

# Assessment of the Condition of High Altitude Pastures in South Tibet Supported by Land Cover Maps Derived from ASTER Satellite Data

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## Abstract

The paper describes and discusses the experience in mapping pasture types on the Tibetan Plateau. After pasture data recording in the field campaign of 2004 the application of remote sensing and GIS to refine the vegetation mapping became viable. The vegetation types that resulted from the analysis of the field data were aggregated into four main categories ('Kobresia pasture', 'Miscellaneous', 'Steppe', '(Semi) desert'). These categories correspond to the amount of biomass. ASTER satellite data were used to produce base maps for the field studies and to classify the different vegetation types and stages according to their quality and potential use as pasture.

The map provides useful information about the pasture productivity. Concerning the fodder quality, it must be interpreted with caution, because vegetation dominated by poisonous plants can not be differentiated from valuable pasture types within the category 'Miscellaneous'.

KEY WORDS: Pasture condition, Tibet, ASTER satellite data, land cover classification, NDV

## 1. Introduction

The initial concerns for this study were snow catastrophes that caused winter starvation of livestock, and reports about pasture degradation in Tibet. The causes of pasture degradation are complex and varied. Contemporary changes in land use among pastoral communities play a crucial role. According to our hypothesis, the traditional pasture management was sustainable in the sense that the quality and yield of the pastures have been preserved over a long period of time (Holzner and Kriechbaum 2000) as the grazing land has supported pastoral cultures for thousands of years and pastoralism is still the main livelihood there. Pasture degradation is a recent problem in many areas. In a pilot project indicators were developed that allow a rapid assessment of pasture condition (Holzner and Kriechbaum 2000). Later on an interdisciplinary case study in south western Tibet in Porong (Nyalam County, Shigatse Prefecture) was initiated to assess the condition of pastures there and to identify causes for their degradation, as well as to develop management strategies in a participatory way. The first step was an inventory of the pasture vegetation according to dominating plants, pasture quality and pasture management in cooperation with a local expert. Cooperation was built with anthropologists and Tibetologists, who worked in Porong on concepts of territory (Diemberger 2002, Ramble 2002). It was planned to compare historical land use according to documents from the region dating back to the 18th century that record pasture boundaries, taxation rates and stocking rates with the contemporary boundaries and management system.

In the course of the field work in Porong in the year 2002 the idea came up to develop a pasture map displaying the boundaries and areas of grazings with different quality and productivity. Such a map would provide

- a tool for decision support on pasture management
- information to compare to the former land use practices in order to find clues for the cause of the recent pasture degradation
- a basis for an adaptation of livestock numbers appropriate to the productivity of the pastures today.

For this purpose it was planned to extrapolate pasture types from reference areas to the landscape level by combining field work data and remote sensing information.

The paper describes and discusses the experiences in the application of remote sensing for this purpose. The role of GIS and remote sensing for planning strategies for sustainable pasture management is gaining importance (e. g. Ryavec 1998, Rasmussen et al. 1999, van Lynden and Mantel 2001).

## 2. Study area

The study area is located in south-western Tibet (Nyalam County, Shigatse Prefecture), about 700 km west from the capital Lhasa and only a short distance from the main border crossing with Nepal. To the south are the mountains Shishapangma and Gangponchen, to the west the area is bordered by the lake Paiku (Tso). Due to the harsh climate, intensive agriculture is only possible in a very small area close to the lake. All other land is pasture land. The average altitude of winter pastures is 4700 m, while in summer the livestock grazes up to 5500 m. The nearest climate station is located in Dingri (Xegar Dzong) at 4300 m. The average yearly temperature recorded there is 1.9° and the average yearly precipitation is only 263.1 mm.

Today the toponym Porong is used primarily as the name of a „xiang“, which is rendered in English as a township, but actually it is a village cluster. „Greater Porong“ corresponds to an ancient nomad principality governed by a local ruler. The territory of the ancient Porong extended to Dingri and Ngamring County to the north and Kyirong County to the south. We focus on „New Porong“, namely the township Shabkar and its five chief human settlements. According to a census by Dawa Kjutog, carried out in 1998, there were 2000 inhabitants. Today Shabkar is the main village of Porong xiang. It was just a small campsite with no permanent houses before the administrative reforms, according to land rights documents of the former Porong administration. Until 1959 the area was ruled by a semi-autonomous political system sanctioned by the central government of Lhasa and by a body of rituals derived from various traditions of Tibetan Buddhism. The administrative reforms in Porong took place with the framework of the so-called „Democratic Reforms“ that were implemented in 1960. During these reforms the social, political and administrative structure of Tibet were completely changed. In the mid-1960s communes were introduced, in 1980 they were dissolved. In 1990 the whole area has become part of the Qomolangma Nature Preserve.

## 3. Methods

### 3.1. Field data

Vegetation studies were carried out in 2000, 2002 and 2004 using the Central European standard method (Braun Blanquet 1964). The pasture vegetation was classified into 11 pasture types according to the floristic composition and vegetation cover. Gradual transitions between the pasture types are common. GPS was used to geo-reference the vegetation data recorded during the field work in 2004.

### 3.2. Remote sensing data

ASTER satellite data were used because of the availability of scenes covering the temporal and spatial extension of the field study area. Furthermore, ASTER images are free of charge, have a high spatial resolution and provide spectral information suitable for vegetation mapping purposes. The high spatial resolution is necessary to identify one of the most important pasture types in this area, the 'Kobresia pasture', which can grow in small areas undetectable by lower resolution sensors.

ASTER is a multispectral imaging system mounted on TERRA, a satellite launched in December 1999 as part of NASA's Earth Observing System (EOS). An ASTER scene covering 61.5 km x 63.0 km contains data from 14 spectral bands, i.e. three bands in the visible and near infrared spectral range (VNIR, 0.5-1.0  $\mu\text{m}$ ) with 15 m spatial resolution. In the VNIR one nadir-looking (3N, 0.76-0.86  $\mu\text{m}$ ) and one backward-looking (3B, 27.7° off-nadir) telescope provide black-and-white stereo images, which generate an along-track stereo image pair with a base-to-height ratio of about 0.6 (Kamp et al., 2003).

The precondition of low cloud cover was fulfilled by two ASTER scenes (Level 1B), May 17th and October 24th, 2001. The two ASTER scenes provide information about the study area at two different phenological stages.

Further analysis was performed only with the October ASTER scene, which was acquired after the monsoon time, representing the end of the vegetation period.

### 3.3. Orthorectification

The ASTER satellite images were georeferenced by means of ground control points (GCPs), acquired by GPS. In the peripheral region the number of reliable GPS points for georeferencing was insufficient. The available topographic maps were unfeasible for GCP extraction because of their small scale and low quality. Therefore, additional GCPs from external sources were used. GPS points measured by Prof. Dr. R. Kostka (Technical University Graz) and GCPs taken from Google Earth high resolution satellite images were applied. The geometrical accuracy of this data set was checked by comparing the image coordinates with GPS coordinates in the core area.

For the orthorectification of the ASTER image the freely available Shuttle Radar Topography Mission (SRTM) 90m digital elevation model was used. A digital elevation model with a higher spatial resolution could be derived by the ASTER data itself, but this effort is not necessary for the question of the project.

Finally the overall root mean square (RMS) discrepancies between the original GPS measurements and the image coordinates in the rectified May scene was 1.0 pixel

(~ 15 m) and for the October scene 0.8 pixel (~ 12 m).

### 3.4. Classification

The aim of the classification was to classify the different vegetation types and phenological stages according to their quality and potential use as pasture.

A common index used for vegetation studies is the normalized difference vegetation index (NDVI), which is a measure of the proportion of green biomass (Campbell, 1996; Lillesand and Kiefer, 2000). The NDVI was calculated for the whole image. Based on field work data small areas of main pasture types were delineated in the georeferenced satellite image and the corresponding NDVI ranges were determined (Fig.1). As the supplement of water is also essential for grassland vegetation, therefore water bodies and main rivers were delineated automatically by using thresholds. Manual editing was necessary for ponds and tributaries.

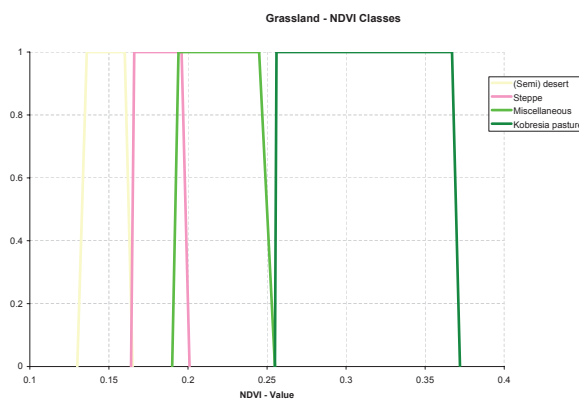


Figure 1: Main pasture categories, classified by NDVI.

## 4. Results

The 11 vegetation types resulting from the analysis of the field data were aggregated into four main categories that could be classified in the ASTER satellite image (Fig. 2):

1. 'Kobresia pasture': a productive pasture type, commonly dominated by *Kobresia schoenoides*
2. 'Miscellaneous': this category comprises of different degradation states of *Kobresia* pastures as well as a 'Steppe' type dominated by *Astragalus*. Poisonous plants, like the locoweed *Astragalus monbeigii*, have increased in area over the last years. This vegetation has a high productivity. It is not only a useless, but even a dangerous pasture. On the map it cannot be distinguished from good pastures with medium productivity.
3. 'Steppe': includes various steppe types dominated by

grasses or grass-like plants (*Carex* spp., *Kobresia* spp., *Stipa* spp., *Trikeriaia hookeri*, *Pennisetum flaccidum*, *Orinus thoroldii*), or by the wormwood (*Artemisia younghusbandii*)

4. '(Semi) desert': strongly degraded pastures with a very low vegetation cover, as well as sand and stone deserts

These categories correspond to the amount of biomass,

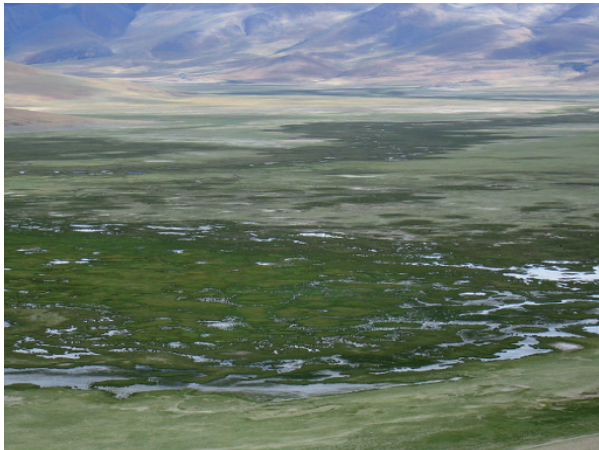


Figure 2a: 'Kobresia pasture': The water level is unusually high due to recent strong precipitation.



Figure 2d: '(Semi) desert' as a result of recent overgrazing; Peku Tso in the background.



Figure 2b: *Astragalus* steppe (category 'Miscellaneous').



Figure 2c: 'Steppe'; Gangponchen in the background.

which is decreasing from 'Kobresia pasture' to '(Semi) desert'. Fig. 3 clearly shows the transition zones from '(Semi) desert' to 'Kobresia pasture' with increasing NDVI.

The October scene was classified as described above and the resulting land cover map is shown in Fig. 4. The analysis of the NDVI reveals that the most important pasture type 'Kobresia' only covers 1% of the area, 5% are covered by the category 'Miscellaneous', 13% are 'Steppe' and 35% of the vegetated area belongs to the '(Semi) desert' class.

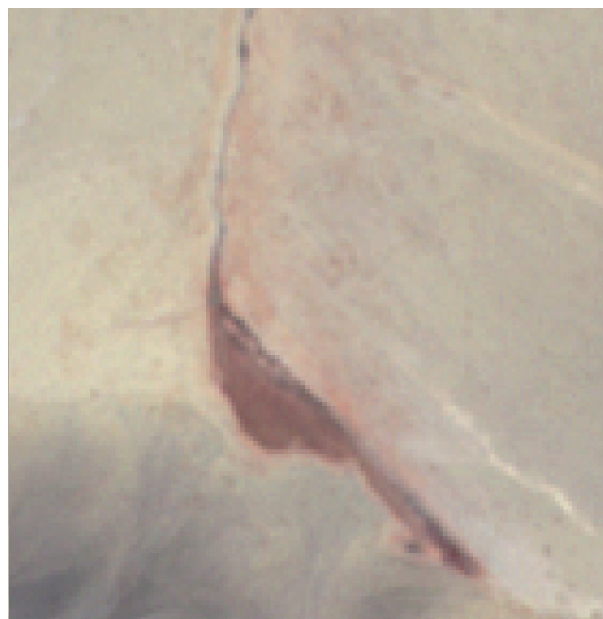
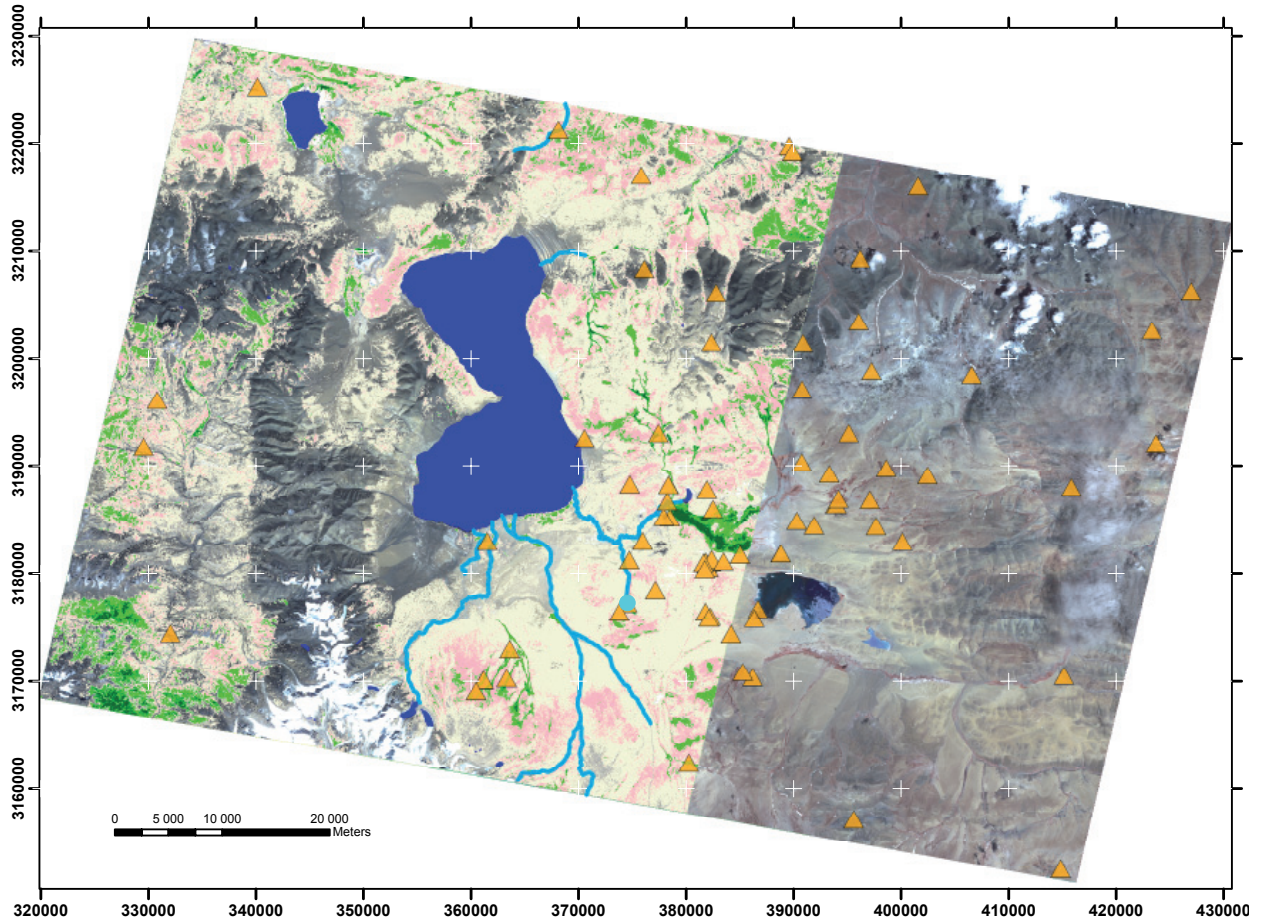


Figure 3a: A detail of the original ASTER satellite image.

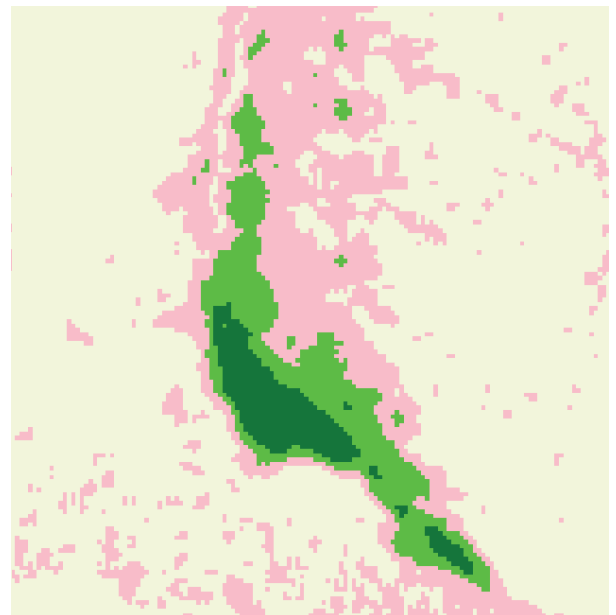
### Porong (Peku Tso)- Tibetan Grassland Management



- Legend**
- ▲ Ground Control Points
  - Main Rivers
  - 1: (Semi) Desert
  - 2: Steppe
  - 3: Miscellaneous
  - 4: Kobresia Pasture
  - 5: Waterbodies

**Figure 4:** Western part: land cover map with classified pasture categories (October 2001); eastern part: unclassified scene (May 2001).

The scene captured in May was acquired shortly after the winter season. The soil is still frozen or wet and the growing season is just beginning. This results in an untypical spectral behaviour of vegetation areas in the image, e.g. the near infrared reflection values of ASTER band 3 are lower than the values of the green and red band (band 1 and 2). Therefore, quantitative analysis of the satellite data was not performed for the May scene. However, this data set is still very useful for the purpose of mapping and documentation of field measurements.



**Figure 3b:** The main pasture categories.

## 5. Discussion

The category 'Kobresia pasture' probably represents the most important and productive pasture type of the region. The vegetation is commonly dominated by large tussocks of „Giant Kobresia“, *Kobresia schoenoides* – na tsa in Tibetan. Under situations where the soil is waterlogged for much of the year, the organic material cannot decompose completely and is deposited as peat. Despite the climatic aridity this phenomenon is quite widespread in Tibet, and can be found not only in the vicinity of lakes and rivers, but over huge areas, where melted water accumulates near the soil surface, because permafrost makes the substrate impermeable. Due to their dark green colour, these „tussock pastures“ are very conspicuous in the landscape. Under increasing grazing pressure the *Kobresia* sp. dies. Its decomposing tussocks are densely covered by small Cyperaceae, forming a pasture type, which is still good as fodder, but is much less productive than the „Giant Kobresia“ bog. The tussocks decompose gradually and partially, and become transformed into rounded hummocks. These „hummock pastures“ with browsing yak or sheep are a common picture in Tibet (and adjacent areas, Holzner and Kriechbaum 1998) and have been included under category 2 ('Miscellaneous').

An greater impact of intensive grazing leads to complete peat decomposition and loss of soil by wind erosion finally resulting in desertification because under the harsh climatic conditions in High Asia the vegetation cannot recover anymore (category 4: 'Semi desert').

The category 'Miscellaneous' is the most problematic from the applied point of view. It includes vegetation types of medium productivity but of different pasture or fodder quality. On the one hand it contains different degradation states of the 'Kobresia pastures' that still are valuable as pasture, but on the other hand it includes *Astragalus steppe* that is dominated by the poisonous *Astragalus monbeigii* and is therefore of no pasture value to yak or sheep.

## 6. Conclusions

The dramatic increase of toxic weeds over vast areas in the last decades is a major problem of the pastures in Tibet. The results show opportunities but also limitations of the usefulness of remote sensing for the assessment of the condition of pastures. The map depicting the different vegetation types provides useful information about the pasture productivity. However, concerning the fodder quality, the pasture map must be interpreted with caution. The dominant pasture weeds, like the „locoweed“ *Astragalus monbeigii*, which features in the 'Miscellaneous' category, is a highly productive but poisonous plant species and cannot be distinguished from palatable pasture species through existing research methods. Further

research is therefore necessary to solve this mapping problem. It is also necessary to test whether the use of satellite data from other seasons when there would exist a phenological change in vegetation such as July or August and intensified field reference mapping with larger sample areas would result in an improved pasture map.

## 7. Acknowledgments

We are grateful to the people of Porong, especially to Kjudog Dawa.

We wish to thank Bernhard Dickoré (Göttingen, Germany) for his assistance in the identification of the plant species and Robert Kostka from the Technical University Graz, Austria for providing field measurements (GPS data)

The pilot study was financially supported by the Commission for development Studies of the Austrian Academy of Science, by the Federal Ministry of Science and Transport of the Government of Austria, and by Eco Himal Salzburg.

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