GIS and multivariate analysis of farmer's spatial crop decision behaviour

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Abstract

Among farmers, differences in decisions about what crops to grow can be attributed to the differences in resources, levels of knowledge, environment, approach in confronting uncertainty, and other factors. In this paper, the spatial dimension of farmer's crop decision behaviour is studied, by analysing the factors they considered important when choosing crops to cultivate. These factors are grouped into few components applying the principal component analysis (PCA) – a multivariate analysis. The result of the analysis is linked with a geographic information system (GIS) to present farmer's crop decision behaviour in a quantified and spatial form, e.g. on a map. The aims are to facilitate better understanding of such behaviour, make it more accessible and manipulable in a computer-based information system. The findings show that these objectives are achieved.

Keywords: spatial crop decision behaviour, GIS and multivariate analysis

Introduction

In many cases, farmers cultivate various crops in a year, or plant them alternately every other year on the same field. Choosing what crop or combination of crops to grow requires experience and knowledge of the physical, biological, economic and social factors, which make up the farmer's environment. This suggests the complexity of the situation in which farmers make decisions.

In a study on land use, Mather (1986) pointed out the complexity of the decision-making process. Decisions about the use of the land involved a multiplicity of factors such as (a) the objectives of the land user; (b) the process or means by which he reaches a decision; and (c) the background factors that consciously or unconsciously influence his decision. These factors may include intrinsic personal and psychological factors as well as external influences stemming from the nature of the land and its broader setting. Given this nature of the decision-making process, Mather assessed that it is a difficult field to investigate.

The spatial dimension of decision-making further adds to this complexity. We may expect that the factors influencing individual decision behaviour will differ from one location to another. The decision-maker, that is to say the farmers, have different goals, different resources, different levels of knowledge, a different environment, a different approach in confronting uncertainty, and others. For example, according to Harvey (1966), differences in the agricultural land use patterns are the geographical expression of individual decisions made at different times often for very different reasons, or no reason at all. This variation can only be understood according to Ilbery (1978) through an understanding of decision-making processes undertaken by different individuals or groups.

In a study of decision-making behaviour of an individual or group, there are several models which can be adopted. The two broad types are: the prescriptive (normative) and descriptive or behavioural (Davis & Olson, 1985). The first model guides the decision-maker how to make decisions; it is based on the concept of optimisation or maximisation. Linear programming and game theory models are good examples of this type of models. By contrast, the second model specifies how the decision-makers actually make decisions. This model appears to be identical to the empirical models of Ilbery (1978), which he defined as those seeking to discover patterns, regularities, or principles in the way people make decisions in a given situation. Examples of these models are Simon's model (1955, 1957, 1960) and Huijsman's model (1986). Likewise, the model of Van Den Ban and Hawkins (1988) seems to incorporate both normative and descriptive approaches in the decision-making process. Decision-making can range from a broad (strategic) concern to day to day (operational) concern. This paper confines itself to tactical decision-making, for example, the decision of what crop to grow.

All models of decision-making have their merits and disadvantages. In this case study, however, we did not consider any of these models because, if we will adopt a particular model or theory, it will only force us to construct a set of procedures which only fits that model or theory. Thus, to understand the actual decision behaviour of the farmers, we studied this matter with an open mind and, instead, formulated the following assumptions:

- The farmers have certain, more-or-less defined objectives to achieve (*objectives*);
- The farmers as vegetable growers are planting different crops and the problem is how to choose the best crop (*alternatives*);
- The farmers have a set of criteria or factors which they considered important in their actual choice of crops to grow (*criteria*);
- The factors considered constitute how farmers perceive their farming environment or setting, and these factors are interrelated (*farmer's environment*); and
- The farmer's perception of what he or she has decided will satisfy his or her objectives (*aspirations*).

The objectives pursued in this case study are: (a) to determine and analyse the farmer's perspective of choosing crops and their spatial dimension; and (b) to link the result of multivariate analysis, the principal component analysis (PCA) in particular, with a geographic information system (GIS).

Methods

Study Area

This case study was undertaken in Buguias municipality located in the northern part of Benguet province, which is one of the provinces in Northern Luzon, Philippines. Its topography is generally characterised by rugged terrain. The elevation ranges from approximately 1200 to 3000 m asl, while the climate is temperate, with an average temperature of 22 °C. Its average annual rainfall is about 3200 mm (Anonymous, 1993). Economically, the municipality depends on agriculture, particularly horticulture.

The inhabitants of the municipality are called *Kankanaey*, the term which is also used for their own dialect. They are one of the two ethnic groups, the other one is the *Ibaloi*, dominantly occupying Benguet province. The Kankanaey farmers were the major source of our primary data.

Selection of farmer-informants

In the selection of our farmer-informants, we geographically identified them. The use of a geographic information system (GIS) in capturing farmers' decision behaviour in spatial form determined this approach. The land management units (updated LMUs) of the Bureau of Soil and Water Management (BSWM) of the Department of Agriculture (Manila) for the area were used. The BSWM uses LMUs as a basic reference in the collection, analysis and interpretation of data for both the physical and agro-socio-economic aspects intended for identifying the management requirements of the inherent resources of a particular area.

These LMUs are subdivisions of geomorphic mapping units (GMUs). Each GMU exhibits a homogenous set of properties in lithology (parent material), climate, soil and topography. LMUs are segregations of the GMUs based on slope, land use and relief. There are eight LMUs present (see Table 1), and they are numbered from one to eight in the study. LMU 7 is small and since it belongs to the same GMU as that of LMU 8, they were combined making the total number of LMUs into seven.

A total of 131 fields were randomly selected within the seven LMUs. Each field was visited more than once, and the farmer-owners were interviewed. The farmers may have one or more fields. In cases, where they have fields in different LMUs, they were asked about the conditions of their fields in other locations as well.

Data collection techniques and analytical tools used

To obtain data on farmer's crop decision behaviour, a number of techniques were applied. These include rapid rural appraisal (RRA); village immersion; the farmer-based interview schedule; field visits and observation (Mendoza Lawas, 1997).

A checklist was used to collect data from the farmers. In this case, quite often, we collected data by conversation. Mostly, we asked open-ended questions, which allowed the farmers to think and talk freely about the subject matter.

Table 1. Description of the land management units (LMUs).

LMU-No. Symbol	Description	Slope %	Drainage	Texture	Soil depth	Elevation (meter)	Erosion	Inherent Fertility
1 (140M)	Intermontane valleys	0–3	Moderately well to well	Medium to fine	Moderately deep to deep	> 1000	None	High
2 (156N)	Shale/sandstone mountains	3–8	Well	Medium	Moderately deep	> 1000	Slight	Medium
3 (156Q)	Shale/sandstone mountains	30–50	Well	Medium	Shallow	>1500	Severe	Low
4 (160N)	Low-meta volcanic mountains	3–8	Moderately well to well	Medium to fine	Moderately deep	> 500	Slight	Medium
5 (161R)	High-meta volcanic mountains	> 50	Well	Medium to fine	Shallow	> 1500	Severe	Low
6 (168N)	Complex volcanic mountains	3–8	Well	Medium to fine	Moderately deep	> 500	Slight	Medium
7 (168Q)	Complex volcanic mountains	30–50	Well	Medium to fine	Shallow	> 1500	Severe	Low
8 (168R)	Complex volcanic mountains	> 50	Well	Medium to fine	Shallow	> 1500	Severe	Low

NOTE:
M, 0–3% – level to nearly level
N, 3–8% – gently sloping to undulating
O, 8–18% – undulating to rolling
P, 18–30% – rolling to moderately steep
Q, 30–50% – steep
R, >50% – very steep

Source: BSWM, DA, Manila

The statistical tools used were multivariate analysis, in particular principal component analysis; Pearson correlation coefficient and Spearman's Rho coefficient. For the storage, analysis and presentation of farmer's crop decision behaviour in spatial form, a geographic information system (GIS) was used.

A GIS has been defined as a collection of instruments for the collection, storage, retrieval, display and analysis of spatially referenced data which can be used for planning, decision-making or predicting (Mendoza Lawas, 1997; Lawas & Luning, 1996). The specific GIS software used was the 'Integrated Land and Water Information Systems (ILWIS).' This software is a product developed by the International Institute for Aerospace Survey and Earth Sciences (ITC).

Steps involved in data Analysis

To start with the case study, we identified the different crops being grown by farmers. These crops were ranked to know the farmer's most and least preferred ones. This was done by computing the relative weights (expressed in percentages) of farmer's behaviour, *always growing* (at least once a year) and *sometime growing* (a crop is not often grown in a year) for each crop. The interest here is to know which crop is always grown by farmers at least once a year.

The factors associated by farmers to their choice of crops were analysed using the factor listing approach. This approach is based on three considerations: (a) ask the farmers the major criteria or factors they consider important in selecting the crop they want to grow; (b) count the number of times each factor is mentioned and calculate the percentages; and (c) assume that the percentages represent the factors' importance. Percentages here are considered as weights of each factor.

The overall importance of each factor was determined from the affirmative responses of the farmers per LMU using the formula:

$$WAR = AR/N\ (100) \qquad (1)$$

where WAR = weight of affirmative response, AR = affirmative response, N = total number of farmers per land management unit.

The use of a PCA allowed the computation of Pearson correlation coefficients which showed the interrelationships among factors. This result was compared with the result of the Spearman correlation coefficient to check whether there is a big difference in both results, which may reveal unusual meanings. Likewise, PCA was used in grouping farmer's crop decision factors into few components. The PCA model may be compactly expressed as:

$$Z_j = a_{j1}F_1 + a_{j2}F_2 + \ldots + a_{jn}F_n \qquad (2)$$

where each of the n observed variables is described linearly in terms of n new orthogonal components F1, F2, ... Fn. Each of these uncorrelated components is in turn defined as linear combination of the n original variables (Nie *et al.*, 1970). See also Rummel (1970), Youngman (1979), Ilbery (1983) and Wilkinson *et al.* (1992).

The primary reasons of using PCA are to identify group of inter-related variables, to reduce the number of variables being studied, and to re-write data sets in order to remove the collinearity between and among variables (Johnston. 1978).

The results of the PCA were obtained using a computer-based statistical software SYSTAT (see Wilkinson *et al.*, 1992).

Results and discussion

Farmer's major crops, practices and objectives

Today, most of the people of Buguias municipality are economically dependent on vegetable growing. They long abandoned cultivating rice and sweet potatoes which they used to subsist on. The major vegetable crops they cultivate are (in order of importance) potato, cabbage, Chinese cabbage, lettuce and carrot. The farmers grow two or more of these crops in a year. Their cropping systems can be generally grouped into two: growing a single crop in the field every cropping season; and growing two or more crops simultaneously in the field. The intensity of cropping depends on various factors, but the most limiting of all is the availability of water according to farmers.

The farmers have their own agro-ecological zonings, which they named as: *cada* which includes those areas located at higher altitude or those nearly close to the mountain peaks; *dagdag* which the farmers described as those areas in the lower or valley portion of the study area; and *nalamag* which covers those landscapes lying between *cada* and *dagdag*. In *cada*, generally the farmers can only plant one to two times a year as most fields are rainfed, whereas in *dagdag* zone, farmers can have two to four times cropping seasons because of the availability of irrigation. In *nalamag* zone, in areas close to *cada*, usually the farmers have two cropping seasons while those close to *dagdag* zone, obviously, the farmers can plant three to four times a year.

As regards cropping patterns, we observed two common patterns: planting potato in the first growing season, followed by leafy vegetables, i.e. cabbages, which is obviously popular among farmers who have only two cropping seasons a year; and planting potato during the first growing season, followed by leafy vegetables during the second cropping season, and potato again or other root vegetables during the third cropping season. In the first cropping pattern, the first growing season begins during the start of the rainy season (between the later part of April and first week of May), while the second cropping starts during the middle of August or first week of September. For the second cropping pattern, farmers usually start their first, second and third growing periods either in January or February, late March or early April and late August or early September, respectively.

The farmers have fixed crop management practices, which could imply that these practices might also have some influence on their crop decision behaviour.

In broad terms, the farmers' objective in cultivating a crop or a group of crops is 'to produce more,' which will ensure them of sufficient income (net income excluding the cost of family labour) to sustain their families' requirements for food, shelter, education and other basic needs. In addition, the farmers explicitly noted that they also want to acquire farm implements and a vehicle for transporting their own harvests. They argued that with own transport, they could avoid losses, as harvesting and marketing could be effectively planned. Vegetables are highly perishable, particularly leafy ones, hence a delay in marketing after harvesting could result in losses. They further emphasized that they could also earn extra income from renting out their vehicle to other farmers.

The farmers' crops are entirely commercial crops. Growing these crops seems to suggest that it is more profitable than their subsistence crops – rice and sweet potatoes. A farmer-informant, when asked why the farmers in the study area abandoned growing subsistence crops as their primary crops, said that there is more income in vegetables. For rice, for instance, a farmer can only harvest once a year, and the harvest is only used for the subsistence of the family. For vegetables, however, a farmer can harvest three or even four times a year. This appears to illustrate that the Kankanaey farmers belong to the group of profit maximisers (Upton, 1987).

Farmer's crop decision criteria

In order to achieve the objective of having more net income, the farmers must have been following a set of criteria or factors in their choice of crops to grow. These criteria are considered here as factors limiting the crop choice of the farmers. In identifying such factors, we did not follow the conventional approach in which farmers are asked according to previously identified and listed factors. We simply asked them about the major factors they consider important when choosing what crop to grow.

Several factors were identified by the Kankanaey farmers as important in making a decision of what crop to grow. Among these factors, only seven were found to be frequently mentioned by farmers in relation to LMUs. Hence, we focused our analysis on those factors. The seven factors are listed in Table 2; their equivalent meanings are given below:

- *Season* refers to dry and rainy seasons or weather conditions;
- *M-price* refers to the timing of harvesting a crop during the period when it will command a good price in the market;

Table 2. Consideration weights (expressed in percent) of farmers for each decision factor in seven management units.

	Decision factors						
LMU	Season	M-Price	G-Income	Soil	Climate	P-Mater	Pes-Dis
1	85	70	60	25	25	20	0
2	93	65	20	48	17	15	11
3	82	73	55	9	9	0	0
4	71	86	71	0	43	14	14
5	58	67	75	17	50	8	8
6	96	59	26	41	37	15	7
7	100	63	13	38	25	0	0

- *G-income* relates to which crop will give more income in a specific period;
- *Soil* refers to the suitability of the crop to a particular type of soil;
- *Climate* refers to the existing microclimate in the study area;
- *P-mater* refers to the availability of planting materials; and
- *Pes-Dis* refers to the occurrence of pests and diseases in a particular period.

The three most important decision factors for farmers in all land management units are *season*, *market price* and *income*. This means that the timing of planting of crops depends much on these factors. As for season, in the study area there are places where farmers have to wait for the rain to be able to start planting; and there are also other areas where flooding or waterlogging occur when there is a heavy rain, which is not favourable for some crops. For example, the farmers asserted that potato should be best grown during the dry period; and leafy vegetables during the rainy season.

Most farmers agreed that market price is an important factor to consider. Subsequently, the high income earner crop will be preferred by farmers in cases other factors are favourable for the crop to grow. Potato, for instance, it is the most stable crop in terms of return, although there are some limitations as to the timing of planting. As earlier mentioned, according to the farmers, potato is best planted during the dry months period, particularly in the valley region (*dagdag*) as some areas get waterlogged and flooded during the rainy period. In this case, the soil is too wet and the tubers can easily rot. Moreover, the control of pests and diseases during the rainy season is more problematic because they occur in greater numbers. However, farmers in highly elevated region revealed that their advantage is they can grow potato even during the rainy period, the only risk is that potato is too sensitive to heavy rains, particularly when accompanied by strong wind. Another advantage of choosing potato is that harvesting can be delayed or tubers can be stored for a longer period to wait for a better price as compared to leafy vegetables.

The farmers also recognized the importance of crop rotation, although they admit that sometime they do not practice it. They observed that planting the same crop successively, i.e. potato after potato results to low yield of the second crop; and the control of pests and diseases is more expensive.

The above factors identified by farmers as limiting in their choice of crop reflect the multidisciplinary nature of their knowledge and experience. This further shows the complexity of the decisions they have to make for every cropping period. Moreover, we note that these factors are mostly those over which the farmers have no direct control.

Interrelationships among decision factors

The use of principal component analysis allows the examination of the interrelationships between variables. The outputs which are usually derived from this analysis are: Pearson correlation coefficient matrix, latent roots or eigenvalues, component and rotated loadings, factor score coefficients and component scores.

Concerning the result on Pearson correlation coefficients, we tried to compare its matrix to the result of the Spearman correlation coefficients to check the reliability of the information. In general, similar trends of results were observed in both tests. For instance, the factor *season* is moderately correlated with the factor *soil* in both results, while it is highly correlated with factor *income* albeit in a negative sense. Correlation also exists between *market price* and *income* and *soil* (negative). The correlation coefficients for other combination of factors can also be gleaned from Table 3. The extent of correlations varies according to the combination of factors. The importance of correlation results in PCA is that it determines the possible groupings of related variables, and that it is necessary for the entire sequence of analysis involved in PCA.

Table 4 lists the eigenvalues and the percentage variance associated with the 6 principal components for the 7 variable inputs. The sum of the eigenvalues (total variance in correlation matrix) equals the total number of variables, since they are standardized to unit variance. The ratio of each eigenvalue to this total represents the proportion of each principal component in representing the variability of the first combination of variables. For instance, in our case, the percent variance (proportion) of the first principal component is computed as 3.382/7.0 = 48.314. Every component contributes to the overall variance explained. This means that the variance for an individual component is measured by its eigenvalue (Youngman, 1979), which is in turn obtained by squaring the variable loadings for that component. Using Table 4 to illustrate the calculation of eigenvalue, for the first component we have:

$$E_1 = (0.925)^2 + (-0.921)^2 + \ldots + (0.447)^2 = 3.382 \quad (3)$$

According to Youngman (1979), components with eigenvalues greater than 1.0 should be considered significant as they account for more than chance variation. Thus, in the present case, we have considered components one and two, i.e. we have reduced the number of components from six to two. These two components account for almost 74 percent of the total variance (see Table 4).

Factor interpretation

With respect to interpreting factors, we considered the matrix of factor-variable correlation derived from the rotated component loadings. The component loadings (Table 5) have been subjected to rotation, hence the results are the rotated loadings (Table 6). The purpose of rotation is to clarify further the relationship between vari-

Table 3. Pearson correlation coefficient matrix.

Variables	Season	M-Price	G-Income	Soil	Climate	P-Mater	Pes-Dis
Season	1.000						
M-Price	-0.301	1.000					
G-Income	0.915	0.401	1.000				
Soil	0.739	0.713	0.862	1.000			
Climate	-0.589	0.068	0.451	-0.257	1.000		
P-Mater	0.034	0.226	0.160	0.167	0.281	1.000	
Pes-Dis	-0.367	0.132	0.189	-0.107	0.534	0.435	1.000

Table 4. Eigenvalues and percentage of variance.

Principal component	Eigen value	Percent variance	Cumulative variance
1	3.382	48.314	48.314
2	1.772	25.314	73.628
3	0.779	11.129	84.757
4	0.650	9.286	94.043
5	0.341	4.871	98.914
6	0.076	1.086	100.000

ables so as to make interpretation easier – or somehow to achieve simpler and practically more meaningful factor patterns. There are two methods of rotation: (a) orthogonal; and (b) oblique. In SYSTAT, rotation can be done into three types: varimax, equamax and quartimax (see Wilkinson *et al.*, 1992). We used the varimax, which is a kind of orthogonal method. Varimax incorporates the principle that only very high or near-zero correlations can be reliably interpreted (Youngman, 1979). The varimax criterion is a function of the variance of the column of factor (component) loadings. The orthogonal rotation (varimax) can be computed by maximizing the variance of the squared factor loadings. The formula is (see Nie et al., 1970):

$$n\sum_{p=1}^{m}\sum_{j=1}^{n}\left(\frac{a_{jp}}{h_j}\right)^4 - \sum_{p=1}^{m}\left(\sum_{j=1}^{n}\frac{a_{jp}^2}{h_j^2}\right)^2 \rightarrow \text{maximum} \quad (4)$$

In the result of the rotated component loadings (Table 6), the highest values in RC1 (rotated principal component 1) have positive and negative signs. Since orthogonal loadings are correlations, the high negative loadings are equally important as those with positive signs (Youngman, 1979). To interpret results like this, Rummel (1970) introduced the term *bipolarity*. In this case, one can name the component by single appropriate term. As in many cases bipolar factors (components) are difficult to label with a single appropriate term – that which will incorporate both poles each pole may be interpreted separately. Consequently, the component should be named in an opposite manner.

In RC1, the variables with high positive loadings include *G-Income* and *M-Price*.

Table 5. The component loadings for principal components 1 and 2.

Components Loadings		
Variable	PC1	PC2
G-Income	0.925	0.083
Season	-0.921	0.031
Soil	-0.868	0.436
Climate	0.627	0.524
M-Price	0.563	0.506
P-Mater	0.117	0.786
Pes-Dis	0.447	0.653

Table 6. The rotated loadings for principal components 1 and 2.

Components rotated loadings		
Variable	PC1	PC2
Soil	-0.971	0.020
G-Income	0.871	0.323
Season	-0.818	-0.425
M-Price	0.726	-0.214
Pes-Dis	0.123	0.782
P-Mater	-0.233	0.759
Climate	0.340	0.743

We may interpret these variables as relating to the profitability of the crops in relation to the economic situation in a specific period. This means that farmers' decisions are influenced by the economic gains they will derive from the crops in a certain period of the year. The farmers have much experience to call on when a crop should command a good price. Those variables with high negative loadings (to include variables *Soil* and *Season*) seem to relate to the suitability of the crops in relation to the internal natural environment. For example, potato is considered to be suitable in clay-loam soil and should be grown during the wet-dry season. This means that potato should be planted during the later period of the wet season so that it can be harvested during the beginning of the dry season. In general, principal component 1 (RC1) may be labeled as combining both the profitability and suitability of the crops to the internal natural environment as exemplified by the factors soil and season.

In RC2, all the highest values have a positive sign. The three variables include *Pes-Dis*, *P-Mater* and *Climate*. The values are quite close, ranging from 0.743 to 0.782. This component appears to relate to the manageability of the crops in relation to biological as well as microclimatic factors prevailing in the area. In this case, farmers' decisions seem to be affected by the management requirements of the crops with regard to biological and microclimatic factors.

Groupings of LMUs by decision factors based on component scores

As mentioned, one of the outputs of PCA are component scores. The availability of these scores for each LMU has enabled us to present spatially the groupings of the type of factors considered by most farmers in a specific unit.

Guided by the results on rotated component loadings (Table 6) and by the component score coefficients (Table 7), the land management units (Table 8) were grouped according to the farmers' crop decision behaviour, which is indicated by the component scores of the units. The groupings made for component one and two are shown as maps in Figures 1 and 2. In *component 1*, three groupings were made, whereas *component 2* has two groups.

As discussed, *component 1* consists of bipolar decision factors. Thus the group-

Table 7. Component score coefficients for principal components 1 and 2.

Component score coefficients		
Variable	CSC1	CSC2
Soil	-0.338	0.112
G-Income	0.267	0.075
Season	-0.238	-0.133
M-Price	0.273	-0.186
Pes-Dis	-0.039	0.389
P-Mater	-0.160	0.415
Climate	0.040	0.347

Table 8. The associated component scores of each land management unit.

Component scores		
LMU	Factor (1)	Factor (2)
1	-0.059	0.067
2	-1.196	0.414
3	0.699	1.525
4	1.341	0.772
5	0.845	0.865
6	-1.158	0.698
7	-0.471	1.291

ings of the LMUs were influenced by such factors. Group 1 in Figure 1 includes LMUs 4 and 5. These management units have the highest positive scores, which indicate that these are the locations where the farmers consider economic factors, e.g. market price and income, more important when choosing a crop. It is interesting to note here that the two units are adjacent to each other, which could suggests that farmers might have influenced one another. LMUs under group 2 include 2 and 6, which have the highest negative scores. In these units, the farmers give more importance to physical factors, e. g. soil and season. The location of these units is exactly the opposite direction of the first group (Figure 1). In group 3, which includes LMUs 1, 3 and 7, the farmers seem less influenced by either group of factors. This appears to indicate that decision behaviour of the farmers varies according to location. This variation may be explained by the inherent characteristics of the LMUs. For instance. the case of group 1 which includes LMUs 4 and 5 , they belong to the region with the highest altitude, hence the coolest region in the area. As compared to other areas, these places are very far from a motorable road; farmers have to walk for about one to two hours from their homestead. With these conditions, the farmers incurred more expenses in transporting farm inputs, i.e. fertilizers, as well as in harvesting or marketing. For marketing, farmers need to hire labour to bring the harvests to the nearest road where transport is available. The same is done for bringing farm inputs to the fields. Thus, it is but rational that the farmers will consider eco-

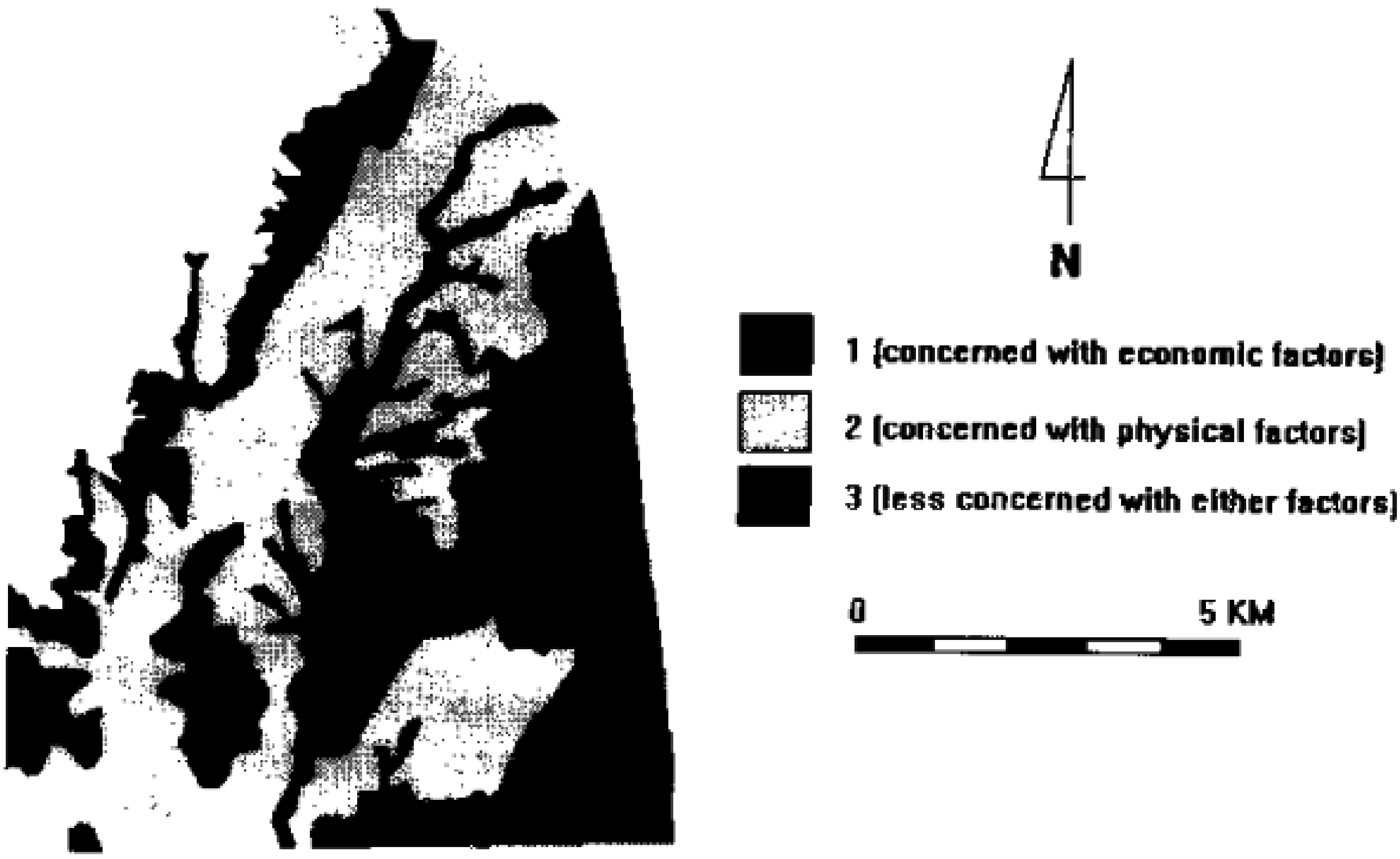

Figure 1. Map of the farmers crop decision behaviour according to component 1.

nomic factors more important over other factors. Meanwhile, the farmers who expressed that physical factors are more important when selecting crops, they are those who perceive that their fields are highly vulnerable to erosion, hence soil fertility

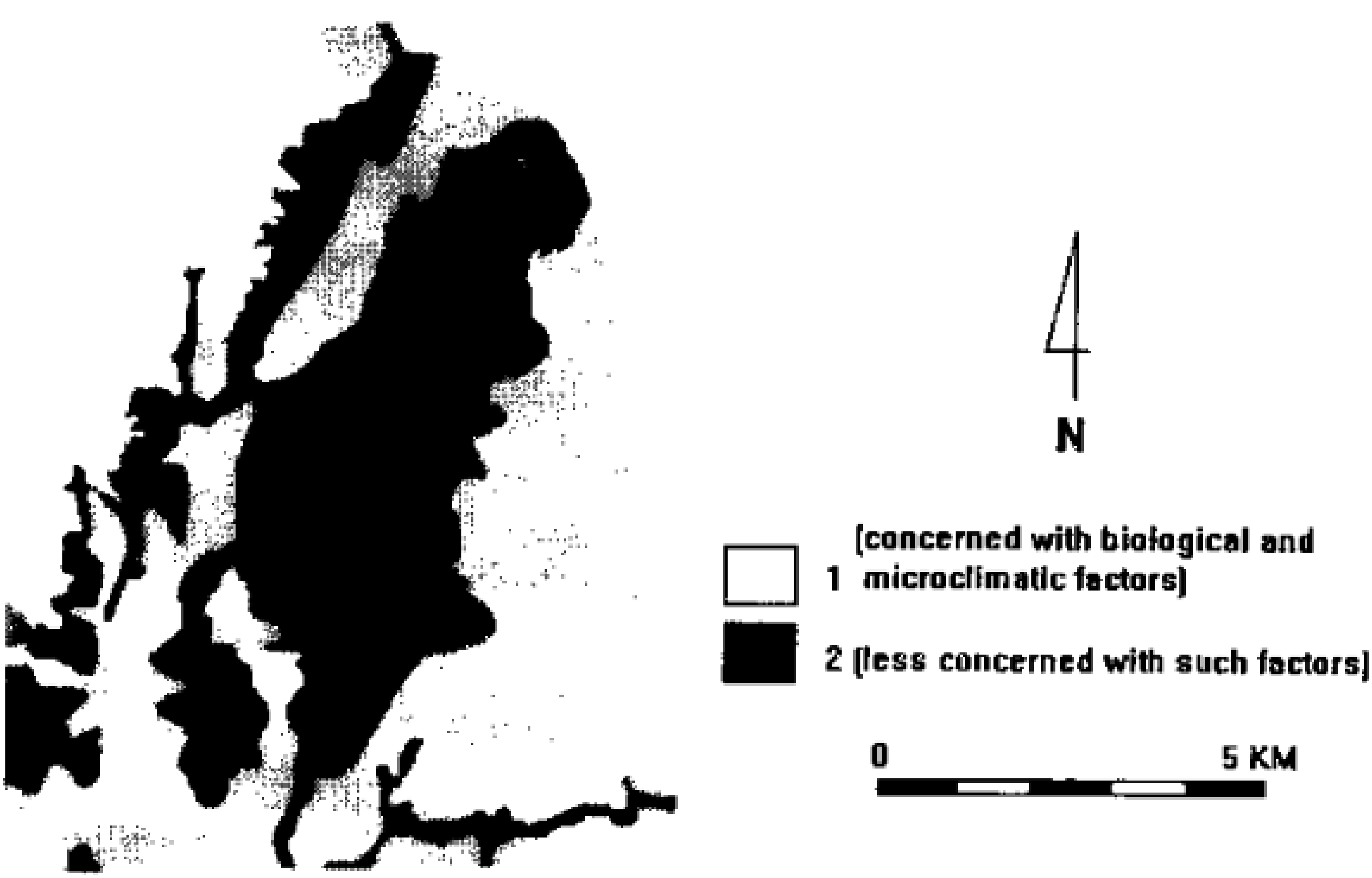

Figure 2. Map of the farmers crop decision behaviour according to component 2.

loss is a problem. In addition, the location of these areas (LMUs 2 and 6) is seen as highly exposed, that when there is strong typhoon accompanied by heavy rains, these places usually encounter enormous damages.

For *component 2* (Figure 2), the first group of LMUs consists of units 4, 5 and 6, which have the highest positive scores in this component. These are the places where the farmers consider biological and microclimatic condition more important factors in deciding which crop to choose. The first two units are adjacent to each other, while the latter is located in the opposite direction of the first two. This may imply that the farmers in this group are in dispersed places, indicating again the spatial nature of the farmer's crop-decision behaviour. The second group of LMUs, however, includes units 1, 2, 3 and 7. The farmers in these units are less influenced by the biological and microclimatic factors considered important by the farmers in the first group of LMUs. For group 1 of this component, which consists of LMUs 4, 5 and 6, these are the same LMUs (except LMU 6) where the farmers are more concerned with economic factors (refer to component 1). Having the coolest temperature, the farmers in these areas stressed that based on their experience, they have to choose crops which are more tolerant to this temperature. In addition, they also select those which do not require intensive pests and diseases management, since because of the distance they could not always visit their fields as often as that when the fields are close to their homestead.

The above discussion seems to indicate that the decision of the farmers of what crop to cultivate is highly influenced by how they perceive their macro- and micro-environment. The factors, i.e. market price, season and climate they cited are examples of the situation existing in their farming environment. How these phenomena are perceived could affect the decision of individual farmers.

Multivariate analysis, principal component analysis in particular, allowed us to group the factors into two components as shown by the result. Each component provides the highest and lowest values which determine what specific factors are important to that component. Each component shows a pattern of the grouping of variables. This makes the interpretation of the results easier. The analysis further permits the presentation of the crop decision behaviour of the farmers in spatial form. This means that we can present the output on a map. We hope that by showing the crop choice behaviour of the farmers through maps, it will facilitate better understanding of such behaviour, as well as making the information be manipulable in computer-based information systems, e.g. GIS.

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