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CLASSIFYING PHYSICAL ENVIRONMENTS AS A TOOL IN CROPPING SYSTEMS RESEARCH: UPLAND RICE IN THE PHILIPPINES 1/

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I. INTRODUCTION

Over the past few years a methodology has been evolving for developing more productive cropping patterns suited to areas where rainfed rice is the basic crop. The process of fitting more optimal cropping patterns is complex because such a great number of factors influence the systems and their effects tend to vary from location to location. These factors range from conditions in the physical environment, especially in rainfall pattern and soils, to conditions in the socio-economic environment, for example prices and costs (Harwood and Price, 1975). The most important factors must be identified and their effects on the relative performance of cropping patterns understood.

The most basic set of factors relating to the performance of crops and cropping patterns are those associated with the physical environment. The rainfall pattern, topography, and soil type of a site play a dominant role in determining the biological productivity of any cropping pattern at that site. These are the farmer's fundamental resources. They are called determinants by cropping pattern potential because they cannot be significantly modified by the farmer (Zandstra, 1976).

Physical environments need to be classified in such a way that the divisions of the classification system reveal predictive information about the biological performance of cropping patterns. In 1974 the working group on the establishment of S.E. Asian cropping systems test sites (IRRI, 1974a) released a rainfall map of the region which attempted to differentiate areas on the basis of the number of rice and following crops potentially possible in the yearly sequence. Oldeman (1975) later completed a more detailed agro-climatic map for the island of Java based on the same procedures. Manalo (1976, unpublished) has finished very similar maps for the Philippines and Bangladesh. These maps will be valuable in increasing the predictive understanding of which rice-based patterns fit where, considering variations in the length and intensity characteristics of the rainy season.

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Beyond the classification of rainfall patterns there are some other useful steps. Environments can be further differentiated by superimposing the rainfall classification onto physiographic and soil classifications. By dealing with several such determinants simultaneously their interactions can be studied.

The goal of this research was to attempt to form such a combined classification based on rainfall, slope, and soil maps, and to explore its usefulness in differentiating the environments in which upland rice is grown in the Philippines. Such information would be very useful in identifying those upland rice areas with environments most appropriate for cropping pattern intensification with present technology.

As of 1971 there were over 370,000 hectares of upland rice grown in the Philippines (Bureau of Census and Statistics, 1975). Cropping intensity on upland rice farms nationwide is generally low (Dozina and Herdt, 1974). The majority of upland rice farmers plant just one crop per year while available climatic data indicate a strong potential for two or more crops per year (Garrity, 1975; IRRI, 1973).

Research on upland rice-based cropping systems has been going on since 1973 at a site in Tanauan, Batangas (IRRI, 1974, 1975). In order to further organize research to test the potential for more intensive cropping patterns much greater understanding was needed concerning the specific environments under which upland rice is presently grown. The most important environments needed to be identified and the crop locations with those environments catalogued. Potential future cropping pattern test sites should be located in the most representative environments. Knowledge of the diverse range of upland rice environments would also be important.

Sufficient data and maps were available to classify all the major locations where upland rice is grown throughout the country in terms of four important physical determinants of cropping pattern potential: rainfall pattern, slope, soil texture, and soil order. The environment of a particular site could then be characterized by the values of the four determinants at that site. Groups of sites with the same values for the determinants could be identified. Such a group of sites sharing the same physical environment, as determined by the classification system, would be termed an <u>environmental complex</u>.

II. METHODOLOGY

A. The classification system

The classification system involved four determinants: rainfall pattern, slope, soil texture, and soil order. Each was originally mapped separately. A hieriarchical classification was formed in which the rainfall pattern was judged to be the most important determinant of cropping pattern potential and was placed at the highest level of the system. Slope was placed as the second highest level. Soil texture was the third level, and soil order was placed at the fourth and lowest level. The bases for this particular order are discussed further in connection with the methodology concerning each determinant.

It should be recognized that these four levels do not include all the determinants required to specify the environments in which upland rice is grown. More physical determinants could be included were data and maps to become available. But it is felt the four which could be included were of major if not dominant importance.

B. Selection of the sample of upland rice municipalities

The area of upland rice[3/] in each municipality in every province of the Philippines was collected from the 1971 Census of Agriculture (Bureau of Census and Statistics, 1975, unpublished). The crop was grown in over 1000 municipalities. The set of municipalities with more than 300 hectares each in upland rice was selected for the classification analysis. This sample, which included exactly 300 municipalities, had a combined upland rice area of 85% of the national total. The municipality thus became the geographical mapping unit. The sample was designed to cover all localities in which the crop was produced to a significant extent.

C. Classification of the rainfall pattern in the sample municipalities

Virtually 100% of Philippine upland rice is rainfed. Of all the environmental factors influencing upland rice cultivation and the cropping patterns associated with it, the most important limiting factor is the amount and duration of rainfall (IRRI, 1973; Yoshida, 1975). The choice of rainfall pattern as the highest level of classification followed this conclusion expressed by the Working Group on the Establishment of Southeast Asian Cropping Systems Test Sites.

The working group considered that periods with at least 200 mm of rainfall per month were needed to successfully cultivate lowland rainfed rice in Southeast Asia, and periods with at least 100 mm per month were needed to maintain upland crops. These lower limits to feasible crop cultiation were largely based on the extensive data collected by Kung (1971). Oldeman (1975) discusses the assumptions concerning crop consumptive use and soil moisture-holding characteristics that led to the selection of these arbitrary limits.

Manalo (1976, unpublished) has produced two maps of the rainfall patterns of the Philippines using a system based on the above criteria and the rainfall data of 150 weather stations throughout the country. Using these maps the 300 sample municipalities were each classified in terms of (1) the number of consecutive months per year

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[3/] Upland rice was defined for census purposes as rice that is "grown on soil usually dry on the surface." It is a type which "does not require standing water during its period of growth."

with rainfall above 100 mm/month and (2) the number of months with rainfall above 200 mm/month. Figure 1 is the map of rainfall zones based on the number of months above 100 mm/month.

D. Classification of slope, soil texture, and soil order in the sample municipalities

Slope was chosen as the second highest level of classification of upland rice production environments. It acts as a strong determinant of the potential for intensive cropping systems in the Philippines and the tropics in general. All but the gentlest of slopes are potentially subject to severe erosion and rapid loss of fertility when cultivated through the wet season (Lal, 1975; Nye and Greenland, 1961). Steep slopes may rule out field crop cultivation entirely, unless painstakingly terraced. Because of these conditions slope was selected to supersede soil type.

The dominant and secondary slope classes in each of the sample municipalities were recorded from the Slope Map of the Philippines (University of the Philippines, 1966). The dominant slope class was considered that which occupied the greatest area of municipality. Three general slope classes were formulated: flat to gently rolling (GR), rolling to steeply hilly (SR), and mountainous terrain (M). The relationship of these classes to the map units is shown in Table 3.

Soil texture was the third level of classification. Texture has an important influence on the capability for tillage operations to be carried out under low and high moisture conditions (Harwood and Price, 1975). Tillage on heavy soils may be severely limited by dry or wet conditions, while lighter textured soils present much more flexibility in tillage. Texture also determines the water holding capacity of soils, and influences soil fertility, making light textured soils potentially less favorable in both these respects.

To classify upland rice areas in terms of soil texture the soil series and textures for each sample municipality were obtained from either the provincial soil survey reports of the Bureau of Soils, or from a soil map constructed from the provincial soil surveys by the Soils Department, University of the Philippines at Los Baños. These soil textures were of the surface plowlayer. They were grouped according to three general classes: Light (L), medium (M), and heavy (H) as shown in Table 6.

Soil order was the fourth and lowest level of the classification. Differences in soil order indicate major differences in the physico-chemical characteristics of different soils, many of which determine soil fertility and manageability. These differences may have important bearing on the types of soil management needed and on the cropping pattern potential (Mariano and Valmidiano; IRRI, 1974).

Whether soil order should have been placed third instead of fourth was not clearcut and was a somewhat arbitrary choice. But as will be noticed later the results of the classification would be essentially the same either way. The soil orders of each municipality were determined from the Soil Map of the Philippines (Mariano and Valmidiano, 1973; IRRI, 1974). The map used the U.S. Department of Agriculture Comprehensive Soil Classification System. When more than one soil order was present in a municipality they were ranked as dominant and secondary, depending upon the relative area that each occupied.

III. RESULTS AND DISCUSSIONS

The 300 upland rice-growing municipalities which made up the study sample are mapped in Figure 2. The distribution of upland rice area throughout the Philippines is shown by the map in Figure 3. Upland rice production is widely scattered, but there are several concentrated production regions. Foremost among these are North Cotabato and Batangas. Several other concentrated production areas exist in Albay, Iloilo, Zamboanga del Sur and Lanao. Upland rice is conspicuously absent, however, all along the west coast of Luzon.

The results of the process of classification will first be analyzed for each determinant separately. This will lead into a discussion of the outcome when all four determinants are incorporated into a combined classification system which distributes the sample upland rice localities into various environmental complexes.

A. The Distribution of upland rice area by rainfall pattern

A rainfall classification which could indicate the length of the yearly growing season for upland crops is potentially useful in determining differences in cropping pattern potential among upland rice-growing areas. Knowledge of the number of months available for crop growth gives broad information on the maximum number of crops possible and the type of crops most likely suitable.

Table 1 shows the distribution of upland rice area in terms of the number of months available for crop growth each year. The classification system assumes that only months with greater than 100 mm were suitable for crop growth.[4] Based on this criterion over one-fifth of the upland rice area has a year-round rainfall distribution that may be adequate for upland crop production. Concentrated most heavily in Lanao del Norte and Sur, this rainfall pattern also claims upland rice areas in Zamboanga del Sur, Bukidnon, Cotabato and a few locations outside of Mindanao.

4/ See Oldeman (1975) for a discussion of the data underlying the selection of this limit.

The bulk of Philippine upland rice area (55%) has 8-10 months of growing season. Areas in this rainfall pattern may still be strongly suited to three crops per year as long as slope and soil fertility are not limiting. Table 2 outlines how cropping pattern potentials may differ under the different rainfall patterns, showing the number of consecutive field crops per year that are likely.

Another 17 percent of the upland rice area has 6-7 months with adequate rainfall. Experience in Tanauan, Batangas indicates that field crop potentials in these areas may be confined to two crops per year, except for a 3-crop pattern involving rice-sorghum-sorghum (ratoon). Although 2 crops per year is fairly certain, three crops may only be possible with good timing and a drought tolerant final crop.

Very little of the land area of the Philippines has less than 6 months with under 100 mm per month (about 1%). Consequently the percentage of upland rice in this rainfall pattern is a low proportion of the total upland rice area (2%).

Figure 4 (graph A) shows a comparison between the proportion of the country's land area in each rainfall pattern and the proportion of all upland rice in that pattern. This is a crude test of the selectivity of the classification in defining separate rainfall environments which differ in their suitability to upland rice production. If the proportion of total land area is the same as the proportion of upland rice area for each rainfall pattern then the classification may be viewed as non-selective, and was not therefore defining environments which differed in their relative suitability for the production of this crop.

The classification appears generally not to be selective for upland rice. The large proportion of upland rice in the 8-10 month growing season zone is apparently large because such a large proportion of the Philippine land mass is within that zone, not because that particular environment is relatively more conducive to upland rice production. The figure indicates however a tendency for more upland rice to be produced per unit of land area in zones that have either a year-round growing season (11-12 months) or a very short growing season (0-5 months) than in zones with intermediate growing seasons.

It is not surprising that the classification is apparently non-selective for upland rice environments, since it was intended to characterize the potential member of crops per year that may be expected, of which upland rice may be only one crop in a sequence of two or three. A selective rainfall classification for upland rice alone would most likely deal with the rainfall characteristics of the crop's four month growing season, not the environment present over the entire year. An earlier attempt to relate crop occurrence in the Philippines to rainfall patterns was the work of Philipson et al. (1972). Upland rice was included among several crops whose relative importance was studied among different rainfall classes of the Coronas systems.

The upland rice sample municipalities were also classified according to the number of consecutive months that rainfall averaged over 200 mm/mo. Such information could specify further differences between upland environments in terms of rainfall intensity. This information was not incorporated into the classification system, but could easily be included as sub-units of each of the four 100 mm/month rainfall classes. This step, however, would have greatly expanded the number of distinct environmental complexes and made summarization more difficult. The data on this determinant are, however, given in Appendix 1 for each sample municipality.

In carrying out the classification at the 200 mm/month limit some observations could be made on the relationship of this classification to upland rice cultivation. Since this 200 mm limit was set as the minimum rainfall needed for lowland rice it might be supposed that it would have little application in specifying where upland rice is grown. Upland rice would presumably have a lower water requirement, at or near the 100 mm/mo. limit.

This classification is also apparently non-selective for upland rice environments. The distribution of Philippine land area in each of the five rainfall classes is fairly similar to the distribution of the percentage of upland rice area in each of these classes. (Figure 4, graph B). Considerable upland rice is grown in areas of Cotabato which do not average 200 mm/month at any time during the year and one-sixth of all upland rice is grown in areas with from 0-2 months above 200 mm/month Figure 4).

The classification system dealing with the number of months above 100 mm/month was used in the combined classification. It is the one that is more relevant to the potential upland crop growing season.

B. The distribution of upland rice area by slope gradient

A considerable portion of Philippine upland rice is cultivated on very steep slopes. This is shown by Tables 4 and 5. Table 4 distributes the upland rice area according to slope types such that where combinations of more than one slope type were found within a municipality these combinations are shown separately. About 40% of the total upland rice area was found to be in localities where a combination of slopes occurred. The remainder was in municipalities where only a single slope type was present.

In a municipality with a combination of slope types (e.g. GR/SR) there was no way to determine the amount of upland rice in that locality that was grown on each respective slope type. Table 5 groups the data into dominant slope types by assuming that all upland rice in a municipality occurs on that municipality's dominant slope type.

With this simplifying assumption it is estimated that approximately 60 percent of Philippine upland rice is grown on slopes of less than 8 percent, that is, flat to gently rolling. Work on intensifying upland rice cropping patterns would of practical necessity be mainly limited to this portion of the industry, where the severe limitations of slope would not be present. Some permanent farming areas that are classified as SR and have slopes of 8-15%, (e.g. western Tanauan, Batangas) may also be a potentially productive focus of cropping pattern research to a limited extent. Most of the upland rice cultivated on steep slopes is, however, managed within shifting cultivation systems. Being generally remote and inaccessible the shifting cultivator has a very small resource base. This presents difficult challenges to the development of permanent cropping systems. Past research on this transition has not been successful (Garrity, 1976).

Slope has important interactions with rainfall, such that an area with gentle slopes may be less suitable for permanent cropping systems than one with somewhat steeper slopes, should rainfall be in such quantity and intensity in the first case as to create a greater erosion potential. Such interactions will be discussed further in interpreting the combined classification.

C. The distribution of upland rice area by soil texture

Philippine upland rice is predominantly found on medium textured soils (the loams). Table 7 and 8 show that medium textured soils account for an estimated 68 percent of total upland rice area. Only 2 percent of the upland rice is found on light textured soils (the sands). About one hectare in six is on heavy soils.

The dominance of medium textures tends to indicate that intensive soil management with animal power is quite feasible in the majority of upland areas where slope is not a constraint. Table 9 shows a breakdown of these medium-textured soils, and reveals that over two-thirds are clay loams or silt loams. These data agree with the analysis of a nationwide soil sampling of upland rice farms (Dozina and Herdt, 1974).

Soil textures at the IRRI-BPI research site in Batangas vary from clay loam to sandy loam (Garrity et al., 1975). Soils in this range were observed to offer high flexibility in tillage over a wide range of soil moisture conditions (Samson et. al., 1975).

D. The distribution of upland rice by soil order

The two most common soil orders associated with upland rice present a striking contrast in cropping pattern potential. Ultisols occupy the largest upland rice area (Tables 10 and 11). The low base saturation and low pH of these comparatively old, more weathered soils indicate major management problems for field crop production (Mariano and Valmidiano, 1973). The inceptisols under upland rice, the second most important group, are on the other hand some of the most fertile soils in the country.

Philippine inceptisols are predominantly Eutrandepts derived from fine volcanic ash. With higher CEC's and base saturation these young soils tend to have good potential for intensive crop production. They are concentrated in Batangas province and parts of Camarines Norte, Camarines Sur, Lanao del Sur, and South Cotabato.

Alfisols, the third most important soil order in the sample are also generally quite productive, and are considered by Mariano and Valmidiano (1973) to have much greater potential thant ultisols for intensive cropping. Vertisols and entisols have very little importance in upland rice production (Table 10). These two soil orders occupy relatively areas of Philippine soils. Thus, their low proportion of upland rice area does not necessarily indicate that they are ralatively unsuitable for the crop.

It is a significant point that in those upland rice areas having the most common soil order (ultisols) we may anticipate major soil fertility constraints to further crop intensification.

E. Upland rice environmental complexes

By the classification process discussed above, each sample municipality was assigned a set of values for all four environmental components: Rainfall pattern, slope, soil texture, and soil order. These four values determine the physical environment for that municipality. For example, the physical environment of Tanauan, Batangas the present upland rice cropping systems research site, was determined to be 6-7:GR:M:I. The values are arranged in order from the highest category (rainfall) to the lowest(soil order). Table 12 gives this data for the municipalities in Bukidnon province as an example. The data for all 300 municipalities is included in Appendix 1 (under separate cover).

An environmental complex can be defined as a union of sites which share the same physical environment, that is, which have the same values for the identified physical cropping pattern determinants. This study employed the municipality as a sampling unit, so that for the purpose of this study the environmental complex can be defined as a group of municipalities which have similar values for the physical determinants studies. Figure 5 is a distribution of the second order upland rice environmental complexes wherein only the two highest order determinants, rainfall pattern and slope, are considered. These are graphed against the upland rice area found within each complex.

Figure 6 shows the distribution of the fourth order environment complexes where all four determinants are considered. The environmental complex containing Tanauan, Batangas, 6-7:GR:M:I, is shared by 20 municipalities with a total upland rice area of approximately 23,000 hectares.

Table 13 lists all municipalities which are included in the most important complex, 8-10: GR:M:U. Appendix 2 is a compilation of the municipalities in every environmental complex (under Separate cover).

The full height of the columns in Figure 6 represent the upland rice area in each of the third order environmental complexes. These involve similar values for rainfall, slope, and soil texture, while soil order is variable. The third order environmental complex for Tanauan, 6-7:GR:M is shared by 36 municipalities having 40,000 hectares of upland rice.

Figure 6 shows a number of general trends among the physical determinants. Most of the upland rice in every rainfall pattern is on gently rolling slopes. Also, soil texture is predominantly medium across all slope types in every rainfall pattern. Medium textures are strongly associated with upland rice both in gently sloping areas and in steeply sloping areas. However, light textured soils are found only in gently sloping areas, being totally absent in association with upland rice on steeper slopes.

The major environmental complexes for upland rice, considering the three higher categories only, are represented by the three tallest columns in Figure 6. These are: 6-7:GR:M,8-10:GR:M, and 10-12:GR:M. Having similar and favorable slope and soil textural characteristics, they differ only in their highest category, rainfall. Examining these on the soil order level we may observed the six most important 4th order environment complexes:

6-7GR:M:I	8-10:GR:M:U	11-12:GR:M:U
	8-10:GR:M:I	11-12:GR:M:I
	8-10:GR:M:A	

Research sites in these six environments would seem to be representative of the widest areas of upland rice land in the Philippines that are potentially conducive to more intensive cropping.[5/] The location of municipalities within the three largest of these environmental complexes are mapped in Figure 7.

Sites in different parts of the country within the same environmental complex may be presumed to be agro-ecological analogues. The identification of such analoguos environments can have an important function in the efficient transferral of cropping patterns just as crop ecologists and plant

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5/ The environmental complex 8-10:SR:M:U is also quite large but was not included due to the strong limitation that steep slopes may present to multiple cropping based on upland rice.

breeders have long effectively utilized this concept in the introduction of plant materials from one location to another (Nuttonson, 1947).

With a tentative identification of the more important environmental complexes an important issue arises:

> Do localities in the same environmental complex actually have a similar cropping pattern potential, and do localities in separate environmental complexes have differences in their cropping pattern potential?

The above question is actually one of how well the environmental complexes succeed in delineating agronomic production complexes.6/ If an environmental complex is well-defined there exist only one agronomic production complex for every site within that environmental complex. If more than one agronomic production complex can be defined within a single environmental complex, this is an indication that one or more important physical determinants have been overlooked in the definition of the environmental complex.

In some cases, however, cropping pattern potential may be the same over two environmental complexes. This is due to an interaction among determinants or by the replaceability of determinants (Rubel, 1935). An example is the discussion of the potential interaction between rainfall and slope in section IIIB.

One of the basic aims of cropping systems research is to define these agronomic production complexes, within which the researcher is confident that cropping pattern technology will perform fairly uniformly. This activity depends heavily on accurately characterizing environmental complexes to which cropping pattern potential must be related in order for a workable understanding to be gained.

The information in this study may be useful in determining several representative new sites for upland rice cropping systems work, based on those environmental complexes observed to be most important. The experience gained at these new sites would in turn test the effectiveness of this classification system in delineating areas in different parts of the country with similar or differing cropping pattern potential.

The methodology used here for classifying upland rice environments with available data could easily be adapted to systems based on other crops, such as corn or lowland rice or even forest or grassland systems. The determinants, however, may vary in content and priority when classifying the environments of different systems. In lowland rice based systems for example, water control variables would be of great importance in the classification system.

6/ Zandstra (1976) defines an agronomic production complex as "a union of sites described by values of agronomic determinants in which the relative performance of cropping patterns is substantially similar". Relative performance would be judged in terms of physical productivity in this case. Economic variables are not considered.

FINAL NOTE

A separate set of appendices are available which are not included in this printing of the paper. They include two tables: 1) the definition of the physical environment of each of the 300 sample municipalities in terms of the four determinants. (This is an expansion of Table 12). 2) a compilation of the municipalities composing each fourth order environmental complex. (An expansion of Table 13).

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DEFINITION OF TERMS USED IN THIS PAPER

Cropping pattern.[7/] The spatial and temporal combination of cultivars in any one field. Generally time is limited to one year and a field is defined as a contiguous area of land receiving the same management during a defined period (one year).

Cropping system.[7/] The relation of cropping patterns used on a farm to a given set of resources as specified by a technology.

Determinants.[7/] Variables which determine the performance of cropping patterns which are not readily modifiable.

Environmental complex. A union of sites which share the same values for those physical cropping pattern determinants that have been identified.

Agronomic production complex.[7/] A union of sites described by values of agronomic determinants in which the relative performance of cropping patterns is substantially similar.

7/ Zandstra (1976).

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Table 1. The municipalities and area in upland rice distributed according to rainfall pattern.

Rainfall pattern	Number of municipalities	Area in upland rice	Percentage area in upland rice
(No. of mos. with >100 mm rainfall per mo.)			
0- 5	6	6,492.6	1.98
6- 7	54	56,103.6	17.07
8-10	160	179,312.1	54.56
11-12	67	74,487.7	22.66
Unclassified	13	12,262.1	3.73
	300	328,658.1	100

Table 2. How cropping pattern potentials may differ with differences in the rainfall determinant. Slope and soil fertility assumed not limiting.

No. of months w/ $\geq$ 100 mm/mo.	No. of crops following upland rice: Definite	Possible	Some possible cropping patterns
0 - 3	0	0	Upland rice unlikely
4 - 5	0	1	Upland rice-mung Upland rice-sorghum
6 - 7	1	2	Upland rice-corn Upland rice-legume Upland rice-sorghum-sorghum (ratoon)
8 -10	1	2	Upland rice-corn-legume Upland rice-sorghum sorghum (ratoon)
11- 12	2	2	Upland rice-corn-corn Upland rice-sorghum-sorghum

Table 3. The slope classes used in classifying upland rice municipalities

Slope Class	Code	Percentage slope	Corresponding units on the slope map of the Philippines
Flat to gently rolling	GR	0 - 8	1 - 2
Rolling to steeply rolling	SR	8 - 30	3 - 4
Steeply hilly to mountainous	M	30	5 - 6

Table 4. Upland rice municipalities and area distributed according to slope type.

Slope types	Number of municipalities	Total area in upland rice	%total area in upland rice
GR	123	135,880.8	41.34
SR	42	44,658.3	13.59
M	118	17,226.5	5.24
GR/SR	48	53,813.4	16.37
GR/M	14	8,920.4	2.71
SR/GR	30	36,760.1	11.13
SR/M	11	14,893.0	4.53
M/GR	4	2,894.9	0.90
M/SR	6	7,419.2	2.26
Not surveyed	4	6,191.5	1.88
	300	328,658.1	100

Table 5. Upland rice municipalities and area distributed according to the dominant slope type.

Slope types	Number of municipalities	Area in upland rice	% age area in upland rice
GR	185	198,614.6	60.34
SR	83	96,311.4	29.30
M	28	27,540.6	8.39
Not surveyed	4	6,191.5	1.88
Total	300	328,658.1	100

Table 6. The soil textural classes used in classifying upland rice municipalities.

Light (L)	-	Includes all sands
Medium (M)	-	Includes all loams (e.g. sandy loam, clay loam, etc.)
Heavy (H)	-	Includes all clays (silty clay, sandy clay, etc.)
Others (O)	-	Localities where soil texture not distinguishable.

Table 7. Upland rice municipalities and area classified according to soil textural class.

Soil textural class[a]	No. of municipalities	Area in upland rice	% of the area in upland rice
M	193	208,722.4	63.51
M/H	14	10,665.8	3.25
M/L	2	1,051.1	0.32
M/O	6	4,214.4	1.28
H	40	40,301.6	12.26
H/M	6	15,045.6	4.58
L	4	4,633.5	1.41
L/M	4	2,027.7	0.62
L/H	1	334.3	0.10
O	24	37,980.1	11.56
O/M	2	1,439.2	0.44
Unclassified	4	2,242.4	0.68
Total	300	328,658.1	100

a/ When more than one textural class is present in the municipality the dominant class is listed first, the secondary class second.

Table 8. Upland rice municipalities and area distributed according to dominant soil textural class.

Dominant soil textural class	No. of municipalities	Area in upland rice	% age area in upland rice
M	215	224,653.7	68.35
H	46	55,347.2	16.84
L	9	6,995.5	2.13
O	26	39,419.3	11.99
Unclassified	4	2,242.4	0.68
	300	328,658.1	100

Table 9. The number of municipalities and total upland rice area under medium soil type.

Medium soil classification	No.of municipalities	% number of municipalities	Total area in upland rice	% total area in upland rice
Light loam (i.e. sandy loam)	33	15.35	23,633.3	10.52
Medium loam (i.e. loam, sandy clay loam)	41	19.07	41,772.1	18.59
Heavy loam (i.e. silt loam, clay loam, silty clay loam)	141	65.58	159,248.3	70.88
Total	215	100	224,653.7	100

Table 10. Upland rice municipalities and area distributed according to dominant soil order.

Rank	Soil orders	Code	No.of munici-palities	Total area in upland rice	% total area in upland rice
1	Ultisols	(U)	122	118,810.7	36.15
2	Inceptisols	(I)	77	91,437.2	27.82
3	Alfisols	(A)	33	51,107.5	15.55
4	Mountain soils	(M)	20	20,865.2	6.35
5	Vertisols	(V)	14	15,343.3	4.67
6	Entisols	(E)	13	11,456.6	3.49
	Unclassified		23	19,637.6	5.98
	Total		300	328,658.1	100

Table 11. Number of municipalities and total area in upland rice classified according to soil order.

Soil orders	No.of muni-cipalities	% number of municipalities	Total area in upland rice	% total area in upland rice
U	76	25.33	71,529.3	21.76
U/A	8	2.67	11,816.8	3.59
U/E	A	1.33	2,639.6	0.80
U/V	8	2.67	9,615.5	2.93
U/I	14	4.67	11,157.2	3.39
U/M	12	4	12,061.3	3.67
A	25	8.33	40,757.8	12.40
A/M	5	1.67	7,336.4	2.24
A/U	1	0.33	480.1	0.15
A/I	2	0.67	2,503.2	0.76
M	14	4.67	16,837.5	5.12
M/U	6	2	4,027.7	1.22
E	10	3.33	8,908.7	2.71
E/U	2	0.67	1,332.0	0.41
E/I	1	0.33	1,215.9	0.37
I	42	14	58,954.0	17.94
I/M	8	2.67	8,927.8	2.72
I/U	25	8.33	23,555.4	7.17
V	5	1.67	6,821.8	2.07
V/U	7	2.33	7,281.9	2.22
V/A	1	0.33	884.5	0.27
V/I	1	0.33	355.1	0.11
Unclassi-fied	23	7.67	19,637.6	5.98
Total	300	100	328,658.1	100

Table 12. Definition of the environment of each of the municipalities in Bukidnon province with more than 300 ha in upland rice.

Bukidnon							
Municipality	Upland rice area (ha)	Rainfall pattern	Slope type	Soil texture	Soil textural class	Soil order	Environmental complex
1. Kibawe	3106	8-10	GR	CL	M	U	8-10:GR:M:U
2. Kalilangan	2263	8-10	GR/SR	C	H	U	8-10:SR:H:U
3. Pangantocan	2232	8-10	M/SR	C	H	U/M	8-10:M:H:U
4. Maramag	1939	8-10	GR	C	H	V/U	8-10:GR:H:V
5. San Carlos	1123	-	SR	C	H	-	-
6. San Fernando	1025	8-10	SR/M	M	O	U/M	8-10:SR:O:U
7. Malaybalay	886	11-12	SR	C/CL	H/M	V/U	11-12:SR:H:V
8. Baungon	821	11-12	SR	C	H	U	11-12:SR:H:U
9. Kitakitad	648	8-10	GR	CL	M	U	8-10:GR:M:U
10. Manalo Fortich	636	8-10	GR	C	H	U	8-10:GR:H:U
11. Talakag	452	11-12	SR/GR	C/CL	H/M	U	11-12:SR:H:U
12. Quezon	410	8-10	GR	C	H	V/U	8-10:GR:H:V

Table 13. The municipalities included in the 4th order environmental complex with the largest area in upland rice.[a/] The complex: 8-10:GR:M:U. Total upland rice area: 22,441.

Municipality	Province	Upland rice area (ha)
Kibawe	Bukidnon	3,106.3
Kita Okitao	Bukidnon	647.9
Dolores	Quezon	469.4
Alicia	Zamboanga del Sur	1,828.7
Dimatalig	Zamboanga del Sur	1,274.8
Leon	Iloilo	1,797.1
Malangas	Zamboanga del Sur	809.0
Igbaras	Iloilo	1,678.0
Calinog	Iloilo	1,197.6
Sipocot	Camarines Sur	973.6
Sindangan	Zamboanga del Norte	825.3
Manukan	Zamboanga del Norte	349.7
Lopez	Quezon	791.2
San Antonio	Quezon	227.4
Malita	Davao del Sur	783.0
Pigkawayan	Cotabato	722.3
Kabacan	Cotabato	584.5
Parang	Cotabato	466.6
Sn. Mariano	Isabela	518.5
Jalajala	Rizal	473.4
Boac	Marinduque	468.6
Castilla	Sorsogon	461.8
Masbate	Masbate	397.0
Leyte	Leyte	392.5
Sta. Maria	Laguna	359.8
Pudtol	Kalinga-Apayao	335.9
Ubay	Bohol	300.9

a/ The municipalities included in every 4th order environmental complex are found in Appendix 2 (under separate cover).

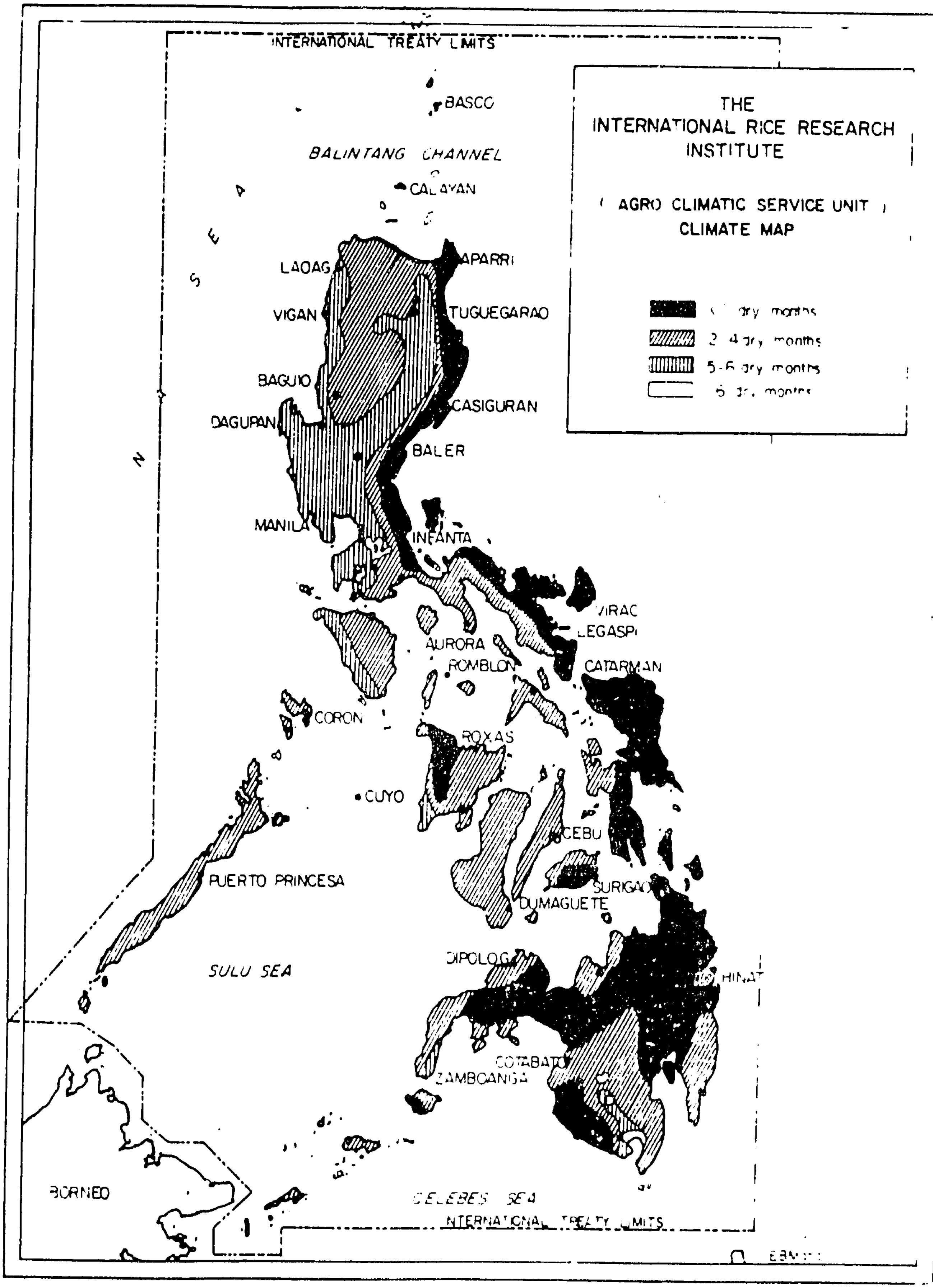

Fig. 1. Agroclimatic map of the Philippines based on the no. of months during the year when average rainfall is less than 100mm per month.

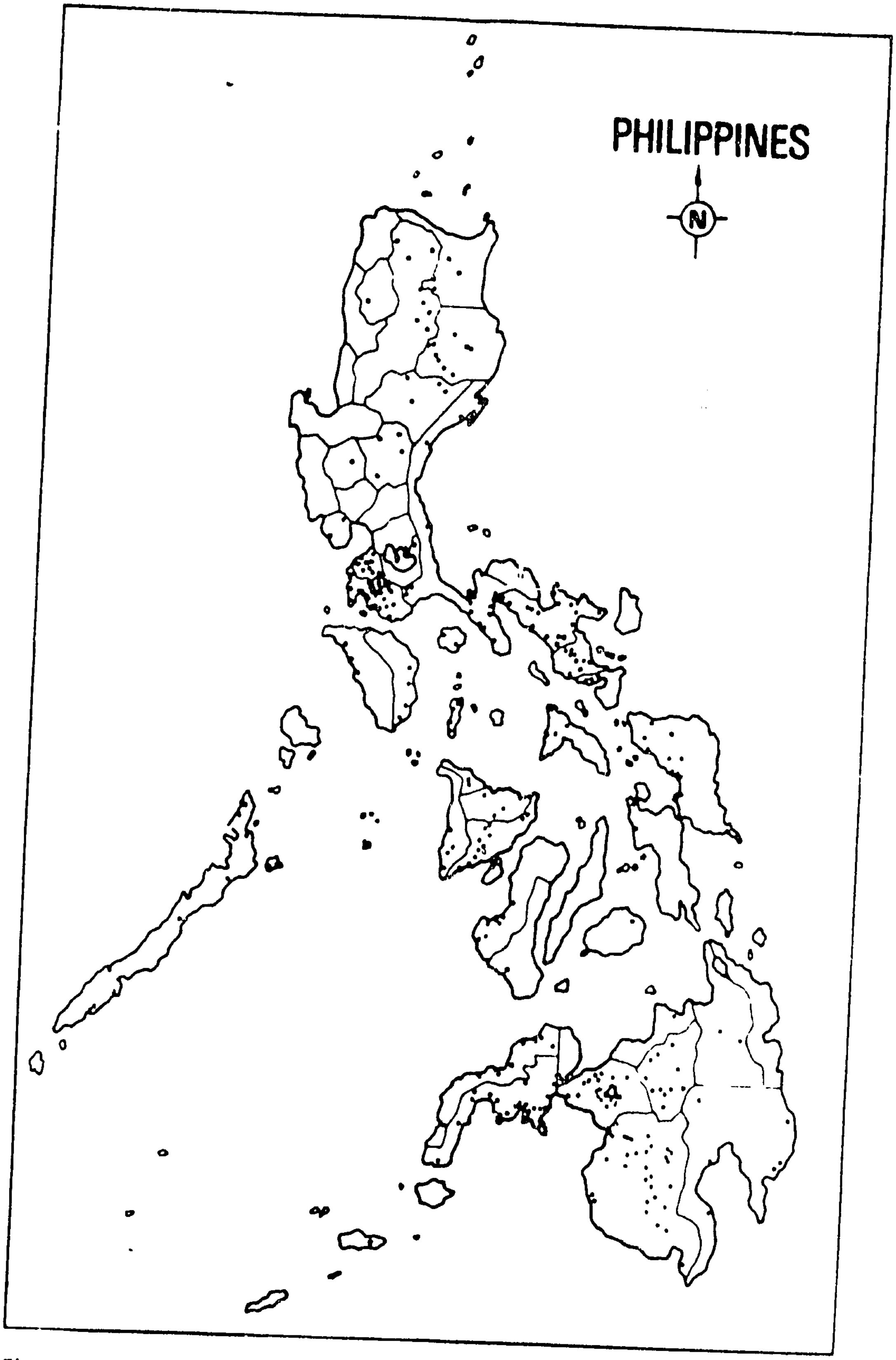

Fig. 2. The locations of all Philippine municipalities with $\geq$ 300 hectares in upland rice. Source: 1971 Census of the Philippines.

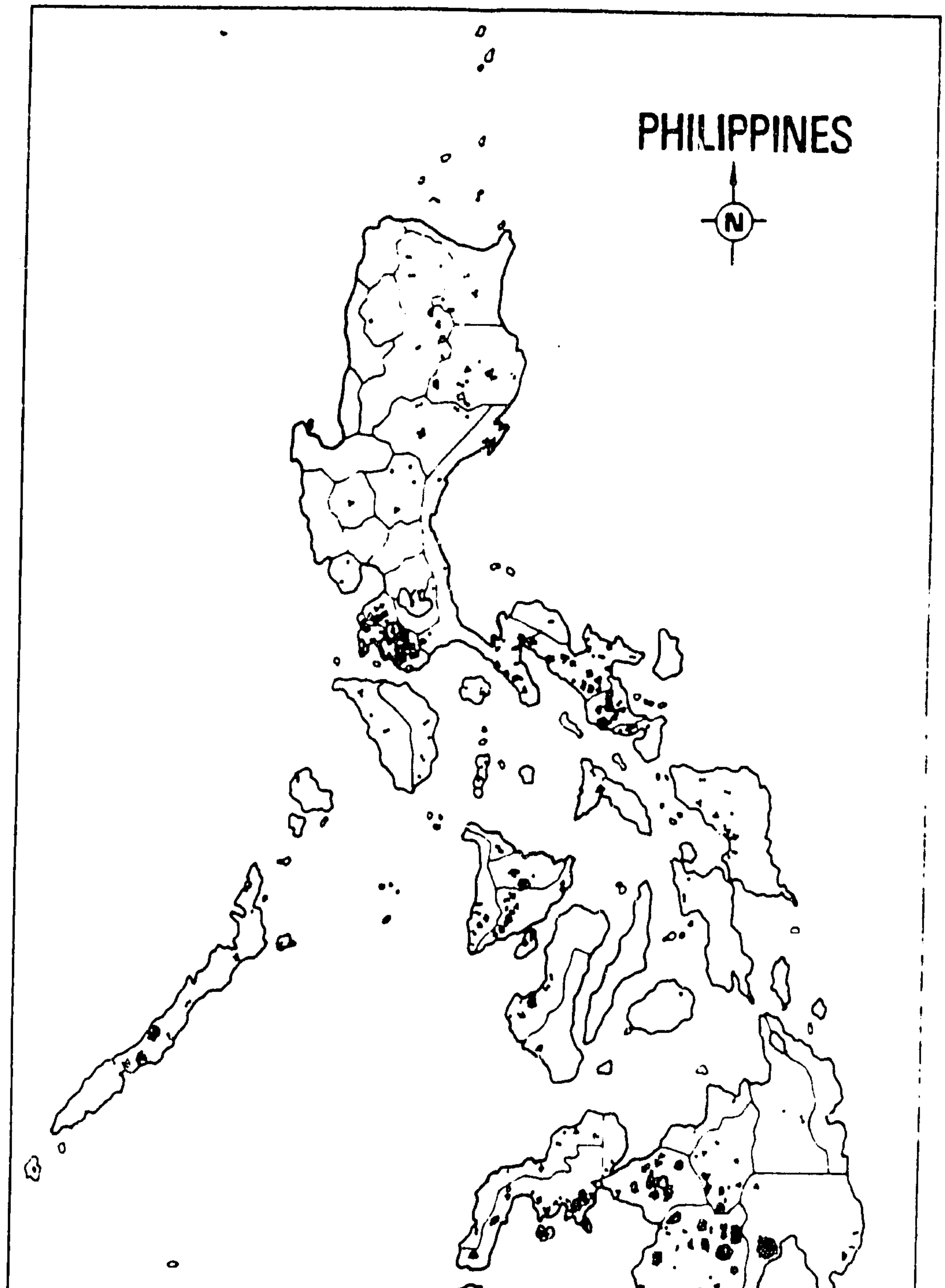

Fig. 3. The distribution of upland rice by area planted. Each dot represents 300 hectares. Source: 1971 Census of Agriculture.

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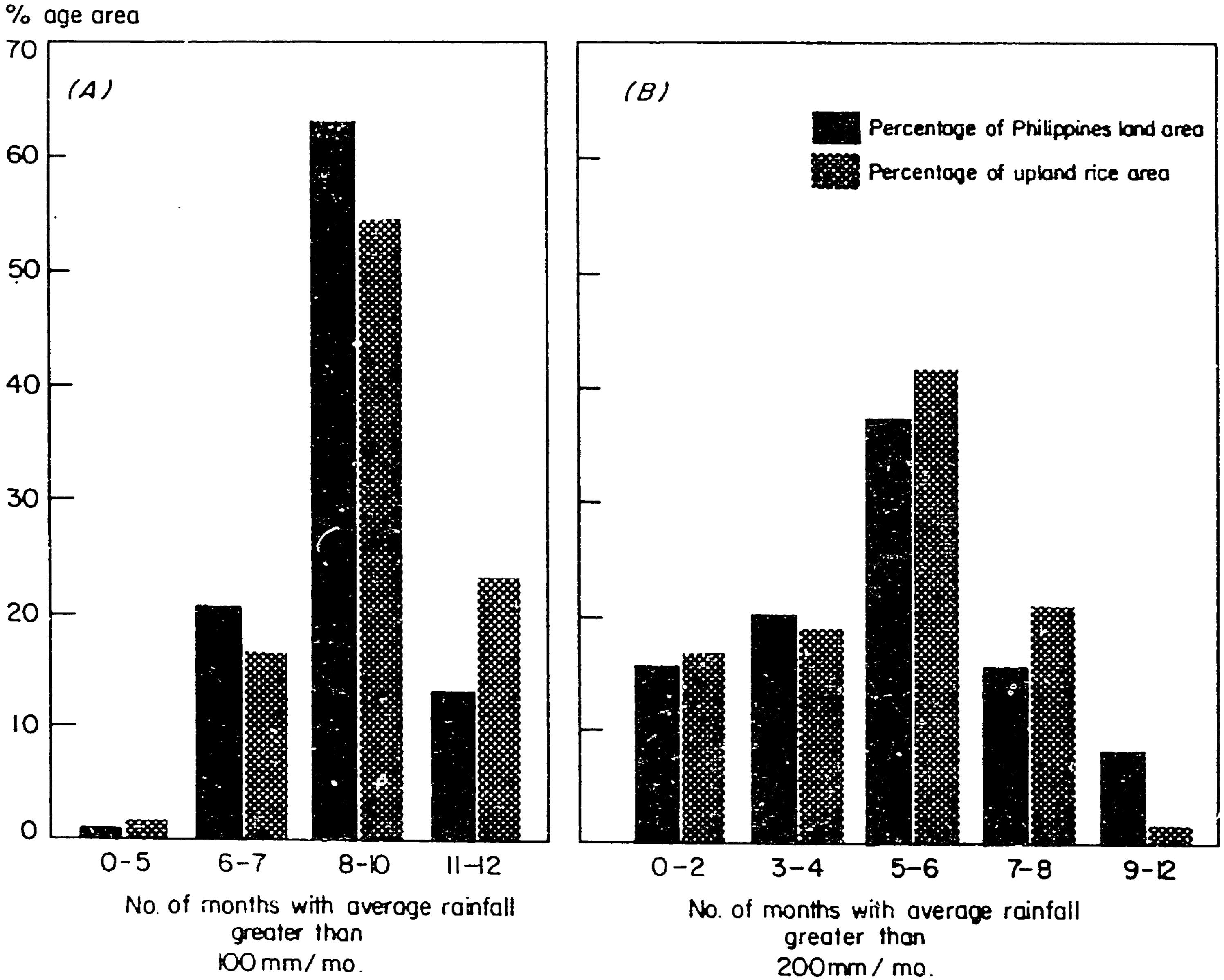

FIG. 4. THE DISTRIBUTION OF PHILIPPINE LAND AREA AND UPLAND RICE AREA IN TERMS OF THE NUMBER OF MONTHS WITH AVERAGE RAINFALL IN EXCESS OF A CRITICAL LOWER LIMIT.

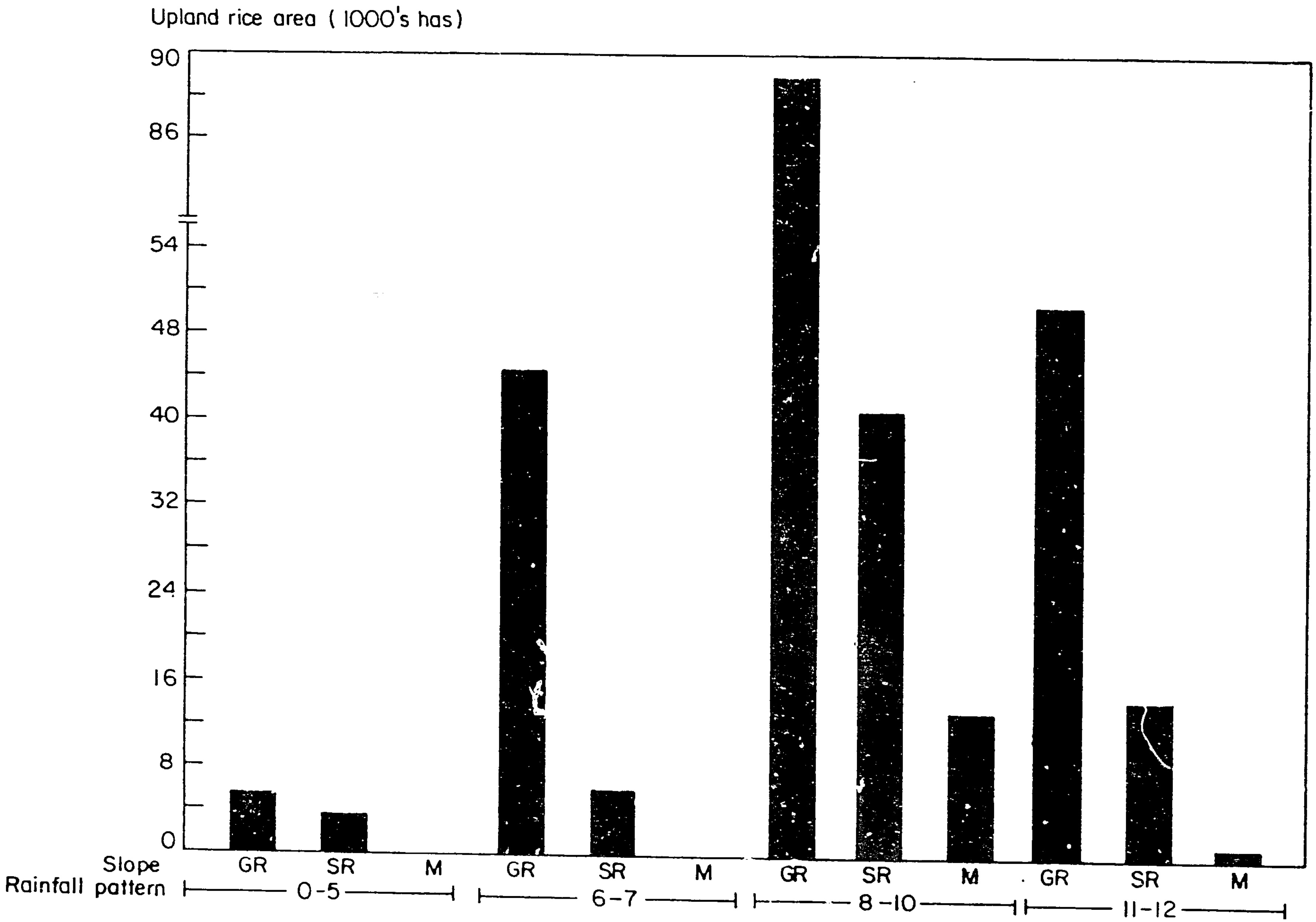

FIG. 5. THE 2ND ORDER ENVIRONMENTAL COMPLEXES AND THE AREA OF PHILIPPINE UPLAND RICE FOUND IN EACH COMPLEX. THE DETERMINANTS ARE RAINFALL PATTERN AND SLOPE.

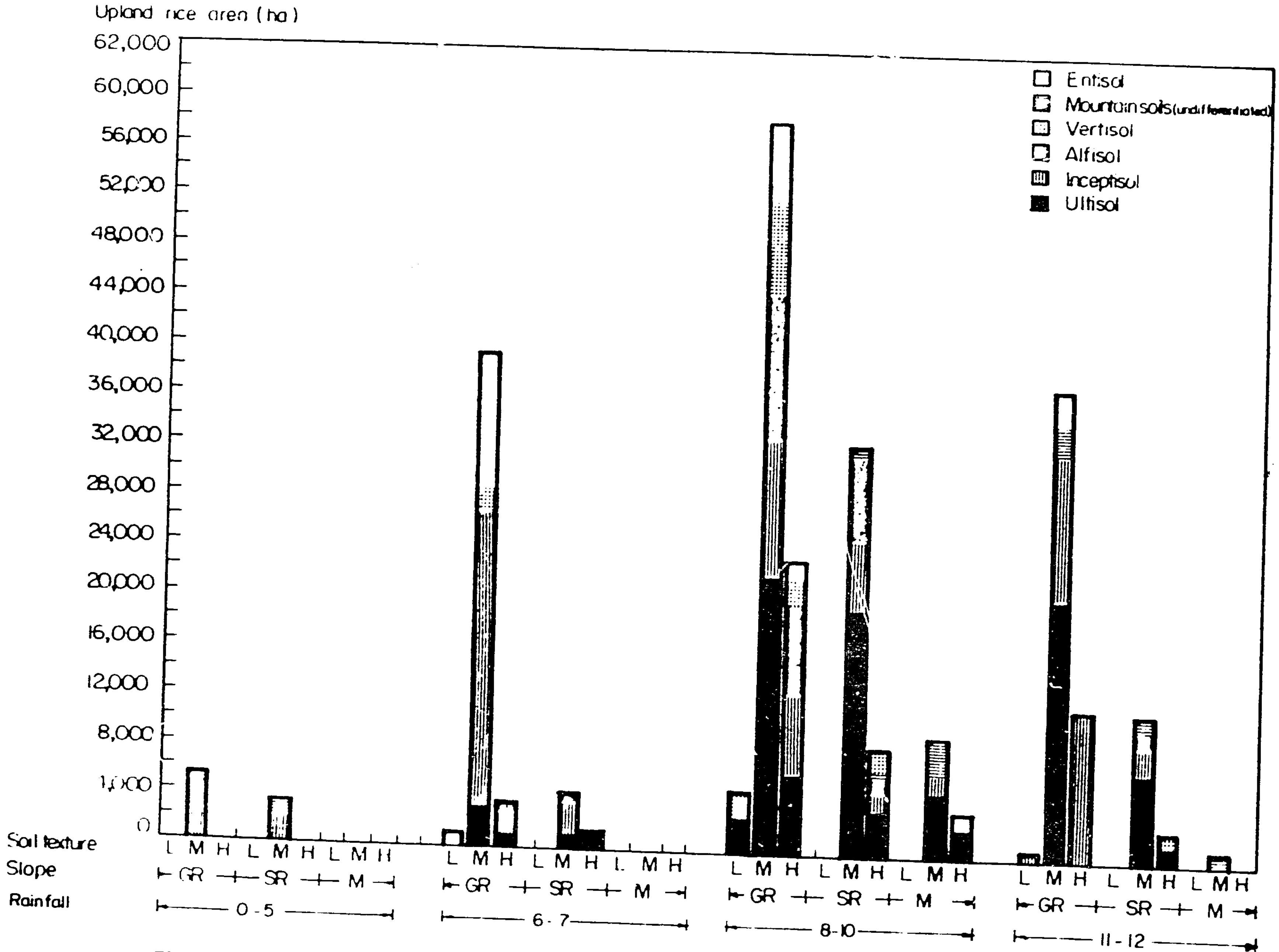

Fig. 6. The 4th order environmental complexes and the area of Philippine upland rice found in each complex. The four determinants are rainfall pattern, slope, soil texture and soil order.

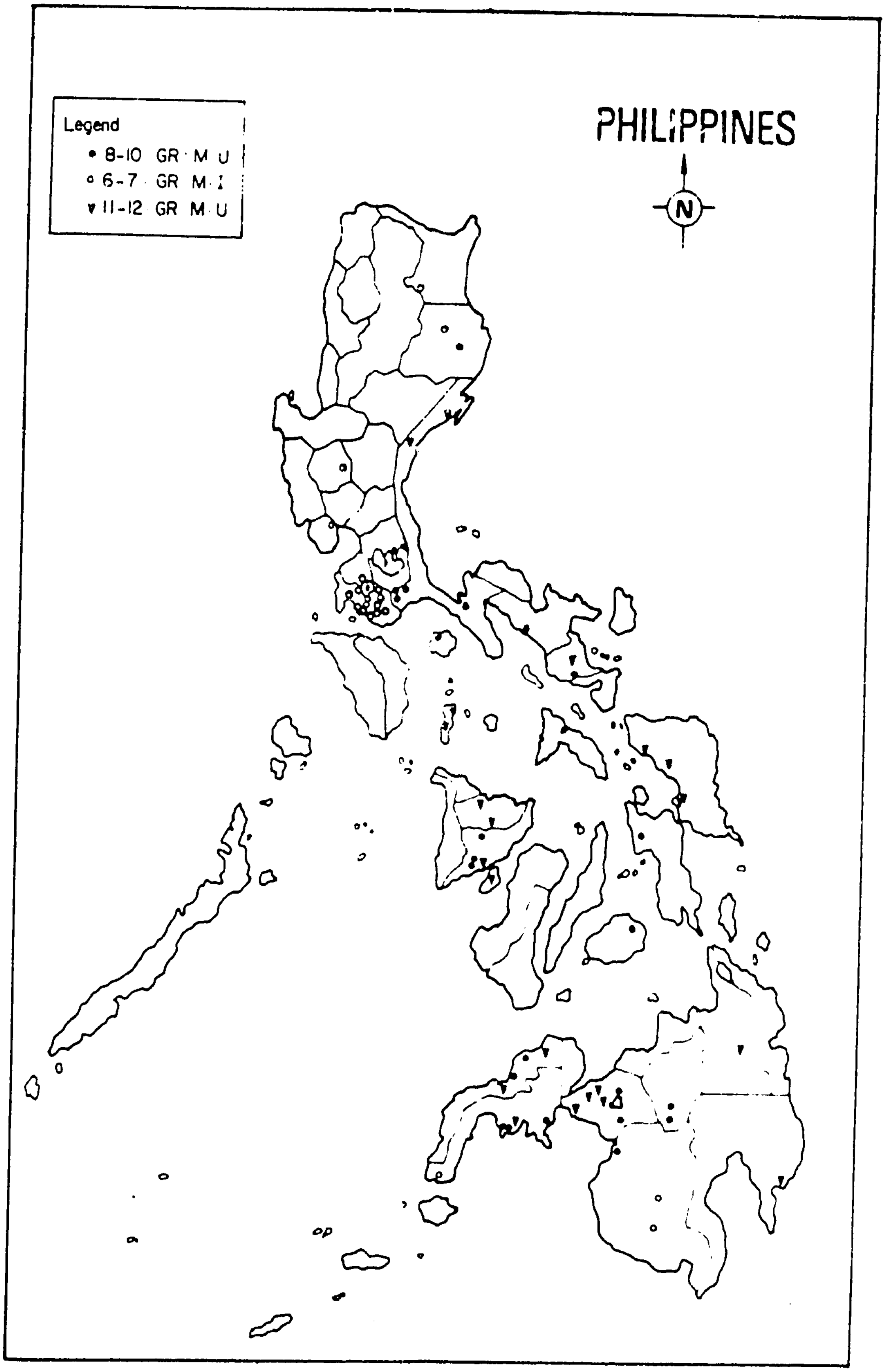

Fig. 7. The location of the municipalities included in each of the three largest 4 th order environmental complexes.

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