Botanica Orientalis – Journal of Plant Science (2020) **14**: 1–13 ISSN 1726-6858

Research article

Creating a historical baseline: economically important alpine plant communities in central Himalaya, Nepal

Carsten Smith-Hall*

Department of Food and Resource Economics, Faculty of Science, University of Copenhagen, Rolighedsvej 25, 1958 Frederiksberg C, Copenhagen, Denmark

Abstract

There is a lack of historical data on the composition of alpine plant communities in the Himalayas. Such baseline data is essential to understand community dynamics and changes over time. Here, for the first time, we present data and findings on the composition of economically important alpine communities in central Nepal using data from 1994. Lower alpine vegetation on the south-eastern side of Himal Chuli in Gorkha District in central Nepal was phytosociologically examined with particular reference to the occurrence of commercial medicinal and aromatic plants. Eight new plant communities were recognized, comprising five meadow communities and three shrub communities. They were classified into two new groups (higher-ranked syntaxa): lower alpine *Rhododendron anthopogon-Bergenia purpurascens* shrub found on north-facing slopes and lower alpine *Cremanthodium* meadows on south-facing slopes. Twelve commercial medicinal and aromatic plant species were found; of main economic importance were *Nardostachys jatamansi, Dactylorhiza hatagirea, Aconitum orochryseum, Picrorhiza scrophulariiflora*, and *Rheum australe*. Both north and south-facing communities were important with regard to the collection of plants and income for the local farmers. Harvester risks, e.g. arising from price fluctuations, were reduced with access to many plant communities. Of particular economic importance were the vegetation types *Kobresia* meadows for the harvest of *Nardostachys jatamansi* and *Cyananthus* meadows for the harvest of *Dactylorhiza hatagirea*.

Key-words: Alpine vegetation, Environmental income, Medicinal and aromatic plants, Phytosociology, Rural development.

Introduction

The extensive areas of vegetation in the alpine regions of the Himalaya constitute a vital resource to the local communities controlling access and usage (e.g., Pyakurel *et al*. 2018). Major functions and uses of the alpine vegetation types include grazing for livestock; cash income through collection of commercial medicinal and aromatic plants (MAPs); improvement of health conditions by supplying raw materials to traditional medical systems; and supplementing diets by providing wild food (e.g., Bauer 2004, Rayamajhi *et al*. 2012).

In Nepal, there were and are large areas of high altitude grazing lands. In the early 1990s, some 12% of the country's land area was classified as grazing land, with 79% of total grazing area occurring above 2,500 m and 49% above 4,000 m (Rai and Thapa 1993). In most locations, the vegetation has been modified by disturbances, especially fire and grazing. The occurrence of alpine plant communities was determined mainly by altitude, rainfall, and aspect; edaphic factors are generally not important though the water holding capacity

*Corresponding email address: cso@ifro.ku.dk
Tel. +4521308683

during the dry season does occasionally determine the vegetation type (Dobremez 1976; Polunin and Stainton 1984).

The first phytosociological investigation of alpine plant communities in the Himalayas was by Kaul and Sarin (1971) in Jammu and Kashmir State in India; since then a limited number of studies in India and China have been published. In Nepal, phytosociological analyses of plant communities above the timberline are rare (Bürzle *et al*. 2017; Kikuchi 1991; Kikuchi and Ohba 1988; Miehe 1982, 1990) and the alpine resource base, i.e. the extent, composition and dynamics of the plant communities, remains mostly unknown.

Commercial MAPs were and are essential to rural household incomes in high altitude communities (e.g., Olsen 2005, Olsen and Helles 2009, Olsen and Larsen 2003, Pyakurel *et al*. 2018), yet information on the resource base is scant. This paper provides detailed baseline information on the characteristics of economically important alpine plant communities in central Nepal in the mid-1990s.

Materials and Methods

STUDY AREA

Gorkha District (27°45'-28°45' N latitude and 84°27'-85°12' E longitude) in central Nepal has an area of 3,642 sq. km; it is bounded by the Tibetan Autonomous Region of China in the north, in the east by Dhading, in the west by Lamjung, and in the south by Tanahun and Chitwan districts. Across Gorkha District, the 80 km from Beni Ghat in the south to the peak of Manaslu in the north, there is an elevation gradient of almost 8,000 meters. Precipitation is in the form of summer monsoon rain lasting from mid of June to mid of September. The northern part of the district, the inner valley area, is relatively dry as it lies in the partial rain shadow of the Manaslu, Himal Chuli, and Ganesh Himal mountain ranges; while the Himals' south-facing slopes are relatively wet. Annual rainfall in the district varies from 500 to 2,500 mm. The large variations in climate and habitat are reflected in the district's botanical richness, e.g. a species such as *Prunus himalaica* is endemic to the district.

The district population is predominantly rural; the composition varies from Bahuns and Chhetris in the south to communities of Tibetan origin in the north. All elevation type villages are found in the district: from low elevation type villages in the south depending on rice cultivation to inner valley village types in the north traditionally dependent on trade and cultivation of barley and buckwheat.

The area studied, an alpine valley covering approximately 15 sq. km around 28°18' N latitude and 84°49' E longitude in Gorkha District, is part of the upland area of an upper elevation production type village located at 1,850 m to the east of Himal Chuli above the Budi Gandaki river. As other upper elevation villages in the district, it is characterized by lack of irrigated fields; predominance of three crops per two years on large areas of rainfed fields; and cultivation of the main crops maize, millet, barley, and wheat. Furthermore, the village has access to large areas of alpine plant communities of which the inhabitants have *de facto* control. These areas are used for grazing livestock (mainly goats and sheep) in the summer and collect commercial medicinal plants. Local medicinal plant harvesters were followed to a high altitude valley on the south-eastern side of Himal Chuli, where they stayed in rock caves for up to two weeks. The valley is east-west located, i.e. with north and south-facing slopes only. The valley floor is at 3,500 m.a.s.l., the highest south-facing slopes reach 4,400 m and the north-facing slopes 4,000 m.

Local villagers have collected MAPs in this area for generations. The valley is intensively utilized for grazing, and the south-facing slopes are purposely burned every year. The north-facing slopes are too humid to burn. Perhaps due to human activity, there is no forest in the valley; in the surrounding area in general, the forest, dominated by *Abies spectabilis*, *Betula utilis* and *Rhododendron campanulatum*, does not reach 3,600 m. Compared to the altitudinal range of alpine areas in Nepal in general (Hara *et al*. 1978; Polunin and Stainton

1984), the alpine vegetation in the valley is found at a comparatively low altitude. Ohba (1988) notes that it is difficult to delimit the alpine zone by altitude since alpine flora variations also depend on local environments. The valley belongs to the alpine/humid agro-climatic zone; the area of this zone in the district is estimated from 193 to 340 sq. km (Trapp 1995). It constitutes an estimated 27–35% of the total alpine area.

None of the famous early botanists, who participated in the exploration of Nepal, e.g. N. Wallich and J.D. Hooker, visited Gorkha District. The first to collect plants in the district was Sasuke Nakao who participated in the two Japanese expeditions in 1952 and 1953 (Kawakita 1956; Kitamura 1955; Nakao 1955). J.D.A. Stainton visited upper Gorkha District in 1962 and the middle part of the district in 1967 (Stainton 1972); J.F. Dobremez collected in the upper and middle parts of the district in 1970 (Dobremez and Jest 1976); and the Department of Plant Resources have made extensive collections in the Ganesh Himal area. A few early sources based on fieldwork in various parts of the district have been published (Fort 1979; Gardner 1954; Manandhar 1990; McEachern *et al*. 1995; Olsen 1995; Schilling 1985; Trapp 1995; Warth 1993), mainly focused on forests but also containing short lists of plants and brief observations on the plant communities above the tree line.

Of the three major botanical regions of the Himalaya (Singh and Singh 1987; Subedi 1992), Gorkha District lies in the border area between the central and eastern regions. Using the more detailed climatic and vegetational division of Nepal proposed by Stainton (1972), upper Gorkha District is the easternmost of the western inner valleys; and the middle and southern parts of the district, including the study area, are part of the central midlands. A number of early authors (Dobremez 1976; Numata 1983; Ohsawa *et al*. 1986; Singh and Singh 1987; Stainton 1972) showed that the vertical distribution patterns of vegetation zones vary from district to district in the Himalaya as does the composition of plant communities. The following studies have been conducted in areas considered similar to the study site, i.e. above the tree line in the central midlands: Kikuchi (1991), Kikuchi and Ohba (1988), part of HMG (1976), Miehe (1990), and Yoda (1968). Miehe (1982) focused on a western inner valley (between the Dhaulagiri and Annapurna Himals) considered similar to the northern Gorkha District's inner valley. The inner valley area of Langtang Himal studied by HMG (1976) and Miehe (1990) is the westernmost of the eastern inner valleys.

METHODS

Due to an indigenous system of management of MAP resources practiced in the studied valley and surrounding areas, it was possible to time the fieldwork to undertake it just before the villagers commenced collection. Voucher specimens were collected of all species; identification was done using appropriate floras (Hara *et al*. 1978, 1982; Hara and Williams 1979; HMG 1976; Polunin and Stainton 1984; Stainton 1988) and by reference to the herbarium collections at Godavari (KATH) in Nepal and the British Museum, Natural History (BM) in London. Collected voucher specimens are lodged in the Kathmandu National Herbarium (KATH) in Godavari, Nepal.

The data were collected in August and September 1994. The survey exclusively focused on plant communities where commercial plant species were harvested. The Braun-Blanquet method (the Zürich-Montpellier school of subjective classification) as detailed by Mueller-Dombois and Ellenberg (1974) was followed; the main vegetation descriptions and analysis in similar areas of the Nepal Himalaya (Kikuchi 1991; Kikuchi and Ohba 1988; Miehe 1990) are also based on this approach which enabled comparisons. The vegetation in the valley was segmented into five distinct types: vertical north-facing rock walls; areas around *goths* (shelters used by herdsmen accompanying animals taken to graze outside the village); marshes and areas along streams; shrub communities on north-facing slopes; and meadows on south-facing slopes. According to harvesters, only the two latter

types, covering the larger part of the valley, were important in connection to commercial collection of MAPs and thus investigated. The meadows on the south-facing slopes were further divided into the vegetation on low-lying relatively flat land and vegetation on sloping higher land. Vegetation relevés were made on homogenous and representative locations, considering such factors as access limitations, the extent of grazing and other anthropogenic influences, and local micro-environmental and micro-habitat variations. Relevé size was 1 × 1 m. At each location, notes were made on altitude, exposition, topography, slope inclination, vegetation physiognomy, and the horizontal cover of shrubs and herbs. Species were recorded if they were rooted in the relevé. Algae, fungi, and mosses were not recorded. The nomenclature follows POWO (2019). However, in the case of sedges (*Kobresia* spp.), traditional nomenclature was followed (Hara *et al*. 1978).

A total of 45 relevés was included in the analysis. Ordination of relevés was carried out subjectively in a spreadsheet file. Vegetation types were recognized based on characteristic and differentiating species groups. The Braun-Blanquet cover/abundance scale for individual species in a relevé is: r = solitary, with low cover; + = few plants, with low cover; 1 = numerous, but ≤ 5% cover; 2 = 6–25% cover; 3= 26–50% cover; 4 = 51–75% cover; and 5 = more than 75% cover (only given when a species is present, i.e. reflects the cover where the species occurs).

Results

An overview of the number of families, genera, and species found in the investigated plots is given in Table 1. The distribution between groups is supported by the observations of Dobremez (1976) and Ohba (1988) who note that dicotyledons are far more frequent in Himalayan alpine plant communities than Cyperaceae and Gramineae.

Table 1. Analysis of families, genera, and species.

Group	Families		Genera		Species	
	No.	%	No.	%	No.	%
Pteridophyta	2	5.7	4	5.5	5	5.0
Monocotyledons	7	20.0	14	19.2	14	14.0
Dicotyledons	26	74.3	55	75.3	81	81.0
Total	35		73		100	

The vegetation classification results are presented in a synoptic table (Table 2); companion species are listed in Appendix 1. Eight vegetation types were recognized, comprising five meadow communities and three shrub communities. Each vegetation type's characteristics are discussed below; an overview of the communities in relation to position in the landscape, formation, altitudinal range, and aspect is presented in Table 3. Plant communities I–V occur on south-facing slopes only; plant communities VI–VIII are exclusively found on north-facing slopes. All south-facing communities are characterized by *Cremanthodium purpureifolium* and *Saxifraga parnassifolia*; furthermore, the three communities on steep slopes are all dominated by *Geranium donianum* and *Kobresia nepalensis*. The three north-facing communities are all characterized by *Rhododendron anthopogon*, *Bergenia purpurascens*, and *Athyrium spinulosum*.

I. The *Anaphalis busua* community

The community is characterized by the forbs *Aletris pauciflora*, *Anaphalis busua*, *Bistorta amplexicaulis*, and *Fritillaria cirrhosa*. The community ranges from 30 to 50 cm in height; it covers 100% of the ground. Commercially important MAPs found in this community type are *Nardostachys jatamansi* and *Dactylorhiza hatagirea*.

Table 2. Synoptic table of species in eight alpine communities in central Nepal. Constancy values: 1 = 1-20%; 2 = 21-40%; 3 = 41-60%; 4 = 61-80%; 5 = 81-100%. When less than four relevés make a group the absolute number of relevés in which a species was recorded is given in roman numerals. Abbreviations of community types: Anaph = *Anaphalis busua*, Morina = *Morina polyphylla*, Nardo = *Nardostachys jatamansi*, Cyanan = *Cyananthus lobatus*, Imp-Hym = *Impatiens occultans-Hymenidium hookeri*, Pot-Lig = *Potentilla eriocarpa-Ligularia fischeri*, Bis-Lyco = *Bistorta vaccinifolia-Lycopodium clavatum*, Salix = *Salix lindleyana*.

Community type	Anaph	Morina	Nardo	Cyanan	Imp-Hym	Pot-Lig	Bis-Lyco	Salix
Number of relevés	7	5	7	8	3	9	2	4
Cremanthodium purpureifolium Kitam.	5.1	5.1	5.1	5.+	III.+	-	-	-
Saxifraga parnassifolia D. Don	3.1	5.+	5.1	4.+	III.1	-	-	-
Geranium donianum Sweet	5.2	5.1	5.1	4.1	-	-	-	-
Kobresia nepalensis (Nees) Kük.	5.2	5.3	5.3	1.2	II.+	-	-	-
Anaphalis busua (Buch.-Ham. ex D. Don) DC.	5.1	-	-	-	-	-	-	-
Aletris pauciflora (Klotsch) Hand.-Mazz.	5.1	4.+	1.+	-	-	-	-	-
Bistorta amplexicaulis (D. Don) Greene	4.1	-	3.1	-	II.1	4.+	-	-
Fritillaria cirrhosa D. Don	4.+	2.r	-	1.r	-	-	-	-
Saussurea uniflora Wall. ex Sch. Bip	1.+	5.+	3.+	-	-	-	-	-
Morina polyphylla Wall. ex DC.	2.r	5.2	1.r	-	-	-	-	-
Bistorta vivipara (L.) Delarbre	-	5.1	1.1	-	-	-	-	-
Primula sikkimensis Hook. f.	-	4.+	-	-	II.2	-	-	-
Potentilla cuneata Wall. ex Lehm.	3.+	4.+	-	-	II.+	-	-	-
Stellaria patens D. Don		5.+	-	1.r	-	-	-	-
Anaphalis nepalensis (Spreng.) Hand.-Mazz.	-	5.+	5.1	-	II.1	-	-	-
Nardostachys jatamansi (D. Don) DC.	3.2	1.2	5.1	-	-	-	-	-
Euphorbia stracheyi Boiss.	3.1	-	5.1	-	-	-	-	-
Acronema handelii H. Wolff	2.1	-	4.+	-	-	-	-	-
Primula reticulata Wall.	4.1	-	-	5.1	-	-	-	-
Cyananthus lobatus Wall. ex Benth.	-	-	-	5.2	-	-	-	-
Aster tricephalus C.B. Clarke	1.+	-	-	5.1	-	1.r	-	-
Anemonastrum polyanthes (D. Don) Holub	2.1	1.+	2.1	5.+	-	-	-	-
Persicaria runcinata (Buch.-Ham. ex D. Don) H. Gross	-	-	-	5.+	-	-	-	-
Epilobium roseum Schreb.	3.+	1.r	3.+	5.+	II.+	-	-	-
Sida acuta Burm. f.	3.+	-	-	4.+	-	-	-	-
Thalictrum chelidonii DC.	2.+	-	-	4.+	-	-	-	-
Himalaiella auriculata (DC.) Raab-Straube	-	-	-	4.2	-	-	-	-
Rhodiola bupleuroides (Wall. ex Hook. f. & Thomson) S.H. Fu	3.+	-	-	4.+	II.1	-	-	-
Stellaria sikkimensis Hook. f. ex Edgew. & Hook. f.	-	-	-	4.+	III.+	-	-	-
Hymenidium hookeri (C.B. Clarke) Pimenov & Kljuykov	-	1.r	-	-	III.+	-	-	-
Geum elatum Wall. ex G. Don	3.1	3.+	-	-	III.2	-	-	-
Aconitum orochryseum Stapf	-	-	-	-	II.1	2.+	-	-
Dryopteris barbigera (Hook.) Kuntze	3.r	1.r	-	2.2	II.2	-	-	-
Polystichum prescottianum (Wall. ex Mett.) Moore	1.r	1.+	-	2.+	II.1	-	-	-
Eriocapitella rivularis (Buch.-Ham. ex DC.) Christenh. & Byng	-	1.+	-	-	II.+	-	-	-
Impatiens occultans Hook. f.	-	-	-	-	II.1	-	-	-
Rhododendron anthopogon D. Don	-	-	-	-	-	5.4	II.4	5.3
Bergenia purpurascens (Hook. f. & Thomson) Engl.	-	-	-	-	-	5.1	II.2	5.2
Athyrium spinulosum (Maxim.) Milde	-	-	-	-	-	5.1	II.+	2.+

Community type	Anaph	Morina	Nardo	Cyanan	Imp-Hym	Pot-Lig	Bis-Lyco	Salix
Number of relevés	7	5	7	8	3	9	2	4
Ligularia fischeri (Ledeb.) Turcz.	-	1.+	-	-	II.1	5.1	I.r	-
Potentilla eriocarpa Wall. ex Lehm.	-	-	-	-	-	3.1	-	-
Impatiens sp.	-	-	-	-	-	3.+	-	-
Lycopodium clavatum L.	-	-	-	-	-	1.+	II.1	-
Bistorta vacciniifolia (Wall. ex Meisn.) Greene	-	-	-	-	-	-	II.1	-
Salix lindleyana Wall. ex Andersson	-	-	-	-	-	-	-	5.1
Argentina lineata (Trevir.) Soják	-	-	-	-	-	-	-	5.1
Argentina commutata (Lehm.) Soják	-	-	-	-	-	-	-	4.1
Primula stuartii Wall.	-	-	-	-	II.1	-	I.+	4.+

II. The *Morina polyphylla* community

The community is characterized by forbs such as *Saussurea uniflora, Bistorta vivipara, Morina polyphylla, Stellaria patens*, and *Anaphalis nepalensis*. Ground cover is 100% and the height usually around 50 cm. The only important MAP species occurring is *Nardostachys jatamansi*.

III. The *Nardostachys jatamansi* community

The forbs *Nardostachys jatamansi, Euphorbia stracheyi*, *Acronema handelii*, and *Anaphalis nepalensis* characterize this community. The height is from 25 to 35 cm, and the vegetation usually covers 100% of the ground. Again, the only important MAP species occurring is *Nardostachys jatamansi*.

IV. The *Cyananthus lobatus* community

It is characterized by forbs such as *Cyananthus lobatus, Aster tricephalus, Anemonastrum polyanthes, Persicaria runcinata*, and *Himalaiella auriculata*. A number of companion species, such as *Corydalis meifolia*, occur exclusively in this species-rich community. Attains a height of 50 to 135 cm, occasionally higher specimens of, e.g., *Koenigia mollis*, and covers 100% of the ground. The community is botanically well defined and only occurs on lower slopes where the grazing pressure is highest (*Cyananthus lobatus* is locally known as "blue poison"). The only important MAP species occurring is *Dactylorhiza hatagirea*.

V. The *Impatiens occultans-Hymenidium hookeri* community

It is characterized by forbs such as *Geum elatum, Hymenidium hookeri, Stellaria sikkimensis, Impatiens occultans*, and *Aconitum orochryseum*; and the ferns *Dryopteris barbigera* and *Polystichum prescottianum*. Grasses are very few, and *Geranium donianum* is conspicuously absent from this community. The community is high, from 60 to 90 cm, and limited to protected sites on the sides of gullies on south-facing slopes. The vegetation cover is dense, usually 100%. The economically important MAP species *Aconitum orochryseum* and *Rheum australe* are found in this community.

VI. The *Potentilla eriocarpa-Ligularia fischeri* community

The forbs *Ligularia fischeri, Potentilla eriocarpa*, and *Impatiens* sp. are characteristic. Like the other shrub communities on north-facing slopes (VII and VIII) this community is species-poor, and grasses and sedges are virtually absent. The height of the community is usually 100 cm, and the vegetation cover is 100%. The most important commercial MAP species occurring is *Aconitum orochryseum*; also found are *Bergenia purpurascens* and *Lycopodium clavatum*.

VII. The *Bistorta vacciniifolia-Lycopodium clavatum* community

It is characterized by the occurrence of *Lycopodium clavatum* and *Bistorta vacciniifolia*. Only one companion species, *Carex daltonii*, is found. The height of the community is 100 cm, and the ground cover is 100%. Only less important commercial

species are found here, viz. *Bergenia purpurascens* and *Lycopodium clavatum*.

VIII. The *Salix lindleyana* community

The community is characterized by *Primula stuartii, Argentina lineata, A. commutata,* and *Salix lindleyana*; the two latter form mats. The fern *Athyrium spinulosum*, common in the other shrub communities on north-facing slopes, is less frequent in this vegetation type. It attains a height of 60 to 80 cm; the ground cover is variable: 50 to 100%. The economically important *Picrorhiza scrophulariiflora* is only found in this community; also occurring is *Bergenia purpurascens*.

Table 3. Distinguishing community types by main features.

	Community type	Landscape	Formation	Altitude (m)	Aspect
I.	*Anaphalis busua*	Steep slope	Meadow	3700–4300	S
II.	*Morina polyphylla*	Steep slope	Meadow	3700–4300	S
III.	*Nardostachys jatamansi*	Steep slope	Meadow	3700–4300	S
IV.	*Cyananthus lobatus*	Flat slope	Meadow	3500–3700	S
V.	*Impatiens occultans - Hymenidium hookeri*	Gully	Meadow	3700–4100	S
VI.	*Potentilla eriocarpa - Ligularia fischeri*	Steep slope	Shrubland	3600–4000	N
VII.	*Bistorta vacciniifolia - Lycopodium clavatum*	Steep slope	Shrubland	3600–4000	N
VIII.	*Salix lindleyana*	Steep and flat slopes	Shrubland	3600–4000	N

Discussion

CLASSIFICATION OF THE DESCRIBED COMMUNITIES

A few species are found on both north- and south-facing slopes, but in general the species composition of the shaded north-facing slope communities (types VI-VIII) is very homogeneous and distinctly different from the composition of the five south-facing communities. Based on the dominant species they have in common, i.e. *Rhododendron anthopogon, Bergenia purpurascens*, and *Athyrium spinulosum*, the north-facing communities are classified into one group: lower alpine *Rhododendron anthopogon-Bergenia purpurascens* community. This group is found on north-facing, shady and humid slopes from 3,600 to 4,000 m. The communities are not disturbed by fire or grazing and form a closed layer.

Two forbs are very common on the south-facing slopes and occurred in virtually all relevés: *Cremanthodium purpureifolium* and *Saxifraga parnassifolia*. All five described plant communities on the south-facing slopes are considered to belong to the same group: lower alpine humid *Cremanthodium* meadows. The group is found on south-facing sunny, but humid slopes from 3,500 m to 4,300 m. The communities are burned annually and influenced by grazing.

Based on differential species, it is further possible to distinguish three sub-groups on the south-facing slopes. *Kobresia* meadows, consisting of community types I–III dominated by *Kobresia nepalensis* and *Geranium donianum*, cover large areas from 3,700 to 4,300 m. *Cyananthus* meadows, consisting of community type IV dominated by *Cyananthus lobatus*, cover heavily grazed and frequently burned areas on more level land on the valley floor from 3,500 to 3,700 m. Gully vegetation, consisting of community type V, is found in limited areas on protected sides of gullies running down the south-facing slopes from 3,700 to 4,100 m. All sub-groups are "contaminated" with elements of the other sub-groups.

Of the three classes of plant communities proposed by Miehe (1990) in Nepal's alpine belt

(using Braun-Blanquet's floristic association system), the two groups and eight communities described above would all belong to the class 'Kobresietea nepalensis prov.' (Himalayan-alpine *Rhododendron-Kobresia* mats) comprising most natural climax communities and many anthropo-zoogenic replacement communities. However, the vegetation records presented here indicate that *Rhododendron* shrublands and *Kobresia* mats should be distinguished at the class level.

When comparing the lower alpine plant communities described here to those detailed by Miehe (1990) on the southern side of the Himalayan main range in the Langtang and Helambu area, no communities are so similar as to justify classifying them in the larger vegetation units distinguished by Miehe in the Kobresietea nepalensis class. There is some resemblance between Miehe's *Bergenia purpurascens-Rhododendron anthopogon-Zwergstrauchheide* community and the described north-facing communities. They probably belong to the same unidentified higher-ranked syntaxa (but not the 'lower alpine *Salix calyculata-Rhododendron anthopogon* dwarf-scrub' described by Miehe). It is proposed that the two groups distinguished here should be regarded as two new larger unranked vegetation units. Miehe (1982) in Dhaulagiri and Annapurna Himalaya and Kikuchi and Ohba (1988) in the Rolwaling Himal have also reported plant communities dominated by *Kobresia nepalensis*. These communities are, however, different from those found in our studied valley.

Without further vegetation records, the ranking of higher vegetation units is premature; this is especially true for anthropo-zoogenically heavily influenced communities such as those on the south-facing slopes in the studied valley. Thus, it is considered too early to determine whether any of the two groups, three sub-groups, or eight plant communities constitute associations. It is not possible to confirm that the alpine areas in the central midlands should be regarded as one vegetational unit. Much detailed phytosociological work is still required in the Nepal Himalaya before even a preliminary classification can be arrived at.

Regarding the distribution patterns of plant communities (Kikuchi 1991; Kikuchi and Ohba 1988) the following is noted: (i) the extreme vegetational difference between slopes facing north and south is evident in the valley; (ii) the altitudinal distribution of *Rhododendron* shrub communities can be extended down to 3,600 m; and (iii) the altitudinal distribution of *Kobresia* meadows extends down to 3,700 m.

THE PLANT COMMUNITIES IN RELATION TO MEDICINAL AND AROMATIC PLANTS

Economically important plant species at the time of the fieldwork have been reported by Olsen and Helles (1997). Table 4 relates plants of economic value to the vegetation types in which they occur in the studied valley. The table includes companion species that are found in the vegetation type but were not described in the relevés, e.g. the occurrence of *Rheum moorcroftianum* in the gully vegetation (the *Impatiens occultans-Hymenidium hookeri* community). Details on the commercially important MAPs are provided in Table 5.

The economically most important plants for local harvesters were *Nardostachys jatamansi* and *Dactylorhiza hatagirea* followed by *Aconitum orochryseum, Picrorhiza scrophulariiflora,* and *Rheum australe* (Olsen and Helles 1997). Of only marginal importance are *Bergenia purpurascens* and *Lycopodium clavatum*. The species *Rhododendron anthopogon, Fritillaria cirrhosa*, and *Allium wallichii*, though traded elsewhere in Nepal, were not commercially utilized in the study area. *Rheum moorcroftianum* (after harvest mixed with *R. australe*) *and Aconitum heterophyllum (after harvest mixed with A. orochryseum) occur only in small quantities*. All plants are dried, transported south, and sold unprocessed to local traders.

Given the distribution of commercial MAPs in the plant communities, both south- and north-facing communities are important with regard to the collection of plants and household incomes. However, of particular importance are the *Kobresia* meadows for *Nardostachys jatamansi* and the *Cyananthus* meadows for *Dactylorhiza hatagirea*.

Table 4. The occurrence of commercial medicinal and aromatic plant species in alpine plant communities, Gorkha District, central Nepal.

Vegetation	Alt range	Medicinal plant species	Frequency[1]
Lower alpine humid *Cremanthodium* meadows	3,500 - 4,300		
Kobresia meadows	3,700 - 4,300	*Nardostachys jatamansi*	common
		Dactylorhiza hatagirea	some
		Fritillaria cirrhosa	common
		Allium wallichii	some
Cyananthus meadows	3,500 - 3,700	*Dactylorhiza hatagirea*	common
		Fritillaria cirrhosa	common
		Allium wallichii	some
Gully vegetation	3,700 - 4,100	*Aconitum orochryseum*	some
		Rheum australe	some
		Rheum moorcroftianum	few
Lower alpine *Rhododendron - Bergenia* shrub	3,600 - 4,000	*Picrorhiza scrophulariiflora*	some
		Aconitum orochryseum	some
		Aconitum heterophyllum	few
		Rheum australe	some
		Bergenia purpurascens	very common
		Lycopodium clavatum	some
		Rhododendron anthopogon	very common

[1] Frequency is based on field observations of collectors and interviews; it is a simple index of the availability of a given species in a plant community from a collector's point of view

Table 5. Commercial medicinal and aromatic plant species, Gorkha District, central Nepal

Species	Family	Nepali name[1]	Morphology	Product	Ranking[2]
Lycopodium clavatum	Lycopodiaceae	Nagbeli	Herb	Spores	6
Dactylorhiza hatagirea	Orchidaceae	Panchaunle	Herb	Tubers	2
Allium wallichii	Amaryllidaceae	-	Herb	Flowers	not collected
Fritillaria cirrhosa	Liliaceae	-	Herb	Bulbs	not collected
Rhododendron anthopogon	Ericaceae	-	Shrub	Leaves	not collected
Picrorhiza scrophulariiflora	Plantaginaceae	Kutki	Herb	Rootstock	4
Rheum australe	Polygonaceae	Padamchal	Herb	Roots	5
		Amalbed		Aerial parts	
Rheum moorcroftianum	Polygonaceae	Padamchal	Herb	Roots	9
		Amalbed		Aerial parts	
Aconitum heterophyllum	Ranunculaceae	Nirmashi	Herb	Tubers	8
Aconitum orochryseum	Ranunculaceae	Nirmashi	Herb	Tubers	3
Bergenia purpurascens	Saxifragaceae	Pashanved	Herb	Rootstock	7
Nardostachys jatamansi	Caprifoliaceae	Jatamansi	Herb	Rhizomes	1

[1] Name used by collectors in Gorkha District, only given for traded products.

[2] Importance of listed species per average collector value at district level (based on Olsen and Helles 1997).

This indicates that pasture management regimes, such as the annual burning of south-facing plant communities, are important for maintaining MAPs and supporting household incomes. Among the north-facing communities, the *Impatiens occultans-Hymenidium hookeri* community is important for *Aconitum orochryseum* and *Rheum australe* while the *Salix lindleyana* community is important for *Picrorhiza scrophulariiflora*. By having access to a number of alpine plant communities harbouring

different species of valuable MAPs, the source of income (collecting commercial MAPs) becomes less vulnerable to variations in market prices for individual products (risk reduction).

Conclusion

The present paper provides historical baseline information on alpine plant communities in the Nepal Himalaya's central midlands, among other things constituting a reference point for contemporary studies assessing temporal changes. It also points towards further research: (i) additional phytosociological investigations to track changes in alpine communities over time – also as commercial medicinal plant harvesting continues to be of high economic importance to a large number of households in Nepal; (ii) improved understanding of the effect of human activities upon the plant communities; and (iii) estimating productivity and annual sustainable harvests for key species across different plant communities.

Acknowledgements

I am indebted to the many harvesters who shared their alpine communities with me. I am also grateful for the untiring efforts of my research assistants P. Lama, T. Nissen, and KR Bhattarai. The staffs at the Kathmandu National Herbarium are acknowledged for their helpfulness and support. The nomenclature support provided by Suresh Ghimire is acknowledged and appreciated. Funding was provided by the Research Committee for Development Research (FFU) of the Danish Ministry of Foreign Affairs (inter alia Grant no. 13–07KU).

References

Bauer K.M. 2004. *High frontiers*. Columbia University Press, New York.

Bürzle B., Schickhoff U., Schwab N., Oldeland J., Müller M., Böhner J., Chaudhary R.P., Scholten T. and Dickoré W.B. 2017. Phytosociology and ecology of treeline ecotone vegetation in Rolwaling Himal, Nepal. *Phytocoenologia*, 47(2): 197–220. https://doi.org/10.1127/phyto/2017/0130

Dobremez J.F. 1976. *Le Népal: Écologie et Biogéographie*. Centre National de la Recherche Scientifique, Paris, France.

Dobremez J.F. and Jest C. 1976. *Manaslu: Hommes et Milieux des Vallées du Népal Central*. Centre National de la Recherche Scientifique, Paris, France.

Fort M. 1979. *Études sur le Quaternaire de l´Himalaya; la Haute Vallée de la Buri Gandaki, Népal*. Centre National de la Recherche Scientifique, Paris, France.

Gardner P.C. 1954. Natural gardens in the Himalaya. In: *Himalayan Holiday – an Account of the New Zealand Himalayan Expedition, 1953* (A.R. Roberts *et al*., eds.), pp. 38–40. Christchurch.

Hara H., Stearn W.T. and Williams L.H.J. 1978. *An Enumeration of the Flowering Plants of Nepal. Vol. 1*. British Museum (Natural History), London, UK.

Hara H. and Williams L.H.J. 1979. *An Enumeration of the Flowering Plants of Nepal. Vol. 2*. British Museum (Natural History), London, UK.

Hara H., Chater A.O. and Williams L.H.J. 1982. *An Enumeration of the Flowering Plants of Nepal. Vol. 3*. British Museum (Natural History), London, UK.

HMG. 1976. *Flora of Langtang and Cross Section Vegetation Survey (Central Zone)*. His Majesty's Government, Department of Medicinal Plants, Kathmandu, Nepal.

Kaul V. and Sarin Y.K. 1971. The phytosociology of some alpine meadows in NW Himalayas. *Vegetatio*, 23: 361–369. https://doi.org/10.1007/BF02326671

Kawakita J. 1956. Vegetation. In: *Land and Crops of the Nepal Himalaya, Vol. II* (H. Kihara, ed.), pp. 1–65. Fauna and Flora Research Society, Kyoto, Japan.

Kikuchi T. 1991. Micro-scale vegetation patterns on talus in the alpine region of the Himalaya. In: *The Himalayan Plants, Vol. 2* (H. Ohba and S.B. Malla, eds.), pp. 1–9. The University of Tokyo, Bulletin no. 34, Tokyo, Japan. http://umdb.um.u-tokyo.ac.jp/DKankoub/Bulletin/no34/no34003.html

Kikuchi T. and Ohba H. 1988. Preliminary study of the alpine vegetation of the Himalayas, with special reference to the small-scale distribution patterns of plant communities. In: *The Himalayan Plants, Vol. 1* (H. Ohba and S.B. Malla, eds.), pp. 47–70. The University of Tokyo, Bulletin no. 31, Tokyo, Japan.

Kitamura S. 1955. Flowering plants and ferns. In: *Fauna and Flora of Nepal Himalaya, Vol. I* (H. Kihara, ed.), pp. 73–278. Fauna and Flora Research Society, Kyoto, Japan.

Manandhar N.P. 1990. Medico botany of Gorkha District, Nepal - an elucidation of medicinal plants. *International Journal of Crude Drug Research*, 1: 17–25. https://doi.org/10.3109/13880209009082768

McEachern J., Shah S.G., Shrestha T.B., Pande B.D. and Bhusal N.P. 1995. *Prospects for Tourism in Manaslu - a Reconnaissance Survey*. IUCN - the World Conservation Union, Kathmandu, Nepal.

Miehe G. 1982. *Vegetationsgeographische Untersuchungen im Dhaulagiri- und Annapurna-Himalaya*. Dissertationes Botanicæ Band 66, 1/2.

Miehe G. 1990. *Langtang Himal, Flora und Vegetation als Klimazeiger und -zeugen im Himalaya (A Prodomus of the Vegetation Ecology of the Himalayas)*. Dissertationes Botanicæ Band 158.

Mueller-Dombois D. and Ellenberg H. 1974. *Aims and Methods of Vegetation Analysis*. John Wiley & Sons, London, UK.

Nakao S. 1955. Ecological notes. In: *Fauna and flora of Nepal Himalaya, Vol. I* (H. Kihara, ed.), pp. 278–290. Fauna and Flora Research Society, Kyoto, Japan.

Numata M. 1983. Ecological studies in the Nepal Himalayas. In: *Biota and Ecology of Eastern Nepal* (M. Numata, ed.), pp. 1–13. The Himalayan Committee of Chiba University, Chiba, Japan.

Ohba H. 1988. The alpine flora of the Nepal Himalayas: an introductory note. In: *The Himalayan Plants, Vol. 1* (H. Ohba and S.B. Malla, eds.), pp. 19-46. The University of Tokyo, Bulletin no. 31, Tokyo, Japan.

Ohsawa M., Shakya P.R. and Numata M. 1986. Distribution and succession of west Himalaya forest types in the eastern part of the Nepal Himalaya. *Mountain Research and Development*, 6: 143–157. https://doi.org/10.2307/3673268

Olsen C.S. 2005. Valuation of commercial central Himalayan medicinal plants. *Ambio*, 34(8): 607–610. https://doi.org/10.1579/0044-7447-34.8.607

Olsen C.S. and Helles F. 1997. Medicinal plants, markets and margins in Nepal Himalaya: trouble in paradise. *Mountain Research and Development*, 17(4): 363–374. https://doi.org/10.2307/3674025

Olsen C.S. and Helles F. 2009. Market efficiency and benefit distribution in medicinal plant markets: empirical evidence from South Asia. *International Journal of Biodiversity Science and Management*, 5(2): 53–62. https://doi.org/10.1080/17451590903063129

Olsen C.S. and Larsen H.O. 2003. Alpine medicinal plant trade and Himalayan mountain livelihood strategies. *Geographical Journal*, 169(3): 243–254. https://doi.org/10.1111/1475-4959.00088

Polunin O. and Stainton A. 1984. *Flowers of the Himalaya*. Oxford University Press, New Delhi, India.

POWO. 2019. *Plants of the World Online*. Facilitated by the Royal Botanic Gardens, Kew. Published on the Internet; http://www.plantsoftheworldonline.org/

Pyakurel D., Sharma I.B. and Smith-Hall C. 2018. Patterns of change: the dynamics of medicinal plant trade in far-western Nepal. *Journal Ethnopharmacology*, 224: 323–334. https://doi.org/10.1016/j.jep.2018.06.004

Rai N.K. and Thapa M.B. 1993. Indigenous pasture management systems in high altitude Nepal: a review. HMG Ministry of Agriculture, Winrock International, Research Report Series no. 22, Kathmandu, Nepal.

Rayamajhi S., Smith-Hall C. and Helles F. 2012. Empirical evidence of the economic importance of Central Himalayan forests to rural households. *Forest Policy and Economics*, 20: 25–35. https://doi.org/10.1016/j.forpol.2012.02.007

Schilling T. 1985. Flowers and forests of the Gurkha Himal. *The Garden*, 110: 170–174.

Singh J.S. and Singh S.P. 1987. Forest vegetation of the Himalaya. *The Botanical Review*, 53: 80–192. https://doi.org/10.1007/BF02858183

Stainton A. 1988. *Flowers of the Himalaya: a Supplement*. Oxford University Press, New Delhi, India.

Stainton J.D.A. 1972. *The Forests of Nepal*. John Murray, London, UK.

Subedi M.N. 1992. Usage of the eastern and western Himalaya in relation to floristic study. *Newsletter of Himalayan Botany*, 12: 17–21.

Trapp H. 1995. Application of GIS for planning agricultural development in Gorkha District (draft). International Centre for Integrated Mountain Development and Gorkha Development Project, Kathmandu Nepal.

Warth H. 1993. Mountain people in their environment. Vol. 1: A socio-economic survey and assessment of project activities. Gorkha Development Project, Kathmandu, Nepal.

Yoda K. 1968. A preliminary survey of the forest vegetation of eastern Nepal. *Journal of the College of Arts and Sciences*, 5: 277–302.

Appendix 1. Companion species not included in the synoptic table. The first figure indicates the constancy value, the second the average cover/abundance class when the species is present (abbreviations of community types in Table 2).

Species	Community types							
	Anaph	Morina	Nardo	Cyanan	Imp-Hym	Pot-Lig	Bis-Lyco	Salix
Koenigia mollis (D. Don) T.M. Schust. & Reveal	-	-	-	2.3	-	1.+	-	-
Agrostis pilosula Trin.	2.+	2.+	3.+	4.1	I.+	-	-	-
Allium wallichii Kunth	1.r	-	-	3.+	-	-	-	-
Arisaema griffithii Schott	-	-	-	2.r	-	-	-	-
Berberis concinna Hook. f.	-	-	-	2.2	-	-	-	-
Bupleurum falcatum L.	-	-	-	1.+	-	-	-	-
Carex daltonii Boott	3.1	-	-	-	-	1.+	I.r	-
Melanoseris macrantha (C.B. Clarke) N. Kilian & J.W. Zhang	-	-	-	1.+	-	-	-	-
Corydalis juncea Wall.	1.+	2.+	-	2.+	-	-	-	-
Corydalis meifolia Wall.	-	-	-	3.+	-	-	-	-
Dactylorhiza hatagirea (D. Don) Soó	1.r	-	-	1.r	-	-	-	-
Delphinium williamsii Munz	3.+	-	-	-	-	-	-	-
Dipsacus inermis Wall. var. *mitis* (D. Don) Y.J. Nasir	-	-	-	1.2	-	-	-	-
Athyrium wallichianum Ching	1.+	-	-	-	I.3	1.+	-	-
Dubyaea hispida DC.	1.+	-	-	-	-	-	-	-
Unknown fern sp.	-	-	-	1.+	-	-	-	-
Festuca ovina L.	1.1	-	-	1.+	-	-	-	-
Galium acutum Edgew.	-	-	-	4.+	-	-	-	-
Gentiana sp.	-	-	-	3.+	-	-	-	-
Geum roylei Wall. ex Bolle	-	-	2.+	-	-	-	-	-
Unknown grass sp.	-	-	-	2.1	-	-	-	-
Tetrataenium wallichii (DC.) Manden.	-	-	1.+	4.+	-	-	-	-
Herminium josephi Rchb. f	1.+	-	-	-	-	-	-	-
Juncus leucanthus Royle ex D. Don	3.1	-	3.+	3.+	-	-	-	-
Koenigia delicatula (Meisn.) Hara	-	1.1	-	-	-	-	-	-
Leontopodium jacotianum Beauverd	-	-	1.r	-	-	-	-	-
Luzula multiflora (Retz.) Lej.	-	1.+	-	2.1	-	-	-	-
Parnassia pusilla Wall. ex Arn.	1.+	-	-	-	-	-	-	-
Pedicularis mollis Wall. ex Benth.	3.+	4.+	-	2.r	-	-	-	-
Pedicularis pectinata Wall. ex Benth.	1.+	-	-	1.r	-	-	-	-
Pedicularis scullyana Prain ex Maxim.	3.+	3.+	-	2.+	I.+	-	-	-
Pedicularis sp.	-	-	3.1	-	-	-	-	-
Phlomoides macrophylla (Benth.) Kamelin & Makhm.	1.1	-	-	1.r	-	-	-	-
Physospermopsis obtusiuscula (DC.) C. Norman	-	3.+	-	-	-	-	-	-
Picrorhiza scrophulariiflora Pennell	-	-	-	-	-	-	-	3.1
Polygonatum cirrhifolium (Wall.) Royle	-	-	-	3.+	-	-	-	-
Argentina festiva (Soják) Soják	3.+	-	-	-	-	-	-	-
Potentilla griffithii Hook. f.	2.+	-	-	1.+	-	-	-	-
Primula sp.	-	-	-	3.+	-	-	-	-
Rheum australe D. Don	-	-	-	-	I.3	2.1	-	-
Rhodiola himalensis (D. Don) S.H. Fu	-	-	-	2.+	-	-	-	-
Rhodiola sinuata (Royle ex Edgew.) S.H. Fu	1.+	1.1	2.1	-	-	-	-	2.+

Species	Community types							
	Anaph	Morina	Nardo	Cyanan	Imp-Hym	Pot-Lig	Bis-Lyco	Salix
Salix bistyla Hand.-Mazz.	-	-	-	-	-	-	-	2.+
Salix sp.	-	-	-	-	-	1.r	-	-
Salix thomsoniana Andersson	-	-	-	-	-	1.2	-	-
Scrophularia pauciflora Benth.	-	-	-	-	I.1	-	-	-
Ligusticopsis wallichiana (DC.) Pimenov & Kljuyk	-	-	-	2.r	-	-	-	-
Silene himalayensis (Rohrb.) Majumdar	1.+	-	-	-	I.+	-	-	-
Maianthemum purpureum (Wall.) LaFrankie	-	-	-	3.+	-	1.+	-	-
Sorbus microphylla (Wall. ex Hook. f.) Wenz.	-	-	-	-	-	1.2	-	-
Spiraea bella Sims	-	-	-	1.5	-	-	-	-
Strobilanthes atropurpurea Nees	-	-	-	2.1	-	-	-	-
Swertia racemosa (Griseb.) Wall. ex C.B. Clarke	3.r	-	-	1.r	-	-	-	-
Taraxacum parvulum DC.	-	-	-	2.1	-	-	-	-