

Weed Communities in Main Croplands and Rangeland Vegetation of Bhutan

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We conducted preliminary observations on the natural and semi-natural vegetation of Bhutan, particularly forests, grasslands and farmlands, in 1984, 1985 and 1989 (Numata, 1987a, b, 1991). My interest was to document gradual changes in vegetation from natural to secondary forests, from forests to grasslands, particularly pastures, and from natural and semi-natural vegetation to farmlands or plantations (cf. Beg, 1981; Mohammad, 1989). In 1985, we conducted further observations with a climatologist and a soil scientist as part of a research group. Many VIPs of the Government of Bhutan assisted us. Dasho C. Dorji (Secretary, Ministry of Trade, Industry and Power, former Director of the Department of Forestry), Dasho Dorjee Tenzin (Director, Department of Forestry, former Director of the Department of Animal Husbandry), Dasho Tseten Dorji (Director, Department of Animal Husbandry) and Dasho K. Nishioka (Bondy Farm) gave us useful information on the bio-industry of Bhutan. With regard to general affairs, Lyonpo Sangye Penjor (Minister for Social Services), Dasho Lam Penjor (Deputy Minister, Planning Commission), Dasho K. Letho (Deputy Minister, Ministry of Communication and Tourism) and Mr. Jigmi Tshultim (General Manager, Bhutan Tourism Corporation) also provided valuable help.

"An Unexplored Land-Bhutan" is the title of a book in Japanese written by S. Nakao (1959). It is well known that before this time, Tokan Tada entered Lhasa via Bhutan to study Buddhism. Recently, television films and some books, such as "Flowers of Bhutan" written by S. Nakao and K. Nishioka (1984), have provided rich information. Also, "Bhutan, A Kingdom of the Eastern Himala-

yas" by F. P. Imaeda and Y. Imaeda (1984, in Fench, English and Japanese) is a very good manual for foreign researchers. After Nakao, the Tokyo University team (Leader; H. Hara) and the Kyoto University team (Leader; M. Matsuo) conducted nature expeditions in Bhutan, both in 1967.

As I stated earlier, I have been to Bhutan with my colleagues three times: in 1984 (24 April–4 May), 1985 (11–25 September) and 1989 (9–21 October). I studied weed vegetation in croplands of strawberry (*Fragaria × ananassa*), cabbage (*Brassica oleracea* var. *capitata*), radish (*Raphanus sativus*), lettuce (*Lactuca sativa*), red pepper (*Capsicum annuum*), and buckwheat (*Fagopyrum tataricum*), and pasture vegetation in the rangeland. Dr. T. Ohba identified the plant specimens collected at the survey sites. Also, Mr. Chris Stapleton gave information on bamboos in Bhutan. Some of the weed vegetation of croplands was studied at the Bondy Farm of Dasho Kenji Nishioka. I am very grateful to these persons for their kindness. The data and reports of the Chiba University's expedition to Bhutan have been edited by M. Ohsawa (1987, 1991).

In the former survey, a dwarf bamboo (*Arundinaria racemosa*) grassland at Nikkachu, central Bhutan, was of considerable interest to me because it had very similar physiognomy and utilization for grazing animals to the *Pleiblastus* grasslands of southwestern Japan.

In the survey of pasture vegetation in the rangeland in 1989, the bamboo grassland dominated by *Yushania microphylla* around Gangtei Gompa and Pele La was most interesting to me. I was informed about the site

near Gangtei Gompa by Mr. Y. Imaeda.

Observations

According to recent statistics of land use in Bhutan, forest land accounts for 67.39% of the whole land area. This is almost the same proportion as that for forest land in Japan. The area of pasture land is 3%, that of agricultural land including settlements, orchards and shifting cultivation (Fig. 1) is 8%, and the rest is ice and snow, and barren, exposed and rocky areas. The grazing animals are said to be yak, Brown Swiss, Jersey cow, etc., although during my visit to central Bhutan in 1985, beef cattle, Indian cattle and horses seemed to be the most common (Fig. 2). When we visited central Bhutan in September of that year, sheep and goats were still present at higher altitudes, and some pigs were grazed in small areas. A farmer in the Rukubji District near Nikkachu told me that he had arranged to exchange his sheep and goats with those of a friend living in at a higher location for management according to the season. That is, sheep and goats are grazed in the highlands in summer, and in lowlands in winter. He said that his sheep and goats and those of his friend would return to Rukubji together at the end of September. The forest grazing of sheep and goats is prohibited because it causes great damage to forest regeneration. There are many pastures in the Rukubji District, and the forested area is small. The soil profile there includes charcoal, indicating that forests present there in the early days were burnt to make pastures. The soil profile also contains cattle dung in a layer several centimeters thick beneath the surface. This may suggest repeated landslides. There are terraces on the slope and a network of cattle paths, producing a very characteristic topography. The network of cattle paths is seen on most terraces, suggesting that the terraces were formed by repeated small-scale landslides.

In the central and southern parts of Bhutan, forage plants such as Italian ryegrass, fescues and clovers are sometimes used. For fodder in the winter, fodder trees are the recommended plant. In Nepal, leaves

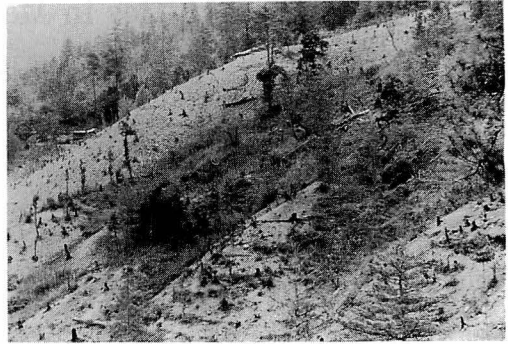


Fig. 1. Shifting cultivation in central Bhutan.

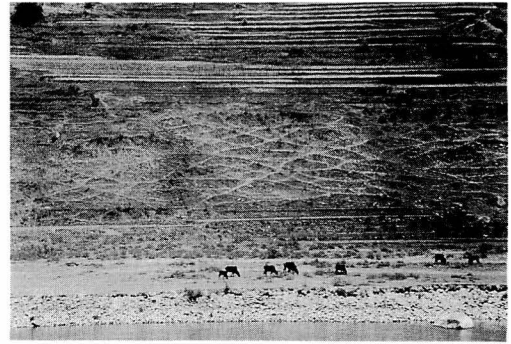


Fig. 2. Grazing in the paddy field after harvesting rice and the network of cattle paths behind.

with twigs from various kinds of trees are used as fodder, not only in the winter (Panday, 1982). However in Bhutan, the utilization of tree leaves as fodder is prohibited from the standpoint of forest conservation. Straws of rice, barley and wheat are used as winter fodder. Surprisingly, in a barley field there was a large quantity of weeds, mostly *Persicaria nepalensis*, which may be a noxious species (Fig. 3). When I asked a farmer about the most common weed, *P. nepalensis*, he told me that it is not a weed, but an important fodder in the winter. Although it actually decreases the yield of the barley, it is more important as a fodder. After the ripening of the barley, the heads are harvested and then the straw and *P. nepalensis* are cut together to make hay, which is used in the winter. However, *P. nepalensis* is actually a noxious weed for potato, buckwheat and winter wheat. The height of barley was 65



Fig. 3. Barley field with weeds such as *Persicaria nepalensis*.

cm and that of *Persicaria* was 25 cm when I measured them on September 19th. There are some rotations of barley-winter wheat, and barley-potato-radish-turnip. Radish and turnip are widely cultivated as the fodder for pigs and other animals. I saw a characteristic rotation of forest-pasture-farmland in eastern Nepal (Numata, 1966a, 1985), but no such rotation of land use was evident in central Bhutan, because 99% of the forest is state forest and the authorities place heavy emphasis on forest conservation (Dorji, 1985).

Main crops are rice, barley, wheat and maize, and shifting of cultivation is prohibited by the Government. Dashi C. Dorji has said: "We must get this evil practice out of the people's hands, help them in their livelihood, and reduce manpower demands. Shifting of cultivation will be very difficult to eradicate in a short time, because it has been practised since time immemorial, and affects the poorer section of the community. In order to try and curb it, the Government has launched a regular resettlement programme, and they think that over the next five or ten years, they will be able to solve this problem" (Dorji, 1985). The relict of charcoal in the soil profile mentioned above might be related to this shifting of cultivation.

I frequently observed such cultivation of small fields on river banks and steep slopes. In such cases in eastern Nepal, farmers select these places by judging the productivity from the height of the native grasses. I



Fig. 4. A farmer's house and his farmland on the left. There is a fence between them.

wonder whether farmers in Bhutan have a similar criterion. There is very little flat land, and the farmland sites selected are not always suitable.

When I wanted to examine the weeds in a farmland, it was generally difficult to enter, because farmlands are usually rigidly fenced off (Fig. 4). Usually the fences are made of bamboo to keep out domestic and wild animals. Recently, the Department of Animal Husbandry has recommended that farmers make double (bamboo and electric) fences. The former is only to make it difficult for large animals to gain entry. For domestic animals, the Government is considering the promotion of ensilage in central Bhutan.

One more characteristic feature of pasture is the use of bamboo. In front of the Guest House of Dochula (3050 m alt.), there is a good *Tsuga-Acer* forest stand. Around the stupa along the road, there was an overgrazed pasture dominated by *Carex nubigena* and *Sagina japonica* with *Iris clarkei* and *Rumex nepalensis* and without bamboo. However, there were many bamboos (*Arundinaria racemosa*) in the forest on the opposite side of the overgrazed pasture. These bamboos were shorter to taller from the margin near the road to the inner part of the forest. The shape of the bamboo shoots also changed from the dwarf form with dense leaves on the nodes, to normal growth (Fig. 5). The heights of aerial shoots were 13.3 cm at the edge, 36.7 cm, 43.8 cm, and 85.2 cm in the middle, and 2–3 m in the interior. The density of above-



Fig. 5. The growth of *Arundinaria racemosa* under the pressure of grazing as the undergrowth of the *Tsuga dumosa*-*Acer campbellii* forest at Dochula (3,050 m).

ground separately measurable shoots did not show such a clear trend, because it was affected by other constituent species.

Arundinaria-type pastures and meadows are found in southwestern Japan, particularly in Kyushu (Numata, 1974). However, their ecological susceptibility and tolerance to the grazing are different. In Japan *Arundinaria* (*Pleiobrastus*) *chino* var. *viridis* is very tolerant to grazing, and its form is almost similar to *Zoysia japonica* under strong grazing pressure. However, *Arundinaria chino* in central Japan is ecologically different from *A. chino* var. *viridis* and deteriorates under strong grazing pressure, the bamboo bushes becoming annual grassland (Numata, 1966 b). In eastern Nepal, I saw bamboo similar to the undergrowth of *Tsuga dumosa* and *Abies wallichii* forests. The growth form of the bamboo at the edge of the forests was very similar to the Bhutanese one described before. In central Bhutan, I found that almost all pastures have dwarf bamboo with shortened culms as perennial grasses, along with many other grasses and herbs (Fig. 6). However, I was unable to find similar types of pasture with dwarf bamboos in eastern Nepal.

The data included in this paper (Tables 1–34) are shown as the floristic composition with SDR (the summed dominance ratio = relative importance based on cover ratio and height ratio), l (left span), n (the number of species), G (the percentage of graminoid



Fig. 6. A dwarf bamboo pasture (*Arundinaria racemosa*) at Nikkachu (2,530 m) in central Bhutan.

Table 1. A roadside fragment of vegetation, Thimpu, vegetation cover 100%, alt. 2400 m, 16 September 1985.

Species	SDR	l
<i>Cynodon dactylon</i>	67	10
<i>Cosmos bipinnatus</i>	55	1
<i>Galinsoga parviflora</i>	43	1
<i>Chrysopogon aciculatus</i>	40	10
<i>Potentilla griffithii</i>	40	10
<i>Lepidium virginicum</i>	20	10
<i>Oxalis corniculatus</i>	10	10
<i>Mazus delavayi</i>	9	10

n=8, G=25, L=0, F=75, Th=25, DS=245.

Table 2. A roadside fragment of vegetation, outskirts of Thimpu, vegetation cover 100%, alt. 2400 m, 16 September 1985.

Species	SDR	l
<i>Artemisia dubia</i>	63	10
<i>Cynodon dactylon</i>	62	10
<i>Crotalaria</i> sp.	54	10
<i>Callicarpa rubella</i>	54	10
<i>Themeda</i> sp.	51	10
<i>Desmodium multiflora</i>	51	10
<i>Gnaphalium hypoleucum</i>	42	10
<i>Senecio chrysanthemoides</i>	42	1
<i>Galinsoga parviflora</i>	29	1
<i>Digitaria ciliaris</i>	21	1
<i>Verbascum thapsus</i>	19	1
<i>Acacia pennata</i>	17	50
<i>Gueldenstaedtia himalaica</i>	17	10
<i>Lespedeza gerardiana</i>	9	10
<i>Cassia mimosoides</i> subsp. <i>mimosoides</i>	9	10
<i>Carex nubigena</i>	9	10
<i>Viola tuberifera</i>	9	10

n=17, G=24, L=29, F=47, Th=24, DS=312.

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Table 3. A weed community at a cabbage field, suburbs of Thimpu, vegetation cover 70%, alt. 2600 m, SDR of cabbage=75, 16 September 1985. *Quercus semecarpifolia* forest and bracken grassland were closely found.

Species	SDR	l
<i>Rumex nepalensis</i>	57	10
<i>Amaranthus viridis</i>	54	1
<i>Conyza stricta</i>	48	10
<i>Galinsoga parviflora</i>	40	1
<i>Echinochloa crus-galli</i>	34	1
<i>Digitaria cruciata</i>	32	10
<i>Persicaria nepalensis</i>	29	1
<i>Picreus</i> sp.	26	10
<i>Chenopodium album</i>	26	1
<i>Cyperus</i> sp.	19	10
<i>Oxalis corniculata</i>	7	10

n=11, G=27, L=0, F=73, Th=45, DS=106.

Table 4. A weed community at a maize field, height and cover of maize are 300 cm and 90%, vegetation cover of weed community=5%, at a field after burning of forests, potato, maize and pumpkin were cultivated.

Species	SDR	l
<i>Amaranthus lividus</i>	67	1
<i>Chenopodium album</i>	51	1
<i>Digitaria cruciata</i>	37	1
<i>Galinsoga parviflora</i>	18	1
<i>Geranium nepalensis</i>	10	10
<i>Persicaria nepalensis</i>	10	1

n=6, G=17, L=0, F=83, Th=83, DS=27.

Table 5. A fragment of vegetation along the road from Thimpu to Dochula, vegetation cover 100%, alt. 2800 m, *Picea spinulosa* forest, fields of potato and radish were closely found.

Species	SDR	l
<i>Pteridium aquilinum</i> var. <i>wightianum</i>	82	10
<i>Gnaphalium hypoleucum</i>	67	10
<i>Onyrium japonicum</i>	52	10
<i>Umbelliferae</i> sp.	42	10
<i>Picea spinulosa</i>	38	100
<i>Pinus wallichiana</i>	32	100
<i>Agropyron</i> sp.	20	10
<i>Populus ciliata</i>	20	50
<i>Adenophora triphylla</i>	20	10
<i>Agrimonia pilosa</i> var. <i>nepalensis</i>	13	10
<i>Gueldenstaedtia himalaica</i>	7	10

n=11, G=9, L=0, F=0, Th=0, Ph=18, DS=985.

Table 6. A pasture in front of Dochula Cafeteria, vegetation cover 100%, alt. 3050 m, 16 September 1985.

Species	SDR	l
<i>Sagina japonica</i>	52	1
<i>Senecio chrysanthemoides</i>	51	1
<i>Iris clarkei</i>	42	10
<i>Rumex nepalensis</i>	34	10
<i>Arundinaria racemosa</i>	22	50
<i>Plantago erosa</i>	19	10
<i>Poa annua</i>	14	1
<i>Potentilla griffithii</i>	14	10
<i>Galium asperifolium</i>	13	1
<i>Carex nubigena</i>	6	10

n=10, G=30, L=0, F=70, Th=40, DS=220.

Table 7. A pasture for horses under the canopy of *Acer-Tsuga* forest*, vegetation cover 100%, alt. 3050 m, at Dochula.

Species	SDR	l
<i>Arundinaria racemosa</i>	90	50
<i>Duchesnea indica</i>	51	10
<i>Senecio chrysanthemoides</i>	43	1
<i>Iris clarkei</i>	38	10
<i>Daphne bholua</i>	23	10
<i>Aconitum laciniatum</i>	21	10
<i>Myriactis nepalensis</i>	18	1
<i>Geranium procurrens</i>	17	10
<i>Pteridium aquilinum</i> var. <i>wightianum</i>	16	10
<i>Athyrium strigollosum</i>	15	10
<i>Potentilla chrysanthemoides</i>	14	10
<i>Hypnum daajeelingense</i>	14	10
<i>Prunella vulgaris</i>	13	10
<i>Aspidiaceae</i> sp.	11	10
<i>Galium asperifolium</i>	6	1

n=15, G=7, L=0, F=93, Th=20, DS=690.

* Bamboos of understorey of *Tsuga-Acer* Forest near Dochula are *Thamnocalamus aristatus*, *Yushania hirsuta*, *Arundinaria racemosa*, and *Fargesia* sp. (by courtesy of a letter dated 29th Aug. 1990 from Mr. C. M. A. Stapleton, Forestry Department, Aberdeen University).

Table 8. An overgrazed pasture along the road, calcareous sandstone soil, Dochula, 17 September 1985.

Species	SDR	l
<i>Pteridium aquilinum</i> var. <i>wightianum</i>	59	10
<i>Senecio chrysanthemoides</i>	59	1
<i>Potentilla griffithii</i>	53	10
<i>Carex nubigena</i>	46	10
<i>Iris clarkei</i>	40	10
<i>Plantago erosa</i>	37	10
<i>Sagina japonica</i>	36	1
<i>Duchesnea indica</i>	32	10
<i>Prunella vulgaris</i>	29	10
<i>Rumex nepalensis</i>	16	10
<i>Anaphalis busua</i>	13	10
<i>Agrostis pilosula</i>	7	10
<i>Clinopodium umbrosum</i>	4	10

n = 13, G = 15, L = 0, F = 85, Th = 15, DS = 235.

Table 9. A pasture near the guest house at Nikkachu, alt. 2530 m, 18 September 1985.

Species	SDR	l
<i>Senecio chrysanthemoides</i>	78	1
<i>Arthraxon sikkimensis</i>	55	10
<i>Paspalum commersoni</i>	55	10
<i>Pteridium aquilinum</i> var. <i>wightianum</i>	33	10
<i>Arundinaria racemosa</i>	31	50
<i>Elymus sikkimensis</i>	28	10
<i>Rosa sericea</i>	28	50
<i>Potentilla griffithii</i>	28	10
<i>Digitaria ciliaris</i>	25	1
<i>Persicaria nepalensis</i>	24	1
<i>Poa annua</i>	23	1
<i>Geranium nepalensis</i>	16	10
<i>Commelina paludosa</i>	16	10
<i>Anaphalis triplinervis</i>	16	10
<i>Amaranthus viridis</i>	15	1
<i>Artemisia indica</i>	15	10
<i>Eleocharis congesta</i>	14	10
<i>Bulbostylis densa</i>	12	1
<i>Plantago erosa</i>	12	10
<i>Setaria glauca</i>	8	1
<i>Poa sikkimensis</i>	7	10

n = 21, G = 43, L = 0, F = 57, Th = 33, DS = 290.

Table 10. A weed community at a radish field, scattered seedlings of radish, vegetation cover (radish) = 75%, Nikkachu, 18 September 1985.

Species	SDR	l
<i>Galinsoga parviflora</i>	100	1
<i>Amaranthus lividus</i>	83	1
<i>Vicia angustifolia</i>	74	10
<i>Poa annua</i>	60	1
<i>Stellaria media</i>	57	1

n = 5, G = 20, L = 20, F = 60, Th = 80, DS = 197.

Table 11. A weed community at a barley field used for fodder of yak, scattered seedlings, vegetation cover = 20% (barley), 80% (weeds), Nikkachu.

Species	SDR	l
<i>Galinsoga parviflora</i>	78	1
<i>Amaranthus viridis</i>	72	1
<i>Persicaria nepalensis</i>	60	1
<i>Digitaria ciliaris</i>	54	1
<i>Pteridium aquilinum</i> var. <i>wightianum</i>	51	10
<i>Siegesbeckia orientalis</i>	34	1
<i>Geranium procurrens</i>	27	10
<i>Setaria glauca</i>	26	1

n = 8, G = 25, L = 0, F = 75, Th = 75, DS = 157.

Table 12. A weed community in a radish field, scattered seedlings, strong weeding.

Species	SDR	l
<i>Raphanus sativus</i>	100	1
<i>Persicaria nepalensis</i>	34	1
<i>Stellaria media</i>	22	1
<i>Poa annua</i>	21	1

n = 4, G = 25, L = 0, F = 75, Th = 100, DS = 40.

Table 13. A weed community in a barley field, barley is cut at the end of September, winter wheat is cultivated from October to June.

Species	SDR	l
<i>Hordeum vulgare</i>	94	1
<i>Persicaria nepalensis</i>	67	1
<i>Siegesbeckia orientalis</i>	23	1
<i>Digitaria ciliaris</i>	17	1
<i>Rumex nepalensis</i>	17	10
<i>Galium asperifolium</i>	16	1
<i>Poa annua</i>	14	1

n = 7, G = 43, L = 0, F = 57, Th = 86, DS = 57.

Table 14. A weed community in a barley field near the guest house of Nikkachu.

Species	SDR	l
<i>Hordeum vulgare</i>	100	1
<i>Persicaria nepalensis</i>	56	1
<i>Galium asperifolium</i>	31	1
<i>Raphanus sativus</i>	31	1
<i>Brassica rapa</i>	28	1
<i>Galinsoga parviflora</i>	28	1

n = 6, G = 20, L = 0, F = 80, DS = 46.

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Table 15. Pasture under grazing of horses and cattle near the guest house of Nikkachu, *Picea spinulosa* saplings 2 m high.

Species	SDR	l
<i>Arundinaria racemosa</i>	65	50
<i>Arundinella hookeri</i>	60	10
<i>Eleagnus parviflora</i>	53	100
<i>Eragrostis nigra</i>	48	10
<i>Dryopteris paleacea</i>	43	10
<i>Echinochloa crus-galli</i>	33	1
<i>Artemisia indica</i>	33	10
<i>Potentilla griffithii</i>	32	10
<i>Pteridium aquilinum</i> var. <i>wightianum</i>	28	10
<i>Haloragis micrantha</i>	23	10
<i>Onychium japonicum</i>	18	10
<i>Primula listeri</i>	18	10
<i>Hallenia elliptica</i>	18	1
<i>Anaphalis margaritacea</i>	13	10
<i>Eleocharis congesta</i>	10	10
<i>Drymaria diandra</i>	8	1
<i>Selaginella tamariscina</i>	6	10

n = 17, G = 24, L = 0, F = 76, Th = 18, DS = 691.

Table 16. Weeds in a strawberry field, Bondy Farm, Paro, alt. 2360 m, 10 October 1989.

Species	SDR	SDR'	l
<i>Fragaria</i> × <i>ananassa</i>	79	—	10
<i>Rumex nepalensis</i>	51	60	10
<i>Erigeron canadensis</i>	51	60	1
<i>Echinochloa colonum</i>	31	79	1
<i>Persicaria nepalensis</i>	31	79	1
<i>Eragrostis</i> sp.	26	35	10
<i>Setaria glauca</i>	26	45	1
<i>Digitaria sanguinalis</i>	24	72	1
<i>Equisetum arvensis</i>	23	42	10
<i>Equisetum ramosissimum</i>	23	42	10
<i>Galinsoga ciliata</i>	22	32	1
<i>Polypogon fugax</i>	22	32	1
<i>Amaranthus retroflex</i>	19	38	1
<i>Trifolium repens</i> var. <i>giganteum</i>	12	31	10
<i>Taraxacum officinale</i>	9	37	10
<i>Eclipta prostrata</i>	8	17	1

n = 16, G = 38%, L = 6%, F = 56%, Th = 44%, DS = 154.

n = 15, G = 40%, L = 6%, F = 54%, Th = 47%, DS = 190.

Table 17. Weeds in a cabbage field, Bondy Farm, Paro, alt. 2360 m, 10 October 1989.

Species	SDR	SDR'	l
<i>Brassica oleracea</i> var. <i>capitata</i>	100	—	10
<i>Setaria glauca</i>	52	100	1
<i>Echinochloa colonum</i>	51	100	1
<i>Eclipta prostrata</i>	28	48	10
<i>Amaranthus hybridus</i>	24	60	1
<i>Acalypha australis</i>	22	26	1
<i>Galinsoga ciliata</i>	21	40	1

n = 7, G = 29, L = 0, F = 71, Th = 72, DS = 134.

n = 6, G = 33, L = 0, F = 67, Th = 83, DS = 207.

Table 18. Weeds in a radish field, Bondy Farm, Paro, alt. 2360 m, 10 October 1989.

Species	SDR	SDR'	l
<i>Raphanus sativus</i>	100	—	10
<i>Siegesbeckia orientalis</i>	40	60	1
<i>Equisetum arvensis</i>	33	54	10
<i>Amaranthus hybridus</i>	28	43	1
<i>Polygonum</i> sp.	28	48	1
<i>Digitaria sanguinalis</i>	17	64	1
<i>Cynodon dactylon</i>	15	39	10
<i>Malva</i> sp.	15	29	10

n = 8, G = 25, L = 0, F = 75, Th = 50, DS = 218.

n = 7, G = 29, L = 0, F = 71, Th = 57, DS = 205.

Table 19. Weeds in a lettuce field, Bondy Farm, Paro, alt. 2360 m, 10 October 1989.

Species	SDR	SDR'	l
<i>Lactuca sativa</i>	100	—	10
<i>Digitaria sanguinalis</i>	44	55	1
<i>Equisetum arvensis</i>	44	55	10
<i>Chenopodium album</i>	36	47	1
<i>Juncus griesebachii</i>	36	47	10
<i>Aconogonum polystachyum</i>	34	43	10
<i>Brachypodium sylvaticum</i>	34	43	10
<i>Capsella bursa-pastoris</i>	22	26	1
<i>Amaranthus emarginatus</i>	22	26	1
<i>Potentilla leuconota</i>	22	26	10
<i>Anaphalis contorta</i>	22	26	10
<i>Echinochloa colonum</i>	22	26	1
<i>Spergula arvensis</i>	17	24	1
<i>Oxalis corymbosa</i>	17	58	10
<i>Spergularia rubra</i>	17	24	1
<i>Rumex nepalensis</i>	17	24	1
<i>Lapsana communis</i>	17	24	1
<i>Portlaca oleracea</i>	17	24	1
<i>Poa annua</i>	17	24	1
<i>Taraxacum officinalis</i>	8	13	10

n = 20, G = 25, L = 0, Th = 50, F = 75, DS = 171.

n = 19, G = 26, L = 0, Th = 53, F = 74, DS = 155.

Table 20. A pasture near the Olathang Hotel, vegetation cover 100%, alt. 2500 m.

Species	SDR	l
<i>Themeda triandra</i>	70	10
<i>Bothriochloa punctata</i>	67	10
<i>Andropogon yunnanensis</i>	65	10
<i>Tripogon filiformis</i>	65	10
<i>Cynodon dactylon</i>	63	10
<i>Erigeron canadensis</i>	52	1
<i>Gnaphalium hypoleucum</i>	39	1
<i>Digitaria ischaemum</i>	37	1
<i>Eragrostis nigra</i>	31	10
<i>Bulbostylis densa</i>	30	1
<i>Lespedeza</i> sp.	30	10
<i>Potentilla griffithii</i>	26	10
<i>Clinopodium repens</i>	22	10
<i>Geranium nepalensis</i>	22	10
<i>Myriactis nepalensis</i>	20	1
<i>Oxalis corniculata</i>	17	10
<i>Rosa sericea</i>	17	50
<i>Micromeria</i> sp.	17	10
<i>Schizachyrium brevifolium</i>	14	10

n = 19, G = 47.4, L = 5.3, F = 47.4, Th = 26, Shrub = 5, DS = 322.

Table 21. Weeds in a red pepper field, Paro, alt. 2360 m, 10 October 1989.

Species	SDR	SDR'	l
<i>Capsicum annuum</i>	100	—	10
<i>Gnaphalium affine</i>	24	65	1
<i>Erigeron canadensis</i>	19	63	1
<i>Eleusine indica</i>	16	40	10
<i>Persicaria nepalensis</i>	16	31	1
<i>Bidens tripartita</i>	16	31	1
<i>Lobelia alsinoides</i>	15	25	10
<i>Clinopodium repens</i>	15	25	10
<i>Siegesbeckia orientalis</i>	15	25	1
Compositae sp.	14	22	10
<i>Pycnopus sanguinolentus</i>	11	21	1
<i>Lindernia nummularifolia</i>	11	21	1
<i>Potentilla griffithii</i>	11	21	10
<i>Dicrocephala integrifolia</i>	9	24	1
<i>Ranunculus cantoniensis</i>	9	22	10
<i>Ammannia multiflora</i>	9	12	10
<i>Drymaria villora</i>	8	13	10
<i>Sagina japonica</i>	7	15	1
<i>Cardamine flexuosa</i>	6	15	1

n = 19, G = 11, L = 0, F = 89, Th = 58, DS = 111.

n = 18, G = 11, L = 0, F = 89, Th = 61, DS = 111.

Table 22. A pasture of horse and cow near Paro Chu, vegetation cover 100%, alt. 2360 m, 11 October 1989.

Species	SDR	l
<i>Cynodon dactylon</i>	65	10
<i>Erigeron canadensis</i>	59	1
<i>Bothriochloa ischaemum</i>	49	10
<i>Cynoglossum zeylanicum</i>	45	1
<i>Artemisia indica</i>	44	10
<i>Gnaphalium hypoleucum</i>	38	1
<i>Verbascum thapsus</i>	38	1
<i>Carpesium nepalense</i>	35	10
<i>Amaranthus retroflexus</i>	35	1
<i>Cannabis sativa</i>	31	1
<i>Plantago erosa</i>	29	10
<i>Eleusine indica</i>	24	10
<i>Euphorbia chamaecyce</i>	20	1
Compositae sp.	11	10

n = 14, G = 21, L = 0, F = 79, Th = 50, DS = 78.

Table 23. A pasture of horse around the Motithang Hotel, vegetation cover 85%, alt. 2640 m, 12 October 1989.

Species	SDR	l
<i>Bulbostylis densa</i>	75	10
<i>Erigeron canadensis</i>	68	1
<i>Sporobolus fertilis</i>	62	10
<i>Bothriochloa ischaemum</i>	61	10
<i>Persicaria nepalensis</i>	61	1
<i>Artemisia indica</i>	54	10
<i>Persicaria runcinata</i>	53	1
<i>Pinus excelsa</i>	48	100
<i>Lysimachia debilis</i>	47	10
<i>Taraxacum officinale</i>	42	1
<i>Swertia hispidicalyx</i>	39	1
<i>Potentilla leuconota</i>	37	10
<i>Dipsacus mitis</i>	32	10
<i>Vicatia conifolia</i>	27	10
Leguminosae sp.	20	1

n = 15, G = 27, L = 7, F = 66, Tree = 7, DS = 602.

Table 24. Grassland vegetation in Royal Bhutan Golf Link with 9 holes, Thimpu, vegetation cover 100%, 12 October 1989.

Species	SDR	l
<i>Trifolium repens</i>	69	10
<i>Calamagrostis epigeios</i>	63	10
<i>Cynodon dactylon</i>	57	10
<i>Eragrostis nigra</i>	51	10
<i>Erigeron canadensis</i>	47	1
<i>Bulbostylis densa</i>	46	1
<i>Fimbristylis quinqueangularis</i>	39	10
<i>Lespedeza juncea</i>	39	10
<i>Pycnus sanguinolentus</i>	39	1
<i>Juncus effusus</i>	39	10
<i>Carex pleistogyna</i>	39	10
<i>Artemisa indica</i>	39	10
<i>Sporobolus fertilis</i>	32	10
<i>Smithia ciliata</i>	28	10
<i>Setaria glauca</i>	26	1
<i>Potentilla sundaica</i>	25	10
<i>Asparagus</i> sp.	7	10

n = 17, G = 59, L = 18, F = 23, Th = 24, DS = 342.

Table 25. A pasture around Gangtei Gompa, vegetation cover 100%, 13 October 1989.

Species	SDR	l
<i>Yushania microphylla</i>	100	50
<i>Agrostis gigantea</i>	33	10
<i>Myriactis nepalensis</i>	27	1
<i>Phymatopsis</i> sp.	27	1
<i>Saxifraga strigosa</i>	27	1
<i>Anaphalis triplinervis</i> var. <i>monocephala</i>	26	10
<i>Helenia elliptica</i>	26	1
<i>Cyananthus inflatus</i>	21	1
<i>Vicatia coniiifolia</i>	21	10
<i>Elscholtzia fruticosa</i>	16	1
<i>Herminium</i> sp.	16	1

n = 11, G = 27, L = 0, F = 73, Th = 64, DS = 542.

plants), L (the percentage of Leguminosae), F (the percentage of forbs including weeds), Th (the percentage of annuals) and DS (the degree of succession).

Good-quality pasture has high ratios of G

Table 26. Bamboo pasture at Pelela, vegetation cover 100%, alt. 3380 m, 13 October 1989.

Species	SDR	l
<i>Yushania microphylla</i>	100	50
<i>Gaultheria nummularioides</i>	40	50
<i>Rosa sericea</i>	40	50
<i>Cirsium nishiokae</i>	34	10
<i>Spiraea canescens</i>	34	10
<i>Brachypodium sylvaticum</i>	34	10
<i>Senecio diversifolius</i>	28	10
<i>Anaphalis margaritacea</i>	28	10
<i>Cyananthus inflatus</i>	28	1
<i>Asyneuma fulgens</i>	28	10
<i>Anaphalis contorta</i>	26	10
<i>Anaphalis triplinervis</i> var. <i>monocephala</i>	26	10
<i>Hemiphragma heterophylla</i>	17	10
<i>Potentilla leuconota</i>	17	10

n = 14, G = 22, L = 0, F = 78, Th = 7, Shrub = 21, DS = 815.

Table 27. A pasture around the Sherabuling Guest House, Tongsa, vegetation cover 100%, alt. 2100 m, 14 October 1989.

Species	SDR	l
<i>Eragrostis nigra</i>	60	10
<i>Fimbristylis</i> sp.	54	10
<i>Siegesbeckia orientalis</i>	33	1
Compositae sp.	31	10
<i>Hypoestes triflora</i>	27	10
<i>Artemisia indica</i>	24	10
<i>Erigeron canadensis</i>	24	1
<i>Anaphalis contorta</i>	22	10
<i>Chenopodium ambrosioides</i> var. <i>anthemidifolia</i>	19	1
<i>Stellaria vestita</i>	16	10
<i>Trifolium repens</i>	16	10
<i>Rumex nepalensis</i>	14	10
<i>Drymaria villosa</i>	14	10
<i>Stipa</i> sp.	9	10

n = 14, G = 21, L = 7, F = 72, Th = 21, DS = 210.

and L and low ratios of F, shrubs and trees. The ratio of Leguminosae is relatively low. Annual grasses in pastures include *Digitaria cruciata*, *D. ischaemum*, *Setaria glauca*, *Bulbostylis densa*, etc. Perennial grasses in pastures

Table 28. Bracken pasture under overgrazing at Yotongla, vegetation cover 100%, alt. 3500 m, 15 October 1989.

Species	SDR	l
<i>Pteridium revolutum</i>	100	10
<i>Yushania microphylla</i>	48	50
<i>Lepedeza gerardiana</i>	45	10
<i>Eragrostis nigra</i>	37	10
<i>Persicaria runcinata</i>	30	1
<i>Aconogonum molle</i>	22	10
<i>Myriactis wightii</i>	22	1
<i>Hypericum choisianum</i>	21	10
<i>Fragaria nilgerrensis</i>	19	10
<i>Cynoglossum zeylanicum</i>	19	1
<i>Potentilla leuconota</i>	19	10
<i>Myriactis nepalensis</i>	18	1
<i>Digitaria ischaemum</i>	18	1
<i>Potentilla caliginosa</i>	18	10
<i>Lycopodium japonicum</i>	15	10
<i>Clinopodium repens</i>	15	10
<i>Halenia elliptica</i>	14	1

n = 17, G = 18, L = 6, F = 76, Th = 35, DS = 331.

Table 29. Degraded bamboo pasture at Yotongla, vegetation cover 100%, alt. 3530 m, 15 October 1989.

Species	SDR	l
<i>Pteridium revolutum</i>	100	10
<i>Miscanthus nepalensis</i>	92	10
<i>Yushania microphylla</i>	88	50
<i>Erianthus fulvus</i>	63	10
<i>Aster</i> sp.	46	10
<i>Primula</i> sp.	45	10
<i>Deutzia</i> sp.	44	50
Gramineae sp.	40	10
<i>Satyrium ciliatum</i>	28	10
<i>Aconogonum molle</i>	27	10
<i>Cirsium falconeri</i>	27	10
<i>Geranium nepalensis</i>	27	10
<i>Stellaria vertita</i>	23	10
Compositae sp.	21	10
<i>Anaphalis contorta</i>	21	10

n = 15, G = 20, L = 0, F = 80, Th = 0, DS = 775.

include *Botriochloa punctata*, *B. ischaemum*, *Eragrostis nigra*, *Cynodon dactylon*, *Tripogon filiformis*, *Themeda triandra*, *Andropogon yunnanensis*, *Eleusine indica*, *Sporobolus fertilis*, *Calamagrostis epigeios*, *Brachypodium sylvaticum*, *Agrostis gigantea*, *Stipa* sp., etc. *Yushania*

Table 30. Buckwheat field harvested one week ago, 15 cows grazing in 4 acre, vegetation cover 100%, Bumtang, alt. 2580 m, 16 October 1989.

Species	SDR	SDR'	l
<i>Fagopyrum tataricum</i>	88	—	10
<i>Setaria glauca</i>	100	100	1
<i>Cannabis sativa</i>	100	100	10
<i>Persicaria nepalensis</i>	71	71	1
<i>Echinochloa colonum</i>	58	58	1
<i>Capsella bursa-pastoris</i>	54	54	1
<i>Digitaria cruciata</i>	52	52	1
<i>Erigeron canadensis</i>	48	48	1
<i>Chenopodium album</i>	36	36	1
<i>Eragrostis nigra</i>	35	35	10
<i>Poa alpina</i>	23	23	10
<i>Fimbristylis</i> sp.	23	23	10

n = 12, G = 50, L = 0, F = 50, Th = 58, DS = 259.

n = 11, G = 55, L = 0, F = 45, Th = 64, DS = 283.

Table 31. Abandoned field in Bumtang, cows and horses were grazing from April to October, vegetation cover 80%, alt. 2580 m, 16 October 1989.

Species	SDR	l
<i>Anaphalis margaritacea</i>	92	10
<i>Erigeron canadensis</i>	54	1
<i>Cirsium tibeticum</i>	52	10
<i>Digitaria cruciata</i>	18	1
<i>Oxalis corniculata</i>	18	10
<i>Plantago erosa</i>	18	10
<i>Potentilla sundaica</i>	18	10
<i>Potentilla griffithii</i>	18	10
<i>Clinopodium repens</i>	16	10
<i>Potentilla leuconota</i>	7	10
<i>Swertia angustifolia</i>	7	1
<i>Myriactis</i> sp.	7	1

n = 12, G = 8, L = 0, F = 92, Th = 33, DS = 210.

microphylla, a dominant species of bamboo grassland, is most remarkable in the rangeland. It constitutes an alpine pasture at 3,000 m or so altitude, and is used for yearlong grazing of yaks as an evergreen bamboo.

In eastern Nepal, I classified the pastures

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Table 32. A pasture on a slope of Bumtang, bracken grassland was found upper this pasture, alt. 2580 m.

Species	SDR	l
<i>Eragrostis nigra</i>	63	10
<i>Andropogon yunnanensis</i>	63	10
<i>Trifolium repens</i>	63	10
<i>Cannabis sativa</i>	57	10
<i>Scirpus rosthornii</i>	53	10
<i>Setaria glauca</i>	50	1
<i>Helictorichon virescens</i>	45	10
<i>Arundinella bengalensis</i>	45	10
<i>Rumex obtusifolius</i>	44	10
<i>Carex nubigena</i>	42	10
<i>Pycnus flavidus</i>	40	1
<i>Potentilla griffithii</i>	37	10
<i>Potentilla leuconota</i>	37	10
<i>Agrimonia pilosa</i> var. <i>nepalensis</i>	35	10
<i>Origanum vulgare</i>	28	10
<i>Verbascum thapsus</i>	27	1

n=17, G=41, L=6, F=53, Th=18, DS=350.

Table 33. Sheep Development Project by Department of Animal Husbandry at Dichen Pebri-thang, vegetation cover 100%, 16 October 1989.

Species	SDR	l
<i>Dactylis glomerata</i>	75	10
<i>Trifolium repens</i>	63	10
<i>Cosmos bipinnatus</i>	60	1
<i>Artemisia japonica</i>	59	10
<i>Chenopodium album</i>	48	1
<i>Rumex obtusifolius</i>	48	10
<i>Setaria glauca</i>	42	10
<i>Potentilla griffithii</i>	40	10
<i>Galinsoga ciliata</i>	39	1
<i>Eragrostis nigra</i>	29	10
<i>Mariscus sumatrensis</i>	28	10

n=12, G=33, L=8, F=59, Th=25, DS=380.

into the *Imperata-Cynodon* type in lowlands, and *Festuca-Poa-Agrostis* type in highlands (Numata, 1980). This is also applicable to the distribution of pastures in Bhutan.

Regarding weed vegetation in croplands, weeds in fields of strawberry, cabbage, radish, lettuce, red pepper and buckwheat were surveyed in relation to crops. Summer weeds and winter weeds are mostly separated in Japan and the Mediterranean area, although in Bhutan weeds of both types were mixed at the time of survey in October. This may be caused by the high altitude in the

Table 34. Good lawn rangeland grazed by 20 bulls, cows and calves near Jinbeylhakhang Monastery, vegetation cover 100%, 16 October 1989.

Species	SDR	l
<i>Arundinella bengalensis</i>	66	10
<i>Anaphalis tibetica</i>	60	10
<i>Artemisia indica</i>	56	10
<i>Senecio diversifolius</i>	50	10
<i>Sporobolus fertilis</i>	50	10
<i>Artemisia japonica</i>	50	10
<i>Eragrostis nigra</i>	50	10
<i>Poa alpina</i>	40	10
<i>Carex nubigena</i>	36	10
<i>Brunella vulgaris</i>	36	10
<i>Trifolium repens</i>	30	10
<i>Rumex nepalensis</i>	25	10
<i>Plantago erosa</i>	24	10
<i>Potentilla leuconota</i>	23	10
<i>Bulbostylis densa</i>	22	1
<i>Oxalis corniculata</i>	20	10

n=16, G=38, L=6, F=56, Th=6, DS=348.

subtropical zone. *Poa annua* was not found in September, and it was not estimation. I found that it was distributed up to 3,800 m in altitude in May in eastern Nepal.

The weed vegetation in the fields containing the six crops is summarized in Table 35: n, G, L, F, Th and DS are shown in the same way as in the tables on pastures. However, these indices are shown for two cases n (n including a crop expressed with SDR and n excluding a crop (only weed vegetation) expressed with SDR'). For example, n=16, G=38, L=6, F=56, Th=44, DS=154 when strawberry is included, and n=15, G=40, L=6, F=54, Th=47, DS=190 for only weed vegetation (Table 16).

The weed flora in the fields of lettuce and red pepper was somewhat different from that in other croplands. Lettuce is cultivated on non-cropping land or on seasonally dry land. *Chenopodium album* and *Capsella bursa-pastoris* are common weeds, but *Brachypodium sylvaticum*, *Potentilla leuconota*, etc. are weeds of dry grassland or plowed grassland, and *Poa annua* of lettuce fields and *Eleusine indica* of red pepper fields are weeds of the seasonally transitional type. The weed flora of red pepper fields seems to be particularly different from that of other croplands. This

Table 35. SDR of crops and weeds in Bondy Fram, Paro, and others.

Species	Crops					
	1	2	3	4	5	6
Crops:						
1. <i>Fragaria</i> × <i>ananassa</i>	79	—	—	—	—	—
2. <i>Brassica oleracea</i> var. <i>capitata</i>	—100	—	—	—	—	—
3. <i>Raphanus sativus</i>	—	—100	—	—	—	—
4. <i>Lactuca sativa</i>	—	—	—100	—	—	—
5. <i>Capsicum annuum</i>	—	—	—	—100	—	—
6. <i>Fagopyrum tataricum</i>	—	—	—	—	—	88
Weeds:						
<i>Erigeron canadensis</i>	51	—	—	—	19	48
<i>Rumex nepalensis</i>	51	—	—	17	—	—
<i>Echinochloa colonum</i>	31	51	—	22	16	58
<i>Persicaria nepalensis</i>	31	—	—	—	—	71
<i>Setaria glauca</i>	26	52	—	—	—	100
<i>Eragrostis nigra</i>	26	—	—	—	—	35
<i>Digitaria sanguinalis</i>	24	—	17	44	—	—
<i>Equisetum arvensis</i>	23	—	33	44	—	—
<i>Equisetum ramosissimum</i>	23	—	—	—	—	—
<i>Galinsoga ciliata</i>	22	21	—	—	—	—
<i>Polygonum fugax</i>	22	—	—	—	—	—
<i>Amaranthus retroflex</i>	19	—	—	—	—	—
<i>Trifolium repens</i> var. <i>giganteum</i>	12	—	—	—	—	—
<i>Taraxacum officinalis</i>	9	—	—	8	—	—
<i>Eclipta prostrata</i>	8	28	—	—	—	—
<i>Amaranthus hybridus</i>	—	24	28	—	—	—
<i>Acalypha australis</i>	—	22	—	—	—	—
<i>Siegesbeckia orientalis</i>	—	—	40	—	15	—
<i>Polygonum</i> sp.	—	—	28	—	—	—
<i>Cynodon dactylon</i>	—	—	15	—	—	—
<i>Malva</i> sp.	—	—	15	—	—	—
<i>Oxalis corymbosa</i>	—	—	15	17	—	—
<i>Juncus griesebachii</i>	—	—	—	36	—	—
<i>Chenopodium album</i>	—	—	—	36	—	36
<i>Aconogonon polystachyum</i>	—	—	—	34	—	—
<i>Brachypodium sylvaticum</i>	—	—	—	34	—	—
<i>Capsella bursa-pastoris</i>	—	—	—	22	—	54
<i>Amaranthus emarginatus</i>	—	—	—	22	—	—
<i>Potentilla leuconota</i>	—	—	—	22	—	—
<i>Anaphalis contorta</i>	—	—	—	22	—	—
<i>Spergula arvensis</i>	—	—	—	17	—	—
<i>Spergularia rubra</i>	—	—	—	17	—	—
<i>Lapsana communis</i>	—	—	—	17	—	—
<i>Portulaca oleracea</i>	—	—	—	17	—	—
<i>Poa annua</i>	—	—	—	17	—	—
<i>Gnaphalium affine</i>	—	—	—	—	24	—
<i>Eleusine indica</i>	—	—	—	—	16	—
<i>Bidens tripartita</i>	—	—	—	—	16	—
<i>Lobelia alsinoides</i>	—	—	—	—	15	—
<i>Clinopodium repens</i>	—	—	—	—	15	—
<i>Compositae</i> sp.	—	—	—	—	14	—
<i>Pycnus sanguinolentus</i>	—	—	—	—	11	—
<i>Lindernia nummularifolia</i>	—	—	—	—	11	—
<i>Potentilla griffithii</i>	—	—	—	—	11	—
<i>Dicrocephala integrifolia</i>	—	—	—	—	9	—
<i>Ranunculus cantoniensis</i>	—	—	—	—	9	—
<i>Ammannia multiflora</i>	—	—	—	—	9	—
<i>Drymaria villosa</i>	—	—	—	—	8	—
<i>Sagina japonica</i>	—	—	—	—	7	—
<i>Cardamine flexuosa</i>	—	—	—	—	6	—
<i>Cannabis sativa</i>	—	—	—	—	—	100
<i>Digitaria cruciata</i>	—	—	—	—	—	52
<i>Poa alpina</i>	—	—	—	—	—	23
<i>Fimbristylis</i> sp.	—	—	—	—	—	23

may be due to an allelopathic effect. There are tropical weeds such as *Lindernia nummularifolia*, and temperate wetland weeds such as *Pycnus sanguinolentus*, *Ammannia multiflora*, *Cardamine flexuosa*, etc. which seem to be similar to those of onion fields.

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