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Urban Expansion and Forestry in CO_2 Sequestration

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***Abstract*—The objective of this research was to determine the implications of urban expansion and forestry on carbon sequestration in the northern districts of Lima. On the other hand, a five-year, non-experimental, longitudinal design was used. The information from the Geographic Information System (GIS) was used in the development of the project; first, for the mapping; then, the delimitation of urban areas, vegetation in the urbanized and non-urbanized territory. Using Arc View Gis 8.3 software, the five-yearly register was compiled starting in 1980. Finally, the results have proven that urban expansion and the destruction of vegetation have implications on CO2 sequestration due to the sustained growth of the urban area, which led to the determination of the model: Y = 8050.92 - 0.11 X1+ 48.64 X2.**

***Keywords*—Trees, emissions, sinkhole, expansion, biodiversity.**

INTRODUCTION

The unplanned growth of cities is a problem in the municipal context, due to the migration from rural areas and the countryside to the cities. This paper derives from the research on "Urban expansion and forestry in CO2 sequestration" conducted during the years 1980 and 2015 in Lima, Peru, northern districts, in the bioeconomy research line [1]. Likewise, in Colombia, regulations on urban tree management come into force, and a policy of an approach to Urban Forestry is proposed by the National University of Colombia [2]; in Chile, the Faculty of Forestry Sciences of the University of Chile deals with the management of urban trees in Maipú with health-friendly criteria [3]; and, the Food and Agriculture Organization of the United Nations FAO [4] states that the great wealth of natural biodiversity and cities have been located and grown under natural conditions in the three large regions of the country, so it would be important to recover them and face climate change. In this context, the following question is posed as a general problem: Have urban expansion due to population growth and urban forestry had implications on CO2 sequestration in the districts of San Martin de Porres, Los Olivos, and Comas in the period between 1980 and 2015?

MATERIALS AND METHODS

The approach of the study is quantitative, the type is descriptive, explanatory and the design is non-experimental and longitudinal, for changes in five-year periods between 1980 and 2015. The design of the analysis of results showed a causal relationship, analyzed by multiple regression, applying the mathematical model: $Y_{ij} = \beta_o + \beta_1 x_{i1} + \beta_2 x_{i2} + E_{ij}$; being: Y_{ij} the CO2 sequestration response variable; β_o Rate of increase (constant); $\beta_1 x_{i1}$ the urban expansion variable; and, $\beta_2 x_{i2}$ the urban forestry variable. The model provided insight into the reality of the implications of urban expansion and forestry on CO2 sequestration, without losing sight of oxygen release. The coordinates of the three districts: 6° 10' 19" North Latitude and 75° 35'09" West of the Greenwich Meridian. Initially, it was planned to use the basic cartography, scale 1:1000 provided by the National Geophysical Institute, but 24 maps were required in eight five-year periods since 1980. For this reason, satellite information was used, with the Arc View GIS 8.3 platform. The tree inventory took into account plants taller than 1.30 m.; the Entity-Relationship Model (MER) was used for their organization; and, for the database, Microsoft Access was used.

RESULTS

Urban expansion

Figure 1 and 2, of the district of San Martin de Porres, has the largest urbanized area in the southern extreme; Los Olivos, the most urbanized; and, Comas, in the southern extreme, still has cultivated areas and a larger territory of uncultivated land and slopes [1].

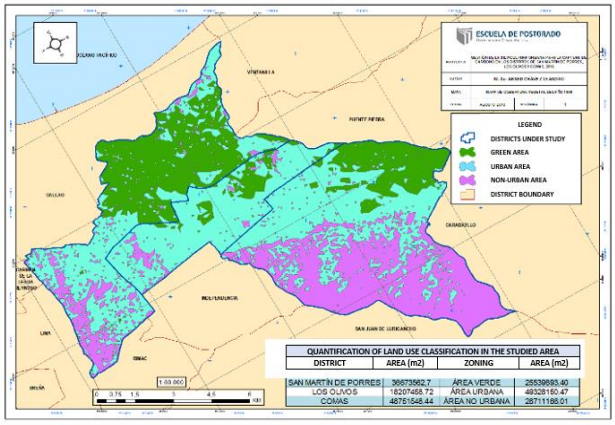

Figure 1 Classification Of Land Use In Urban Expansion And The Reality Of Forestry In The Territory Of Northern Lima And Urban Expansion 1980-2015

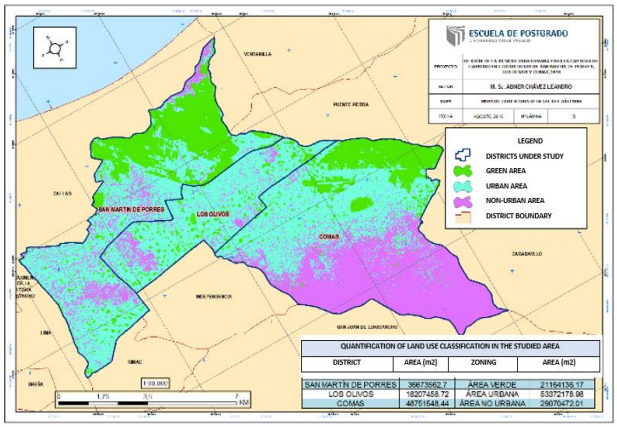

Figure 3 Urban Expansion And Forestry In The Territory Of Northern Lima, 1980-2015.

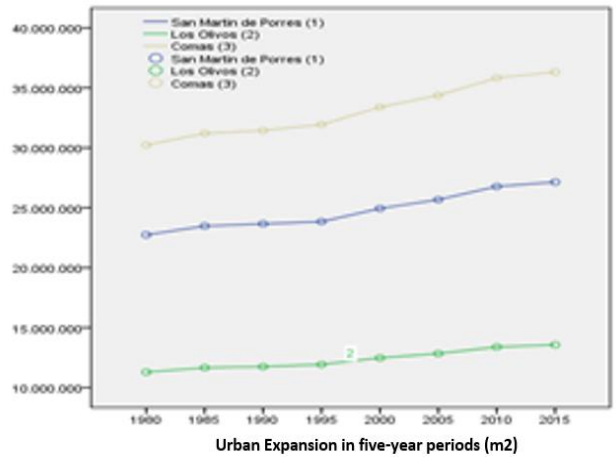

Figure 2 Urban Expansion In Five Years Periods (M2)

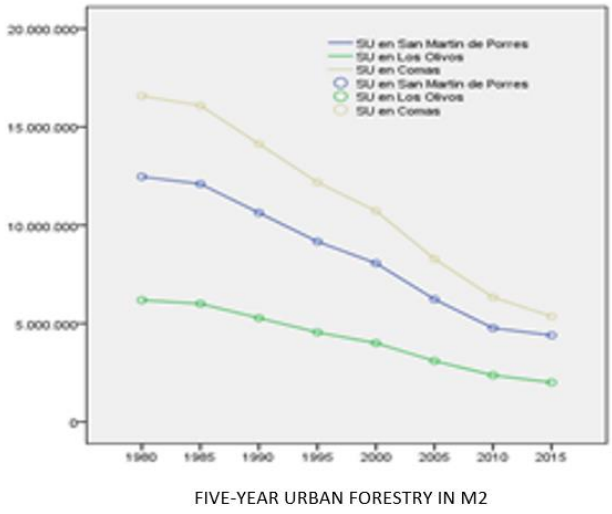

Figure 4 Urban Forestry In Five Years Periods (M2).

Urban Silviculture

Figure 3 and 4, shows a decrease in the rate greate than the urban expansion, thus, in San Martin de Porres, it decreases by 5229.37 m2 which represents a loss of 51.53 % of the green area in the period from 1980 to 2016. In Los Olivos, in the same period, it decreases by 2678.84 m2 which means a loss of 50.52 % of the green area; and, in Comas, it loses 7172.76 m2 which represents a decrease of 50.59 % of the green area that is eventually occupied by buildings in the advance of urban expansion.

Urban Biodiversity

The figures below show urban expansion and the loss of green areas, which is being somewhat mitigated by aesthetic trees in parks, sidewalks, and avenues. In Figure 5 and 6, 21 species of ornamental trees and fruit trees were identified, ranging from 4 to 20 species in the district of San Martin de Porres; 6 to 30 species in Los Olivos; and, 1 to 21 species in Comas.

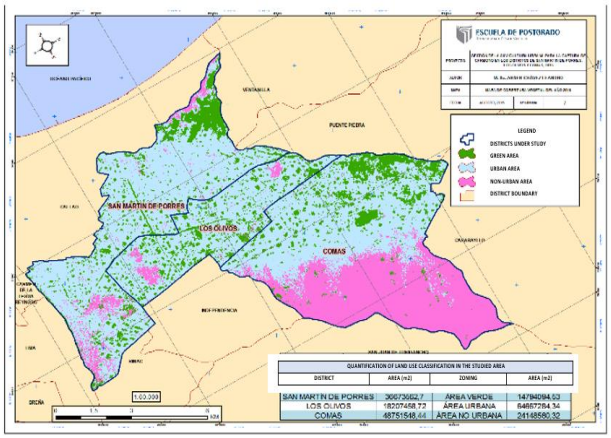

Figure 5 Classification Of Land Use In Urban Expansion And The Reality Of Forestry In 2015 In The Territory Of Northern Lima And Biodiversity In 2015.

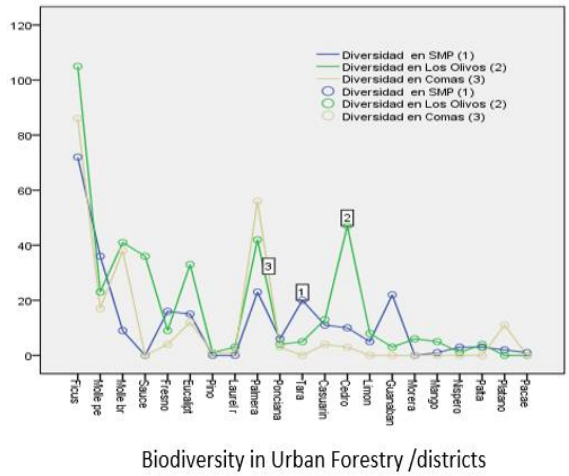

Figure 6 Biodiversity In Urban Forestry / Districts.

Carbon sequestration

Carbon sequestration from the air is expressed in mt/ha/year. Table 1 indicates that, in Comas, an average of 51.67 mt was sequestered, having in 1980 a total of 68.19 mt and, in 2015, a total of 35.14 mt, which represents a decrease of 51.57 %; in San Martin de Porres, with an average sequestration efficiency of 39.21 mt/ha/year, its sequestration capacity drops by 52.52%. Los Olivos is the lowest in terms of the amount of carbon sequestered, because it registers an average of 25.35 mt/ha/year, with an average rate of less loss of 51.53%.

TABLE I
POSITION MEASUREMENTS AND CARBON SEQUESTRATION VARIATION (KG/M2/YEAR) OF URBAN TREES OVER FIVE YEARS IN SAN MARTIN DE PORRES (SMP), LOS OLIVOS (LO), AND COMAS (C)

Districts	N	Mean	Standard deviation	Standard error	95% confidence interval		Increment rate
					Lower L.	Upper L.	
SMP	8	39,2066	14,59685	5,16077	27,0033	51,4098	-0,5252
LO	8	25,3524	9,69934	3,42924	17,2436	33,4613	-0,5153
C	8	51,6688	19,76749	6,98886	35,1428	68,1949	-0,5157
Total	24	38,7426	18,24720	3,72469	31,0375	46,4477	

Urban growth and forestry in CO2 sequestration.

In order to decide on the application of the statistical analysis, the goodness-of-fit of the model was taken into account, with a result of 0.831. This coefficient allows us to consider the applicable regression to generate the prediction model that would be taken into account in the carbon sequestration in Northern Lima.

TABLE II
ANALYSIS OF VARIANCE TEST (ANOVA) OF URBAN EXPANSION AND FORESTRY ON CARBON SEQUESTRATION IN THE DISTRICTS OF SAN MARTIN DE PORRES, LOS OLIVOS, COMAS IN 1980-2015

Model	Sum of squares	gl	Quadratic mean	F	Sig.
Regression	1358772,00	2	679386,5	76,41	,000[b]
Residual	45,47	5	88,95		
Total	1358773, 80	7			

a. Dependent variable: Carbon sequestration Kg/m2/yr.

b. Predictor variables: (Constant), Urban forestry m2, Total urban expansion in Ha.

DISCUSSION

All title and author details must be in single-column format and must be centered. Every word in a title must be capitalized. Email address is compulsory for the corresponding author.

The results obtained demonstrate the relationship between the growth of the urbanized area and urban forestry, since there has been a sustained trend of urban expansion towards croplands and now towards the hillside area. The green areas that made up the crops, afforestation and green areas of the city follow a decreasing trend.

The resulting model was: Y = 8050.92 - 0.11 X1+ 48.64 X2, which indicates that carbon sequestration decreases as urban expansion grows and, as for forestry, carbon sequestration increases as urban forestry also grows. The model indicates that for each unit of forestry, carbon sequestration would increase in units of carbon. If the measurements were m2 of the tree canopy, 48,639 kg/m2/year would be accumulated. Carbon sequestration in the district of Comas is 51.67 mt/ha/year and, in San Martin de Porres, it is 39.21 mt/ha/year. No statistical difference was found; similar results were found for San Martin de Porres and Los Olivos even though they registered 25.35 mt/ha/year. These differences can be attributed to three main factors: The first one is caused by the predominant exotic species such as ficus; the second one, the age of the trees, and the third one is the photosynthetic capacity due to habitat management [1]. Thus, Villee [5], commenting on reports by different authors, says that tree shade can reduce the average temperature of a building by 5ºC, reduce wind speed by up to 60% in wooded areas, reduce the influence of solar radiation by 90% or more, avoiding the heating of the air from surfaces under the tree canopy. In addition, he claims that individual trees, with a DBH between 60-90 cm, can retain up to 50 kg of carbon per year. Moreover, in Santiago, Chile, trees with diameters at breast height (DBH) between 10 and 50 cm sequester about 70% of annual carbon [3].

CONCLUSIONS

Urban expansion, in response to population growth and forestry, has significant implications for CO2 sequestration in the Districts of San Martin de Porres, Los Olivos, and Comas. The data from 1980 to 2015 were analyzed and verified according to the mathematical model: Y = 8050.92 - 0.11 X1 + 48.64X2. The calculations show urban expansion as a response to population growth, estimating the population growth rate for the district of San Martin de Porres at 0.0739, which expanded over 2478 hectares; for the district of Los Olivos, with a growth rate of 0.0772, which expanded over 1236 hectares; and for the district of Comas, with a growth rate of 0.0775, which expanded over 3309 hectares.

Urban forestry also showed its response to urban expansion (there are significant differences in its decrease). Thus, in the District of Comas, with a rate of -0.506, an average of 1121.1 Has/ five-year period is lost; in San Martin de Porres, with a rate of 0.515, 890 Has/ five-year period is lost without significant differences between periods; and, in Los Olivos, with a rate of -0.505, 418.71 Has/ five-year period is lost.

Likewise, CO2 sequestration revealed in response that the decline of urban forestry shows significant differences according to the reality of the districts being investigated in the period from 1980 to 2015.

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