

# Multivariate Analysis Applied to Forestry Agricultural Sciences: The Model-Directed Study

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**Abstract**— This is a literature review that aimed to find articles that exemplify and describe the use of multivariate analysis in different fields of Forest Agricultural Sciences, considering effective practices using multivariate statistical techniques for the simultaneous processing of data. For data collection were selected for the meta-analysis of 70 technical articles of which 54 were employed in the study directed to the use of multivariate techniques applied in the areas of agricultural sciences. The results showed that studies directed to certain areas within the Forest Agricultural Sciences exhibit some regularity in the use of multivariate analysis, and most application analyzes were more usual as the Cluster Analysis (AA) and Principal Component Analysis (PCA). Thus the use of multivariate analysis studies and evaluations of experiments in Agricultural Sciences proved to great value to allow greater clarity and better interpretation of dealing with complex phenomena.

**Keywords**— Multivariate Analysis, Multivariate Methods, Forest Agricultural Sciences.

## I. INTRODUCTION

Statistically data analysis is classified into univariate or multivariate, i.e., it variables alone or jointly respectively. According VICINI, 2005 until the advent of computers the data were treated only in isolation, and when a phenomenon depends on many variables such analysis became unfeasible.

Multivariate analysis corresponds to a large number of methods and techniques that utilize, simultaneously, all variables in the theoretical interpretation of the set of obtained data (Neto,

2004). According to Hair et al., (2009) multivariate techniques are popular because they allow organizations to create knowledge, thereby improving their decision-making. Multivariate analysis refers to all the statistical techniques that simultaneously analyze multiple measurements on individuals or objects under investigation.

For Gerhardt, et al., 2001 multivariate analysis comes to data through a set of statistical techniques considering measures many variables simultaneously. And to obtain such results some multivariate methods are applied to data depending on the research objectives, since it is known that an exploratory data analysis, aims to generate hypotheses that is exactly the goal of the multivariate analysis (VICINI, 2005).

Multivariate analysis is a vast field in which even experienced statistical move carefully, because this is a new area of science, much is yet to be discovered. The art of the use of multivariate analysis is the choice of the most appropriate options to detect the standards expected in the data (MAGNUSSON, 2003).

The purpose of their application may be to reduce data or structural simplification, sort and group, to investigate the dependency between variables, prediction and develop hypotheses and test them (JOHNSON; WICHERN, 1992).

Multivariate techniques can meet the specific interests of a forestry company or a research institution, aiming at a particular interest, apart from a property or set of properties. Thus, this study aims to quantify and clarify what and how the main tools of multivariate analysis applied in various areas of study of forest agricultural sciences are used, reviewing a number of literature

articles updated where various techniques of multivariate analysis are used.

## II. REVIEW

The application of multivariate analysis is a combination of multiple information entered in the experimental unit, so that the selection is based on a complete set of important variables that discriminate between materials that are more promising (Maeda et al., 2001). Since the multivariate techniques have numerous applications, one needs to know about the main of them being applied in the areas of Forest Agricultural Sciences, its functions and objectives. We as the main examples of multivariate techniques, multivariate normal distribution, matrix and vectors, quadratic forms, eigenvalues and eigenvectors, analysis of multivariate variance - MANOVA, the multivariate linear regression models, simultaneous tests on several variables, multivariate distances, component analysis, factors analysis, cluster analysis and discriminant, canonical correlation analysis.

### Factor analysis

Factor Analysis (FA) aim to reduce the number of initial analysis with the least possible waste of information, taking advantage of a set statistical techniques (VICINI, 2005). CARVALHO, 2013 says that whenever there is a strong correlation with variables is conceivable to group them into a group, since different variable groups have weak correlation.

Factor analysis is applied when there is a large number of variables and correlated, includes principal component analysis and analysis of common factors, in order to identify a smaller number of new alternatives variables, uncorrelated and that somehow, summarize the main information of the original variables finding factors or latent variables (Mingoti, 2005).

According to Carvalho, 2013 generic formula for applying a factor analysis is defined by:

$$X = \mu + \Lambda F + \varepsilon \quad (1)$$

Whereas  $X = [X_1 X_2 \dots X_p]^T$  as a real random vector of dimension  $P$ , with mean vector  $\mu = [\mu_1 \mu_2 \dots \mu_p]^T$  and covariance matrix  $\Sigma$  variance-defined positive. The model of factorial analysis each observable variable  $X_i$  expressed as a linear function of  $m$  random variables  $F_1, F_2, \dots, F_m$  ( $m < p$ ), called common factors, and one factor or error,  $\varepsilon_i$ ,  $i = 1, 2, \dots, P$ . Which it is also a random variable that explains the part of the respective variable variance not explained by common factors. Already  $\Lambda$  would be the matrix (PXM), the common factors  $m$  and  $p$  only factors are not observable.

### Method Kaiser-Meyer-Olkin (KMO)

Using factor analysis there is an adequacy of data that is very important proposal by Kaiser-Meyer-Olkin (KMO). The KMO test is based on the principle

that the inverse correlation matrix approaches the diagonal matrix, therefore compares the correlations between observed variables Solomon et al., (2012).

According VICINI, 2005 KMO can be obtained by the following equation:

$$KMO = \frac{\sum_i \sum_j r_{ij}^2}{\sum_i \sum_j r_{ij}^2 + \sum_i \sum_j a_{ij}^2} \quad (2)$$

The ratio of the sum of the squares of the correlations of all variables is divided by itself, plus the sum of the squares of the partial correlations of all variables.

At where:

=  $r_{ij}$  is the correlation coefficient between the observed variables  $i$  and  $j$ .

=  $a_{ij}$  is the partial correlation coefficient between the same variables. The  $a_{ij}$  should be close to zero, because the factors are orthogonal to each other.

So that the data can fit the factor analysis should be noted the following regarding the value found in Kaiser's equation:

Table.1: Relationship between the KMO and the use of Factor Analysis

KMO	Recommendation AF
$\geq 0.9$	Great
$\geq 0.8$ and $< 0.9$	Good
$\geq 0.7$ and $< 0.8$	Average
$\geq 0.6$ and $< 0.7$	Acceptable
$\geq 0.5$ and $< 0.6$	weak
$\leq 0.5$	Unacceptable

Source: CARVALHO, 2013

### Sphericity test Bartlett

Another test used widely in the factor analysis is to Bartlett sphericity test (BTS), which tests the following hypothesis: the correlation matrix is an identity matrix, ie the values of the main diagonal are equal to 1 and the other figures be zero, concluding that its determinant is equal to 1. This means that the variables have no correlation and the null hypothesis can be rejected if the adopted  $\alpha$  is equal to 0.05 or 5% and the value found is less than the value of  $\alpha$ . (Pereira, 2001).

Bartlett's test evaluates the overall significance of the correlation matrix, i.e. tests the null hypothesis that the correlation matrix is an identity matrix Solomon et al., (2012).

### Principal Component Analysis

The goal of the principal component analysis (PCA) is to address issues such as the generation, selection and interpretation of the investigated components. Intending thereby determine the most

influential variables in the formation of each component (VICINI, 2005).

According to Castro et al., 2013 by the ACP, a random vector can be explained by the variance and covariance structure (composed of random variables  $p$ ) by constructing linear combinations of the original variables.

Through data covariance matrix becomes a major component estimated. For the application of analysis it is necessary to standardize the data so that the whole series will have the same magnitude of values. After obtain the eigenvectors that are values representing the weights of each component in each variable and range of (-1 to 1) and function as correlation coefficients that represents the contribution of each component to explain the total variation of the data (Ruhoff et al., 2009).

### Clusters analysis

The Cluster Analysis or Cluster (AA) in multivariate data identifies groups of objects. The goal is

to form groups with homogeneous properties of large heterogeneous samples. Should be sought more homogeneous groups possible and that the differences between them are as large as possible (Hair et al., 2005).

The AA encompasses a variety of techniques and algorithms, and the goal is to find and separate similar data in the same group and are distinct from the data of the other groups (VICINI, 2005).

According to Ruhoff et al., 2009 AA seeks to group data elements that are more like each other. The groups are determined so as to obtain homogeneity between the elements of the groups and heterogeneity between them.

### Dendrogram

As a result of AA we get the dendrogram or phenograms also known as graphic tree that is graphic with a summary of the groups obtained by the analysis.

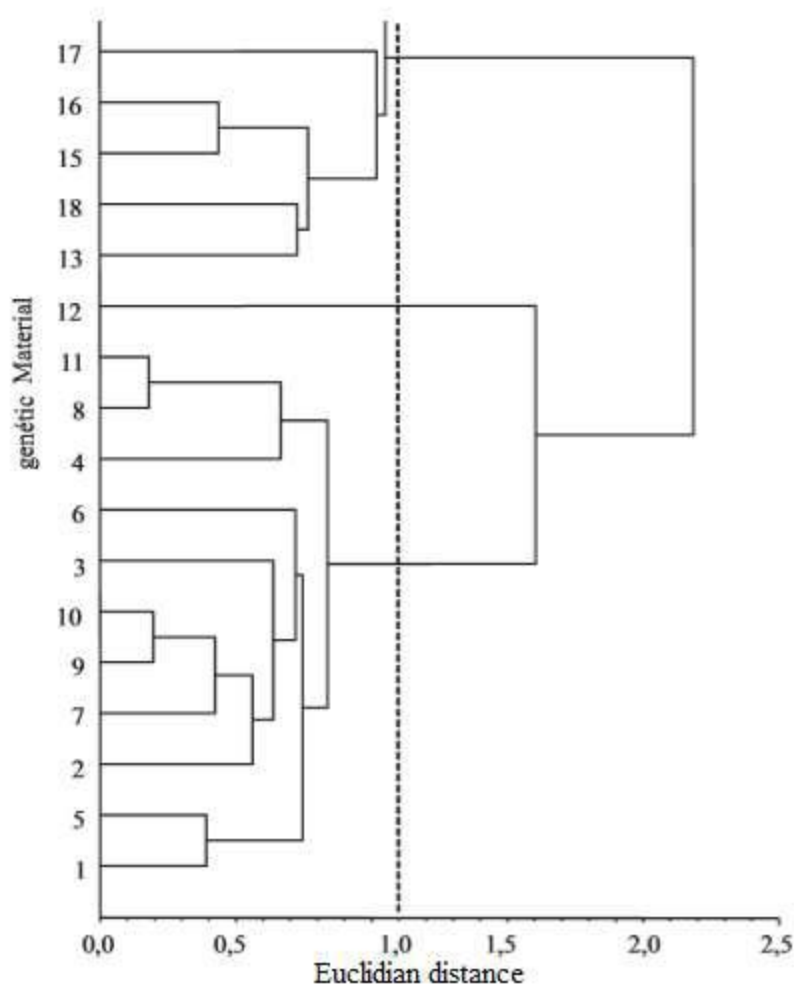


Fig.1: Grouping according to the quality of wood for the production of charcoal, obtained by simple connection method to use the Euclidean distance.

Source: CASTRO et al, 2013.

It is observed in Figure 1 that the genetic material of 11:08 have the greatest similarity dendrogram, by having the smallest Euclidean distance being such as

to form the first group. So then come variables 10:09, and after 1 and 5, and so on, the variables are grouped in descending similarity order, ie 12 variable formed the last

group of the dendrogram, which remained If different from the other groups formed, because this variable has little resemblance to the others.

#### Distance Euclidean

In Cluster Analysis some distance measurement coefficients are important, and among them is the Euclidean distance also known as dissimilarity measure. According PARENTS; SILVA; Ferreira (2012) considering two points A and B, the Euclidean distance can be calculated with the following formula:

$$\text{Distance between A and B} = DAB = \sqrt{\sum p_j = 1 (x_{ja} - x_{jb})^2} \quad (3)$$

In matrix form, this distance is given by:

$$DAB = \sqrt{(x_a - x_b)' \cdot (X_a - X_b)} \quad (4)$$

#### Mahalanobis distance

The similarity between samples (treatment, individuals, populations) correlated to a set of characteristics and the distance between any pairs of sampling units, the degree of dependence between variables must be considered. To quantify distance between two populations when there is data repetition, it is recommended to use the Mahalanobis distance ( $d^2$ ) (VICINI, 2005).

#### Canonical Correlation Analysis

The Canonical Correlation Analysis (CCA) has as its main objective the study of existing linear relationship between two sets of variables. Applying this analysis summarizes the information of each response variables set in linear combinations seeking to maximize the correlation between the two sets (Mingoti, 2005). The ACC is a type of statistical technique in the multivariate analysis which aims according to Protasio et al., 2012 to check associations between groups with different characteristics.

This multivariate analysis model allows to discover the relationship between two groups or sets of variables, increasing the correlation between the vectors of independent and dependent variables Burt, (2015).

#### Multiple Regression Analysis

Multiple regression provides the changes in the dependent variable in accordance with changes in the independent variables. The method is suitable when there is a single analysis dependent variable metric related to two or more independent variables (Hair et al., 2005).

#### Discriminant analysis

The multiple discriminant analysis consists of a set of tools and methods used to distinguish populations groups and classifying new observations in certain groups and used when groups are known a priori (Mingoti, 2005).

#### MANOVA / MANCOVA

The multivariate analysis of variance and covariance is also known as MANOVA (multivariate analysis of variance) and MANCOVA (multivariate analysis of covariance), aim to verify the similarity between multivariate groups simultaneously exploring the relationship between several independent variables and two or more variables dependent metrics (Hair et al, 2005).

### III. RESULTS AND DISCUSSIONS

In this study we selected 54 subjects who treat articles that are inserted in the area of Agricultural Sciences Forest with the application of multiple multivariate statistical methods. The articles selected were published between 1990 and 2018 and in this range in 2015 has been the year with most publications, 8 in total, followed by 2003 and 2012 with 6 each publications. In contrast the years 1990, 2002, 2005, 2011, 2016 and 2017 contributed one article.

Dealing with multivariate analyzes, among the most used in the selected works we can mention among the most important the grouping or cluster analysis used 25 times, followed by Component Analysis Principal 20 times, the factor analysis 10 times, a Canonical Correspondence Analysis which was used 9 times and 8 times Discriminant Analysis.

Since the case of the multivariate analysis used in each study, we observed a pattern between the multivariate method used and certain lines of research in the area has been established. Knowing this we sought to verify this pattern lines separating the search by subject and quantifying which types of multivariate method used was more.

#### Multivariate analysis ins studies involving managements soil

Of the 11 works found in this area can be seen in studies Freitas et al. (2015b) and Mantovanelli et al.(2015) using the same multivariate Cluster Analysis (AA), Principal Component Analysis (PCA) and MANOVA the applicant ACP and the most jobs found in this area as it is noted in studies SILVA; et al., (2010a) SILVA; et al., (2010b), Oliveira; et al., (2015) (JORDAN, 2018) SILVA et al., (2009), BARRETO et al., (2006). In addition to the AA already applicant, it was also used multivariate techniques such as discriminant analysis (DA), Canonical Correspondence Analysis (CCA) and factor analysis as noted in the articles ofGerhardt; et al. (2001), Baretta;Baretta; Cardoso(2008) and BENITES et al., (2010).

#### Multivariate Analysis in environmental studies

This area of study other 12 works were selected of which can be seen the use of factor analysis the most recurrent among multivariate methods as noted in the study Scatena, (2005), Campos et al., (2015), Cunha et

al., (2008) Parents; Silva; Ferreira (2012), Pinto; Col., (2014), Silva; Feather; Souza (2015). Other analyzes Multivariate as Regression Analysis Calijuri et al. (2009), Discriminant Analysis Braga et al. (2009), Clustered SILVA Analysis, (2003) were also used to a lesser extent in this area of study.

Articles of BERTOSSI, (2013), BERTOSSI et al., (2013), HUGO et al., (2012), applying multivariate analysis data indicators of water quality, it is noted that all studies Valley ACP main multivariate analysis to analyze the data.

#### **Technical analysis of multivariate in experiments involving forests and Forest products of origin**

In this part of 31 studies not fit this line of research which were separated in sub-items for better visualization of multivariate analysis applied in the aforementioned area of study.

Considering the application of multivariate analysis of floristic data analysis 7 items fall into this issue where there was no standard in the use of multivariate methods getting use well distributed in this type of study, it was noted that HIGUCHI et al., (2012 ) and Higuchi et al., (2013) took advantage of the ACP and the AA to analyze your data and dealing with similar themes applied in different areas in areas of Santa Catarina methods have adapted perfectly to the proposed studies. In PEIXOTO work (2004) in Rio de Janeiro and Narvaes; LONGHI; BRENA, (2008) in Rio Grande do Sul, also because it is similar studies in different areas of the same multivariate technique can be applied to both studies and AA managed to separate the similar data in different groups where using the dendrogram and Euclidean distance data were easily spotted. Still treating the flora analysis Souza et al., (2003a) and BERTANI (2001) took advantage of the ACC to analyze the floristic diversity in riparian forests. Lastly SOLOMON; JUNIOR; SANTANA, (2012) used the factor analysis to carry out the floristic analysis of primary forest for restoration of a mined area.

In studies dealing with the quality of wood for energy purposes, each author made use of different multivariate statistics for the analysis of data as can be seen in Protasio et al., (2012) with only the ACC could verify the associations between the group formed by the characteristics of Eucalyptus clones with the characteristics of the group formed by her charcoal obtained. Already Castro et al., (2013) used three multivariate analysis they being the ACC ACP and AA that through them it can be concluded that the properties of charcoal are strongly correlated to the wood, especially the apparent density of charcoal and the gravimetric yield. GADELHA et al. (2015) has focused his study of this same area MANOVA multivariate method used to

evaluate which clones of eucalyptus is the production for energy purposes.

In plant stratification 3 selected studies make use of the same methodology for the processing AA and AD as can be seen in the articles of SOUZA et al., (2003b), Souza et al. (2006) and Souza et al. (2012) and multivariate classification of the forest classes of volumetric stocks proved to be an efficient method for laminating homogeneous areas in the three types of forest, which can be constituted by extracts, compartments, site classes and annual production units .

Reforestation of mined areas CUNHA et al. (2003) and / or degraded LOSCHI et al., (2011) there was a similarity in the use of multivariate ACC that despite distinct areas there was a similarity in the results presented by the same analysis. Oliveira et al. (2016) made use of the ACP which showed efficient use of multivariate analysis in response to a high variance data, is used as a tool for annual use, may best reference ecological standards of the area, can be used to identify indicators of forest restoration.

In studies aimed at planting was unanimous the use of AA as noted in Article developed by Grigolo et al. (2018). In four studies selected 3 of them also used the ACP to complement the study as noted in studies of NETO et al., (2018) and Ruhoff et al. (2009). The use of principal components showed that higher yields are correlated with proper growth of the shoot, in conditions of lower bulk density, providing high dry matter production of roots (FREDDI; FERRAUDO; CENTURION, 2008).

In studies involving forests of the 11 selected articles met similarity in the use of multivariate analysis in studies Rovedder et al., (2014) and LÚCIO et al. (2006) They used the ACP to reduce the maximum number of variables that could represent possible and most of the variance found. However, studies Almeida et al. (2015) and CANUTO et al., (2015) used the AA to separate the samples that have greater similarity in different groups and thus can make a better analysis of the sampled data. In the study by MACHADO (2004) Rectified Correspondence Analysis, LONGHIL et al., (2009) Regression Analysis, Silva et al., (2012) Factor Analysis, MARTINS; SAUCER; OLIVEIRA, (2002) and MANOVA Canonical Correspondence Analysis (ACC), TRUGILHO; LIME; MORI (2003) ACC Oliveira et al. (2017) Discriminant analysis (DA), Souza et al. (1990) AD and Cluster Analysis, We can not show a pattern in the use of multivariate analysis where each author made use of a different method to analyze your data.

#### **IV. CONCLUSION**

Presented results it is seen that studies directed to certain areas within the Forest Agricultural Sciences have



certain regularity in the use of multivariate analysis, making use of the same techniques to observe its data. And that because of the use of multivariate analysis deduce from some knowledge, very complex methods are rarely used in the searched items in exchange for simpler analysis that were most useful as the Cluster Analysis (AA) and Principal Components Analysis (PCA) which were the most widely used. But the determining factor in the choice of multivariate analysis applied is the purpose of the analysis, which generally applies in the simultaneous analysis of multiple sets of factors when it needs to reduce data, identify relationships between variables, split group of similar factors among others.

The use of multivariate analysis studies and evaluations of experiments in Agricultural Sciences proved to great value to allow greater clarity and better interpretability of dealing with complex phenomena.

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