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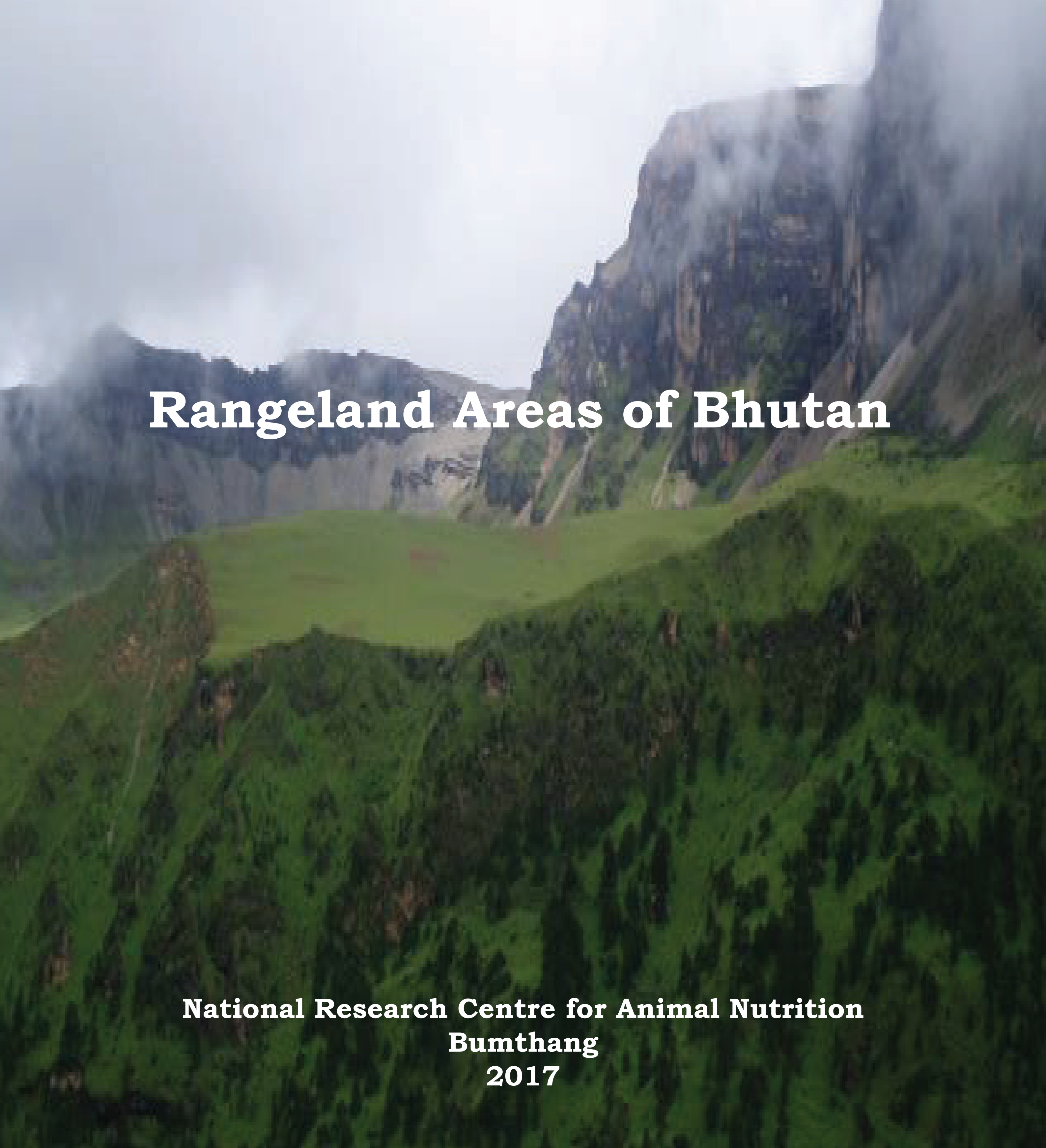

# Rangeland Areas of Bhutan

**National Research Centre for Animal Nutrition**
**Bumthang**
**2017**

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Ministry of Agriculture and Forests
DEPARTMENT OF LIVESTOCK

DoL

# Rangeland Areas of Bhutan

Pema Wangda

**National Research Centre for Animal Nutrition**
**Bumthang**
**2017**

དཔལ་ལྡན་འབྲུག་གཞུང་།
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ROYAL GOVERNMENT OF BHUTAN
Ministry of Agriculture and Forests
Department of Livestock
Thimphu

DoL

# FOREWORD

It gives me immense pleasure to be associated with the publication on the "Rangeland Areas of Bhutan", which is first of its kind in the country, published by the National Research Centre for Animal Nutrition, Jakar, Bumthang, Department of Livestock. This publication, which highlights the total area of rangelands in the country, further sub-divided into different agro-ecological zones in 20 Dzongkhags, will be critical for key decision making and planning in rangeland management and development.

Rangelands play a pivotal role in the Bhutanese livestock production system since rangelands provide a major share of foraging resources for livestock in the country. Besides grazing resource, rangeland ecosystem provides diverse functions in terms of biodiversity conservation, protection of important watersheds and preservation of traditions and culture. Therefore, it is crucial for us to know the area of rangelands and its location in different parts of the country. This publication will help planners and rangeland managers to develop sustainable rangeland management practices. The publication comes as a befitting response to the growing need for data and information for effective planning and management of natural resources in the country. It is thoughtfully designed in acquiring data and information on rangeland areas at different agro-ecological zones of the country, which will also serve as a reference for researchers, teachers and students in rangeland management and development.

On behalf of the National Research Centre for Animal Nutrition and the Department of Livestock, I would like to take this opportunity to express my sincere gratitude to the Bhutan Trust Fund for Environmental Conservation (BTFEC) for their continued support. I would like to especially thank the inputs and innovations of Mr. Pema Wangda, Project Manager for his pro-activeness and taking the lead role in publishing this important document. Please allow me to also commend all the technical advisors and the field work team members for their inputs. I am sure this publication will be an invaluable resource for all those working in rangeland management and development. I would also like to compliment the National Research Centre for Animal Nutrition, Jakar for bringing out this publication.

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## LIST OF ACRONYMS

| | |
|---|---|
| ALOS | Advanced Land Observation System |
| asl | above mean sea level |
| DEM | Digital Elevation Model |
| DoFPS | Department of Forests & Park Services |
| DoL | Department of Livestock |
| ESP | Estimation of Scale Parameters |
| FAO | Food and Agriculture Organization |
| GIS | Geographic Information System |
| GPS | Global Positioning System |
| LCCS | Land Cover Classification Scheme |
| LCMP | Land Cover Assessment Project |
| MIR | Middle Infra Red |
| NDBI | Normalized Difference Built-up Index |
| NDVI | Normalized Difference Vegetation Index |
| NDSI | Normalized Difference Snow Index |
| NDWI | Normalized Difference Water Index |
| NIR | Near Infra Red |
| NSSC | National Soil Service Centre |
| OBIA | Object Based Image Analysis |
| OLI | Operational Land Imager |
| PPD | Policy and Planning Division |
| RS | Remote Sensing |
| SRTM | Shuttle Radar Topography Mission |
| UNEP | United Nations Environment Programme |

# 1. INTRODUCTION

## 1.1. Background

Rangelands in Bhutan are synonym with the term *"Tsamdro"*, which basically means grazing land for livestock and wild ungulates. Rangelands are important source of livelihood for majority of the rural population in Bhutan, as rangelands provide wide array of economic, social and ecological functions. Globally, rangeland is defined as "those areas of land, which by reason of physical limitations, low and erratic precipitation, rough topography, poor, drainage or extreme temperature, are unsuited for cultivation, and which are a source of forage for free ranging native and domestic animals as well as a source of woody products, water and wildlife" (Stoddart et al., 1975). Theoretically, Bhutan has about 4,00,000 hectares of registered grazing (Roder et al., 2001) registered in the name of individuals, communities and institutions. However, the registered "*Tsamdro"*/grazing areas has very little relevance to the area actually utilized for grazing by the grazers (Tshering, 2004). This is because the livestock are found to be grazing in the forests and scrublands adjoining the villages and dwellings. Rangelands in Bhutan are also known as "*ri*" in Dzongkha, which means a range shed when used in the context as a source of grazing, collection of firewood and non-edible products, medicinal or incense plants (Gyamtsho, 1996). The rangelands in Bhutan extend from subtropical zones in the south to the alpine zones in the northern parts of the country. The subtropical and temperate rangelands are found at elevations ranging from 150 to 3600 metres asl and the alpine meadows are found at an elevation range of 3600 – 5000 metres asl.

## 1.2. Importance of rangeland mapping

"*Tsamdro*" in Bhutan is one of the important natural resources from the socio-economic, socio cultural and environmental perspectives since time immemorial. Traditionally, the importance of "*Tsamdro*" is associated with livestock rearing and it provides as an important source of livelihoods to herders and communities in harsh high altitude environments. However, with the impacts of climate change and unsustainable utilization of rangeland resources, it has become increasingly important to devise sustainable management of rangelands. Sustainable management of rangeland resources are important not only from the socio-economic and cultural perspectives, but also for the sustenance of wide array of ecological services such as maintenance of rich habitat for endangered flora and fauna, protection of important upstream water source and watersheds, sequestration of carbon in rangeland ecosystem and climate stabilization. The most common traditional rangeland management practice adopted by the rangeland users in Bhutan was burning of rangelands, but a ban on burning was imposed in 1970s. Since then, there were no proper management practices in place. Many studies have indicated that rangelands in Bhutan have been deteriorating in terms of both quality and quality (Chophyel, 2009; Gyaltsen et al., 2002; Gyamtsho, 1996; Tshering, 2004), notably being the encroachment of the rangelands by shrubs. However, there is no concrete information or data to quantify degradation of rangelands by shrub encroachment. Therefore, there is a need to generate accurate and up to date information on land cover changes with emphasis on the rangeland areas in different agro-ecological zones.

Over the years, the importance of rangeland resources management is being increasingly recognised due to their economic, ecological importance and the vulnerability of the rangelands to various forms of land degradation. Therefore, accurate and up-to-date information on rangeland area is crucial for rangeland management planning, decision-making and ecosystem monitoring. Remote sensing and GIS is globally recognized as an important role in gathering reliable and up-to-date information of land cover over large areas in relatively shorter time periods. Many studies have been conducted using mid-resolution satellite imageries for land cover and land use mapping including the rangeland resources. However, the remote sensing and GIS techniques have not been widely applied for mapping of rangelands especially in Bhutan due to high cost in terms of data and image processing software, unskilled manpower, etc. With the availability of readily downloadable remote sensing data, reduction in data cost and the skilled human resources in GIS and remote sensing, the GIS and remote sensing techniques will make greater play an important role in updating and generating data and information needed for planning and decision-making agencies. Moreover, the availability of historical remote sensing data enables providing relevant past data and information on land cover changes for monitoring purposes at various temporal and spatial scales.

Land cover and land use classification for Bhutan using remotely sensed data were undertaken in 1995 and 2010, but the land cover maps generated are very broad comprising of general land cover classes. Therefore, this study was carried out to classify and map the rangeland area coverage in all 20 Dzongkhags. Moreover, rangeland areas were further classified into different agro-ecological zones of the country.

### 1.3. Objectives

The objective of this study is to classify and map the rangeland areas of Bhutan. Using the Landsat TM images (30 m spatial resolution), SRTM Digital Elevation Model (DEM 30m spatial resolution) and other GIS ancillary data, an Object Based Image Analysis (OBIA) techniques was applied for rangeland area mapping.

## 2. DESCRIPTION OF THE STUDY AREA

### 2.1. Study Area

Bhutan is situated between longitude 88° 54’ and 92° 10’ East and latitude 26° 40’ and 28° 15’ North. Bhutan is bordered by China in the North and India in the East, West and South. The entire 38,394 sq. km of geographical area of Bhutan is mountainous with little flat plain limited to southern parts of the country. The elevation varies from 100m asl in the southern foothills to more than 7,700m asl in the northern mountains. Bhutan has a wide variety of climatic conditions influenced by the topography, elevation and rainfall patterns.

The study area encompasses the entire country which stretches approximately 300km from East to West and approximately 150km from North to South. Grazing areas in Bhutan is locally known as *“Tsamdro”.* Many *“Tsamdro”* in Bhutan were registered either in the name of individuals, communities or institutions, maintaining their user rights prior to Land Act 2007 of Bhutan. However, the Land Act 2007 nationalized all *“Tsamdro”* with the provisions to avail the nationalized *“Tsamdro”* on lease by any Bhutanese citizen, whose livelihood is dependent on livestock rearing.

## 2.2 Climate and Agroecological zones

Climate in Bhutan is dominated by monsoon with dry winters and high precipitation during the summer months starting from June till September. Bhutan is divided into six agro-ecological zones namely alpine, cool temperate, warm temperate, dry sub-tropical, humid subtropical and wet subtropical (PPD, 2015). Table 2.1 shows the agro-ecological zones of Bhutan.

Table 2.1: Agro-ecological Zones; (PPD,2015)

| Agro-ecological Zones | Altitude (m) |
|---|---|
| Alpine | >3600 |
| Cool temperate | 2600-3600 |
| Warm temperate | 1800-2600 |
| Dry sub-tropical | 1200-1800 |
| Humid subtropical | 600-1200 |
| Wet subtropical | 100-600 |

In this report, the agro-ecological zones are adopted to include three broad areas of alpine, temperate and sub-tropical zones as shown in table 2.2.

Table 2.2: Adopted Agro-ecological zones

| Agro-ecological Zones | Altitude (m) |
|---|---|
| Alpine | >3600 |
| Temperate | 1800-3600 |
| Subtropical | 100-1800 |

## 2.3 Land Cover Classes

The latest land cover classification for Bhutan was carried out by National Soil Service Centre (NSSC) and the Policy and Planning Division (PPD) of the Ministry of Agriculture and Forests, Royal Government of Bhutan in 2010. The classification was carried out using ALOS images (AVNIR-2) with 10m spatial resolution from the 2006-2009 winter seasons. The LCMP 2010 report has identified eleven broad land cover classes in Bhutan which is presented in Table 2.2.

Table 2.3: Land Cover types of Bhutan; Source (MoAF, 2010)

| Land Cover Class | Area (Hectares) | % of Area |
|---|---|---|
| Forests | 2705291.2 | 70.46 |
| Shrubs | 400526.40 | 10.43 |
| Meadows | 157568.51 | 4.10 |
| Cultivated/Agricultural Land | 112556.21 | 2.93 |
| Built-up Areas | 6150.87 | 0.16 |
| Non-Built up Areas | 330.10 | 0.01 |
| Snow cover | 285479.22 | 7.44 |
| Bare Areas | 122973.58 | 3.20 |
| Water bodies | 27568.78 | 0.72 |
| Marshy land | 319.47 | 0.01 |
| Degraded Areas | 20635.44 | 0.54 |

# 3. DESCRIPTION OF METHOD AND DATA USED

## 3.1. Dataset and Materials used

- 3 tiles of Landsat TM images (30m spatial resolution) from January and February 2016
- SRTM DEM (30m spatial resolution)
- Google Earth Image
- Bhutan boundary shape file and other ancillary data
- Dzongkhag and Gewog boundary shape file
- ArcMap 2010, ERDAS Imagine, eCognition Developer version 8

## 3.2. Methods

The overall methodologies include selection of image classification scheme, acquisition of the satellite images, image rectification and enhancement, legend formulation, image classification, collecting of validation data and the object based image analysis. The object based image analysis is further subdivided into image segmentation and image classification. The detailed methodology is described in the subsequent paragraphs. The general methodology for identification and classification of rangeland is shown as a schematic representation in Figure 3.1.

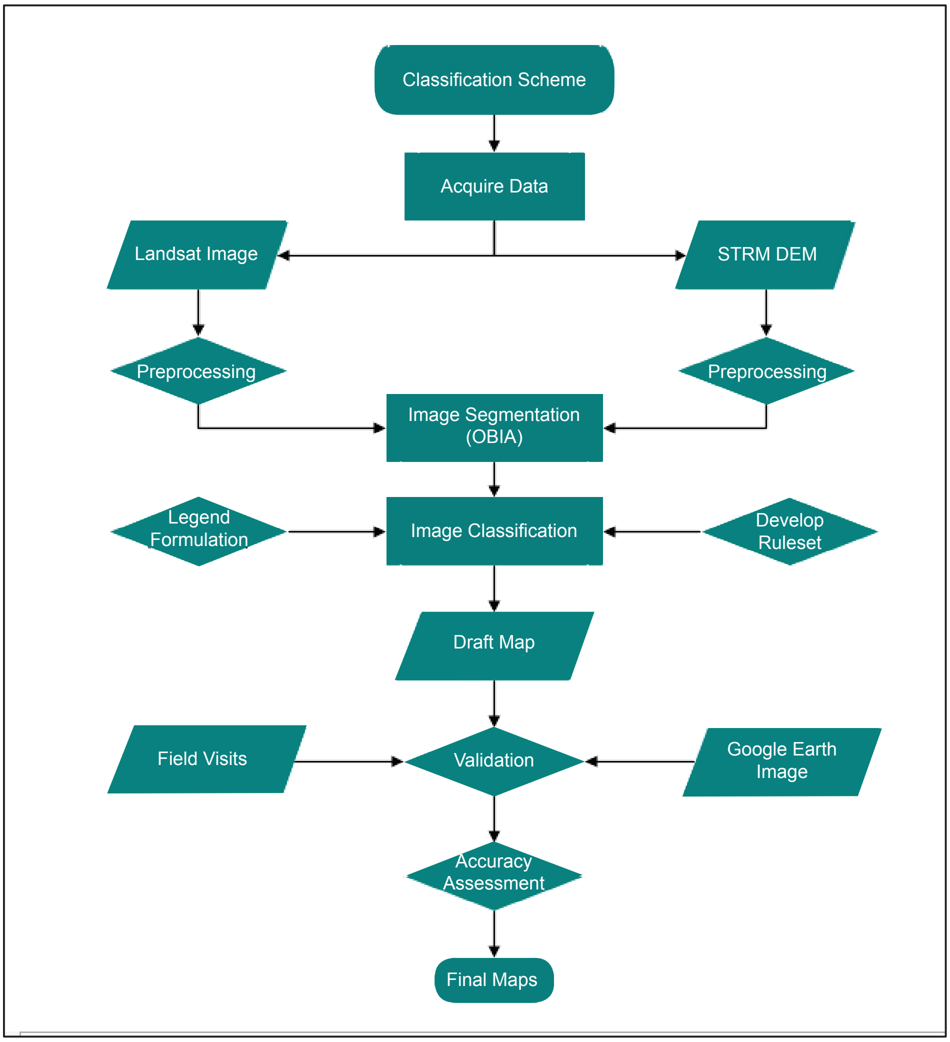



Figure 3.1: The methodological flowchart for classification

### 3.2.1. Pre-processing of optical data

Image pre-processing also called as image restoration and rectification is usually carried out prior to data analysis. The pre-processing corrects for any distortion due to the characteristics of the imaging system and imaging conditions. These procedures include radiometric correction to correct for uneven sensor response over the whole image and geometric correction to correct for geometric distortion due to Earth's rotation and other imaging conditions. The Landsat 8 OLI images were pre-processed and geo-referenced to DRUKREF03 projection system. Parts of three separate Landsat image tiles acquired during the month of January and February 2016 covered the entire country. The Landsat image tiles were atmospherically corrected followed by mosiacking and then sub setting the mosiaked image to the study area.

### 3.2.2. Image filtering

Image filtering is an image enhancement technique for improving the visual interpretability of an image. Filtering produces more homogeneous image segments and reduces the amount of convolution in the final segmented objects (Mora et al., 2010). The filtering process enhances the distinction between image objects and the background by removing the image noise occurred during data acquisition (Ke et al., 2011). An average filter size of 3x3 pixels window were used since, it gave better visualization when applied to the mosaicked Landsat image.

## 3.3. Object based image segmentation

The basic units for object based image classification are the image objects or the segments rather than the pixels as compared to traditional pixel based classification (Blaschke, 2010). In addition to the spectral information of an image, the object-based classification also uses other information such as shape, texture, and contextual relationships (Ke et al., 2010). The image segmentation is discussed in the following section.

### 3.3.1. Image segmentation

Various image segmentation algorithms are available such as region growing, multi-resolution segmentation, chessboard segmentation etc. Two basic segmentation approaches available in eCognition are top-down approach which cuts objects into smaller pieces and bottom-up approach which merges smaller pieces into larger objects (Definiens, 2009b). Among many image segmentation algorithms, multi-resolution segmentation was chosen in this study because it has been proven to be effective for the more complex structure of land cover classes.

### 3.3.2. Multi-resolution image segmentation

Multi-resolution segmentation is the process of delineating individual objects in the image based on homogeneity criteria such as colour, shape and texture (Definiens, 2009a). For a given number of image objects, it minimizes the average heterogeneity and maximizes their respective homogeneity for producing meaningful objects.

Scale parameter is an important parameter in multi-resolution segmentation and is used to determine the upper limit for a permitted change of heterogeneity throughout the segmentation process (Definiens, 2009b). It also determines the average image object size. The success of multi-resolution segmentation depends on selecting the appropriate scale parameter combinations. In order to select the best parameter combinations, the Estimation of Scale Parameter (ESP) tool was used. The best combination of parameters was chosen as scale 12, shape 0.2 and compactness 0.5 for the segmentation. Using the chosen scale parameters, the image segmentation was performed in eCognition Version 8 software.

### 3.3.3. Generation of image indexes

Vegetation Indices (VI) are optical measures of vegetation canopy greenness widely used as proxies in estimating key measurements for land cover and land cover change detection, natural resource management and sustainable development (Huete et al., 2006). Among the VIs, Normalized Difference Vegetation Index (NDVI) is widely used spectral vegetation indicator of vegetation biophysical measurements. The NDVI was calculated using the equation (i) to extract forest, shrub land and grassland classes.

$$NDVI = \frac{(NIR - RED)}{(NIR + RED)} \dots\dots\dots\dots \text{ Equation (i)}$$

Other key class visible in the image was the presence of snow and glacier in the northern part of the study area. To distinguish the glacier and snow from the background image, the most commonly used index is Normalized Difference Snow Index (NDSI). The NDSI was calculated based on the equation (ii) as proposed by (Hall et al., 1998). Similarly, water bodies such as lakes, rivers, reservoirs and streams was extracted from the image using the Normalized Difference Water Index (NDWI), proposed by Mcfeeters. S (1996), as shown in equation (iii).

$$NDSI = \frac{(Green - MIR)}{(Green + MIR)} \dots\dots\dots\dots \text{Equation (ii)}$$

$$NDWI = \frac{(Green - NIR)}{(Green + NIR)} \dots\dots\dots\dots \text{Equation (iii)}$$

To extract the built-up areas, the built-up land index was produced using the Normalized Difference Built-up Index (NDBI) of (Zha, 2003) with the following equation (iv).

$$NDBI = \frac{(MIR - NIR)}{(MIR + NIR)} \dots\dots\dots\dots \text{Equation (iv)}$$

## 3.4. Legend formulation and assigning classes

The legends for the classification were formulated using Land Cover Classification System (LCCS). LCCS was developed by FAO and UNEP. It is a comprehensive methodology for describing, characterization, classification and comparison of most of land cover features identified anywhere in the world, at any scale or level of details. LCCS is a priori classification system where land cover classes are defined by a combination of set of independent diagnostic criteria that are hierarchically arranged to assure a high degree of geographical accuracy. In this study, following land cover classes were taken into consideration.

1. Forests
2. Shrub land
3. Grassland
4. Settlements
5. Agriculture
6. Bare Areas
7. Snow and Glaciers
8. Water Bodies

### 3.4.1. Description of land cover classes

FORESTS
The class "Forests" are those areas covered by trees and includes coniferous forests, broadleaved forests, mixed coniferous forests and mixed broadleaved conifer forests.

AGRICULTURE LAND
Agriculture land includes those areas that are cultivated such as Chhuzhing (paddy terraces), Kamzhing (dry land) and Horticulture land/orchards.

SHRUBLAND
The class "Shrub land" are those areas with perennial plants consisting of woody stems without any defined main stem. It includes scrubland at high elevations consisting of dwarf rhododendron, dwarf bamboo etc., as well as abandoned agricultural fields with overgrown bushes. This class is further subdivided into three sub-classes based on the elevation into subtropical, temperate and alpine shrub land classes.

GRASSLANDS
The class "Grasslands" include those areas which are dominated by grasses with or without few scattered trees or shrubs on it. It includes both the native grasslands as well as the improved pasture fields and is found in all elevations. This class is further subdivided into three sub-classes based on the elevation into subtropical grassland, temperate grassland and alpine grassland classes.

SETTLEMENTS
The class "settlements" include those areas with houses in rural and urban areas including airports, industrial areas, sports facilities roads, mines, stone quarries, waste dump sites, etc.

BARE AREAS
The class "Bare Areas" include areas with less than 4% vegetation cover such as natural cliffs, rocky areas, scree, bare soils and degraded areas.

WATERBODIES
The class "Water bodies" include lakes, reservoirs and rivers.

SNOW AND GLACIERS
The class "Snow and Glaciers" include areas covered with snow and glacial deposits, mostly found in high elevations.

### 3.4.2. Assigning classes

The segmented image objects were assigned into broad classes of vegetation, snow and glacier, bare areas, agriculture, settlements and water bodies based on the NDVI, NDSI, NDWI, NDBI and the mean layer values of individual bands. Rules sets were developed in eCognition software version 8 to assign the segmented objects into meaningful classes. Each of the segmented objects were assigned into different land cover classes.

## 3.5. Collection of validation data

The validation samples were collected in the field through vigorous field visit to the rangeland and non-rangeland sites. From the total of 2800 validation points used, 1500 validation points were collected from the field using the Global Positioning System (GPS) and the 1300 remaining validation points were gathered from the Google earth image.

### 3.6. Image classification based on elevation

Further classification was based on a geo-referenced DEM according to the different agro-ecological zones. Out of the six agro-ecological zones, three broad agro-ecological zones were selected for this namely alpine zone (above 3600 m asl), temperate zone (1800-3600m asl) and subtropical zone (below 1800m asl) for classifying the shrub land and grassland classes into alpine, temperate and subtropical zones.

### 3.7. Accuracy assessment of the classified image

Accuracy assessment is a quality assurance step in which classification results are compared with the land cover types on the ground. The accuracy assessment of the classified image determines the quality of the information derived from remotely sensed data. The accuracy of the classified map is the most important component of image classification to ensure reliability of the classified maps. The classification accuracy was carried out to ensure the reliability of the map.

# 4. RESULTS

## 4.1. Main findings

The objective of this report was to generate a reliable rangeland map of Bhutan through GIS and remote sensing technique. Using the Object Based Image Analysis (OBIA) technique, a land cover map was developed followed by further classification of rangelands based on the agro-ecological zones of the country. The general land cover map generated is shown in Figure 4.1.

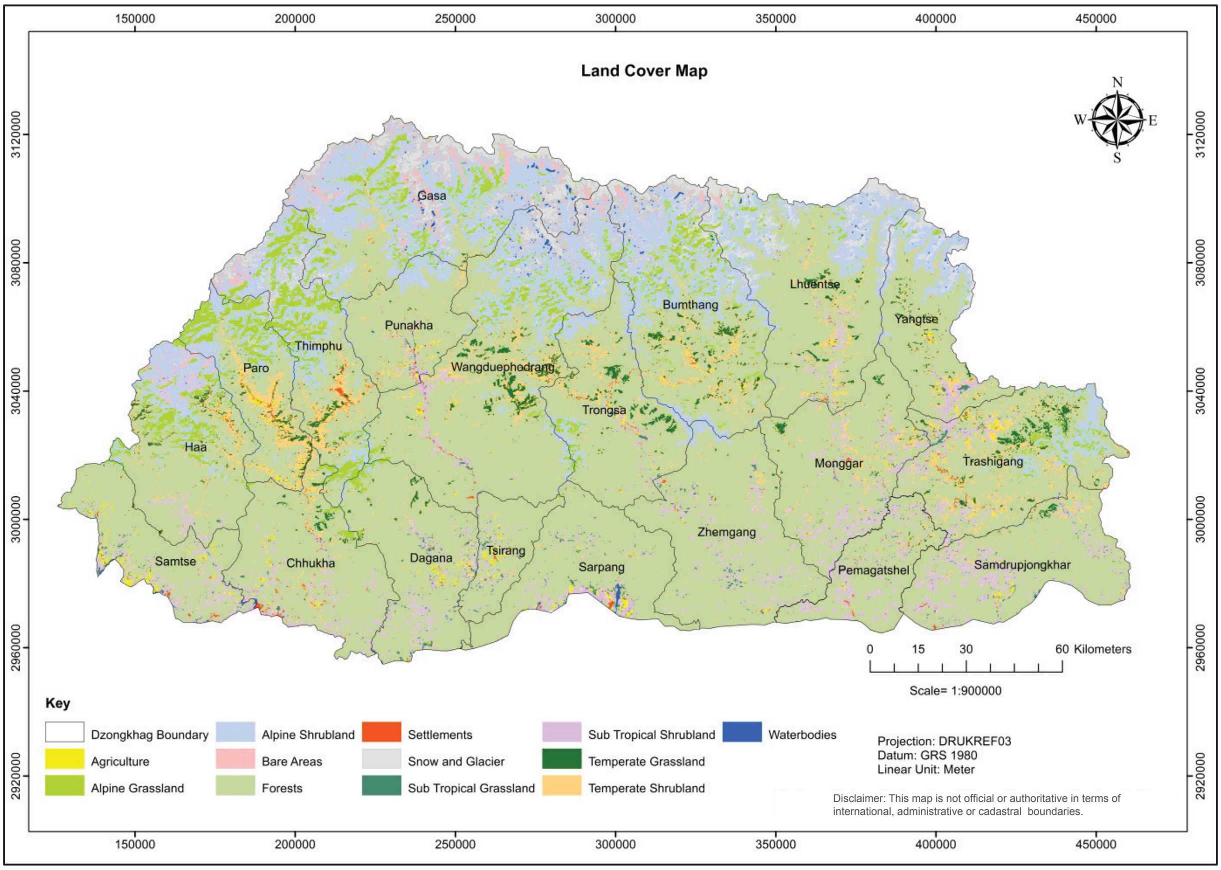



Figure 4.1: Land Cover Map

Of the Bhutan's total area of 38,394.00 $km^2$, the shrub land and grassland covers an area of 5002.62 $km^2$ and 1034.63 $km^2$ respectively. An area of 28269.72 $km^2$ (73.63%) is covered by other classes such as forests, agriculture, water bodies, snow and glaciers, bare areas and settlements as indicated in Table 4.1. Within the other classes, the forests is the major land cover type at 70.67% of the country land, followed by snow and glaciers at 7.52%, agriculture land at 2.75% and bare areas at 2.51%. Water bodies and settlements constitute 0.62% and 0.20% respectively. The class wise coverage of different land cover types is shown in table 4.1

Table 4.1: Coverage of different land cover classes

| Sl. No | Land Cover Class | Area (Sq. km) | Area (Hectares) | Area (Acres) | % Area |
|---|---|---|---|---|---|
| 1 | Forests | 27134.56 | 2713455.24 | 6705093.92 | 70.67 |
| 2 | Shrub land | 5002.62 | 500262.26 | 1236175.01 | 13.03 |
| 3 | Grassland | 1034.63 | 103463.49 | 255663.83 | 2.69 |
| 4 | Agriculture land | 1056.50 | 105650.02 | 261066.88 | 2.75 |
| 5 | Bare Areas | 965.23 | 96522.65 | 238512.66 | 2.51 |
| 6 | Settlements | 78.66 | 7865.42 | 19435.88 | 0.21 |
| 7 | Snow and Glaciers | 2885.32 | 288532.15 | 712978.47 | 7.52 |
| 8 | Water bodies | 236.49 | 23648.77 | 58437.36 | 0.62 |
| | Total | 38394.00 | 3839400.00 | 9487364.01 | 100 |

The figure 4.2 shows that the forest constitutes 70.67% and shrub land 13.03% of the country's total area, while agriculture land and meadows account for 2.75% and 2.69 % respectively. The snow and glaciers constitute 7.52 %, while bare areas constitute 2.51%. Settlements and water bodies constitute 0.21 % and 0.62% respectively.

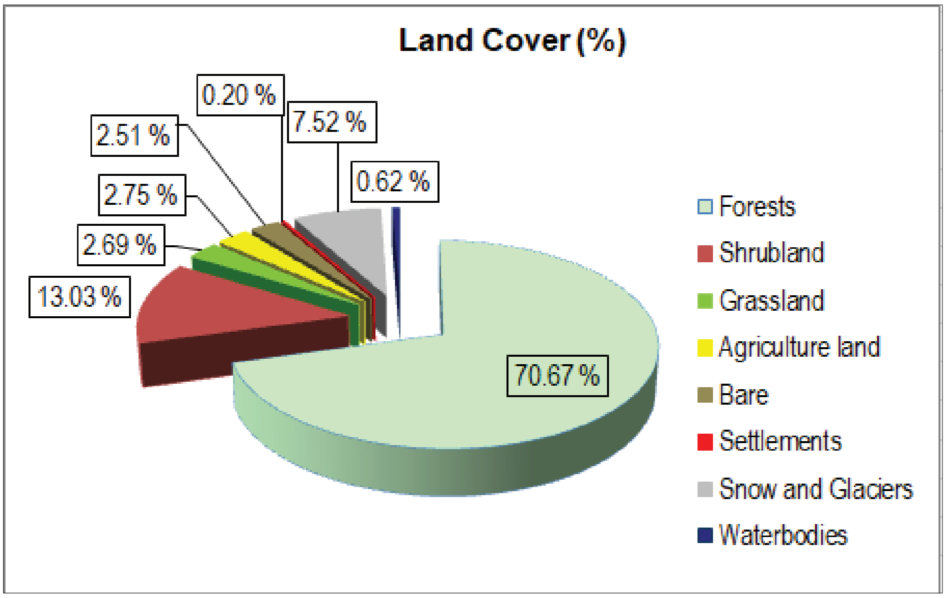



Figure 4.2: Land cover types in percentage

## 4.2. Accuracy of the classification

A total of 2800 objects were used for assessing the classification accuracy. Accuracy assessment was carried out using the standard accuracy assessment procedure of an error matrix in ERDAS imagine software. Users and Producers accuracy were computed from the error matrix. The table 4.2 shows the accuracy totals of the classification for all classes.

Table 4.2: Accuracy totals of the classification for all classes

| Class Name | Reference Totals | Classified Totals | Number Correct | Producers Accuracy | Users Accuracy |
|---|---|---|---|---|---|
| Agriculture land | 70 | 74 | 70 | 100.00% | 94.59% |
| Bare Areas | 504 | 532 | 476 | 94.44% | 89.47% |
| Forests | 276 | 290 | 262 | 94.93% | 90.34% |
| Grassland | 207 | 202 | 198 | 95.65% | 98.02% |
| Shrub land | 982 | 997 | 965 | 98.27% | 96.79% |
| Snow & glaciers | 273 | 231 | 210 | 76.92% | 90.91% |
| Settlements | 194 | 185 | 164 | 84.54% | 88.65% |
| Water bodies | 294 | 289 | 221 | 75.17% | 76.47% |
| Totals | 2800 | 2800 | 2566 | | |

The overall classification accuracy for the land cover map is 91.39% with a kappa statistics of 0.89. The conditional kappa statistics for each category is given in Table 4.3.

Table 4.3: Conditional kappa statistics

| Class Name | Kappa |
|---|---|
| Agriculture land | 0.94 |
| Bare Area | 0.87 |
| Forests | 0.89 |
| Grassland | 0.94 |
| Shrub land | 0.95 |
| Snow & Glaciers | 0.89 |
| Settlements | 0.87 |
| Water bodies | 0.74 |

## 4.3. Mapping rangeland areas

The classified and validated land cover map was reclassified into rangeland and non-rangeland types. The land cover under rangeland types includes the classes “shrub land and grassland” at broad agro-ecological zones of sub-tropical, temperate and alpine zones. The non-rangeland type includes forests, settlements, snow and glaciers, bare areas, agriculture and water bodies. The rangeland map based on the elevation range is shown in figure 4.3.

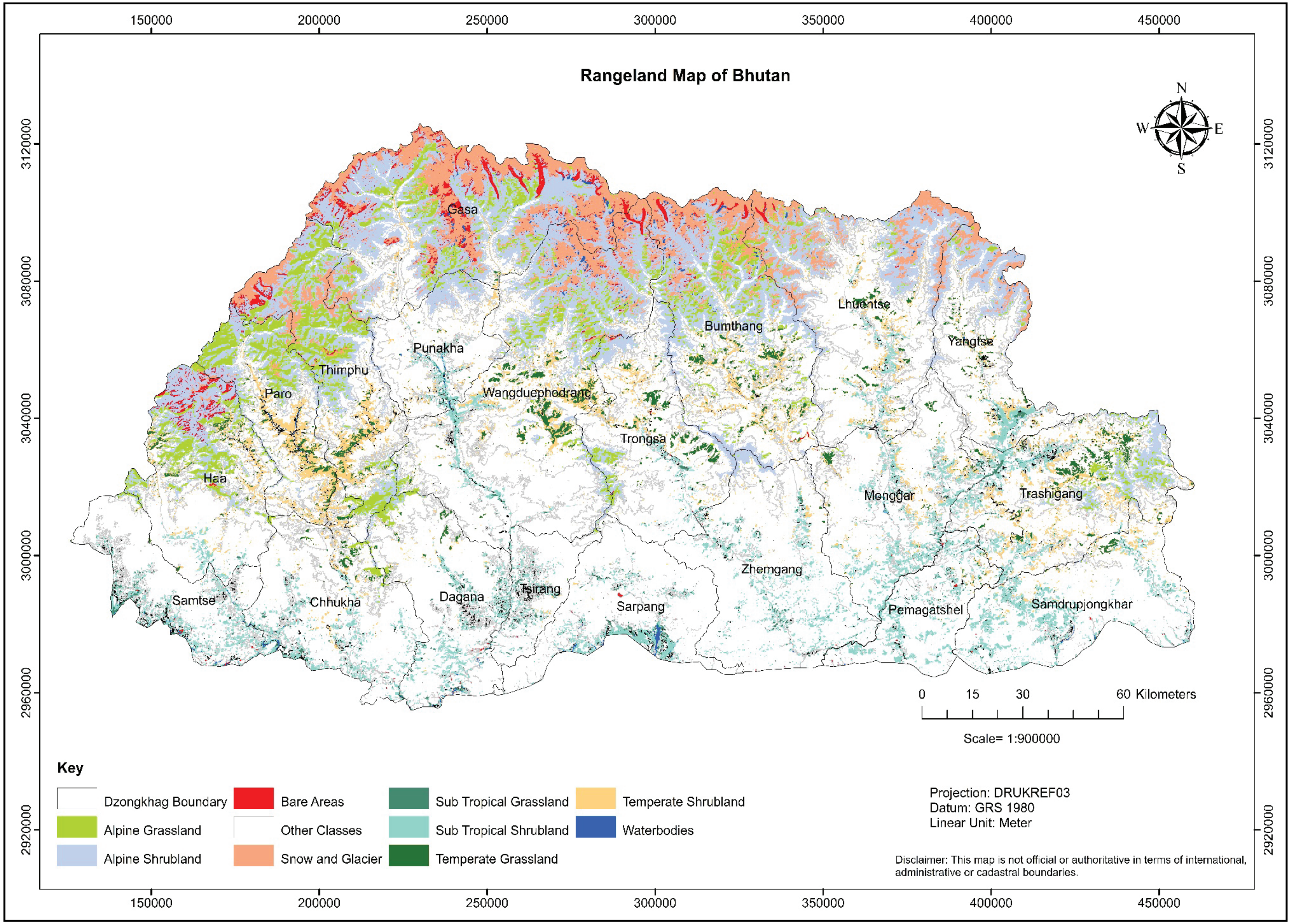



Figure 4.3: Rangeland Map

Rangeland in this report means the classes "Shrub land and Grassland", which is further divided into alpine, temperate and subtropical classes. Table 4.2 shows the rangeland cover types of according to the agro-ecological zones.

Table 4.2: Rangeland cover types according to agro ecological zones

| Sl. No | Rangeland Types | Area (Sq. km) | Area (Ha) | Area(Acres) |
|---|---|---|---|---|
| 1 | Alpine Grassland | 736.34 | 73634.44 | 181954.66 |
| 2 | Alpine Shrub land | 3952.63 | 395262.70 | 976715.40 |
| 3 | Sub-Tropical Grassland | 64.80 | 6480.04 | 16012.53 |
| 4 | Sub-Tropical Shrub land | 475.97 | 47597.36 | 117615.64 |
| 5 | Temperate Grassland | 233.49 | 23436.45 | 57912.73 |
| 6 | Temperate Shrub land | 574.02 | 57314.75 | 141627.88 |
| | | 6037.26 | 603725.74 | 1491838.83 |

Rangeland (shrubland and grassland) covers an area of 6037.26 km² which constitute about 15.72% of the country's total area. From the 6037.26 km² (15.72%) of the classified rangeland areas, the shrub land comprises an area of 5002.62 sq. km (13.03%) and the grassland constitutes an area of 1034.63 km² (2.69%). Figure 4.3 shows the percentage of alpine, temperate and sub-tropical rangeland classes from the country's total area.

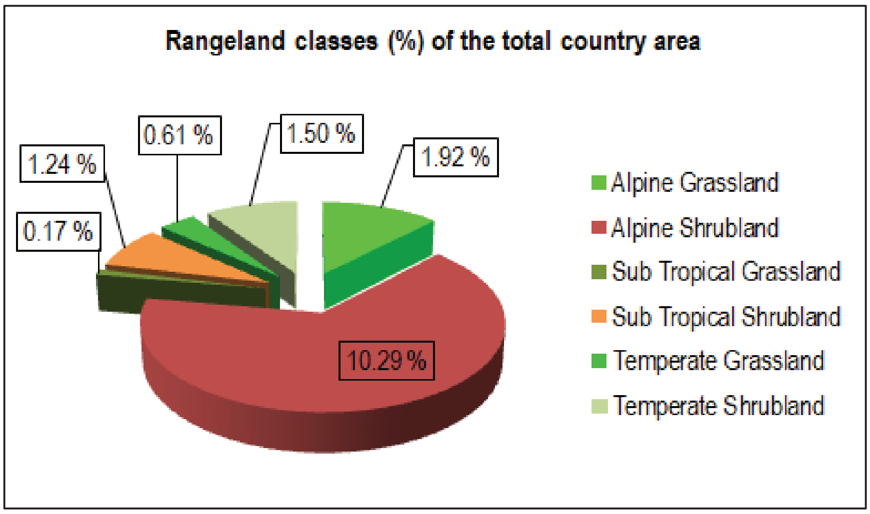



*Figure 4.4: Rangeland class of the total country area in percentage*

Within the 15.72% rangeland class, the alpine shrub land constitutes a major portion with an area of 3952.63 km² (65.47% of the total rangeland area), followed by alpine grassland at 736.34 km² (12.2%). The areas for temperate shrub land and temperate grassland are 574.02 km² (9.51%) and 233.49 km² (3.87%). Subtropical shrub land and grassland constitutes an area of 475.97 km² (7.88 %) and 64.80 km² (1.07%) respectively.

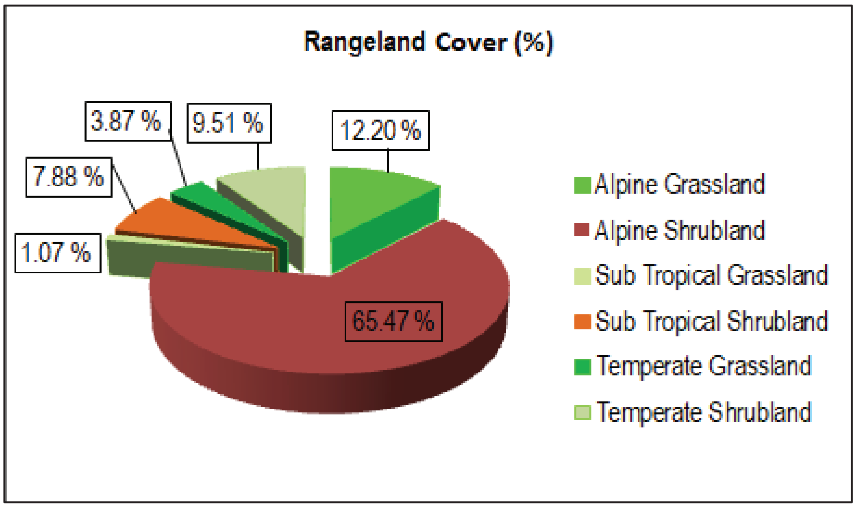
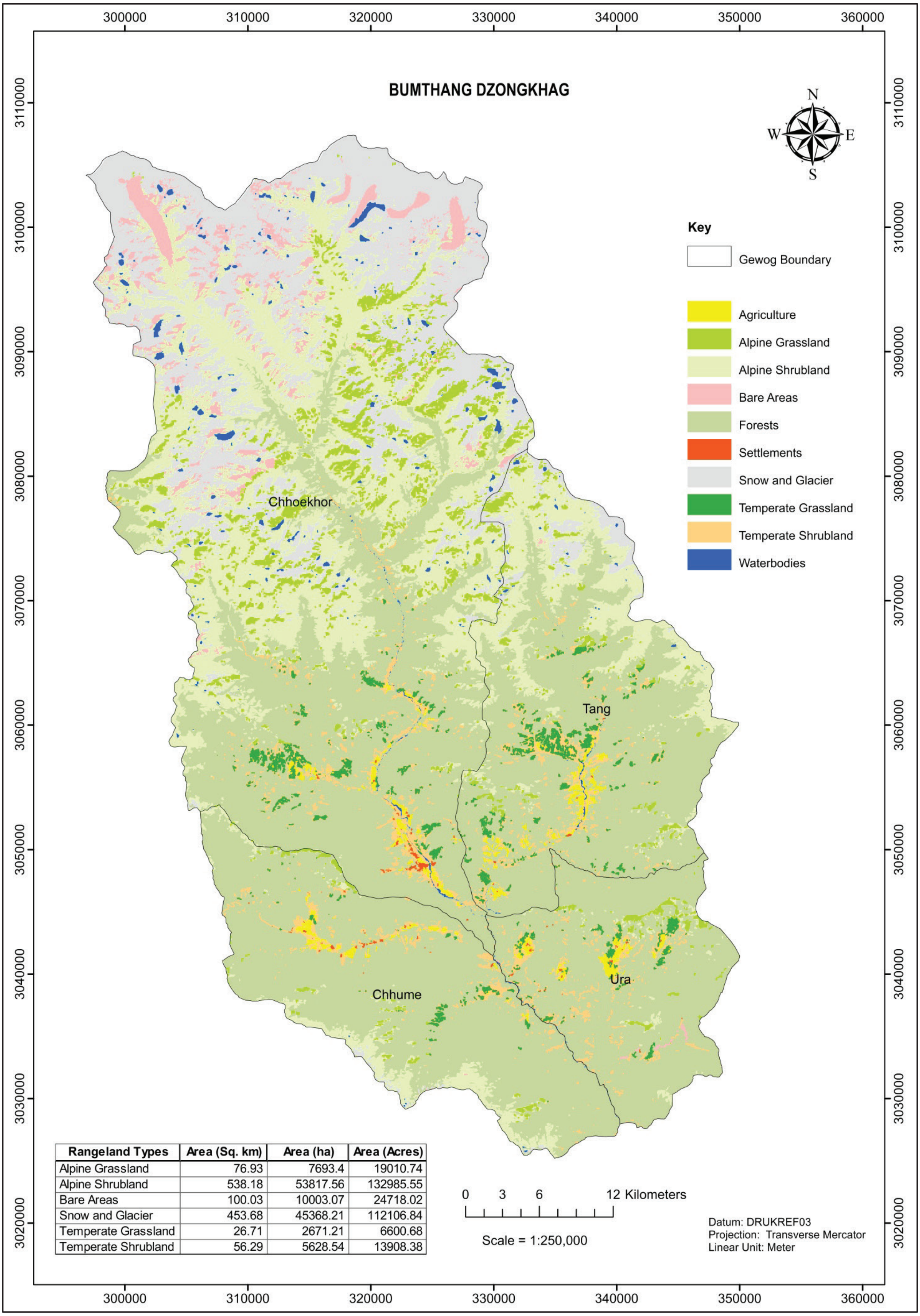



*Figure 4.5 Rangeland cover in percentage*

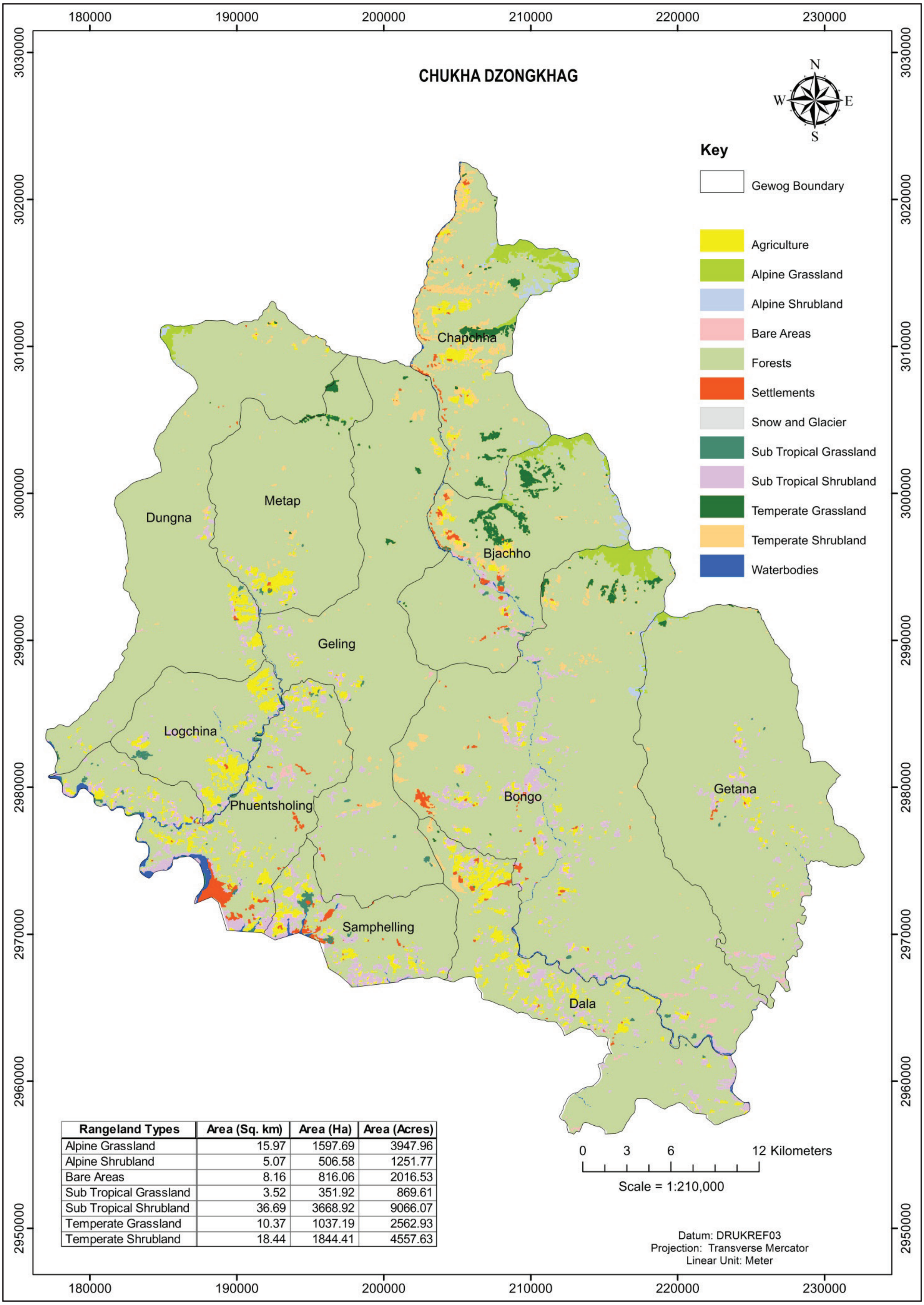
## 5. DZONGKHAG WISE RANGELAND MAPS

## Bumthang Dzongkhag



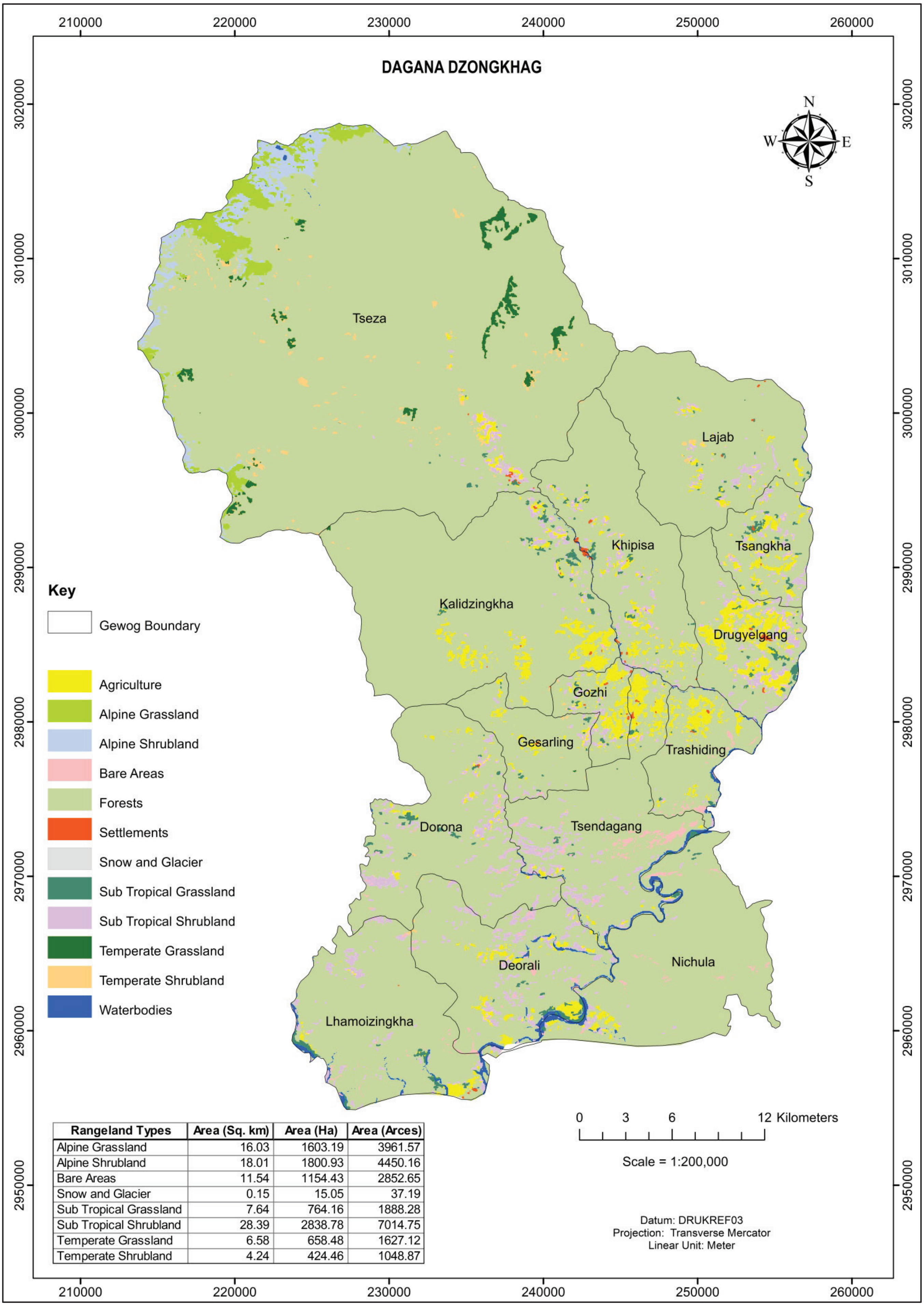

| Rangeland Types | Area (Sq. km) | Area (ha) | Area (Acres) |
|---|---|---|---|
| Alpine Grassland | 76.93 | 7693.4 | 19010.74 |
| Alpine Shrubland | 538.18 | 53817.56 | 132985.55 |
| Bare Areas | 100.03 | 10003.07 | 24718.02 |
| Snow and Glacier | 453.68 | 45368.21 | 112106.84 |
| Temperate Grassland | 26.71 | 2671.21 | 6600.68 |
| Temperate Shrubland | 56.29 | 5628.54 | 13908.38 |

## Chukha Dzongkhag



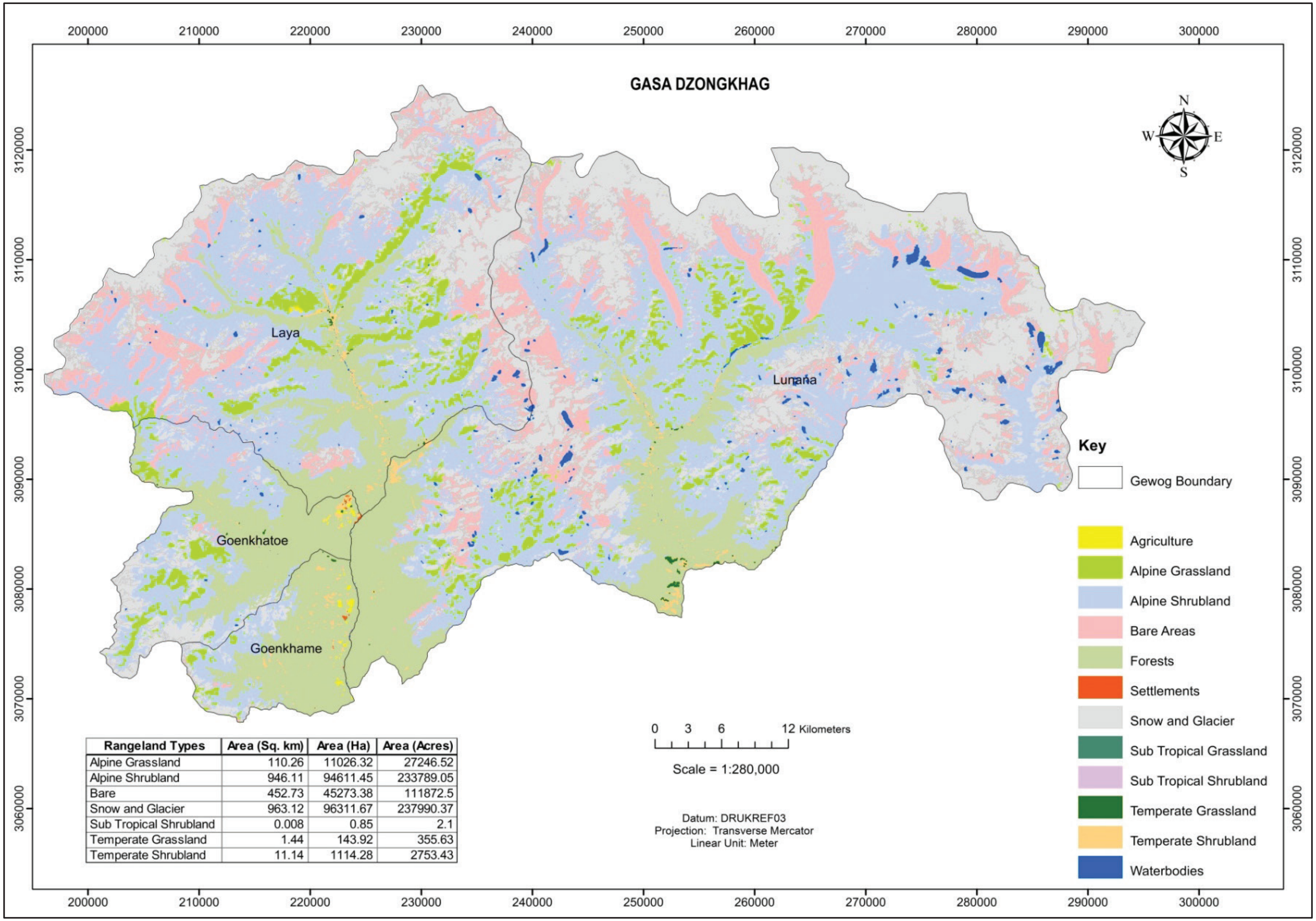

| Rangeland Types | Area (Sq. km) | Area (Ha) | Area (Acres) |
|---|---|---|---|
| Alpine Grassland | 15.97 | 1597.69 | 3947.96 |
| Alpine Shrubland | 5.07 | 506.58 | 1251.77 |
| Bare Areas | 8.16 | 816.06 | 2016.53 |
| Sub Tropical Grassland | 3.52 | 351.92 | 869.61 |
| Sub Tropical Shrubland | 36.69 | 3668.92 | 9066.07 |
| Temperate Grassland | 10.37 | 1037.19 | 2562.93 |
| Temperate Shrubland | 18.44 | 1844.41 | 4557.63 |

## Dagana Dzongkhag



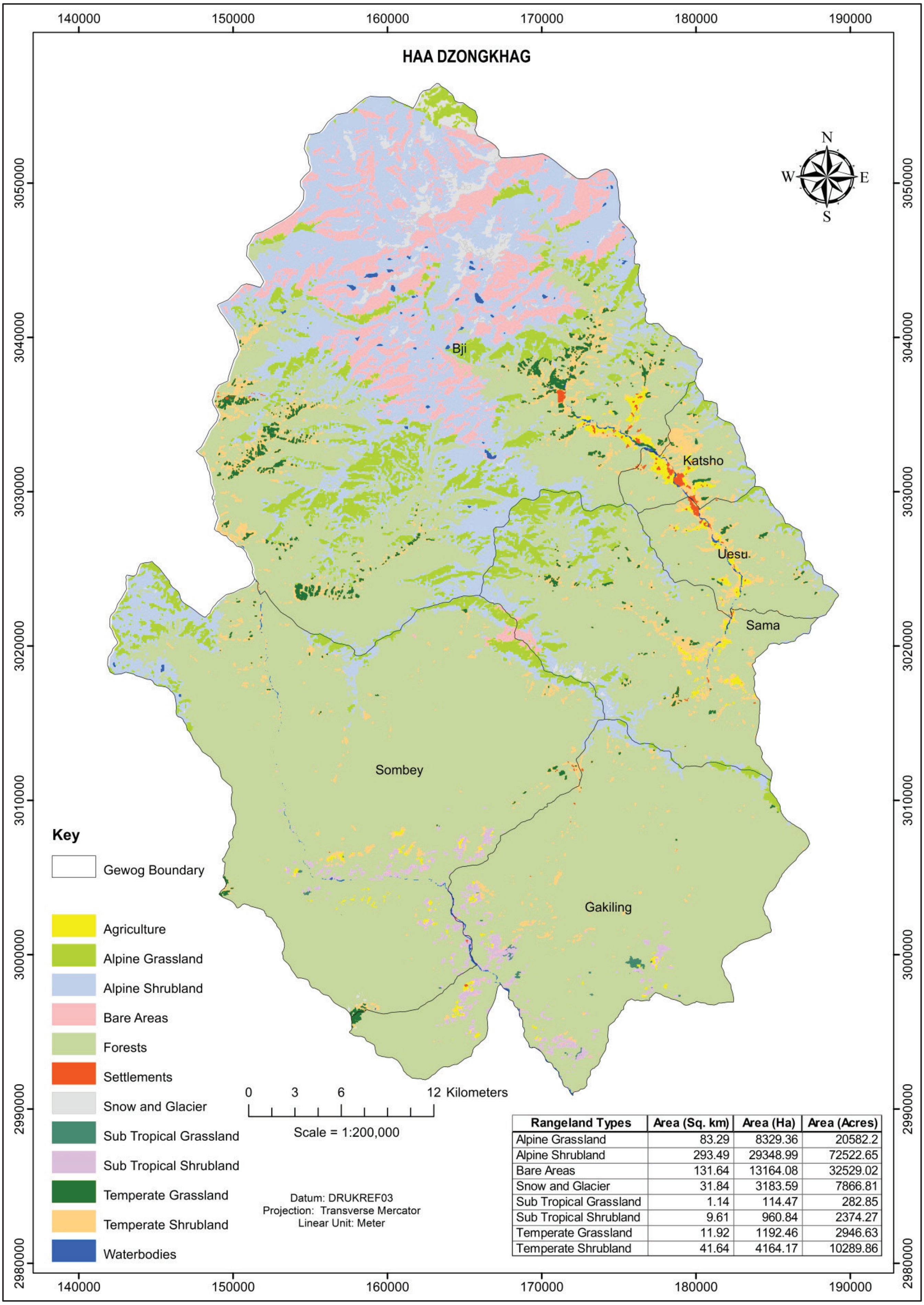

| Rangeland Types | Area (Sq. km) | Area (Ha) | Area (Arces) |
|---|---|---|---|
| Alpine Grassland | 16.03 | 1603.19 | 3961.57 |
| Alpine Shrubland | 18.01 | 1800.93 | 4450.16 |
| Bare Areas | 11.54 | 1154.43 | 2852.65 |
| Snow and Glacier | 0.15 | 15.05 | 37.19 |
| Sub Tropical Grassland | 7.64 | 764.16 | 1888.28 |
| Sub Tropical Shrubland | 28.39 | 2838.78 | 7014.75 |
| Temperate Grassland | 6.58 | 658.48 | 1627.12 |
| Temperate Shrubland | 4.24 | 424.46 | 1048.87 |

## Gasa Dzongkhag



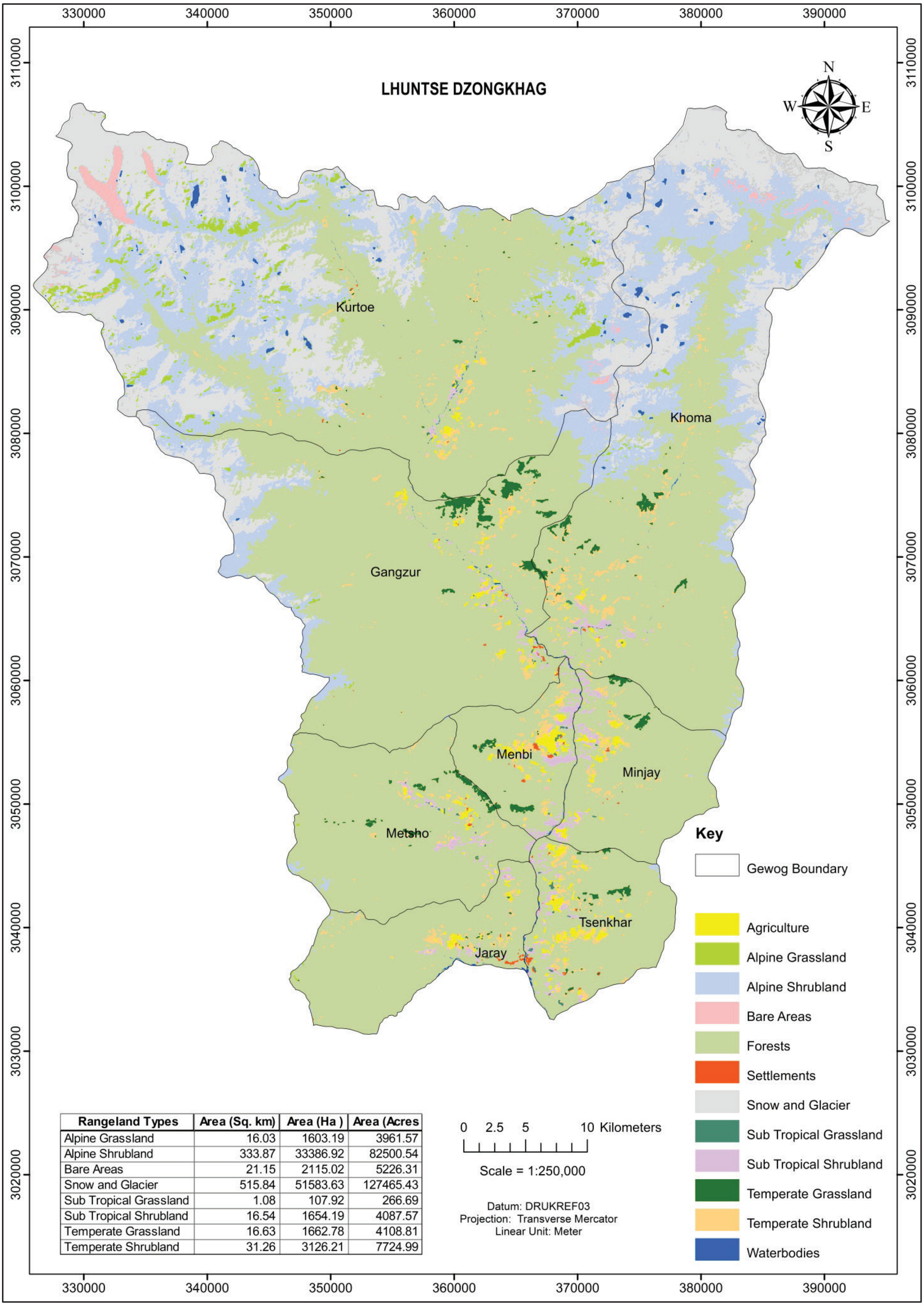

| Rangeland Types | Area (Sq. km) | Area (Ha) | Area (Acres) |
|---|---|---|---|
| Alpine Grassland | 110.26 | 11026.32 | 27246.52 |
| Alpine Shrubland | 946.11 | 94611.45 | 233789.05 |
| Bare | 452.73 | 45273.38 | 111872.5 |
| Snow and Glacier | 963.12 | 96311.67 | 237990.37 |
| Sub Tropical Shrubland | 0.008 | 0.85 | 2.1 |
| Temperate Grassland | 1.44 | 143.92 | 355.63 |
| Temperate Shrubland | 11.14 | 1114.28 | 2753.43 |

## Haa Dzongkhag



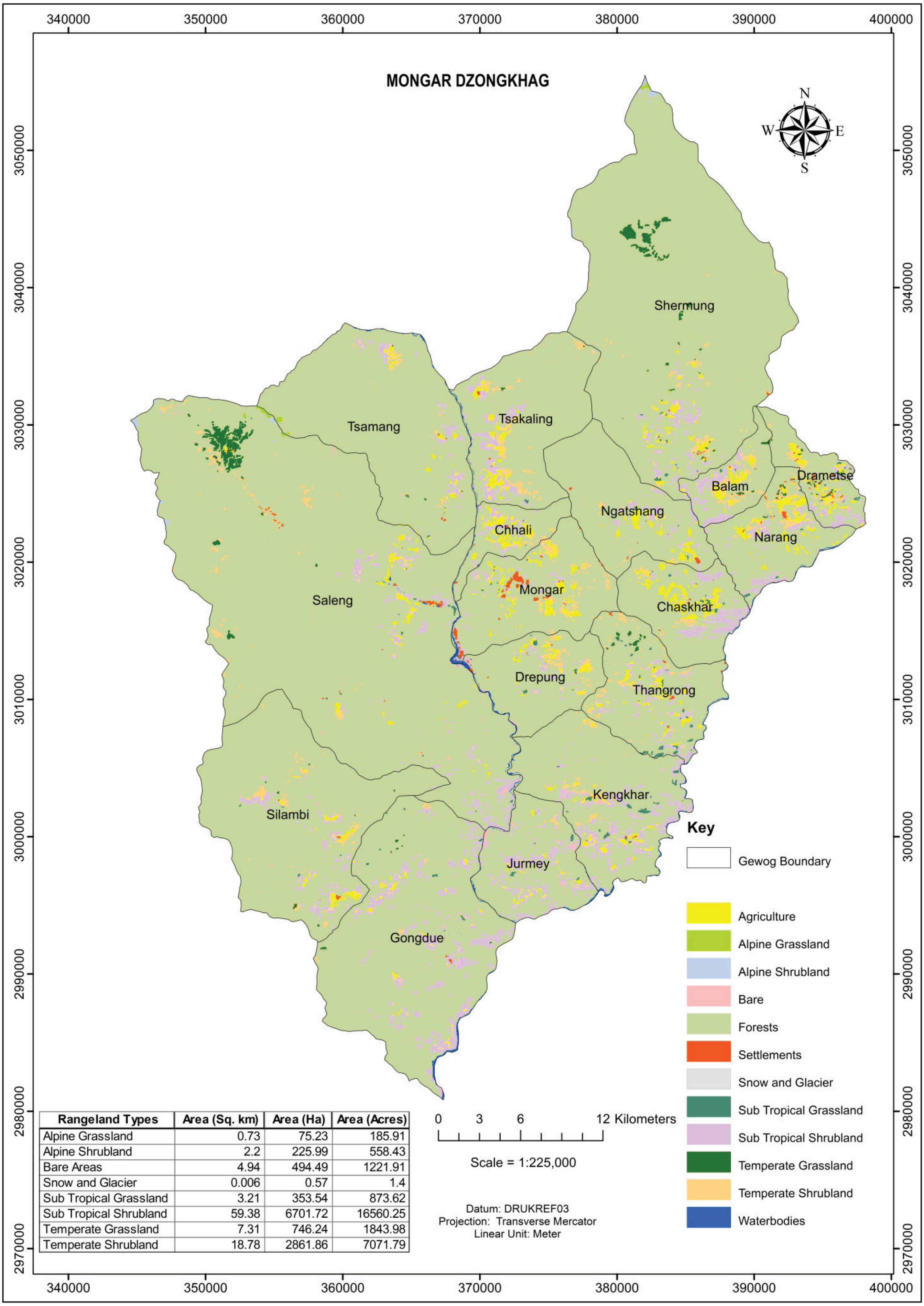

| Rangeland Types | Area (Sq. km) | Area (Ha) | Area (Acres) |
|---|---|---|---|
| Alpine Grassland | 83.29 | 8329.36 | 20582.2 |
| Alpine Shrubland | 293.49 | 29348.99 | 72522.65 |
| Bare Areas | 131.64 | 13164.08 | 32529.02 |
| Snow and Glacier | 31.84 | 3183.59 | 7866.81 |
| Sub Tropical Grassland | 1.14 | 114.47 | 282.85 |
| Sub Tropical Shrubland | 9.61 | 960.84 | 2374.27 |
| Temperate Grassland | 11.92 | 1192.46 | 2946.63 |
| Temperate Shrubland | 41.64 | 4164.17 | 10289.86 |

## Lhuntse Dzongkhag



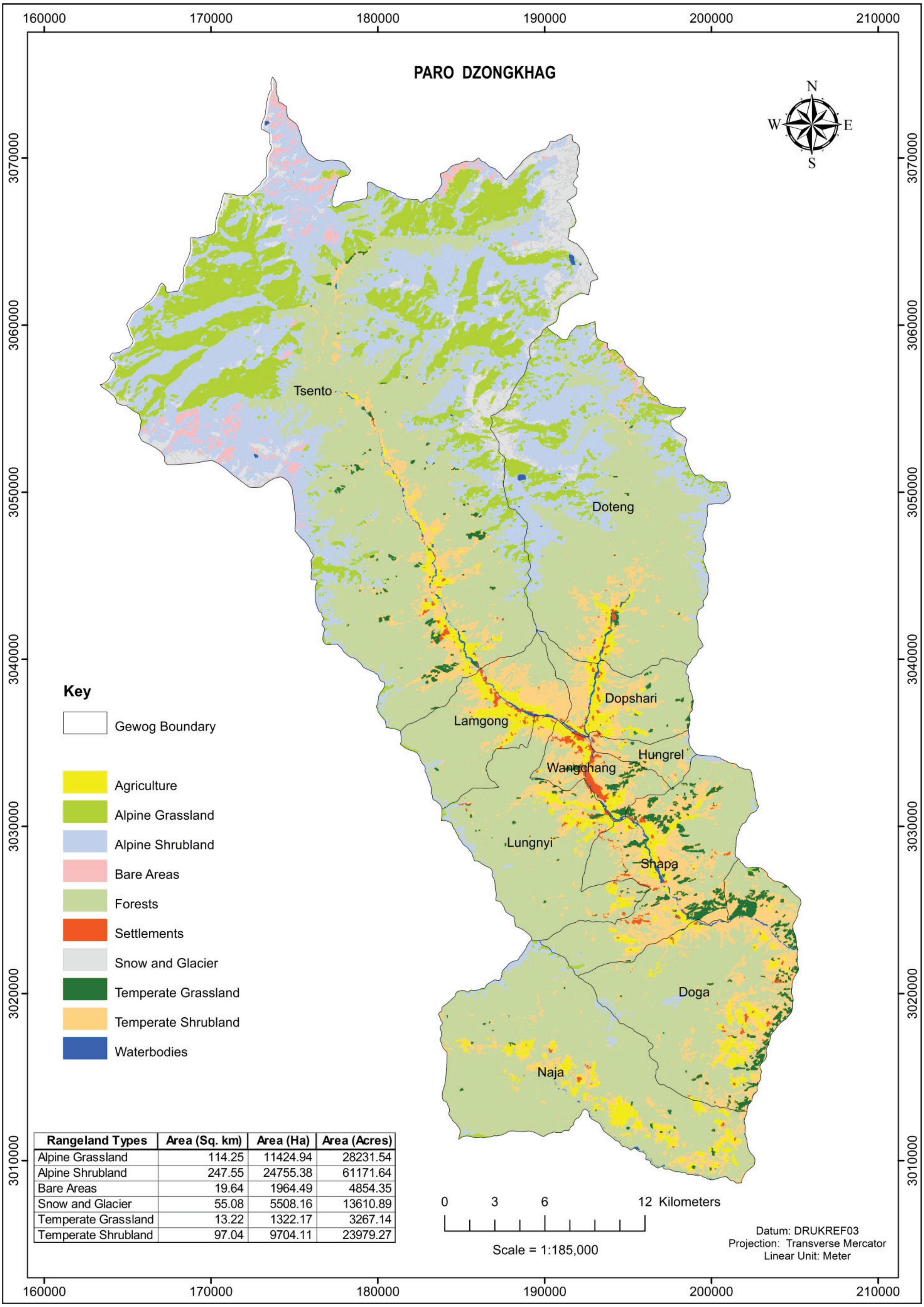

| Rangeland Types | Area (Sq. km) | Area (Ha ) | Area (Acres |
|---|---|---|---|
| Alpine Grassland | 16.03 | 1603.19 | 3961.57 |
| Alpine Shrubland | 333.87 | 33386.92 | 82500.54 |
| Bare Areas | 21.15 | 2115.02 | 5226.31 |
| Snow and Glacier | 515.84 | 51583.63 | 127465.43 |
| Sub Tropical Grassland | 1.08 | 107.92 | 266.69 |
| Sub Tropical Shrubland | 16.54 | 1654.19 | 4087.57 |
| Temperate Grassland | 16.63 | 1662.78 | 4108.81 |
| Temperate Shrubland | 31.26 | 3126.21 | 7724.99 |

## Mongar Dzongkhag



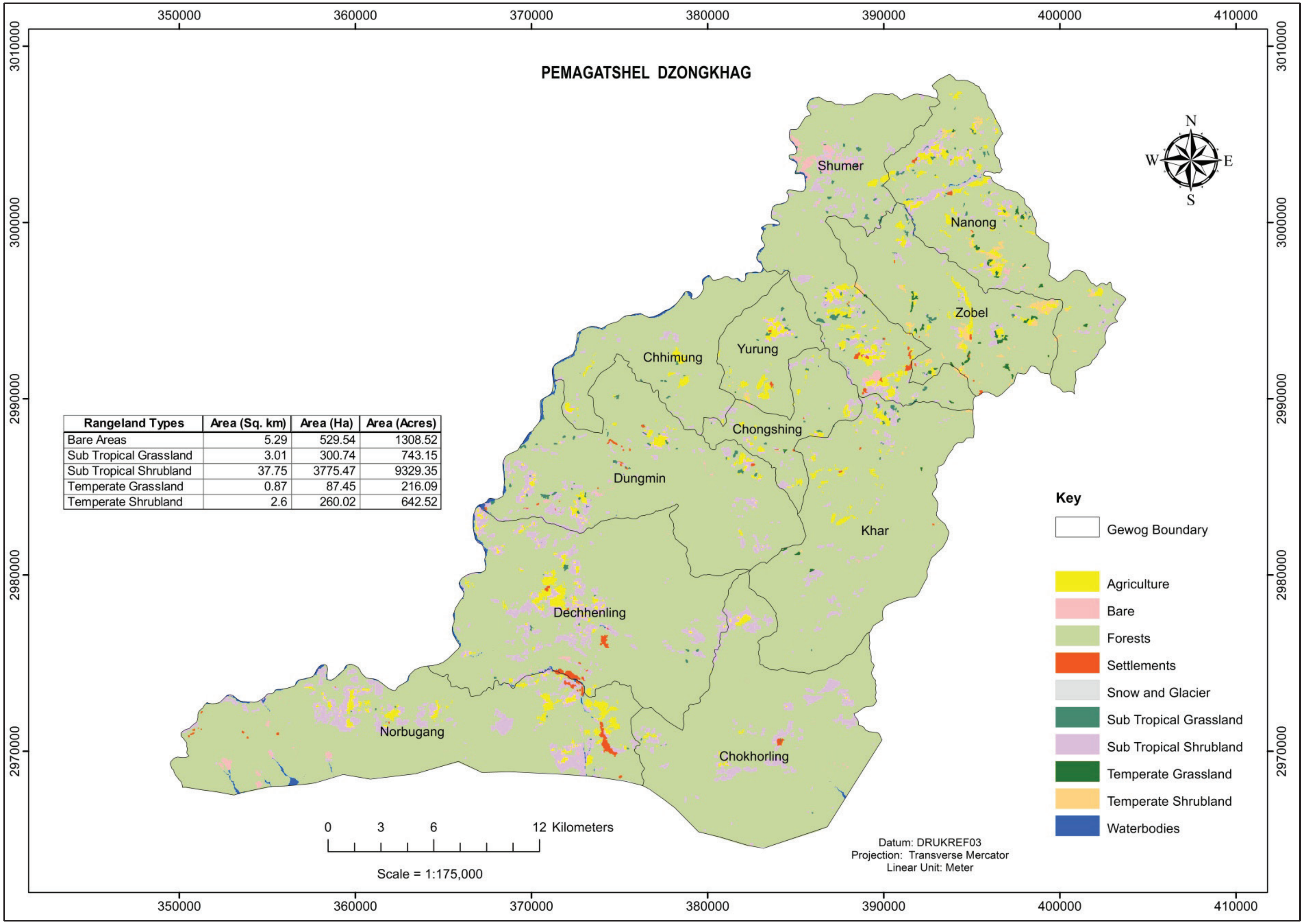

| Rangeland Types | Area (Sq. km) | Area (Ha) | Area (Acres) |
|---|---|---|---|
| Alpine Grassland | 0.73 | 75.23 | 185.91 |
| Alpine Shrubland | 2.2 | 225.99 | 558.43 |
| Bare Areas | 4.94 | 494.49 | 1221.91 |
| Snow and Glacier | 0.006 | 0.57 | 1.4 |
| Sub Tropical Grassland | 3.21 | 353.54 | 873.62 |
| Sub Tropical Shrubland | 59.38 | 6701.72 | 16560.25 |
| Temperate Grassland | 7.31 | 746.24 | 1843.98 |
| Temperate Shrubland | 18.78 | 2861.86 | 7071.79 |

## Paro Dzongkhag



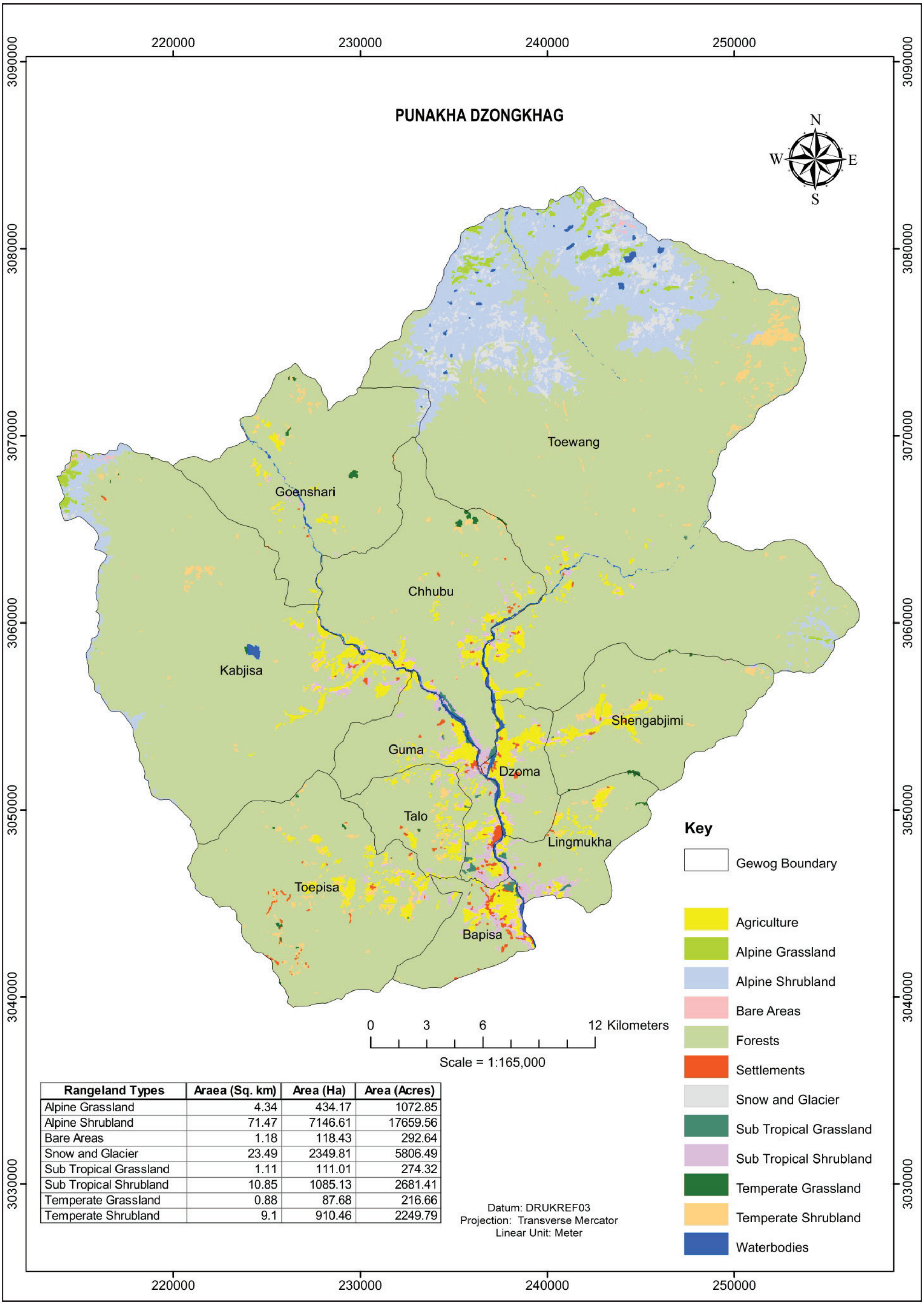

| Rangeland Types | Area (Sq. km) | Area (Ha) | Area (Acres) |
|---|---|---|---|
| Alpine Grassland | 114.25 | 11424.94 | 28231.54 |
| Alpine Shrubland | 247.55 | 24755.38 | 61171.64 |
| Bare Areas | 19.64 | 1964.49 | 4854.35 |
| Snow and Glacier | 55.08 | 5508.16 | 13610.89 |
| Temperate Grassland | 13.22 | 1322.17 | 3267.14 |
| Temperate Shrubland | 97.04 | 9704.11 | 23979.27 |

## Pemagatshel Dzongkhag



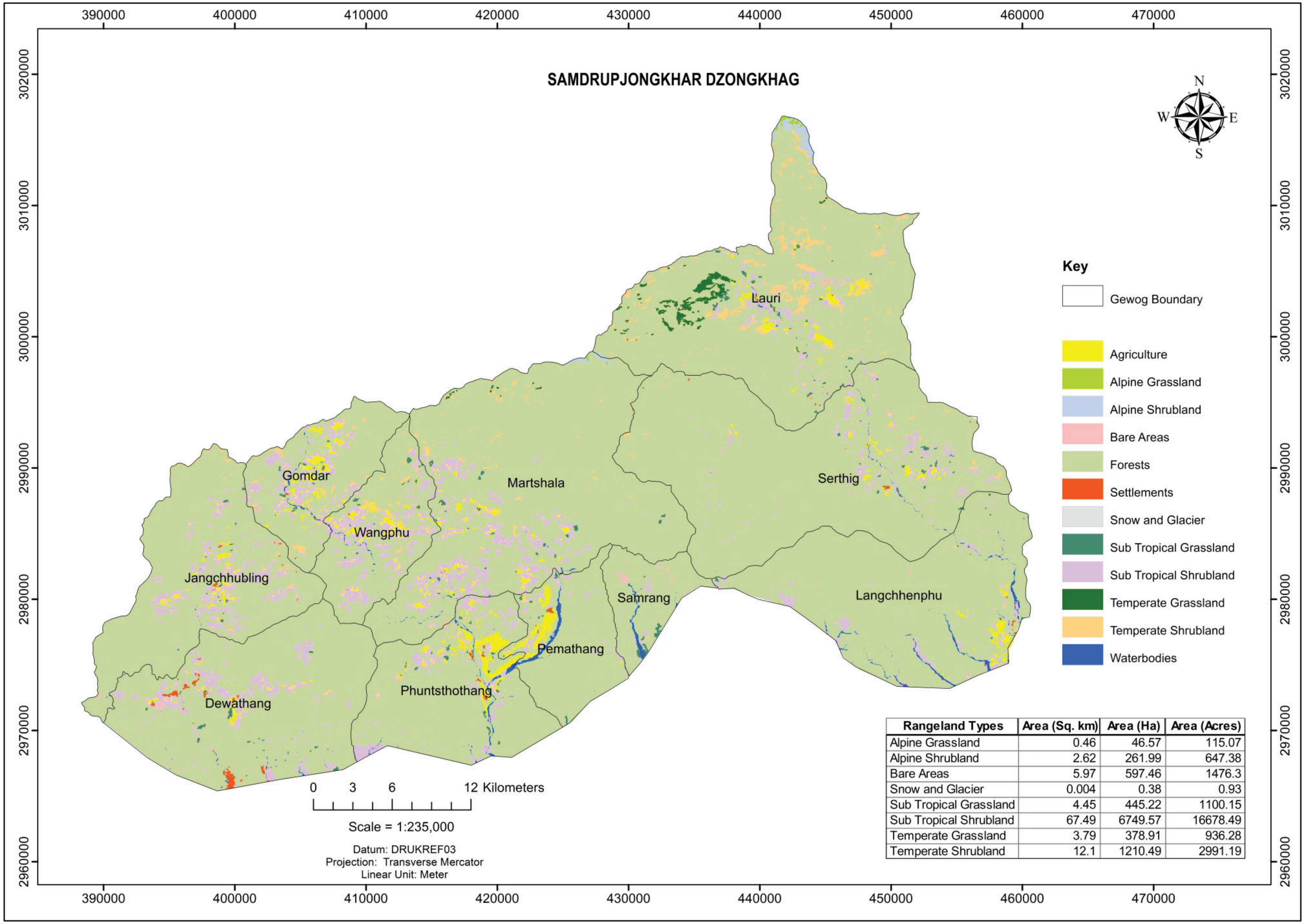

| Rangeland Types | Area (Sq. km) | Area (Ha) | Area (Acres) |
|---|---|---|---|
| Bare Areas | 5.29 | 529.54 | 1308.52 |
| Sub Tropical Grassland | 3.01 | 300.74 | 743.15 |
| Sub Tropical Shrubland | 37.75 | 3775.47 | 9329.35 |
| Temperate Grassland | 0.87 | 87.45 | 216.09 |
| Temperate Shrubland | 2.6 | 260.02 | 642.52 |

# Punakha Dzongkhag



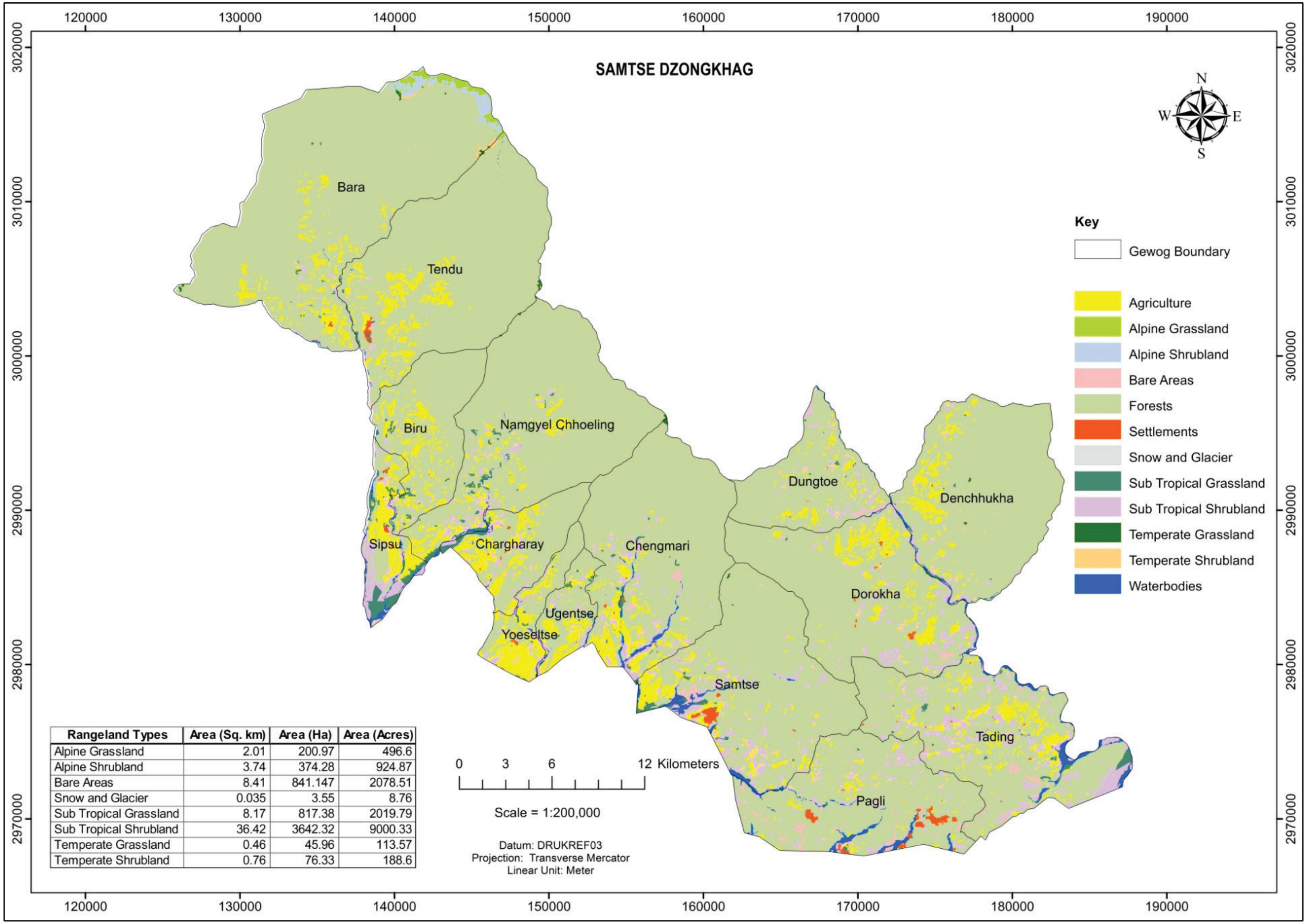

| Rangeland Types | Araea (Sq. km) | Area (Ha) | Area (Acres) |
|---|---|---|---|
| Alpine Grassland | 4.34 | 434.17 | 1072.85 |
| Alpine Shrubland | 71.47 | 7146.61 | 17659.56 |
| Bare Areas | 1.18 | 118.43 | 292.64 |
| Snow and Glacier | 23.49 | 2349.81 | 5806.49 |
| Sub Tropical Grassland | 1.11 | 111.01 | 274.32 |
| Sub Tropical Shrubland | 10.85 | 1085.13 | 2681.41 |
| Temperate Grassland | 0.88 | 87.68 | 216.66 |
| Temperate Shrubland | 9.1 | 910.46 | 2249.79 |

# Samdrupjongkhar Dzongkhag



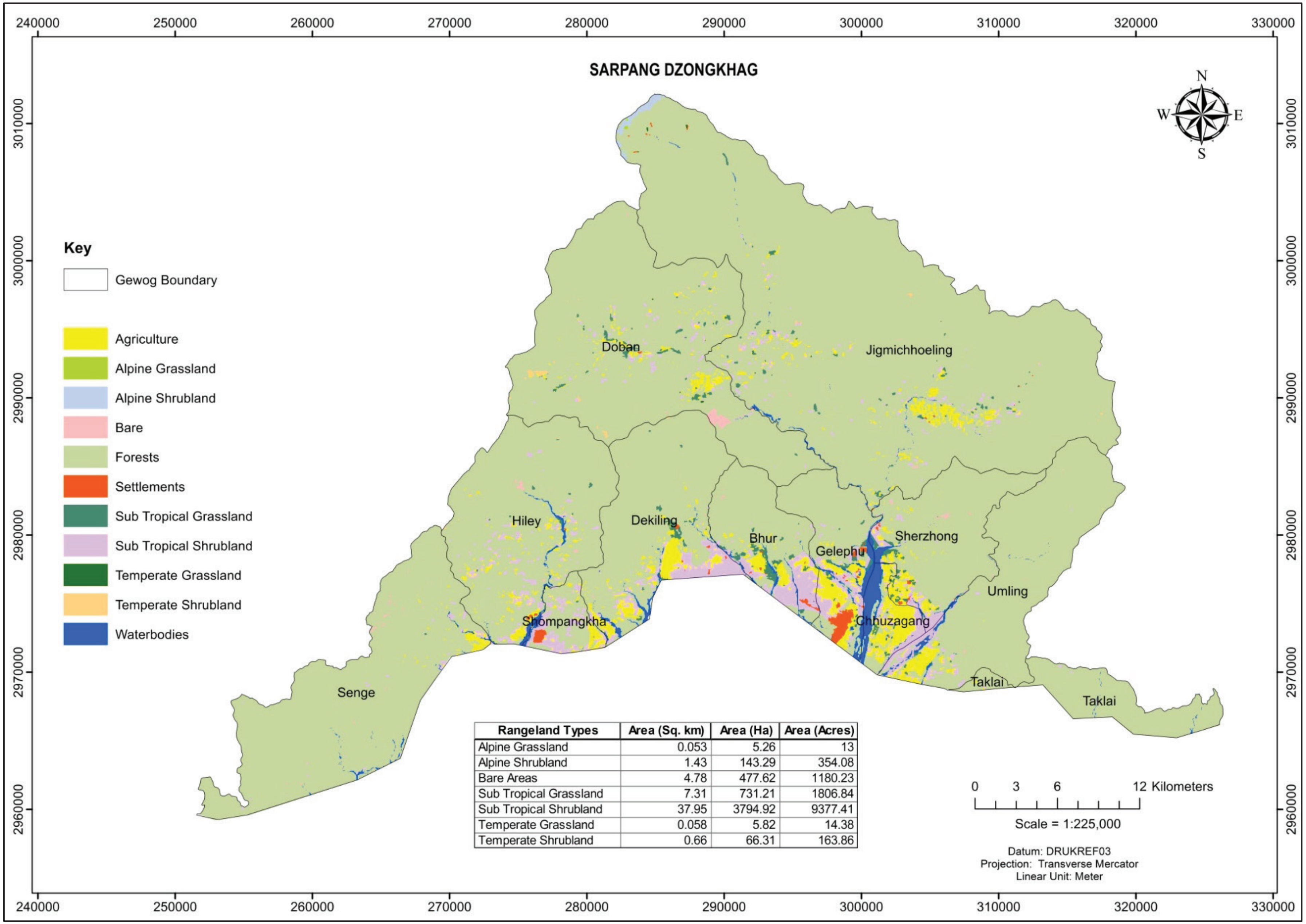

| Rangeland Types | Area (Sq. km) | Area (Ha) | Area (Acres) |
|---|---|---|---|
| Alpine Grassland | 0.46 | 46.57 | 115.07 |
| Alpine Shrubland | 2.62 | 261.99 | 647.38 |
| Bare Areas | 5.97 | 597.46 | 1476.3 |
| Snow and Glacier | 0.004 | 0.38 | 0.93 |
| Sub Tropical Grassland | 4.45 | 445.22 | 1100.15 |
| Sub Tropical Shrubland | 67.49 | 6749.57 | 16678.49 |
| Temperate Grassland | 3.79 | 378.91 | 936.28 |
| Temperate Shrubland | 12.1 | 1210.49 | 2991.19 |

## Samtse Dzongkhag



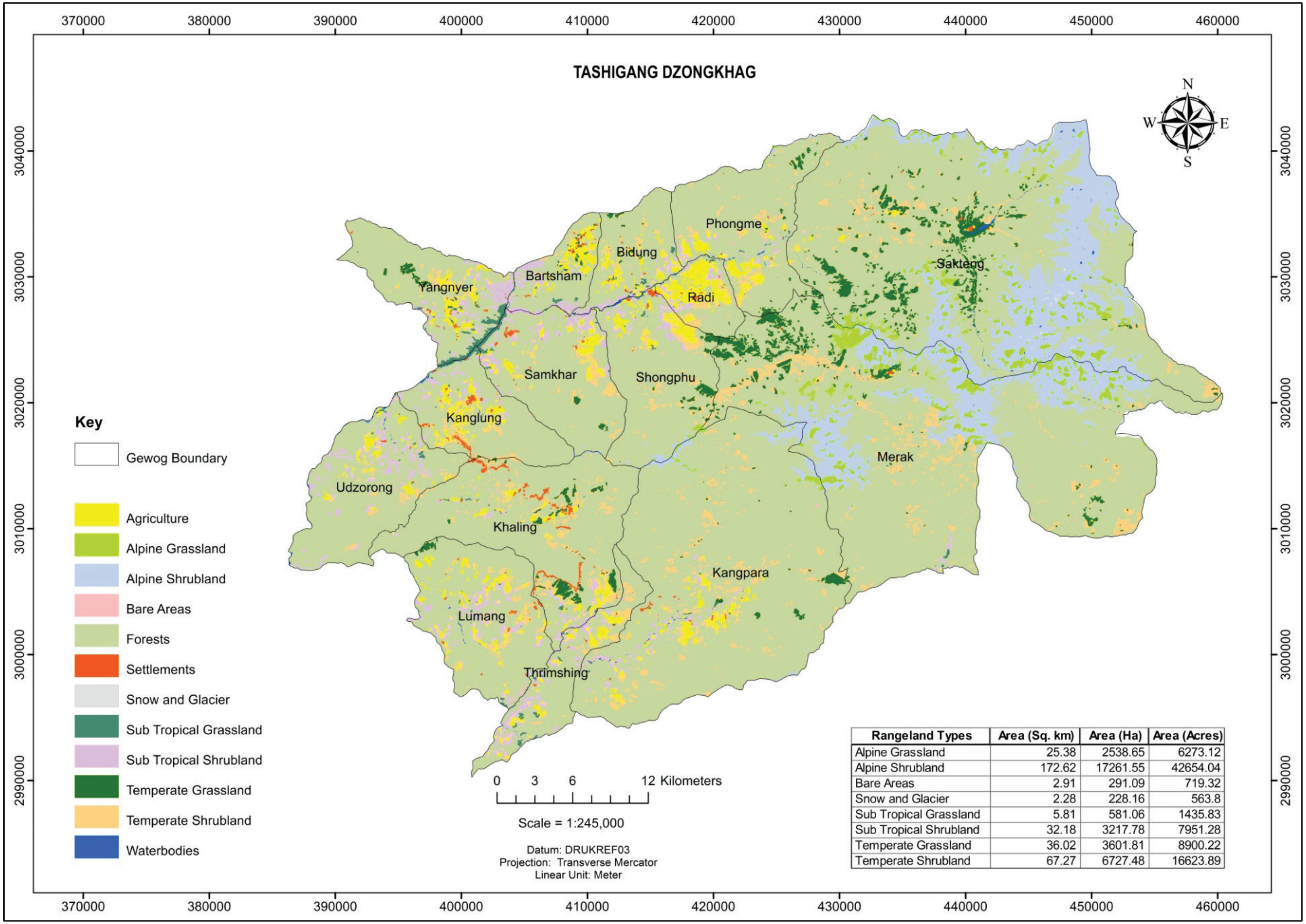

| Rangeland Types | Area (Sq. km) | Area (Ha) | Area (Acres) |
|---|---|---|---|
| Alpine Grassland | 2.01 | 200.97 | 496.6 |
| Alpine Shrubland | 3.74 | 374.28 | 924.87 |
| Bare Areas | 8.41 | 841.147 | 2078.51 |
| Snow and Glacier | 0.035 | 3.55 | 8.76 |
| Sub Tropical Grassland | 8.17 | 817.38 | 2019.79 |
| Sub Tropical Shrubland | 36.42 | 3642.32 | 9000.33 |
| Temperate Grassland | 0.46 | 45.96 | 113.57 |
| Temperate Shrubland | 0.76 | 76.33 | 188.6 |

## Sarpang Dzongkhag



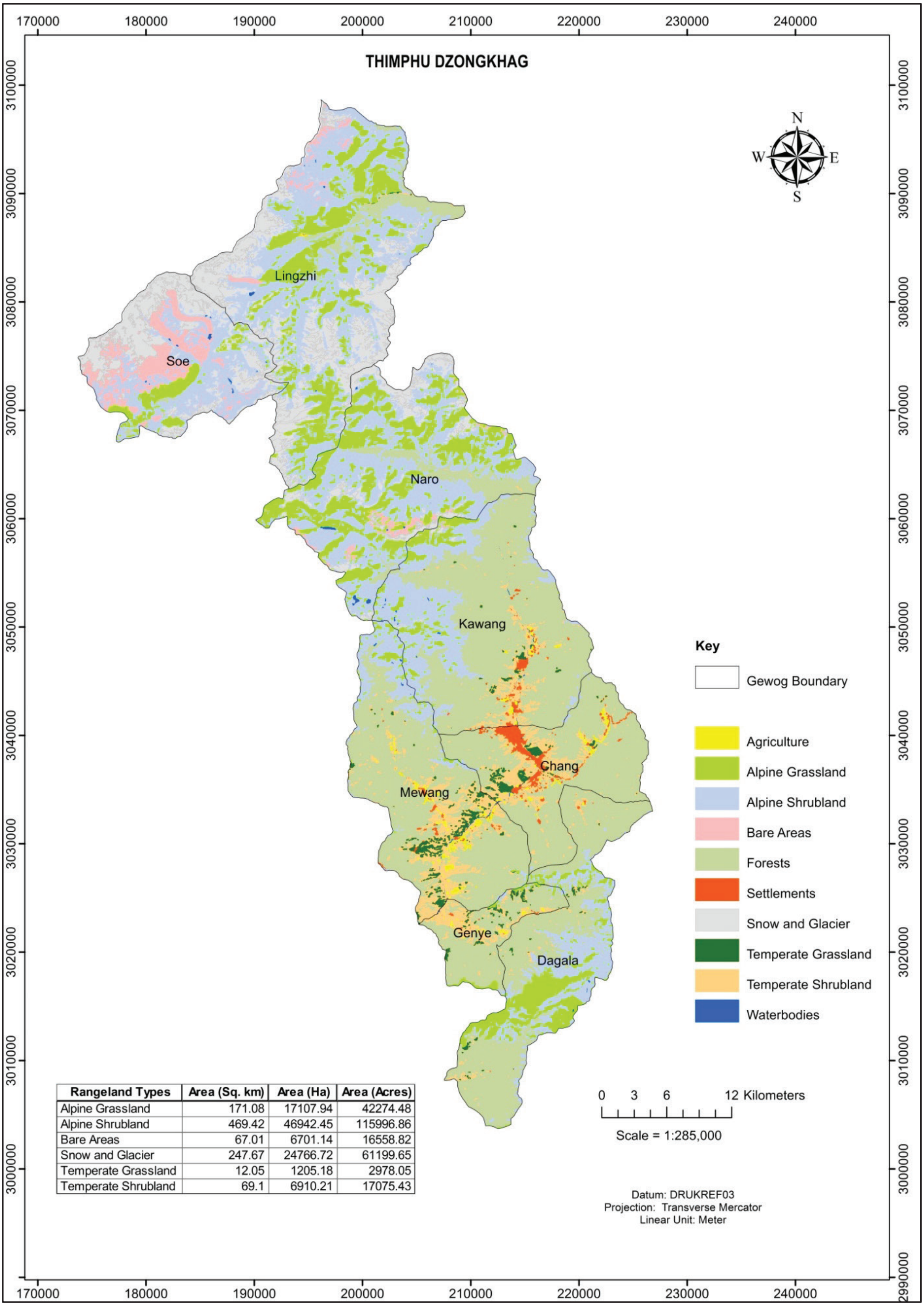

| Rangeland Types | Area (Sq. km) | Area (Ha) | Area (Acres) |
|---|---|---|---|
| Alpine Grassland | 0.053 | 5.26 | 13 |
| Alpine Shrubland | 1.43 | 143.29 | 354.08 |
| Bare Areas | 4.78 | 477.62 | 1180.23 |
| Sub Tropical Grassland | 7.31 | 731.21 | 1806.84 |
| Sub Tropical Shrubland | 37.95 | 3794.92 | 9377.41 |
| Temperate Grassland | 0.058 | 5.82 | 14.38 |
| Temperate Shrubland | 0.66 | 66.31 | 163.86 |

## Tashigang Dzongkhag



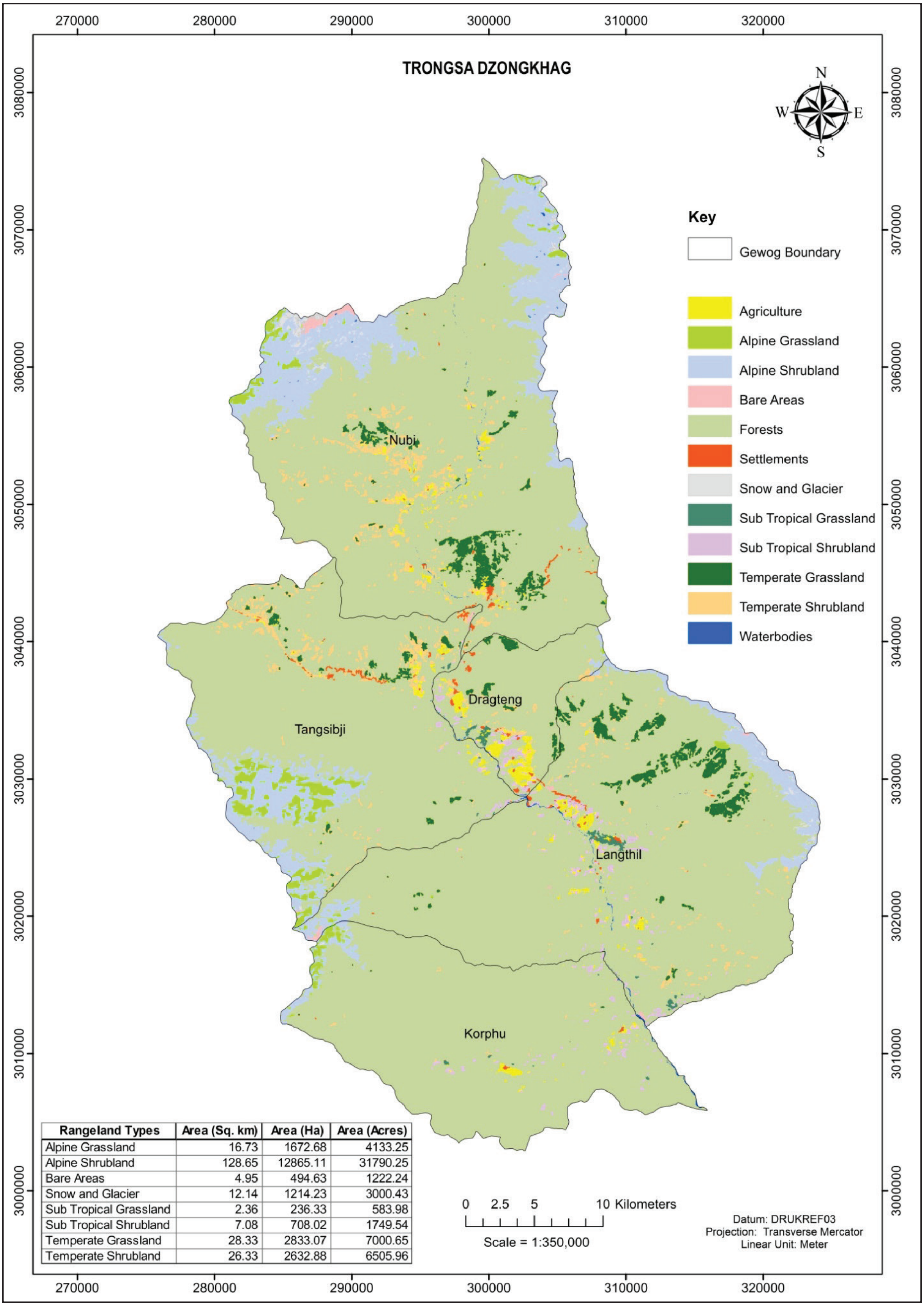

| Rangeland Types | Area (Sq. km) | Area (Ha) | Area (Acres) |
|---|---|---|---|
| Alpine Grassland | 25.38 | 2538.65 | 6273.12 |
| Alpine Shrubland | 172.62 | 17261.55 | 42654.04 |
| Bare Areas | 2.91 | 291.09 | 719.32 |
| Snow and Glacier | 2.28 | 228.16 | 563.8 |
| Sub Tropical Grassland | 5.81 | 581.06 | 1435.83 |
| Sub Tropical Shrubland | 32.18 | 3217.78 | 7951.28 |
| Temperate Grassland | 36.02 | 3601.81 | 8900.22 |
| Temperate Shrubland | 67.27 | 6727.48 | 16623.89 |

## Thimphu Dzongkhag



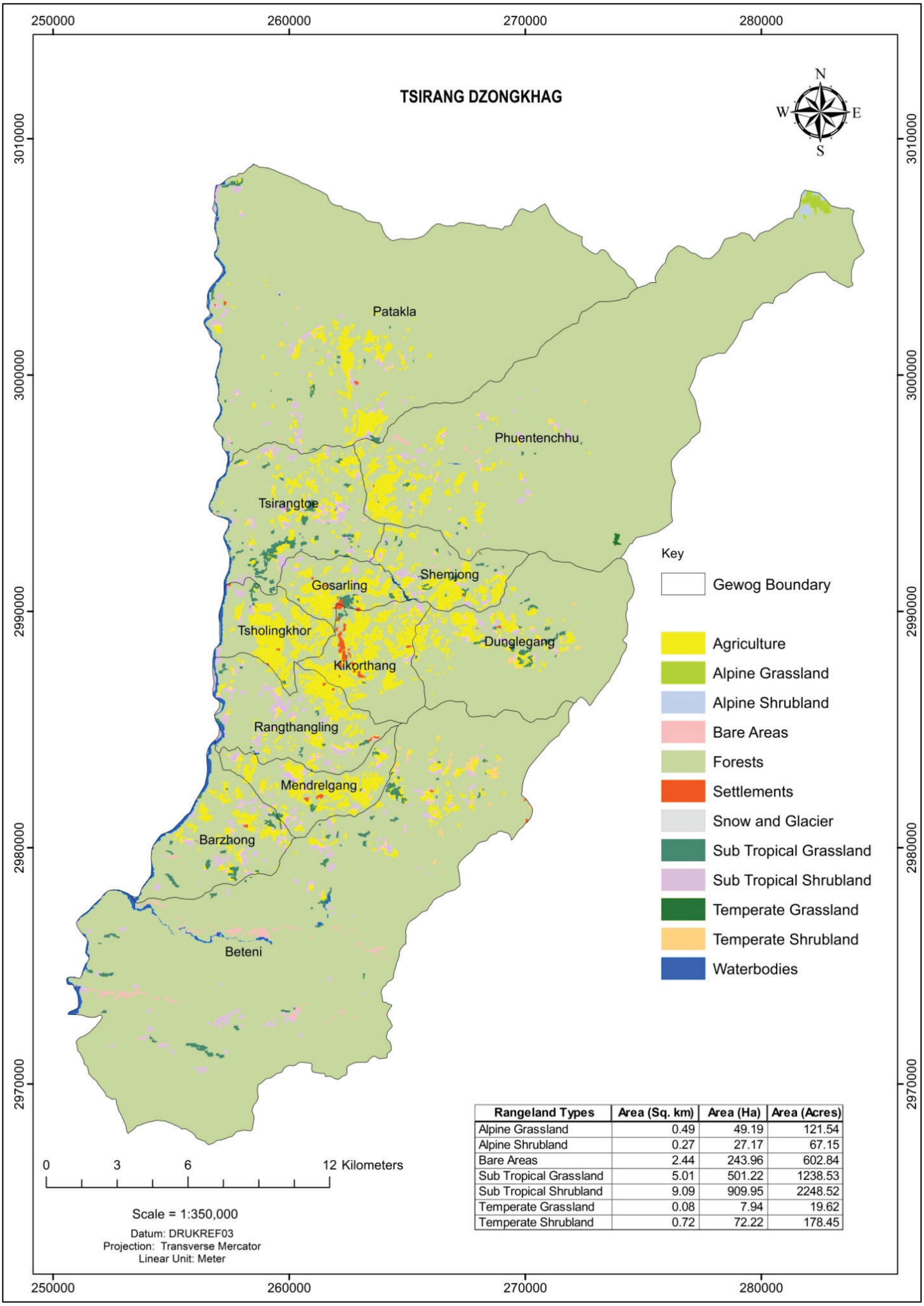

| Rangeland Types | Area (Sq. km) | Area (Ha) | Area (Acres) |
|---|---|---|---|
| Alpine Grassland | 171.08 | 17107.94 | 42274.48 |
| Alpine Shrubland | 469.42 | 46942.45 | 115996.86 |
| Bare Areas | 67.01 | 6701.14 | 16558.82 |
| Snow and Glacier | 247.67 | 24766.72 | 61199.65 |
| Temperate Grassland | 12.05 | 1205.18 | 2978.05 |
| Temperate Shrubland | 69.1 | 6910.21 | 17075.43 |

## Tongsa Dzongkhag



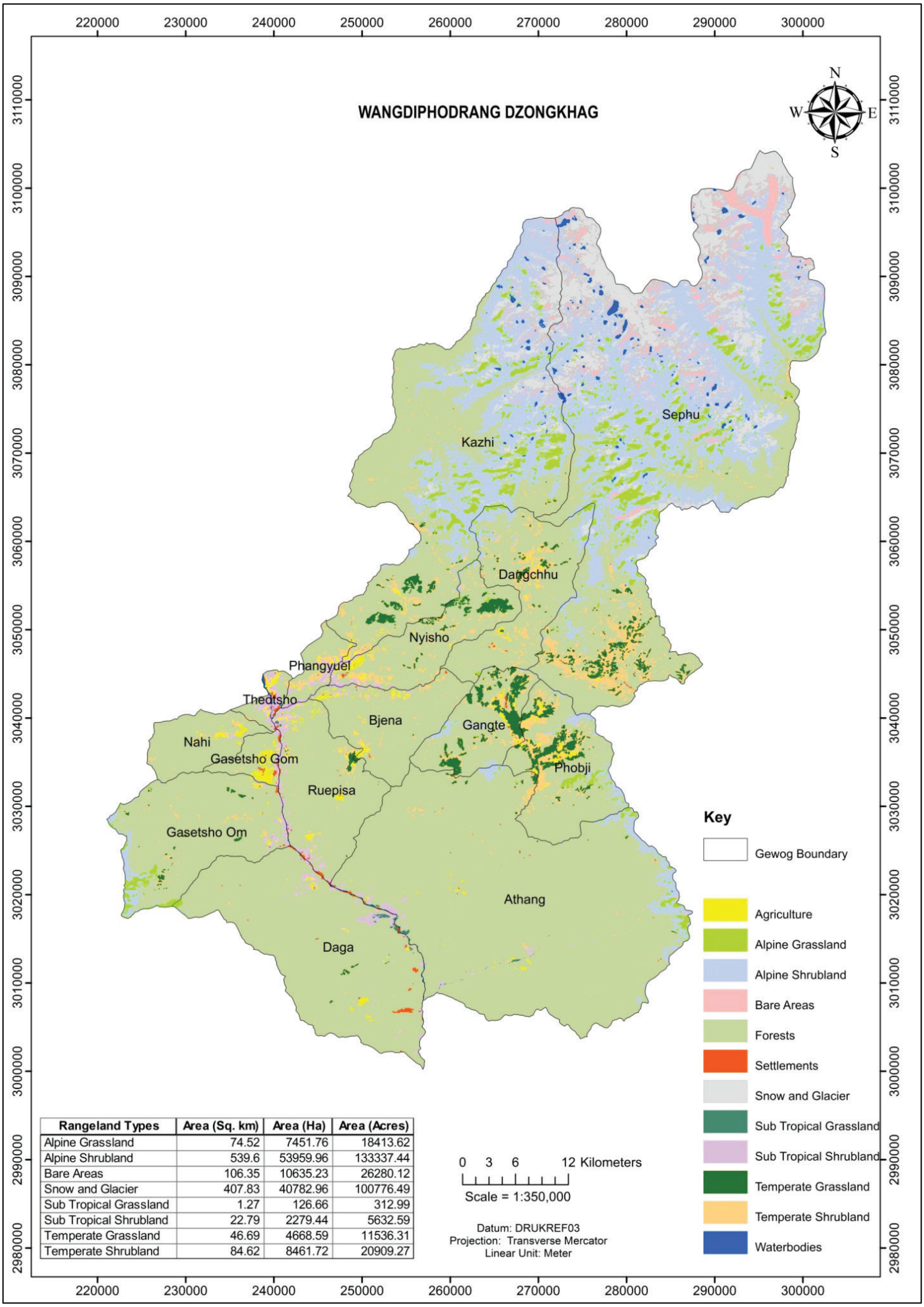

| Rangeland Types | Area (Sq. km) | Area (Ha) | Area (Acres) |
|---|---|---|---|
| Alpine Grassland | 16.73 | 1672.68 | 4133.25 |
| Alpine Shrubland | 128.65 | 12865.11 | 31790.25 |
| Bare Areas | 4.95 | 494.63 | 1222.24 |
| Snow and Glacier | 12.14 | 1214.23 | 3000.43 |
| Sub Tropical Grassland | 2.36 | 236.33 | 583.98 |
| Sub Tropical Shrubland | 7.08 | 708.02 | 1749.54 |
| Temperate Grassland | 28.33 | 2833.07 | 7000.65 |
| Temperate Shrubland | 26.33 | 2632.88 | 6505.96 |

## Tsirang Dzongkhag



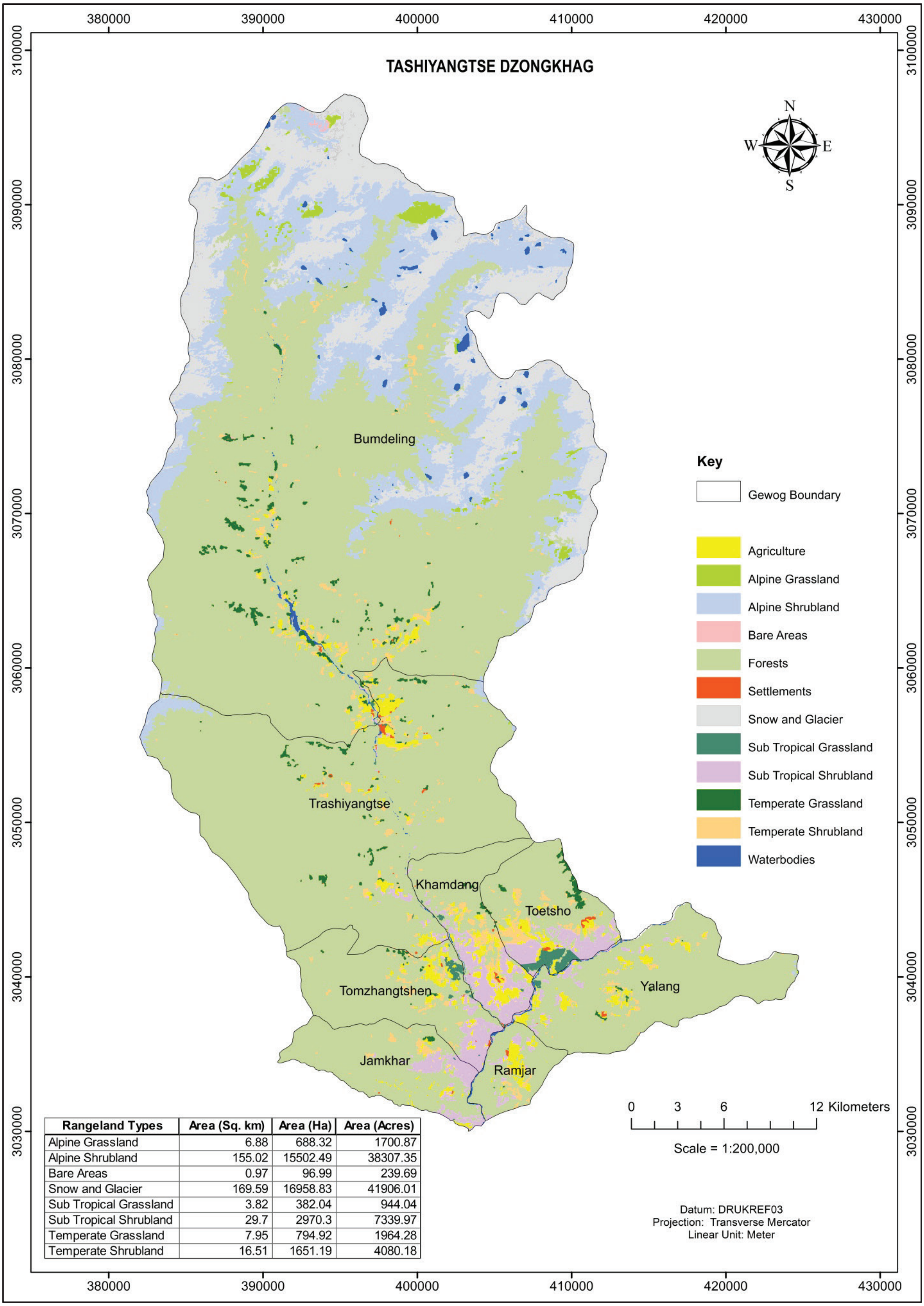

| Rangeland Types | Area (Sq. km) | Area (Ha) | Area (Acres) |
|---|---|---|---|
| Alpine Grassland | 0.49 | 49.19 | 121.54 |
| Alpine Shrubland | 0.27 | 27.17 | 67.15 |
| Bare Areas | 2.44 | 243.96 | 602.84 |
| Sub Tropical Grassland | 5.01 | 501.22 | 1238.53 |
| Sub Tropical Shrubland | 9.09 | 909.95 | 2248.52 |
| Temperate Grassland | 0.08 | 7.94 | 19.62 |
| Temperate Shrubland | 0.72 | 72.22 | 178.45 |

## Wangdiphodrang Dzongkhag



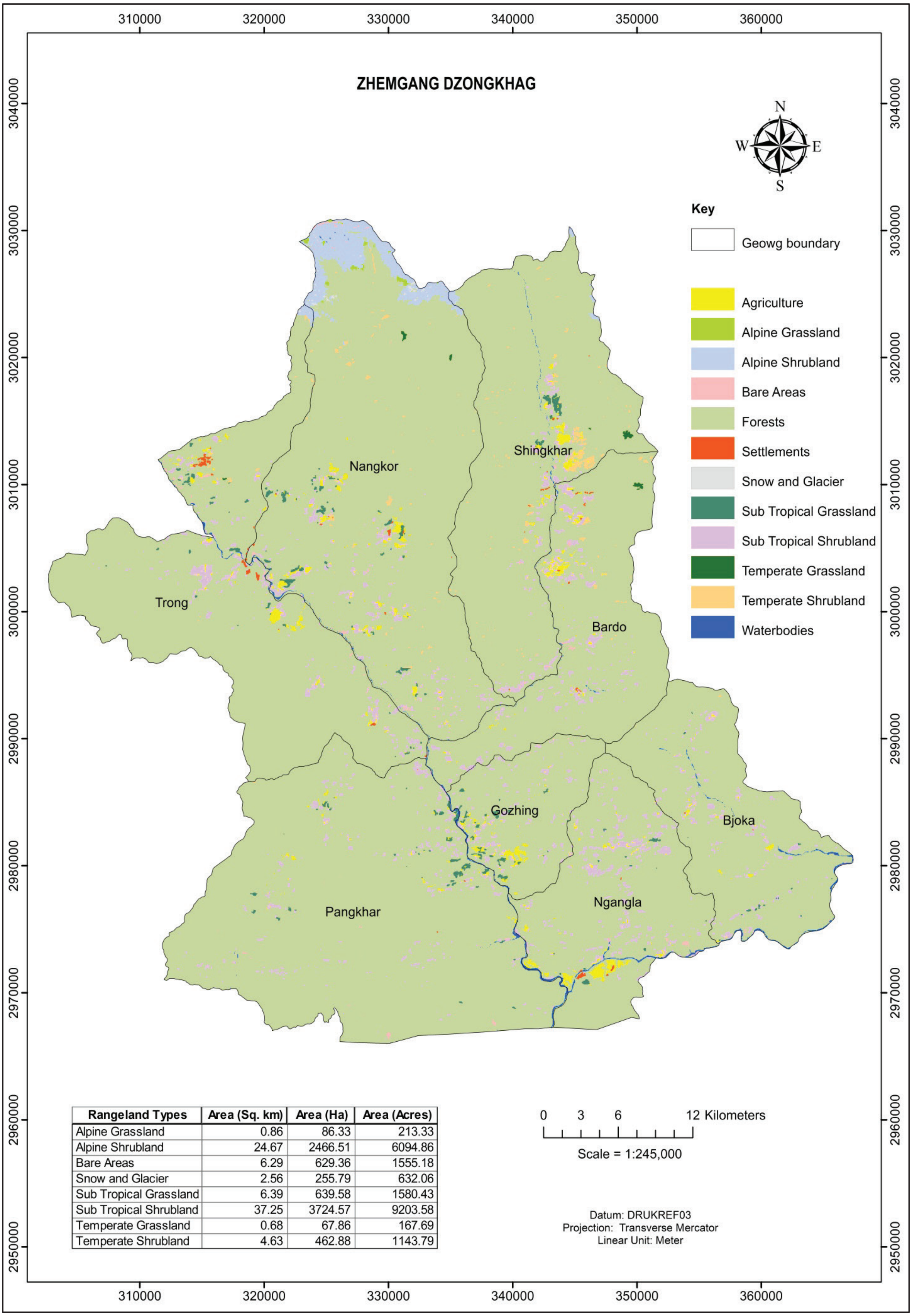

| Rangeland Types | Area (Sq. km) | Area (Ha) | Area (Acres) |
|---|---|---|---|
| Alpine Grassland | 74.52 | 7451.76 | 18413.62 |
| Alpine Shrubland | 539.6 | 53959.96 | 133337.44 |
| Bare Areas | 106.35 | 10635.23 | 26280.12 |
| Snow and Glacier | 407.83 | 40782.96 | 100776.49 |
| Sub Tropical Grassland | 1.27 | 126.66 | 312.99 |
| Sub Tropical Shrubland | 22.79 | 2279.44 | 5632.59 |
| Temperate Grassland | 46.69 | 4668.59 | 11536.31 |
| Temperate Shrubland | 84.62 | 8461.72 | 20909.27 |

## Yangtse Dzongkhag




| Rangeland Types | Area (Sq. km) | Area (Ha) | Area (Acres) |
|---|---|---|---|
| Alpine Grassland | 6.88 | 688.32 | 1700.87 |
| Alpine Shrubland | 155.02 | 15502.49 | 38307.35 |
| Bare Areas | 0.97 | 96.99 | 239.69 |
| Snow and Glacier | 169.59 | 16958.83 | 41906.01 |
| Sub Tropical Grassland | 3.82 | 382.04 | 944.04 |
| Sub Tropical Shrubland | 29.7 | 2970.3 | 7339.97 |
| Temperate Grassland | 7.95 | 794.92 | 1964.28 |
| Temperate Shrubland | 16.51 | 1651.19 | 4080.18 |

## Zhemgang Dzongkhag




| Rangeland Types | Area (Sq. km) | Area (Ha) | Area (Acres) |
|---|---|---|---|
| Alpine Grassland | 0.86 | 86.33 | 213.33 |
| Alpine Shrubland | 24.67 | 2466.51 | 6094.86 |
| Bare Areas | 6.29 | 629.36 | 1555.18 |
| Snow and Glacier | 2.56 | 255.79 | 632.06 |
| Sub Tropical Grassland | 6.39 | 639.58 | 1580.43 |
| Sub Tropical Shrubland | 37.25 | 3724.57 | 9203.58 |
| Temperate Grassland | 0.68 | 67.86 | 167.69 |
| Temperate Shrubland | 4.63 | 462.88 | 1143.79 |

# 6. DZONGKHAG WISE RANGELAND COVER FIGURES (AREA IN ACRES)

The Dzongkhag wise rangeland cover figure in acres is given in table 5.1.

Table 5.1 Dzongkhag wise rangeland cover figures in acres

| Dzongkhags | Alpine Grassland | Temperate Grassland | Subtropical Grassland | Alpine Shrub land | Temperate Shrub land | Subtropical Shrub land |
|---|---|---|---|---|---|---|
| Bumthang | 19010.74 | 6600.68 | 0.00 | 132985.55 | 13908.38 | 0.00 |
| Chukha | 3947.96 | 2562.93 | 869.61 | 1251.77 | 4557.63 | 9066.07 |
| Dagana | 3961.57 | 1627.12 | 1888.28 | 4450.16 | 1048.87 | 7014.75 |
| Gasa | 27246.52 | 355.63 | 0.00 | 233789.05 | 2753.43 | 2.10 |
| Haa | 20582.2 | 2946.63 | 282.85 | 72522.65 | 10289.86 | 2374.27 |
| Lhuntse | 3961.57 | 4108.81 | 266.69 | 82500.54 | 7724.99 | 4087.57 |
| Mongar | 185.91 | 1843.98 | 873.62 | 558.43 | 7071.79 | 16560.25 |
| Paro | 28231.54 | 3267.14 | 0.00 | 61171.64 | 23979.27 | 0.00 |
| P/gatshel | 0.00 | 216.09 | 743.15 | 0.00 | 642.52 | 9329.35 |
| Punakha | 1072.85 | 216.66 | 274.32 | 17659.56 | 2681.41 | 2249.79 |
| S/jongkhar | 115.07 | 936.28 | 1100.15 | 647.38 | 2991.19 | 16678.49 |
| Samtse | 496.60 | 113.57 | 2019.79 | 924.87 | 188.6 | 9000.33 |
| Sarpang | 13.00 | 14.38 | 1806.84 | 354.08 | 163.86 | 9377.41 |
| Tashigang | 6273.12 | 8900.22 | 1435.83 | 42654.04 | 16623.89 | 7951.28 |
| Thimphu | 42274.48 | 2978.05 | 0.00 | 115996.86 | 17075.43 | 0.00 |
| Tongsa | 4133.25 | 7000.65 | 583.98 | 31790.25 | 6505.96 | 1749.54 |
| Tsirang | 121.54 | 19.62 | 1238.53 | 67.15 | 178.45 | 2248.52 |
| Wangdi | 18413.62 | 11536.31 | 312.99 | 133337.44 | 20909.27 | 5632.59 |
| T/Yangtse | 1700.87 | 1964.28 | 944.04 | 38307.35 | 4080.18 | 7339.97 |
| Zhemgang | 213.33 | 167.69 | 1580.43 | 6094.86 | 1143.79 | 9203.58 |
| Total Rangeland Area (Acres) | 181955.74 | 57376.72 | 16221.10 | 977063.63 | 144518.77 | 119865.86 |
| Total Rangeland Area (%) | 12.15 | 3.83 | 1.08 | 65.27 | 9.65 | 8.01 |

# 7. CONCLUSION AND LIMITATIONS

## 7.1. Conclusion

Geographic Information System (GIS) and remote sensing data are useful for general land cover classification as well as for vegetation classification because of its cheaper and quicker method of obtaining updated information over large areas as compared to extensive field surveys. This particularly holds true in the high mountainous regions like Bhutan, where most of the areas are inaccessible due to the rugged terrain and harsh environmental conditions. Therefore, remote sensing has significant promise for the development of reliable and economically feasible up-to-date information and data on rangeland resources over large areas.

The rangeland resource mapping using GIS and RS techniques presently being carried out is the first of its kind in Bhutan. As mentioned in the limitations, there are scopes of further improving the classification results. Moreover, many studies have reported that rangelands in Bhutan have degraded both in terms of quality and quantity over the past few decades. Therefore, application of GIS/Remote sensing techniques using historical and multi-temporal satellite imageries will be important tool to assess the extent of rangeland degradation for its effective planning and management in future.

## 7.2. Limitations

1. Could free Landsat images were available only during the off-growth season in the month of January and February 2016, where most of the vegetation will be photo-synthetically inactive. This makes the classification of different vegetation types difficult due to less distinct spectral signatures between different vegetation types.

2. Although, the field work for ground validation was carried out, most of the places could not be visited due to limitations posed by shortage of time and resources. Nonetheless, the validation of the each classified object was carried out by using the google earth image and the accuracy of the classification is desirably high.

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