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A STUDY OF THE EFFECTS OF THE CHANGES IN DATA STRUCTURE ON A PRELIMINARY LAND CLASSIFICATION OF THE IBERIAN PENINSULA

by

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PREFACE

1 The study demonstrates the ability of the land classification procedure to utilise whatever data are readily available, even if these are at a low level of detail. Regional classes that show clear cut regional patterns are still produced.

2 Such classifications can be carried out rapidly - an important feature in some applications, eg the setting up of a sampling system for a Third World country. The levels of detail can be improved as required.

3 Some useful methodological developments are explored in the study which have subsequently been built into other projects.

4 The project is a good example of a collaborative venture, with the three authors sharing various tasks in the work.

Since returning to Spain Dr Rossello has applied the principles of the land classification procedure to several projects, eg on the growth of *Quercus pyrenaica* in central Spain and a paper on the methodology in Spanish. Currently a classification of Navarra has been completed and is at present being evaluated for planning purposes. Preliminary results show well defined geographical groupings that are readily interpretable. This project is being used as a pilot scheme for possible extension to Spain as a whole. It is hoped that there will be further collaboration on this project and that contact will be maintained in future.

R G H BUNCE
August 1984

1 INTRODUCTION

Early in 1982, I was given a grant by the Instituto Nacional de Investigaciones Agrarias to spend 4 months (June-October, 1982) at Merlewood Research Station, Grange-over-Sands, Cumbria, one of the component research establishments of the Institute of Terrestrial Ecology, which, in turn, is part of the Natural Environment Research Council. My principal objective was to investigate methods of stratification of ecological data, especially the method developed at Merlewood for the classification of land-use data (Hill et al. 1975). This method, the basis of which is a statistical procedure known as Indicator Species Analysis (I.S.A.), has been extended to produce a land classification of Great Britain (Bunce et al. 1983).

It became evident at an early stage that the most practical way in which to master the relevant statistical procedures would be to work out a land classification of the Iberian peninsula using map data. This would then give me an opportunity to employ the classification as a means of learning how to use the statistical methods of I.S.A., and would also provide a land classification, albeit crude, of the Iberian peninsula which subsequently might be extended and refined. Further, the opportunity to test the method on a country with quite different ecology and climate than those of Great Britain would provide a useful test of the method.

After completing the classification, I proceeded to test the method for robustness, by modification of the attributes used, i.e. by manipulation of the cut-off points within the variables chosen.

As a result, the gained experience will allow me to handle confidently, in similar fashion, my botanical data, particularly on the regional and local levels, on returning to my Institute.

2 SAMPLING, DATA-RECORDING AND DATA-ANALYSIS

The method used in producing the classification described in this paper is based on Indicator Species Analysis (I.S.A.) as described by Hill *et al.* (1975). Bunce & Smith (1978) adapted the technique for use in their ecological survey of Cumbria and in the land classification of Great Britain.

The land classification of the Iberian peninsula so produced is a preliminary classification for which the sampling procedure was designed differently from that used in previous land classifications. The basic data were taken from 3 different sources:

1 Climate: values for temperature and rainfall were abstracted from the Climatic Atlas of Europe (W.M.O. 1970). (Scale 1:10.000.000).

2 Physiography: altitude, relief and exposition were as recorded in the Times Atlas of the World (The Times 1968) (Scale 1:2 500 000).

3 Geology: the International Geological Map of Europe (Hannover 1971) provided the data for the geology of the study area. (Scale 1:5 000 000).

4 Details of other features, such as roads and towns, were also taken from the Times Atlas.

Even though these are small scale data sources, they were considered adequate for the production of this provisional land classification; for a definitive classification the use of detailed data sources would be essential. With small scale maps it is not possible to design a sampling technique such as that used by Bunce et al. (1983) in the land classification of Great Britain.

Using a 50 km grid the Iberian peninsula was divided into 260 squares, each square measuring 2 500 km^2. Of these, a sample of 204 squares was chosen systematically for analysis, leaving the remaining 56 squares to test the resulting stratification.

The ecological features to be recorded were chosen in accordance with the square size and the available information. These features are the 64 variables shown in Figure 1.

a. The climatic variables (4) were selected because of the remarkable contrast existing in the Iberian climates. The climatic extremes of Continental versus Maritime and Mediterranean versus Atlantic are present. The same objective determined the choice of the "location" variables (2).
b. The geological (30) and altitudinal (21) variables were recorded in 2 different ways. Both square centre records and surrounding records were taken. In this way, an attempt was made to provide information about land continuity.
c. Aspect was chosen as a very important, ecological, Mediterranean feature, although it is very difficult to measure in sample squares of this small size.
d. The final variables were those concerned with the presence of human artefacts such as towns and roads (6).

The variables described were recorded for each of the 204 squares of the sample and are displayed in a 204 row by 64 column data table, referred to as the data base.

Once the data had been assembled, the analysis was carried out on a Digital Computer at Merlewood Research Station.

The data base so produced was stored in a file within the computer. The first analysis carried out was to divide the original variables into specific qualitative attributes, so that an ISA might be undertaken. This is a unique component of the ITE classification method and is discussed later in this paper. The method demands that each variable is capable of being subdivided into a number of discrete ranges within the extremes.

The procedure used initially was the breaking down of each variable into 4 attributes by means of 3 cut-off points which were the equidistant between the full range extremes of each variable. The attribute list of the first land classification appears in Figure 2. The program used in this stage was SPANAT.BAS. The result of the application of this

Square No: Grid Ref: Date:

	Code	Measure	Description of variable	Unit of measurement
CLIMATE	1		Mean Daily Temp. March	°C
	2		Mean Daily Temp. July	°C
	3		Rainfall January	mm.
	4		Rainfall September	mm.
LOCATION	5		Distance to W. Coast	Squares
	6		Distance to S. Coast	Squares
GEOLOGY (centre)	7		Quaternary	%
	8		Tertiary	%
	9		Cretaceous	%
	10		Jurassic	%
	11		Triassic	%
	12		Permian	%
	13		Carboniferous	%
	14		Devonian	%
	15		Silurian	%
	16		Ordovician	%
	17		Cambrian	%
	18		Precambrian	%
	19		Metamorphism	%
	20		Effus. Ign. Rocks	%
	21		Int. Ign. Rocks	%
GEOLOGY (surrounding)	22		Quaternary	No. squares
	23		Tertiary	No. squares
	24		Cretaceous	No. squares
	25		Jurassic	No. squares
	26		Triassic	No. squares
	27		Permian	No. squares
	28		Carboniferous	No. squares
	29		Devonian	No. squares
	30		Silurian	No. squares
	31		Ordovician	No. squares
	32		Cambrian	No. squares
	33		Precambrian	No. squares
	34		Metamorphism	No. squares
	35		Effus. Ign. Rocks	No. squares
	36		Intr. Ign. Rocks	No. squares
TOPOGRAPHY	37		Dist. between Low High	mm.
	38		Maximum Elevation	Metres
	39		Minimum Elevation	Metres
ALTITUDE (centre)	40		Sea	No. of dots
	41		0 - 100	No. of dots
	42		100 - 200	No. of dots
	43		200 - 500	No. of dots
	44		500 - 1000	No. of dots
	45		1000 - 1500	No. of dots
	46		1500 - 2000	No. of dots
	47		2000 - 3000	No. of dots
	48		> 3000	No. of dots
ALTITUDE (surrounding)	49		Sea	No. squares
	50		0 - 100	No. squares
	51		100 - 200	No. squares
	52		200 - 500	No. squares
	53		500 - 1000	No. squares
	54		1000 - 1500	No. squares
	55		1500 - 2000	No. squares
	56		2000 - 3000	No. squares
	57		> 3000	No. squares
OTHER FEATURES	58		Exposition	Degrees from N.
	59		Length of Rivers	mm.
	60		Length of Small Roads	mm.
	61		Length of Main Roads	mm.
	62		Occur. Main Towns	Number
	63		Occur. Small Towns	Number
	64		Occur. Villages	Number

Figure 1. Variables used in the study.

Variable	1	gives attributes ...	1	[	5.3]	2	[	8.0]	3	[	10.8]	4
Variable	2	gives attributes ...	5	[	13.0]	6	[	18.0]	7	[	23.0]	8
Variable	3	gives attributes ...	9	[	67.5]	10	[	115.0]	11	[	162.5]	12
Variable	4	gives attributes ...	13	[	42.5]	14	[	65.0]	15	[	87.5]	16
Variable	5	gives attributes ...	17	[	5.0]	18	[	10.0]	19	[	15.0]	20
Variable	6	gives attributes ...	21	[	5.0]	22	[	10.0]	23	[	15.0]	24
Variable	7	gives attributes ...	25	[	25.0]	26	[	50.0]	27	[	75.0]	28
Variable	8	gives attributes ...	29	[	25.0]	30	[	50.0]	31	[	75.0]	32
Variable	9	gives attributes ...	33	[	25.0]	34	[	50.0]	35	[	75.0]	36
Variable	10	gives attributes ...	37	[	25.0]	38	[	50.0]	39	[	75.0]	40
Variable	11	gives attributes ...	41	[	25.0]	42	[	50.0]	43	[	75.0]	44
Variable	12	gives attributes ...	45	[	25.0]	46	[	50.0]	47	[	75.0]	48
Variable	13	gives attributes ...	49	[	25.0]	50	[	50.0]	51	[	75.0]	52
Variable	14	gives attributes ...	53	[	25.0]	54	[	50.0]	55	[	75.0]	56
Variable	15	gives attributes ...	57	[	25.0]	58	[	50.0]	59	[	75.0]	60
Variable	16	gives attributes ...	61	[	25.0]	62	[	50.0]	63	[	75.0]	64
Variable	17	gives attributes ...	65	[	25.0]	66	[	50.0]	67	[	75.0]	68
Variable	18	gives attributes ...	69	[	25.0]	70	[	50.0]	71	[	75.0]	72
Variable	19	gives attributes ...	73	[	25.0]	74	[	50.0]	75	[	75.0]	76
Variable	20	gives attributes ...	77	[	25.0]	78	[	50.0]	79	[	75.0]	80
Variable	21	gives attributes ...	81	[	25.0]	82	[	50.0]	83	[	75.0]	84
Variable	22	gives attributes ...	85	[	2.0]	86	[	4.0]	87	[	6.0]	88
Variable	23	gives attributes ...	89	[	2.0]	90	[	4.0]	91	[	6.0]	92
Variable	24	gives attributes ...	93	[	2.0]	94	[	4.0]	95	[	6.0]	96
Variable	25	gives attributes ...	97	[	2.0]	98	[	4.0]	99	[	6.0]	100
Variable	26	gives attributes ...	101	[	2.0]	102	[	4.0]	103	[	6.0]	104
Variable	27	gives attributes ...	105	[	2.0]	106	[	4.0]	107	[	6.0]	108
Variable	28	gives attributes ...	109	[	2.0]	110	[	4.0]	111	[	6.0]	112
Variable	29	gives attributes ...	113	[	2.0]	114	[	4.0]	115	[	6.0]	116
Variable	30	gives attributes ...	117	[	2.0]	118	[	4.0]	119	[	6.0]	120
Variable	31	gives attributes ...	121	[	2.0]	122	[	4.0]	123	[	6.0]	124
Variable	32	gives attributes ...	125	[	2.0]	126	[	4.0]	127	[	6.0]	128
Variable	33	gives attributes ...	129	[	2.0]	130	[	4.0]	131	[	6.0]	132
Variable	34	gives attributes ...	133	[	2.0]	134	[	4.0]	135	[	6.0]	136
Variable	35	gives attributes ...	137	[	2.0]	138	[	4.0]	139	[	6.0]	140
Variable	36	gives attributes ...	141	[	2.0]	142	[	4.0]	143	[	6.0]	144
Variable	37	gives attributes ...	145	[	1.6]	146	[	3.2]	147	[	4.8]	148
Variable	38	gives attributes ...	149	[	870.5]	150	[	1741.5]	151	[	2611.5]	152
Variable	39	gives attributes ...	153	[	250.0]	154	[	500.0]	155	[	750.0]	156
Variable	40	gives attributes ...	157	[	4.0]	158	[	8.0]	159	[	12.0]	160
Variable	41	gives attributes ...	161	[	4.0]	162	[	8.0]	163	[	12.0]	164
Variable	42	gives attributes ...	165	[	4.0]	166	[	8.0]	167	[	12.0]	168
Variable	43	gives attributes ...	169	[	4.0]	170	[	8.0]	171	[	12.0]	172
Variable	44	gives attributes ...	173	[	4.0]	174	[	8.0]	175	[	12.0]	176
Variable	45	gives attributes ...	177	[	4.0]	178	[	8.0]	179	[	12.0]	180
Variable	46	gives attributes ...	181	[	4.0]	182	[	8.0]	183	[	12.0]	184
Variable	47	gives attributes ...	185	[	4.0]	186	[	8.0]	187	[	12.0]	188
Variable	48	gives attributes ...	189	[	4.0]	190	[	8.0]	191	[	12.0]	192
Variable	49	gives attributes ...	193	[	2.0]	194	[	4.0]	195	[	6.0]	196
Variable	50	gives attributes ...	197	[	2.0]	198	[	4.0]	199	[	6.0]	200
Variable	51	gives attributes ...	201	[	2.0]	202	[	4.0]	203	[	6.0]	204
Variable	52	gives attributes ...	205	[	2.0]	206	[	4.0]	207	[	6.0]	208
Variable	53	gives attributes ...	209	[	2.0]	210	[	4.0]	211	[	6.0]	212
Variable	54	gives attributes ...	213	[	2.0]	214	[	4.0]	215	[	6.0]	216
Variable	55	gives attributes ...	217	[	2.0]	218	[	4.0]	219	[	6.0]	220
Variable	56	gives attributes ...	221	[	2.0]	222	[	4.0]	223	[	6.0]	224
Variable	57	gives attributes ...	225	[	2.0]	226	[	4.0]	227	[	6.0]	228
Variable	58	gives attributes ...	229	[	90.0]	230	[	180.0]	231	[	270.0]	232
Variable	59	gives attributes ...	233	[	25.0]	234	[	50.0]	235	[	75.0]	236
Variable	60	gives attributes ...	237	[	25.0]	238	[	50.0]	239	[	75.0]	240
Variable	61	gives attributes ...	241	[	20.0]	242	[	40.0]	243	[	60.0]	244
Variable	62	gives attributes ...	245	[	2.0]	246	[	4.0]	247	[	6.0]	248
Variable	63	gives attributes ...	249	[	2.0]	250	[	4.0]	251	[	6.0]	252
Variable	64	gives attributes ...	253	[	2.0]	254	[	4.0]	255	[	6.0]	256

Figure 2. List of attributes in the Standard ISA structure.

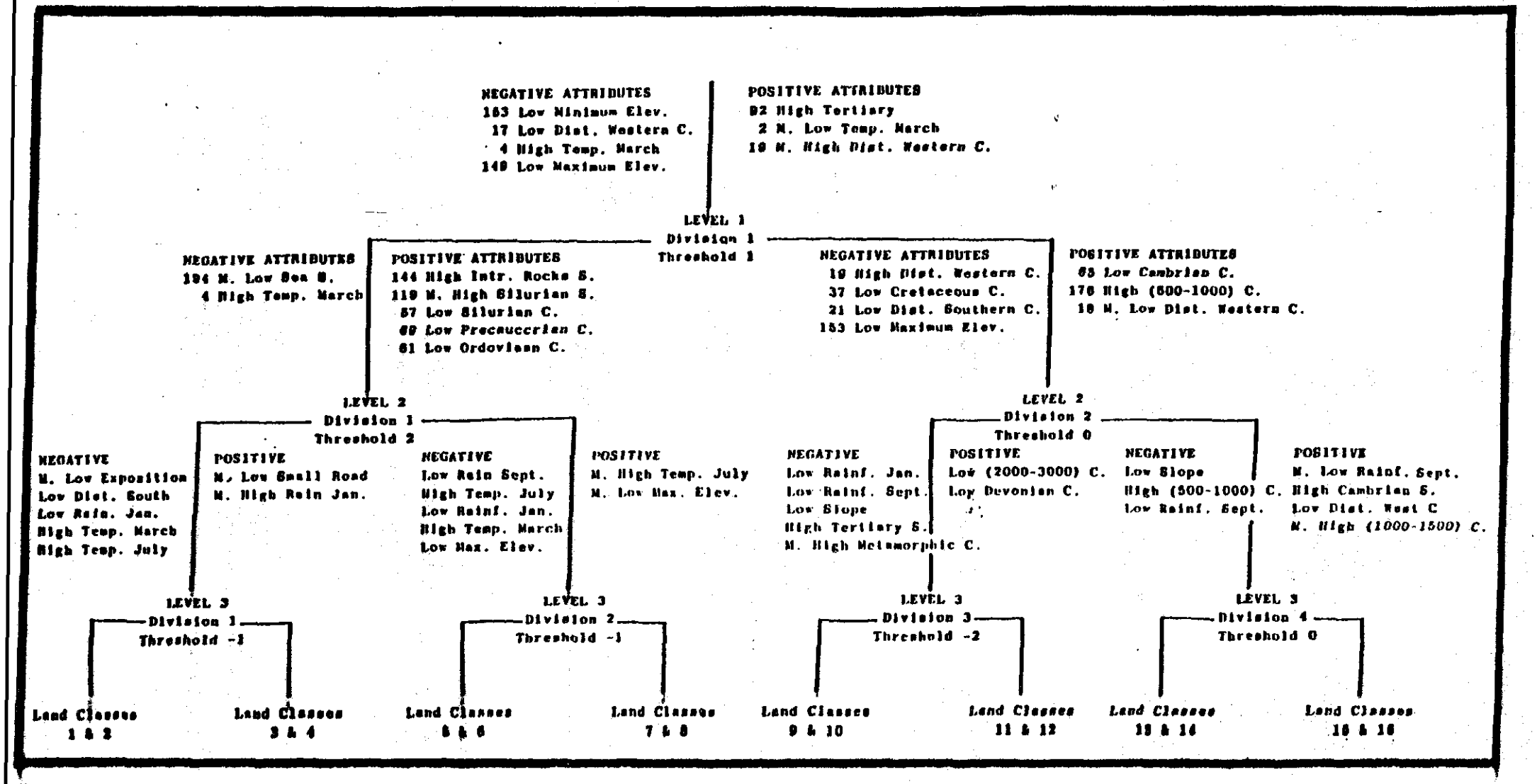
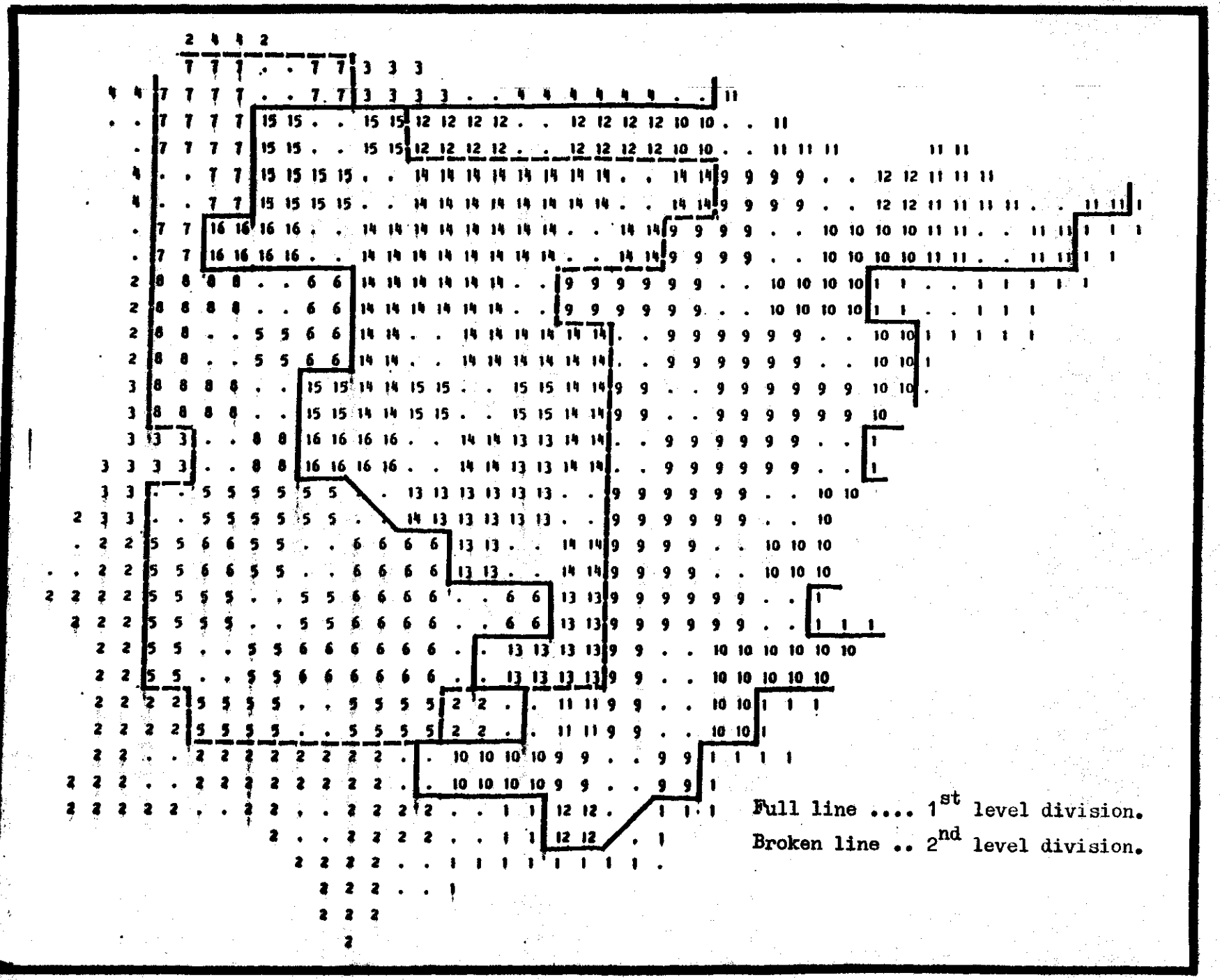


Figure 3. Hierarchical key of the Standard ISA Land Classification.


Full line .... 1st level division.
Broken line .. 2nd level division.

program to the data base was a new 204 row by 256 column data table. These data have the structure that the ISA requires. The relative frequency variation range of the variables is from 0.2 to 60%.

3 STANDARD ISA LAND CLASSIFICATION

When the ISA was applied to the data table described above, the result was the division of the 204 squares into 16 classes by use of the hierarchical key shown in Figure 3.

The cartographic expression of this land classification, called Standard ISA because it was carried out by means of the usual ISA procedure is shown in Figure 4.

Following this procedure, 14 unused squares from the north-west corner of the Iberian peninsula were tested with the hierarchical key. The test was completely positive in every case and is presented in the Figure 5. The criterion used to decide if the square in question had been correctly classified was its homogeneity with the surrounding squares and the continuum of ecological homogeneity.

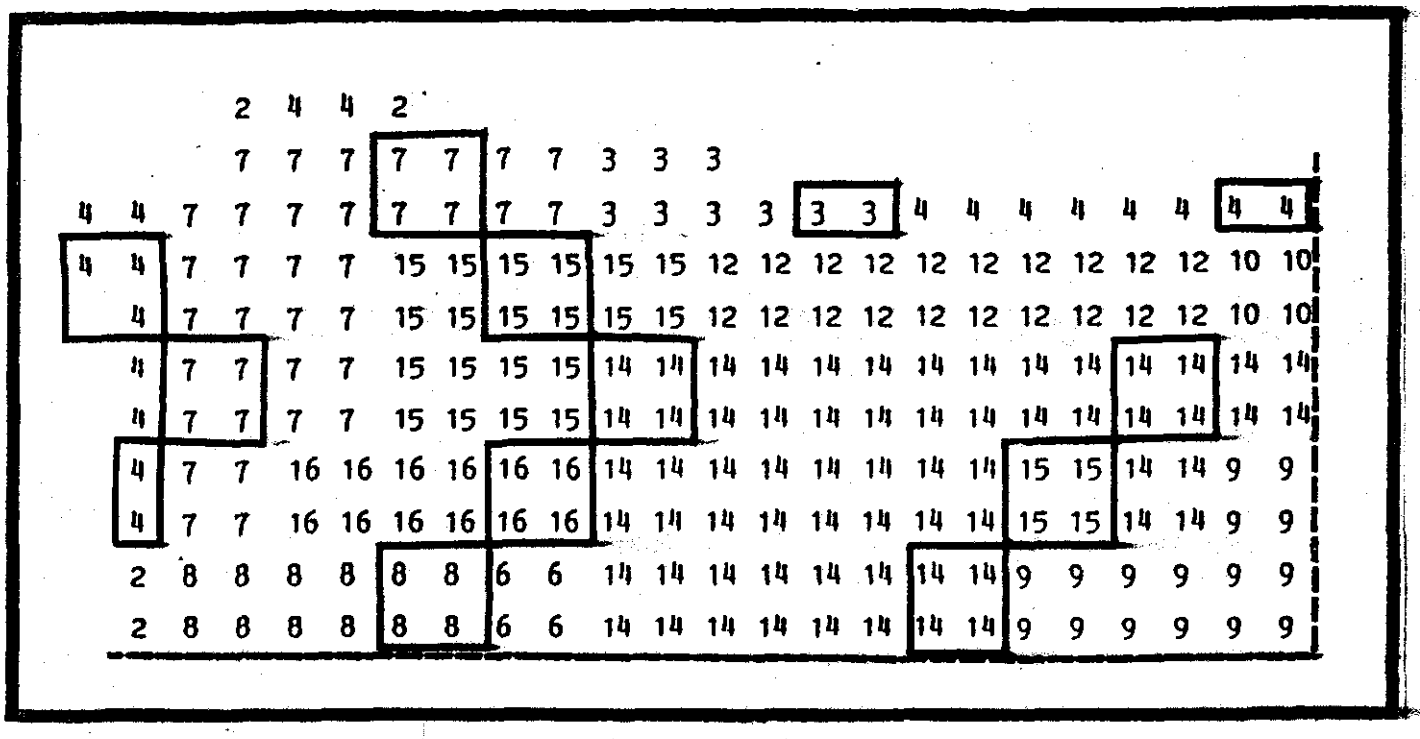


Figure 5. Tested squares using the Standard ISA key.

In an overall appraisal of the hierarchical key, 2 main lines appear as the ecological criteria under the key. At the first level, the criterion appears to be an altitudinal element. Thus, Land Classes

1 to 8 are mainly lowlands and Classes 9 to 16 are plateaux and mountains. At the second level, the criterion followed was geological. Thus, Classes 1 to 4 and 9 to 12 are calcareous regions and the remaining Classes are mainly siliceous regions. At the third and fourth levels, the divisions appear to be more complex, and consequently are more difficult to interpret.

After classification, the next phase was to characterise the classes. Two approaches are possible:

1 A more detailed study of the indicator attributes appearing in the hierarchical key.

2 The acquisition of more ecological information from further map sources, with regard to soil, natural vegetation, agricultural uses, ... etc.

Such additional data were added to the results of the analysis and it became evident that the classification could be confidently described to the fourth level (16 classes). The descriptions of the land classes given below are based on the attributes at fourth level.

Land Class 1

Mediterranean coastal lowlands

Characterised by the following indicator attributes:

- Low minimum altitude
- Medium-low maximum altitude
- High rainfall in September

The soils are mainly Calcic cambisols.

The main agricultural land-uses are fruit trees orchards and arable crops.

The natural vegetation is chiefly Thermomediterranean and Provencal type of Mesomediterranean with *Quercus ilex*.

The area is densely populated with many industrial centres, especially in the north-east.

Land Class 2

South Atlantic lowlands

Defined by these indicator attributes:

- Low slope angles
- High temperature in July
- Low maximum altitude

The soils are very variable but the predominant soils are Calcic cambisols.

The land-uses are arable and woodland.

The natural vegetation is predominantly Thermomediterranean.

This Land Class is quite well populated and has 2 industrial and urban centres at the mouth of 2 major rivers: Tagus and Guadalquivir.

Land Class 3

Median Atlantic and Asturias Coast

This Land Class occurs in 2 quite different geographical areas, Asturias in the northern Spain, and the central Portugal. The common features between them are climatic and geological.

This Class is defined by these indicator attributes:

- Low presence of Cretaceous rocks
- Low presence of Jurassic rocks

The soils are frequently Humic cambisols, Calcic cambisols and Orthic podzols.

The main agricultural use is woodland.

The natural vegetation is Thermophilous oakwood and Atlantic beechwood in Asturias, and Thermomediterranean and Atlantico-Mediterranean with *Quercus pyrenaica* in Central Portugal.

The area has high population and many industrial centres, mainly in the north; coal mining is important.

Land Class 4

Inner Southern Iberian Peninsula

This very homogeneous area, in the geographical sense, is characterised by the following indicator attributes:

- Low minimum elevation
- High temperature in July
- Medium-low presence of Cambrian rocks
- Low presence of intrusive rocks

It is an inland Class with warm climate and Cambrian and Pre-Cambrian geology, mainly acidic.

The soils are quite varied, but they are mainly Eutric cambisols.

The land uses are arable and Mediterranean woodland.

The natural vegetation is Mesomediterranean with *Quercus ilex*.

This Land Class has a low population density with no important industrial or urban centre.

Land Class 5

North Atlantic and Cantabrian coast

This Land Class is a quite homogeneous area with these indicator attributes:

- Medium-low rainfall in January
- Medium-high rainfall in September
- Long distance to the south coast

The main characteristic of this Class is the very wet climate.

The soils are Humic cambisols and Clacic cambisols.

The land-uses are predominantly grassland and woodland.

The natural vegetation is Thermophilous oakwood.

Typical of the Iberian coast, this Land Class is very highly populated and has important industrial and mining centres, especially on the north coast.

Land Class 6

Eastern Extremadura and Middle Douro

This is another discontinuous Land Class that is characterised by these indicator attributes:

- Medium-high minimum elevation
- Medium-high rainfall in January

The Land Class is widespread over the western side of the central Iberian plateaux. Climatically, it occupies an intermediate position between the Oceanic and Continental climates.

The soils are Eutric cambisols, Distric cambisols, Chromic luvisols and Dystic planosols.

The main land uses are arable and rough grazing.

The natural vegetation is Mesomediterranean with *Quercus suber*.

This Land Class has a low population and there are no industrial or urban centres.

Land Class 7

Inner Galicia

This Land Class is represented in the north-west corner of the Iberian peninsula. The area is geologically the oldest region of the peninsula. It is also the region with the highest rainfall. It is defined by:

- Medium-high rainfall in January
- Low maximum elevation
- Low metamorphic in centre squares
- Low metamorphic rocks in surrounding squares

The soils are Humic cambisols and Rankers.

The land use is mainly woodland.

The natural vegetation is Thermophilous oakwood.

There is moderate population but without any important town.

Land Class 8

Northern Portugal

This Land Class is, in many aspects, similar to Land Class 7, old rocks and high rainfall, but occurs further south. Its indicator attributes are:

- Medium-low maximum elevation
- Medium-low minimum elevation

The soils are Humic cambisols, Rankers and Litosols as in the Land Class 7.

The land uses are woodland and rough grazing.

The natural vegetation is Thermophilous oakwood and Atlantic-Mediterranean with *Quercus pyrenaica*.

The population is similar to that of Land Class 7.

Land Class 9

Iberic Range

This is a large Land Class widespread in eastern Spain and mainly comprises the Iberic mountain system. This Land Class is thus mainly limestone mountains of a high median altitude. The indicator attributes are:

- Medium-high minimum elevation
- Medium-low distance to the south coast
- Medium-low temperature in March

The climate is Mediterranean and Continental.

The main land uses are arable and woodland.

The soils are Calcic cambisols.

The natural vegetation is formed by Mesomediterranean with *Quercus ilex* and Supramediterranean.

There is a low population throughout the region.

Land Class 10

Mediterranean lowlands

This Land Class is geographically located between Land Classes 1 and 9. It is thus an inland Land Class but with "mediterranean" characteristics. This Land Class occurs in the south of the Ebro valley, the west of the Guadalquivir valley and in the Valencia region. The indicator attributes are:

- High temperature in July
- Low minimum elevation

The soils are Calcic cambisols or Eutric fluvisols.

The land uses are arable and woodland.

The natural vegetation is Mesomediterranean with *Quercus ilex* and Thermomediterranean.

There is a high population density, with two industrial and urban centres in the Ebro valley and in Valencia.

Land Class 11

Pyrenees Mountains

This Land Class is located in the north-east of Spain and is characterised by the Pyrenean mountains. It is altitudinally the highest Land Class and the geology is mainly Tertiary and Secondary but with some rocks of other geological periods. The indicator attributes are:

- Low altitude 1500-2000 m. (ie indicative of high altitude)
- Medium-low Jurassic

The soils are quite varied, but are mainly Rankers, Litosols and Calcic cambisols.

The land uses are woodland and rough grazing.

The natural vegetation is a vegetation-complex which is characteristic of this side of Pyrenees and Iberic-Oromediterranean.

This Land Class has a low population density and no urban and industrial centres are present.

Land Class 12

Cantabrian Range

This Land Class is located in the Northern Cantabrian Mountains which separate the northern coast and the central plateaux. The indicator attributes are:

- Medium-low temperature in July
- Medium-low rainfall in January
- Medium-high Jurassic geology
- Medium-low temperature in March

The soils are Calcic cambisols, Rankers and Humic cambisols.

The natural vegetation is Atlantic montane beechwood and Supramediterranean.

The population is higher in the east side of the area, with some important urban and industrial centres.

Land Class 13

Southern Plateau

This Land Class is situated on the southern plateau. The median height is 600 metres. Geologically, it is a sedimentary region with Tertiary rocks. The climate is Continental. The indicator attributes are:

- Medium-high temperature in March
- High temperature in July
- Low slope angles

The soils are Eutric cambisols, Eutric fluvisols and Vertic luvisols.

The main land use is arable.

The natural vegetation is Mesomediterranean with *Quercus suber* and *Quercus ilex*.

This Land Class is not heavily populated and is concentrated in only one town: Madrid.

Land Class 14

Northern Plateaux

This Land Class occupies the northern plateaux and the north side of the southern Plateaux. It is different from class 13 in that it has a higher median elevation. The indicator attributes are:

- Medium low temperature in March
- High Quaternary geology
- Medium high distance from the south coast

The soils are Calcic cambisols and Gleyic cambisols.

The land use is arable.

The natural vegetation is Mesomediterranean with *Quercus ilex* and Supramediterranean.

There is low population density concentrated in medium size towns.

Land Class 15

Siliceous higher mountains

This Land Class occurs in two areas, i.e. the western extreme of the Cantabrian range and the central range. Geologically, these are old mountains with acid rocks. The indicator attributes are:

- Medium-high elevation between 1000-1500 m..
- Low Precambric geology
- Low Silurian geology

The soils are Humic cambisols, Rankers and Distric cambisols.

The land use is woodland and rough grazing.

The natural vegetation is Atlantic-Mediterranean with *Quercus pyrenaica*.

Both areas have a very low population density.

Land Class 16

Siliceous median mountains

This Land Class is located geographically west of the area of Land Class 15. Its average altitude is lower than Land Class 15,

but the other features are quite similar with the exception of a more Atlantic climate. The indicator attributes are:

- High intrusive rocks
- Medium low Precambric geology

The soils are Humic cambisols.

The land use is rough grazing.

The natural vegetation is Atlantic mediterranean with *Quercus pyrenaica*.

This Land Class has quite a low population density.

4 MODIFIED ITE LAND CLASSIFICATIONS

Several points for investigation arose during the ecological interpretation of the standard ITE Land Classification. Some Land Classes were very heterogeneous (e.g. Nos. 3 and 10) and others did not show large discontinuities from adjacent Land Classes (e.g. Nos. 5 and 6). I therefore proceeded to test the stability of the results of the first ISA.

There were two possible ways in which to do this:

1 To check if too many attributes had been used, causing spurious "noise" in the results.

2 To check if the attributes used provided the best way to split the original variables.

Consequently, both lines were followed. In the first case, only the most important attributes were selected. The criterion followed was to choose the indicator attributes which appear in the hierarchical key. Accordingly, the amount of information used in this new land classification was less than that used in the original classification, but was the most important available.

Two further land classifications were next produced.

a. The first was carried out using only the climatic and locational data (24). This classification is shown as C1 in Figure 6.
b. In the second classification 88 selected attributes were employed. This is shown as C2 in Figure 6.

It is very difficult to interpret these 2 classifications in an ecological sense, but, taken together, they are of value in following evolution in the results of the ISA when the quantity of information is increased. It seems, then, that reducing the number of attributes made interpretation very difficult.

The ISA is an objective method of classification but there is a stage in the procedure that is subjective: i.e. the choice of the cut-off points.

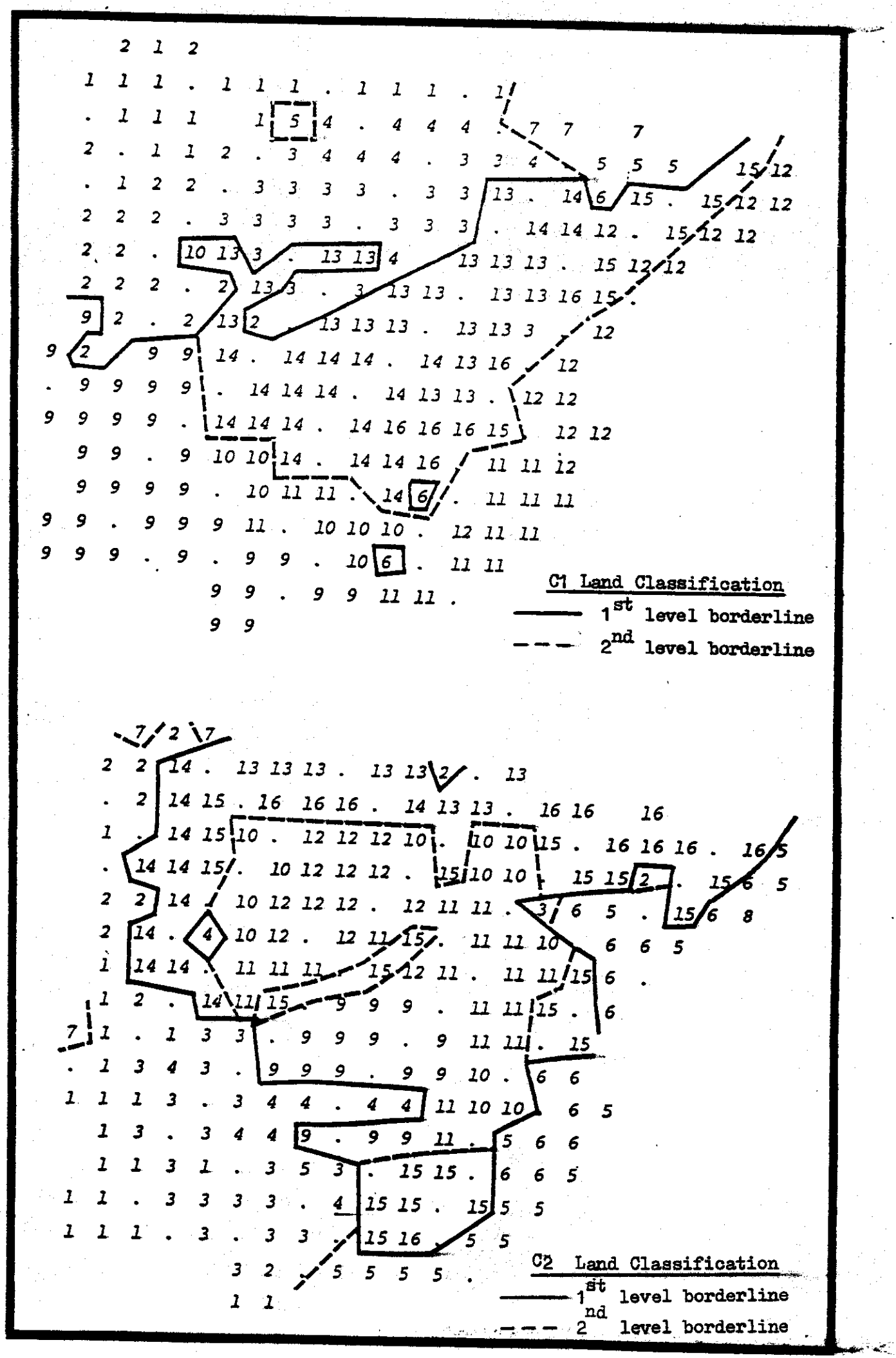


Figure 6. Maps of Land Classifications made with reduced

If different cut-off points are chosen, different attributes might be produced and therefore a different Land Classification might be obtained. Therefore modification of the cut-off points might prove to be a test of the ISA as a land classification method.

The criterion used in the modification of the original cut-off points, was that the new cut-off points should provide attributes with a predetermined relative frequency. This was done to avoid those attributes at the extremes of the range of relative frequency. Such extreme attributes are rejected during the ISA procedures. It is thus possible that much information is not used if the attributes have very low or very high relative frequencies.

Consequently, new cut-off points were defined, in order to provide attributes with relative frequencies of between 10% and 40%. These new attributes are shown in Figure 7. The land classification produced using these new attributes appears as N1 in Figure 8.

Further, a classification using intermediate attributes between the original and the new attributes was made, using relative frequencies of 3% and 50%. The result of this analysis is shown as N2 in Figure 9.

When these various classifications were studied, yet another way to carry out land classification appeared: this new way was called the "Two step" Analysis.

It is well known that it is necessary to observe different attributes according to the scale of the ecological studies. A scale of ecological perception has been designed with the different variables appropriate to the size of area studied.

It is therefore not theoretically valid to use the same attributes to stratify a small area. Another Land Classification was carried out. The ISA was applied to the 4 different groups at the second level of the first Land Classification. In each of these trials different cut-off points were used, in accordance with the ecological characteristics. This second level was chosen after testing the stability of the different classifications. The classification was found to be stable up until the second level, with large differences appearing at the subsequent levels.

Figure 10 illustrates the bases of the "Two-step" data structure.

Figures 11 to 14 show the attribute lists of the 4 different ISA analyses. The cut-off points were chosen to produce attributes of relative frequency between 2% and 50%, within each group.

The "Two-step" Land Classification is shown in Figure 15.

5 DISCUSSION

The resulting different Land Classifications were analysed in order to show the properties and weaknesses that emerged. It was then possible to decide the best data structure to improve the results.

Hill (1973(showed a close relationship between the 2 first axes when the Reciprocal Averaging Ordination (RAO) is applied to a floristic data base, although this could have been a property of the particular data set used.

The RAO is a preliminary step in ordination by ISA. The ISA uses only the first axis RAO at each level because, theoretically this preliminary axis is closely correlated with the second axis, as Hill demonstrated.

Variable	1	gives	attributes	...	1	[	7.0]	2	[	9.0]	3	[	12.0]	4
Variable	2	gives	attributes	...	5	[	19.0]	6	[	23.0]	7	[	26.0]	8
Variable	3	gives	attributes	...	9	[	30.0]	10	[	67.5]	11	[	115.0]	12
Variable	4	gives	attributes	...	13	[	30.0]	14	[	42.0]	15	[	65.0]	16
Variable	5	gives	attributes	...	17	[	4.0]	18	[	8.0]	19	[	12.0]	20
Variable	6	gives	attributes	...	21	[	3.0]	22	[	6.0]	23	[	10.0]	24
Variable	7	gives	attributes	...	25	[	20.0]	26	[	110.0]	27	[	110.0]	28
Variable	8	gives	attributes	...	29	[	20.0]	30	[	40.0]	31	[	110.0]	32
Variable	9	gives	attributes	...	33	[	25.0]	34	[	110.0]	35	[	110.0]	36
Variable	10	gives	attributes	...	37	[	15.0]	38	[	110.0]	39	[	110.0]	40
Variable	11	gives	attributes	...	41	[	100.0]	42	[	110.0]	43	[	110.0]	44
Variable	12	gives	attributes	...	45	[	0.0]	46	[	0.0]	47	[	0.0]	48
Variable	13	gives	attributes	...	49	[	100.0]	50	[	110.0]	51	[	110.0]	52
Variable	14	gives	attributes	...	53	[	100.0]	54	[	110.0]	55	[	110.0]	56
Variable	15	gives	attributes	...	57	[	20.0]	58	[	110.0]	59	[	110.0]	60
Variable	16	gives	attributes	...	61	[	15.0]	62	[	110.0]	63	[	110.0]	64
Variable	17	gives	attributes	...	65	[	20.0]	66	[	110.0]	67	[	110.0]	68
Variable	18	gives	attributes	...	69	[	100.0]	70	[	110.0]	71	[	110.0]	72
Variable	19	gives	attributes	...	73	[	100.0]	74	[	110.0]	75	[	110.0]	76
Variable	20	gives	attributes	...	77	[	0.0]	78	[	0.0]	79	[	0.0]	80
Variable	21	gives	attributes	...	81	[	25.0]	82	[	110.0]	83	[	110.0]	84
Variable	22	gives	attributes	...	85	[	1.5]	86	[	5.0]	87	[	10.0]	88
Variable	23	gives	attributes	...	89	[	4.0]	90	[	6.5]	91	[	10.0]	92
Variable	24	gives	attributes	...	93	[	2.5]	94	[	5.0]	95	[	109.0]	96
Variable	25	gives	attributes	...	97	[	2.0]	98	[	4.0]	99	[	10.0]	100
Variable	26	gives	attributes	...	101	[	2.0]	102	[	10.0]	103	[	10.0]	104
Variable	27	gives	attributes	...	105	[	0.0]	106	[	0.0]	107	[	0.0]	108
Variable	28	gives	attributes	...	109	[	1.5]	110	[	10.0]	111	[	10.0]	112
Variable	29	gives	attributes	...	113	[	1.5]	114	[	10.0]	115	[	10.0]	116
Variable	30	gives	attributes	...	117	[	2.0]	118	[	4.0]	119	[	10.0]	120
Variable	31	gives	attributes	...	121	[	1.5]	122	[	3.5]	123	[	10.0]	124
Variable	32	gives	attributes	...	125	[	2.0]	126	[	4.0]	127	[	10.0]	128
Variable	33	gives	attributes	...	129	[	3.5]	130	[	10.0]	131	[	10.0]	132
Variable	34	gives	attributes	...	133	[	8.0]	134	[	10.0]	135	[	10.0]	136
Variable	35	gives	attributes	...	137	[	8.0]	138	[	10.0]	139	[	10.0]	140
Variable	36	gives	attributes	...	141	[	2.0]	142	[	5.0]	143	[	10.0]	144
Variable	37	gives	attributes	...	145	[	1.0]	146	[	1.5]	147	[	2.5]	148
Variable	38	gives	attributes	...	149	[	500.0]	150	[	1000.0]	151	[	1500.0]	152
Variable	39	gives	attributes	...	153	[	100.0]	154	[	250.0]	155	[	500.0]	156
Variable	40	gives	attributes	...	157	[	16.0]	158	[	20.0]	159	[	20.0]	160
Variable	41	gives	attributes	...	161	[	3.0]	162	[	20.0]	163	[	20.0]	164
Variable	42	gives	attributes	...	165	[	3.0]	166	[	20.0]	167	[	20.0]	168
Variable	43	gives	attributes	...	169	[	4.0]	170	[	20.0]	171	[	20.0]	172
Variable	44	gives	attributes	...	173	[	4.0]	174	[	8.0]	175	[	12.0]	176
Variable	45	gives	attributes	...	177	[	4.0]	178	[	20.0]	179	[	20.0]	180
Variable	46	gives	attributes	...	181	[	16.0]	182	[	20.0]	183	[	20.0]	184
Variable	47	gives	attributes	...	185	[	0.0]	186	[	0.0]	187	[	0.0]	188
Variable	48	gives	attributes	...	189	[	0.0]	190	[	0.0]	191	[	0.0]	192
Variable	49	gives	attributes	...	193	[	3.0]	194	[	10.0]	195	[	10.0]	196
Variable	50	gives	attributes	...	197	[	1.5]	198	[	10.0]	199	[	10.0]	200
Variable	51	gives	attributes	...	201	[	8.0]	202	[	10.0]	203	[	10.0]	204
Variable	52	gives	attributes	...	205	[	2.0]	206	[	10.0]	207	[	10.0]	208
Variable	53	gives	attributes	...	209	[	2.0]	210	[	4.0]	211	[	10.0]	212
Variable	54	gives	attributes	...	213	[	2.0]	214	[	10.0]	215	[	10.0]	216
Variable	55	gives	attributes	...	217	[	8.0]	218	[	10.0]	219	[	10.0]	220
Variable	56	gives	attributes	...	221	[	0.0]	222	[	0.0]	223	[	0.0]	224
Variable	57	gives	attributes	...	225	[	0.0]	226	[	0.0]	227	[	0.0]	228
Variable	58	gives	attributes	...	229	[	90.0]	230	[	180.0]	231	[	270.0]	232
Variable	59	gives	attributes	...	233	[	40.0]	234	[	55.0]	235	[	70.0]	236
Variable	60	gives	attributes	...	237	[	15.0]	238	[	30.0]	239	[	45.0]	240
Variable	61	gives	attributes	...	241	[	20.0]	242	[	30.0]	243	[	50.0]	244
Variable	62	gives	attributes	...	245	[	1.0]	246	[	30.0]	247	[	30.0]	248
Variable	63	gives	attributes	...	249	[	1.0]	250	[	3.0]	251	[	90.0]	252
Variable	64	gives	attributes	...	253	[	2.0]	254	[	3.0]	255	[	4.0]	256

Figure 7. List of attributes with restricted relative frequency.

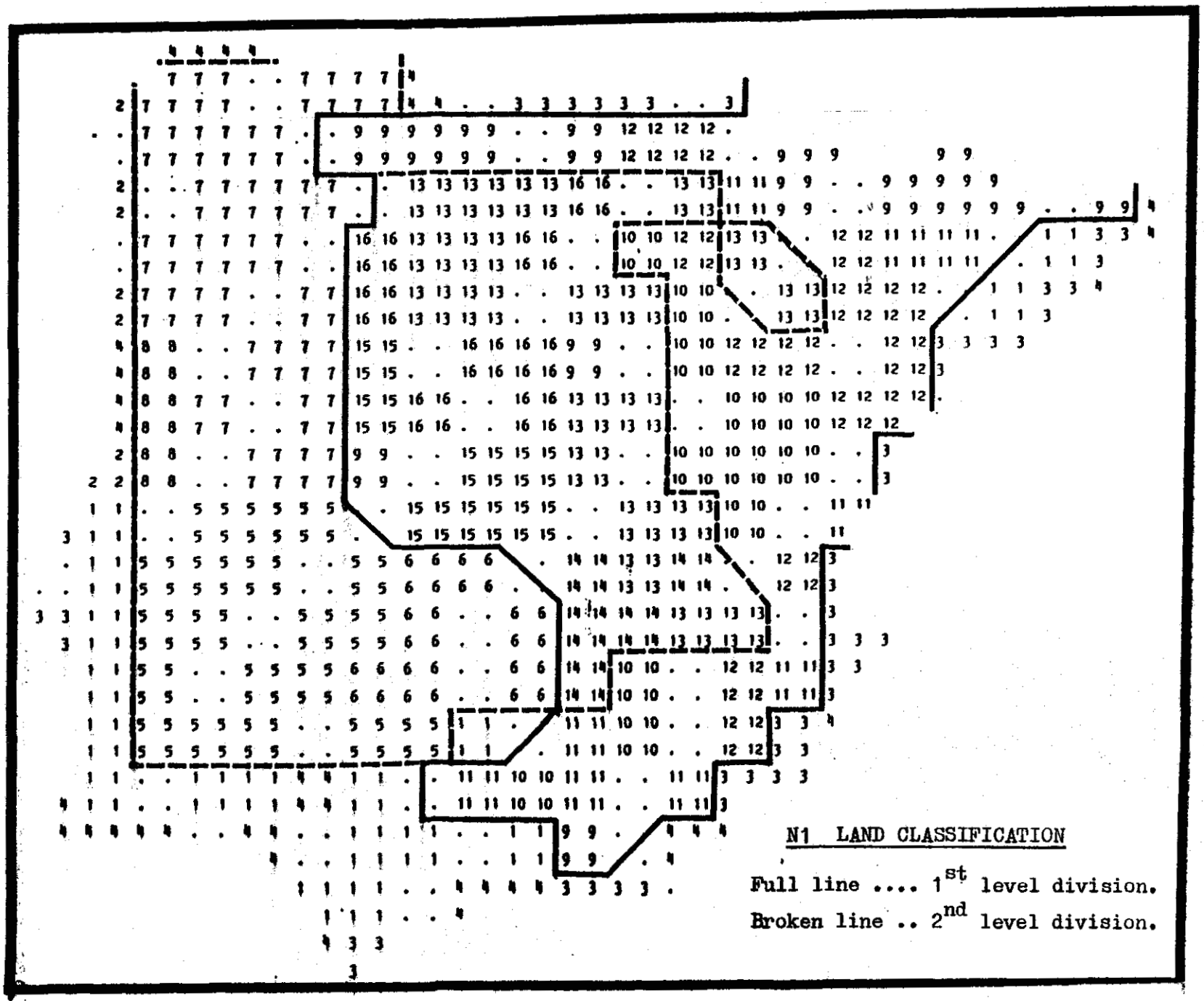


Figure 8. Map of land classes using the N1 Land Classification.

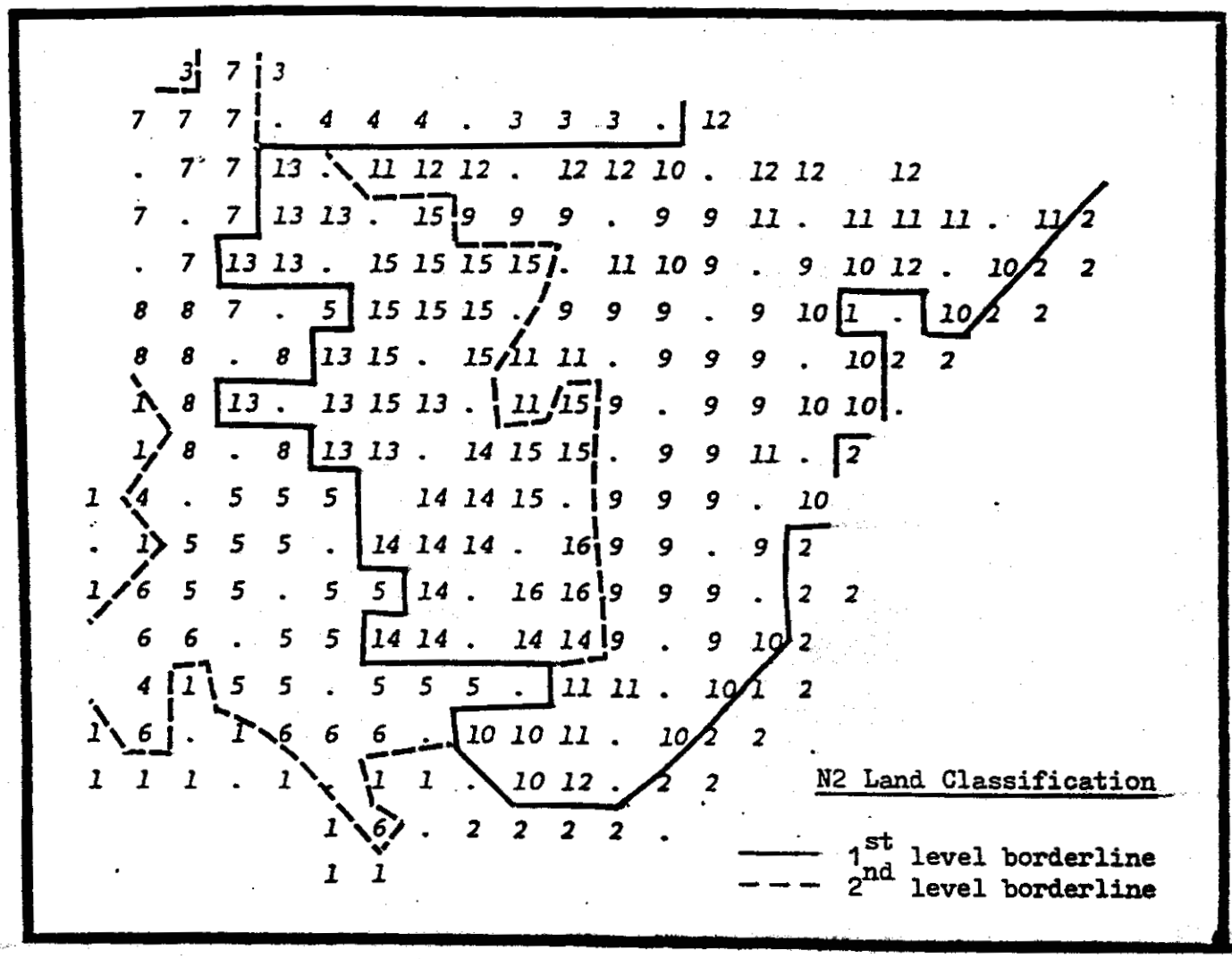


Figure 9. Map of land classes using the N2 Land Classification.

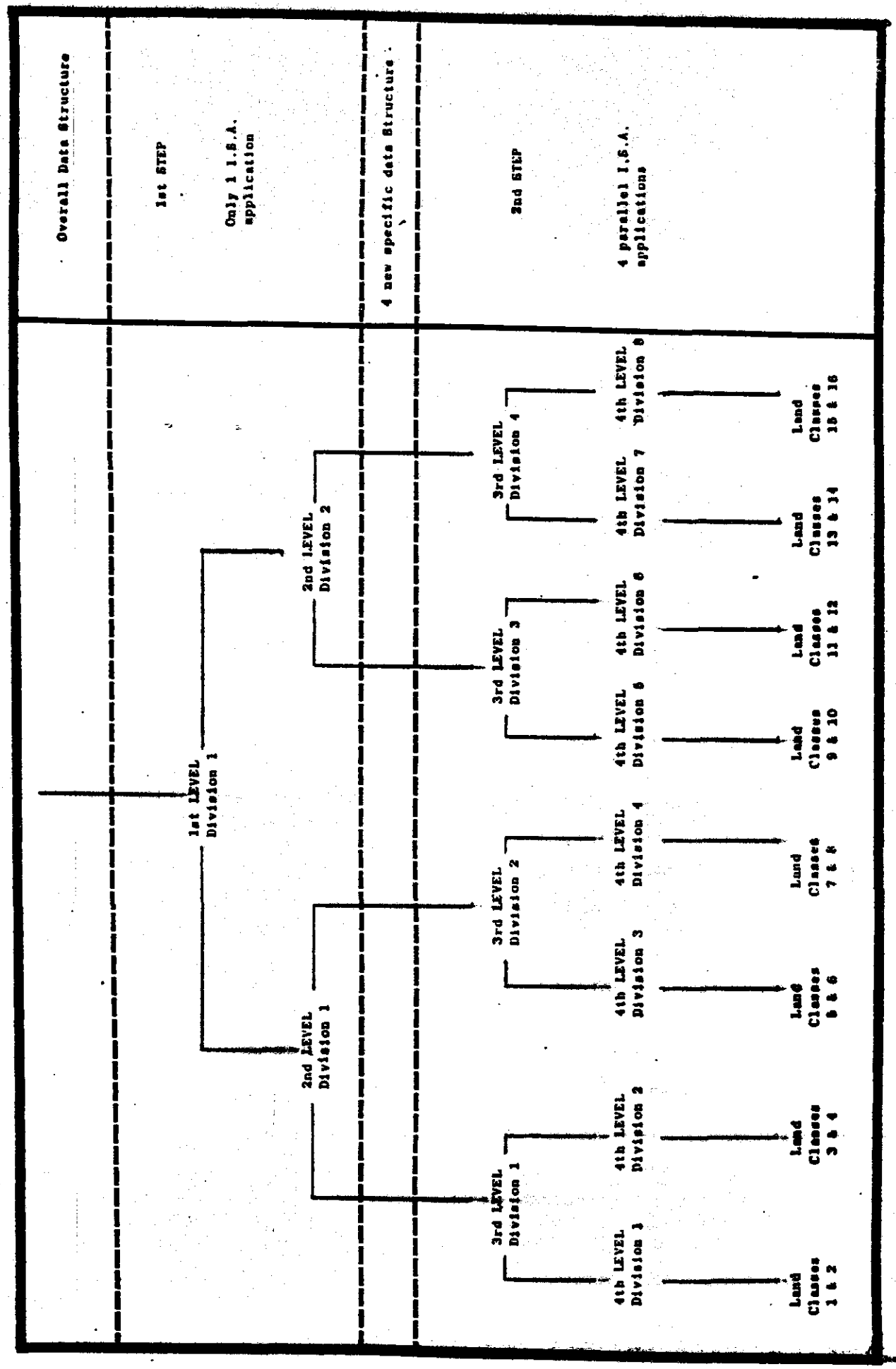


Figure 10. Scheme of the "Two step" Analysis.

Variable	1	gives	attributes	...	1	[	10.0]	2	[	12.0]	3	[14.0]	4
Variable	2	gives	attributes	...	5	[	19.0]	6	[	24.0]	7	[30.0]	8
Variable	3	gives	attributes	...	9	[	65.0]	10	[	110.0]	11	[160.0]	12
Variable	4	gives	attributes	...	13	[	30.0]	14	[	50.0]	15	[80.0]	16
Variable	5	gives	attributes	...	17	[	2.0]	18	[	8.0]	19	[15.0]	20
Variable	6	gives	attributes	...	21	[	3.0]	22	[	6.0]	23	[10.0]	24
Variable	7	gives	attributes	...	25	[	20.0]	26	[	50.0]	27	[100.0]	28
Variable	8	gives	attributes	...	29	[	25.0]	30	[	50.0]	31	[100.0]	32
Variable	9	gives	attributes	...	33	[	25.0]	34	[	50.0]	35	[100.0]	36
Variable	10	gives	attributes	...	37	[	25.0]	38	[	100.0]	39	[100.0]	40
Variable	11	gives	attributes	...	41	[	25.0]	42	[	100.0]	43	[100.0]	44
Variable	12	gives	attributes	...	45	[	100.0]	46	[	100.0]	47	[100.0]	48
Variable	13	gives	attributes	...	49	[	25.0]	50	[	100.0]	51	[100.0]	52
Variable	14	gives	attributes	...	53	[	100.0]	54	[	100.0]	55	[100.0]	56
Variable	15	gives	attributes	...	57	[	100.0]	58	[	100.0]	59	[100.0]	60
Variable	16	gives	attributes	...	61	[	100.0]	62	[	100.0]	63	[100.0]	64
Variable	17	gives	attributes	...	65	[	25.0]	66	[	100.0]	67	[100.0]	68
Variable	18	gives	attributes	...	69	[	100.0]	70	[	100.0]	71	[100.0]	72
Variable	19	gives	attributes	...	73	[	25.0]	74	[	100.0]	75	[100.0]	76
Variable	20	gives	attributes	...	77	[	100.0]	78	[	100.0]	79	[100.0]	80
Variable	21	gives	attributes	...	81	[	25.0]	82	[	100.0]	83	[100.0]	84
Variable	22	gives	attributes	...	85	[	1.0]	86	[	3.0]	87	[8.0]	88
Variable	23	gives	attributes	...	89	[	2.0]	90	[	4.0]	91	[6.0]	92
Variable	24	gives	attributes	...	93	[	1.0]	94	[	3.0]	95	[8.0]	96
Variable	25	gives	attributes	...	97	[	1.0]	98	[	3.0]	99	[8.0]	100
Variable	26	gives	attributes	...	101	[	2.0]	102	[	8.0]	103	[8.0]	104
Variable	27	gives	attributes	...	105	[	8.0]	106	[	8.0]	107	[8.0]	108
Variable	28	gives	attributes	...	109	[	1.0]	110	[	3.0]	111	[8.0]	112
Variable	29	gives	attributes	...	113	[	1.0]	114	[	3.0]	115	[8.0]	116
Variable	30	gives	attributes	...	117	[	1.0]	118	[	3.0]	119	[8.0]	120
Variable	31	gives	attributes	...	121	[	1.0]	122	[	3.0]	123	[8.0]	124
Variable	32	gives	attributes	...	125	[	1.0]	126	[	3.0]	127	[8.0]	128
Variable	33	gives	attributes	...	129	[	2.0]	130	[	8.0]	131	[8.0]	132
Variable	34	gives	attributes	...	133	[	2.0]	134	[	8.0]	135	[8.0]	136
Variable	35	gives	attributes	...	137	[	8.0]	138	[	8.0]	139	[8.0]	140
Variable	36	gives	attributes	...	141	[	2.0]	142	[	8.0]	143	[8.0]	144
Variable	37	gives	attributes	...	145	[	1.0]	146	[	1.6]	147	[3.2]	148
Variable	38	gives	attributes	...	149	[	250.0]	150	[	500.0]	151	[1000.0]	152
Variable	39	gives	attributes	...	153	[	10.0]	154	[	30.0]	155	[50.0]	156
Variable	40	gives	attributes	...	157	[	4.0]	158	[	8.0]	159	[12.0]	160
Variable	41	gives	attributes	...	161	[	2.0]	162	[	5.0]	163	[8.0]	164
Variable	42	gives	attributes	...	165	[	2.0]	166	[	3.0]	167	[4.0]	168
Variable	43	gives	attributes	...	169	[	2.0]	170	[	3.0]	171	[4.0]	172
Variable	44	gives	attributes	...	173	[	2.0]	174	[	3.0]	175	[12.0]	176
Variable	45	gives	attributes	...	177	[	12.0]	178	[	12.0]	179	[12.0]	180
Variable	46	gives	attributes	...	181	[	12.0]	182	[	12.0]	183	[12.0]	184
Variable	47	gives	attributes	...	185	[	12.0]	186	[	12.0]	187	[12.0]	188
Variable	48	gives	attributes	...	189	[	12.0]	190	[	12.0]	191	[12.0]	192
Variable	49	gives	attributes	...	193	[	2.0]	194	[	3.0]	195	[5.0]	196
Variable	50	gives	attributes	...	197	[	1.0]	198	[	2.0]	199	[8.0]	200
Variable	51	gives	attributes	...	201	[	8.0]	202	[	8.0]	203	[8.0]	204
Variable	52	gives	attributes	...	205	[	1.0]	206	[	2.0]	207	[8.0]	208
Variable	53	gives	attributes	...	209	[	1.0]	210	[	2.0]	211	[8.0]	212
Variable	54	gives	attributes	...	213	[	2.0]	214	[	8.0]	215	[8.0]	216
Variable	55	gives	attributes	...	217	[	8.0]	218	[	8.0]	219	[8.0]	220
Variable	56	gives	attributes	...	221	[	8.0]	222	[	8.0]	223	[8.0]	224
Variable	57	gives	attributes	...	225	[	8.0]	226	[	8.0]	227	[8.0]	228
Variable	58	gives	attributes	...	229	[	90.0]	230	[	180.0]	231	[270.0]	232
Variable	59	gives	attributes	...	233	[	20.0]	234	[	40.0]	235	[60.0]	236
Variable	60	gives	attributes	...	237	[	10.0]	238	[	20.0]	239	[30.0]	240
Variable	61	gives	attributes	...	241	[	15.0]	242	[	30.0]	243	[100.0]	244
Variable	62	gives	attributes	...	245	[	1.0]	246	[	10.0]	247	[10.0]	248
Variable	63	gives	attributes	...	249	[	1.0]	250	[	10.0]	251	[10.0]	252
Variable	64	gives	attributes	...	253	[	1.0]	254	[	3.0]	255	[5.0]	256

Figure 11. List of attributes in the 1st group of the "Two step" structure.

Variable	1	gives attributes ...	1	[	8.0]	2	[	9.5]	3	[	11.0]	4
Variable	2	gives attributes ...	5	[	18.0]	6	[	22.0]	7	[	26.0]	8
Variable	3	gives attributes ...	9	[	67.5]	10	[	115.0]	11	[	162.0]	12
Variable	4	gives attributes ...	13	[	35.0]	14	[	50.0]	15	[	65.0]	16
Variable	5	gives attributes ...	17	[	4.0]	18	[	7.0]	19	[	16.0]	20
Variable	6	gives attributes ...	21	[	8.0]	22	[	12.0]	23	[	20.0]	24
Variable	7	gives attributes ...	25	[	100.0]	26	[	100.0]	27	[	100.0]	28
Variable	8	gives attributes ...	29	[	10.0]	30	[	25.0]	31	[	100.0]	32
Variable	9	gives attributes ...	33	[	100.0]	34	[	100.0]	35	[	100.0]	36
Variable	10	gives attributes ...	37	[	100.0]	38	[	100.0]	39	[	100.0]	40
Variable	11	gives attributes ...	41	[	100.0]	42	[	100.0]	43	[	100.0]	44
Variable	12	gives attributes ...	45	[	100.0]	46	[	100.0]	47	[	100.0]	48
Variable	13	gives attributes ...	49	[	100.0]	50	[	100.0]	51	[	100.0]	52
Variable	14	gives attributes ...	53	[	100.0]	54	[	100.0]	55	[	100.0]	56
Variable	15	gives attributes ...	57	[	10.0]	58	[	100.0]	59	[	100.0]	60
Variable	16	gives attributes ...	61	[	10.0]	62	[	100.0]	63	[	100.0]	64
Variable	17	gives attributes ...	65	[	10.0]	66	[	25.0]	67	[	100.0]	68
Variable	18	gives attributes ...	69	[	10.0]	70	[	100.0]	71	[	100.0]	72
Variable	19	gives attributes ...	73	[	100.0]	74	[	100.0]	75	[	100.0]	76
Variable	20	gives attributes ...	77	[	100.0]	78	[	100.0]	79	[	100.0]	80
Variable	21	gives attributes ...	81	[	10.0]	82	[	25.0]	83	[	50.0]	84
Variable	22	gives attributes ...	85	[	2.0]	86	[	8.0]	87	[	8.0]	88
Variable	23	gives attributes ...	89	[	2.0]	90	[	4.0]	91	[	6.0]	92
Variable	24	gives attributes ...	93	[	8.0]	94	[	8.0]	95	[	8.0]	96
Variable	25	gives attributes ...	97	[	8.0]	98	[	8.0]	99	[	8.0]	100
Variable	26	gives attributes ...	101	[	8.0]	102	[	8.0]	103	[	8.0]	104
Variable	27	gives attributes ...	105	[	8.0]	106	[	8.0]	107	[	8.0]	108
Variable	28	gives attributes ...	109	[	2.0]	110	[	4.0]	111	[	8.0]	112
Variable	29	gives attributes ...	113	[	2.0]	114	[	8.0]	115	[	8.0]	116
Variable	30	gives attributes ...	117	[	3.0]	118	[	4.0]	119	[	8.0]	120
Variable	31	gives attributes ...	121	[	4.0]	122	[	5.0]	123	[	6.0]	124
Variable	32	gives attributes ...	125	[	4.0]	126	[	5.0]	127	[	6.0]	128
Variable	33	gives attributes ...	129	[	2.0]	130	[	4.0]	131	[	6.0]	132
Variable	34	gives attributes ...	133	[	8.0]	134	[	8.0]	135	[	8.0]	136
Variable	35	gives attributes ...	137	[	8.0]	138	[	8.0]	139	[	8.0]	140
Variable	36	gives attributes ...	141	[	5.0]	142	[	6.0]	143	[	7.0]	144
Variable	37	gives attributes ...	145	[	0.5]	146	[	1.0]	147	[	1.6]	148
Variable	38	gives attributes ...	149	[	500.0]	150	[	800.0]	151	[	1200.0]	152
Variable	39	gives attributes ...	153	[	50.0]	154	[	150.0]	155	[	250.0]	156
Variable	40	gives attributes ...	157	[	16.0]	158	[	16.0]	159	[	16.0]	160
Variable	41	gives attributes ...	161	[	16.0]	162	[	16.0]	163	[	16.0]	164
Variable	42	gives attributes ...	165	[	2.0]	166	[	4.0]	167	[	16.0]	168
Variable	43	gives attributes ...	169	[	4.0]	170	[	8.0]	171	[	12.0]	172
Variable	44	gives attributes ...	173	[	4.0]	174	[	8.0]	175	[	12.0]	176
Variable	45	gives attributes ...	177	[	16.0]	178	[	16.0]	179	[	16.0]	180
Variable	46	gives attributes ...	181	[	16.0]	182	[	16.0]	183	[	16.0]	184
Variable	47	gives attributes ...	185	[	16.0]	186	[	16.0]	187	[	16.0]	188
Variable	48	gives attributes ...	189	[	16.0]	190	[	16.0]	191	[	16.0]	192
Variable	49	gives attributes ...	193	[	8.0]	194	[	8.0]	195	[	8.0]	196
Variable	50	gives attributes ...	197	[	2.0]	198	[	8.0]	199	[	8.0]	200
Variable	51	gives attributes ...	201	[	2.0]	202	[	8.0]	203	[	8.0]	204
Variable	52	gives attributes ...	205	[	2.0]	206	[	4.0]	207	[	6.0]	208
Variable	53	gives attributes ...	209	[	2.0]	210	[	4.0]	211	[	6.0]	212
Variable	54	gives attributes ...	213	[	8.0]	214	[	8.0]	215	[	8.0]	216
Variable	55	gives attributes ...	217	[	8.0]	218	[	8.0]	219	[	8.0]	220
Variable	56	gives attributes ...	221	[	8.0]	222	[	8.0]	223	[	8.0]	224
Variable	57	gives attributes ...	225	[	8.0]	226	[	8.0]	227	[	8.0]	228
Variable	58	gives attributes ...	229	[	180.0]	230	[	225.0]	231	[	270.0]	232
Variable	59	gives attributes ...	233	[	50.0]	234	[	65.0]	235	[	75.0]	236
Variable	60	gives attributes ...	237	[	25.0]	238	[	40.0]	239	[	50.0]	240
Variable	61	gives attributes ...	241	[	20.0]	242	[	100.0]	243	[	100.0]	244
Variable	62	gives attributes ...	245	[	100.0]	246	[	100.0]	247	[	100.0]	248
Variable	63	gives attributes ...	249	[	1.0]	250	[	4.0]	251	[	4.0]	252
Variable	64	gives attributes ...	253	[	2.0]	254	[	3.0]	255	[	4.0]	256

Figure 12. List of attributes in the 2nd group of the "Two step" structure.

Variable	1	gives attributes ...	1	[	5.0]	2	[	8.0]	3	[	10.8]	4
Variable	2	gives attributes ...	5	[	18.0]	6	[	21.0]	7	[	24.0]	8
Variable	3	gives attributes ...	9	[	30.0]	10	[	50.0]	11	[	70.0]	12
Variable	4	gives attributes ...	13	[	40.0]	14	[	65.0]	15	[	85.0]	16
Variable	5	gives attributes ...	17	[	10.0]	18	[	12.0]	19	[	15.0]	20
Variable	6	gives attributes ...	21	[	3.0]	22	[	5.0]	23	[	10.0]	24
Variable	7	gives attributes ...	25	[	15.0]	26	[	25.0]	27	[	100.0]	28
Variable	8	gives attributes ...	29	[	25.0]	30	[	50.0]	31	[	75.0]	32
Variable	9	gives attributes ...	33	[	15.0]	34	[	25.0]	35	[	50.0]	36
Variable	10	gives attributes ...	37	[	10.0]	38	[	15.0]	39	[	25.0]	40
Variable	11	gives attributes ...	41	[	15.0]	42	[	25.0]	43	[	100.0]	44
Variable	12	gives attributes ...	45	[	100.0]	46	[	100.0]	47	[	100.0]	48
Variable	13	gives attributes ...	49	[	100.0]	50	[	100.0]	51	[	100.0]	52
Variable	14	gives attributes ...	53	[	100.0]	54	[	100.0]	55	[	100.0]	56
Variable	15	gives attributes ...	57	[	100.0]	58	[	100.0]	59	[	100.0]	60
Variable	16	gives attributes ...	61	[	100.0]	62	[	100.0]	63	[	100.0]	64
Variable	17	gives attributes ...	65	[	100.0]	66	[	100.0]	67	[	100.0]	68
Variable	18	gives attributes ...	69	[	100.0]	70	[	100.0]	71	[	100.0]	72
Variable	19	gives attributes ...	73	[	100.0]	74	[	100.0]	75	[	100.0]	76
Variable	20	gives attributes ...	77	[	100.0]	78	[	100.0]	79	[	100.0]	80
Variable	21	gives attributes ...	81	[	100.0]	82	[	100.0]	83	[	100.0]	84
Variable	22	gives attributes ...	85	[	2.0]	86	[	3.0]	87	[	5.0]	88
Variable	23	gives attributes ...	89	[	5.0]	90	[	6.0]	91	[	7.0]	92
Variable	24	gives attributes ...	93	[	3.0]	94	[	5.0]	95	[	6.0]	96
Variable	25	gives attributes ...	97	[	2.0]	98	[	4.0]	99	[	6.0]	100
Variable	26	gives attributes ...	101	[	2.0]	102	[	4.0]	103	[	6.0]	104
Variable	27	gives attributes ...	105	[	8.0]	106	[	8.0]	107	[	8.0]	108
Variable	28	gives attributes ...	109	[	2.0]	110	[	8.0]	111	[	8.0]	112
Variable	29	gives attributes ...	113	[	2.0]	114	[	8.0]	115	[	8.0]	116
Variable	30	gives attributes ...	117	[	2.0]	118	[	8.0]	119	[	8.0]	120
Variable	31	gives attributes ...	121	[	8.0]	122	[	8.0]	123	[	8.0]	124
Variable	32	gives attributes ...	125	[	8.0]	126	[	8.0]	127	[	8.0]	128
Variable	33	gives attributes ...	129	[	8.0]	130	[	8.0]	131	[	8.0]	132
Variable	34	gives attributes ...	133	[	8.0]	134	[	8.0]	135	[	8.0]	136
Variable	35	gives attributes ...	137	[	8.0]	138	[	8.0]	139	[	8.0]	140
Variable	36	gives attributes ...	141	[	2.0]	142	[	8.0]	143	[	8.0]	144
Variable	37	gives attributes ...	145	[	1.0]	146	[	1.6]	147	[	3.2]	148
Variable	38	gives attributes ...	149	[	870.0]	150	[	1741.0]	151	[	2611.0]	152
Variable	39	gives attributes ...	153	[	250.0]	154	[	500.0]	155	[	750.0]	156
Variable	40	gives attributes ...	157	[	16.0]	158	[	16.0]	159	[	16.0]	160
Variable	41	gives attributes ...	161	[	16.0]	162	[	16.0]	163	[	16.0]	164
Variable	42	gives attributes ...	165	[	16.0]	166	[	16.0]	167	[	16.0]	168
Variable	43	gives attributes ...	169	[	4.0]	170	[	8.0]	171	[	16.0]	172
Variable	44	gives attributes ...	173	[	4.0]	174	[	8.0]	175	[	16.0]	176
Variable	45	gives attributes ...	177	[	4.0]	178	[	8.0]	179	[	16.0]	180
Variable	46	gives attributes ...	181	[	4.0]	182	[	16.0]	183	[	16.0]	184
Variable	47	gives attributes ...	185	[	16.0]	186	[	16.0]	187	[	16.0]	188
Variable	48	gives attributes ...	189	[	16.0]	190	[	16.0]	191	[	16.0]	192
Variable	49	gives attributes ...	193	[	2.0]	194	[	8.0]	195	[	8.0]	196
Variable	50	gives attributes ...	197	[	8.0]	198	[	8.0]	199	[	8.0]	200
Variable	51	gives attributes ...	201	[	8.0]	202	[	8.0]	203	[	8.0]	204
Variable	52	gives attributes ...	205	[	2.0]	206	[	8.0]	207	[	8.0]	208
Variable	53	gives attributes ...	209	[	2.0]	210	[	4.0]	211	[	6.0]	212
Variable	54	gives attributes ...	213	[	2.0]	214	[	8.0]	215	[	8.0]	216
Variable	55	gives attributes ...	217	[	1.0]	218	[	8.0]	219	[	8.0]	220
Variable	56	gives attributes ...	221	[	8.0]	222	[	8.0]	223	[	8.0]	224
Variable	57	gives attributes ...	225	[	8.0]	226	[	8.0]	227	[	8.0]	228
Variable	58	gives attributes ...	229	[	90.0]	230	[	180.0]	231	[	270.0]	232
Variable	59	gives attributes ...	233	[	30.0]	234	[	50.0]	235	[	70.0]	236
Variable	60	gives attributes ...	237	[	15.0]	238	[	25.0]	239	[	40.0]	240
Variable	61	gives attributes ...	241	[	20.0]	242	[	35.0]	243	[	100.0]	244
Variable	62	gives attributes ...	245	[	10.0]	246	[	10.0]	247	[	10.0]	248
Variable	63	gives attributes ...	249	[	1.0]	250	[	10.0]	251	[	10.0]	252
Variable	64	gives attributes ...	253	[	2.0]	254	[	3.0]	255	[	4.0]	256

Figure 13. List of attributes in the 3rd group of the "Two step" structure.

Variable	1	gives	attributes	...	1	[	7.0]	2	[	8.0]	3	[	9.0]	4
Variable	2	gives	attributes	...	5	[	18.0]	6	[	20.5]	7	[	23.0]	8
Variable	3	gives	attributes	...	9	[	30.0]	10	[	60.0]	11	[	100.0]	12
Variable	4	gives	attributes	...	13	[	20.0]	14	[	30.0]	15	[	45.0]	16
Variable	5	gives	attributes	...	17	[	4.0]	18	[	6.0]	19	[	8.0]	20
Variable	6	gives	attributes	...	21	[	5.0]	22	[	8.0]	23	[	12.0]	24
Variable	7	gives	attributes	...	25	[	25.0]	26	[	50.0]	27	[	100.0]	28
Variable	8	gives	attributes	...	29	[	25.0]	30	[	50.0]	31	[	100.0]	32
Variable	9	gives	attributes	...	33	[	100.0]	34	[	100.0]	35	[	100.0]	36
Variable	10	gives	attributes	...	37	[	100.0]	38	[	100.0]	39	[	100.0]	40
Variable	11	gives	attributes	...	41	[	100.0]	42	[	100.0]	43	[	100.0]	44
Variable	12	gives	attributes	...	45	[	100.0]	46	[	100.0]	47	[	100.0]	48
Variable	13	gives	attributes	...	49	[	100.0]	50	[	100.0]	51	[	100.0]	52
Variable	14	gives	attributes	...	53	[	100.0]	54	[	100.0]	55	[	100.0]	56
Variable	15	gives	attributes	...	57	[	25.0]	58	[	100.0]	59	[	100.0]	60
Variable	16	gives	attributes	...	61	[	100.0]	62	[	100.0]	63	[	100.0]	64
Variable	17	gives	attributes	...	65	[	15.0]	66	[	25.0]	67	[	100.0]	68
Variable	18	gives	attributes	...	69	[	100.0]	70	[	100.0]	71	[	100.0]	72
Variable	19	gives	attributes	...	73	[	100.0]	74	[	100.0]	75	[	100.0]	76
Variable	20	gives	attributes	...	77	[	100.0]	78	[	100.0]	79	[	100.0]	80
Variable	21	gives	attributes	...	81	[	25.0]	82	[	100.0]	83	[	100.0]	84
Variable	22	gives	attributes	...	85	[	2.0]	86	[	4.0]	87	[	6.0]	88
Variable	23	gives	attributes	...	89	[	4.0]	90	[	6.0]	91	[	7.0]	92
Variable	24	gives	attributes	...	93	[	2.0]	94	[	4.0]	95	[	8.0]	96
Variable	25	gives	attributes	...	97	[	2.0]	98	[	4.0]	99	[	8.0]	100
Variable	26	gives	attributes	...	101	[	2.0]	102	[	8.0]	103	[	8.0]	104
Variable	27	gives	attributes	...	105	[	8.0]	106	[	8.0]	107	[	8.0]	108
Variable	28	gives	attributes	...	109	[	2.0]	110	[	8.0]	111	[	8.0]	112
Variable	29	gives	attributes	...	113	[	8.0]	114	[	8.0]	115	[	8.0]	116
Variable	30	gives	attributes	...	117	[	2.0]	118	[	4.0]	119	[	8.0]	120
Variable	31	gives	attributes	...	121	[	2.0]	122	[	4.0]	123	[	8.0]	124
Variable	32	gives	attributes	...	125	[	2.0]	126	[	4.0]	127	[	6.0]	128
Variable	33	gives	attributes	...	129	[	2.0]	130	[	4.0]	131	[	8.0]	132
Variable	34	gives	attributes	...	133	[	8.0]	134	[	8.0]	135	[	8.0]	136
Variable	35	gives	attributes	...	137	[	8.0]	138	[	8.0]	139	[	8.0]	140
Variable	36	gives	attributes	...	141	[	2.0]	142	[	4.0]	143	[	6.0]	144
Variable	37	gives	attributes	...	145	[	0.7]	146	[	1.5]	147	[	3.0]	148
Variable	38	gives	attributes	...	149	[	1000.0]	150	[	1500.0]	151	[	2000.0]	152
Variable	39	gives	attributes	...	153	[	400.0]	154	[	600.0]	155	[	800.0]	156
Variable	40	gives	attributes	...	157	[	16.0]	158	[	16.0]	159	[	16.0]	160
Variable	41	gives	attributes	...	161	[	16.0]	162	[	16.0]	163	[	16.0]	164
Variable	42	gives	attributes	...	165	[	16.0]	166	[	16.0]	167	[	16.0]	168
Variable	43	gives	attributes	...	169	[	4.0]	170	[	16.0]	171	[	16.0]	172
Variable	44	gives	attributes	...	173	[	8.0]	174	[	12.0]	175	[	14.0]	176
Variable	45	gives	attributes	...	177	[	6.0]	178	[	16.0]	179	[	16.0]	180
Variable	46	gives	attributes	...	181	[	16.0]	182	[	16.0]	183	[	16.0]	184
Variable	47	gives	attributes	...	185	[	16.0]	186	[	16.0]	187	[	16.0]	188
Variable	48	gives	attributes	...	189	[	16.0]	190	[	16.0]	191	[	16.0]	192
Variable	49	gives	attributes	...	193	[	8.0]	194	[	8.0]	195	[	8.0]	196
Variable	50	gives	attributes	...	197	[	8.0]	198	[	8.0]	199	[	8.0]	200
Variable	51	gives	attributes	...	201	[	8.0]	202	[	8.0]	203	[	8.0]	204
Variable	52	gives	attributes	...	205	[	2.0]	206	[	8.0]	207	[	8.0]	208
Variable	53	gives	attributes	...	209	[	4.0]	210	[	5.0]	211	[	6.0]	212
Variable	54	gives	attributes	...	213	[	1.0]	214	[	2.0]	215	[	8.0]	216
Variable	55	gives	attributes	...	217	[	8.0]	218	[	8.0]	219	[	8.0]	220
Variable	56	gives	attributes	...	221	[	8.0]	222	[	8.0]	223	[	8.0]	224
Variable	57	gives	attributes	...	225	[	8.0]	226	[	8.0]	227	[	8.0]	228
Variable	58	gives	attributes	...	229	[	90.0]	230	[	180.0]	231	[	270.0]	232
Variable	59	gives	attributes	...	233	[	50.0]	234	[	62.0]	235	[	75.0]	236
Variable	60	gives	attributes	...	237	[	30.0]	238	[	30.0]	239	[	40.0]	240
Variable	61	gives	attributes	...	241	[	25.0]	242	[	30.0]	243	[	40.0]	244
Variable	62	gives	attributes	...	245	[	10.0]	246	[	10.0]	247	[	10.0]	248
Variable	63	gives	attributes	...	249	[	10.0]	250	[	10.0]	251	[	10.0]	252
Variable	64	gives	attributes	...	253	[	1.0]	254	[	2.0]	255	[	4.0]	256

Figure 14. Listof attributes in the 4th group of the "Two step" structure.

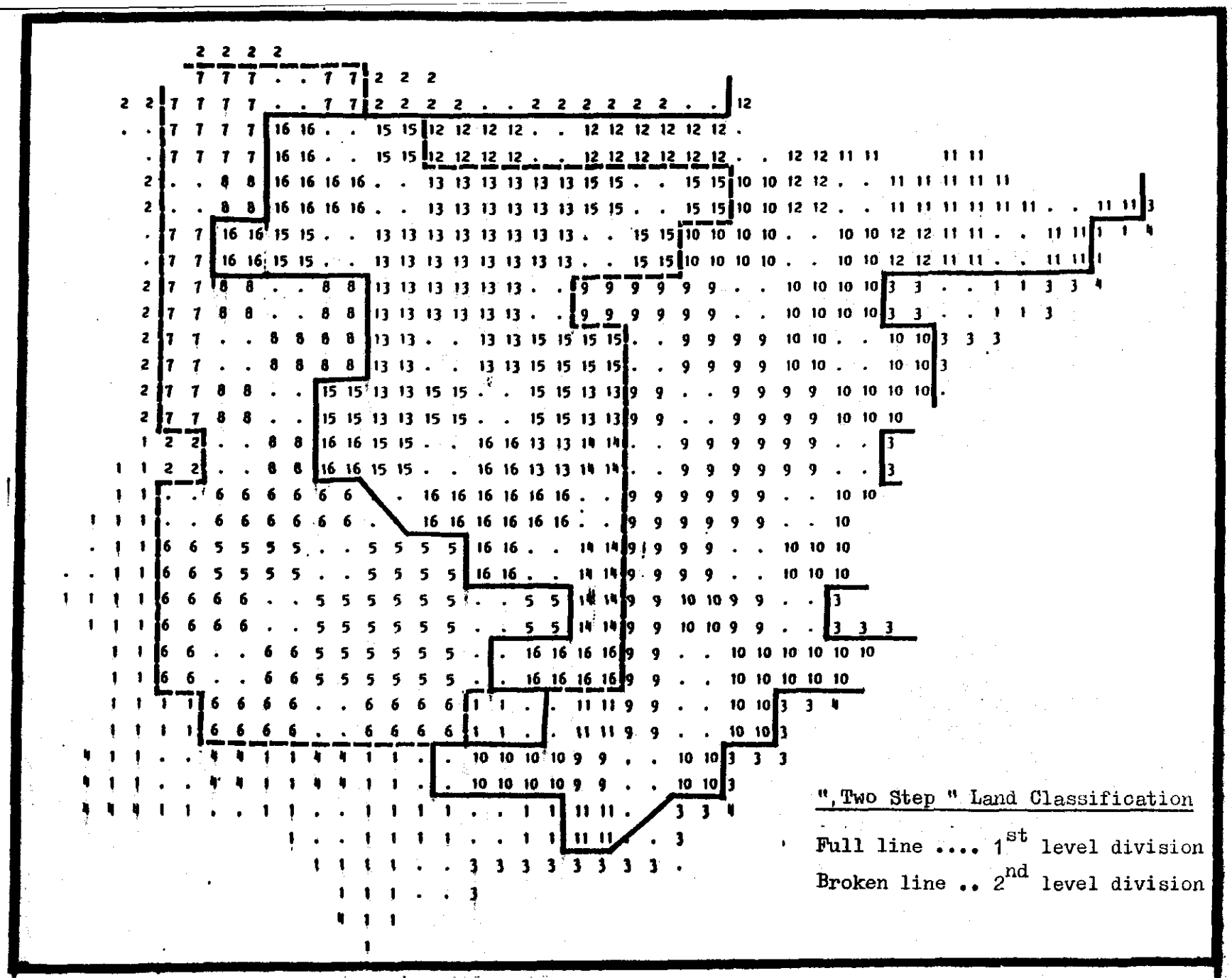


Figure 15. Map of Land Classes using "Two step" structure.

However, there is not a high correlation between the axes when using the present data set. RAO was applied to the data base of the Standard ISA Land Classification. The 2 first axes did not present as high a correlation as Hill showed with floristic data. The relationship between both axes is shown in Figure 16. Further investigation indicated a quite different interpretation of the 2 first RAO axes. The first axis is a climatic and altitudinal ordination, and this is evident at the first level of the Standard ISA Land Classification map in Figure 4. However, the second axis is a geological ordination of the squares. Figure 18 shows a map of the squares plotted with their second RAO axis value. The squares with higher values are primary areas, whereas the lower values belong to secondary and tertiary areas. The quaternary areas have intermediate values.

Therefore, the RAO axes are independent when the data are not homogeneous.

Further, the study of a scatter diagram of the 2 first axes showed that the second RAO axis was the criterion followed to ordinate the squares at the second ISA level.

Although the ISA only uses the first RAO axis to split the 204 squares, the second RAO is robust enough if it is applied to heterogeneous information as used in land classification. The 4 groups resulting from the second ISA division in the scatter diagram are shown in Figure 17.

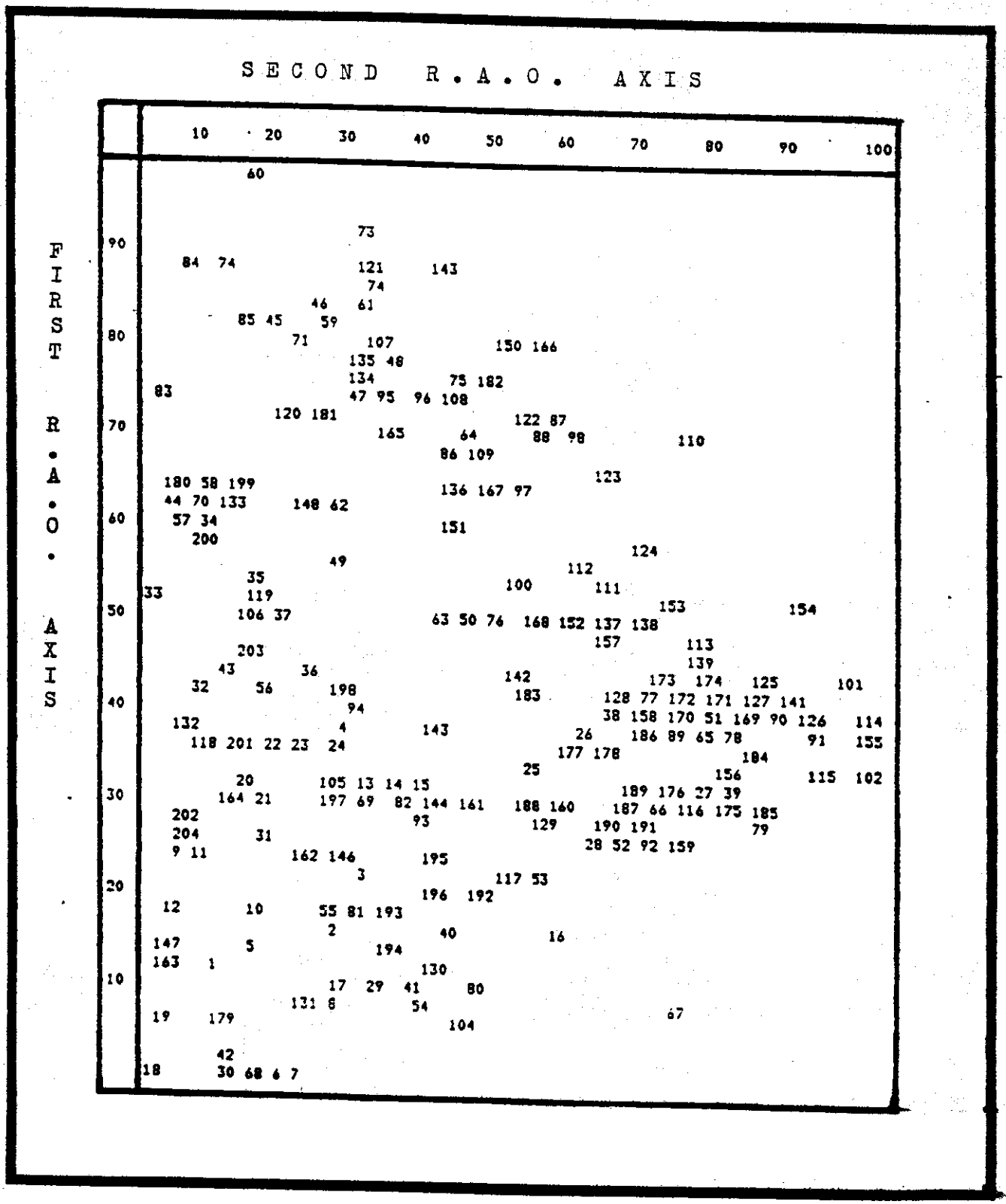


Figure 16. Scatter diagram of the first two RAO axes.

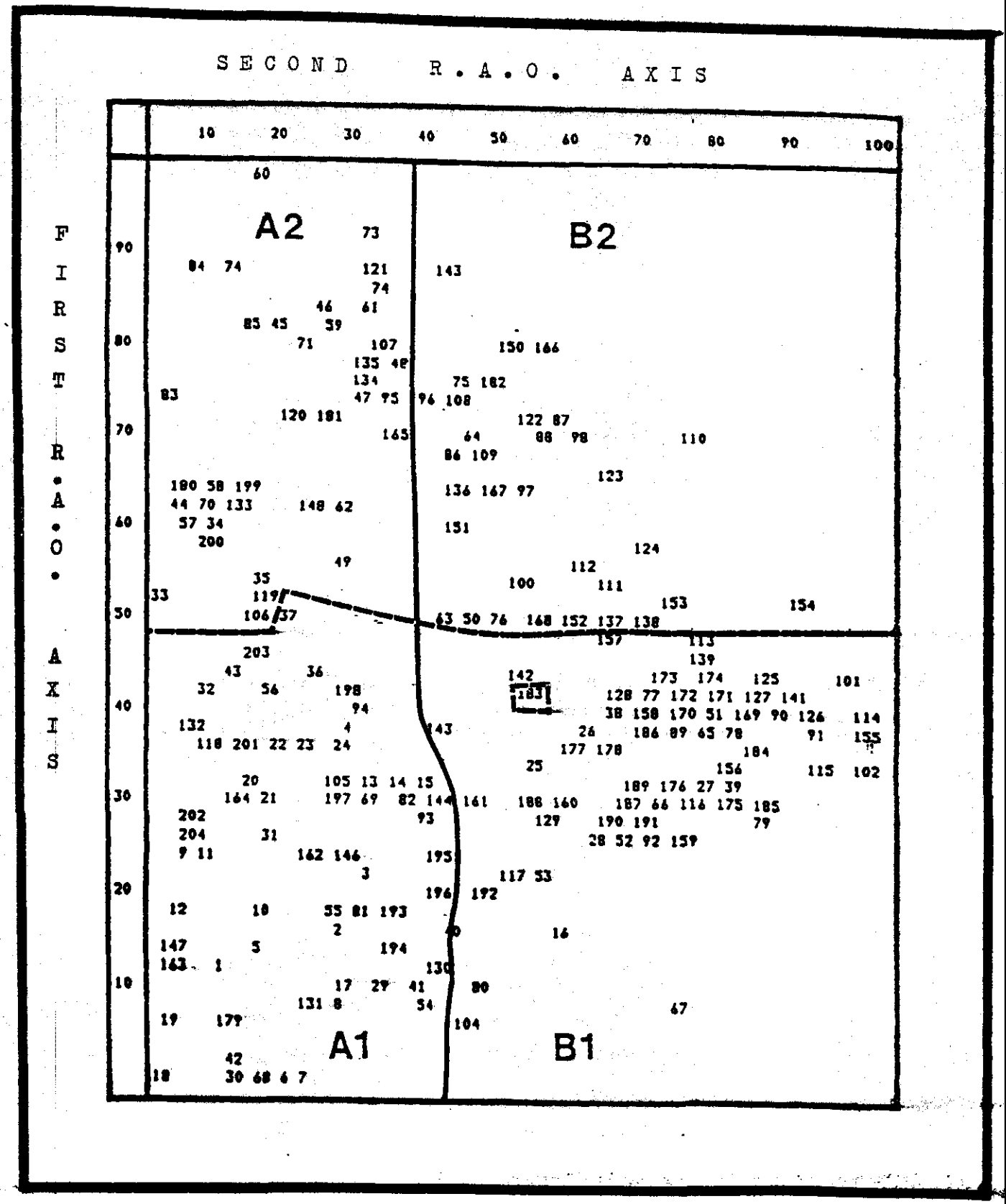


Figure 17. Scatter diagram of first two RAO axes showing the distribution of the land classes at the 2nd level.

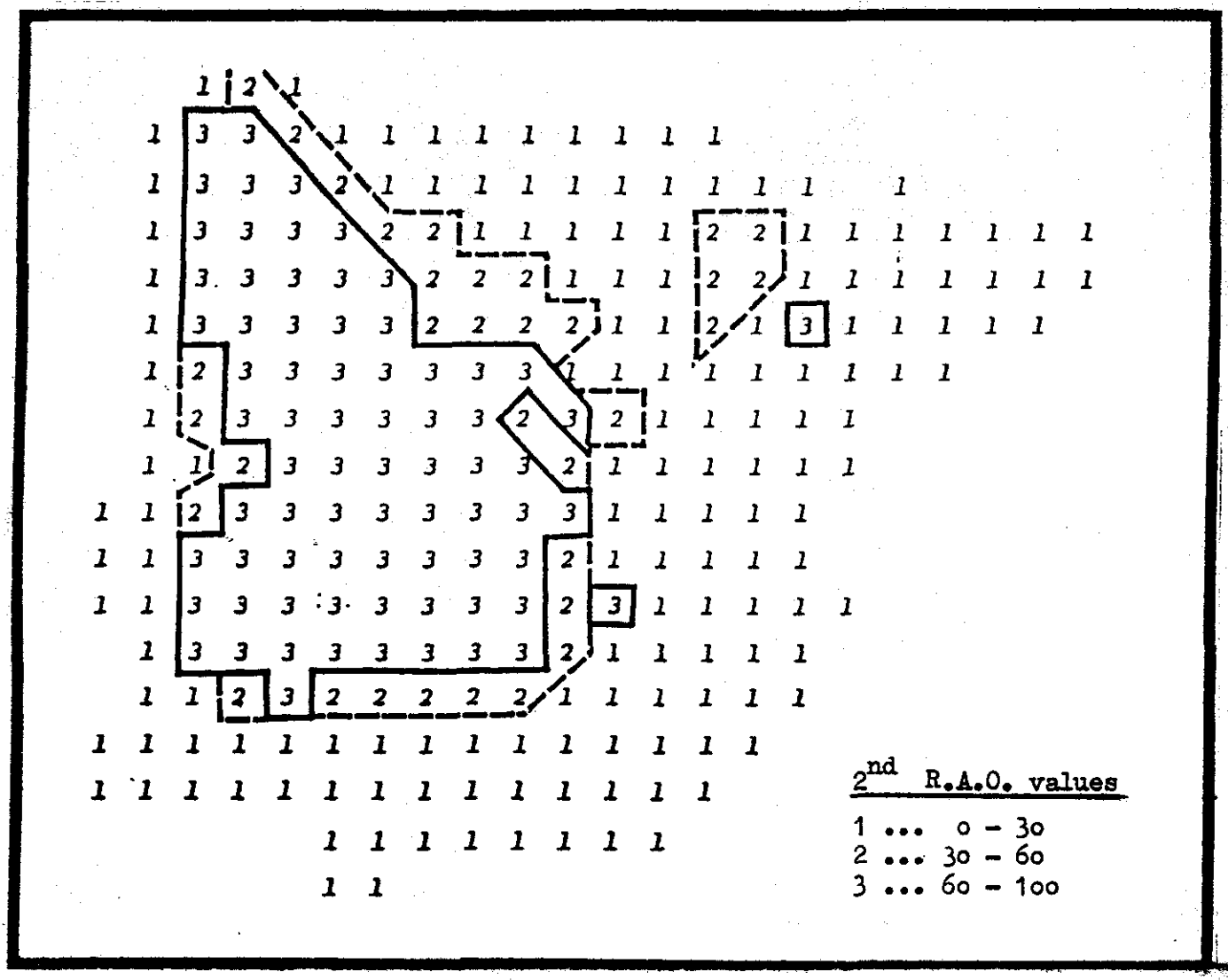


Figure 18. Second RAO axis values.

The next stage was to test the ecological value of the different land classifications and to validate them statistically.

The reduction of the number of original attributes produced 2 land classifications without the overall ecological validity of the initial analysis of the entire data.

The C1 Land Classification is simply a climatic classification. The C2 Land Classification is more complete and meaningful than the C1 but has not the ecological homogeneity that is produced with the standard ISA classification. Despite using the best attributes, the classification did not differentiate the northern coast. Therefore, the ISA requires as much information as possible to make a robust land classification that expresses the maximum variability.

However, the reduction of the number of attributes appears to provide a very interesting way to interpret some land classes with less ecological significance. A reduced data ISA may be made; for instance from climatic, geological or locational data for particular purposes.

The land classification where the cut-off points were manipulated are quite similar but the N1 presents more internal homogeneity in its land classes.

On the other hand, the 2 first levels in these classifications have similar geographic distribution to the same levels in the standard ISA classification.

It is possible to assess the quantity of information used by the ISA in each classification demonstrating the attributes used in each level. Figure 19 shows the attributes used at each level and by each classification.

	Standard I.S.A.		N1		N2	
	No Att.	%	No Att.	%	No Att.	%
1st LEVEL	204	100	140	100	178	100
2nd LEVEL	188	92	137	98	168	94
3rd LEVEL	156	77	116	83	147	82
4th LEVEL	128	63	115	82	126	70

Figure 19. Use of attributes within each classification.

It is seen, then, that a reduction in the range of the relative frequency of the attributes produces an increase in the number of attributes used at the lower levels. As the original information was the same in the 3 classifications, the N1 Land Classification is seen to be the most "efficient".

The efficiency level of the N2 Land Classification is similar to that of the standard ISA Land Classification; and therefore the N1 was chosen to compare statistically with the original classification.

Finally, 3 classifications were selected as the most useful for comparative purposes: i.e. the ISA in the standard way, the N1 and the "Two-step" Land Classifications.

The theoretical differences between them were:

- The N1 Land Classification uses more information at the lower levels but in the same way that is used in the higher levels.

- The "Two step" handles the information in a way determined by the characteristics of the lower levels.

Therefore, the first supposes a modification in the quantity of information and the second an improvement in the quality of the information.

The validation of the classification needs independent information from the original data, and to test its overall links with the land classification. The independent information selected for this was the Natural Vegetation of the Iberian Peninsula. Following the procedure described by Fourt et al. (1971) and used by Bunce (1983), the natural vegetation cover was recorded in each square. Each square was defined by 18 vegetation variables. Further, the vegetation mean values were obtained in each of the 16 land classes, and a Principal Components Analysis (PCA) was applied to the resulting data table. The principal axes were selected until a level of observed cumulated variance of 74% was reached.

At the same time, the mean values of the RAO first level for each land class were calculated.

In order to compare the validation of the 3 classifications a weighted correlation coefficient was used. First, the correlation coefficient between the RAO axis and each Principal Component was calculated. Further, each correlation coefficient was weighted by the precentage of the total variance observed in the axis. The addition of these values provides a method to compare the ecological validation, provided that all the different parameters are constant in the 3 classifications. Figure 20 shows the values of the simple correlation coefficients as well as the weighted correlation coefficients in the 3 land classifications.

Although the correlation coefficients are not very high, the "Two step" land classification appears as the best validated classification and the ISA in the standard way appears as the worst validated Land Classification.

These results demonstrate the improvement in the land classification when the data structure is modified in the way described above. Generally, however, the levels of validation are quite similar in the 3 classifications and therefore the features of the classification will decide which data structure must be used. For example: a classification with a high number of levels would require a "Two step" data structure. Nevertheless, the ISA standard data structure maintains an objective component that the other structures do not have.

6 CONCLUSIONS

1. Ecological significant classifications were produced for the Iberian peninsula using very simple data. The method used was ISA and the data were organised in different ways in order to check the robustness of this method.

   After a preliminary analysis, 3 approaches appeared as the most valuable: : the standard ISA structure, the limited relative frequency of attributes structure, and the "Two step" structure.

	'Standard I.S.A.'					'N-1' New Classification					Two Step I.S.A.				
	% V. (a)	% C.V.	R	R^2 (b)	(axb) (c)	% V (a)	% C.V.	R	R^2 (b)	(axb) (c)	% V (a)	% C.V.	R	R^2 (b)	(axb) (c)
1st P.C.	21.0	21.0	-0.58	0.34	7.14	22.5	22.5	0.66 ++	0.44	9.90	22.5	22.5	-0.34	0.12	2.71
2nd P.C.	17.8	38.8	0.51 +	0.26	4.62	16.3	38.8	0.45 +	0.20	3.26	19.0	41.6	-0.71 ++	0.51	9.69
3rd P.C.	13.6	52.4	0.20	0.04	0.54	14.4	53.3	-0.20	0.04	0.58	13.8	55.3	-0.41	0.17	2.35
4th P.C.	11.8	64.2	0.22	0.05	0.59	12.5	65.7	0.16	0.03	0.38	11.3	66.6	-0.15	0.02	0.24
5th P.C.	9.0	73.2	0.33	0.11	0.99	8.6	74.3	-0.27	0.07	0.60	8.5	75.0	0.09	0.01	0.09
$f = \Sigma c$					13.88					14.72					15.08
$Rw = \sqrt{f}$					0.36					0.38					0.39

\+ Significant P less than 0.05
\+ + Significant P less than 0.01
+++ Significant P less than 0.001

Figure 20. Simple and weighted correlation coefficient values.

2. The reduction in the quantity of information, expressed by a reduction in the number of attributes, even when they were the more informative attributes, produced a loss in the ecological significance of the land classification. Therefore, the use of ISA in land classification requires as much information as possible.

3. The first RAO axes obtained from non floristic data do not have the relationship that Hill showed with floristic data. Therefore, the second axis at the first ISA level is used in lower levels of the ISA.

4. The statistical validation of the 3 most important approaches, using the Natural Vegetation in order to test them, showed that the "Two-step" structure had the highest correlation coefficient. Meanwhile, the standard ISA structure presented lower significance. Nevertheless, the differences between them were small and were not statistically significant. As the statistical differences are not as high as expected, the Standard ISA is equally applicable because the possible loss in objectivity of "Two-step" is not compensated by the increase in the statistical significance of its results.

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