Remote Sensing-Based Regional Bamboo Resource Assessment Report of Ethiopia, Kenya and Uganda

Tsinghua University, Beijing, China
International Bamboo and Rattan Organisation (INBAR)

Supported by:

Ministry of Foreign Affairs

KENYA Forest Service

NFA National Forestry Authority

International Bamboo and Rattan Organisation

INBAR, the International Bamboo and Rattan Organisation, is an intergovernmental organisation bringing together some 43 countries for the promotion of the ecosystem benefits and values of bamboo and rattan.

International Bamboo and Rattan Organisation

PO Box 100102-86, Beijing 100102, P.R.China
Tel: +86 10 64706161; Fax: +86 10 6470 2166
Email: info@inbar.int
www.inbar.int

ISBN: 978-92-990082-8-7

Printed on recycled paper

Contents

List of Figures

County maps of bamboo-growing areas in Kenya

Sub-Regional maps of bamboo growing areas in Uganda

List of Tables

Acronyms

ASL	Above Sea Level
EEFRI	Ethiopian Environment and Forest Research Institute
FAO	Food and Agriculture Organisation
FROM-GLC	Finer Resolution Observation and Monitoring of Global Land Cover
Ha	Hectares
IRS	Indian Remote Sensing Satellite
KEFRI	Kenya Forest Research Institute
Km	Kilometre
Km^2	Square Kilometre
LISS	Linear Imaging Self Scanner
M	Metre
MoEFCC	Ministry of Environment Forest and Climate Change
NDVI	Normalised Difference Vegetation Index
NFA	National Forestry Authority
PAN	Panchromatic
SNNPRS	Southern Nations, Nationalities and Peoples' Regional State
SRTM	Shuttle Radar Topography Mission
Sq. M	Square Metre
TM	Thematic Mapper

Hans Friederich

Director General, International Bamboo and Rattan Organisation

Foreword

Bamboo is a hugely versatile grass, which can be used to create thousands of products, restore degraded lands, store carbon and build resilient housing. However, lack of data on bamboos' quantity and location has long prevented many countries from realising the full potential of this strategic plant.

This assessment aims to address such knowledge gaps. By using remote sensing technology, it was possible to build a comprehensive inventory of bamboo resources, across three countries where there is very little information: Ethiopia, Kenya and Uganda. Unlike traditional assessments of bamboo stocks, which are often cumbersome, time-intensive and expensive, this project used satellite imagery to map full coverage of bamboo resources – a method which takes far less time to implement at scale, and is more cost-effective. As a result of the assessment, we were delighted to find that there is more bamboo in these three countries than we previously thought.

This effort was led by the International Bamboo and Rattan Organisation (INBAR), with the support of a number of partners. It is part of the Dutch-Sino-East Africa Bamboo Development Programme, funded by the Ministry of Foreign Affairs of the Netherlands – an innovative trilateral initiative, which aims to use Chinese and Dutch expertise to help unlock the potential of abundant bamboo resources in Ethiopia, Kenya and Uganda.

These assessments also form an important starting point for INBAR's Global Assessment of Bamboo and Rattan (GABAR): an initiative established in 2016 to create a robust inventory and evidence base to support decision making about bamboo and rattan. With more data on bamboo resources, we can create better-informed policies, strategies and action plans. These will help us to use bamboo to alleviate poverty, combat climate change and contribute to important global initiatives.

I welcome this report as an important step forward in our mission: to unlock bamboo's potential for sustainable development.

Chapter 1 Introduction

1.1 Bamboo resources

Bamboo is a variety of perennial woody grass. There are more than 1600 species of bamboo that are most widely distributed in tropical and sub-tropical regions of the world (Vorontsova et al., 2016). Bamboo grows in at least 37 million hectares (ha) worldwide and covers 3.2 per cent of the forest areas of its host countries, or about one per cent of the global forest area (Lobovikov et al., 2007). It is widely recognised as a plant of great cultural and practical importance in many Asian, African and Central and Southern American countries (Banik, 2000; Widenoja, 2007). Bamboo plays an increasing role in ecosystem services, biodiversity conservation and socio-economic development. It has been recognized to be an important carbon sink and has potential for mitigating climate change (Song et al., 2011; Dubey et al., 2016; Agarwal and Purwar, 2017). Bamboo has also been proven to have an ecological function of soil and water conservation (Zhou et al., 2005). Bamboo is an irreplaceable habitat for a lot of wildlife, serving as a food source and escape cover (Schaller, 1985; Kratter, 1997; Bystriakova et al., 2004; Reid et al., 2004; Linderman et al., 2005). An annual crop with a wide range of product possibilities, bamboo offers opportunities for household, small-scale and medium-scale enterprises. Bamboo has traditionally been used by rural communities to meet their subsistence and income needs. Because of technological innovations in bamboo utilisation as well as an increased need for eco-friendly materials, bamboo is presently a value-added, high quality, durable material. In the past two decades, numerous value-added products in the form of wood substitutes, bamboo flooring, food and beverages, cloth, artefacts, bamboo charcoal, activated carbon, pharmaceutical applications and bamboo furniture have been developed (Zhang et al., 2002; Lobovikov et al., 2007; Kaur et al., 2016; Sofiana et al., 2017). Bamboo is a key component in lifting rural people out of poverty by providing job opportunities (Mishra, 2015; Chen et al., 2017). For example, bamboo weaving is a good income-earning opportunity for disadvantaged groups (Das, 2017).

1.2 Bamboo in the study area

Bamboo is widely distributed in Asia, Africa and Latin America, mainly in the tropical and subtropical regions. Based on the FAO-INBAR World Bamboo assessment report (Lobovikov et al., 2007), six countries in Africa (Ethiopia, Kenya, Nigeria, Uganda, Tanzania and Zimbabwe) have over 2.7 million hectares. Other key African countries with bamboo resources include Angola, Benin, Burundi, Cameroon, Central African Republic, Comoros, Côte d'Ivoire, Democratic Republic of Congo, Eritrea, Gabon, the Gambia, Ghana, Guinea, Guinea Bissau, Liberia, Madagascar, Malawi, Mozambique, Nigeria, Réunion, Rwanda, Senegal, Sierra Leone, South Africa, Sudan, Togo, and Zambia (Personal Communication, 2017). Ohrnberger et al. (1988) indicate that at least 25 countries in Africa have at least one bamboo species. It is important to note that the information on species diversity and quantity of bamboo resources in Africa is partial.

According to Lobovikov et al., 2007, Ethiopia, Kenya and Uganda possess significant bamboo resources. However, bamboo species diversity is low. Two indigenous species of bamboo in these East Africa countries are *Yushania alpina K. Schumach* (highland bamboo) and *Oxytenanthera abyssinica A. Rich* (lowland bamboo). In addition, the Kenya Forest Research Institute (KEFRI) has introduced over 20 bamboo species; the Ethiopian Environment and Forest Research Institute (EEFRI) has introduced about 23 different bamboo species from seven genera (Mulatu et al., 2016).

It is important to note that the natural bamboo forests are under threat from deforestation and degradation. Bamboo forests are converted into other competing land uses such as residential plots. Lack of control and sustainable management practices has resulted in degradation of bamboo forests. For example, lowland bamboo in the Benishangul Gumuz Region of Ethiopia was found converted to agricultural land, and if the same trend continues, the bamboo resource will vanish soon (Bessie et al., 2016). The same scenario applies for highland bamboo areas. The highland bamboo forests have been converted into croplands, grazing lands and human settlements, which causes increasing habitat loss and fragmentation for wild animals, such as Bale monkeys (Mekonnen et al., 2017). Timely mapping of the distribution of bamboo is necessary for biodiversity conservation, resource management and policymaking for rural poverty reduction.

1.3 Previous inventories on bamboo resources

A review of inventories or mapping of bamboo resources shows that the information available for these three countries are limited. FAO-INBAR: A thematic study prepared in the framework of the Global Forest Resources Assessment 2005 (Lobovikov et al., 2007), estimated a total bamboo-growing area of 849,000 ha, 124,000 ha, and 67,000 ha in Ethiopia, Kenya and Uganda respectively. This accounts for about 6.5 per cent, 3.5 per cent and 1.8 per cent of the total forest areas in Ethiopia, Kenya and Uganda. The report indicates same bamboo-growing areas for the three reporting periods: 1990, 2000 and 2005, which is believed to be unreasonable due to the fact that bamboo area is decreasing due to land conversion and population pressure. Kigomo et al. (1988) quantified the regional bamboo distribution data and reported that the estimated area of bamboo resources in Kenya was 156,000 ha. These data were reported by each country, so the data quality was affected due to the inconsistency in the countries' methodologies adopted for resource assessment. From the review of previous inventories, we found that there is a lack of accurate, comparable, up-to-date, spatially explicit data/maps of bamboo resources.

1.4 Application of remote sensing to bamboo resources assessment

Remote sensing has its advantages when mapping and monitoring the Earth's surface, providing up to date, comparatively cheap and dynamic information for many applications. Remote sensing techniques are widely used for vegetation mapping, natural resource assessment, change detection, management and monitoring (Rogan et al., 2002; Joshi et al., 2006; Lobovikov et al., 2007; Tucker and Townshend, 2000). However, bamboo is very difficult to identify using remote sensing in comparison with other land cover classes. Firstly, some species grow as understorey or mixed forest with other canopies. Secondly, bamboo has similar spectral properties with other vegetation classes, implying that spectrum is not adequate to separate bamboo from other vegetation. Thirdly, many species of bamboo are distributed in smaller patches (planted in homesteads, farm boundary/linear planting), which require high-resolution imagery to locate them. Finally, bamboo is among the fastest-growing plants on Earth and is frequently changing, which heightens the difficulties on sample collection.

A few attempts have been made to identify bamboo using remotely sensed data. Wang et al. (2009) mapped the understorey bamboo in part of the Xinglongling and Tianhuashan giant panda habitats in the Qinling Mountains of China. They used an Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) image acquired in the month of May when the leaves on the canopy of trees started to emerge. Bharadwaj et al. (2003) used IRS 1D LISS III imagery for species-wise bamboo and other natural resource assessment. The study used supervised classification and knowledge-based classification techniques.

Linderman et al. (2004) used Landsat (TM) imagery and a non-linear artificial neutral network method to map the spatial distribution of understory bamboo in Wolong natural reserve (Southwestern China). Satellite imagery during the growing season was acquired and their classification could achieve 80 per cent accuracy.

Nelson and Irmão (1998) used a Landsat Thematic Mapper (TM) image from 1975 to 1994 to study the phenomenon of bamboo flowering and susceptibility to fire in the Amazon forest. The study showed Band 3, 4, 5 as BGR false-colour composite is suitable for detecting synchronous bamboo flowering and fire scars. Hiroshi et al. (2009) used QuickBird satellite imagery (2.5 m MSS/0.6 m PAN image) and object-based land cover classification to extract areas of bamboo flowering. Han et al. (2014) mapped Moso bamboo in the northeast of Anji County, Zhejiang Province of China using a SPOT-5 image. Due to the high spatial resolution, they used an object-based image analysis method and texture measures derived from gray level co-occurrence matrices.

Ghosh and Joshi (2014) also made good use of high-resolution data in mapping bamboo. They used the WorldView-2 imagery, which provides 2 m multi-spectral and 0.5 m panchromatic spatial resolution. The study area was in the lower Gangetic plains in West Bengal, India, and the study team used an image acquired in the returning monsoon season. Temporal information was not used in these bamboo-mapping studies since they only used one single image.

Li et al. (2016) tried to map the distribution of bamboo in Zhejiang Province of China using four Landsat images, and the importance of temporal information in bamboo mapping was proven. These mapping works were limited to small study areas, and there has been no study focused on mapping bamboo at a national or a regional scale.

Chapter 2 Methodology

2.1 Data

2.1.1 Satellite imagery

Level 1 terrain-corrected (L1T) Landsat 8 images acquired between 2013 and 2017 were used in this study, but the images acquired in 2016 were used in the highest priority. Ancillary data includes MODIS Normalised Difference Vegetation Index (NDVI) time series, climate data (WorldClim Version2), and topography data (Shuttle Radar Topography Mission, SRTM).

2.1.2 Field sample

Ground truth samples were collected during several field trips. The location of ground truth samples is shown in Figure 1. The study team undertook field trips (in total around 3300 km) in these three countries in January 2017, accompanied by local experts, and collected 31 sample sets of location data mainly at Kiambu (Kenya), Migori (Kenya), Kabale (Uganda), Assosa (Ethiopia) and Butajira (Ethiopia).

Since the distribution of bamboo is scattered, local experts continued to contribute field samples to the dataset after this field trip. In total, local experts contributed 268 sample sites of bamboo from three countries (65 from Kenya, 37 from Uganda and 166 from Ethiopia).

For each sample in the training dataset, the team measured the extended radius from the centre point to be a homogeneous sample, which determined how many pixels we could spatially expand in training. The reason for expanding the training sample temporally and spatially was to enrich the spectral diversity of the training dataset (Zhao et al., 2016).

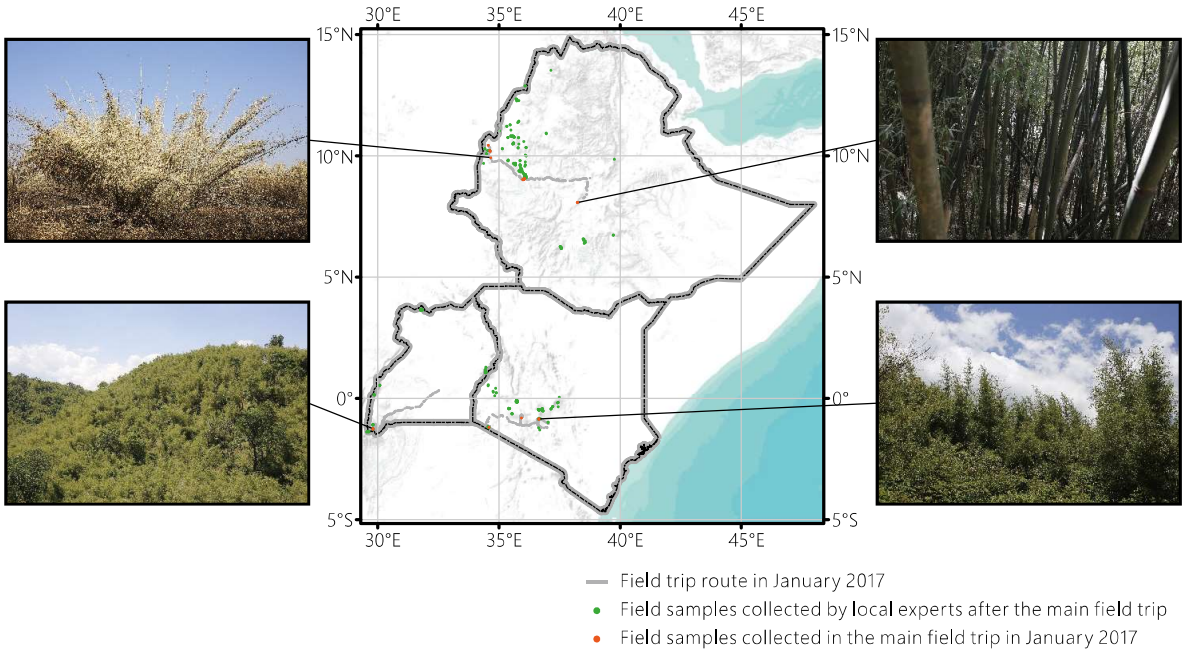

Figure 1: Ground truth sample collection locations

2.2 Mapping scheme, class definition and limitation

The map produced during this study includes not only bamboo classes, but also nine classes of other land cover types for better application. The nine classes are croplands, forests, grasslands, shrublands, wetlands, water bodies, impervious surfaces, bare lands, snow and ice in the classification scheme of FROM-GLC (Gong et al., 2013).

Based on the FAO definition, a forest is defined as an area of land spanning more than 0.5 hectares with trees higher than five metres and a canopy cover of more than 10 per cent, or trees able to reach these thresholds in situ. It does not include land that is predominantly under agricultural or urban use. In this study, bamboo mapped areas is defined as a land spanning more than 900 m^2 with a canopy cover consisting of at least 50 per cent of bamboo. This limitation arise mainly due to the resolution of imagery used in the study (Landsat imagery – 30 m x 30 m pixels). In addition, the length and/or width of a bamboo patch may not always align with the Landsat image pixel. Therefore, there is a chance that the small bamboo patches (with an area of 900 m^2 or with a length/width of 30 m) may not be identified in the mapping result.

Please note, during field visits to Ethiopia, Kenya and Uganda, the study team observed a large number of bamboo patches growing in smallholder farms as block planting, farm boundary planting, shelter belts (linear planting) and homestead planting. The size of bamboo cover in most of the farms was small (< 900 sq. m contiguous patch) and /or did not meet the criteria (above paragraph). So there is a high probability that the smallholder farm plantings were not captured in the study result due to the resolution of imagery, small size of farm planting and alignment of imagery pixels vs bamboo plots. In addition, there could be a slight overestimation of bamboo in some areas due to similar spectral properties of bamboo with other vegetation classes as explained in Section 1.4.

2.3 Mapping process

Figure 2 shows the flowchart of bamboo-mapping process or methodology adopted in this study which includes data preparation, sample collection, image classification, post-processing and accuracy assessment.

The study team chose a random forest classifier and a combined feature set of spectral bands, phenological metrics, topographic and climate characteristics. All Landsat images were classified and integrated according to the priority of different land cover classes. More information about methodology can be found in Zhao et al. (2018).

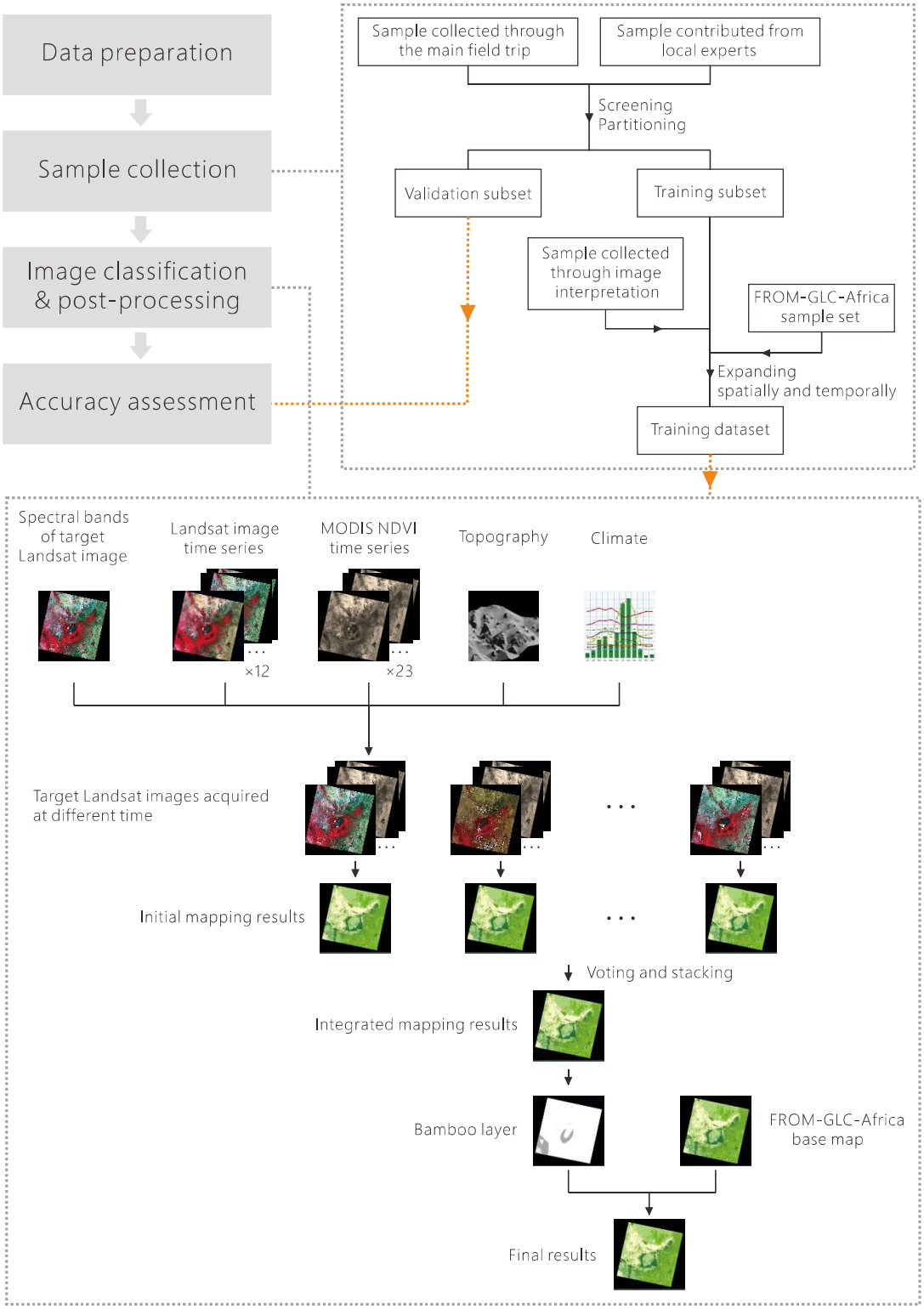

Figure 2: Work flow/methodology for bamboo mapping

Chapter 3
National Assessment for Ethiopia

3.1 Distribution pattern

3.1.1 Lowland bamboo

Oxytenanthera abyssinica, or lowland bamboo, is widely distributed in the western part of Ethiopia (see Figure 3). Lowland bamboo is drought-resistant, it occurs in the vast savanna woodlands, along the river valleys, and spreads around on the hills, mainly in Benishangul-Gumuz, the western part of the Amhara and Oromia regions. The lowland bamboo covers a range of elevation between 540 to 1750 m ASL, according to the statistics of the habitat mapped in this study.

An example is shown in Figure 3A, which is located 25 km east of Ghimbi. The River Didessa can be seen on the right, flowing in a northwestern direction. In lower elevations along the valley, the land cover type is dominated by woodlands, while most of the hill slopes are covered with bamboo. A further zoomed-in block on the top of Figure 3A shows the pattern of bamboo (left-bottom part of the block), shrubs (right-upper corner of the block) and trees (down in the gully). The high-resolution image on Google Earth was also presented here for the same area.

3.1.2 Highland bamboo

Yushania alpina or highland bamboo, is found in the south, southwest, central and northwest highlands of Ethiopia, mainly in Amhara; Southern Nations, Nationalities, and Peoples' Regional State (SNNPRS) and the Oromia Region.

Highland bamboo usually grows on volcanic soils such as those found on Tepi, a basaltic shield volcano in southwestern Ethiopia shown in Figure 3B. The hill slope is mainly covered by dense forest at a lower elevation and bamboo at a higher elevation above 2480 m ASL. The bamboo coverage is around 19.96 km^2 by the area statistics in the study.

The Bonga Forest Reserve bordering between Oromia Region and SNNPRS is one of the last remaining subtropical montane cloud forests in Ethiopia (Nune, 2008). As shown in Figure 3C, the Bonga Forest Reserve is covered mainly by forests and bamboo. The highland bamboo is found at an altitudinal range between 2780 and 3285 m ASL, covering an area of 16.90 km^2.

Located in the Oromia Region, the Bale Mountains are a mountain range of the southern Ethiopian Highlands. The Bale Mountains contain a diverse landscape, including grasslands, afro-alpine plants, shrub lands, bamboo and montane forests (see Figure 3D). The region is home to many endemic animals (Yalden, 1988), and this special landscape provides them with good habitats. For example, the Bale Mountains vervet monkeys inhabits tropical montane forests and bamboo, and bamboo makes up the majority of its diet. The estimated area of bamboo cover is 78.36 km^2, and most of the bamboo grows on an elevation of 2400 to 3300 m ASL, according to the mapping result of this study. Highland bamboo is also grown on the farm in small patches or as farm boundaries, which was not captured in this study, due to the spatial resolution of Landsat imagery.

3.2 Area statistics

The total area of bamboo in Ethiopia is 14744.63 km^2, shown in Figure 4 with the administrative boundaries.

The first administrative subdivision of Ethiopia is ethno-linguistically-based regional states and chartered cities. As can be seen from in Table 1, the area of bamboo is unevenly distributed across the regions. Among all regions in Ethiopia, the most bamboo-rich region is Benishangul-Gumuz, accounting for 64 per cent of the country's total bamboo area, followed by the Amhara Region, the Oromia Region and the SNNPRS.

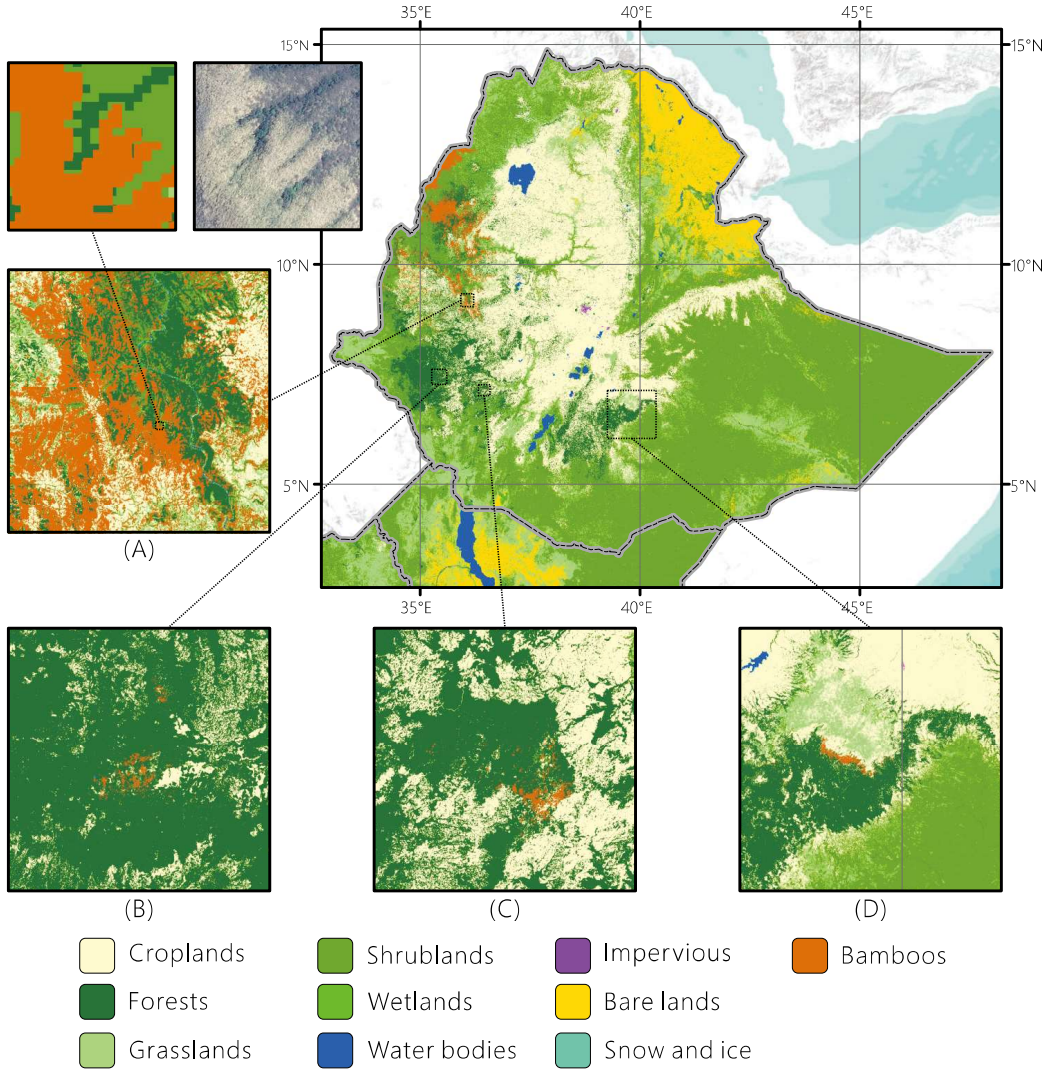

Figure 3: The bamboo cover map of Ethiopia and four zoomed-in areas with abundant bamboo, overlaid with other land cover classes in the classification scheme of FROM-GLC.

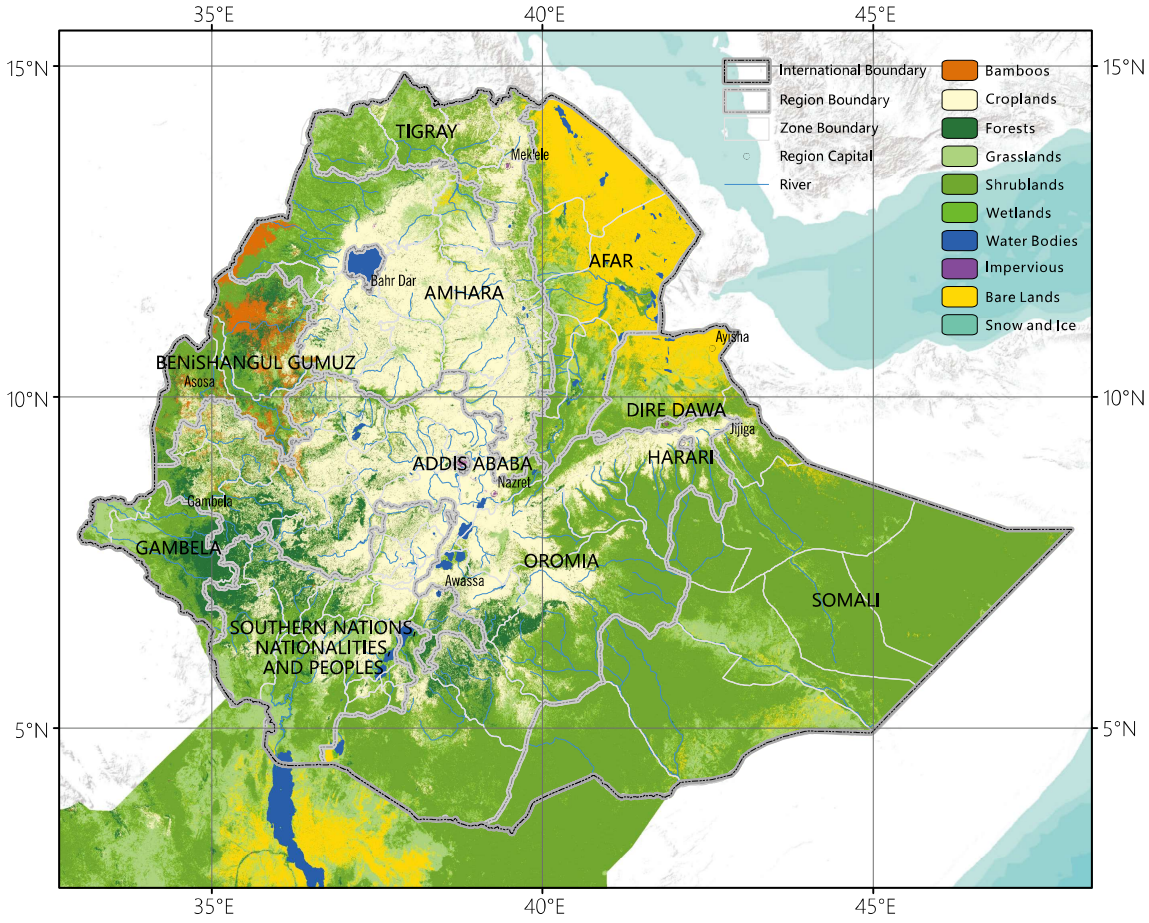

Figure 4: The bamboo cover map of Ethiopia, overlaid on the administrative boundaries

Table 1: Bamboo area by region in Ethiopia

Region	Bamboo area in km²
Benishangul-Gumuz Region	9447.59
Amhara Region	3122.29
Oromia Region	2117.24
SNNPRS	48.56
Gambela Region	8.94
Total Area	**14744.63**

The regions of Ethiopia are further administratively divided into several zones. Information on the area of bamboo by zone can be found in Table 2. In Figure 5, the distribution of bamboo resources in different zones of each region is presented. In Benishangul-Gumuz, the Metekel Zone has the largest extent of bamboo, accounting for 72 per cent of the total area in this region. Similarly, most of the bamboo in the Amhara Region is found in North Gondar Zone, representing 92 per cent of the total area. In the Oromia Region, West Wellega and East Wellega host most of the bamboo growing areas, accounting for 40 and 33 per cent respectively. In the Southern Nations, Nationalities, and Peoples' Regional State, a high proportion of bamboo forests is found in the Keffa and Bench Maji Zones.

Table 2: Bamboo area by zone in Ethiopia

Zone	Bamboo Area in Km²
Benishangul-Gumuz Region	
Metekel	6797.40
Kemashi	1548.42
Assosa	1101.78
Subtotal	9447.59
Amhara Region	
North Gondar	2864.64
Agew Awi	202.25
West Gojjam	54.61
East Gojjam	0.79
South Wollo	0.01
Subtotal	3122.29
Oromia Region	
West Wellega	856.53
East Wellega	689.88
Illubabor	286.79
Kelem Wellega	244.12
Horo Guduru	31.46
Jimma	6.86
Bale	1.10
West Shewa	0.30
West Arsi	0.17
Guji	0.02
Subtotal	2117.24
Southern Nations, Nationalities, and Peoples Regional State	
Keffa	19.09
Bench Maji	11.96
Sheka	9.47
Konta Special	4.39
Dawro	1.86
South Omo	1.04
Gamo Gofa	0.66
Gurage	0.02
Gedeo	0.02
Derashe Special	0.01
Kembata Alaba Tembaro	0.01
Sidama	0.01
Yem Special	0.01
Subtotal	48.56
Gambela Region	
Anuak	8.66
Mezhenger	0.28
Subtotal	8.94
Total	**14744.63**

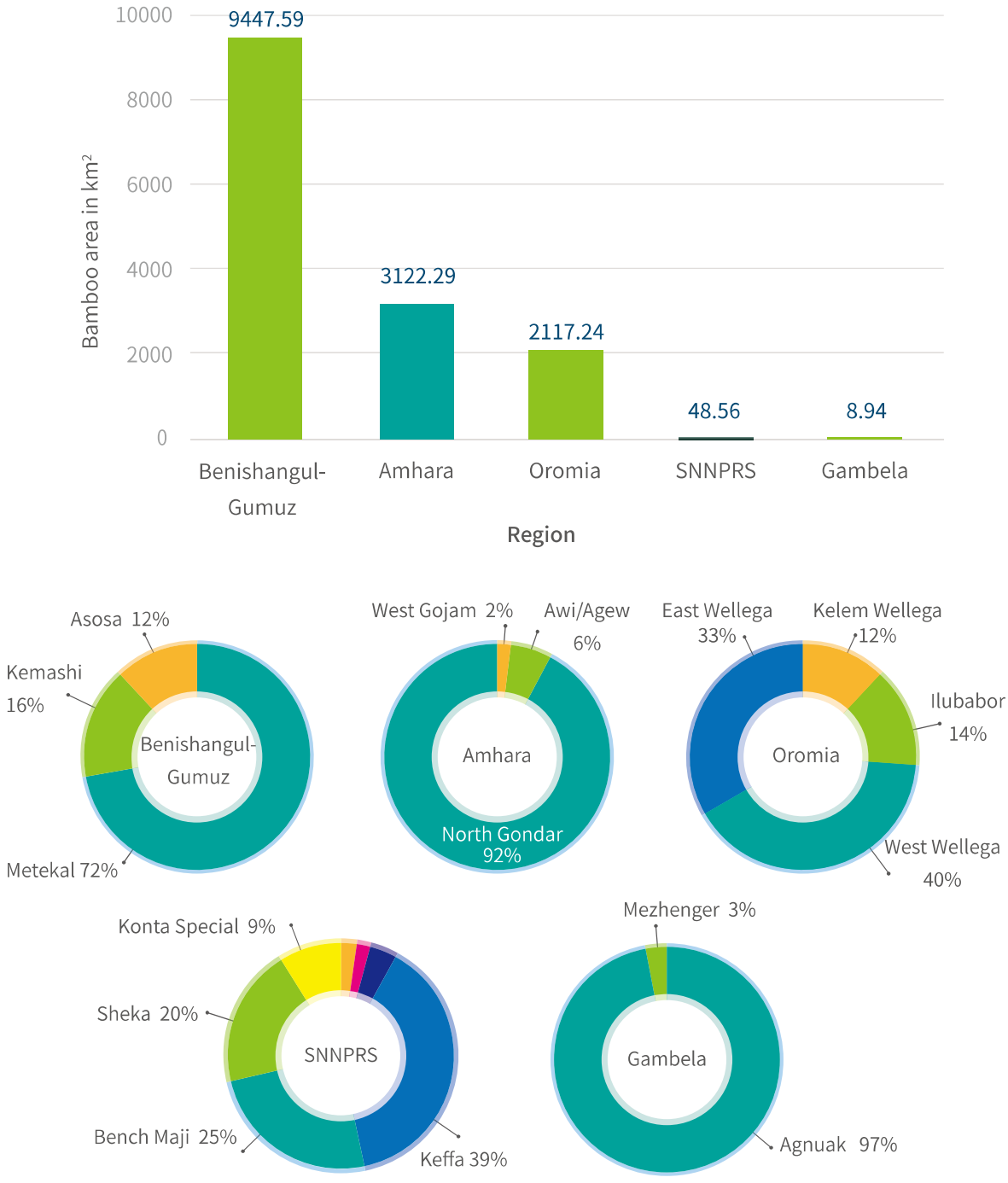

Figure 5: Bar and pie chart depiction of bamboo areas in each region and zone of Ethiopia.

Woredas, or districts, are the third-level administrative divisions of Ethiopia, under zone. The woredas with the largest bamboo areas are listed in Table 3.

Table 3: Top 25 bamboo-growing woredas in Ethiopia

Woreda	Zone	Region	Bamboo Area in Km²
Quara	North Gondar	Amhara	2662.75
Guba	Metekel	Benishangul-Gumuz	2575.12
Dangura	Metekel	Benishangul-Gumuz	1295.37
Wenbera	Metekel	Benishangul-Gumuz	1137.85
Bulen	Metekel	Benishangul-Gumuz	846.41
Dibat	Metekel	Benishangul-Gumuz	524.37
Kemashi	Kemashi	Benishangul-Gumuz	470.66
Yaso	Kemashi	Benishangul-Gumuz	380.38
Mandura	Metekel	Benishangul-Gumuz	360.29
Agalometi	Kemashi	Benishangul-Gumuz	315.69
Bilidigilu	Assosa	Benishangul-Gumuz	296.32
Assosa	Assosa	Benishangul-Gumuz	236.98
Bio Jiganifado	Kemashi	Benishangul-Gumuz	213.46
Mana Sibu	West Wellega	Oromia	198.85
Metema	North Gondar	Amhara	197.02
Haro Limu	East Wellega	Oromia	189.20
Homosha	Assosa	Benishangul-Gumuz	174.04
Sirba Abay	Kemashi	Benishangul-Gumuz	168.27
Guangua	Agew Awi	Amhara	147.42
Gimbi	West Wellega	Oromia	147.01
Bambasi	Assosa	Benishangul-Gumuz	137.10
Gida Kiremu	East Wellega	Oromia	114.33
Gudetu Kondole	West Wellega	Oromia	109.00
Chwaka	Illubabor	Oromia	98.19
Mao-Komo Special	Assosa	Benishangul-Gumuz	95.56

Chapter 4
National Assessment for Kenya

4.1 Distribution pattern

In Kenya, the dominant species of bamboo mapped in this study is *Yushania alpina* K. Schumach, and it was found mainly in Mount Elgon, Mount Kenya, Cherangany Hills, the Mau Forest and the Aberdare Range. The distribution of bamboo in different mountain ranges or in protected areas is as described in Table 4.

Table 4: Bamboo areas in mountain ranges of Kenya

Mountain Ranges	Area in km²	Map
Mount Elgon	143.41	Figure 6A
Mount Kenya	259.66	Figure 6B
Cherangany Hills	81.80	Figure 6C
Mau Forest	301.96	Figure 6D
Aberdare Range	500.38	Figure 6E

Mount Elgon is a large extinct volcano bordering Uganda and Kenya. The vegetation belts are savanna woodlands and croplands, montane forests, bamboo and moorlands from the bottom to the top. The bamboo covers an area of 342.01 km^2 in total for both sides of Mount Elgon (estimated 143.41 km^2 in Kenya). The West Elgon gets the most rainfall, followed by the South, the East and the North (Dale et al., 1940). Shown in Figure 6A, the bamboo belt is contiguous and wide on the south and west side, starting at an elevation of 2500 m ASL, while it is less dense and restricted in patches above 2700 m ASL on the east and north side.

Mount Kenya, which is the highest mountain in Kenya, is located in central Kenya, 0.15 degrees south of the equator. From the base to the top, Mount Kenya has different vegetation belts due to the altitudinal climate difference, including croplands, montane forests, bamboo, timberline forests, heathlands and chaparrals, afro-alpine plants (giant groundsels and giant lobelias) and a nival zone as the altitude increases (Coe, 2012). The zoomed-in map (Figure 6B) shows the distribution of bamboo on Mount Kenya, covering an area of 259.66 km^2. The bamboo belt is usually between an altitude of 2290 and 3150 m ASL, which is wider in the southeastern slopes and is partitioned into small patches in the northern slopes, caused mainly by the difference in moisture.

The Cherangany Hills are a series of hills in western Kenya, on the western ridge of the East African Rift. The hills are among the most important water catchment areas in Kenya and there are many forest reserves. The bamboo occurs at an elevation higher than 2600 m ASL in the highland forests of Lelan, Embobut, Kipkunurr and Kapchemutwo from south to north (see Figure 6C), especially growing in patches along the stream valleys. The estimated area of bamboo in this area is around 81.80 km^2.

The Mau Forest is another important indigenous montane forest in Kenya (Kinyan-jui et al., 2014), which is the source of many rivers draining into Lake Victoria. In the Mau Forest, bamboo covers 301.96 km^2. On the western side, the rainfall is higher, with no marked dry season, and the bamboo is found on lower elevations ranging starting from 2300 m ASL. On the other side, with less rainfall bamboo is found only on the uppermost parts of the forests, as shown in Figure 6D.

The Aberdare Range is located in West-Central Kenya, north of Nairobi, and forms a part of the eastern rim of the Great Rift Valley. The range is a vital water catchment area supplying water for the Tana and Athi rivers. Bamboo cover in Aberdare range is shown in Figure 6E. Bamboo forests are found in mid-altitudinal belts. The vegetation changes from croplands at the foot of the mountain to montane forests, bamboo and moorlands on the top. The bamboo is found at an altitude of 2400 to 3100 m ASL on the eastern and southern slopes, and 2700 to 3320 m ASL on the drier northern slopes. The estimated area of bamboo in the Aberdare Range is 500.38 km^2.

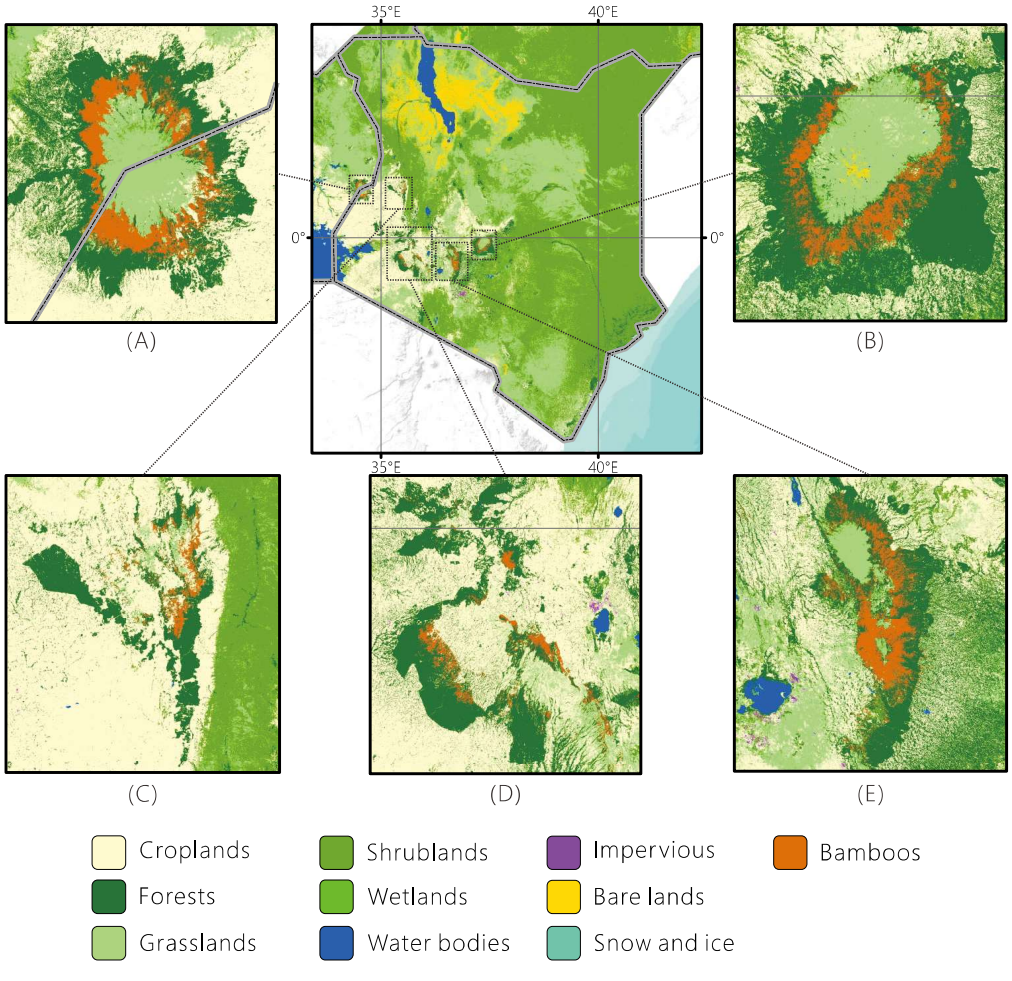

Figure 6: The bamboo cover map of Kenya and five zoomed-in areas with abundant bamboo, overlaid with other land cover classes in the classification scheme of FROM-GLC.

4.2 Area statistics

The bamboo area is estimated to be 1332.73 km^2 in Kenya, shown in Figure 7 with the county boundary. Most of the bamboo resources are distributed in the Central Province, Western Province and Rift Valley Province. It is also important to note that about 97 per cent of the bamboo is found in mountain ranges and/or in protected areas managed by the government.

The districts with the largest bamboo areas are listed in Table 5.

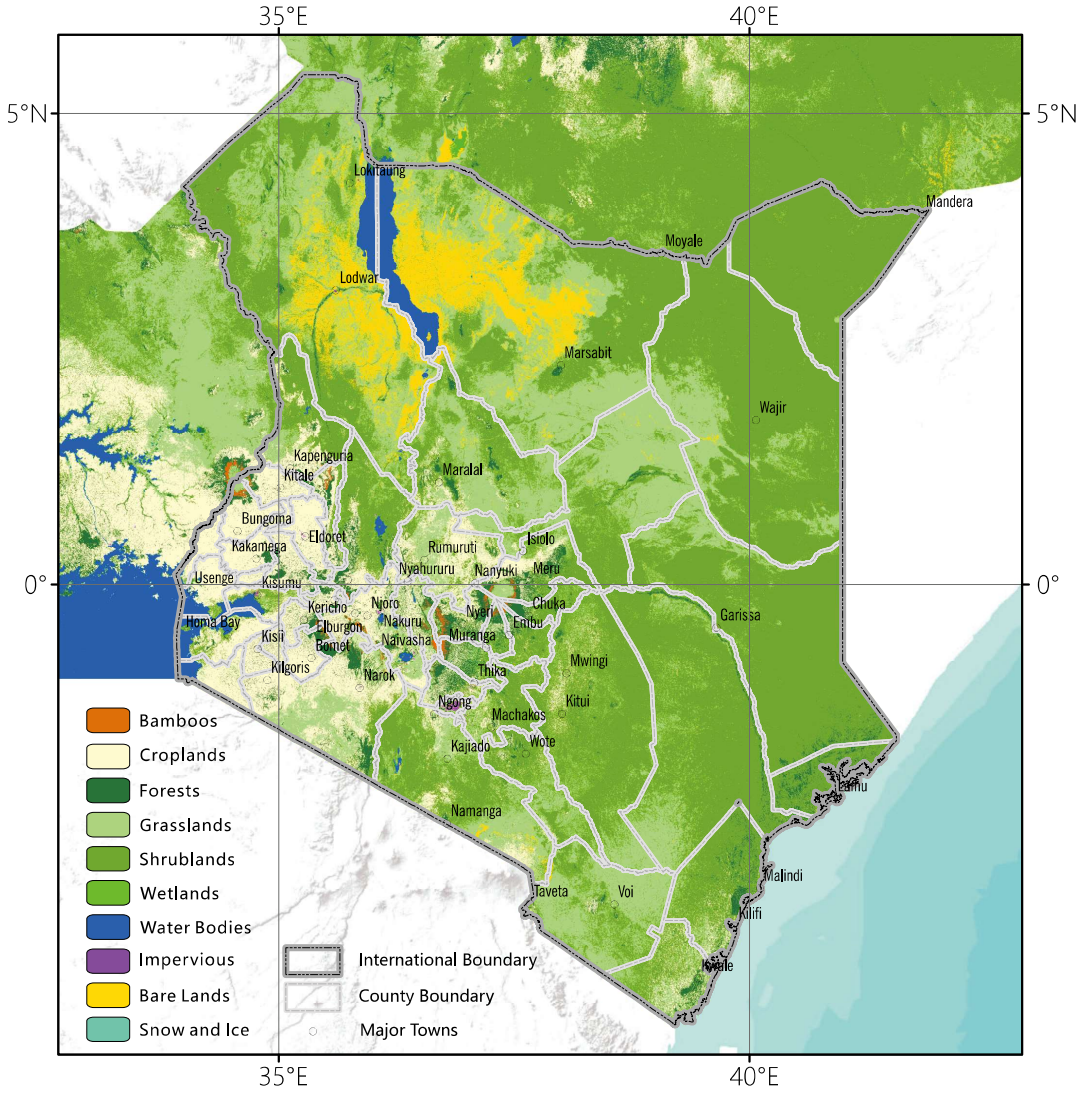

Figure 7: The bamboo cover map of Kenya overlaid with administrative boundaries

Table 5: Top 20 bamboo-growing districts in Kenya

District	Province	Bamboo area in km²
Nyeri	Central Province	256.85
Nyandarua	Central Province	185.77
Murang'a	Central Province	123.00
Bungoma	Western Province	111.12
Nakuru	Rift Valley Province	105.31
Meru	Eastern Province	91.94
Narok	Rift Valley Province	77.96
Elgeyo-Marakwet	Rift Valley Province	69.05
Bomet	Rift Valley Province	56.21
Kirinyaga	Central Province	43.19
Trans Nzoia	Rift Valley Province	41.10
Kericho	Rift Valley Province	36.68
Embu	Eastern Province	34.42
Tharaka-Nithi	Eastern Province	28.45
Baringo	Rift Valley Province	27.88
Kiambu	Central Province	20.84
West Pokot	Rift Valley Province	16.86
Uasin Gishu	Rift Valley Province	4.46
Nandi	Rift Valley Province	1.46
Nairobi	City of Nairobi	0.06

Chapter 5
National Assessment for Uganda

5.1 Distribution pattern

There are two predominant indigenous bamboo species in Uganda. They are *Oxytenanthera abyssinica* (commonly known as lowland bamboo) and *Yushania alpina* (commonly known as highland bamboo). The distribution of bamboo in national parks/central forest reserves is listed in Table 6.

Table 6: Bamboo areas in Uganda's national parks/central forest reserves

Mountain Ranges	Area in km²	Map
Otzi Forest Reserve	87.74	Figure 8A
Agoro-Agu Central Forest Reserve	20.40	Figure 8B
Rwenzori Mountains	191.00	Figure 8C
Mount Elgon	198.70	Figure 8D
Mgahinga Gorilla National Park	8.66	Figure 8E
Echuya Forest	1.04	Figure 8F

5.1.1 Lowland bamboo

Lowland bamboo in Uganda is found mainly in the northeastern parts of the country: the Otzi Mountains and Metu, as well as the Agoro-Agu Central Forest Reserve in the southern part of Imatong Mountains.

The Otzi Forest Reserve, situated in northern Uganda's Moyo District, is famous for its rich biodiversity (Owiny, 2011). There has been evidence of the presence of chimpanzees (Acanakwo, 2011), and it is also well-known for the white rhino sanctuary. The terrain is rugged, with an elevation range from 700 to 1600 m ASL. The Otzi Mountains are an important water catchment situated in a relatively low precipitation area with a prolonged dry season. Bamboo value-addition activities, mainly the conversion of bamboo into basketry and sales of bamboo poles, are wide-spread. This area has long been a main source of bamboo products, especially bamboo poles for building materials. From the map shown in Figure 8A, the Otzi Forest Reserve is covered by woody savanna and the bamboo stands are usually mixed with thickets and bushes. The total area where bamboo grows is 87.74 km^2 in the Otzi Mountains and Metu.

The Agoro-Agu Central Forest Reserve is located at the border between Uganda and South Sudan. It is the extension of Imatong Mountains into the northern region of Uganda, and basically lower than the southern part in South Sudan. The land cover map (Figure 8B) indicates that the vegetation of this area includes afromontane forests, shrublands, woody grasslands and bamboo. Bamboo is distributed widely on the slopes between an elevation of 1170 and 1905 m ASL, covering an area of 20.40 km^2.

5.1.2 Highland bamboo

The most typical regions of highland bamboo mapped in Uganda are the Rwenzori Mountains, Mgahinga Gorilla National Park, Echuya and Mount Elgon.

The Rwenzori Mountains are located in the equatorial zone, on the border between Uganda and the Democratic Republic of the Congo. Shown in Figure 8C, largely similar to other tropical mountains, the Rwenzori Mountains have different vegetation zones, including tropical

rainforests, bamboo, montane cloud forests, heathlands, afro-alpine plants, bare rocks and snow. An estimated bamboo-growing area of 191.00 km^2 is mostly found at an elevation ranging from 2625 to 3406 m ASL, sandwiched between the two forest layers.

Situated in the southwestern part of Uganda, Mgahinga Gorilla National Park includes three of the eight Virunga Mountains volcanoes: Mount Sabyinyo, Mount Gahinga and Mount Muhabura. Mgahinga Gorilla National Park was established to protect the habitat of the mountain gorilla and other endangered animals. The vegetation types include woodlands and montane forests at the base or lower elevation, bamboo in the middle altitudes and an afro-alpine zone covered with grasslands and shrub lands on the top (Figure 8E). The bamboo belts surrounding the three volcanic mountains are found in altitudes ranging from 2700 to 3100 m ASL, covering a total area of 8.66 km^2.

The Echuya Forest is located in the southwestern part of Uganda, which is a Central Forest Reserve (CFR) managed by the National Forestry Authority (NFA). This is the only bamboo site where the GIS remote sensing data collection team visited during field data collection during January 2017. The field survey and data collection was done along the profile from the ridgetop, walking down across the valley and sampled different land cover types of pure bamboo, mosaic of bamboo and rainforests, pure rainforests and swamps. The bamboo is found along the upper slope of eastern side (see Figure 8F), covering an area of 1.04 km^2. Local people and some researchers reported that bamboo has been replaced by other vegetation classes (Banana and Tweheyo, 2001). Continuous remote sensing-based monitoring to detect future changes is proposed by the study team.

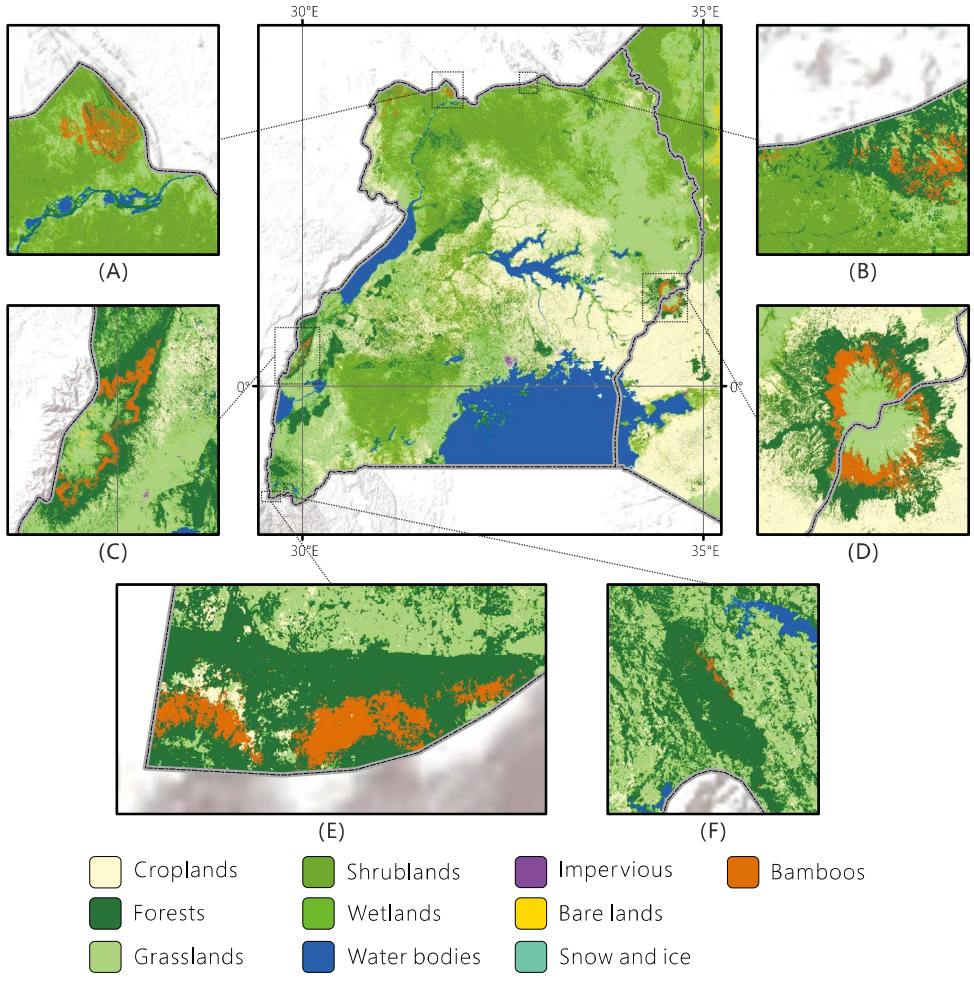

Figure 8: The bamboo cover map of Uganda and six zoomed in areas with abundant bamboo, overlaid with other land cover classes in the classification scheme of FROM-GLC.

5.2 Area statistics

The bamboo-growing area in Uganda is estimated at 545.33 km^2. Figure 9 is the map of bamboo distribution with the administrative boundaries. A comparison between this and Table 6 above shows that over 90 per cent of the bamboo in Uganda is located within national parks and in forest reserves.

Administratively, Uganda is divided into sub-regions and further into districts. Bamboo-growing area in each of the sub-regions is shown in Table 7.

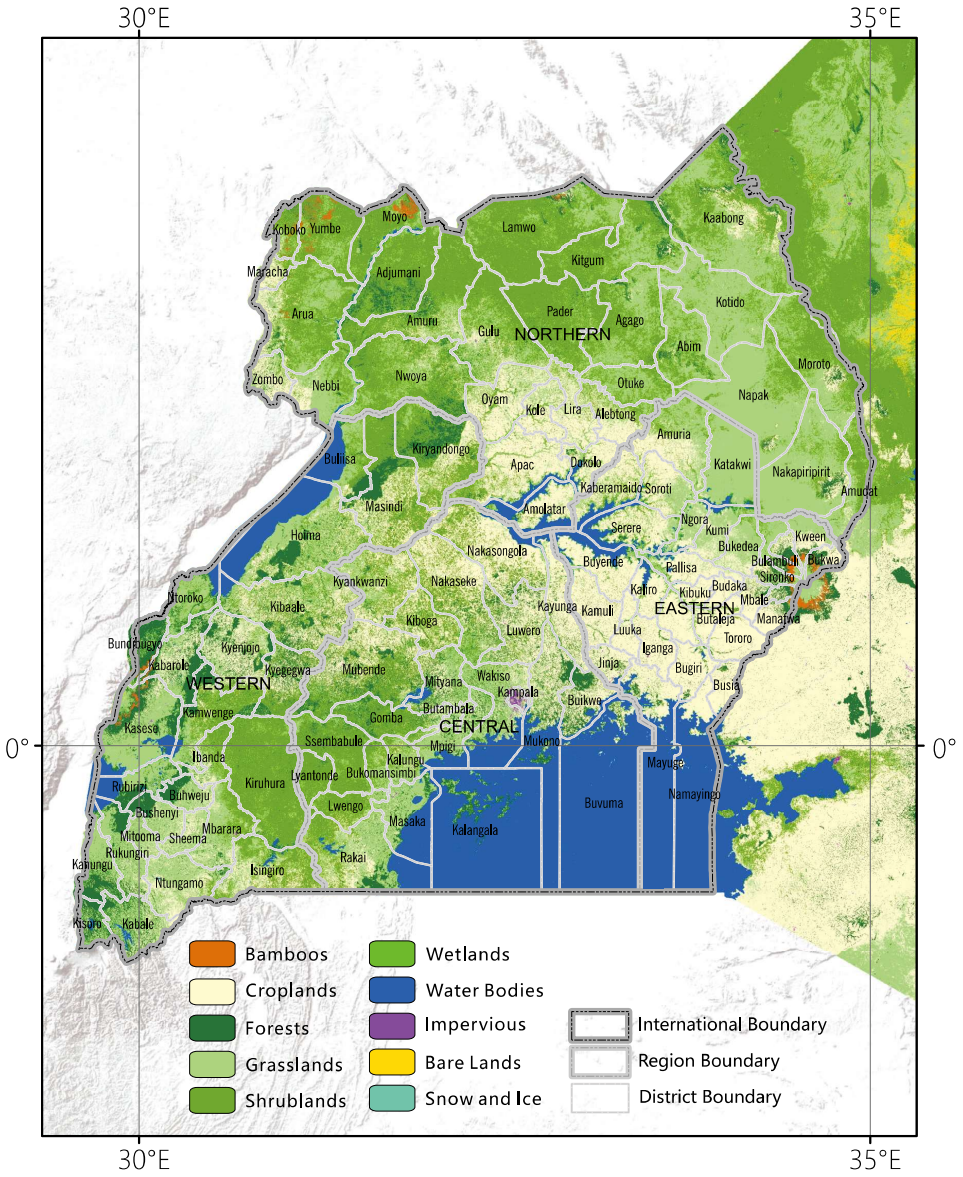

Figure 9: The bamboo cover map of Uganda, overlaid with the administrative boundaries.

Mt. Elgon's sub-region has the largest bamboo-growing area in Uganda, accounting for about 36 per cent of total bamboo. Western Uganda stands in second place in all sub-regions, accounting for 32 per cent of the total bamboo area. The West Nile is the third sub-region, with over 25 per cent of the bamboo forests in the country.

Table 7: Bamboo area by sub-region in Uganda

Sub-Region	Bamboo area in km²
Mt. Elgon	198.70
Western Uganda	173.89
West Nile	138.83
Acholi	24.42
Southwestern Uganda	8.80
Karamoja	0.65
Albertine	0.04
Total	**545.33**

The bamboo-growing areas, listed under each sub-region according to district boundaries, are presented in Table 8. Figure 10 shows that bamboo forests are found evenly in many districts of Mount Elgon, including Bulambuli (22%), Bukwa (19%), Manafwa (16%), Kapchorwa (15%), Kween (11%), Sironko (10%) and Bududa (7%). In Western Uganda, almost half of the bamboo area is located in the Kasese district, followed by Bundibugyo (31%) and Kabarole (21%). Moyo is the district in the West Nile Region that has the largest bamboo-growing area of 90.02 km^2, accounting for 65 per cent of the total bamboo area in this sub-region. In addition, Lamwo district in the Acholi Region has considerable bamboo resources (21.36 km^2).

Table 8: Bamboo area by district in Uganda

District	Bamboo area in km²
Mt. Elgon Sub-Region	
Bulambuli	42.94
Bukwa	37.69
Manafwa	31.21
Kapchorwa	29.18
Kween	23.06
Sironko	20.62
Bududa	14.00
Subtotal	**198.70**

District	Bamboo area in km²
Western Uganda Sub-Region	
Kasese	83.33
Bundibugyo	54.08
Kabarole	36.45
Kyenjojo	0.03
Subtotal	173.88
West Nile Sub-Region	
Moyo	90.02
Yumbe	27.62
Koboko	15.76
Arua	5.02
Zombo	0.23
Maracha	0.18
Subtotal	138.83
Acholi Sub-Region	
Lamwo	21.36
Agago	1.22
Amuru	0.94
Kitgum	0.56
Gulu	0.18
Adjumani	0.13
Nwoya	0.03
Subtotal	24.43
Southwestern Uganda Sub-Region	
Kisoro	7.40
Kabale	1.35
Kanungu	0.05
Subtotal	8.80
Karamoja Sub-Region	
Kaabong	0.28
Abim	0.27
Moroto	0.10
Subtotal	0.65
Albertine Sub-Region	
Ntoroko	0.02
Hoima	0.02
Subtotal	0.04
Total	**545.33**

Figure 10 shows a depiction of bamboo-growing areas according to region (bar chart) and districts (pie chart).

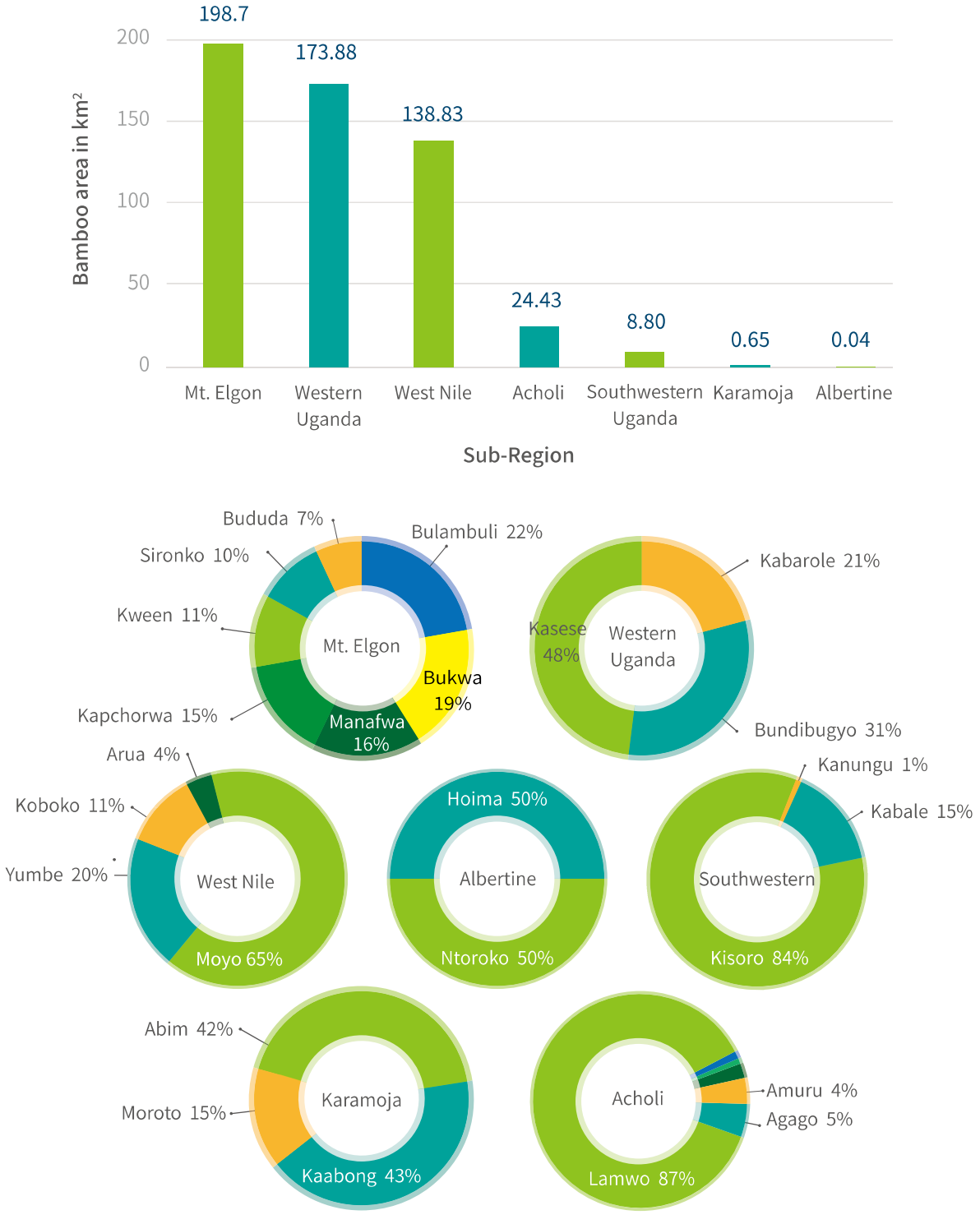

Figure 10: Bar and pie chart depiction of bamboo-growing regions and districts in Uganda

The 20 districts with the largest bamboo areas in Uganda are listed in Table 9.

Table 9: Top 20 bamboo-growing districts in Uganda

District	Sub-Region	Bamboo area in km²
Moyo	West Nile	90.02
Kasese	Western Uganda	83.33
Bundibugyo	Western Uganda	54.08
Bulambuli	Mt. Elgon	42.94
Bukwa	Mt. Elgon	37.69
Kabarole	Western Uganda	36.45
Manafwa	Mt. Elgon	31.21
Kapchorwa	Mt. Elgon	29.18
Yumbe	West Nile	27.62
Kween	Mt. Elgon	23.06
Lamwo	Acholi	21.36
Sironko	Mt. Elgon	20.62
Koboko	West Nile	15.76
Bududa	Mt. Elgon	14.00
Kisoro	Southwestern Uganda	7.40
Arua	West Nile	5.02
Kabale	Southwestern Uganda	1.35
Agago	Acholi	1.22
Amuru	Acholi	0.94
Kitgum	Acholi	0.56

Chapter 6 Conclusion

Mapping the spatial distribution of bamboo is necessary for biodiversity conservation, resource evaluation and ecosystem service management. This study produced a contemporary bamboo map of Ethiopia, Kenya and Uganda for the year 2016 using 30 m spatial resolution imagery. This is the first remote sensing-based bamboo resources map of its kind for these three East African countries that possess most of the African bamboo resources. The study team collected a highly reliable training and validation sample dataset by field survey and image interpretation, and developed an effective mapping process using multi-temporal image series of high temporal resolution. The producer's and user's accuracy of bamboo are 79.2 per cent and 84.0 per cent, respectively.

According to our mapping result, the total coverage of bamboo is estimated to be 14744.63 km^2, 1332.73 km^2 and 545.33 km^2 in Ethiopia, Kenya and Uganda, respectively. In Ethiopia, lowland bamboo is widely distributed in the northwestern part (Benishangul Gomuz, Assosa and Oromia regions) while highland bamboo are found in the south and central parts of the country. In Kenya, highland bamboo was found mainly in Mount Elgon, Mount Kenya, Cherangany Hills, the Mau Forest and the Aberdare Range. In Uganda, the study found lowland bamboo in the Otzi Mountains and the Agoro-Agu Central Forest Reserve, and highland bamboo in the Rwenzori Mountains, Mgahinga Gorilla National Park, Echuya and Mount Elgon. The coverage of bamboo was also estimated for each region, as well as the elevation of its habitat.

The bamboo area was also calculated for the administrative units at different level for the three countries according to the available official administrative boundaries. The administrative units with the largest bamboo area were listed in this report for more applications.

It is important to note that due to usage of 30 m spatial resolution imagery, most of the bamboo grown in smallholder farms may not have been mapped by this study. Future studies on a country scale, as well as on a regional scale, could use high-resolution imagery. In addition, mobile/android-based applications could be developed to inventory the bamboo in smallholder farms.

Bibliography

Acanakwo, E. F. (2011). ***Tree diversity, use and land cover changes in Mt. Otzi Forest Reserve, Northern Uganda***. PhD thesis, Makerere University.

Agarwal, A. and Purwar, J. (2017). Carbon sequestration and above ground biomass produced by bambusa spp. in the mid-Himalayan region of Uttarakhand, India. ***Indian Forester***, 143(4):303–306.

Banana, A. Y. and Tweheyo, M. (2001). The ecological changes of Echuya afromontane bamboo forest, Uganda. ***African journal of Ecology***, 39(4):366– 373.

Banik, R. L. (2000). Silviculture and field guide to priority bamboos of Bangladesh and South Asia.

Bessie, S., Beyene, F., Hundie, B., Goshu, D., Mulatu, Y., et al. (2016). Land use/land cover change and its effects on bamboo forest in Benishangul Gumuz Region, Ethiopia. ***International Journal of Sustainable Development & World Policy***, 5(1):1–11.

Bharadwaj, S. P., Subramanian, S., Manda, S., Ray, T., Mukherjee, P. and Rao, I. R. (2003). Bamboo livelihood development planning, monitoring and analysis through gis and remote sensing. ***Journal of Bamboo and Rattan***, 2(4):453–461.

Bystriakova, N., Kapos, V. and Lysenko, I. (2004). ***Bamboo biodiversity: Africa, Madagascar and the Americas***. Number 19. UNEP/Earthprint.

Chen, H., Yu, Y., Zhong, T., Wu, Y., Li, Y., Wu, Z. and Fei, B. (2017). Effect of alkali treatment on microstructure and mechanical properties of individual bamboo fibers. ***Cellulose***, 24(1):333–347.

Coe, M. J. (2012). ***The ecology of the alpine zone of Mount Kenya***, volume 17. Springer Science & Business Media.

Dale, I. et al. (1940). The forest types of Mount Elgon. ***The Journal of the East Africa and Uganda Natural History Society***, 15(1/2):74–82.

Das, A. (2017). Bamboo growing and its marmet development potential for sustaining rural livelihoods and poverty reduction in eastern Nepal. ***Banko Janakari***, 12(1):8–19.

Dubey, A., Trivedi, N. and Joshi, T. (2016). Bamboo: An effective carbon sequester and phytolith. ***Agroforestry***, page 85.

Ghosh, A. and Joshi, P. (2014). A comparison of selected classification algorithms for mapping bamboo patches in lower Gangetic plains using very high resolution WorldView 2 imagery. ***International Journal of Applied Earth Observation and Geoinformation***, 26:298–311.

Gong, P., Wang, J., Yu, L., Zhao, Y., Zhao, Y., Liang, L., Niu, Z., Huang, X., Fu, H., Liu, S., et al. (2013). Finer resolution observation and monitoring of global land cover: first mapping results with Landsat TM and ETM+ data. ***International Journal of Remote Sensing***, 34(7):2607–2654.

Han, N., Du, H., Zhou, G., Sun, X., Ge, H. and Xu, X. (2014). Object-based classification using spot-5 imagery for Moso bamboo forest mapping. ***International journal of remote sensing***, 35(3):1126–1142.

Hiroshi, M., Hisashi, H., Manoru, K. and Shozo, S. (2009). Gregarious flowering of *melocanna baccifera* around north east India: Extraction of the flowering event by using satellite image data. In ***VIII World Bamboo Congress Proceedings***, volume 5, pages 101–107.

Joshi, P. K., Roy, P., Singh, S., Agrawal, S. and Yadav, D. (2006). Vegetation cover mapping in India using multi-temporal IRS wide field sensor (WiFS) data. ***Remote Sensing of Environment***, 103(2):190–202.

Kaur, P. J., Pant, K., Satya, S. and Naik, S. (2016). Bamboo: The material of future. ***International Journal Series in Multidisciplinary Research (IJSMR)*** *(ISSN: 2455-2461)*, 2(2):27–34.

Kigomo, B. et al. (1988). Distribution, cultivation and research status of bamboo in Eastern Africa.

Kinyanjui, M. J., Latva-Käyrä, P., Bhuwneshwar, P. S., Kariuki, P., Gichu, A. and Wamichwe, K. (2014). An inventory of the above ground biomass in the Mau Forest ecosystem, Kenya. ***Open Journal of Ecology***, 4(10):619.

Kratter, A. W. (1997). Bamboo specialization by Amazonian birds. ***Biotropica***, 29(1):100–110.

Li, M., Li, C., Jiang, H., Fang, C., Yang, J., Zhu, Z., Shi, L., Liu, S. and Gong, P. (2016). Tracking bamboo dynamics in Zhejiang, china, using time-series of Landsat data from 1990 to 2014. ***International Journal of Remote Sensing***, 37(7):1714–1729.

Linderman, M., Bearer, S., An, L., Tan, Y., Ouyang, Z. and Liu, J. (2005). The effects of understory bamboo on broad-scale estimates of giant panda habitat. ***Biological Conservation***, 121(3):383–390.

Linderman, M., Liu, J., Qi, J., An, L., Ouyang, Z., Yang, J., and Tan, Y. (2004). Using artificial neural networks to map the spatial distribution of understorey bamboo from remote sensing data. ***International Journal of Remote Sensing***, 25(9):1685–1700.

Lobovikov, M., Ball, L., Guardia, M., and Russo, L. (2007). ***World bamboo resources: a thematic study prepared in the framework of the global forest resources assessment 2005***. Number 18. Food & Agriculture Organisation.

Mekonnen, A., Fashing, P. J., Bekele, A., Hernandez-Aguilar, R. A., Rueness, E. K., Nguyen, N. and Stenseth, N. C. (2017). Impacts of habitat loss and fragmentation on the activity budget, ranging ecology and habitat use of Bale monkeys (Chlorocebus djamdjamensis) in the southern Ethiopian highlands. ***American Journal of Primatology***.

Mishra, V. (2015). Bamboo and its connectivity to the different fields of economics: A potential resource of modern India. ***International Journal of Innovative Research and Development***, 4(2).

Mulatu, Y., Alemayehu, A. and Tadesse, Z. (2016). Biology and management of indigenous bamboo species of Ethiopia. ***Ethiopian Environment and Forest Research Institute***.

Nelson, B. W. and Irmão, M. N. (1998). Fire penetration in standing Amazon forests. In ***Proceedings of the Ninth Brazilian Remote Sensing Symposium, Santos, Brazil***.

Nune, S. (2008). Flora biodiversity assessment in Bonga, Boginda and Mankira Forest, Kafa, Ethiopia. *Addis Ababa, Ethiopia,* ***Ethiopian Wildlife and Natural History Society***.

Ohrnberger, D., Goerrings, J., et al. (1988). ***The bamboos of the world.***

Owiny, A. A. (2011). Regeneration status of indigenous forest tree species of Mt. Otzi forest reserve, Moyo District.

Reid, S., Díaz, I. A., Armesto, J. J. and Willson, M. F. (2004). Importance of native bamboo for understory birds in Chilean temperate forests. ***The Auk***, 121(2):515–525.

Rogan, J., Franklin, J., and Roberts, D. A. (2002). A comparison of methods for monitoring multitemporal vegetation change using Thematic Mapper imagery. ***Remote Sensing of Environment***, 80(1):143–156.

Schaller, G. B. (1985). ***Giant pandas of Wolong***. University of Chicago Press.

Sofiana, Y., Sylvia, C. O. and Purbasari, M. (2017). Potential of bamboo as material for furniture in rural areas in Indonesia. ***Advanced Science Letters***, 23(1):263–266.

Song, X., Zhou, G., Jiang, H., Yu, S., Fu, J., Li, W., Wang, W., Ma, Z. and Peng, C. (2011). Carbon sequestration by Chinese bamboo forests and their ecological benefits: assessment of potential, problems and future challenges. ***Environmental Reviews***, 19(NA):418–428.

Tucker, C. J. and Townshend, J. R. (2000). Strategies for monitoring tropical deforestation using satellite data. ***International Journal of Remote Sensing***, 21(6-7):1461–1471.

Vorontsova, M., Clark, L., Dransfield, J., Govaerts, R. and Baker, W. (2016). World checklist of bamboos and rattans.

Wang, T., Skidmore, A. and Toxopeus, A. (2009). Improved understorey bamboo cover mapping using a novel hybrid neural network and expert system. ***International Journal of Remote Sensing***, 30(4):965–981.

Widenoja, R. (2007). ***Sub-optimal equilibriums in the carbon forestry game: Why bamboo should win but will not***. PhD thesis, Thesis. The Fletcher School of Law and Diplomacy.

Yalden, D. (1988). Small mammals of the Bale Mountains, Ethiopia. ***African Journal of Ecology***, 26(4):281–294.

Zhang, Q., Jiang, S. and Tang, Y. (2002). ***Industrial utilization on bamboo***. International Network for Bamboo and Rattan.

Zhao, Y., Feng, D., Jayaraman, D., Belay, D., Sebrala, H., Ngugi, J., Maina, E., Akombo, R., Otuoma, J., Mutyaba, J., et al. (2018). Bamboo mapping of Ethiopia, Kenya and Uganda for the year 2016 using multi-temporal Landsat imagery. ***International Journal of Applied Earth Observation and Geoinformation***, 66:116–125.

Zhao, Y., Feng, D., Yu, L., Wang, X., Chen, Y., Bai, Y., Hernández, H. J., Galleguillos, M., Estades, C., Biging, G. S., et al. (2016). Detailed dynamic land cover mapping of Chile: Accuracy improvement by integrating multi- temporal data. ***Remote Sensing of Environment***, 183:170–185.

Zhou, B.-Z., Fu, M.-Y., Xie, J.-Z., Yang X-S. and Li, Z.-C. (2005). Ecological functions of bamboo forest: research and application. ***Journal of Forestry Research***, 16(2):143–147.

Appendix A

Regional maps of bamboo-growing areas in Ethiopia

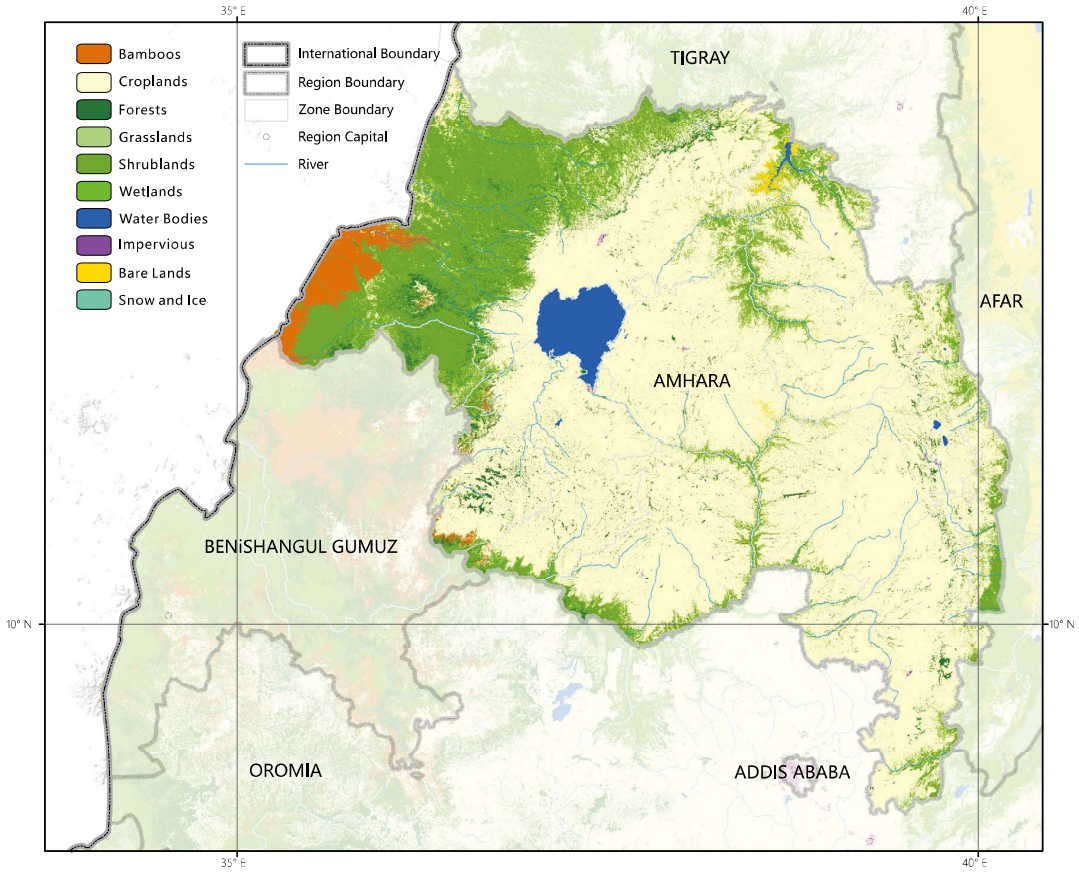

Figure 11: Bamboo distribution of Amhara Region

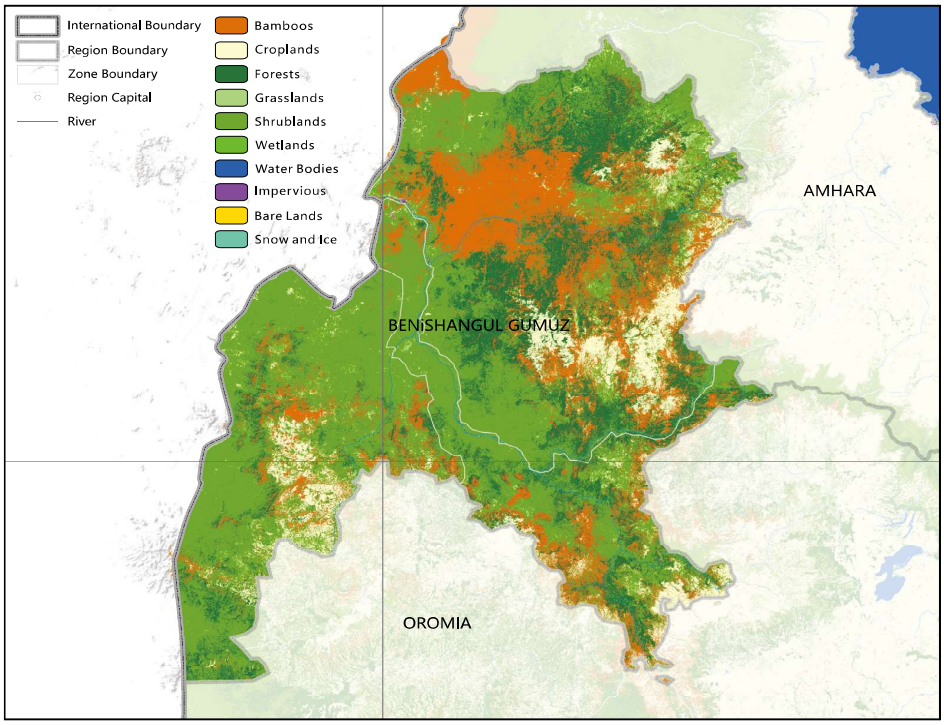

Figure 12: Bamboo distribution of Benishangul-Gumuz Region

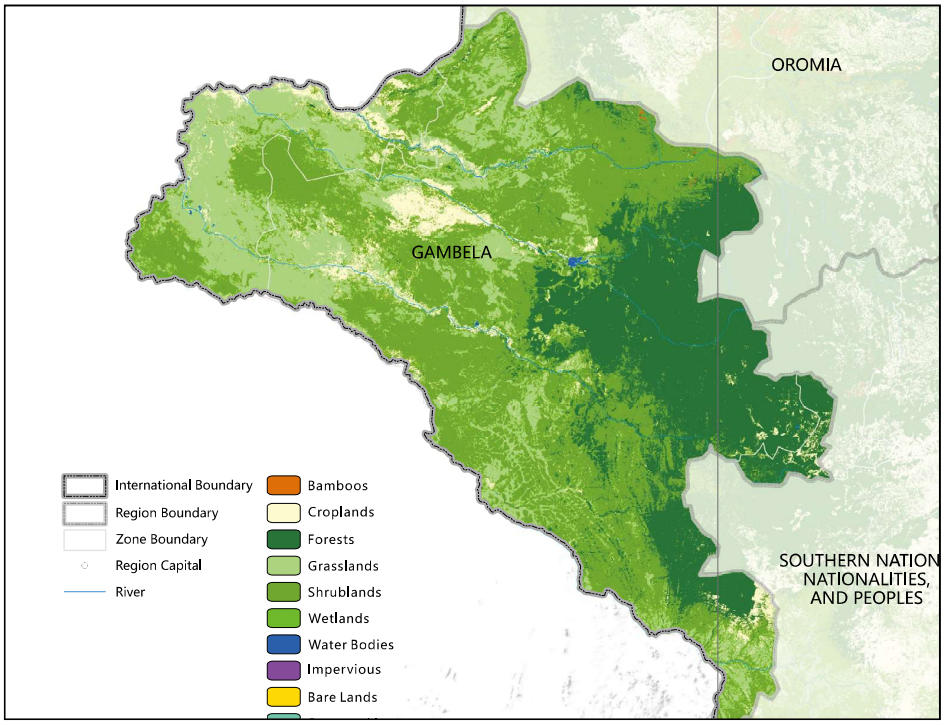

Figure 13: Bamboo distribution of Gambela Region

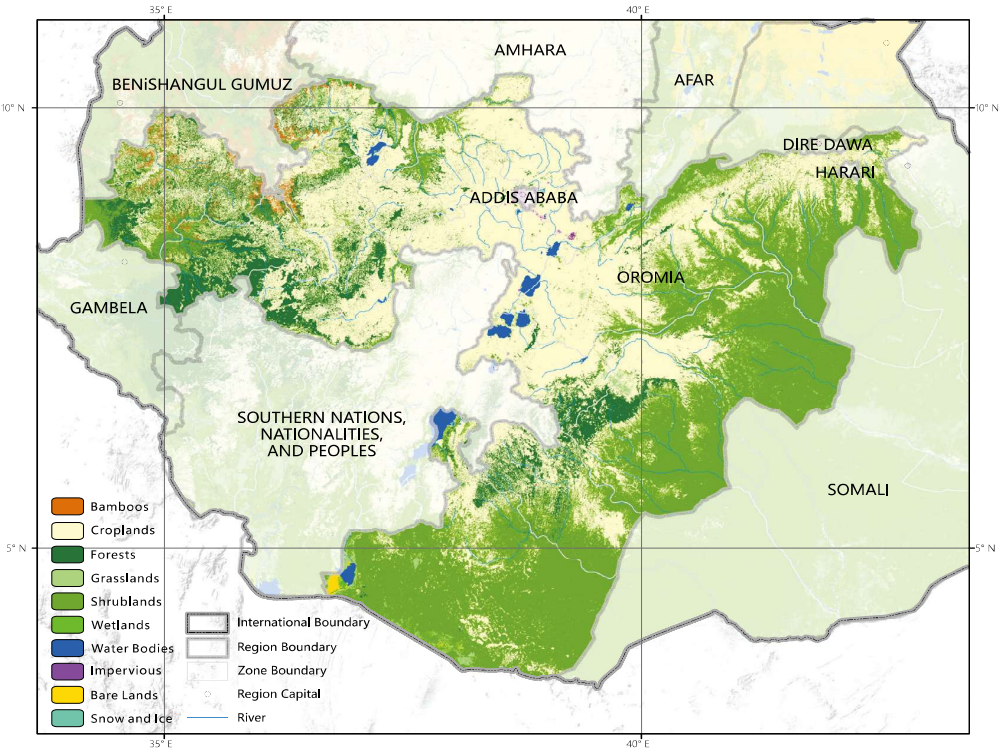

Figure 14: Bamboo distribution of Oromia Region

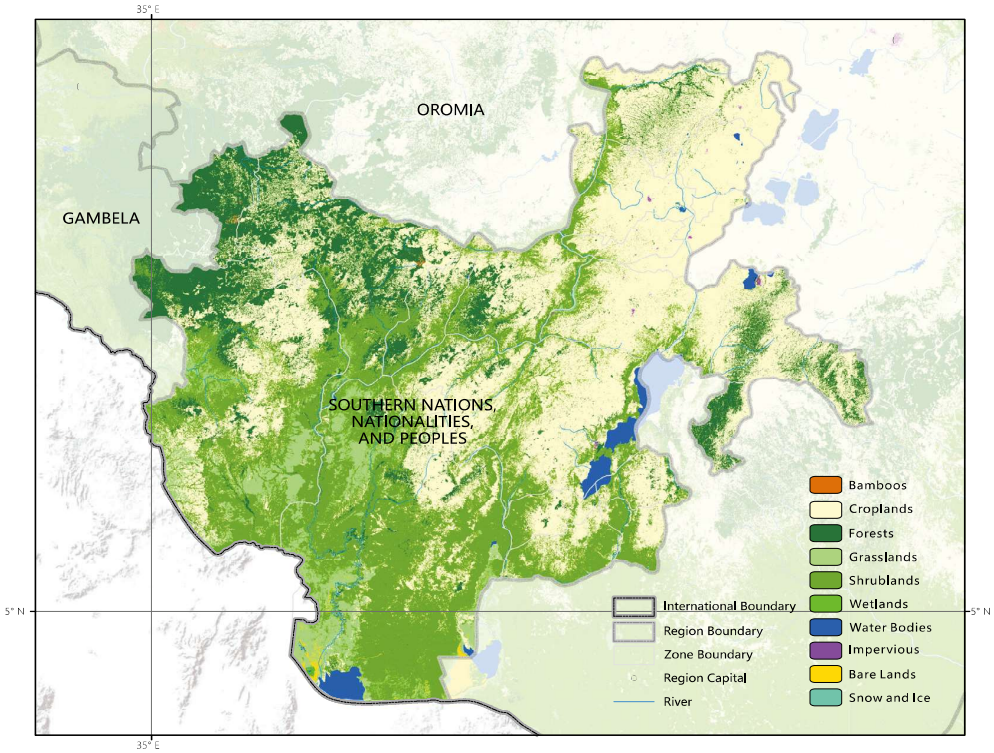

Figure 15: Bamboo distribution of SNNPRS

Appendix B

County maps of bamboo-growing areas in Kenya

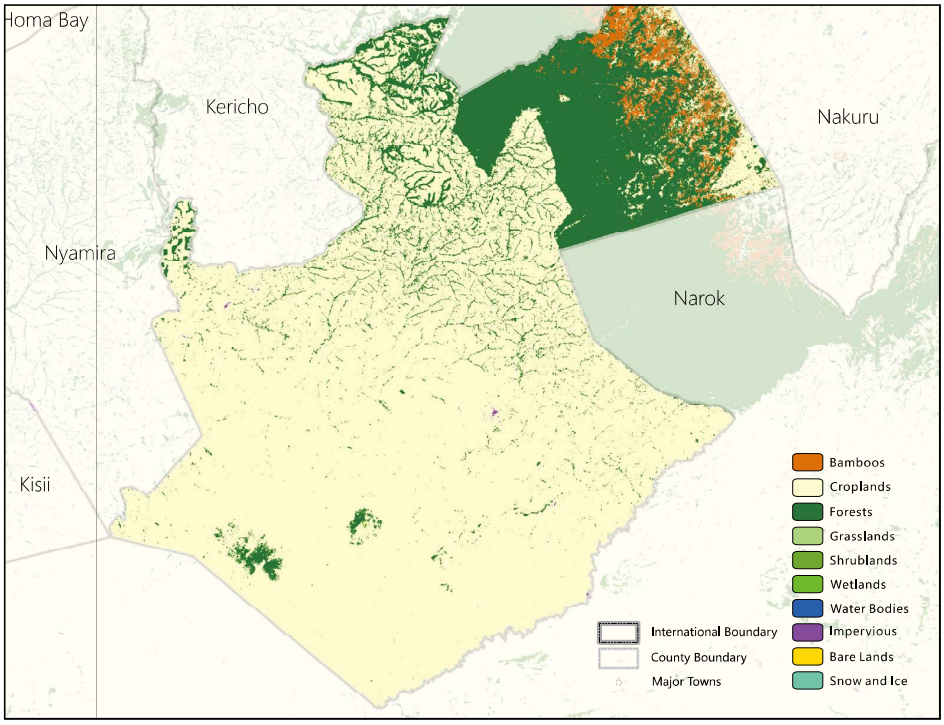

Figure 16: Bamboo distribution of Bomet County

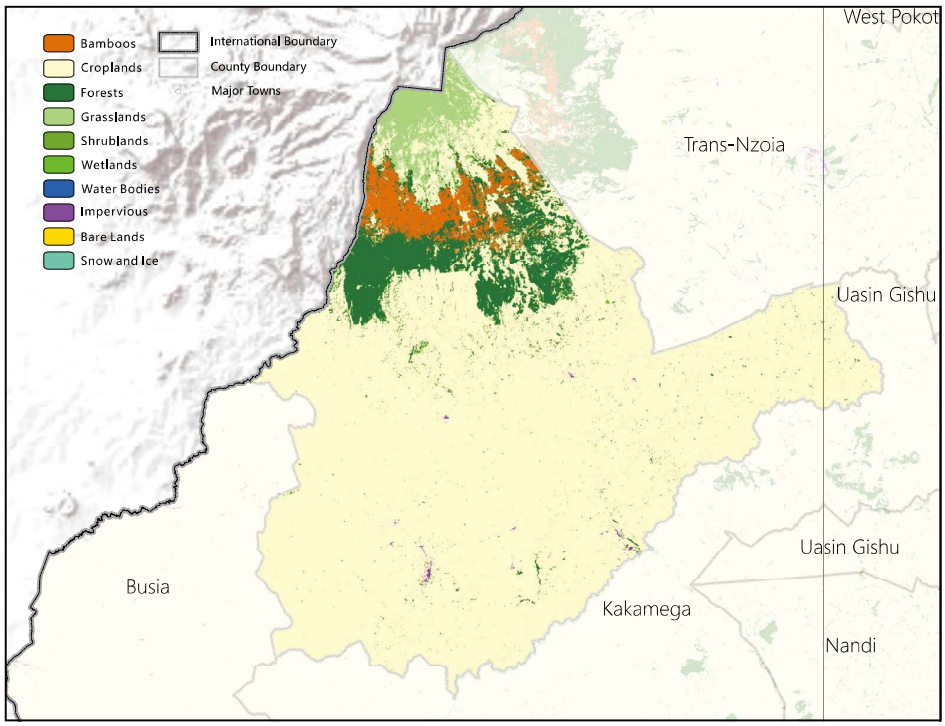

Figure 17: Bamboo distribution of Bungoma Country

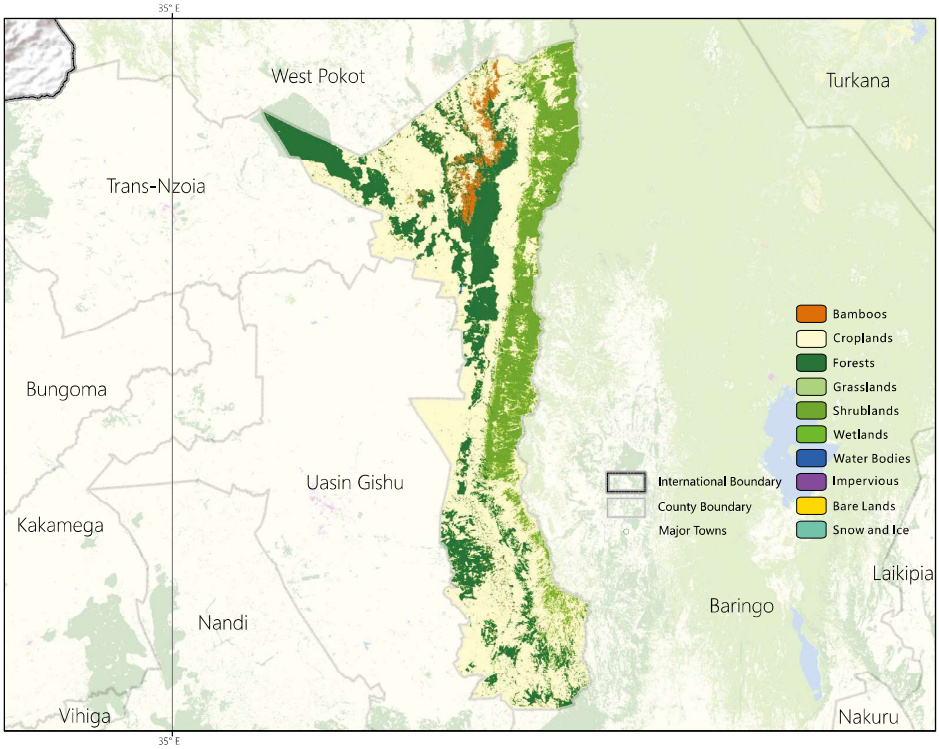

Figure 18: Bamboo distribution of Elgeyo-Marakwet County

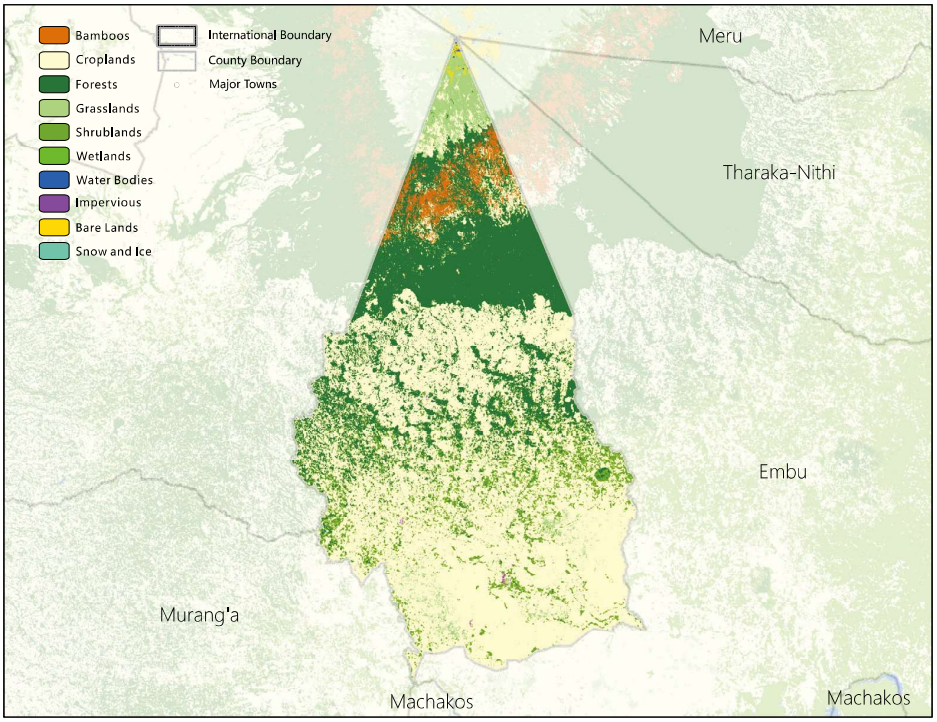

Figure 19: Bamboo distribution of Kirinyaga County

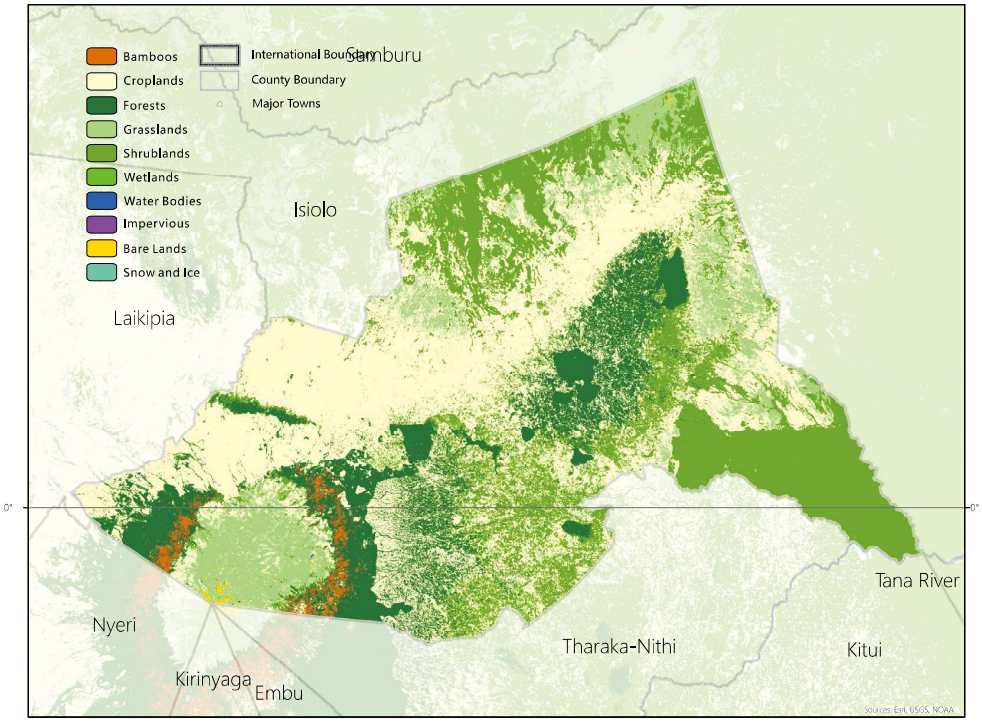

Figure 20: Bamboo distribution of Meru County

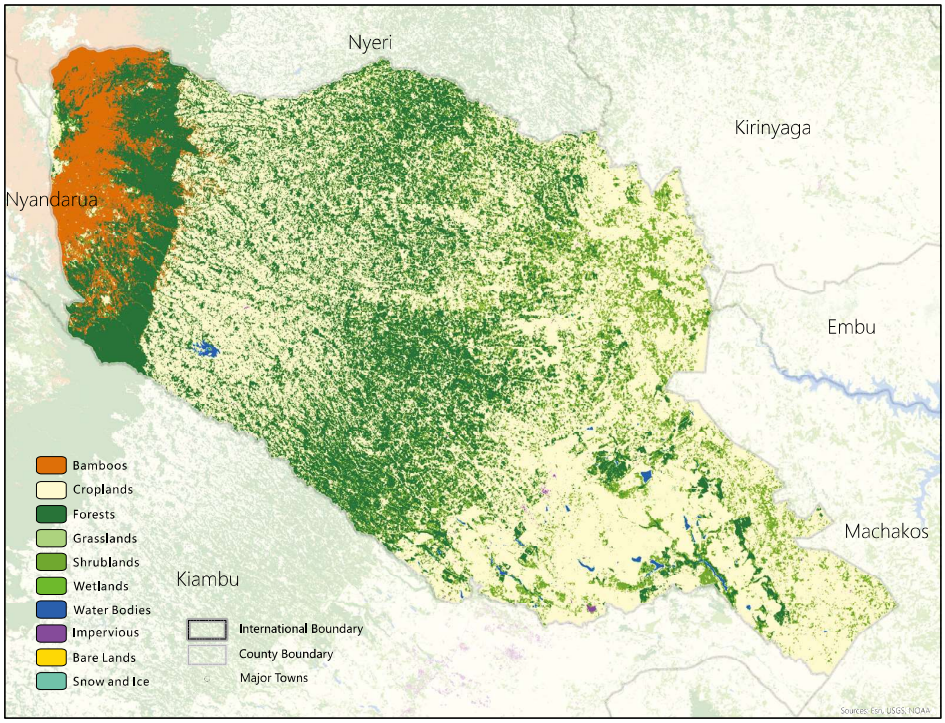

Figure 21: Bamboo distribution of Murang'a County

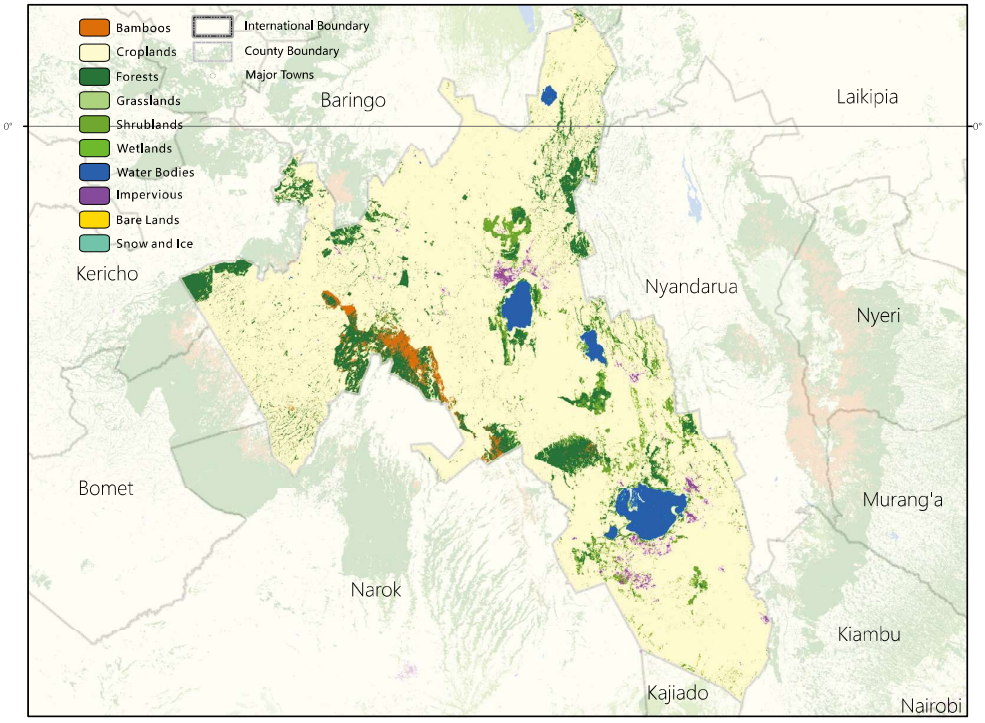

Figure 22: Bamboo distribution of Nakuru County

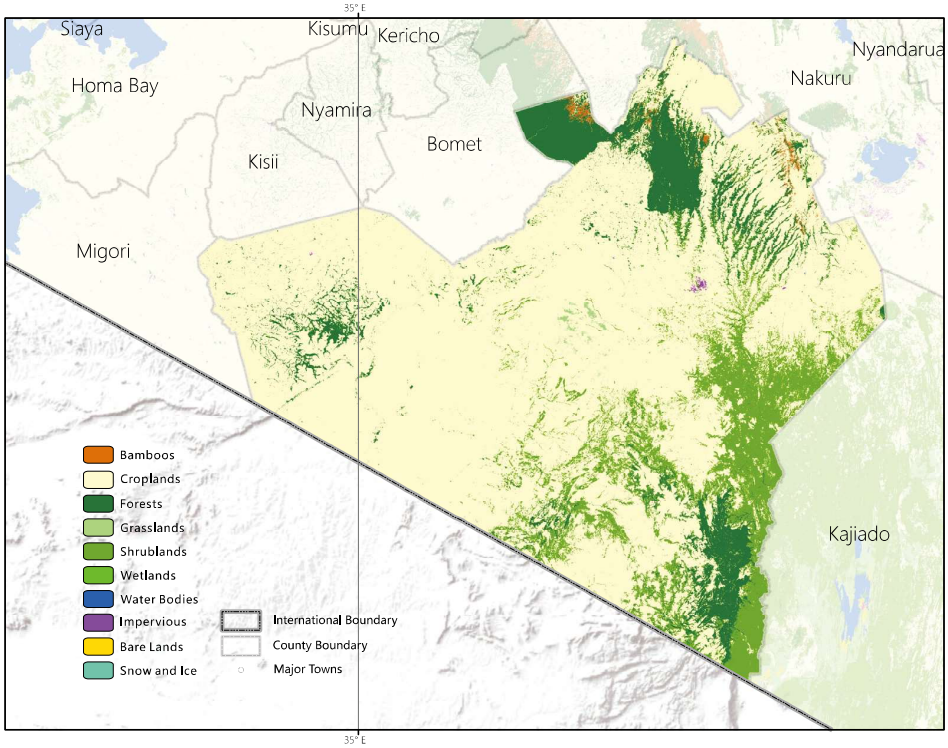

Figure 23: Bamboo distribution of Narok County

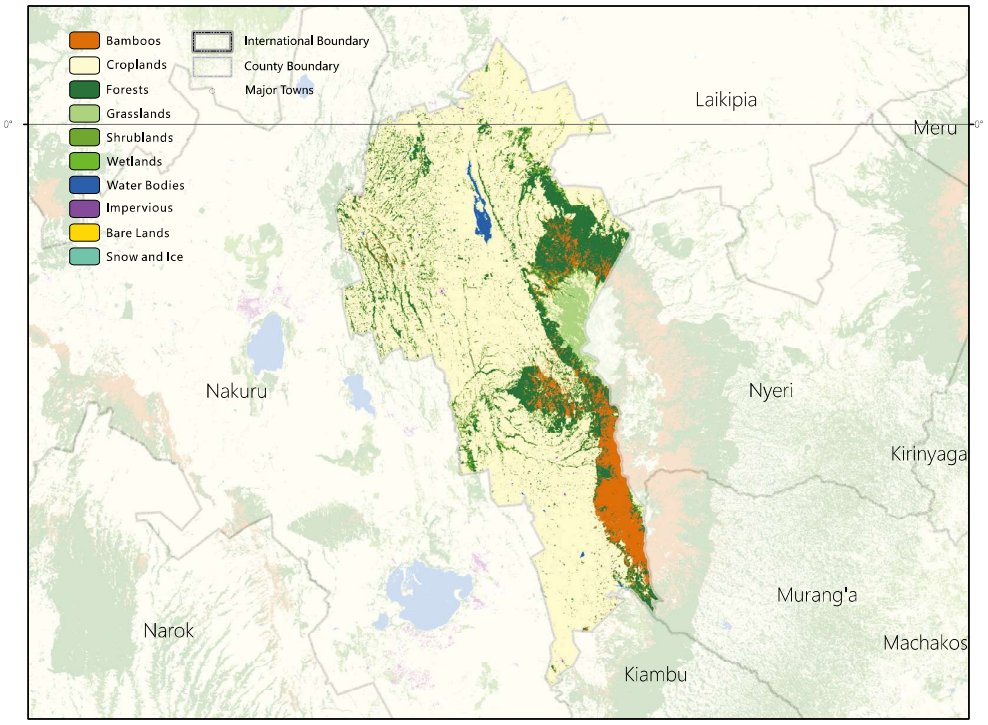

Figure 24: Bamboo distribution of Nyandarua County

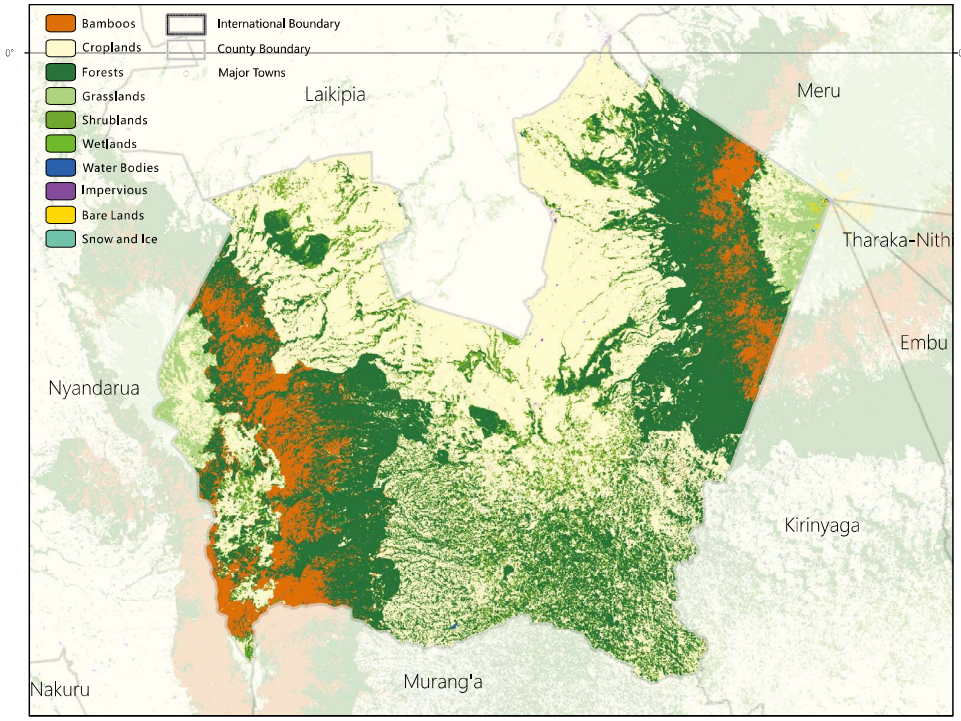

Figure 25: Bamboo distribution of Nyeri County

Appendix C

Sub-Regional maps of bamboo-growing areas in Uganda

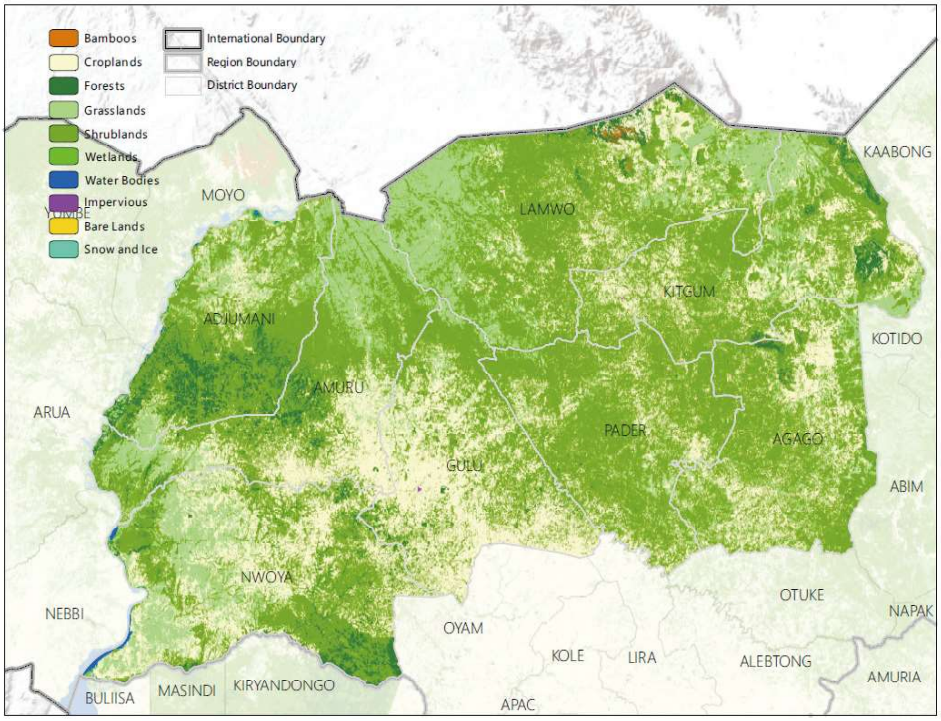

Figure 26: Bamboo distribution in Acholi Sub-Region

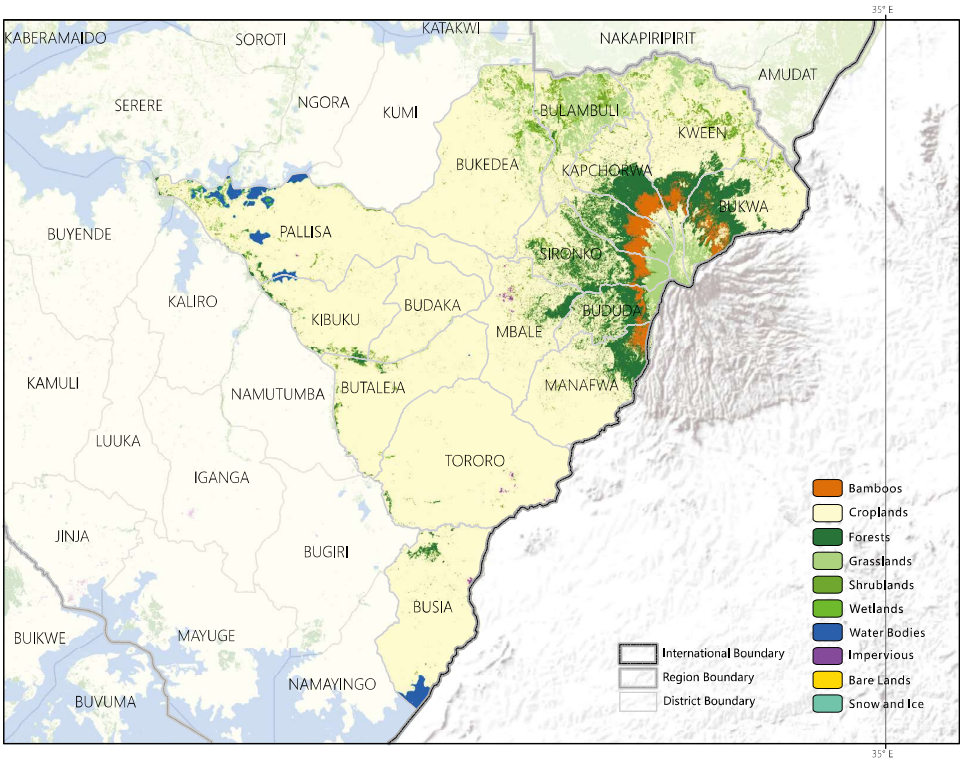

Figure 27: Bamboo distribution of Mt. Elgon Sub-Region

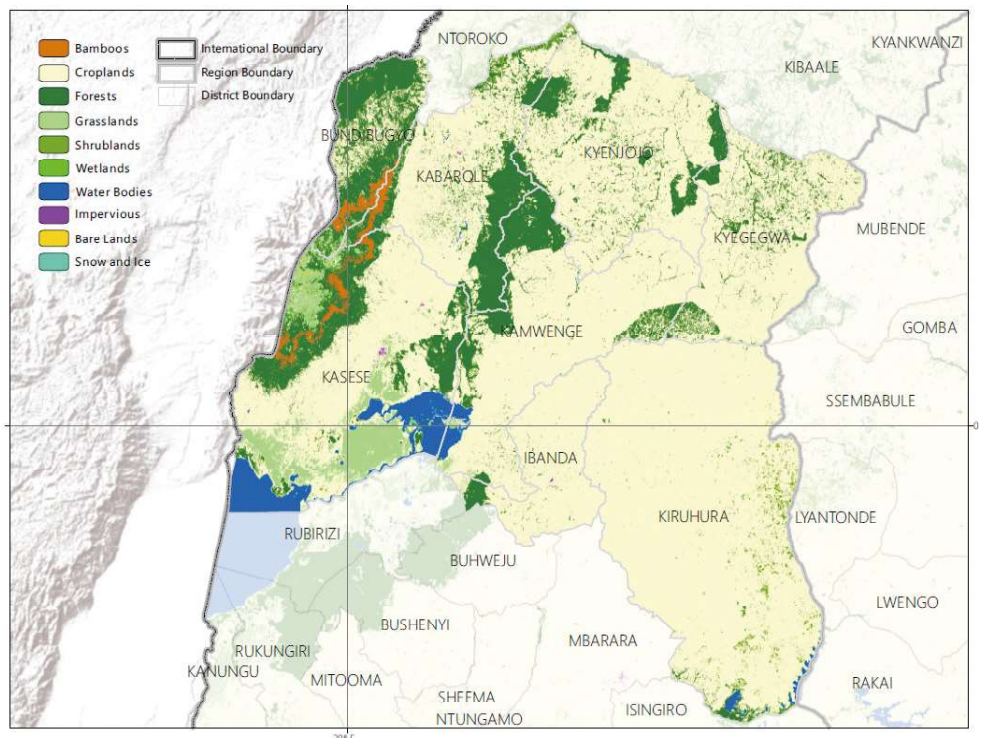

Figure 28:Bamboo distribution of Western Uganda Sub-Region

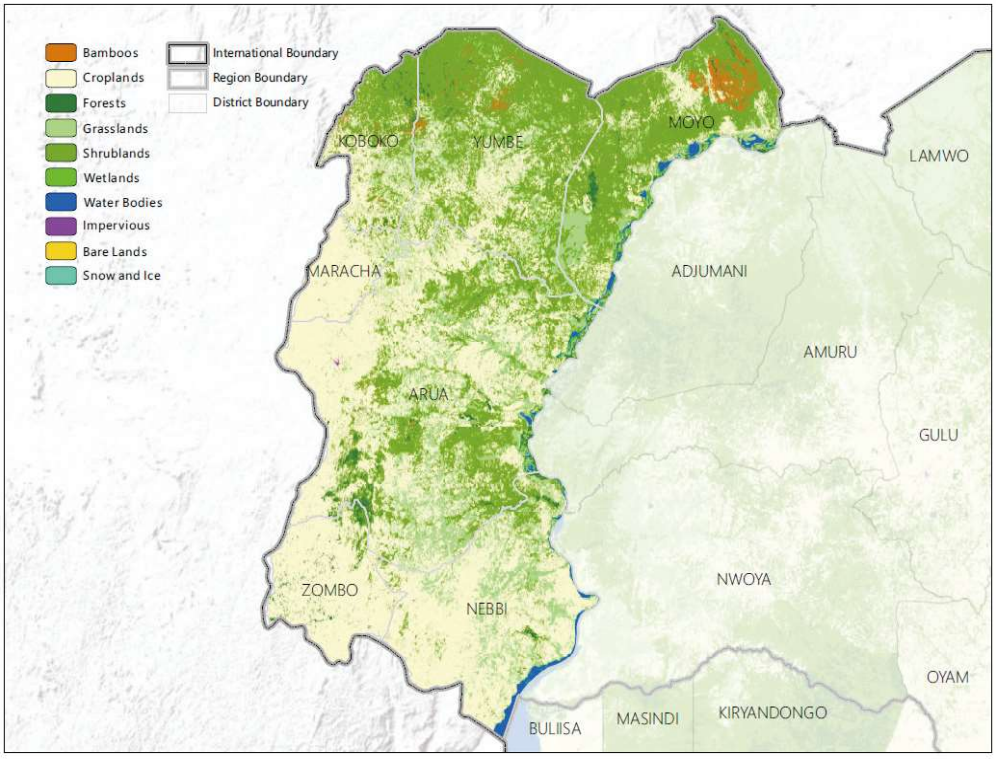

Figure 29: Bamboo distribution of West Nile Sub-Region