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ENVIRONMENTAL SUSTAINABILITY STRATEGIES FOR COUNTERACTING EROSION EFFECTS AND SOIL DEGRADATION IN THE TATACOA DESSERT

Jennifer Katiusca Castro, Nestor Enrique Cerquera and Freddy Humberto Escobar
Universidad Surcolombiana, Avenida Pastrana, Neiva, Huila, Colombia
E-Mail: jenniferkatiusca.castro@usco.edu.co

ABSTRACT

Three procedures aimed at establishing environmental sustainability strategies to counter the effects of erosion and soil degradation which contribute to improve productivity and biodiversity in the ecoregion of the Desert Tatacoa located in Neiva, Huila State, Colombia (South America). Phytogeographicalindex affinity of the Tatacoa Desert with other areas of tropical dry forest (bs-T) of Colombia were determined; the results allowed establishing the most suitable species living in this area for regreening work, promoting the conservation of native species of tropical dry forest in the Tatacoa Desert and knowing an existing phytogeographic affinity between other parts of the country to improve plant cover of all affected areas. Likewise, a model to estimate the gross value of agricultural production was built and found that the advance of the desertification process of this ecoregion has a significant reducing effect on soils' production. Finally, a comparative analysis of respiratory activity and the mineralization rate of soil organic matter from different localities of the tropical dry forest (bs-T)of Huila state, which showed a different behavior for each treatment reflected as significant respiration changes and a mineralization rate whichprove that the potential degradation of soil microorganisms, for middle- and low organic matter content is low. This document attempts to benefit the community that lives in the study area and the academic community that provides advisory and assistance to the population of the mentioned area.

Keywords: phytogeographic affinity, tropical dry forest, economic valuation, respirometry, mineralization rate.

INTRODUCTION

Desertification and soil damage threaten to finish the strategic ecosystems and endangered economic activities of the eco-region people which leads to reduce their life quality.

According to Ortiz (2013), desertification is the degradation of arid soils, semi-arid and dry sub-humid zones caused mainly by climatic variations and such human activities as crop and excessive grazing, deforestation and scarcity of water. According to UN through the program for the environment (PNUMA) (1994), desertification threatens one fourth of the planet's life, affects directly more than 250 million people and endangers the living resources of people from more than 100 countries since soil productivity for agriculture and cattle rising is reduced.

In Huila State (Colombia) this type of inconvenient is presented in arid and semi-arid zones belonging to the Tatacoa desert eco-region in the mayorship of Villavieja. It is located in the north part of the Huila state and according to Espinal (1990), is has two zones with bio-temperature in °C and rain precipitation en mm corresponding to: very dry tropical woodland (bms-T) with +- 24°C, rain 500-1000 mm; dry tropical woodland (bs-T) +- 24°C, rain 1000-2000 mm.

Olaya, Sanchez and Acebedo (2001) affirm that in the Tatacoa desert predominate surface soils, eroded with rock outcrops and many natural drainage channels and dry-sterile edaphic association with shorter availability of water periods and longer humidity deficit periods. Soils of these zones present sedimentary accumulation materials very sensitive to erosion. Cattle, sheep and goats belonging to the zone are fed with native grass and bushes which leads to create erosion process and to impede the vegetable cover development. Furthermore, certain amount of water rain falls as intensive heavy rain, then, water precipitation and surface rain-off are very erosive. These two factors plus the anthropic effect have generated the formation of furrows and the activation of collapse and caving in the terrains with low vegetation. Besides, it is important to perform researches highly contributing to direct efforts towards improving economic and social by adequate soil and water use according to the desert potential.

This study has a result a model for the economic value of the desertification effects and soil degradation in the Tatacoa desert.

1. INTRODUCTION

The Tatacoa is a region belonging Villavieja (Huila state) municipality. It is located at the north of Huila state, in the Magdalena River Valley. It presents dry and erosive conditions where the native plants are adapted by morphologic and physiologic characteristics.

According the bioclimatic system proposed by Holdridge (1967), the Tatacoa belongs to tropical dry forest and very dry tropical forest (Espinal, 1990; Olaya, 1995). These types of forest is found in Colombia especially in the inter andean valleys of Magdalena, Patía and Chicamocha Rivers (Llanos, 2001).

Forero (2005) affirms that only 3% or less of original natural forest exists in such zones asTatacoa.This is because the cover plant was remived in the region for implementing extensive cattle activities which, in few years, caused degradation problems and lost of soil natural capability to infiltrate and conserve humidity. Currently,

the Tatacoa presents extensive erosion processes, increase of salt levels, desertification and scarcity of live in the soil. The deteriorating factors of soil resources reduce the biologic diversity and, therefore, prevent to reach the sustainable development goals, (Cortés, 2002).

Several researches on strategic ecosystems have been carried out in Colombia. To name some of them: Vargas (2001) studied the geological aspects of the Tatacoa Desert and Malagón (2003), studied the soils' typologies by región in Colombia; Calvachi (2012); Mendoza (1999); Rangel & Franco (1985) and Llanos (2001), have performed inventories of vegetable species of the Tatacoa Desert and phytoecological observations in several life regions in the Colombian Central mountain chain.

Ortiz &Polanía (2013), described the advance of the desertification process in this ecoregion, Delgado, Hernández &Castaño (2012) made a computational study on the radiation of the desert atmosphere. By the same token, Guerrero, Sarmiento & Navarrete (2000) analyzed the cretacic replacement of the Magdalena River Valley; Setoguchi*et al.*(1985) found primate fossilsfrom the medium Miocen; Villaroel, Brieva& Cadena (2012) found fossils of mammals belonging to the late Pleistocene and Sánchez (2001) found some fossil remains of invertebrate, fish, reptiles and birds.

Olaya& Sánchez (2001) have documented the interaction of Tatacoa Desert with important hydric resources of the High Magdalena River. As far as the fauna is concerned, Losada& Molina (2011) built and inventory of bird species existing in the life zone of dry tropical forest; Acosta-Galvis (2012) found amphibious in the dry enclaves of Tatacoa and its influence area in the High Magdalena. Sánchez &Olaya (2001) mentionedzoological groups predominating in the higher extension environment and the ecologic role of them in the Tatacoa region.

Although the Tatacoa Desert has been researched by several science disciplines, it was necessary to establish the index of phytogeographical affinity that allows measuring the inclusion of foreign species into the diverse similarity resulting as a consequence of the environmental changes caused by human activity groups. Nevertheless, it is important to perform researches contributing significantly to orientate the social and economic development towards soil use and use of water resources more accordant with the potential use of the desert.Likewise, the respiratory activity and the mineralization index of organic matter accompanied of studies of physical and chemical characteristics of soils of the dry tropical forest zone will allow making appropriate decisions on management of soil resources.

Considering the above issue, this paper presents methodologies seeking to improve productivity and biological diversity of the soils in the Tatacoa Desert. By publishing this document we try to benefit the community living in the studied area and the academic collectivity that provide consulting and guidance to the people of such zone.

2. METHODOLOGICAL PROCEDURE

2.1. Phytogeographical affinity

A literature review of the number of existing documented vegetable species in the Tatacoa zone and other national zones were carried out to elaborate a consolidated document so the Jacard similarity indexes can be determined using a commercial statistics software by conforming n x P size matrix (102x9) where the vegetable species of the Tatacoa Desert represented the hundred and two rows (n) and the area where the life Bs-T zone in Colombia is presented corresponds to the nine columns (P). The Jacard similarity index is binary which indicate that forming the similarity matrix a number one (1) is written if the specie is present in a given ecoregión and zero (0) if it is absent. Subsequently, the phytogeographical affinity index (PAI) and estimated by Equation (1) following the methodology proposed by Herrmann & Tappan (2013):

$$PAI = \sum_{i=0}^{n}(PA_i * AC_i) / \sum_{i=0}^{n}(AC_i) \quad (1)$$

being *n* the species number in the place, PA is the similarity index and y AC abundance category (Rare: 1, scarce: 2, common: 3, very common: 4, native: 5). The results permitted to establish not only the more common species in the studied zone but also what species can be cultivated in other biogeographical zones of the country.

2.2. Economical assessment of the erosion process advance

The basic aggregated model was utilized. This allowed observing the desertification effect on the "capital and work" variables expressed in the model as "bulk value of agriculture production" (VBP). For the economical assessment of the advance in the erosion process was employed the basic aggregated model according to the methodology used by Morales (2012), which permits to observe the desertification effects on "capital and work" variables, expressed as "bulk value of agriculture production" (VBP).

Regressions on this linearized functions was performed with the ordinary minimum square method (MCO) with commercial software. The dependent variable was set to be the "bulk value of agriculture production" (VBP) and the explanatory variables of the basic productive factors were: terrain (*ti*), capital (*ki*) andwork (*li*); in order to represent the desertification phenomenon a binary "dummy" variable (DES) was introducedand an interaction variable between the terrain factor and desertification (*DES***ti*) was taken to explain the desertification effects on elasticity *VBP*-terrain. Equation (2).

$$VBP = \beta_0 + \beta_1 * ti + \beta_2 * ki + \beta_3 * li + \beta_4 * DES * ti + \beta_5 * DES + \varepsilon i \quad (2)$$

where*VBP*: represents the natural logarithm of "bulk value of agriculture production", β: coefficients of *yi*, *ti*, *ki* and

li, (natural logarithms of productive factors), *DES*: "dummy" desertification variable, where*DES*=1 if the territorial unity where the estate is affected by high desertification and *DES*=0 otherwise, *εi*: representsthe error term.

The described procedure was performed by setting a zero value to the *DES*variable in those observations of unities affected by desertification with the purpose of estimating the model variance for the hypothetical case of occurring estates unaffected by the problem.

2.3. Respiratory activity and the mineralization index of the organic matter of the bs-T soils

The comparative analysis of the carbon dioxide emission and the mineralization index of the organic matter among the soils located in three locations of dry tropical forest (bs-T) zones of Huila state, Colombia, were carried out by the adaptation of a statics model used by Mora (2006) and validated by Ochoa &Urroz (2011). The purpose of this was to estimate the biological activity, measured by microorganisms breathing which are presented in the soils.The treatment were defined by taking into account the soil source, as follows, soil from estate of "El Caguán" locality (*T*1), soil from a estate of ecoregion "Tatacoa Desert" (*T*2) and soil from estate of Neiva City (*T*3). Two kilograms were collected for each material according to the protocol InstitutoGeográficoAgustínCodazzi IGAC (2014). Soils were characterized before and after performing the monitoring respiratory test. Each treatment was subject to such measurements as: pH (according procedure by NTC 5264) with a WTW Inst equipment, model 330 Set, organic carbon (%CO), (modified NTC 5403), cationic exchange capacity (*CIC*), (modified NTC 5268), temperature (°C) (IGAC, 2006) and organoleptic texture (Torrente, 2014), to evaluate the behavior of these properties during the process. Later, a variance analysis was made with two factors using a widely used spreadsheet with significance level of 5%. Each property was measured three times.

Then, the mineralization index for each soil type was calculated from organic carbon content and grams of CO_2released during breathing, (Rosales *et al*. 2008).

3. RESULTS AND DISCUSSIONS

3.1. Phytogeografical index

The bs-T is distributed in the regions of the Caribbean planes and interAndean valleys of the Magdalena and Cauca Rivers and covers the following Colombian states: Valle del Cauca, Cauca, Huila, Santander, Norte de Santander, Cesar, Magdalena, San Andrés & Providencia and Guajira. According to Sarmiento (1975) and Hernández (1992), cited by Instituto Alexander Von Humboldt (1998), the dry forest of the inter Andean valleys possess compound coming from dry vegetation from the Caribbean planes. This shows that in the past probably this regions were connected with the same type of vegetation and possessed similar climatic conditions.

Zones with higher similarity index with respect to the Tatacoa Desert are the Península of La Guajira-Riohacha and the Chicamocha cannon. In the Dendograme given in Fugure-1 a well-defined aggrupation is clearly observed among these three zones. The similarity coefficients found show evidence of the potential owned by these zones for providing a restocking with native vegetable species ofbs-T and with the adaption facilities since they are the same ecoregions will permit the regreening in an effective manner than foreign vegetable species. Likewise, it can observe zones corresponding the aggrupation formed by Convención and Ocaña, and Patía River Valley possess very low similarity coefficients, with values among 0,03 to 0,38 and 0,10 to 0,30 respectively, showing low similarity with other zones of analyzed bs-T.
Figure-2 shows the number of species registering a phytogeografical affinity index of species that are common with respect to the Tatacoa Desert zone. The corresponding zone of Convención and Ocaña holds three species that are tolerant to the conditions of the Tatacoa Desert: *Pseudosamaneaguachapele (Kunth) Harás, Gliricidiasepium (Jacq.) Kunth ex Walp*and*Gynandropsisgracilis (T & P) Killip*.

For the Dagua cannon the following common species were found: *Bauhinia guianensisAubl, Gliricidiasepium (Jacq.) Kunth ex Walp.,Gynandropsisgracilis (T & P) Killip, Pseudosamaneaguachapele (Kunth) Harás, Senna pallida (Vahl) Irwin &Barneby, Senna obtusifolia (L.) H.S. Irwin &Barneby, Senna spectabilis (DC.)H.S. Irwin &Barneby, Senna tomentosaBatka.*

In the zones corresponding to Gamarra and San Andrés & Providencia nine species with phytogeographical affinity were found. The more common species for Gamarra are: *Bauhinia guianensisAubl.,Capparisodoratissima Jacq., Gliricidiasepium (Jacq.) Kunth ex Walp.,Gliricidiasepium (Jacq.) Kunth ex Walp., Gynandropsisgracilis (T & P) Killip, Machaerium capote Triana ex Dugand, Paulliniadensiflora Smith, Pseudosamaneaguachapele (Kunth) Harás, Randiaarmata (Sw.) DC., Randiaaculeata L.; para San Andrés y Providencia son: Bauhinia guianensisAubl., Capparisodoratissima Jacq., Gliricidiasepium (Jacq.) Kunth ex Walp., Gynandropsisgracilis (T & P) Killip, Machaerium capote Triana ex Dugand, Paulliniadensiflora Smith, Pseudosamaneaguachapele (Kunth) Harás, Randiaarmata (Sw.) DC., Randiaaculeata L.*

In the Patio River Valley the more common species are: *Croton ferrugineusKunth, Croton glabellus L., Gliricidiasepium (Jacq.) Kunth ex Walp., Guazumaulmifolia Lam., Gynandropsisgracilis (T & P) Killip, Ipomoea sp., Ipomoea carnea Jacq., Pseudosamaneaguachapele (Kunth) Harás, Sidajamaicensis L., Sida SP. En Santa Marta se encuentran quince especies tolerantes: BauhiniaguianensisAubl., CapparisodoratissimaJacq., Ficus sp., Gliricidiasepium (Jacq.) Kunth ex Walp.,*

Guazumaulmifolia Lam., Gynandropsisgracilis (T & P) Killip, Machaerium capote Triana ex Dugand, Paulliniadensiflora Smith, Pseudosamaneaguachapele (Kunth) Harás, Randiaarmata (Sw.) DC., Randiaaculeata L., Sennapallida (Vahl) Irwin&Barneby, Sennaobtusifolia (L.) H.S. Irwin&Barneby, Sennaspectabilis (DC.) H.S. Irwin&Barneby, Senna tomentosa Batka.

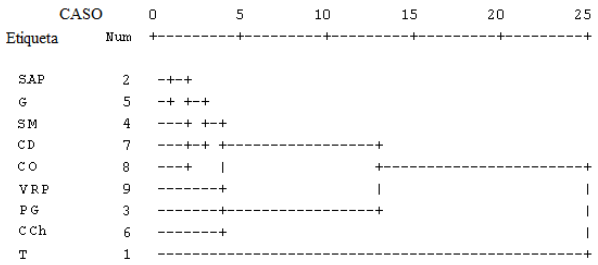

Figure-1. Dendograme of similarity for species bs-T zones.

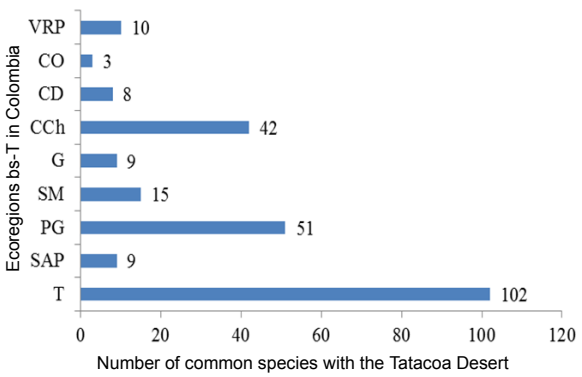

Figure-2. Number of common species with the Tatacoa Desert.

It was found forty two species common with the Tatacoa Desert ecoregion for the case of Chicamocha cannon: Abutilon giganteum (Jacq.) Sweet, Acacia decurrensWilld, Acacia farnesiana (L.)Willd.LEG, Acanthocereustetragonus (L.)Hummelinck, Bastardiabivalvis (Cav.) Kunth ex Griseb, Bouteloua sp., CaesalpiniacassioidesWilld, Cereus hexagonus (L.) Mill, Cortaderia sp., Croton ferrugineusKunth, Desmodiumadscendens (Sw.) DC, DesmodiumincanumDC.,Gliricidiasepium (Jacq.) Kunth ex Walp.,Gynandropsisgracilis (T & P) Killip, Hylocereusundatus (Haw.) Britton & Rose, Ipomoea sp., Ipomoea carnea Jacq., Jatropha gossypiifolia L., Jatropha urens L., Lonchocarpus punctatus H.B.K., Machaerium capote Triana ex Dugand, Macluratinctoria (L.) D. Don ex Steud.,Macroptiliumatropurpureum (Sessé&Moc. Ex DC.)Urb.,Malvastrumamericanum (L.) Torr., MelocactuscurvispinusPfeiff., Opuntiadepauperata Britton & Rose, Opuntiaschumannii F.A.C. Wever ex A. Berjer, Parkinsoniaaculeata L., Pedilanthustithymaloides (L.) Poit.,Pithecellobiumdulce (Roxb.) Benth., Praecereuseuchlorus (F.A.C.Weber) N.P.Taylor, Prosopisjuliflora (Sw.) DC., Pseudosamaneaguachapele (Kunth) Harás, Rhynchelytrumroseum (Nees) Stapf& C.E. Hubb., Senegaliahuilana Britton &Killip, Senna pallida (Vahl) Irwin &Barneby, Senna obtusifolia(L.) H.S. Irwin &Barneby, Senna tomentosaBatka.,Sidajamaicensis L., Sida SP.

The zone with the highest similarity index also presentshe highest phytogeographical affinity.This is the case of the Guajira-RiohachaPeninsula which has fifty one common species: Abutilon giganteum (Jacq.) Sweet, Acacia decurrensWilld., Acacia farnesiana (L.) Willd.LEG, Acanthocereustetragonus (L.)Hummelinck, Bauhinia guianensisAubl, Bastardiabivalvis (Cav.) Kunth ex Griseb., Bouteloua sp., CaesalpiniacassioidesWilld., Calotropisprocera (Aiton) W.T. Aiton, Capparisodoratissima Jacq., Cereus hexagonus (L.) Mill,Cortaderia sp., Croton ferrugineusKunth, Desmodiumadscendens (Sw.) DC.,Desmodiumincanum DC., Gliricidiasepium (Jacq.) Kunth ex Walp.,Gynandropsisgracilis (T & P) Killip, Hylocereusundatus (Haw.) Britton & Rose, Ipomoea sp., Ipomoea carnea Jacq., Jacquemontiasphaerostigma (Cav.) Rusby, Jatropha gossypiifolia L., Jatropha urens L., Lonchocarpus punctatus H.B.K., Machaerium capote Triana ex Dugand, Macroptiliumatropurpureum (Sessé&Moc. Ex DC.)Urb.,Malvastrumamericanum (L.) Torr.,MelocactuscurvispinusPfeiff., Merremiadissecta (Jacq.) Hallier F., Merremiaumbellata (L.)Hallier F., Opuntiadepauperata Britton & Rose, Opuntiaschumannii F.A.C. Wever ex A. Berjer, Paulliniadensiflora Smith, Parkinsoniaaculeata L., Pithecellobiumdulce (Roxb.) Benth., Praecereuseuchlorus (F.A.C.Weber) N.P.Taylor, Prosopisjuliflora (Sw.) DC., Pseudosamaneaguachapele (Kunth) Harás, Randiaarmata (Sw.) DC., Randiaaculeata L., Rhynchelytrumroseum (Nees) Stapf& C.E. Hubb., Sarcostemmaclausum (Jacq.) Schult.,Senegaliahuilana Britton &Killip, Senna pallida (Vahl) Irwin &Barneby, Senna obtusifolia (L.) H.S. Irwin &Barneby, Senna tomentosaBatka.,Sidajamaicensis L., Sida SP. Stenocereusgriseus (Haw.) Buxb.

According to the above, the zones with highest phytogeographical affinity with the Tatacoa Desert are, from highest to lowest: Guajira Peninsulawithfifty one species and the Chicamochacannonwith forty twp species followed by Santa Marta withfifteen species, Patía River Valley with ten species, Gamarra and San Andrés & Providencia with nine common species in each zone, Dagua cannon with eight species and Convención and Ocaña with three common species.

3.2. Bulk value of Agriculture production

Table-1 presents the values of the **β**coefficients for the variables: β_0 = 3.151, β_1=0.189, β_2=0.083, β_3=0.176, β_4=0.029 andβ_5=-0.031. Replacing the coefficients into Equation (2), the "bulk value of agriculture production is generated as shown below:

$$VBP = 3.151 + 0.189*ti + 0.083*ki + 0.176*li + 0.029*DES*ti + (-0.031)*DES + \varepsilon i \quad (3)$$

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It is observed in the obtained model that the coefficient of the DESvariablehas a reducing significant effect on soil production of the Tatacoa desert; coefficient DES*tiis not so significant; then, there will be no incidence on elasticity VBP/terrain caused by the desertification.

By analyzing the behavior of R-squared is observed that its value is greater than 0.06which indicatesthat, holistically, the variables are affectingthe "bulk value of agriculture production". The probability value for *ti* variable is 0.012 which is lower than 0.05, which means that this variable, individually,does not explainthe behavior of"bulk value of agriculture production". Variables ki, li, DES*ti and DES present values of probability greater than 0.05, this means, individually, these variables explain the behavior of "bulk value of agriculture production".

Table-1. Obtained results for the model of economical assessment by the ordinary minimum squared method.

Variable	Coefficient β	Std. Error	t-statistic	Prob.
X0	3.151	0.408	7.721	0.000
Ti	0.189	0.070	2.693	0.012
Ki	0.083	0.044	1.881	0.072
Li	0.176	0.133	1.319	0.199
DES*ti	0.029	0.161	0.182	0.856
DES	-0.031	0.213	-0.149	0.882
R-square	0.514	Media sample Depend. Variable		4.510
R-squareadjusted	0.413	S.D. dependent variable		0.293
Regression S.E.	0.224	Criterion info Akaike		0.030
Resid. squaresumm.	1.214	Schwarz Criterion		0.311
probability log	5.535	Durbin-Watson		1.727

Table-2 presents the results for the model of "bulk value of agriculture production" without taking into account the desertification (DES) and the interaction variable between the terrain and desertification (*DES*ti*).

When analyzing the behavior of the R-squarecan be observed that its value is greater than 0.06 indicating, as a whole, the variables affect the bulk value of production.The probability value for variables *ti*, *ki*and*li*areless than 0.05, which means, under these new conditions, individually, do not explain the behavior of the "bulk value of agriculture production".

Comparison of the probabilities found for each case, it can be affirmed that variables *DES* and *DES*ti* in the model of "bulk value of agriculture production", the probability values of *ti*, *ki* and *li*, have a different behavior: variable *ti* varies in 43.30%, *ki*has a variation of 69.34%, and variable *li*has a small variation of 6.17%. This indicates that variables *ti* y *ki* summed to *DES* and *DES*ti* allow explaining the behavior of the "bulk value of agriculture production".

Table-2. Results obtained from the economical assessment model by the ordinary minimum squared method excluding the desertification variable.

Variable	Coefficient β	Std. Error	t-statistic	Prob.
X0	3.159	0.383	8.250	0.000
Ti	0.187	0.062	3.029	0.005
Ki	0.081	0.039	2.056	0.050
Li	0.195	0.073	2.692	0.012
R-square	0.514	Media sampleDepend. Variable		4.511
R-squareadjusted	0.456	S.D. dependent variable		0.294
Regression S.E.	0.216	Criterion info Akaike		-0.101
Resid. squaresumm.	1.216	Schwarz Criterion		0.086
Probability log	5.515	Durbin-Watson		1.709

The studies conducted by Morales (2012) in Chile, show similar results in the aggregated analysis where coefficients *DES* and *DES*ti* for four desertic zones negatively affect the productivity of the estates located in zones with desertification process and also show significant differences with those not going through this phenomenon.Moreover, the provide calculation sof R-square values ranging from 0.50 and 0.57, validating, as in this research, that the desertification has a negative impact on bulk value of agriculture production.

3.3. Respirometry of soils and determination of organic matter mineralization index

Figure-3 shows the evolution of CO2 concentration in the treatments with respect to time. It is observed that T1 presents the lowest respiratory activity with average values of 0,0026 g of CO_2. In T2 was presented the highest respiratory activity with 0,0066 g of CO_2, whichassures that soils with medium organic matter content conditions and high humidity favour the proliferation of microorganisms and its mineralizing activity.Investigations carried out by García *et al.*(2003) and Peña (2004) demonstrate the susceptibility of the response of microbial activity to variations of soils handling, showing that organisms sensitive to temperature changes, humidity-drying effectsand organic matter content with results present same tendencies as these from this paper.

Biological activity of treatments, measured by CO_2 concentration emitted by microorganisms presented in soils, grew during the first 48 hours in the three treatments and later, presented a decreasing behavior in all the treatment. Table-4 allows observing that the respiratory behavior with respect to the time is different among the treatments with a significant level of 5%; this change in breathing activity is significant and indicates that microorganisms in the soils released CO_2. There was a reduction of organic matter content in treatment T2 at the end of the process. This indicates that existing microorganisms contributed to soilorganic matter decomposition.

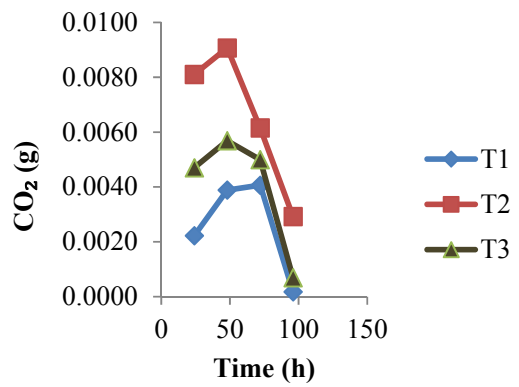

Figure-3. Concentration of CO_2emitted by soils throughout the time.

Table-3. Variance analysis of CO_2emitted with respect to time among the treatments.

Variation source	Square Summ.	Freedom degree	Square average	F	Probability	Critical value for F
Treatment	3,234E-05	2	1,617E-05	26,103	0,037	19
Time	7,635E-06	1	7,635E-06	12,325	0,072	18,512
Error	1,239E-06	2	6,195E-07	-	-	-
Total	4,122E-05	5				

The mineralization index calculation was carried out after analysing the respiratory behavior of the treatments. These practices allowed evaluating the variations of the biotic and abiotic factor son organic matter decomposition. The mineralization studies can be used to evaluate the susceptibility and decomposition velocity of natural and synthetic organic compounds (Ochoa &Urroz, 2011).

Figure-4 shows the behavior of the mineralization index of the treatmentsat both the beginning and end of the respirometry processes. It is shown there that the highest mineralization indexes give for T3 with values higher than 100 %. This index presents results similar to those from the work by Acuña (2006), who found that soils with higher organic matter content possess lower mineralization indexes due to accumulation of organic substrate; Gómez (2000) affirmsthat in soils rich in organic matter and microbial activity is an indicator of high fertility and nutrients availability. The variety of microorganisms utilizecarbon energy for their metabolism; therefore, there exists a direct relationship among microorganisms, soil fertility and soil organic matter content.

According to Zibilske (1994), cited by Ochoa and Urroz (2011), the determination of the soil mineralization index allows finding information regarding the physiological state or metabolic activity of the existing microbial population, the biomassand microorganism's contribution of the total flow of carbon from the soil. Considering this, the obtained mineralization index values indicate that the degradation potential of the soil microorganisms, for medium content and low organic matter, sources of food in these processes, is not metabolized, then, its activity is low. According to Ceccantiand García (1994), is the labile fraction of the organic matter that induces the increase of the microbial activity.The labile fraction contributes to keep a high

microbial activity which favors the release of nutrients and the degradation of contaminant compounds.

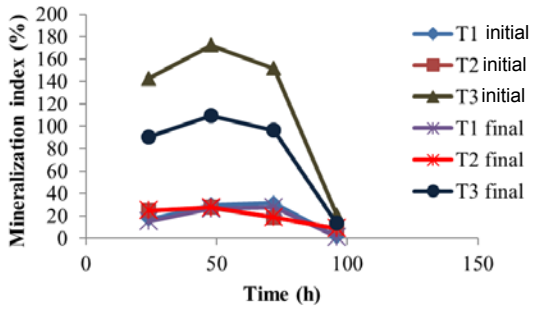

Figure-4. Behavior of the mineralization index throughout the time.

The behavior of the mineralization index curves in the different treatments keeps the same tendency and do not present significant differences among them (Table-4). The mineralization indexes (IM) of soils present significant differences which leads to conclude that in spite the organic matter metabolic activity is low; there was activity of the labile fraction which allowed that the existing microorganisms in the soil were able to generate CO_2emitted by breathing. Treatment 2 shows a stable behavior with a low mineralization index and medium %CO, with a respiration rate higher than the other two treatments, since the existence of microorganisms in this treatment utilize a great amount of energy to decompose the organic matter of the samples under study.

Table-4. Variance analysis of mineralization index with respect to time.

Variation source	Square Summ.	Freedom degree	Square average	F	Probability	Critical value for F
Treatments	13261,548	6	2210,258	1,535	0,307	4,283
IM	19188,790	1	19188,790	13,329	0,010	5,987
Error	8637,124	6	1439,520	-	-	-
Total	41087,463	13				

4. CONCLUSIONS

a) It could be established the number of more common species in the life zone of tropical dry forest, for regreening activities, promoting the preservation of native species of the Tatacoa Desert. Likewise, this research permits the determination of the existing phytogeographical affinity in other zones of the country, and to work together for the improvement of the plant cover of the affected areas.

b) This study allowed identifying the existence of high similarity indexes among other ecoregions: between Santa Marta zone and the zones San Andrés and Providencia islands and Gamarra.Likewise, between the zone of the Guajira-Riohachapenínsula and the Chicamocha cannon. Between the Santa Marta zone and Dagua cannon zone where the similarity index is medium.

c) An inverse behavior between DES variable corresponding to desertification and "bulk value of agriculture production". The coefficient of DES variable has an important impact on reducing the agriculture production in the soils of the Tatacoa desert.

d) The interaction between the terrain factor and desertification has no incidence on the elasticity VBP/terraincaused by desertification. The model variables affect as a whole the "bulk value of agriculture production". Capital, terrain, desertification and interaction between the terrain factor and desertification, are variables that, individually, explainthe bulk value of agriculture production.

e) CO_2concentration emitted by existing microorganisms in the analyzed treatments had low growing in the first 48 hours. Respiratory behavior among the treatments with respect to time was different. There was a reduction in organic matter content at the end of the process for treatment T2.This indicates that existing microorganisms contributed to soil organic matter decomposition.

f) The highest mineralization indexes were found for treatment T3 with values above 100 %. The obtained mineralization index values for medium and low organic matter content indicate a low microorganisms degradation potential in this type of soils.

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