Multivariate Analysis of Soil-Vegetation Interrelationships in a South-Southern Secondary Forest of Nigeria

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Abstract

Multivariate statistical techniques were employed to study soil-vegetation interrelationships in a secondary forest of South-Southern Nigeria. The grid system of vegetation sampling was used to randomly collect vegetation and soil data from fifteen quadrats of 10m x 10m. The result of principal components analysis identified seven basic sets of soil-vegetation variables that enhanced the interrelationships. Canonical correlation result indicated a positive association between organic matter and tree size, while the linear association between organic matter and tree density revealed an inverse relationship. The result of redundancy coefficient indicated that 18 percent of the variance in vegetation characteristics was accounted for by the variability in soil properties whereas, 81 percent of the variance in soil properties was accounted for by the variability in vegetation characteristics. The regression analyses on the other hand indicated that exchangeable sodium positively influenced tree species composition and richness; and that tree size as well as tree density exerted substantial influence on the contents of organic matter and total nitrogen of the soil. However, drawing inference from results of canonical correlation analysis and those of multiple regression analysis, it was concluded that soil and vegetation components of the secondary forest vegetation were mutually dependent and therefore exerted joint influences on each another.

Keywords: Canonical correlation, Redundancy coefficient, Multiple regression, Soil properties, Vegetation characteristics

1. Introduction

Vegetation and soil are interrelated and exert reciprocal effects on each other. This is because soil gives support in terms of moisture, nutrient and anchorage to vegetation to grow effectively on the one hand, and on the other, vegetation provides protective cover for soil, suppresses soil erosion as well as helps to maintain soil nutrient through litter accumulation and subsequent decay (Eni *et al*., 2011). Both soil and vegetation are multivariate in nature, as such, the relationships of soil and vegetation components can be analysed by multivariate statistical methods (Aweto, 1981; Ukpong, 1994). This reciprocal relationship between soil and vegetation demands a multivariate approach in order to determine critical vegetation and soil properties that sustain this integrative association. On this premise, multivariate analytical techniques (principal component analysis, canonical correlation analysis, factor analysis, and canonical correspondence analysis among others) are very useful in the analysis of soil and vegetation as each consists of data corresponding to a large number of variables. Thus, analysis via these techniques produces easily interpretable results.

Hauser's (1974) test for multicollinearity indicated that both soil and vegetation variables were highly collinear, which has serious implication for regression analysis (Aweto, 1981), but this problem is resolved through the application of multivariate statistical techniques mostly principal component analysis (PCA), which helps to make variables uncorrelated through orthogonal rotation. Multivariate techniques minimize this because they allow for simultaneous comparisons among the variables rather than requiring many statistical tests be conducted. The lowland secondary forest of Tinapa Resort is a regenerative forest approaching secondary climax, after series of anthropogenic disturbances notably food crop cultivation, fuelwood gathering and illegal logging activities. The forest vegetation over nine years of abandonment following its acquisition by the Cross River State government is characterized by a luxuriant forest canopy and diverse tree species. There is therefore need to identify the basic soil and vegetation parameters encouraging the regenerative capacity of this once degraded forest and impoverished soil.

Studies on the application of multivariate statistics in understanding the relationships between soil and vegetation have not been properly documented in the rainforest belt of southern, Nigeria; available studies show locational and ecosystem biases. For instance, Aweto (1981) and Aweto and Areola (1979) studied these interrelationships in the south-western ecological zone of Nigeria, while Ukpong (1994) and Alakpodia (1992) studied soil-vegetation interrelationships in mangrove swamps and riparian microhabitant of River Ethiope Basin of southern Nigeria respectively. These studies identified varying soil proprieties like organic matter, clay, silt and salinity to influence the distribution or zonation of vegetation; as well tree size, vegetation cover, tree density and proportion of mesophanerophytes as vegetation components that influenced soil nutrient. This complex interrelationship between soil and vegetation in the south-southern region of Nigeria has not been fully documented in the literature, mostly among stressed vegetation. It is on this premise that this study attempts to study the relationships between soil and vegetation components of the once stressed forest ecosystem of Tinapa in Cross River State using multivariate statistical techniques notably principal component analysis (PCA), canonical correlation analysis (CCA) and multiple regression analyses (MRA), the aim perhaps is to identify the basic soil and vegetation variables that reciprocally promote, sustain and influence the regenerative capacity of the once disturbed forest vegetation.

2. Materials & Methods

Study area

Tinapa is located between latitude $05^0\ 02^1$ and $05^0\ 04^1$ N and on longitude $08^0\ 07^1$ and $08^0\ 22^1$ E. The area falls along the coastal fringes of Cross River State where raining season lasts for about 10 months. The nearness of the Atlantic Ocean has a moderating effect on temperature with highest average daily maximum of 35^0 C and recorded mean annual temperature of $26\,^o$ C. The area has an average relative humidity of 80-90 percent at 10am during the wet season (Akpabio *et al.,* 2006). The vegetation of the area is a mixture of mangrove and tropical rainforest. The rainforest is further subdivided into the lowland rainforest and the freshwater swamp forest. The mangrove swamp is found in the southern fringe of the area, and stretches from the freshwater limits to the ocean beaches (Iwara, 2009). The rich and luxuriant vegetation of the area has been subjected to severe degradation in the past before the advent of Tinapa; as such, the vegetation comprised of secondary forest approaching climax. The soils are generally deep, porous and weakly structured, and well-drained with low moderate status (Akpabio *et al.,* 2006). The soils in the area are ferrallitic with dominant colour of yellowish-brown (Soil Map of Nigeria, 1964).

Sampling procedure and analysis

The grid system of vegetation sampling was used to superimpose grids of $1cm^2$ on the lowland forest using the vegetation map of the area, the grid intersections were numbered, and then 15 grids were randomly selected. This approach was used to establish fifteen quadrats of 10x 10m in dimension across the area, and in each quadrat, vegetation and soil samples were collected. The floristic and structural vegetation samples determined included tree density, species composition, tree height, tree size/girth, vegetation/crown cover, species diversity index and aboveground biomass. Data on vegetation/crown cover and were obtained using the line-intercept method (Jennings *et al*., 1999; Coulloudon *et al.,* 1999). Tree size/girth was taken a 1.37m DBH. Species diversity indexes were determined using Shannon-Wiener's approaches respectively (Kent and Coker, 1992; Magurran, 1988). Tree height was determined using the trigonometry method (Offwell Woodland & Wildlife Trust, 2000). Aboveground biomass was estimated using the allometric formula given by FAO (1989) for tropical areas as cited by Woomer (2006) as $y = \exp^{(-2.134\ +\ 2.53\ \ln D)}$; where y = Aboveground biomass in kilogrammes per quadrat; exp = 2.71828 and D is the measured diameter at breast height in cm.However, during the collection of vegetation parameters, only mature trees with ≥0.30m girth were enumerated and analyzed.

In the same way, fifteen (15) soil samples were collected using a soil auger at rooting depth of 30cm. The soils were put in a polythene bags with labels; they were thereafter air-dried and taken to the laboratory at the Department of Agronomy, University of Ibadan, Ibadan for analysis of soil physical and chemical properties. Particle size composition was determined using the hydrometer method; organic carbon by the Walkley-Black method (1943), after which values obtained were multiplied by 1.72 (Pluske *et al.,* 2009) to converted to organic matter; total nitrogen by the Kjeldahl method; Available phosphorus was determined by the method of Bray and Kurtz (1945). The soils were leached with 1N neutral ammonium acetate to obtain leachates used to determine exchangeable bases adapted from the method described by Daly *et al.,* (1984). Soil extracts used for determining the level of exchangeable cations were obtained by leaching soil samples using 1 M ammonium acetate. Exchangeable calcium, potassium and sodium were determined by flame photometry and exchangeable magnesium by atomic absorption spectrophotometry. Soil cation exchange capacity was determined by the summation method, while pH values were determined using a glass electrode testronic digital pH meter with a soil: water ratio of 1:2.

Data analysis

Two data matrices representing soil and vegetation characteristics were constructed and the SPSS for windows (Ver. 17.0) and SAS for windows (version 9.0) software packages were used for multivariate statistical analysis (Principal Component Analysis and Canonical Correlation Analysis) and univariate analysis (Multiple Regression Analysis). Aweto (1981) observed that the interpretation of results of canonical correlation analysis is often difficult when the number of variables involved is large. On this note, Principal Components Analysis (PCA) was performed to reduce the data and number of soil-vegetation variables in order to identify the main factors determining the reciprocal effects of soil and vegetation. PCA according to Li *et al*., (2008) are considered useful if their cumulative percentage of variance approached 80 percent. The scores of rotated component loadings (correlation coefficients) from the PCA output were used to identify the main soil and vegetation components. The rotated component loadings for the variables were determined using Varimax rotation (variance maximization); the idea of Varimax rotation is that each variable should load heavily on few components as possible to make interpretation easier (Eni *et al.*, 2011).

Variables were also rotated to obtain new significant and uncorrelated variables called principal components or principal axes. On each component, variables with loadings ≥0.70 were identified as significant variables and used for discussion of the soil-vegetation data structure. In order to determine main components, only principal components with eigenvalues greater than unity (.i.e. 1) were selected, components with eigenvalues < 1 accounted for less variance than did the original variable (which had a variance of 1), and so were of little use, as such were not extracted. From each extracted component, variables with coefficients ≥ ±0.70 were selected and considered significant (Johntson, 1980 and Wotling *et al.,* 2003 quoted in Apper, 2006). However, in order to determine the basic soil and vegetation variables sustaining these interrelationships, the concept of component defining variable (CDV) which stipulates the selection and subsequent naming of variables with the highest component loadings (correlation coefficient) as variables that provide the best relationship (Mbagwu *et al.,* 1994; Johntson, 1980 and Wotling *et al.,* 2003 quoted in Apper, 2006) was employed. Nevertheless, scores of the rotated principal components obtained for both variables (soil and vegetation) were used for canonical correlation and multiple regression analyses. Canonical correlation analysis (CCA) was performed to examine the main ways in which the properties of soil were related to those of vegetation. Theoretically, canonical correlation is a symmetrical technique such that the distinction between predictor and criterion variables is not needed. The essence of canonical analysis is the formation of pairs of linear combinations of two sets of variables in such a way as to maximize the correlation between each pair. This analysis provides a clearer picture of the complex interrelationships between soil and vegetation variables. In addition, multiple regression analysis (MRA) was also performed using the rotated principal components of soil and vegetation data; this linear combination of soil and vegetation variables was used to examine the relative effects of soil components on vegetation characteristics and vice versa.

3. Results

PCA result on soil properties

Table 1 depicts loadings of rotated components on soil properties. It showed that five components with eigenvalue loadings ≥1 were extracted and they accounted for 80 percent of the total variance in the original data set. Based on the threshold of ≥0.70 as significant loadings, two soil properties loaded heavily on component 1, they included exchangeable sodium (0.90) and exchangeable magnesium (0.85); this component measured exchangeable bases and accounted for 2.18 eigenvalue loading and 16.8 percent total variance in soil data set.

On component II, two soil properties loaded heavily on it, these included organic matter (0.90) and total nitrogen (0.79); this component represented organic matter concentration and as such, accounted for 2.18 eigenvalue loading and 16.7 percent total variance in the linear combination of soil variable. Component III had also two soil properties that loaded heavily on it and accounted for 16.0 percent total explanation in the soil data.

The two soil properties identified on this component were cation exchange capacity (-0.84) and base saturation (0.81); this component in essence measured the effect of CEC content in the soil. Also, on component IV, only exchangeable calcium loaded heavily with coefficient value of 0.90. This component exemplified the effect of calcium content and accounted for 15.5 percent of the variance in soil data. In addition, two soil properties loaded heavily on component V, they included sand content (-0.87) and clay content (0.82); this component exemplified soil substrate condition and accounted for 14.4 percent of the total variation in the linear combination of soil variable. However, based on the criteria of CDV, the basic soil factors that supported vegetation productivity and sustainability included exchangeable sodium, organic matter, cation exchange capacity, exchangeable calcium and sand content.

PCA result on vegetation parameters

Likewise, the loadings of rotated components on vegetation parameters are depicted in Table 2 (significant variables were vegetation variables with loadings ≥0.70). From the table, two components with eigenvalue ≥1 (larger than unity) were extracted and they accounted for 81 percent of the total variance in the vegetation data set. Three vegetation parameters loaded heavily on component 1; they included tree size (0.97), aboveground biomass (0.96) and tree height (0.88). This component was regarded as measuring tree size and vegetation structure and accounted for 3.11 of the total eigenvalue loading and 44.5 percent variance in the linear combination of vegetation parameters; while on component II, three parameters also loaded heavily on it, which included tree density (0.96), species diversity (0.93) and species composition (0.72). This component represented tree density and floristic attributes and accounted for 2.58 total eigenvalue loading and 36.9 percent variance in vegetation dimension. Again, in accordance with the concept of component defining coefficients (CDV), it implied that the main vegetation parameters protecting the soil included tree size and tree density (Table 2).

Canonical correlation analysis

Canonical Correlation analysis (CCA) is one of the most general of the multivariate techniques that is used to investigate the overall correlation between two sets of variables. It examines the main ways in which two multivariate measures are related as well as the strength and nature of the interrelationships (Aweto, 1981; Sherry and Henson, 2005). The basic principle behind canonical correlation is determining how much variance in one set of variables is accounted for by the other set along one or more axes, which are orthogonal (uncorrelated). Unlike many other techniques, in CCA there is no designation that one set of variables is independent and the other set dependent, but for clarity, the predictor-criterion language has been used by scholars for presentation (Laessig and Duckett, 1979). However, from the two variables, a linear combination is derived such that the association/relationship between them is maximum these pairs of maximally correlated linear combinations are called canonical variates, (Hair *et al.,* 1998; Aweto, 1981).

Table 3 shows the results of correlating the five soil properties with the two dimensions of vegetation characteristics. The canonical correlations for the first and second canonical functions (or axes) were 0.99 and 0.97 respectively and were significant using the Bartlett's (1941) test at 5 percent significance level. However, in the literature, the significance of the canonical correlation is believed to be insignificant in making valid conclusions, as there are contentious arguments on using the significance of canonical correlation to make conclusion as well as determine the number of canonical variates or functions to retain for the purpose of making inference. The reason being that significance test tells us absolutely nothing about the magnitude of the relationship (that is, it does not reveal the amount of variance shared by the two sets of variables), and its statistical significance is heavily influenced by sample size; as it is possible for the test to be statistically significant with large sample sizes (see Sherry and Henson, 2005; Schul *et al.,* 1983; Lambert and Durand, 1975; Green, 1978; Laessig and Duckett, 1979). On this note, the use of redundancy coefficient and cross loading was suggested as they reveal the amount of variance shared by the two sets of variables (Sherry and Henson, 2005; Schul *et al.,* 1983; Henson and Smith, 2000; Lambert and Durand, 1975).

Redundancy coefficient or index is an asymmetric index that measures how much variance in one set of variable (say soil properties) is shared by the variability in the other set of variable (vegetation characteristics) (Schul *et al.,* 1983). On the same note, Canonical cross-loading involves correlating each of the original observed dependent variables directly with the independent canonical variate, and vice versa. Thus cross-loadings provide a more direct measure of the dependent–independent variable. Another important output of canonical correlation is the canonical loading otherwise referred to as canonical structure correlation. Canonical loading reflects the variance that an observed variable in one set of variables shares with the canonical score for that set. Invariably, canonical loading measures the simple linear correlation between the canonical function (soil and vegetation) and their respective canonical variates (Hair *et al*., 1998). However, the redundancy result in Table 3 shows that the redundancy coefficient for first canonical variate for soil properties indicated that 18 percent of the variance in vegetation characteristics on the first canonical variate was accounted for by the variability in soil properties; likewise, the redundancy coefficient for second canonical variate for soil properties indicates that 12 percent of the variance in vegetation characteristics was accounted for by the variability in soil properties.

The redundancy result for vegetation characteristics equally showed that 81 and 16 percents of the variance in soil properties on the first and second canonical variates were accounted for by the variability in vegetation characteristics. However, an inspection of the cross-loadings for both dimensions of soil and vegetation variables showed that only three soil properties on the first axis (exchangeable sodium, organic matter and substrate condition) had scores above 0.30 level of significance suggested by Schul *et al.,* (1983) as an acceptable minimum loading value, with substrate condition displaying an inverse relationship. While on the second axis, two soil properties, exchangeable sodium and substrate condition had significant values above 0.30. On the vegetation dimension, tree size and tree density had scores greater than 0.30 on the first axis, but only on tree size on the second axis. These results implied that exchangeable sodium, organic matter and substrate condition were positively and negatively related to the vegetation variables (tree size and tree density) on the first variate and on the second, exchangeable sodium and substrate condition happened to be positively related to tree size. Furthermore, results of the three soil properties revealed that 34 percent (0.58^2) variance in exchangeable sodium, 50 percent (0.71^2) variance in organic matter and 9 percent (0.30^2) variance in substrate condition was explained by the first canonical function or axis, while 14 percent (0.37^2) variance in exchangeable sodium and 38 percent (0.62^2) variance in substrate condition were explained by the second axis; on the other hand, 67 percent (0.82^2) and 98 percent (-0.99^2) variance in tree size and tree density attributes were explained by the first; while only 30 percent (0.55^2) variance in tree size was explained by the second canonical axis.

Based on the magnitude of relationships shared by the two sets of variables across the two canonical variates (considering the redundancy coefficient and canonical cross-loadings), the first canonical variate was chosen for further explanation, because it explained a large proportion of the variation in soil and vegetation dimensions. On this note, the results of canonical loading or canonical structure correlation (Table 3) showed that the first linear combination of soil properties loaded positively and heavily on organic matter, while the first linear combination of vegetation characteristics loaded positively and heavily on tree size and negatively on tree density; this therefore implied that positive correlation existed between organic matter and tree size, while the linear association between organic matter and tree density depicted an inverse relationship. In essence, the result of the first canonical function/axis showed that organic matter and tree size were positively and directly related; implying that an increase in organic matter in the soil would result in a corresponding increase in and tree size and vice versa, while tree density and organic matter showed an inverse relationship meaning increase in the levels of organic matter in the soil would affect the growth of trees (tree density) in the area.

Multiple Regression Analysis of Soil-Vegetation Relationship

The soil-vegetation variables selected and used for the multiple regression analysis were obtained from the scores of the rotated soil and vegetation data set (Tables 1 and 2). These rotated factor scores were used to examine the relative effects of soil components on vegetation characteristics and vice versa. The simultaneous method otherwise referred to as ‘enter approach'' was employed in the analysis. According to Landau and Everitt (2004) this method is used if one has no reason to believe that one variable is likely to be more important than another, in this regards, each variable is entered into the model and its contribution assessed. However, among the vegetation characteristics, the effect of a set of soil properties was exerted mostly on species composition which indeed is a measure of floristic composition of vegetation. The regression for species composition (CP) is depicted in equation 1:

$$CP = 6.64 + 1.12(ES) - 0.37(OM) - 1.36(CEC) + 0.81(EC) - 2.63(SC) \qquad (1)$$

Where, ES is exchangeable sodium, OM is organic matter, CEC is cation exchange capacity, EC is exchangeable calcium content and SC is substrate condition. The result in equation 1 showed that exchangeable sodium was the most important soil property that affected the luxuriant and diverse nature of the vegetation. However, the correlation of the set of soil variables with CP showed a high positive association (0.81), while the regression model indicated that 65.9 percent of the variation in CP was accounted for by the combination of the soil properties. However, this high explained variation in CP as well as the positive relationship was insignificant at 5 percent alpha level (F-value$_{5, 7}$ = 2.71, F-$_{crit}$ = 3.97). The effects of explanatory variables (soil properties) on other vegetation components notably tree size, tree density, vegetation cover, species diversity, tree height and aboveground biomass were inconsequential and negligible due to the low explained variation which was below 30 percent. Nevertheless, of the soil properties entered into the regression model, only the linear combination of tree size (TS) and tree density (TD) provided substantial effect on the soil (OM and TN), the regression equation explaining this effect is depicted in equation 2 and 3. However, the regression for soil organic matter is shown in equation 3 as follows:

$$OM = -0.18 + 3.16(TS) + 2.79 \ (TD) \quad (2)$$

The combination of tree size and tree density resulted in 60.2 percent of the variation in the concentration of OM in the soil; and between the two vegetation characteristics, TS exerted the most influence on the soil. The correlation showed there was a high positive relationship (0.78) between vegetation characteristics (TS and TD) and soil organic matter content. This high variation in CP and the positive relationship was insignificant at 5 percent alpha level (F-value$_{2, 4}$ = 3.03, F-$_{crit}$ =6.94). The regression for total nitrogen content (TN) is:

$$TN = -0.03 + 0.42(TS) + 0.39 \ (TD) \quad (3)$$

Like in OM above, the combination of vegetation characteristics (tree size and tree density) resulted in 59.8 percent of the variation in the concentration of TN in the soil; and between the two vegetation characteristics, TS still exerted the most influence on the soil. The correlation showed there was a high positive relationship (0.77) between vegetation characteristics (TS and TD) and soil organic matter content. This positive relationship and explained changes in TN was insignificant at 5 percent alpha level (F-value$_{2, 4}$ = 2.77, F-$_{crit}$ = 6.94). This result implied that vegetation characteristics substantially influenced the levels of organic matter and total nitrogen in the soil of the area.

4. Discussion and Conclusion

The result of the canonical correlation analysis indicated that a pattern of relationship between soil and vegetation. The only retained canonical variate (the first canonical function) based on the results of redundancy coefficient and canonical cross-loading revealed a positive interrelationship between organic matter content and tree size, and an inverse relationship between organic matter concentration and tree density. In essence, it showed that organic matter concentration and tree size were interrelated; which implied that an increase in the content of organic matter in the soil would result in a corresponding increase in tree size and vice versa, while tree density and organic matter content showed an inverse relationship meaning increase in one would negatively affect the other. The importance of tree size in this association was the mere fact that increase in this component would lead to an increase in nutrient accumulation in the forest by increasing litter production and protecting the soil against accelerated nutrient (OM) destruction and subsequent loss through erosion. The implication of this is that tree size helps to improve the content of organic matter in the soil.

The levels of OM in the soil of the area may be attributed to the litter produced by the vegetation components through the dropping and subsequent decay of plant residues. The result of the regression analysis on the effect of vegetation characteristic on soil properties indicated that tree size as well as tree density exerted substantial influence on the availability of OM and consequently TN on the soil; of these two vegetation characteristics, tree size was more influential. This result is in agreement with the findings of Aweto (1981), when he reported tree size and vegetation cover as well as mesophanrophytes and tree density as the most important vegetation components that influenced soil organic matter concentration, CEC and water holding capacity. The signs of the regression coefficients suggested that tree size as well as tree density positively increased the concentration of organic matter and total nitrogen in the soil. This is because the two vegetation components helped to increase the amount of nutrient in the soil through litter accumulation, decay and the protection of the forest floor from nutrient destruction through the regulation of rainstorm and nutrient cycling. The regression for soil properties showed that ES positively influenced the luxuriant and rich nature of the forest in terms of the composition of tree species. However, the signs of the regression coefficients showed that CEC, OM and SC negatively influenced CP. The outcome of this relationship (negative regression coefficients) is unexpected for CEC and SC as simple Pearson's correlation between CP and CEC and SC were all positive, this situation according to Aweto (1981) can be blamed on the use of standardized components scores instead of the actual data in the analyses; but that for OM is expected due to the negative Pearson's correlation. This negative relationship was attributed to the high rate of OM addition through the accumulation of large plant residue (Eni *et al.,* 2011). According to Foth (2006), high organic matter contents in soils are the result of slow decomposition rates rather than high rates of organic matter addition.

However, the results of regression analyses showed that ES exercised potential effect on the rich and diverse nature of the forest ecosystem (species composition). Species composition in this study constituted the only vegetation component highly influenced by the combination of soil properties; this perhaps was evident in the forest ecosystem as its canopy was characterized by diverse tree species which in their individual stands exerted separate influence (climatic and edaphic) on the forest. Nevertheless, the results of both the canonical and regression analyses also suggested that vegetation characteristics most especially tree size exerted the great influence on soil fertility rejuvenation and restoration. This according to Aweto (1981) is expected in an environment with persistent precipitation which is possible to cause rapid destruction and loss of soil nutrient once vegetation is destroyed for infrastructural development as it is pertinent in the area. From the results obtained, it is worthy to say that soil properties as well as those of vegetation were strongly interrelated, and their separate effects on the forest ecosystem were dissimilar as the regression result revealed. At this point is it pertinent to conclude that soil and vegetation components of the secondary forest vegetation were mutually dependent and therefore exerted joint influences on each another as revealed by the results of canonical correlation analyses and those of multiple regression analyses.

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References

Akpabio, I. A; Eniang, E. A. and Egwali, E.C. (2006). Socio-Economic Potentials and Environmental Implications of Coastal Tourism at Adiabo, Cross River State, Nigeria. *Journal of Environment, Development and Sustainability, 10(3):76-82*

Alakpodia, I. J. (1992). *Vegetation-Environment Correlation Study of Riparian Micro-habitats of River Ethiope Basin, Delta State, Nigeria*. Unpublished Ph.D Thesis, University of Ibadan, Nigeria.

Aweto, A. O. (1981). Secondary Succession and Soil Fertility Restoration in South-Western Nigeria: Soil and Vegetation Interrelationships. *J. Ecology, 69, NO. 3:957-963*

Aweto, A. O. and Areola, O. (1979). Soil-Plant Interrelations during Secondary Succession in the Forest Zone of Nigeria, in Okali, D. U. U. (eds) *The Nigerian Rainforest Ecosystem*. Ibadan: MAB,243-261

Bray, R. H. & Kurtz, L. T. (1945). Determination of Total, Organic and Available Forms of Phosphorus in Soils. *Soil Science, 59:39-45*

Coulloudon, B, Eshelman, K, Gianola, J, Habich, N, Hughes, L, Johnson, C, Pellant, M, Podborny, P, Rasmussen, A, Robles, B, Shaver, P, Spehar, J. and Willoughby, J. (1999). *Sampling Vegetation Attributes. Technical Reference 1734-4, U.S*. Department of Agriculture, Natural Resource Conservation Service, Grazing Land Technology Institute.

Daly, B. K, Manu, V. T, Halavatau, S. M. (1984). *Soil and Plant Analysis Methods for use at the Agricultural Research*. New Zealand Soil Bureau Laboratory Report AN2

Eni, D.D., Iwara, A. I. and Offiong, R.A. (2011). Principal Component Analysis of Soil-Vegetation Interrelationships in A South-Southern Secondary Forest Of Nigeria. www.hindawi.com/journals/ijfr/aip/469326.pdf

George, R. J., McFarlane, D. J. and Nulsen, R. A. (1997). Salinity Threatens the Viability of Agriculture and Ecosystems in Western Australia. *Hydrogeology Journal, 5:6–21*

Green, P. E. (1978). *Analyzing Multivariate Data*. Hinsdale, IL: The Dryden Press.

Hair, J. F., Anderson, R.A., Tatham, R. L. and Black, W. C. (1998). *Multivariate Data Analysis,* 5th edition. New York: Prentice Hall, Inc.

Hauser, D. P. (1974). Some Problems in the use of Stepwise Regression Techniques in Geographical Research. *Canadian Geographers, 18:148-158*

Henson, R. K. and Smith, A. D. (2000). State of the Art in Statistical Significance and Effect Size Reporting: A Review of the APA Task Force Report and Current Trends. *Journal of Research and Development in Education, 33,* 284–294.

Iwara, A. I. (2009). *Impact of Road Construction on Soil and Vegetation Resources in Tinapa Area, Cross River State*. Unpublished M. Sc Thesis Submitted to the Dept. of Geography, University of Ibadan, Nigeria

Jennings, S. B, Brown, N. D. and Sheil, D. (1999). Assessing Forest Canopies and Understorey Illumination: Canopy Closure, Canopy Cover and other Measures. *Forestry 72(1): 59–74.*

Kent, M. and Coker, P. (1992). *Vegetation Description and Analysis: A Practical Approach*. New York: John Wiley and Sons

Laessig, R. E. and Duckett, E. J. (1979). Canonical Correlation Analysis: Potential for Environmental Health Planning. *Am. J. Public Health 69:353-359, 1979*

Lambert, Z. V. and Durand, R. M. (1975). Some Precautions in Using Canonical Analysis. *Journal of Marketing Research, 12:468-475*

Landau, S. and Everitt, B.S. (2004). *A Handbook of Statistical Analyses using SPSS*. New York Chapman & Hall/CRC Press LLC

Li, W, Xiao-Jing, L, Khan, M. A. and Gul,B. (2008). Relationship between Soil Characteristics and Halophytic Vegetation in Coastal Region of North China. *Pak. J. Bot., 40(3): 1081-1090*

Magurran, A. E. (1988). *Ecological Diversity and Measurement*. Princeton: Princeton University Press.

Nosetto, M. D., Jobbagy, E. G., Toth, T. and Di Bella, C. M. (2007). The Effects of Tree Establishment on Water and Salt Dynamics in Naturally Salt-Affected Grasslands. *Oecologia (2007) 152:695–705*

Offwell Woodland & Wildlife Trust. (2000). How to Calculate the Height of a Tree. [Online] Available: http://www.offwell.free-online.co.uk/wet_wood_survey_2001/height.ht.

Pluske, W, Murphy, D. and Sheppard. J. (2009). Organic Carbon. *www.soilquality.org.au*

Scanlon, B. R., Reedy, R. C., Stonestrom, D. A., Prudic, D. E. and Dennehy, K. F. (2005). Impact of land use and land cover change on groundwater recharge and quality in the southwestern US. *Global Change Biol 11:1577–1593*

Schul, P. L., Pride, W. M. and Little, T. L. (1983). The Impact of Channel Leadership Behavior on Intrachannel Conflict. *Journal of Marketing,* 47:21-34.

Sherry, A. and Henson, R. K. (2005). Conducting and Interpreting Canonical Correlation Analysis in Personality Research: A User-Friendly Primer. *Journal of Personality Assessment,* 84(1), 37–48.

Soil Map of Nigeria. (1964). [Online] Available: http://eusoils.jrc.ec.europa.eu/esdb_archive/eudasm/africa/maps/ afr ngsm1.htm

Ukpong, I. E. (1994). Soil-Vegetation Interrelationships of Mangrove Swamps as revealed by Multivariate Analyses. *Geoderma,* 64: 167-181.

Walkley, A & Black, I. A. (1934) An Examination of the Detjareff Method for Determining Soil Organic Matter and a Proposed Modification to the Chronic Acid Titration Method. *Soil Science,* 37: 29-38.

Woomer, P. L. (2006). Estimating Carbon Stocks in Smallhold Agricultural Systems. [Online] Available: http://www.formatkenya.org/ormbooks/Chapters/chapter7.htm

Table 1. Rotated components matrix of soil properties[a]

	Principal Components				
Soil Properties	1	2	3	4	5
Exch. Na	.900	.205	.282	-.012	.079
Exch. Mg	.852	.103	-.242	.038	.028
Organic Matter	.035	.903	.295	.000	.128
Total Nitrogen	.292	.798	-.082	-.101	-.241
Ph	-.028	-.639	.131	-.418	.178
CEC	.086	-.082	-.843	.124	.015
Base Saturation	.212	.062	.811	.204	-.269
Av. P	.151	.207	-.516	-.507	.419
Exch. Ca	.149	.048	.064	.896	-.087
Silt Content	.456	-.073	.113	-.622	-.203
Exch. K	.424	.421	.318	.483	.166
Sand Content	-.207	.065	.021	.187	-.873
Clay Content	-.171	-.139	-.283	.237	.823
Eigenvalues	**2.18**	**2.18**	**2.08**	**2.01**	**1.88**
% Variance	**16.78**	**16.73**	**16.01**	**15.50**	**14.44**
Cumulative Explanation	**16.78**	**33.51**	**49.52**	**65.02**	**79.46**

[a]Variables underlined with eigenvectors (coefficients) ≥ ±0.70 are considered significant

Table 2. Rotated components matrix of vegetation parameters[a]

	Principal Components	
Vegetation Parameters	1	2
Tree Size	.965	-.158
Aboveground Biomass	.956	-.105
Tree Height	.878	.138
Vegetation Cover	.670	-.461
Tree Density	-.137	.958
Species Diversity	-.162	.934
Species Composition	.040	.723
Eigenvalues	**3.11**	**2.58**
% Variance	**44.47**	**36.86**
Cumulative Explanation	**44.47**	**81.33**

[a]Variables underlined with eigenvectors (coefficients) ≥ ±0.70 are considered significant

Table 3. Result of canonical correlation analysis of relationships between soil and vegetation[a]

Variables	Canonical loading		Canonical cross loading	
	1	2	1	2
Soil properties				
Content of exchangeable bases	0.58	0.38	0.58	0.37
Organic matter concentration	0.71	0.15	0.71	0.15
Content of CEC	0.04	0.21	0.04	0.20
Calcium content	0.04	0.16	0.04	0.16
Substrate condition	-0.30	0.64	-0.30	0.62
	**Redundancy coefficient		0.18	0.12
Vegetation characteristics				
Tree size & vegetation structure	0.82	0.55	0.82	0.55
Tree density & floristic attributes	-0.99	-0.15	-0.99	0.14
	**Redundancy coefficient		0.81	0.16
Canonical correlation coefficient	0.99	0.97		
X^2	39.17*	28.28*		
Degrees of freedom	10	4		

[a]Variables underlined with canonical loadings ≥ ±0.70 are considered significant

*Significant at 5% significance level