera, pineapple, cantaloupe or watermelon and use the same crop in all pilot methodologies, to establish a comparative analysis on each one efficiency, in terms of production output, maintaining soil health and product with higher nutritional that are considered principle of sustainable agriculture.

2.2.1. General considerations

The area of the experimental plot is 30 m^2, with four (4) repetitions. It has a design of random blocks. Separation between furrows is 0.8 m and between seedlings is 0,4 m. The irrigation sheet for the required treatments is calculated from a hydric balance of the ecoregion and the requirements of the studied cultivation. López-Aguilar *et al.* (2012) advise using a dripping irrigation. Each treatment will have measurements of pH (according Norma Técnica Colombiana NTC 5264), organic carbon (%CO), (modified NTC 5403), cationic Exchange capacity (CIC), (modified NTC 5268), electrical conductivity (CE), interchangeable sodium percentage (PSI),(humidity (%) and temperature (T) (Instituto Agustín Codazzi IGAC, 2006) and organoleptic texture, Torrente (2014), carbon dioxide (CO_2) emission, Castro, Cerquera and Escobar (2015) to compare the behavior of these properties during the process. These measurements are performed to the soil before starting the study and three months after its initiation, with foliate sampling for the last case, collecting samples according the procedure given by IGAC (2016). The statistical analysis of the information is conducted with ANOVA and Tukey test with a significance level of 5%.

2.2.2. Compost application for improving structure and organic matter content of soils

It is planned for this methodology to work an experimental design with 2X4 factorial structure, where the factors are irrigation with two levels (absence and presence) and the compost application doses with four levels (0, 2, 4, 8 $t*ha^{-1}$) for a total of eight treatments.

2.2.3. Combination effect of Mycorrhiza with inoculation of native funguses (AM) and compost doses in arid and semiarid zones

It is planned for this methodology to work an experimental design with 2X2X4 factorial structure, which factors are AM utilization in water extract at 5% v/v (without in oculation, within oculation), irrigation with two levels (absence and presence) and the compost application doses with four levels (0, 2, 4, 8 $t*ha^{-1}$)

2.2.4. Gypsum utilization ($CaSO_4$ $2H_2O$) as improver of absorption of Nutrients in Soils

Likewise, It is planned to work an experimental design with 2X4 factorial structure, where the factors are irrigation with two levels (absence and presence) and gypsum application doses with four levels (0, 2, 4, 8 $t*ha^{-1}$) for a total of eight treatments.

Once the comparative analysis is performed for the effects of these methodologies in the soils of arid and semiarid zones, decisions regarding the recommendation of use and implementation of crops can be performed.

3. CONCLUSIONS

a) Three methodologies for the determination of the effect of adding fertilizers and irrigation to the soils under study. It is expected to generate solutions to vegetal production problems in arid and semiarid zones.
b) The proposal allows researching on the degradation behavior found in these zones and helping the decision making about the best option to optimize soil resource management in the Tatacoa desert.

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