Mapping and monitoring of woodlands and scrub vegetation in Qingua-dalen, South Greenland

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The vegetation in the S Greenland valley Qingua-dalen, containing the best developed, subarctic birch "forest" has been mapped by two different methods. The one combined the use of false infrared air photos with ground truthing, resulting in the map Fig. 5. Besides, a description of the woodland with analyses of the forest floor vegetation is given. The second method includes the use of data recorded by the Multi Spectral Scanner onboard the Landsat satellite. Finally advantages and disadvantages of the two methods are discussed.

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In 1984, the authors participated in the excursion to Qingua-dalen arranged by the Subarctic Birch Project. The area is poorly mapped, although being one of the best known woodland localities in the Julianehåb district, appearing as a subarctic oasis (Böcher 1979) – only slightly grazed by a few roaming sheeps and marked by visitors only to a very small degree.

The summer of 1984 was moreover used for field work as part of projects of the "Working party concerning environment and sheep-breeding in Greenland" (Arbejdsgruppen vedrørende Miljø og Fåreavl), Ministry of Greenland. One project concerned vegetational description (analyses of shoot density and degree of cover) and vegetation mapping (Feilberg 1985), the other concerned monitoring of potential pasture and its regional distribution (Folving 1984). The aims of the projects and their vegetation mapping were quite different, but as they both dealt with the nature of Qingua-dalen (vegetation types, landscape elements) there were obvious reasons for comparing the methods applied.

The area was revisited in 1985 in connection with a campaign to measure spectral reflection from various surface types in the Kugssuaq area and in 1986 in connection with the establishing of reference areas.

The investigation area

Qingua-dalen is situated in the southernmost part of Greenland (60°18'N, 44°30'W), 10 km east of Tasermiut (Fig. 1). It reaches from the east end of lake Tasersuaq (50 m a.s.l.) to a high mountain ridge about 12.5 km northeast. From the bottom of Qingua-dalen, a pass, 700 m a.s.l., leads southeast to the fiord Ilua. The valley is U-shaped with a bottom mainly consisting of glaciofluvial deposits. At several places rock outcrops are forming sort of thresholds, whereas moraines, consisting of concentrations of boulders, are rare, mostly to be found in the interior of the valley. Small crests of till may be found along the lower sides of the valley, and till may also be found in the screes, at most places covering part of the valley sides, especially the northwest-facing side. At several places there are landslides, and loose deposits are found as downwash from the rocks higher up. The luxuriance of the vegetation is decreasing towards the interior, and the area around the meltwater lake is dominated by fell-field. The surrounding high mountains, built up of gneiss and granite, are distinctly alpine, sheltering the valley. Wind-swept barrens are found only at the mouth of the valley, and small dunes can be seen along the shore of the lake. At several places levées are formed along the river which often becomes braided.

Climate

There are no weather records from the valley. The temperature is presumably the same as recorded at the stations in the inner fiords with mean temperature above 10°C during summer. The precipitation is probably influenced by the sheltering effect of the alpine

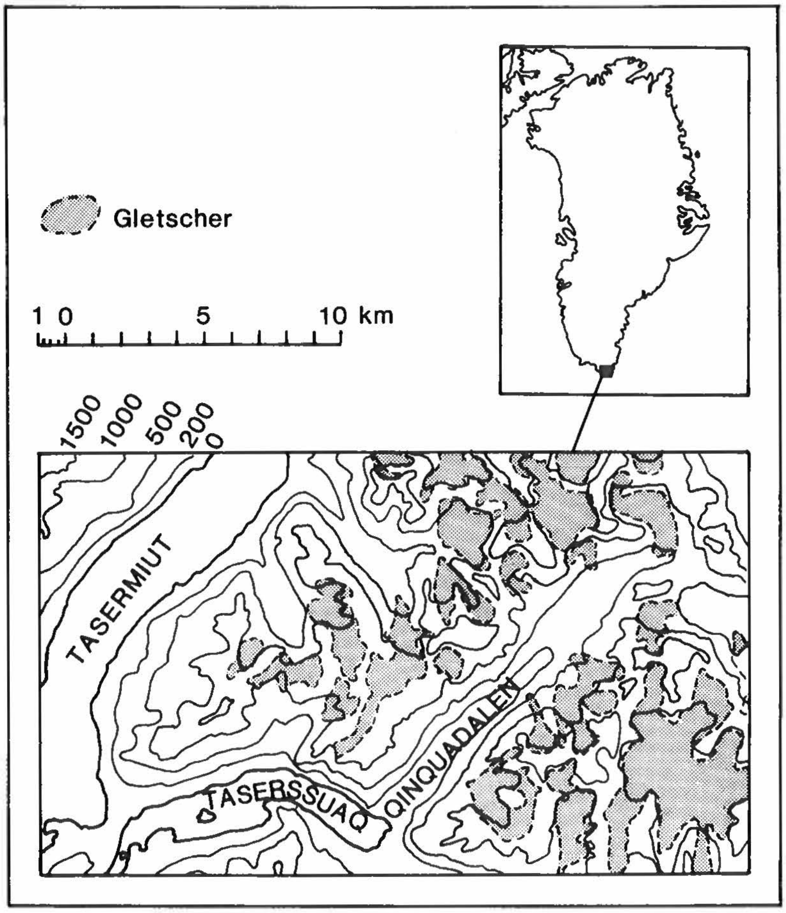


Fig. 1. Sketchmap of Qingua-dalen and the geographical location.

landscape and the specific location of the valley. However, judging from the vegetation, the total amount of precipitation may be greater than recorded at the inland stations farther to the north. The strongest wind is supposedly the foehn, probably never reaching extreme velocities due to the very well sheltered exposure of the valley. The fiord wind from the lake is the most frequent.

Fig. 2 shows hydroterm diagrams from four stations more to the north. The precipitation shelter in Qinguadalen is expected to be somewhat larger than in Narsaq and the continentality to be approximately the same as in Narssarssuaq (Folving 1984, Feilberg 1984).

Vegetation

The luxuriant woodland and scrub-vegetation in Qingua-dalen is unique for Greenland. Dwarf-shrub heaths are characterized by the frequent occurrence of *Ledum groenlandicum*. Common are also *Vaccinium uliginosum* ssp. *microphyllum, Betula glandulosa* and *Juniperus communis,* while *Empetrum nigrum* ssp. *hermaphroditum* and *Phyllodoce coerulea* are less frequent. Lichen heaths cover the well-drained plateaus, often rich in *Betula glandulosa* and *Nardus stricta.* Grassland slopes, here exclusively dominated by *Nardus stricta,* have a remarkably limited distribution compared to other parts of S Greenland. The otherwise typical grassland dominated by *Deschampsia flexuosa* or *Agrostis hyperborea* is not found. Only where snow persists for long periods there are grassland slopes. Fens are dominated by *Carex rostrata, Carex rariflora* and by luxuriant moss communities.

In the transition zone between the birch forest and the rocky sides there are small stripes with herb-slopes, rich in species and being especially remarkable for the luxuriant occurrence of *Streptopus amplexifolius.*

The riverbed is often densely covered with *Chamaenerion latifolium.*

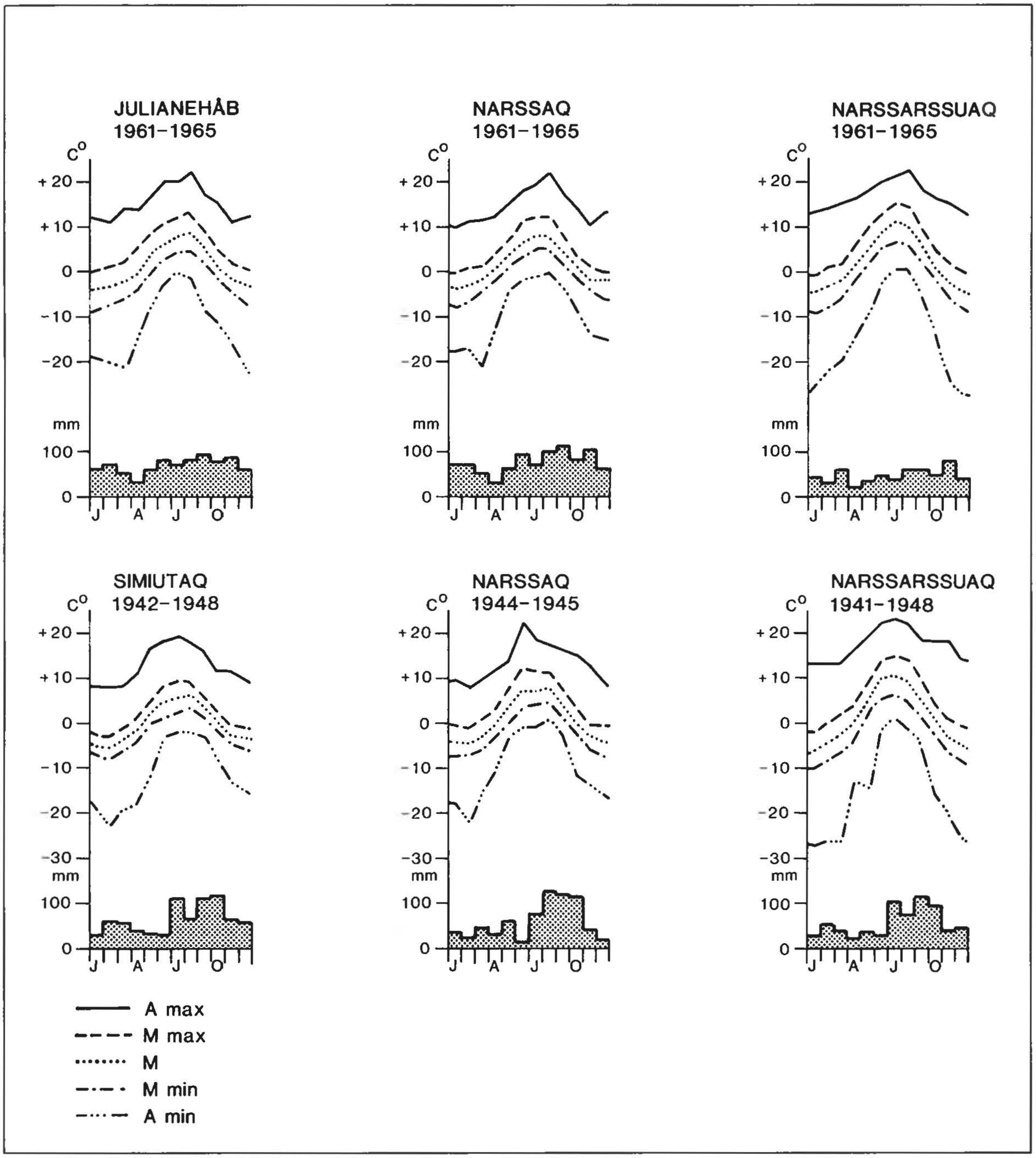


Fig. 2. Hydroterms from two periods from stations representing maritime (Julianehåb and Simiutaq), intermediate (Narssaq) and continental climates (Narssarssuaq).

History

The ruins from the Norse settlers (app. 1000–1400, Krogh 1982) indicate a rather effective exploitation of the woodlands in this period. After the disappearance of the settlers the whole area was left undisturbed for more than three centuries. With the new colonization there was a large need for fuel both for housekeeping and for production of whale oil. So all the accessible, forested areas in the fiords were felled – and to such a degree that in the 1930'es plans were made for replanting the area (Oldendow 1935). Draining was also started in order to further the tree growth, obviously without any effect. Today, the remaining forested area in Qingua-dalen is protected, and after all there is a reasonable hope for the survival of this unique scenery.

Methods

Analyses were made along lines of 20 m. Shoot density was measured for every metre, degree of cover for every fifth metre. For recording the shoot density a modified Raunkjær "circle stick" was used (Böcher 1975). However, instead of Böcher's values 1, 2 and 3, we prefer the values 10, 100 and 1000. The shoot density indexes of each species is the average of all 20 records. In most cases the index is giving an indication of the number of shoots per m^2.

For the determination of degree of cover we used a 0.9×0.9 m frame, divided in dm^2 by means of nylon thread. The measuring was made as follows: When placed on the vegetation, the plant species under each of the 100 points of intersection formed by wire and frame were registered by a thin, vertical steel stick. The degree of cover is the average of four recordings. Degree of cover of vegetations more than knee-high was not dealt with. All results are shown with one significant figure.

Description

The woodland is developed within the lower 7 km of the valley up to an altitude of app. 200 m (Fig. 3). The dominating tree is *Betula pubescens* ssp. *tortuosa* which is also forming the timber line in Scandinavia. It is polycormic and gnarled. The highest tree recorded was 10.25 m (Bjerge, pers. comm.), but there were many trees app. 9 m high. One tree had a trunk that was 14 m long, however, partly lying down. The average height is estimated to be approx. 6 m. The thickest trunk found was approx 40 cm in diameter at a height of one metre.

Sorbus groenlandica, the other tree-species of the valley, was frequently found on the northwest-facing slope but only in small stands. This tree is also polycormic, the trunks are, however, usually erect. The highest tree was approx. 5 m, the diameter of the trunk being 10 cm.

Salix glauca, elsewhere being distinctly shrub-like, sometimes attained dimensions similar to those of *Sorbus.* Due to the polycormic, gnarled *Betula* and the *Salix glauca* copse the woodland is almost impenetrable, and only in well-drained places open woodland-types with sedge-rich vegetation are found.

Four analyses were made on the woodland floor, three in 1984 an one in 1986. Only one vegetation-type was not dealt with: the moss-rich birch woodland which covers parts of the northwest-facing sites in the lower part of the valley.

Fig. 3. Dense, mixed birch forest in Qingua-dalen. (J. Feilberg phot.).

Results (Table 1)

The open birch woodland on drained soil (analysis 82) is rich in species although *Deschampsia flexuosa* is covering the greater part of the area.

The open birch woodland on semi-moist soil (analysis 84, Fig. 4) is rich in species as well, also with a great deal of dwarf-shrubs.

The last two types analysed (nos 209 and 83), are very dense birch woodland, consequently poorer in species, but they are much alike in composition of species.

Fig. 4. Open birch forest in Qingua-dalen, on SW facing slope. Max Hagman as scale (S. Ødum phot.).

Mapping

IR-airphotos

The airhotos used in this study were taken by the Geodetical Institute for "The Commission for Scientific Research in Greenland" at the request of mag. Ingvi Thorsteinsson. The photos were used without geometric rectification.

Method

Mapping was made by a combination of delineating the vegetation types on the airphotos and stereoscopic evaluation. The fairly small scale, app. 1:3.000, and the fact that the photos were taken in false colour, faciliated the interpretation very much. In fact it was in some places possible to identify single trees.

Field observations and photos, especially panoramic photos, taken from the valley sides, in many cases helped the interpretation.

Results

The map (Fig. 5) shows the distribution of plant communities. In some places the vegetation was so patchy, e.g. lichen heaths or willow copses mixed with birch woodland, that a combination of signatures was used.

The largest woodlands cover the south-east side of the river. Here the woodland is only interrupted by ravines or well-drained, wind-swept hills. Willow scrub and dwarf-shrub heath cover the remaining area of the valley side. Fens are mostly developed on the river plain.

The satellite image

The scene used was recorded on August 30, 1979. The data therefore represent the situation during the last part of the period of growth in a year with normal temperature variations, but with only half the normal precipitation (Folving 1984).

The data has been recorded by the Multispectral Scanner (MSS) onboard Landsat – from a height of appr. 900 km. The single picture elements, pixels, represents the average reflection from the ground within four spectral bands: 500–600, 600–700, 700–800 and 800–1100 nm- corresponding to green-, red- and nearinfrared light.

Method

The first step consists of a geometrical rectification of the data. The satellite image has been fitted to a standard 1:250.000 topographical map.

The original data from the multispectral scanner has

Table 1. Analyses of degree of cover (D) and shoot density index (S) in four Mountain birch woodlands in Qingua-dalen.

Analysis no: Drainage condition:	*82* Good	*209* Medium	*84* Medium	*83* Poor
D = Degree of cover % (S) = Shoot density index (1–1000)	D(S)	D(S)	D(S)	D(S)
Shrubs				
Betula pubescens ssp. tortuosa	9(1)	6(50)	8(1)	2(1)
Sorbus groenlandica				+
Dwarfshrubs				
Empetrum nigrum ssp. hermaphroditum			2(50)	
Juniperus communis ssp. nana	5(9)		4(3)	
Ledum groenlandicum	+(1)	1(6)	20(20)	10(70)
Rubus saxatilis	5(20)			
Salix glauca	2(1)	9(3)	2(6)	5(3)
Vaccinium uliginosum ssp. microphyllum			2(1)	
Monocotyledones				
Agrostis hyperborea	1(1)	3(30)	5(100)	1(6)
Calamagrostis hyperborea			5(50)	
Calamagrostis langsdorfii		5(6)		6(6)
Carex atrata	+			
Carex bigelowii	5(60)	10(60)	+	20(30)
Carex macloviana	+			
Deschampsia flexuosa	40(600)	40(500)	20(300)	10(300)
Festuca rubra	3(50)		1(6)	
Listera cordata	+(5)		1(10)	1(50)
Luzula multiflora			+(2)	
Nardus stricta			+(1)	
Platanthera hyperborea			+	
Poa glauca/nemoralis	3(20)		+(2)	
Poa pratensis	3(70)	3(3)	2(10)	3(50)
Roegneria virescens	+(1)			
Streptopus amplexifolius				+
Dicotyledones & Pteridophyta				
Alchemilla filicaulis			+	
Angelica archangelica ssp. norvegica	1(70)	4(2)	7(3)	2(70)
Bartsia alpina			+	
Campanula gieseckiana	9(200)	1(50)	2(200)	
Cerastium alpinum	2(10)			
Cerastium fontanum ssp. scandicum	2(30)			
Chamaenerion angustifolium	1(5)		3(2)	
Coptis trifolia	+(50)		2(100)	+(1)
Equisetum arvense	1(70)	2(50)	1(1)	2(2)
Equisetum silvaticum		5(1)	7(5)	10(20)
Gymnocarpium dryopteris	10(60)		1(6)	
Hieracium lividorubens	1(1)		3(3)	
Lycopodium annotinum	+(3)		1(60)	2(20)
Polygonum viviparum			+	
Potentilla tridentata			1(1)	
Rhinanthus minor	+(6)	+(1)	+(1)	
Stellaria calycantha	+(1)	2(60)		7(100)
Taraxacum croceum			2(2)	
Thalictrum alpinum	5(80)	+(1)	2(30)	
Veronica fruticans	+(1)			
Mosses and lichens	2	7	2	13

been transformed into a vegetation index (Folving 1986) and has been transformed by a Principal Component Analysis (Davis 1973).

A. Vegetation index

The Normalized Vegetation Index (NDVI) is proportional to the amount of biomass and therefore expresses

Fig. 5. Vegetation map of the outher part of the Qingua-dalen, based on field work and interpretation of airphotos.

something about the luxuriance of the vegetation in the area. The index is calculated by dividing the difference between nearinfrared light and red light with their sum. The value of NDVI varies between 1 and −1. Normal healthy vegetation will absorb the red light and reflect most of the infrared light thus giving rize to positive NDVI values; the higher the value the higher the density or vigorousity of the vegetation. Non vegetated areas will normally have negative values. The division removes topographically induced variations in the reflection pattern because the irradiance variation caused by topographical variation is equal for the bands used in the calculation of NDVI. Figure 6 (below, curve A) shows the variation of the index along the profile 2 across the valley.

B. Principal component analysis

The single channels correlates two and two which means that they contain redundant information (Fig. 6). A principal component analysis will, among other things, compress the data: the first principal component carries 95% of the total variation, the second principal component carries a little more than 4% of the variation. It is easily seen that only the two first principal components are needed to express the variation of the original four datasets. At the same time the information are arranged in a very convenient way.

According to the principal component transformation used here the first principal component (Fig. 6, curve B) gives information on both the luxuriance of the vegetation and the topographical variation. The second principal component (Fig. 6, curve C) has been used because it is negatively correlated with the density of the vegetation, and especially because it can be used to eliminate dubious, partly snow covered areas.

C. Classifications

The first principal component, the vegetation index, and the second principal component has been rescaled and used to form a new data set.

The classification has been performed as an autoclassification, which means that the criteria has been purely statistical – i.e. not controlled by ground truth data.

In the first classification the whole data set was used including all areas without vegetation. The second classification, which has a better resolution (see below), has excluded all areas without vegetation, for instance snow and bare rock. The number of classes used is also different – in the first example 20 classes, in the second 25 classes have been used.

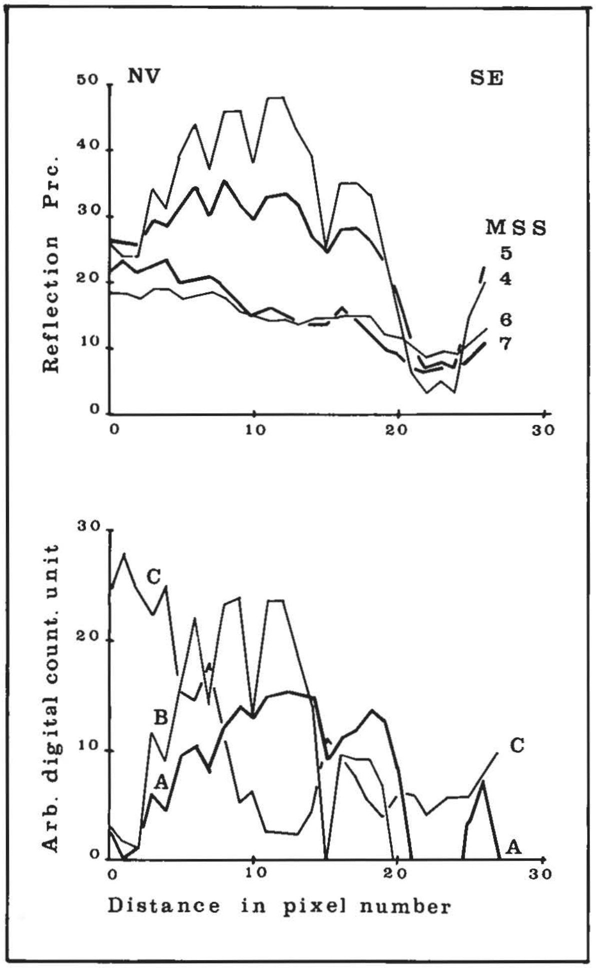


Fig. 6. The variation of the data along profile 2. Above the original data showing the strong, coupled correlation between the visible and the infrared bands.
Below: A = the vegetation index. B = the 1. principal component and C = the 2. principal component.

Results

The contents of the classes according to the first classification is given below – the color refers to the map (Fig. 7). Surface types without color indicated are not included in the map:

1 – rocks (with very little vegetation)	black
2 – mostly heath on level land	light green
3 – snow	
4 – rock	
5 – luxurious scrub etc. S-exposed	dark green
6 – rock	
7 – snow	
8 – S-exposed well vegetated slopes	green
9 – N-exposed very poorly vegetated slopes	red
10 – snow	
11 – water or deep shadow	
12 – luxuriant vegetation on N-facing slopes	yellow
13 – rock in shadow	
14 – snow	
15 – snow	
16 – fairly luxuriant vegetation on N-slope	pink
17 – snow	
18 – rock	
19 – fairly luxuriant vegetation on S-slope	dark greenish
20 – rocks	

The vegetation can be grouped in main types (Fig. 8). Class 5, 8 and 19 (open stars) represent the more luxurious types on the south exposed slopes. Class 9 and 16 (open triangles) represent the less luxuriant scrubs, heaths and grassy areas on north- and northwest facing slopes. The classes 2 and 12 (closed circles) are representative for the luxuriant north- and northwest facing vegetation types. Class number 1 (circle with closed star) is a characteristic transitional type almost without vegetation on south facing slopes.

Fig. 9 (right) shows the centroids of the classes relative to NDVI (x-axis) and first principal component (y-axis).

This preliminary classification gives a rather good impression of the general tendency of the variation in the vegetation of the area but does not allow documentation of a close connection to more well defined plant communities.

The second classification has been carried out in order to achieve a better resolution and a better connection to the dominant plant communities. Since the biomass production in comparative plant communities is directly connected with the solar irradiation, the separation of different exposures is most important.

Fig. 9 (left) shows the centroids of the classes corresponding to this classification in the same way as mentioned above.

The spatial variation of the classes can be seen on the map (Fig. 10). P. 1 show the area in "normal" false color presentation and gives the reason for the use of the rather large number of rock and snow classes which has to be used in order to separate unwanted areas from the vegetation covered land, which is shown as black on this map. P. 2 show the groups which are indicated by roman numerals on Fig. 9. Group I is red, II yellow, III dark green, and IV orange. These "colored areas" corresponds to the total vegetation covered area. All other surface types (incl. water) are shown in grey on this map.

Fig. 10, P. 3 show groups I and II in full resolution: 1 – red, 16 – dark green, 9 – olive, 20 – green, 5 – yellow, 13 – orange and 22 – brown. The other vegetation classes belong to the south- and southeast exposed slopes. All classes in group I belong to scrub-types and in rare cases to the luxurant grass/herbslopes. Group II show heath-types and more steppe-like types and transitional types between scrub and rock surfaces.

The area belonging to group I and II has been shown in black on Fig. 10, P. 4, where the rest of the vegetationclasses is colorcoded as follows: 23 – red, 3 – dark

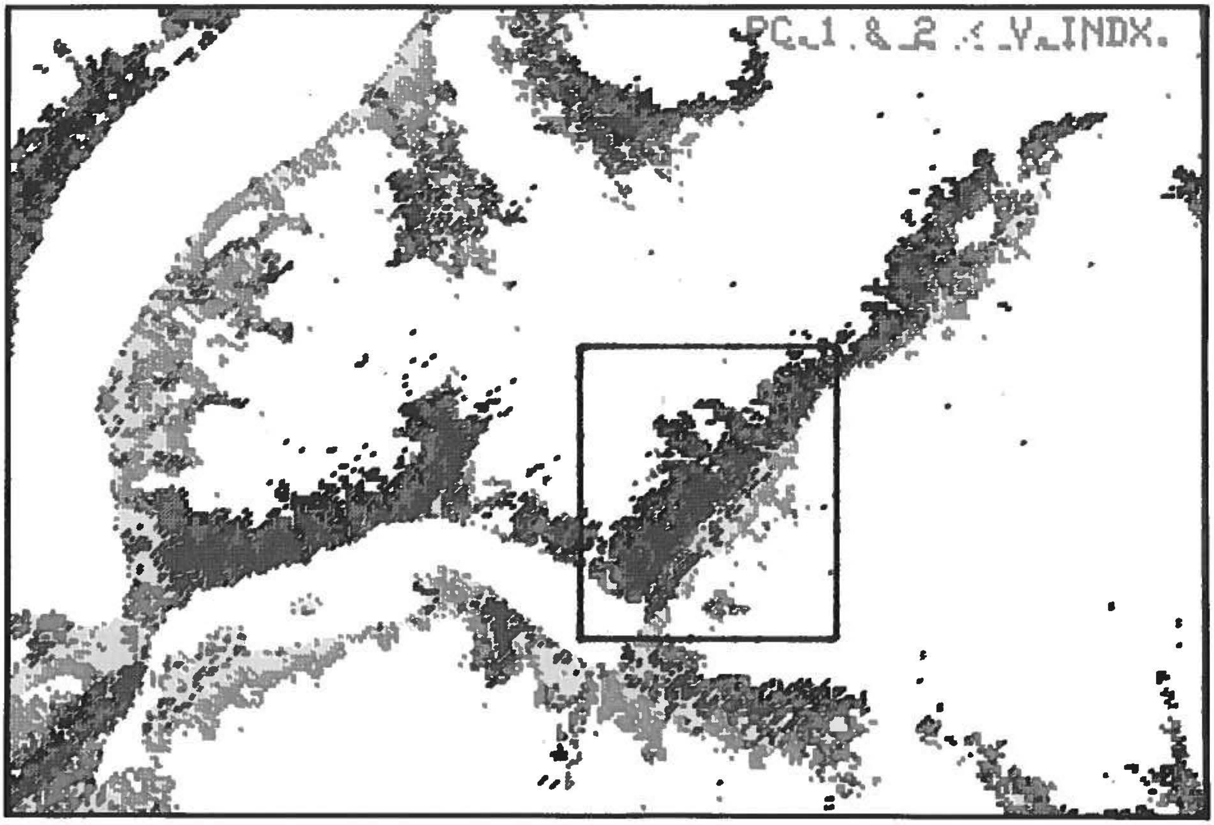
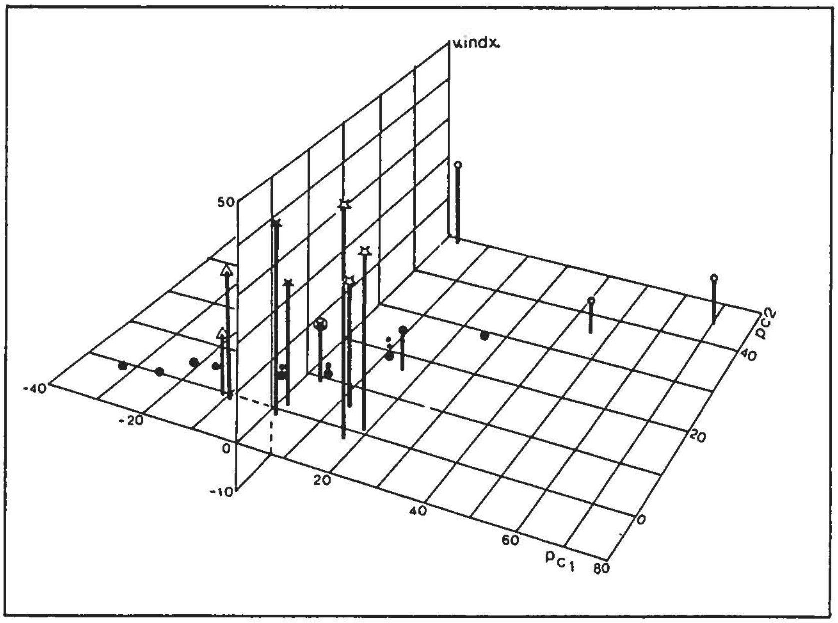


Fig. 7. The vegetated part of Qingua-dalen and its surroundings classified according to the main grouping of the vegetation covered area. Colours: see text p. 16.

Fig. 8. The relation between the centroids of the classes and the transformed data.



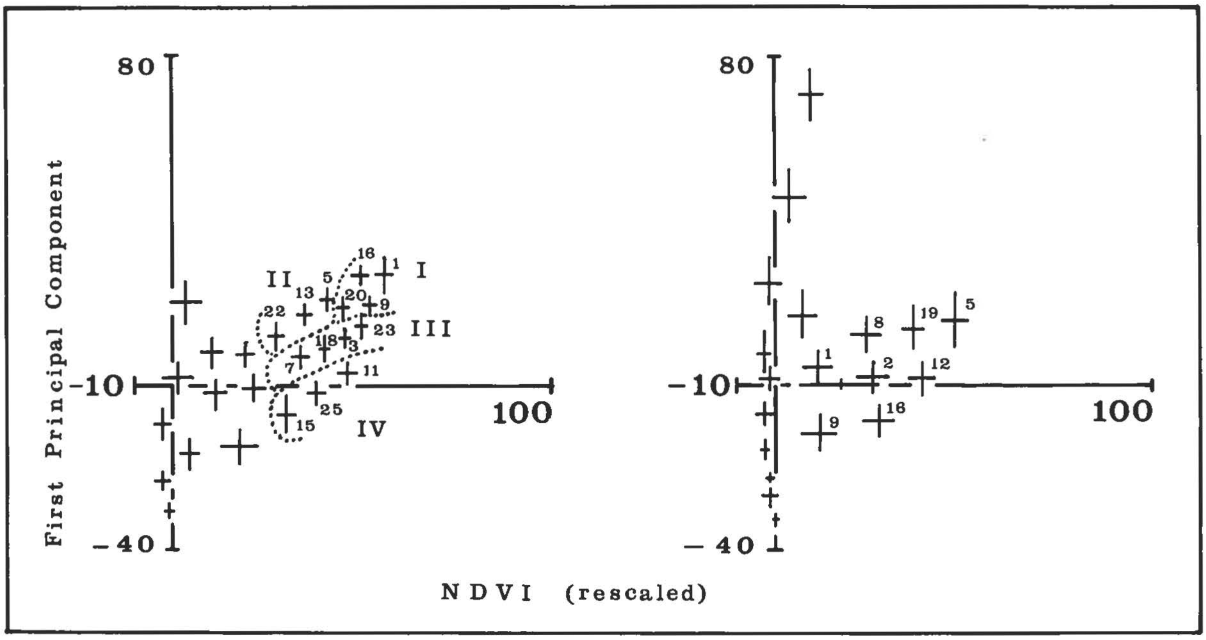


Fig. 9. Comparison of the two classifications. To the left the classification used to distinguish between the topografical location of the plant cover types, to the right the classification used to present the general distribution.

gren, 18 – olive, 7 – green, 11 – yellow, 25 – orange, and 15 – brown. The classes within group IV very clearly show the vegetation on north- and northwest facing slopes: 11 is luxurious scrub, 25 and 15 represents decreasing vigorousity, 15 contains grass, herbs and mosses on the rocky surface.

In group III the luxuriance decreases, from class 23 to class 7, and all types are found on level land or on very gently south sloping ground.

For practical reasons, the numbering of the two classifications are different, however, the position of the centroids (Fig. 9, left and right) are comparable.

Of course the results of the two classifications are very much alike. The first one was more directed toward a representation of the general luxuriance as expressed by the vegetation index, whereas the second divided the types along the first principal component (and to a lesser degree along the second principal component), thereby allowing a much better differentiation of the vegetation types because the exposure is considered.

Discussion

Of course, it cannot be expected that the very different methods presented here should give the same results, nor can it be expected that the cartographic results would show the surface types in identical ways. However, a comparison between Fig. 5 and Fig. 10, P. 3 clearly reveals the common features. On the other hand it is more difficult to compare the maps directly when the satellite data is split up in (too) many classes.

Our results should be seen as a result of two conditions: one is connected with the traditional mapping based on field reconnaissance and photo interpretation by which plant communities can be classified regardless of the degree of cover. The second condition is connected with the fact that the multispectral satellite borne scanner records a mean response from the surface, response i.a. the degree of cover of the vegetation, a factor which is very hard to decode by means of classifications and interpretations. The variation in height of the plants is also a crucial factor, since there is a direct connection between roughness and shadow of the surface.

By means of the traditional method the delineation can be carried out with great spatial accuracy, whereas the use of satellite images forces one to carry out the delineation solely on the raster based spectral reflectance, which very often means that the boundary between plant communities will appear as a group of more or less homogeneous pixels. This will often result in a failing possibility to compare the results visually as the boundaries will be represented as types build by the actual distribution of the plant communities within the pixels from the boundary. On the other hand when compiling from large scale to small scale in the traditional way one very often leave out the smaller areas of the specific plant community – the satellite data will give a better opportunity to take these smaller areas into consideration via the mechanism described above.

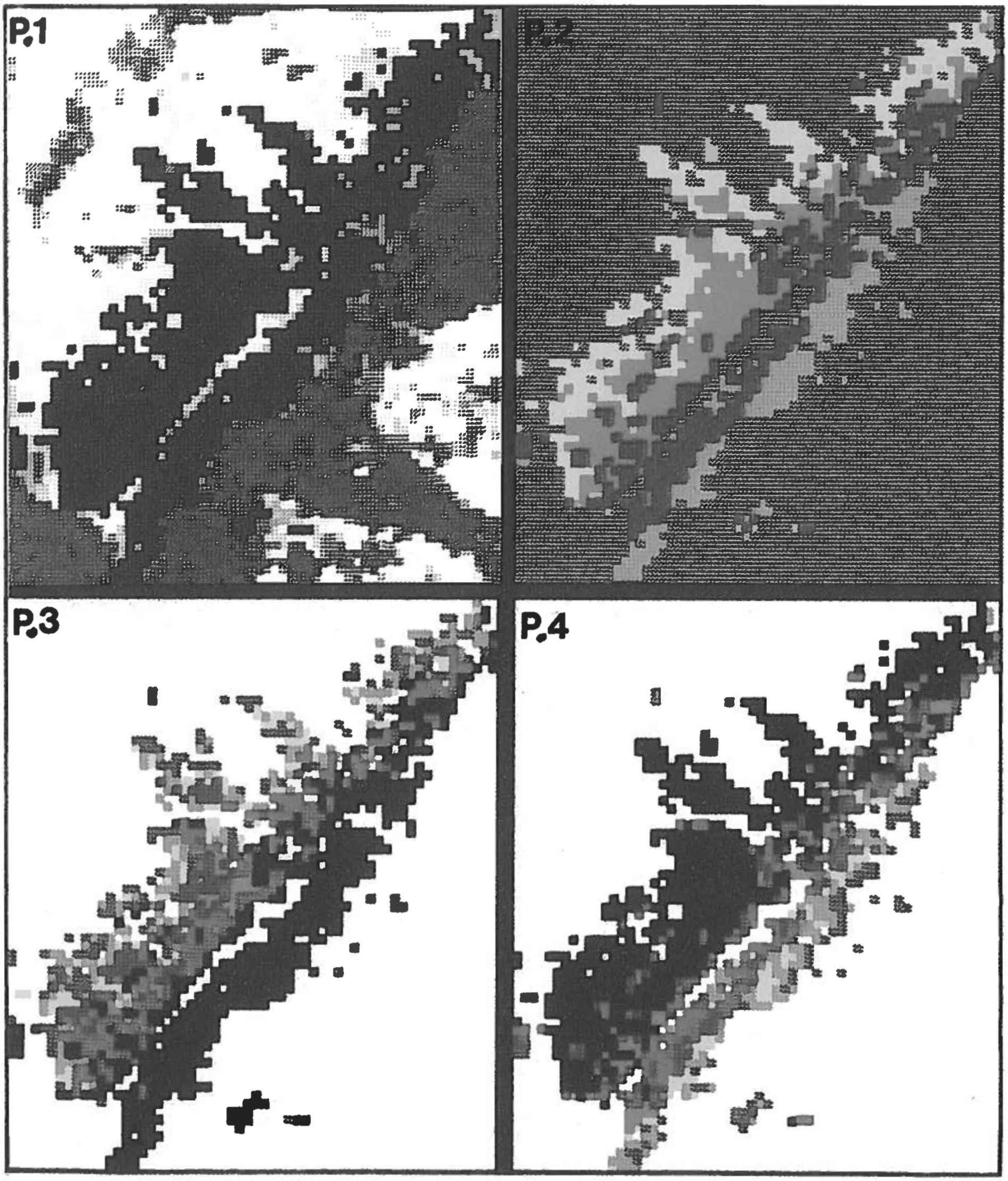


Fig. 10. The result of the classification when the topography is taken into consideration.

Thus, it can be concluded that in small scale mapping there will be very severe problems if one tries to replace traditional vegetation mapping by use of Landsat MSS-data. However, if a reasonably large scale mapping is wanted, classifications of various transformations of satellite data can be used – if the traditional map-appearance can be done without. This means that in the future more investigtions have to be carried out concerning the spectral reflection patterns from patchy surfaces in order to find a reasonable method (algorithm) with which to map the single plant cover types in a rational and fast way.

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