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Sustainability, Farming Systems and the MCDM Paradigm: Typification of Farming Systems for Modelling

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Abstract

In the recent past numerous papers have used mathematical programming methods to analyse the environmental and economic problems of farming systems. Unfortunately the existence of heterogeneity amongst farming systems in any area is not given its due recognition in most of the papers. The current paper uses factor and cluster analysis to construct a typology of peasant farming systems in Central Chile. The main sources of differences amongst the clusters obtained is labour availability for a farming system. This is an important result, as the typological scheme that has been constructed is to form the basis of analysis of the development policies for the region. Despite the difficulties connected with validating the results, the distribution of clusters along established Counties and productive orientation of farming systems, is a strong indication that the scheme captures the structure underlying the data.

Introduction

Sustainable agriculture "... should involve the successful management of resources for agriculture to satisfy changing human needs, while maintaining or enhancing the quality of he environment and conserving the natural resources" (FAO, 1989); thus the improvement of a system's sustainability has to be examined within a systems perspective that would require the satisfaction of multiple and often conflicting objectives. Evidently then multi-criteria decision making (MCDM) methods should provide a convenient tool of analysis. These models are also well suited for environmental and economic research, because 'trade-offs' amongst environmental and economic elements can be evaluated explicitly; the environmental considerations can be included in the model as an objective, as a constraint, as an activity, or as a parameter; and the effect of various policies on the farm production or the environmental impact of a given farming system (FS) can be estimated.

Nevertheless, in such type of research a basic problem is the level of resolution of analysis; lower levels, a field or a farm, are usually not able to cope with the larger political, economic and social environment, while higher levels, regional or national models, use aggregated data, failing to consider the heterogeneity of farming systems. An intermediate or 'micro-regional' perspective on sustainability is proposed, corresponding to a geographic planning area with similar agro-ecological features, similar water availability, a given pattern of FSs, and a recognisable unit of socio-economic integration in terms of access to markets, agro-industries and roads (INDAP, 1993). Despite such a definition of micro-region, FS heterogeneity within it would still exist. Thus typification of existing systems would still be required in such intermediate level analysis. In what follows, a method to construct FS using multivariate statistical analysis is described. Real representative farms from these FSs are subsequently used to analyse the impact of local development policies on the agricultural sustainability of peasants FSs considering the micro-region as the unit of analysis using the MCDM paradigm. However, this paper presents only the results of the typification exercise.

A framework for the typification of farming systems

The ordering of farms into types has been present in agriculture from the beginning of this century. Although it was early recognised that typification had to be based on quantitative methods (Kostrowicki, 1977), FS typification has been usually been done from a geographic point of view or based on simple hierarchical univariate classifications (for example Spedding, 1988 Chapter 7; and Beets, 1990 Chapter 6). Nevertheless, the improvement of computing facilities and the development of powerful statistical tools has allowed to use quantitative methods for the identification of FSs.

The procedure reported here to construct such FSs had four stages (modified from Escobar and Berdegué, 1990): Determination of a specific framework for typification; variable selection and data collection; multivariate statistical analysis; and validation of the typology. The purpose of the typology was to identify relevant FSs and select representative farms from them to evaluate the response of peasant FSs to local development policies. It was hypothesised that these responses would depend essentially on the resources available, that is labour, land and capital and that thus the typology had to be based on those factors.

A typology of peasant FSs in Central Chile

The micro-region under study consists of three Counties located in the Coastal Mountains of Central Chile (VIth Region). A random sample of 67 farms was chosen to collect secondary data regarding location, household structure, available labour and land, productive orientation, and livestock. Four criteria were used to determine which of the variables would be used in clustering. First variables with missing data and then variables which were deemed irrelevant for the purpose of this study were discarded. Next variables with low variability (coefficient of variation < 50%) were discarded as they did not contribute to a measure of dissimilarity between individuals. Finally correlated variables were discarded as the uncritical use of highly correlated variables to compute a measure of similarity is essentially an implicit weighting of these variables (Aldenderfer and Blashfield, 1984). As a result of the initial set of 33 variables 11 were kept for further analysis. The high number of variables discarded, specially because of correlations between them confirms that typification data sets should contain little variables but many observations (Escobar and Berdegué, 1990).

To further reduce the number of variables, principal component analysis was used to construct 11 factors. Considering that a strict selection of variables had be done and that Eigenvalues showed an homogenous reduction (Figure 1), it was decided that a rather large number of factors should be retained. As a result, the first seven factors were extracted explaining 85.4% of the total observed variation and at least 70.0% of every original variable's variation.

The seven retained factors were used to construct the clusters using Ward's minimum variance criterion and the squared Euclidean distance as the distance measure. This method optimises the minimum variance within clusters tending to create clusters of relative equal sizes and shapes as hyperspheres (Aldenderfer and Blashfield, 1984).

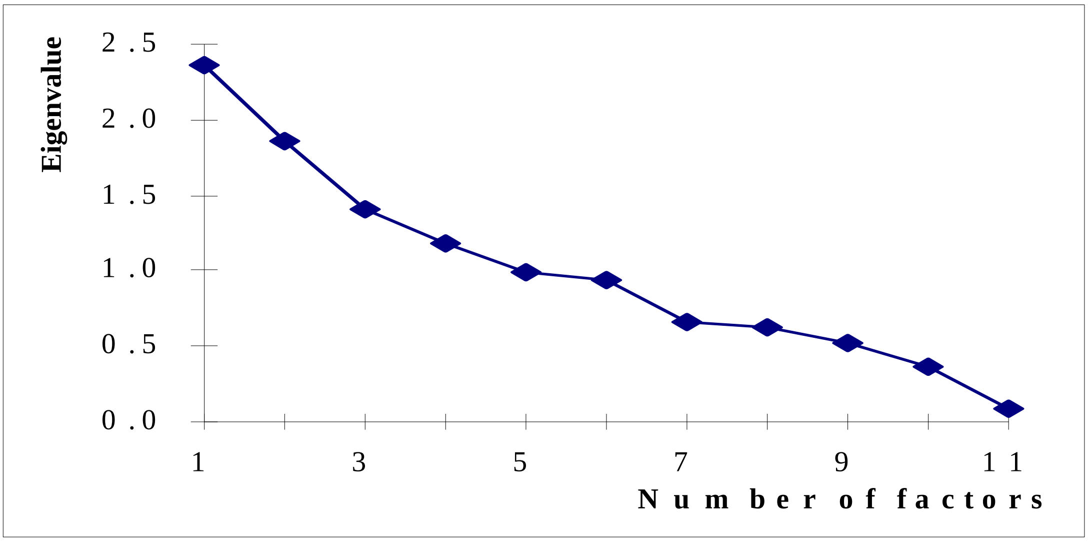

Figure 1: Eigenvalues vs. number of factors

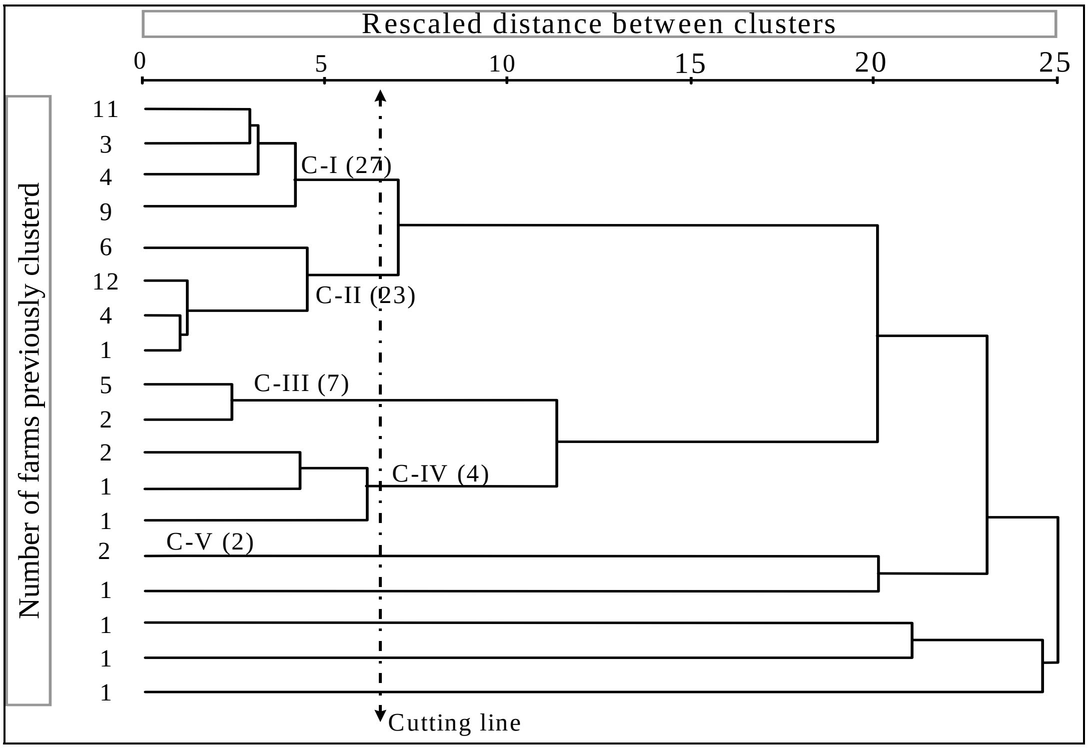

Figure 2.: Dendrogram showing the last 18 mergers, and the selected clusters with their number of observations

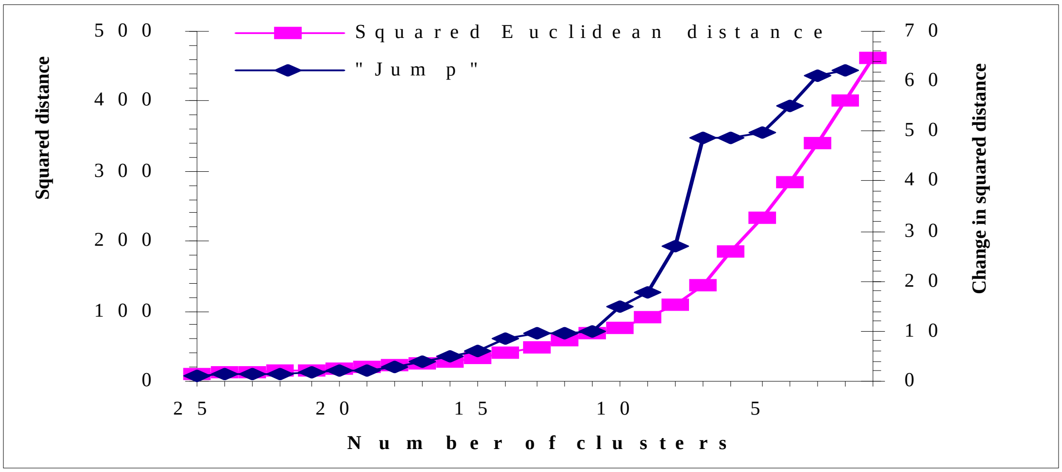

Figure 3: Plot of squared Euclidean distance and change of squared Euclidean distance against number of clusters.

The visual cutting line applied to the dendrogram (Figure 2) showed that 5 clusters could be recognised (C-I to C-V), while 4 farms remained unclassified.Following a more formal approach, both the distance coefficient and its increase were plotted against the number of clusters (Figure 3). It was seen that until 18 clusters remained, the distance between joining clusters was small and without important jumps. Then the increase in the value of coefficient became bigger, but no meaningful jump was observed until 11 clusters were left. The next clustering produced a jump (as did the following stages), suggesting that an appropriate number of clusters was 11. Such a cluster pattern represented six clusters and five unclassified observations and was slightly different from the visual one. The main difference was that Cluster II was split in two and that one farm of Cluster IV remained unclassified. Despite this the clusters were defined using the visual cutting line which represented a relaxed jump criteria.

When comparing the clusters it was seen that labour variables were determinant in differentiating all clusters. The largest source of differences between clusters was labour availability. Female labour distinguished C-I from C-II, while male labour made a difference between these two and C-III and C-IV. Woman labour was also relevant but not unique in distinguishing C-IV from C-V. C-II and specially C-III had less arable land, making a more intensive use of it. Finally the high labour availability of C-IV allowed these farms to have a shorter crop-pasture rotation. The distribution of farms across Counties showed that farms of two Counties concentrated in CL-II while 75 % the farms of the third County belonged to CL-I and none to CL-II. Such a distribution suggested that location has a significant effect over the farm's features and therefore on the typology developed.

Up to this stage no consideration had been taken of the area currently under a given crop or the farm's productive orientation (PO). As the area under specific crops may change between years, it was preferred to consider the qualitative variable PO as a second stage typification criterion. Thus a cross-tabulations between clusters and INDAP's POs was made, and each of these Cluster-PO pairs was then identified as a Farming System. Of a maximum possible of 30 FSs (six POs and five clusters), 8 FSs had four or more observations, 1 had two observations, 8 had only one farm, and 14 were empty. It was also seen that even as the observations for each cluster were spread on various POs, they concentrated in one or two

POs. These results also suggested that the typology was able to identify some of the data's underlying structure.

Conclusions

During the last decades typification has been based on simple single univariate classifications. The availability of computers calls for the use of typologies based upon multivariate methods. This paper presented a straightforward and rather simple method to define such FS types. Crucial points in such an approach are the definition of the typification framework, which basically defines the purpose of the exercise. This is very important as there is no universal typology. In our case a typology is constructed for peasant farmers of Central Chile based on the resources they had available. An important stage before multivariate analysis is the selection of the variables to be used, as it is preferable to construct a typology based on a large number of farms instead of a large number of variables.

Three critical issues were observed during the typification. The first two are the definition of the number of factors to be used in cluster analysis and the number of clusters on which the FSs will be defined. As no widely accepted rule exists to define these numbers, visual and empirical criteria were used. The final problem is the evaluation of the validity of the types defined. Cluster analysis is a powerful tool which allows to group any collection of individuals or observations according to any set of variables. Nevertheless, the distribution of farms classified into a given cluster along Counties as well as along productive orientations, strongly suggests that the typology here developed reflects differences in resource endowments (mainly natural environment) and that it can therefore be used for the evaluation of sustainability.

Acknowledgement

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