Vegetatiemap Juni 1993

Oi: 819158_1-2

TITLE

june 1993, Delft, The Netherlands

E.H. Kloosterman, S. Salamanca, A.M. Cleef

Contents

Summary

This publication describes the semi-detailed vegetation map, scale 1:5.000, of Parque Nacional Natural Los Nevados, Cordillera Central, Colombia. The map is based on the stereoscopic interpretation of black and white panchromatic aerial photographs, applying the Landscape Guided Vegetation Survey and fieldwork in 1980 and 1981. This survey was carried out as part of the ECOANDES/ECODINAMICO project. Next to an explanation of the procedure and the map contents this publication also provides a description of the plant communities in the survey area.

List of figures and tables

1. Introduction

In this chapter the semi-detailed vegetation map, scale 1:50.000, of the national park "Los Nevados" is presented (see appendix A), showing the spatial distribution of the plant communities in relation to their physical environment and, where possible, to the management. This vegetation survey was carried out in 1980/1981 within the frame work of the ECOANDES/ECODINAMICO project. The results of this project contribute to a better understanding of the structure and functioning of the Andean ecosystem and as such provide a basis for development planning. The method adopted for the execution of this survey is known as the landscape Guided Approach and is developed at the International Institute for Aero- Space Surveys and Earth Sciences (ITC), Enschede The Netherlands (see Zonneveld 1979, Zonneveld et al 1979, van Gils et al 1985 and Kloosterman et al 1988). This method has proved its value over the years in numerous surveys (see e.g. Spiers 1978, Hashim and Hermelink 1981, van Duivenvoorde and Sorgendrager 1983, Etter 1985, Loth and Prins 1986, Loth 1988 and Kloosterman et al 1988). It is based on the systematic interpretation of aerial photographs and/or other remote sensing images in combination with field data.

The national park "los Nevados" is located in the central mountain range (Cordillera Central) of the Colombian Andes, between approximately 4°35' - 5°00' N and 75°15' - 75°30' E and covers about 700 km^2 (see location map appendix A). Most of the park lies above the 3800 m contour line and it is situated in the border area of the departments Tolima, Caldas, Quindio and Risaralda. The actual study area covers about 1000 km^2. It includes most of the park and some of the surroundings. The highest water divide in the area is part of the boundary between the drainage basin of the river Cauca in the west and the river Magdalena in the east. Inhabitation of importance only occurs below 3800 m. Above this altitude only a few small farm houses are found. Apart from a number of tracks and two trafficable roads, there is no other infra- structure. For a description of the physical characteristics of the study area is referred to the corresponding publications in vol 1,2 and 4 (this volume) of the series "Studies on Tropical Andean Ecosystems" (Van der Hammen et al 1983, 1989 and en prep), Vis (1989) and Foe a description of the managment practices is referred to Verwey and Beukema (1992), Verwey and Budde (1992) and Verwey (1993).

2 The landscape guided vegetation survey

In this section a short outline of the survey procedure is presented. The landscape guided approach finds its conceptual base in a holistic approach to the phenomenon landscape. Based on this concept the landscape can be considered an integrated entity being the result of the mutual action and interaction of climate, parent material, landform, soil, vegetation, fauna, water and man (after Zonneveld 1979 and Schroevers 1982). Figure 2.1 aims at illustrating this relational complex. This definition implies that the vegetation in a given place, in its turn, is determined by the total complex of properties of the landscape in that area. From this latter statement the following two can be derived:

1) Changes in one or more properties of the landscape in space or time will lead to changes in the vegetation.
2) A change of the vegetation in space or time indicates a change in the properties of the landscape.

The first statement forms one of the fundaments of the mapping procedure applied in this vegetation survey. The second statement forms the basis for the application of these maps in for instance landscape ecological studies (Van Stokkom & Kloosterman 1988). In figure 2.2 the stages in the Landscape Guided Vegetation Survey are shown

The Landscape Guided Approach comprises three stages:

1) Image interpretation / preliminary land-unit map.

Aerial photographs or other remote sensing images show the spatial variation in the physiognomy of the landscape. This variation is visible on the image as differences in *relief, landcover and drainage pattern.* Stereoscopic interpretation of aerial photographs using the landscape guided approach is the process of delineating those landscape boundaries visible on the image, expected to bear significance for the vegetation. This is done by subdividing, in a number of steps, large broadly defined units (main landscapes) into smaller more narrowly defined ones (sub-landscapes) until the level of detail which can still be consistently mapped at the scale of the images concerned. The land-units delineated at this level of detail can either be homogeneous or complex; i.e. consisting of two or more not separately mappable elements. These elements are separately described and their relative contribution to land-unit as a whole is determined. The result of this stage is a hierarchial stratification of the study area (the legend) and a preliminary land unit map.

2) Fieldwork.

Based on the stratification provided by the preliminary land-unit map sample areas are selected. Within these areas representative stands of vegetation are selected. In the actual vegetation sample or relevee, next to floristic composition and vegetation structure, also a short description of the physical characteristics of the site is recorded.

3) Data processing and compilation of final vegetation map.

This stage consists of:

* Vegetation classification

The vegetation relevees with a similar floristic composition are clustered into vegetation types according to the principles of the Braun-Blanquet method (1965). After the floristic classification is completed for each vegetation type (ie. cluster of relevees) the data concerning the vegetation structure and physical characteristics of the sample sites are analyzed and used for further description of the types. The results of this systematic description are presented in section 3.2.

* Compilation of the cross-table

Since each vegetation relevee belongs to a particular vegetation type and at the same time is a representative sample for a preliminary land-unit, it is possible, by means of a correlation matrix or cross-table, to express the preliminary land-units in terms of vegetation types.

* Compilation of the final map

Based on the vegetation contents of the land units can be decided:

- to merge two or more preliminary land-units when their vegetation contents is similar.
- to subdivide a preliminary land-unit into two or more new land-units.
- that leave the boundaries of the land-units unchanged.

Once this stage is passed the boundary of the land-units and their contents in terms of vegetation types is established and the final map with its accompanying legend can be compiled.

For a detailed description of the Landscape Guided Approach is referred to Zonneveld (1979), Zonneveld et al (1979), van Gils et al (1985) and Kloosterman (1988).

3 Vegetation of the study area

In this section the floristic classification is discussed and a description of the plant communities is presented. It should be noted that at the time vegetation survey was carried out phyto-sociological information on the study area was still limited. For this reason the communities distinguished in this survey are compared to the syntaxa as described by Salamanca (1991) and Salamanca et al (1993).

3.1 The floristic classification

After completion of the field work the vegetation relevees were classified according to the principles of Braun-Blanquet (1965). The floristic classification presented in this study is based on the following fieldwork periods:

- january-february 1980 (ECOANDES/ECODINAMICO expedition).
- june 1980. (short expedition of Cleef, Salamanca, Kloosterman and Boonen).
- october-november 1981. (Salamanca, Kloosterman and Boonen.)
- january 1981 (Salamanca).

During this survey the Andean dwarf forest, Andean forest, the aquatic communities in the paramo and superparamo and the moss bogs in the superparamo were not sampled. The floristic characterization of these plant communities is directly derived from the results of the ECOANDES/ ECODINAMICO expedition (see Cleef et al 1983) and oral information of Cleef and van Reenen. These communities are dealt with in a very general way. Due to the limited amount of vegetation relevees and the fact that at the time this classification was carried out phyto-sociological data from the equatorial part of the Central Cordillera were scanty it was decided not to assign a syntaxomonical rank to the vegetation types obtained. All vegetation types are therefore indicated by the term "plant community" (see Mueller-Dombois and Ellenberg 1974). In section 3.3 the communities distinguished in this survey are compared with the syntaxa described by Salamanca (1991) and Salamanca et (1993).

First a pre-ordering of the relevees was made based on obvious floristic and physiognomic differences, resulting in a number of formations listed below. This pre-ordering was guided by the results of previous research of Cleef (1981), Cleef et al (1983) and Cuatrecasas (1934, 1958). The terms between " " are directly derived from Cleef et al (1983).

- Formation I : zonal superparamo communities characterised by low herbaceous vegetation of rosette forbs and matted or tufted grasses, so called "pastzal azul" and pioneer communities.
- Formation II : zonal paramo communities characterised by grasslands consisting of tall tussock grasses ("macollas") and stem composites ("frailejones"), the so called "pajonal".
- Formation III : azonal replacement communities characterised by low matted forbs and matted grasses, so called "prados".
- Formation IV : azonal moss vegetations of escarpments and rock outcrops.
- Formation V : azonal or extra zonal woody vegetation of scree slopes and drainage ways, so called "bosques enanos" and "matoral".
- Formation VI : azonal cushion bogs, the so called "turberas de cojines".

Next to this two more formations are present in the study area which were not included in the field sampling for this survey.

- Formation VII : zonal andean forest communities
- Formation VIII : azonal moss bog communities

Zonal vegetation is defined by Walter (1964, 1979) as those plant communities which reflect a close relation to the current climatic conditions of a larger region and which have developed without significant human interference, on soils with non-extreme properties (see also Mueller-Dombois & Ellenberg 1974). Azonal vegetation is found in places where edafic factors like extreme soil properties or human impact overrule the effect of the macro-climate. Where due to local conditions the influence of the macro-climate is modified (eg. in sheltered places) plant communities similar to the zonal vegetation of one of the neighbouring zones can be found. These communities are referred to as extrazonal vegetation.

The results of the classification is presented in appendix B. This so called "bar diagram" is in fact a graphical synoptic table. It shows the characteristic floristic composition of the plant communities. The importance of each species within a community is indicated by the thickness of the bar. Only those species are included which played a role in the classification. This is about 70% of all species recorded in the superparamo and paramo zone. All species with a very low presence and those species which showed an indifferent distribution over the plant communities combined with a low presence were omitted. One sequence of species was used for all formations. This facilitates comparison of different plant communities and secondly it provides the bases for the recognition of socio-ecolological species groups. During the above mentioned fieldwork periods not all species were correctly identified. For this reason some species listed in the bar-diagram are grouped and dealt with as one species (eg. *Agrostis araucana* and *Agrostis foliata*).

3.2 Description of the plant communities

Formation I: zonal communities of the superparamo.
Within this formation the most important ecological factors determining the distribution of the plant communities are altitude (viz climate) and substrate. The former causes a decrease in total number of species with increasing altitude, while the latter gives rise to specific floristic differences. Floristically this formation can be characterised by *Senecio canescens* and *Cerastium floccosum* and three groups of communities can be distinguished:

1) Group one consists of very sparse, species poor pioneer communities dominated by *Pentacalia gelida* (community h1). This community is found in the highest regions of the study area on coarse grained volcanic ashes, for example on the cone of Nevado del Ruiz.

2) The second group is characterised by *Baccharis ceaspitosa* in combination with *Streocaulon vesuvianum* and *Grammitis moniliformis*. It consists of three communities, h2a, h2b and h2c which, together with the previous group, form an altitudinal sequence and are found only on coarse volcanic ashes. The first community (h2a) is the most species poor and is characterised by dominance of *Agrostis araucana/Agrostis foliata* in combination with *Poa trachyphylla*. The latter species is typical for this community. It occurs in low covers

and is not always present. Within this group of communities *Luzula racemosa* and *Erigeron chianophilus* in combination with dominance of the above mentioned *Agrostis* species and *Festuca breviaristata* characterise community h2b and h2c. The latter community can be distinguished from the former based on the presence of *Lachemilla nivalis* and elevated cover of *Lycopodium crassum.*

3) The third group consists of three communities h3a and h3b and h4. The combination of *Senecio latiflorus* and *Lupinus alopecuroides* is typical for this group. Community h3a and h3b form an altitudinal sequence and are confined to glacial scree. They are mainly found on the cone of Nevado de Santa Isabel. These communities are dominated by mosses. The first one is the most species poor and is found in the highest regions. The second community has next to a high cover of mosses also a high cover of *Agrostis araucana/Agrostis foliata.* Community h4 is found on fine grained volcanic ashes in the superparamo. *Senecio isabellis* is typical for this community. Furthermore it is characterised by a dominance of *Festuca breviaristata.* Most likely also on the fine volcanic ashes there will be floristic variation related to altitude, but the data collected for this survey did not allow distinction of an altitudinal sequence on this type of substrate.

<u>Formation II</u>: Zonal paramo communities
Floristically this zone is characterised by a group of species of which *Geranium siebaldioides*, *Lucillia pussila* and *Espeletia hartwegiana* are typical representatives. This formation consists of four groups of communities, which form an altitudinal sequence. The distribution of the plant communities within each group is determined by a combination of substrate and hydrology.

1) The first group consists of one community (t1). It is found near the upper limit of the paramo and is characterised by a dominance of *Festuca sublimis.*

2) The second group is floristically characterised by the presence of *Calandrinia acaulis* and dominance of *Calamagrostis recta.* Community t2a and t2b still contain a number of species, like *Lycopodium crassum, Cerastium floccosum* and *Montia*

meridense, which are also found in the superparamo. Community t2a is found in relativly dry conditions on sloping areas and is characterised by *Jamesonia goudotii* and *Arcytophyllum spp*. Community t2b is found on transitions to swamps and is floristically very similar to the previous community. It is characterised by the presence of *Carex cf. peucophylla*. These two communities seem to show no preference for a particular substrate type. Community t3a and t3b are floristically very similar. They are found on fine grained ashes. *Halenia sp./Halenia campanulata, Senecio formosus* and *Conyza uliginosa /Conyza sp.* are typical for these communities. The first community is found in relativly dry conditions on sloping areas, while the second one is found on transitions to swamps. It is characterised by *Carex cf. peucophylla*. It is questionable in this case wether it concerns true zonal communities, since the characteristic species (*Halenia sp./Halenia campanulata, Senecio formosus* and *Conyza uliginosa /Conyza sp.*) according to Salamanca (1991) are grazing indicators. This does however not coincide with the results of this survey. Since these species are absent in the grazing communities (see formation III). Hence these communities are included in the zonal vegetation.

3) The third group of communities belongs to the *Calamagrostis recta Calamagrostis effusa* tussock grasslands. Community t4 is found on the cinder fields ("arenales") of Nevado del Ruiz on the transition between the cone and the footslope. This area possibly is a large seepage zone (see fig. 4.4). This may account for the fact that this community is characterised by *Plantago rigida*, which in fact is a species from the cushion bogs. Hence it may be argued that this community should be classified as azonal. Community t5a and t5b are the true *Calamagrostis recta/effusa* tussock grassland. They are floristically very similar and occur on both fine grained and coarse grained ashes. On the latter substrate the upper limit of these communities lies approximately 100 m higher than on the fine grained ashes (compare section 4.4 and fig. 4.2). Community t5a is found in relativly dry conditions on sloping areas, while t5b is found on transitions to swamps. It is characterised by *Carex cf. peucophylla*. Community t5c is poorly documented. It is floristically very similar to t5a. based on additional notes made during the fieldwork it was decided

to recognize this community. It occurs specifically on block lava flows and is characterised by the presence *Escallonia myrtilloides* and *Bidens triplinerva*.

4) Group 4 represents the communities from the Calamagrostis effusa tussock grassland. They are characterised by presence of *Festuca dolichophylla* and dominance of *Calamagrostis effusa*. It should be noted that on the coarse grained ashes the upper limit of this group lies approximately 100 m higher than on the fine grained ashes (see fig. 4.2). Community t6a and t6b are floristically very similar. They occur on fine grained volcanic ashes and can be distinguished from the other communities within this group by the presence of *Calamagrostis recta, Cerastium arvense, Senecio repens, Sisyrinchium trinerve* and *Hypericum laricifolium*. Community t6a is found in relativly dry conditions on sloping areas and is characterised by the presence of the following shrub species, *Gynoxys sp., Baccharis macrantha* and *Pentacalia vaccinoides*. Community t6b is found on transitions to swamps and is characterised by the presence of *Carex cf. peucophylla*. Community t7a, t7b and t8 are also floristically very similar. They can be distinguished from the other communities within this group by the presence of *Castilleja fissifolia, Baccharis genistelloides* and *Bidens triplinerva*. Community t7a and t7b are found on coarse grained ashes, where the first one occupies relative dry sloping areas, while the second community is encountered on transitions to swamps. The latter is characterised by *Carex cf. peucophylla*. Community t8 is confined to the block lava flows and can be distinguished by the presence of *Escallonia myrtilliodes*.

<u>Formation III</u>: Azonal replacement communities
The plant communities of this formation develop when zonal tussock grasslands are being used for grazing. The management practices range from only extensive grazing, to grazing in combination with burning and locally also active removal of the tussocks. A high cover of *Agrostis haenkeana* is characteristic for this formation. The communities pt, p1 and p2 seem to represent a sequence of increased human influence.
Community pt can still be called a tussock grassland. Compared to a well developed zonal tussock grassland the tussocks are lower and have a smaller diameter. Moreover this community is poor in species

and the stem composites of *Espeletia hartwegiana* are lower and in general show signs of burning. Floristically this community is characterised by equal contribution to the total cover of *Calamagrostis recta, Calamagrostis effusa* and *Agrostis haenkeana.*
Community p1 is characterised by dominance of *Agrostis haenkeana* and elevated cover of *Rumex acetosella*. Community p2 is dominated by *Lachemilla orbiculata*. This community covers large areas especially in the lower paramo. *Aciachne pulvinata* is the characteristic species of community p3. In the fieldwork which was carried out for this vegetation survey this community was only found in the basin of Laguna Otun, where it covered the most exposed and dry places on convex slopes.

Formation IV: Azonal moss vegetation of escarpments and rock outcrops
This formation consists of one community (m2) which is dominated by *Racomitrium crispulum/Racomitrium lanuginosum*

Formation V: Azonal or extra zonal woody vegetation
This formation embraces the shrub communities and patches of open low forest within the paramo and superparamo zone. The distribution is ruled by edafic hydrological or climatological conditions.Community s1 is found in the superparamo on outcrops in areas covered with coarse grained volcanic ashes. It is dominated by *Loricaria colombiana* in combination with presence of *Racomitrium crispulum/Racomitrium lanuginosum*. During the fieldwork for this survey this community was mainly encountered on the cinder cone ("arenales") of Nevado del Ruiz. Community s2a and s2b are dominated by *Pentacalia vernicosa* shrubs. The first community is found on scree slopes underneath escarpments near the lower limit of the superparamo and can be distinguished from the second by the presence of *Senecio latiflorus* and *Lupinus alopecuroides* and elevated cover of *Senecio isabellis*. The second community can be found on similar places in the upper paramo and is characterised by co-dominance of *Festuca sublimis* and *Calamagrostis recta*. The sites underneath scarps are sheltered places. During the night they are protected by the escarpment from cold winds coming down from the mountain tops. During the day they favour from the warm air coming up from the valleys. Hence these places have a more favourable climate. In agreement with the definitions of Walter (1964 and 1979) the vegetation of such sites should be considered extra zonal.
Community s3 is characterised by the presence of low *Polylepus*

sericea trees. This so called "bosque enano" is found in the upper paramo in comparable sites as the *Pentacalia vernicosa* shrublands, but it is also encountered in the Andean dwarf forest zone.
Community s4 is characterised by high *Escallonia myrtilloides* shrubs. It was only found on the lateral moraines round Laguna Otun in the middle paramo zone. It is poorly documented, but due to the exceptional hight of the shrubs it was decided not to include it in the *Hypericum laricifolium* shrublands. The synecology of this community is unclear. *Hypericum laricifolium* shrublands (s5a and s5b) are found in the middle and low paramo, where the first one occupies drainage ways and concave slopes transitional to swamps. The second community is found in comparable sites as *Pentacalia vernicosa* shrublands underneath scarps. Community s5a can be distinguished from s5b by co-dominance of *Escallonia myrtilloides*.
Patches of *Gynoxys sp.* forest (community s6a and s6b) are found on scree slopes underneath escarpments in the middle and low paramo. The extra zonal character of these sites is confirmed by the fact that these communities contain a relatively high number of species also occurring in the Andean dwarf forest (*Relbunium hypocarpium* species group, *Myrrhidendron glaucescens* species group and *Cortaderia sericantha* species group). Community s6a is characterised by co-dominance of *Calamagrostis recta* and s6b by the presence of *Cortaderia sericanta*. The last shrub community (s7) is found in swamps in the middle and lower paramo and is dominated by *Pentacalia vaccinoides* and *Plantago rigida*.

<u>Formation VI</u>: Azonal bogs vegetation
Floristically this formation is characterised by *Calamagrostis ligulata* and *Carex cf peucophila*. The occurance of bog vegetation is determined by the hydrological condition. The floristic composition however is also determined by altitude. Community c1 is found only in the superparamo and is floristically characterised by a dominance of *Werneria humilis* and co-dominance of *Distichia muscoides*.
Cushion bogs dominated by *Distichia muscoides* (community c2) are found from the superparamo until the middle paramo. *Calamagrostis coarctata* and *Floscaldasia hypsophila* are typical species for this community.
Community c3 and c4 are dominated by cushions of *Plantago rigida*. The second community can be distinguished due to co-dominance of *Oreobulus obtusangulus* and presence of *Werneria crassa*. Community c3 can be found throughout the whole paramo and upper limit of

Andean dwarf forest, while community c4 is limited to lower and middle paramo.
Cushion bogs dominated by *Werneria crassa* (community c5) are found in middle and lower paramo. Community c7 is not a cushion bog but is dominated by a tufted sedge of *Carex cf peucophila*. It can be found throughout the entire paramo in depressions between the cushion plants.

In table 1 a systematic description of the communities is presented.

3.3 Comparison with existing literature.

In this section cross reference is made between the plant communities as distinguished in this survey and the syntaxa as described by Salamanca (1991) and Salamanca et al (1993). The main part of the vegetation relevees which are collected during the fieldwork period in 1980 and 1981 and on which the vegetation classification presented in section 3.2 is based, are also included in the data set used by Salamanca. The latter data set however is supplemented with additional vegetation relevees collected during a number of additional expeditions. For this reason the communities described by Salamanca are better documented compared to the ones distinguished in this survey. On the other hand during the first mentioned fieldwork period a number so called "quick relevees" is recorded which are not included in the work of Salamanca. These relevees were necessary to obtain vegetation information on land units which are distinguished in the aerial photo interpretation and which are not covered by the sampling scheme of Salamanca. For this reason the classification presented in section 3.2 contains a number of communities which are not distinguished by Salamanca. The result of the comparison is presented in table 1.

4 Description of the legend

In this part the legend is discussed. Section 4.1 deals with the hierarchy in the legend and the criteria applied to come to this classification. In the next two sections the higher hierarchial levels are described. For a detailed description of the plant communities is referred to the previous section and section 5 deals with the substrate.

4.1. The hierarchy of the legend

The legend accompanying the map is in fact a combination of two hierarchial systems, both having the same legend-unit-(element) as the smallest unit (see appendix A) On the right hand side under the heading "terrain" geomorphological criteria were applied, while on the left hand side under the heading "land cover" the hierarchy is guided by properties of the vegetation. In between the two hierarchies there is a number of columns in the legend containing additional information. The legend-unit, indicated in the legend by the "map unit code" is lowest level of detail which can be consistently mapped at the scale concerned. In most cases, even in detailed vegetation surveys, land-units delineated at this level of detail are not homogeneous but consist of a number of not separately mappable elements.

The main difference between the two systems is that the terrain hierarchy is based on analysis of the direct sources of information visible on the image (viz. relief, land cover and drainage pattern) and as such is largely identical to the legend accompanying the preliminary photo interpretation. The land cover hierarchy on the other hand is in fact a rearrangement of the legend units obtained by the photo interpretation guided by vegetation characteristics (ie. inferred information). It can only be constructed after analysis and classification of the field data. The latter hierarchy provides true landscape ecological units since it combines biotic as well as abiotic characteristics.

4.1.1 The "terrain" hierarchy

The hierarchy of this part of the legend is presented in fig.4.1 and in this section the criteria applied for the delineation of each level will be briefly discussed (compare also appendix A).

Main geomorphological landscape

The guiding principles for the delimitation of the main geomorphological landscapes are:

- The geo-genetic process responsible for the actual macro topography.
- Differences in macro topography in genetically linked areas.

Applying these principles resulted in the delineation of the volcanic landscape and the fluvial landscape.

The volcanic landscape consists of two distinctly different areas as far as the macro topography is concerned; a mountain zone at high elevation between approximately 4300 and 5200 m and a footslope zone between approximately 3700 and 4400 m. Within the footslope zone an upper, middle and lower footslope is distinguished reflecting the increased influence of fluvial processes with decreasing altitude. Their delineation was guided by differences in rate of dissection (viz. density and visibility of drainage ways).

The fluvial landscape consists of a mountain zone at lower elevation and is found below 3800 m.

Geomorphological sub-landscape

The sub-landscapes were defined based on differences in relief (viz. size and shape of the features) and genesis. This resulted in the delineation of the following units:

- Within the mountain zone at high elevation only one sub-landscape of volcanic cones and mountain ridges is distinguished.
- The footslope zones is divided into lava fields, cinder fields, block-lava flows, glaciated lava fields and lateral moraines.
- The mountain zone at lower elevation contains two sub-landscapes (viz. alluvial plains and denundational hills and mountains).

Slope form

At the lowest level of detail which can be consistently mapped at this scale (viz. the legend unit level) the sublandscapes are subdivided into areas with a particular combination of slope forms related in space (eg. convex or straight to slight concave slopes). This hierarchial level is indicated in the legend by the "map unit code". The individual slope forms (viz legend-unit-elements) cannot be mapped any more, but are described separately in the legend. They form the lowest hierarchial level. For each legend-unit-element the vegetation contents is established by means of the cross-table (compare section 2). This level is the starting point for the "land cover" hierarchy.

4.1.2 The "landcover" hierarchy

The land cover classification described in this section contains four hierarchial levels (see appendix A). It will be discussed in the way in which it was constructed, that is to say starting from the legend-unit-(element) and its characteristic plant communities.

Characteristic plant communities

The building stone for the land cover hierarchy is the same legend-unit-element as the one forming the lowest level of detail in the previous classification, where it was characterized by a certain slope form. By means of the cross-table the vegetation contents can be determined and every legend-unit is now characterized by a particular (unique) combination of plant communities.

Vegetation belts

Vegetation belts are characterized by the occurance of one or more species which are either:

- almost exclusive for that area as is the case in the *Senecio canescens* belt.
- preferential for a belt, like in the *Hesperomeles-Gynoxys* belt and the *Weinmannia* belt.
- or are the dominant species within the zonal vegetation of that area. This is the case in the *Calamagrostis recta* belt (or upper paramo), the *Calamagrostis recta - C. effusa* belt (or middle paramo) and the *Calamagrostis effusa* belt (or lower paramo).
- In the nival belt vegetation is virtually absent and the land is either bare or covered with perennial snow and glaciers.

The vegetation zones

On the highest level in the hierarchy vegetation belts are grouped into more broadly defined units based on the physiognomy of the zonal vegetation. In the study area four vegetation zones are distinguished.

The superparamo lies approx. between 4400 - 4600 m is characterized by a low vegetation of rosette forbs and matted or tufted grasses.
The paramo zone is situated approx. between 3850 and 4400 m. The physiognomy of the zonal vegetation is dominated by tussock grasses and stemcomposites.
The andean dwarf forest is characterised low trees and high shrubs. This vegetation zone lies between aprox. 3550 and 3900 m.
The andean forest extends far beyond the lower limits of this map. Its upper limit lies somewhere around 3600 m. The vegetation is characterized by an open to closed forest with high trees up to 30 m. In other publications the same vegetation zones are distinguished (see Cuatrecasas 1934, 1958 and 1968, Cleef 1979 and 1981 and Cleef et al 1983).

4.2 Description of the terrain units

The volcanic landscape

Extrusive and effusive volcanic processes were responsible for the architecture of this area, resulting in a number of high strato-volcanoes of Plio-Pleistocene age, of which Nevado del Tolima and Nevado del Ruiz are still active. Due to a number of glaciation periods the relief has been modified in many places (see van der Hammen et al 1983). Basically the drainage pattern in this landscape is radial and, except for Nevado del Ruiz and Nevado del Tolima, poorly developed especially in the higher part of the study area.

Volcanic cones and mountain ridges

This comprises the isolated mountains or mountain ridges with in general steep straight slopes and either a convex summit or a sharp edged crest lines. Locally the slope form has been influenced by glacial scouring and previously straight slopes became slightly concave. This phenomenon is particularly clear on the Santa Isabel and locally on the Nevado del Ruiz. On most cones and ridges a drainage pattern is absent. Except for Nevado del Ruiz and Tolima, where due to a thick layer of volcanic ashes covering the cone, the so called "arenales", a clear radial drainage pattern has developed. The geomorphological processes active in the area are mass movements, like frost heaving and in the arenales gulley and locally even ravine erosion can be encountered.

The footslope zone

As a whole the footslope zone is a concave to straight gently sloping area, consisting of sloping to moderately steep hills. Basically the relief is determined by lava outflows and in a number of places by fluvio-volcanic flows (blocklava's) or thick pyroclastic deposits (cinder fields). When descending an increase of the effect of fluvial processes can be observed, indicated by an increase in gulley density. The modifying influence of glaciers on the relief is most outspoken in the lower part of the footslope zone approximately below 4200 m. Besides a more smooth topography, also more or less well developed U-shaped valleys and lateral moraines are found in these areas.

Lava fields

The landform of this sub-landscape is determined by more or less concentric or fan shaped outflow areas of extrusive igneous rock, consisting of a gently sloping, undulating top surface with small convex elevations and flat bottomed shallow depressions and bordered by steep to scarping side slopes. Due to the morphology of these areas a drainage system has hardly developed. The top area as a whole is poorly drained and stagnant water occurs in most of the shallow depressions and near the edges seepage is a common phenomenon. On the escarpments the layer of volcanic ashes is absent and outcrops of volcanic hard rock occur. Underneath these scarps scree slopes are found.

Cinder fields

This term refers to those areas where a thick layer of pyroclastic material has been deposited on top of the lava fields, to the extend that they completely obscure the underlying landforms. The result is a rolling to hilly smooth topography. In these cinder fields a clear radial drainage pattern has developed, with probably active gulley an ravine erosion. This sub-landscape almost exclusively occurs on the footslope of the Nevado del Tolima. On the Quindio, Nevado del Ruiz and Santa Rosa small areas with a comparable situation can be found.

Blocklava flows

Morphologically these flows can be described as elongated tongue-shaped features, with steep smooth lateral ridges, scarping transversal front slopes and a gently sloping but very rugged top surface. These unconsolidated fluvio-volcanic flows consist of large blocks of volcanic hard rock bedded in mud of pyroclastic origin. Along the lateral ridges forming the contact zone between the blocklava flow and any other sub-landscape, there is always a drainage channel, in the block lava itself a drainage pattern is absent and the water is drained in a sub-surface streams.

Glaciated lava fields

The effect of ancient glaciers on the relief is most clear below 4200 m of altitude. The scouring of the ice has transformed the original lava flow into a moderately steep to steep hilly terrain with well developed U-shaped valleys. The concave to flat valley bottoms are smooth and undulating. The valleys are bordered by in general smooth elongated hills, locally with a nearly flat top-surface or with a sharp crest line. Due to the direction of the valleys the originally radial drainage pattern is modified into a parallel- dendritic pattern. The density of the drainage channels increases with decreasing altitude. Except for some escarpments, where rock outcrops occur, also this area is completely covered by a layer of volcanic ashes. The geomorphological processes active in the area are gulley erosion, especially near the lower limit and colluviation underneath scarps where scree slopes are formed. Locally in the valley bottoms and on the flat topped hills stagnant water occurs.

Lateral moraines

This sublandscape is characterised by a smooth topography consisting of moderately steep elongated convex hills (lateral moraines) with wide U-shaped valleys. The moraine material is deposited on top of the lava fields completely obscuring the original forms and they in their turn are covered again by a layer of volcanic ashes. The drainage pattern in this sub-landscape is parallel dendritic. The slopes of the lateral moraines are well drained and apart from some gulley erosion there are no signs of accelerated erosion. In the valleys on stagnant water occurs.

The fluvial landscape

In most places the hardrock in this main landscape is of volcanic origin. The macro-topography characteristic for this area is caused by the action of fluvial processes most likely combined with tectonism (viz. uplifting). The result of these processes is a steeply incised mountainous to hilly area, with in general sharp V-shaped valleys sharp crest lines and in a few places small alluvial plains. In some places blocklava flows and moraine deposits, going down as far as 3500 m, can be found. Also this main landscape as the previous one is practically completely covered by a layer pyroclastic deposits except on very steep slopes. The drainage pattern in this area is parallel dendritic to sub dendritic. Gulley erosion is probably the most important process on the slopes and vertical river erosion in the valley bottoms.

4.3 Description of the land cover units

The superparamo (4300-4600 m.)
The zonal vegetation in this area consists of very open to almost closed vegetation of rosette forbs and tufted or matted grasses. Next to *Senecio canescens*, which is almost exclusive for this zone, it is also characterized by *Agrostis araucana, Agrostis foliata* and *Festuca breviaristata*. With increasing altitude a gradual decrease in total cover and number of species can be observed. In places covered by glacial scree instead of volcanic ashes, like the summit of the Santa Isabel, plant communities can be found which seem to be exclusive for these conditions. These plant communities are characterised by the presence of *Senecio cf latiflorus* and *Calamagrostis cf ligulata*. In places with stagnant water azonal swamp vegetation has developed. Two types of swamps are distinguished: moss bogs dominated by *Breutelia sp.* and *Bryum sp.* and cushion bogs dominated by *Distichia muscoides*. In the latter bog also cushions of *Plantago rigida* occur. In sheltered places near the lower limit of this zone shrublands characterised by *Pentacalia vernicosa* are found and locally (Nevado del Ruiz) on small rock outcrops shrub vegetation characterised by *Loricaria colombiana* is encountered.

Paramo (3800-4400 m.)
The zonal vegetation in this area is characterized by tussock grasses (*Calamagrostis recta, C. effusa* and *Festuca cf. dolychophylla*) and stemcomposites (*Espeletia hartwegiana ssp. centro-andina*). The tussock grasses in general dominate the vegetation.
The upper paramo or *Calamagrostis recta* belt (4150 - 4400 m) is dominated by tussocks of *Calamagrostis recta*. The two other tussock

grasses are absent.

The middle paramo or *Calamagrostis recta-C.effusa* belt (4000 - 43000 m) is dominated by *Calamagrostis recta* and *Calamagrostis effusa. Festuca cf. dolychophylla* is absent here.

The lower paramo or *Calamagrostis effusa* belt (3850 - 4150 m). In this belt the zonal plant communities are in general dominated by *Calamagrostis effusa.* It is regularly accompanied by the two other tussock grasses. In some places *Festuca cf. dolychophylla* is co-dominant or even dominant. The upper limit of the paramo zone is most likely climatically determined. The lower limit on the other hand is determined by a combination of land-use and terrain conditions. The boundary between the volcanic landscape and the lower footslope zone is indicated by a sharp change in relief and the actual forest line, indicating the boundary between the lower paramo and Andean dwarf forest coincides to a large extend with this break in relief. Within the paramo zone the altitudinal distribution of the vegetation belts shows discontinuities which are related to the substrate viz. the texture of the volcanic ashes (see section 4.4). On slopes which are covered by coarse grained volcanic ashes the upper limit of the lower and middle paramo lie approximately 100-150 m. higher compared to the upper limit of the same belts on slopes covered with fine grained ashes (see ecological diagram). The azonal swamp vegetation in this zone mainly consists of cushion bogs with *Plantago rigida* as characteristic species. In swamps in the upper paramo next to *Plantago rigida* also cushions of *Distichia muscoides* are found. With decreasing altitude the latter species gradually disappears. Shrub vegetation is found in drainage ways, on scree slopes underneath scarps and in the transition from swamp to tussock grassland.

Andean dwarf forest (3550-3900 m.)

The zonal vegetation in this area is medium closed to closed forest with low trees, up to 8 m. and high shrubs, floristically characterized by *Hesperomeles spp.* and *Gynoxys spp.* The swamps are characterised by *Calamagrostis effusa* and *Sphagnum spp.*, but also cushions of *Plantago rigida* are present.

Andean forest (below 3600 m.)

This zonal vegetation consists of medium closed to closed forest with high trees, floristically characterized by *Weinmannia spp.*

4.4 Ecological diagram

In this section the ecological diagram as presented on the vegetation map will be discussed (see appendix A and fig. 4.2). It shows the main landscape ecological relations between the legend units.

The vertical axis

Altitude

The vertical axis represents an altitudinal gradient, which is reflected in the distinction of seven altitudinal vegetation belts (nival belt, superparamo, upper, middle and lower paramo, andean dwarf forest and andean forest). The altitudinal range of the vegetation belts is mainly determined by the macro-climate. In some places however it is modified by the substrate. Therefore these belts can be considered bio-climatological zones. The influence of the substrate is quite evident when considering the altitudinal range of the paramo belts. In places which are covered by a layer of coarse grained volcanic ashes the upper limit of middle and lower paramo lies approximately 100 m higher than in places covered by fine grained ashes.

The horizontal axis

Substrate type

On the horizontal axis the most important factor determining the spatial pattern of the land units is substrate. In the study area four substrate types can be distinguished viz. fine grained volcanic ashes, coarse grained volcanic ashes, glacial scree and peat. Some land units are exclusive for a particular substrate type. This is particulary true for land units within the middle paramo or higher. Based on the results of this survey it can be concluded that, except for an effect on the altitudinal range, in the lower paramo belt the texture of the volcanic ashes is not a discriminating factor any more. Glacial scree is mainly confined to the summit of Nevado de Santa Isabel and below approximately 4400 m this type of substrate does not occur. Hence only the nival belt and superparamo are found here. The same goes for the absence of Andean dwarf forest and Andean forest on coarse grained ashes. Since coarse grained ashes are deposited more near to the point of emission than fine grained ashes, the former does not occur below a certain altitude (ie. distance from the point of emission).

Moisture condition

The second factor represented on the horizontal axis is the moisture condition related to changes in relief. Under this heading in fact two gradients are presented.

* Stagnation and or seepage
  This gradient is going from "relatively dry" conditions, in land units consisting mainly of sloping areas characterised by zonal plant communities, to "wet" conditions due to stagnant water in valley bottoms or depressions dominated by azonal swamp vegetation (see fig. 4.3). "Moist" areas are land units which contain sloping areas as well as depressions or large seepage zones. This first situation occurs for instance on the top area of lava flows (see fig. 4.3), the second situation can be found for round the summit of Nevado del Ruiz in the transition from the cone to the volcanic footslope (see fig. 4.4).

* Infiltration
  The second gradient is indicated by the term infiltration. The "moist" land units in this gradient are places underneath escarpments which receive additional water from higher lying areas (see fig. 4.5). They are characterised by the presence of extrazonal shrub vegetation.

5 Substrate

The analysis of the field data showed a clear relation between distribution of the plant communities and the substrate. It is defined as the kind of material in which the roots of the plants are found. The following substrates occur in the area:

Volcanic ashes

This is by far the most common substrate in the area and carries a variety of plant communities (see legend appendix A). It is subdivided into coarse and fine grained ashes. (see fig 5.1). The coarse grained ashes are characterized by an absolute dominance of particles falling in the coarse sand fraction, variable percentages within the gravel fraction (lapilli) and comparatively low amounts of all other fractions. The fine grained ashes do not have a gravel fraction of importance and display a peak in the medium sand fraction and coarse silt fraction. The possibility of a difference in texture of the ashes was in first instance observed during the photo-interpretation and in second instance confirmed by soil texture data of the volcanic ashes of Vis (1989). The importance of the grain size for the distribution of the plant communities in the paramo is described in section 4.4.

Glacial scree
Glacial scree only plays a role of importance on the cone of the Nevado de Santa Isabel. The distribution of the plant community of *Calamagrostis cf ligulata* and *Senecio cf latiflorus* (h3a) and the community of *Calamagrostis cf ligulata, Senecio cf latiflorus* and *Werneria humilis* (h3b) is restricted to this substrate.

Colluvial scree
This substrate type is consisting of rock debris mixed with volcanic ashes and is found underneath escarpments. In these places very often shrublands are encountered.

Outcrops of volcanic rock
Hardrock outcrops only play a role of importance on the cone of Nevado del Ruiz. The plant community of *Loricaria colombiana* (S1) seems to be restricted to these outcrops.

Peat
Peat is the characteristic substrate for areas with stagnant water. It is found underneath all swamp vegetations

The importance of the substrate as a landscape ecological factor is reflected in the ecological diagram (see fig. 4.3) showing the relations between the landscape ecological factors and the distribution of the plant communities (legend units).

6 References

Braun-Blanquet (1965)
Plant Sociology: The Study of Plant Communities
Hafner, London

Cleef, A.M. (1979)
The Phytogeographical Position of the Neotropical Vascular Paramo Flora with Special Reference to the Colombian Cordillera Oriental.
In: Tropical Botany (Larsen, K. and L.B. Holm -Nielsen, editors).
Academic Press, London

Cleef, A.M. (1981)
The Vegetation of the Paramos of the Colombian Cordillera Oriental.
Diss. Bot., 61
Cramer, Vaduz.

Cleef, A.M., O. Rangel and S. Salamanca (1983)
Reconocimiento de la Vegetación de la Parte Alta del Transecto Parque Los Nevados.
In: Hammen, T. van der, P. Pinto and A. Pérez (Editors)
Studies on Tropical Andean Ecosystems 1.
Cramer, Vaduz, p. 150 - 173.

Cleef (1991)

Cuatrecasas, J. (1934)
Observaciones Geobotanicas en Colombia.
Trab. Mus. Nac. Cienc. Nat.
Ser. Bot., 27: p. 1 - 144.

Cuatrecasas, J. (1958)
Aspectos de la Vegetación Natural
Rev. Ac. Col. Cienc. Ex Fis. Nat.,
10(40): p. 221 - 246.

Duivenvoorde & Sorgendrager (1983)

Etter, A. (1985)
A Landscape Ecological Approach for Grazing Development.
Thesis, ITC, Enschede

Gils, H.A.M. van, I.S. Zonneveld & W. van Wijngaarden (1985)
Vegetation and Rangeland Survey.
ITC, Enschede

Hammen, T. van der, P. Pinto and A. Pérez (Editors) (1983)
Studies on Tropical Andean Ecosystems vol. 1.
Cramer, Vaduz.

Hammen, T. van der, S. Diaz-Piedrahita, V.J. Alvarez (1989)
Studies on Tropical Andean Ecosystems vol. 3.
Cramer, Berlin - Stuttgart.

Hammen, T. van der, ??? (en prep.)
Studies on Tropical Andean Ecosystems vol.

Hashim M., and P. Hermelink (1981)
Landscape Ecological Survey of Kouf National Park in Libya.
ITC, Enschede

Kloosterman, E.H., P. Keyzer & G.J.M. Poot (1988).
Vegetation Map of the Salt Marshes of Texel, Balgzand, Den Oever and Dunes of De Cocksdorp. Explanation of the Vegetation Map. (In Dutch).
Survey Department, Delft

Loth, P.E. and H.Th. Prins (1986)
Spatial Patterns of the Landscape and Vegetation of Lake Manyara
ITC Journal 1986-2, p. 115 - 130
ITC, Enschede

Loth, P.E. (1988)
Vegetation and Landscape of Kora National Reserve, Kenya.
ITC Journal 1988-2, p. 133 - 148
ITC, Enschede

Mueller-Dombois, D. and H. Ellenberg (1974)
Aims and Methods of Vegetation Ecology.
Wiley and Sons, New York.

Schroevers, P.J. (1982)
Landscape Language. A System of Basic Concepts in Landscape Ecology. (In Dutch).
PUDOC, Wageningen

Salamanca Villegas, S.(1991)
The Vegetation of the paramo and its Dynamics in The Volcanic Massif Ruiz-Tolima (Cordillera Central, Colombia)
Thesis, University of Amsterdam.

Salamanca et al (1993)

Spiers (1978)
A Vegetation survey of semi-natural grazing lands (Dehesas) Near Merida, SW Spain. A Basis for land use planning.
ITC Journal, 1987-4, p. 649 - 679
ITC, Enschede, The Netherlands

Stokkom, H.T.C. van & E.H. Kloosterman (1988)
Operational Vegetation Mapping of Coastal Areas for Nature Management and Monitoring.
In: Proceedings of the EARSeL Workshop: Operational and Classification Problems in the Use of Remote Sensing for Monitoring and Inventory of Protected Landscapes.
Capri, Italy, p. 90-89.

U.S. Department of Agriculture, Soil Conservation Service (1975)
Soil Taxonomy, A Basic System of Soil Classification for Making and Interpreting Soil Surveys.
U.S. Government Printing Office, Washington

Verwey, P.A. and H. Beukema (1992)

Verwey, P.A. and P.E. Budde (1992)

Verwey, P.A. (1993)

Vis, M (1989)
Processes and Patterns of Erosion in Natural and Disturbed Andean Forest Ecosystems
Thesis, University of Amsterdam.

Walter (1964)
Die Vegetation der Erde in Oko-physiologischer Betrachtung. I. Die Tropischen und Subtropischen Zonen.
Jena

Walter (1979)
Vegetation und Klimazonen
Ulmer, Stuttgard

Zonneveld, I.S. (1979)
Land Evaluation and Land(scape) Science.
ITC Textbook of Photo Interpretation VII 4
ITC, Enschede

Zonneveld, I.S., H.A.M. van Gils & D.C.P Thalen (1979)
Aspects of the ITC Approach to Vegetation Survey.
Doc. Phytosoc. IV, Lille, France, p. 1029-1063.

Di: 8191 58 - 2

VEGETATION MAP OF THE PARQUE NACIONAL NATURAL LOS NEVADOS
Cordillera Central, Colombia

scale 1 : 50 000 (Approx.)

0 0.5 1 2 3 4 5 KM

Colofon

Map based on aerial photo-interpretation and fieldsurvey in 1980 and 1983

Photo-interpretation: E.H.Kloosterman (1,2)
Fieldsurvey: E.H.Kloosterman, S.Salamanca (3), C.J.M.Boonen, A.M.Cleef (4), ECOANDUS expedition
Map compilation: E.H.Kloosterman
Cartography: A.Wiskerke (1), G.J.M.Poot (1), E.H.Kloosterman
Digital map processing: J.W.Duinker (1), G.J.M.Poot, Reprocart, Rotterdam
Printing: Cartoprint, Den Haag
Supervision: A.M.Cleef, I.S.Zonneveld (2

1) Survey Dept., Rijkswaterstaat, Delft, The Netherlands
2) I.T.C., Enschede, The Netherlands
3) I.G.A.C., Colombia
4) University of Amsterdam, The Netherlands

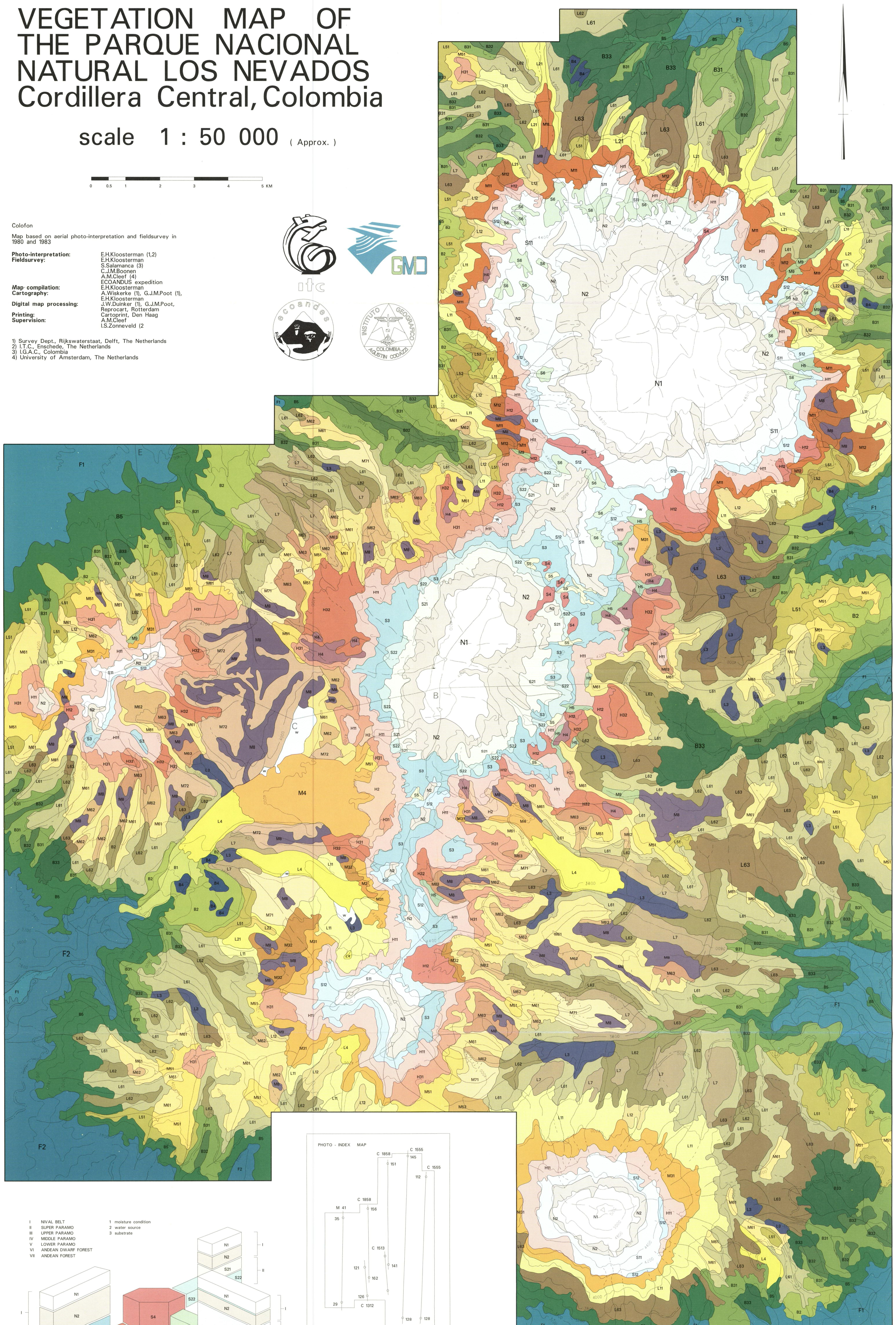


PHOTO - INDEX - MAP

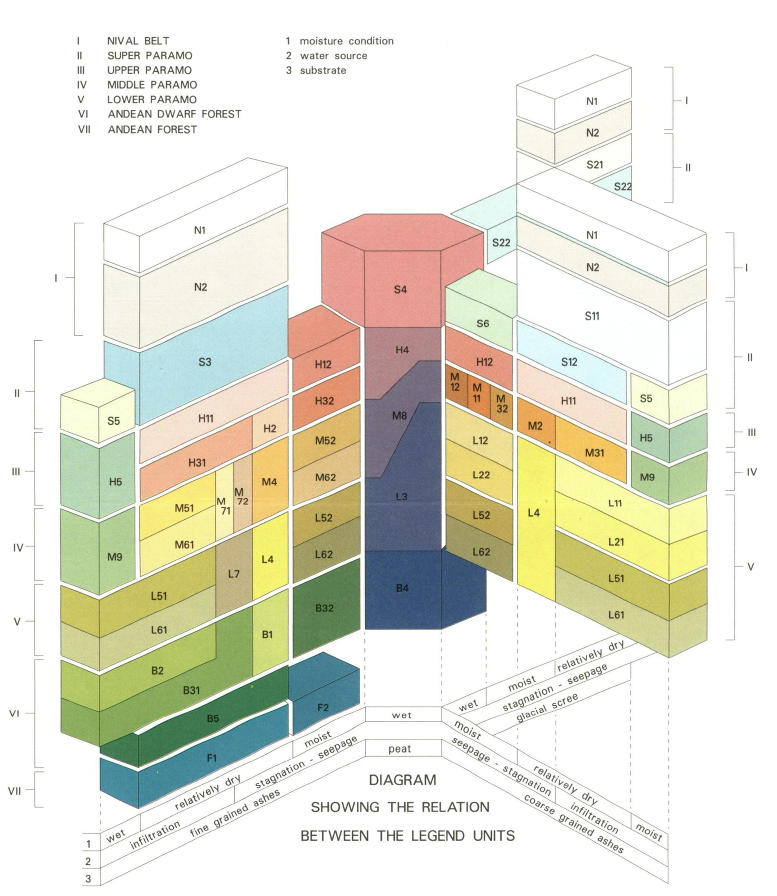
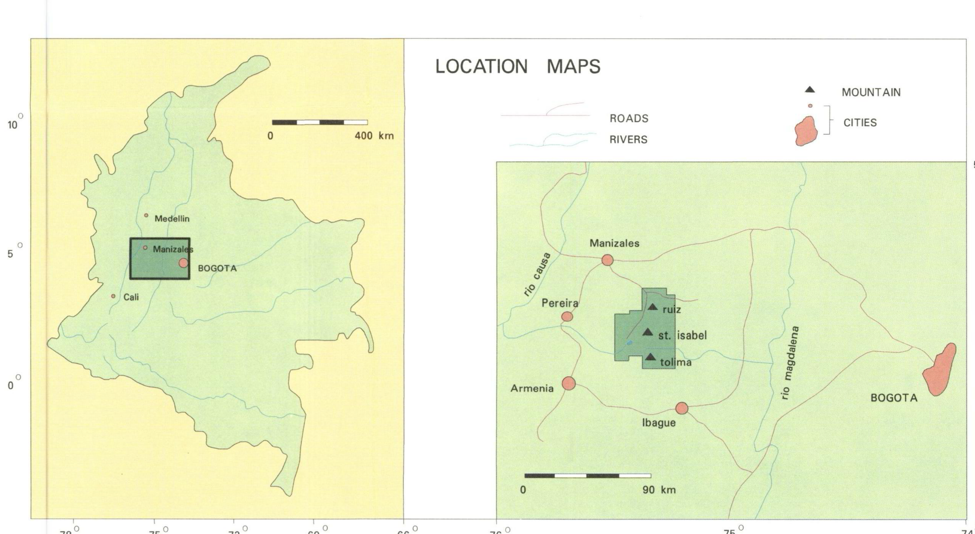
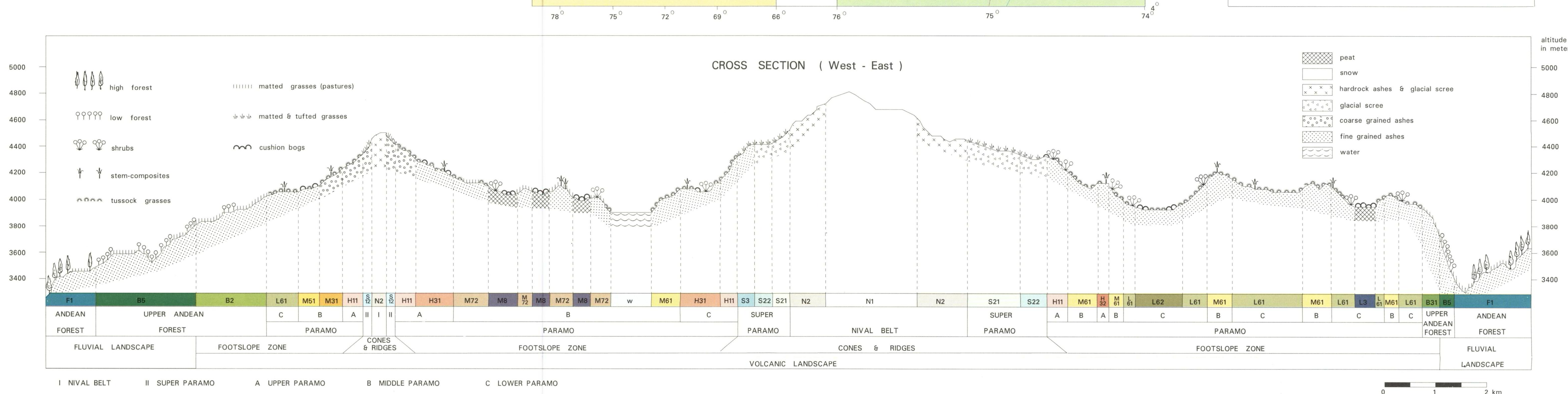


DIAGRAM SHOWING THE RELATION BETWEEN THE LEGEND UNITS



CONVENTIONS

- Water devide
- Crest line
- Drainage ways
- Contour lines
- Boundary of the National Park
- Cross section



LEGEND