Bamboo Resource Assessment (*Outside the Forest Area*) of Nepal

Government of Nepal

Ministry of Forests and Environment

Forest Research and Training Center

Babarmahal, Kathmandu

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Acknowledgement

Nepal is one of nine founding member countries of International Bamboo and Rattan Organization (INBAR) since 1997. It has been elected as the Chair for the 13th Council Session (2023-2025) unanimously in the 12th INBAR Council Meeting held in INBAR headquarters in Beijing.

Bamboo resources occupy a place of pride, being closely interwoven with the lives of people in several ways since time immemorial. Despite having significant importance to rural livelihoods, a detailed assessment of this resource was still lacking in Nepal. Thus, a program on 'Bamboo resource assessment outside the forest area in Nepal' was planned and successfully executed. And, this report is the outcome of that program.

I would like to express my sincere gratitude to all those who have contributed to the completion of this program. The dedication and motivation of some personalities have made this happen for whom I am indebted. Firstly, my sincere thanks go to Forest Research Officer Mr. Ananda Khadka for his dedication and hard work who played the most important role to bring this report at this stage. DDG Mr. Rabindra Maharjan and Former DG Mr. Yam Prasad Pokharel, Under Secretaries Mr. Bimal Kumar Acharya and Mr. Raj Kumar Giri along with the officers Mr. Amul Kumar Acharya, Mr. Kiran Kumar Pokharel, Mr. Prakash Lamichhane , Ms. Muna Nyupane, and Mr. Rajaram Aryal of this centre, were very crucial for the successful accomplishment of this program and took this report to the final stage. Also, contribution of Ms. Sangita Shakya and Ms. Apsara Paudel during the visual interpretation work has also been recognized. I would also like to acknowledge Officers Mr. Bishnu Prasad Dhakal, Mr. Keshav Ghimire and Mr. Pratik Pandeya for their remarkable role during the Quality Assessment Quality Control of this program. Furthermore, all officers of this Centre also played an important role in this regard.

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Rajendra KC, PhD
Director General

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1. INTRODUCTION

1.1 Background

Bamboo is a fast-growing woody perennial evergreen plant belonging to the Poaceae family. In Nepal, bamboos are typically classified into two types: as *bans* and *nigalo* (Das, 1988; Stapleton, 1994). Bamboos with a base diameter greater than 4 cm are referred to as *bans*, while those with a diameter of 4 cm or less are classified as *nigalo*. Globally, there are approximately 136 genera and 1698 species of bamboo found in the world (Lobovikov et. al., 2005, Soreng et al. 2022). Of these, 12 genera and 53 species of bamboo have been recorded in Nepal (Das, 2002). Notably, 7 bamboo species are endemic to Nepal (Stapeleton, 1994; Das, 2002; Rajbhandari et al, 2021).

The global distribution of bamboo species spans from tropical to temperate regions, a pattern also reflected in Nepal. Bamboos are found in diverse climatic zones, ranging from the tropical species of Southeast Asia to the temperate species of Tibet and Bhutan. In Nepal, they are distributed across the Terai and High Mountain regions (ranging from 50 to 4000 meters above sea level), occurring both in natural forests and on farmlands (Karki & Karki, 1995; Ghimire, 2008).

As a perennial woody grass, bamboo is a significant non-timber forest product in Nepal. It belongs to the sub-family Bambusoideae within the Poaceae (Graminae) family. Bamboos are widely distributed from the Terai plains to the high mountain regions up to 4000 meters, occurring extensively throughout Nepal. Large bamboo species are primarily cultivated on farmlands. The most widely distributed species are from the genera *Bambusa* and *Dendrocalamus* (locally referred to as *bans*), which are found across the Terai and Mid-hills of Nepal (Das, 1988). Bamboo distribution is more concentrated in the eastern part of the country, from Dhaulagiri to the Sikkim border, due to the favorable climatic conditions for bamboo growth (Stapleton, 1994). Most of the bamboo species in Nepal possess Pachymorph-type rhizomes and are clump-forming (Stapleton, 1994). Additionally, the Forest Research and Training Center (FRTC) has introduced the monopodial Mosso bamboo (*Phyllostachys pubescens*) to Nepal. However, the country has experienced a loss of many bamboo forests due to overexploitation, gregarious flowering, and extensive forest fires, particularly in the Churia, Terai, and Mid-hills regions, which were once rich in bamboo species.

Bamboo holds a prominent place in Nepalese society, having been closely intertwined with people's lives for centuries. It is an essential component of rural farming systems, playing a pivotal role in the rural economy and supporting the livelihoods of numerous rural households, including socially and economically disadvantaged groups. The rural economy would be unimaginable without bamboo (Das, 2001). Globally, approximately 2.5 billion people rely on bamboo in their daily lives, using it for a variety of purposes (Scurlock et al., 2000). Bamboo is often seen as an alternative to tree species for fulfilling forest product needs. It is commonly referred to as "poor man's timber," "friend of human beings," "green gasoline," "the cradle-to-coffin timber," and is sometimes regarded as "green gold."

The economic and ecological benefits of bamboo, both locally and nationally, are substantial. It contributes to employment, provides fodder, food, shelter, and household materials, and is vital in fulfilling basic human needs. Bamboo has been used for construction, papermaking, fishing, agricultural implements, food, handicrafts, and woven products for thousands of years. Compared to timber, bamboo offers several advantages, including rapid growth, short rotation periods, straight and smooth grain, and fine color and luster. In countries like Nepal, bamboo has significant ecological, economic, and social benefits, with the potential to alleviate poverty, especially in rural areas.

1.2 Rationale of the study

Taxonomic research on bamboo in Nepal began in the early 1980s under the Department of Forest Research and Survey (DFRS), with funding from DFID, UK. However, this research was never fully completed. While large bamboo species are widely cultivated by farmers on their land, outside of forest areas, there is still a lack of comprehensive data regarding the types of bamboo species and their distribution outside these areas. Moreover, information on their density—such as culm, clump, and basal area—across different provinces of Nepal is also missing. The national bamboo inventory outside the forest area is expected to address these gaps.

A review of existing literature on bamboo inventories and mapping of bamboo resources in Nepal reveals a significant lack of national-level statistical data on bamboo. Therefore, it is both urgent and important to collect accurate, up-to-date, and spatially explicit data/maps of bamboo resources across the country. Key information, such as species mapping, taper models, allometric models for bamboo biomass, and the green mass to oven-dry mass conversion ratio, remains notably absent.

This research aims to fill these gaps by generating detailed information on Nepal's bamboo resources, including species types, density in terms of culms, clumps, and basal area, as well as size (diameter and height), and biomass.

Finally, and most importantly, the outcomes of this study will serve as baseline information for the historical assessment of bamboo resources in Nepal.

1.3 Objectives

The overall objective of this program was to assess bamboo resources available outside of forest areas in Nepal. The specific objectives were:

1. To conduct field inventory and prepare maps of bamboo resources available in Nepal
2. To assess the available bamboo species,
3. To develop biomass models and taper equations
4. To generate other bamboo information

2. Methodology

2.1 Study Area

This research was conducted outside of the forest area of Nepal. The non-forest area had been derived from the annual land cover map of year 2019 produced by the National Land Cover Monitoring System (NLCMS) of Nepal (FRTC, 2022). NLCMS was developed to provide annual land cover maps of the country from 2000 to 2019. By using consistent remote sensing datasets, this operational and flexible system is able to produce annual land cover maps of the whole country (FRTC, 2022).

Prior to this assessment, FRTC conducted a study on "Visual interpretation prior to Bamboo Resource Assessment in Nepal", the output of which revealed that bamboo species in Nepal are confined to the area with elevation lower than 3500 m above sea level. This distribution area was also supported by the various literatures, e.g., Das, 1988; Stapleton, 1994; Shrestha, 1998, etc.

Thus, for this research, the non-forest area (besides area occupied by the forests and other wooded land) that are located below an altitude of 3500 m (above mean sea level) across the entire country was taken (Figure 1).

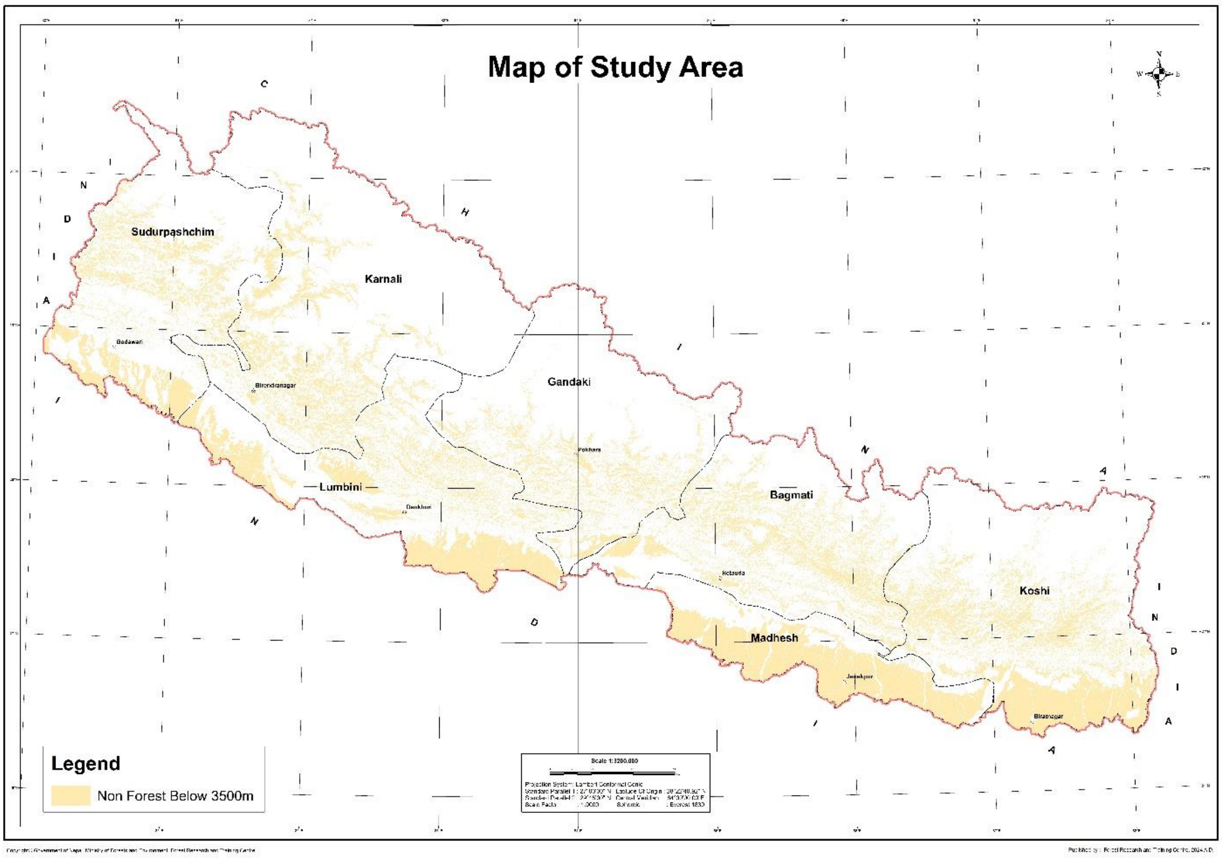

Figure 1: Study area of Bamboo Resources Assessment in Nepal

2.2 Sample plot allocation (inventory plots)

The sample plots for the bamboo resources assessment outside the forest area were designed and selected adopting a two phase stratification approach. In the first phase the sample grids were systematically generated in the "non-forest" area of the entire country and stratified based on Normalized Difference Vegetation Index (NDVI) generated from time series Sentinel-2 and Landsat images. In total 197,108 numbers of plots were generated out of which 106,383 plots were found inside the study area i.e., non-forest area located below of 3500 m altitude. Out of all plots, every 4th plots (26,596 points) were sampled for which visual interpretation was done using Collect Earth Online (CEO). The summary of sample plots generation to the final selection (for field assessment) has been presented in the following table (1).

Table 1: Two phase sampling and allocation of sample plots

SN	Particulars	No. of sample plots
1	Generation of grids throughout Nepal @ 500m spacing interval	588,485
2	First phase sampling: selection of plots in the non-forest area	197,108
3	Sample plots below 3500m elevation	106,383
4	Every 4th sample plots taken for visual interpretation (Bamboo present or absent)	26,596
5	Bamboo presence plots	1468
6	Second phase sampling: Selection of plots for field inventory	800

During the visual interpretation for bamboo availability in the first phase, bamboo clumps were present in 1468 sample plots and for the rest 25077 sample plots, bamboo clumps were not found (absent). In the second phase, the following stratification was performed to allocate sample plots for field inventory/assessment (Table 2).

Table 2: Stratification and field plots allocation

SN	Strata	No. of sample plots
1	Bamboo presence plots	650
2	Bamboo absence plots	100
3	Plots with NDVI≥0.1 and NDVI <0.4 (Probable bamboo area)*	50
	Total	**800**

**Wang et. al. (2009) revealed most bamboo presence area with NDVI > 0.48. Thus, in this research, plots with NDVI more than 0.4 were considered as bamboo presence plots, and plots with NDVI from 0.1 to 0.4 as probable bamboo plots.*

Finally, 800 sample plots were selected, following the simple random sampling, where detailed field inventory was conducted (Figure 2).

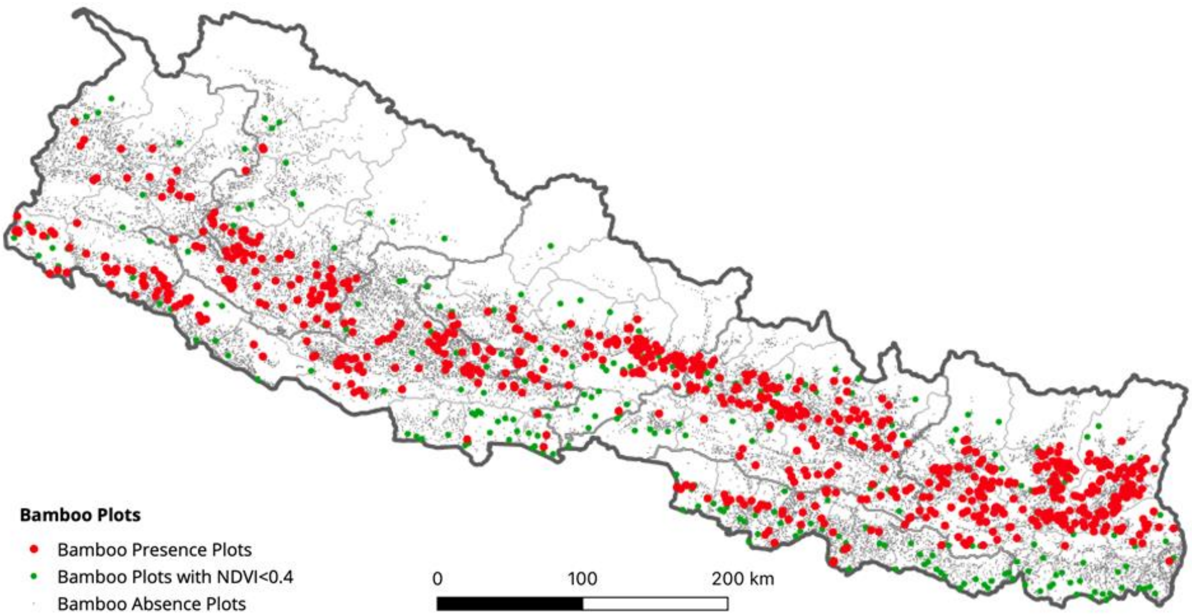

Figure 2: Sample plots for field inventory (assessment)

2.3 Sample plot design and measurement

For the bamboo resource inventory in Nepal, circular sample plots of radius 56.42 m (1 ha area), were designed (Figure 3). Bamboo clumps within the sample plots were assessed, geo-referenced and inventoried to further data collection. The details on location, topography, and other bio-physical attributes like species, sub species, number and size of each individual clump, average diameters and total height of culms, etc. inside the sample plot were recorded.

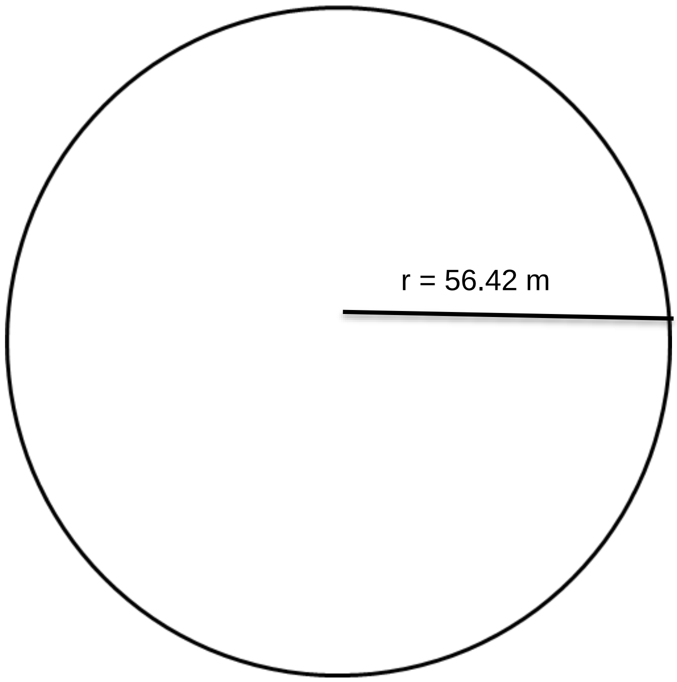

Figure 3: Circular sample plot of 1 ha area

All data, information, samples, measurements, etc. were also collected and recorded in field tally sheets as guided in the field manual (FRTC, 2023).

2.4 Biomass Assessment

Bamboo forests are very important for absorbing significant amount of carbon dioxide from the atmosphere and reducing the effects of climate change (Yiping et al, 2010). The significance of studying bamboo biomass is thus well recognized due to their increasing role in the balance of oxygen and carbon dioxide.

For this study, a total of 367 bamboo culms, from seven species/varieties, of varying sizes were destructively sampled. The species/varieties were selected based on people's preferences, usages, abundance and availability. Those species, along with their distribution for biomass measurement, are listed in Table 3.

Bamboo samples were collected from different districts. A destructive sampling approach was adopted to acquire data on total green mass of bamboo culm, branches and foliage. Besides, green samples of culm, branches and foliage were also collected. The samples were labeled and brought to the FRTC laboratory for drying, where data on fresh, air-dry, and oven-dry weights were subsequently recorded. All procedures from sample selection to the laboratory analysis were performed as guided by the field manual (FRTC, 2023).

Allometric equations were developed in the form of linear and non-linear regressions. Exponential and power models among non-linear regressions were used for estimating total aboveground biomass. Biomass (total green mass on bamboo) was modeled against DBH and height individually and in combination.

Table 3: Species (major seven bamboo species) for biomass assessment

SN	Local name	Botanical name	Altitudinal range	Distribution	Number of samples
1	Dhanu/ Bholka/ Ban/ Harauti/ Harod/ Ghar bans	*Bambusa balcooa*	Terai-1400 m	Cultivated all over the Terai region (flat plains) of Nepal and in the lower mid-hills including Kathmandu, Pokhara and Surkhet Valleys, more common in eastern half of Nepal (from Dhaulagiri region)	51
2	Mal/ Malka/ Lisinga bans	*Bambusa teres* Buch.-Ham.	Terai-1500 m	Commonly cultivated to the east of Ramechhap in the mid-hills and Rautahat in the Terai, but now available in eastern half of the country; also in Chitwan, Makwanpur and other western hills; most commonly cultivated bamboo species on the farmlands east of Bagmati River in the Terai.	52
3	Taru/Tharu/ Sate/Chille bans	*Bambusa nutans*	Terai-1500 m	Commonly cultivated species to the west of Hetauda in central, western and mid-western regions but more common in the hills of central and western Nepal.	58
4	Jhapta/Chav/Kada/Koraincho bans	*Bambusa tulda*	Terai-1200 m	Most commonly cultivated species all over the Terai regions of Nepal including Chitwan district and Kathmandu valley	50
5	Kalo/Bhalu bans	*Dendrocalamus hookeri*	600-2000 m	Cultivated mainly in hills of eastern Nepal but rare in central Nepal	52
6	Choya/Tama/Guliyo/ Dhungre/Ban bans	*Dendrocalamus hamiltonii*	Terai-2000 m	Cultivated all over hills of Nepal; one of the most commonly cultivated bamboo species in the mid-hills; found from Terai to the hills	50
7	Choya/Khasre/Phusre/Tama/Tame bans	*Bambusa nepalensis*	1000-2200 m	Most commonly/widely cultivated species in eastern, central and western hills of Nepal, common from east Nepal to Tansen in the west; found in Kathmandu valley and western mid-hills	54

Source: Stapleton (1994) and Das (2004)

2.5 Development of taper equations

For development of taper equations, firstly diameter at the breast height (DBH) and total height were measured. Then, the bamboo culm was harvested for measurements to be used for biomass assessment and development of taper equations. After felling of culms, diameters at several sections were measured, for instance, at 0.3m, 1.3 m, 2.0 m and so on. Then, consecutive diameters at intervals of 2 m were measured up to the tip of the culm. The length of the culm was also derived.

For derivation of biomass and taper equations, detail calculations were performed in MS Excel and Rstudio (R core team 2022). Final selection of models (equations) was based on the statistical outputs e.g. R^2, SE and RMSE of individual models. Several Rpackages e.g. tidyverse, caret, ggpmisc, splines, ggplot2, dplyr, etc. were used to develop the taper equations in Bspline regression and 5th degree polynomial model.

2.6 Focus Group Discussion

Seventeen focus group discussions were held in 17 districts representing each province and geographic regions (Table 4). Due information on various socio-economic and bio physical aspects of bamboo were collected. Concerned Forest Offices were also consulted in the whole process from identifying participants to the group discussion. Farmers, craft makers, local businessmen, traders and other concerned stakeholders were included.

Table 4: Locations of Focus Group Discussion

Province	**District**
Koshi	Taplejung
	Sankhuwasabha
	Jhapa
Madhesh	Bara
Bagmati	Dhading
	Nuwakot
	Lalitpur
Gandaki	Baglung
	Lamjung
	Gorkha
Lumbini	Palpa
	Rolpa
	Dang
Karnali	Surkhet
	Jajarkot
Sudurpaschim	Kanchanpur
	Dadeldhura

2.7 Mapping of density and distribution of bamboo species

The density of bamboo species (categorised culms per ha and clumps per ha), distribution of bamboo in sample plots were mapped based on the number of culms of each assessed clump and number of clumps in the plot.

To determine clump density, the total number of clumps for each species was calculated per hectare, and for mapping, it was categorised into classes 1-5, 6-10,11-15,16-20 and >20.

Similarly, culm density was assessed by calculating the total number of green culms per hectare for each species. The resulting densities were then classified into classes of 0-50, 50-100, 100-200, 200-400 and >400 for the mapping process.

2.8 Data Analysis

Entered data were analyzed in MS Excel and Rstudio program to get the results on number of clumps per unit area, number of culms per unit area, average number of culms per clump for each species, clump diameter, average basal area per unit area, basal area per unit area, average height, diameter, above ground biomass (AGB) per unit area, culm, branches and foliage biomass per unit area. The analysis also included assessment of species distribution and mapping along with biomass equations based on fresh, air dry and oven dry weight, and taper equations through the destructive sampling technique.

2.9 Quality Assurance/Quality Control

Quality Assessment and Quality Control (QAQC) mechanism was used to check the accuracies of data entry. The QAQC process was performed by selecting 10 % of the total data. QAQC was performed in two stages: firstly, against the field data and collection procedures in which re-assessment of 80 plots (10% of 800 plots) was conducted and later15 % re-validation in terms of data entry and validation.

3 Results

3.1 Information on bamboo clumps and distribution

3.1.1 Altitude of bamboo presence plots

According to the field sample plots of this assessment, bamboo distribution was noticed at the highest altitude of 2007 m (Dhadegaun, Phidim-3, Panchthar) in Koshi province and at the lowest altitude of 57 m (Khutta, Loharpatti-4, Mahottari) in Madhesh province (Table 5).

Table 5: Altitudinal distribution of bamboo

SN	Province	Altitude (m)	
		Maximum	Minimum
1	Koshi	2007	70
2	Madhesh	349	57
3	Bagmati	1941	190
4	Gandaki	1510	117
5	Lumbini	1814	90
6	Karnali	1725	84
7	Sudurpaschim	1943	135

3.1.2 Bamboo clumps per plot by land use

Distribution of bamboo clumps per plot in different types of land use revealed that bamboo distribution in different land use classes does not vary significantly, however the number of clumps was lesser in built-up area (Table 6).

Table 6: Clumps per plot by type of land use

SN	Land use	Clumps per plot
1	Agriculture	4
2	Built up	2
3	Forest	3
4	Marginal Land	4
	Overall mean	4

3.1.3 Province wise distribution of bamboo species

Altogether 14 bamboo species were found in sample plots in different districts and physiographic regions. Major species were *Bambusa teres* (Mal bans), *Bambusa nutans* (Taru bans), *Bambusa balcooa* (Dhanu bans), *Bambusa nepalensis* (Khasre/Fusre bans), *Bambusa tulda* (Chab/Jhapta bans) and *Dendrocalamus hamiltonii* (Tama bans) (Table 7).

Table 7: Bamboo species found in sample plots by provinces

SN	Local name	Latin name	Province						
			Koshi	Madhesh	Bagmati	Gandaki	Lumbini	Karnali	Sudur paschim
1	Mal bans	*Bambusa teres*	*	*	*	*	*	-	*
2	Taru bans	*Bambusa nutans*	-	*	*	*	*	*	*
3	Bhalu bans	*Dendrocalamus hookerii*	*	-	*	-	-	-	-
4	Dhanu bans	*Bambusa balcooa*	-	*	*	*	*	*	-
5	Chab/Jhapta bans	*Bambusa tulda*	-	*	-	-	-	-	-
6	Khasre/Fusre bans	*Bambusa nepalensis*	*	-	*	*	*	*	*
7	Tama bans	*Dendrocalamus hamiltonii*	*	-	*	*	*	*	-
8	Katha bans	*Dendrocalamus strictus*	-	*	*	-	*	*	*
9	Kande bans	*Bambosa bamboos*	-	*	*	-	*	-	*
10	Dhungre bans	*Dendrocalamus giganteus*	*	-	*	-	-	-	-
11	Nigale bans	*Bambusa jaintiana*	-	-	*	*	*	-	*
12	Pahelo bans	*Bambusa vulgaris*	-	-	*	-	-	-	-
13	Murali bans	*Cephalostachyum latifolium*	-	-	*	-	-	-	-
14	Paryang/Padang	*Himalayacalamus hookerianus*	-	-	*	-	-	-	-

3.1.4 Clump size (clump base and crown area)

The average clump base area for all bamboo species was 24.4 m^2. The highest recorded base area was 924 m^2 for *Bambusa teres* whereas the lowest base area was less than 1 m^2 for *Bambusa nepalensis* and *Dendrocalamus giganteus.* (Table 8).

Table 8: Clump base area (sq.m.)

SN	Species	Average	Minimum	Maximum	sd
1	*Bambusa bambos (Kande bans)*	19.9	0.5	118.8	22.0
2	*Bambusa teres (Mal bans)*	54.0	5.0	924.0	74.9
3	*Bambusa jaintiana (Murali bans)*	6.9	0.5	103.6	15.5
4	*Dendrocalamus hookeri (Bhalu bans)*	24.0	0.6	168.0	30.3
5	*Bambusa nepalensis (Tama/choya bans)*	23.0	0.3	192.0	28.0
6	*Dendrocalamus giganteus (Dhungre bans)*	24.7	0.3	270.0	44.8
7	*Dendrocalamus hamiltonii (Tama bans)*	14.7	1.0	127.1	16.5
8	*Bambusa nutans (Taru bans)*	21.6	1.0	672.0	39.1
9	*Bambusa balcooa (Dhanu bans)*	31.2	1.0	683.3	55.2
	Grand Total	**24.4**	**0.3**	**924.0**	**59.0**

Similarly, the average clump crown area for all bamboo species was 86.1 m^2. The highest recorded crown area was 6830 m^2 for mal bans whereas the lowest base area was around 1 m^2 for several species (Table 9).

Table 9: Clump crown area

SN	Species	Clump crown area sq.m	Minimum	Maximum	sd
1	*Bambusa bambos (Kande bans)*	71.8	1.0	240.5	59.3
2	*Bambusa teres (Mal bans)*	116.0	1.0	6830.0	247.0
3	*Bambusa jaintiana (Murali bans)*	19.4	1.0	119.2	24.7
4	*Dendrocalamus hookeri (Bhalu bans)*	77.1	2.0	840.0	101.7
5	*Bambusa nepalensis(Tama/choya bans)*	75.8	6.0	1440.0	133.2
6	*Dendrocalamus giganteus (Dhungre bans)*	47.3	1.2	304.0	52.2
7	*Dendrocalamus hamiltonii (Tama bans)*	40.4	1.0	325.8	38.5
8	*Bambusa nutans (Taru bans)*	54.1	1.0	416.6	51.7
9	*Bambusa balcooa (Dhanu bans)*	89.4	1.0	1147.6	115.3
	Grand Total	**86.1**	**1.0**	**6830.0**	**173.4**

The bamboo clumps found in Koshi and Madhesh provinces had larger crown diameters than that in other provinces. Clump and crown sizes are interrelated to each other, larger of clump base indicating the larger crown. These are related to the number of culms as well. The bamboo clumps with smaller crown diameters contained lesser number of culms in the clumps. The mean crown diameters of bamboo in Sudurpaschim and Gandaki were smaller than other provinces (Table 10). Higher culms regeneration was noticed in the clumps with larger crown diameters.

Table 10: Province wise clump crown diameter of bamboo species

SN	Province	Crown diameter (m)		
		Diameter 1	Diameter 2	Average
1	Koshi	8.4	5.5	7.0
2	Madhesh	7.4	5.5	6.5
3	Bagmati	6.2	3.5	4.9
4	Lumbini	4.9	3.6	4.3
5	Karnali	4.4	3.5	3.9
6	Gandaki	4.2	2.9	3.6
7	Sudurpaschim	3.6	3.1	3.3
	Overall mean	6.4	4.3	5.3

3.1.5 Diameter at breast height (DBH) of different bamboo species

Out of all species of bamboo found in this assessment, the maximum recorded DBH was 18.5 cm of *Dendrocalamus giganteus* (dhungre bans) and the minimum recorded DBH was 0.4 cm of *Bambusa nutans (taru bans).* The average DBH of bamboo was found highest i.e. 10.7 cm and lowest 3.6 cm for *Dendrocalamus giganteus* (dhungre bans) and *Bambusa jaintiana* (murali bans) respectively, with the grand average of 6.4 cm of all species (Table 11).

Table 11: (DBH) of different bamboo species (cm)

Local Name	Species/ size category	Average	Minimum	Maximum	sd
Dhanu bans	*Bambusa balcooa*	7.1	0.7	12.9	1.9
	L	8.8	5.0	12.9	1.3
	M	7.1	3.0	10.0	1.1
	S	5.2	0.7	8.0	1.1
Tama/choya bans	*Bambusa nepalensis*	6.6	0.7	12.9	1.9
	L	8.4	5.0	12.9	1.2
	M	6.8	3.0	10.0	1.1
	S	4.8	0.7	7.9	1.2
Mal bans	*Bambusa teres*	6.2	1.0	17.7	1.5
	L	7.7	5.0	17.7	1.0
	M	6.2	3.3	10.0	0.9
	S	4.7	1.0	7.9	0.9
Taru bans	*Bambusa nutans*	5.8	**0.4**	12.8	1.6
	L	7.2	5.0	12.8	1.1
	M	5.9	3.0	9.7	1.1
	S	4.4	0.4	8.0	1.0
Jhapta bans	*Bambusa tulda*	5.9	2.4	8.9	1.3
	L	7.2	6.1	8.9	0.6
	M	6.0	5.1	7.2	0.6
	S	4.5	2.4	6.1	0.8
Tama bans	*Dendrocalamus hamiltonii*	7.8	1.4	16.0	2.4
	L	10.0	5.1	16.0	1.8
	M	7.7	3.5	10.0	1.3

	S	5.4	1.4	8.0	1.4
Bhalu bans	*Dendrocalamus hookeri*	10.4	2.9	18.2	2.8
	L	12.3	8.0	18.2	2.0
	M	8.9	4.5	10.0	1.0
	S	6.6	2.9	8.0	1.4
Kath bans	*Dendrocalamus strictus*	3.7	1.0	9.2	1.3
	L	6.2	5.0	9.2	1.3
	M	3.9	3.0	8.3	1.1
	S	3.2	1.0	6.7	0.9
Dhungre bans	*Dendrocalamus giganteus.*	**10.7**	5.3	18.5	2.7
	L	12.5	10.2	**18.5**	2.4
	M	9.2	8.4	10.0	0.6
	S	7.1	5.3	8.0	0.8
Kande bans	*Bambusa bambos*	5.7	1.8	10.1	1.6
	L	7.3	5.0	10.1	1.2
	M	5.8	3.3	8.4	1.0
	S	4.2	1.8	6.5	0.9
Murali bans	*Bambusa jaintiana*	**3.6**	0.5	9.0	1.3
	L	6.2	5.0	9.0	1.2
	M	4.0	3.0	6.8	0.9
	S	3.2	0.5	5.8	1.0
	Grand Total	**6.4**	**0.4**	**18.5**	**2.0**

L: large size, M: medium size and S: small size

3.1.6 Base Diameters (D30), internode length and culmination height

The large size bamboos, *Dendrocalamus hookeri* and *Dendrocalamus hamiltonii* had attained the greater D30 (diameter at 0.3 m height from ground) and DBH (Table 12). The mean internode length of seven major bamboo species varied from 28.92 cm for *Dendrocalamus hamiltonii* to 40.22 cm for *Bambusa teres.* As expected, in large bamboos, internode length at 1.3 m was the highest for *Bambusa teres* (Table 16). Average culmination height of culm was the highest (16.27 m) *for Dendrocalamus hookeri* and the lowest (9.19 m) for *Bambusa tulda* (Table 12).

Table 12: Diameters, internode length and culmination height of 7 major bamboo species

SN	Latin name	Mean D30 (cm)	Mean DBH (cm)	Mean internode length at 1.3 m height (cm)	Mean Culmination height (m)	Number of samples
1	*Bambusa balcooa*	7.55	7.05	29.66	13.30	3885
2	*Bambusa nepalensis*	7.13	6.62	31.40	11.38	2198
3	*Bambusa teres*	6.39	6.24	40.22	13.43	8025
4	*Bambusa nutans*	6.36	5.83	31.10	12.29	2572
5	*Bambusa tulda*	6.04	5.90	30.29	9.19	82
6	*Dendrocalamus hamiltonii*	8.92	8.33	28.92	12.12	1135
7	*Dendrocalamus hookeri*	10.82	10.28	34.02	16.27	261

3.1.7 Green, dead/dry and broken culms

Green culms per clump were found the highest for bamboos assessed in Madhesh province, followed by Koshi province (Table 13). Dead/dry culms per clump were not found significantly differing in all provinces, which ranged from 3 culms per clump in Koshi and Sudurpaschim provinces to 7 culms per clump in Gandaki province.

Table 13: Province wise mean green, dead/dry and broken culms

SN	Province	Mean (culms per clump)		
		Green culms	**Dead/dry culms**	**Broken culms**
1	Madhesh	105	4	5
2	Koshi	84	3	3
3	Bagmati	65	5	5
4	Lumbini	64	5	17*
5	Gandaki	61	7	8
6	Sudurpaschim	61	3	2
7	Karnali	50	5	7
	Overall mean	72	4	7

*cut culms included

However, broken culms per clump was found significantly higher in Lumbini, it was mainly due to inclusion of cut culms in Gulmi and Arghakhanchi districts. In these districts, many culms were found top cut for the use of fodder for their cattle. Lumbini province had the highest number of clumps per plot. In general, the number of clumps per plot was found to be similar for all provinces (Table 14).

Table 14: Province - wise average number of clumps

SN	Province	Number of clumps per plot
1	Lumbini	5
2	Koshi	4
3	Madhesh	4
4	Bagmati	4
5	Gandaki	4
6	Karnali	3
7	Sudurpaschim	3
	Average	4

3.1.8 Culms number in Clump by Age and Species

Models were developed to predict the total number of bamboo culms by age and species of clump. The following figure (4) illustrates various models and equations for different bamboo species.

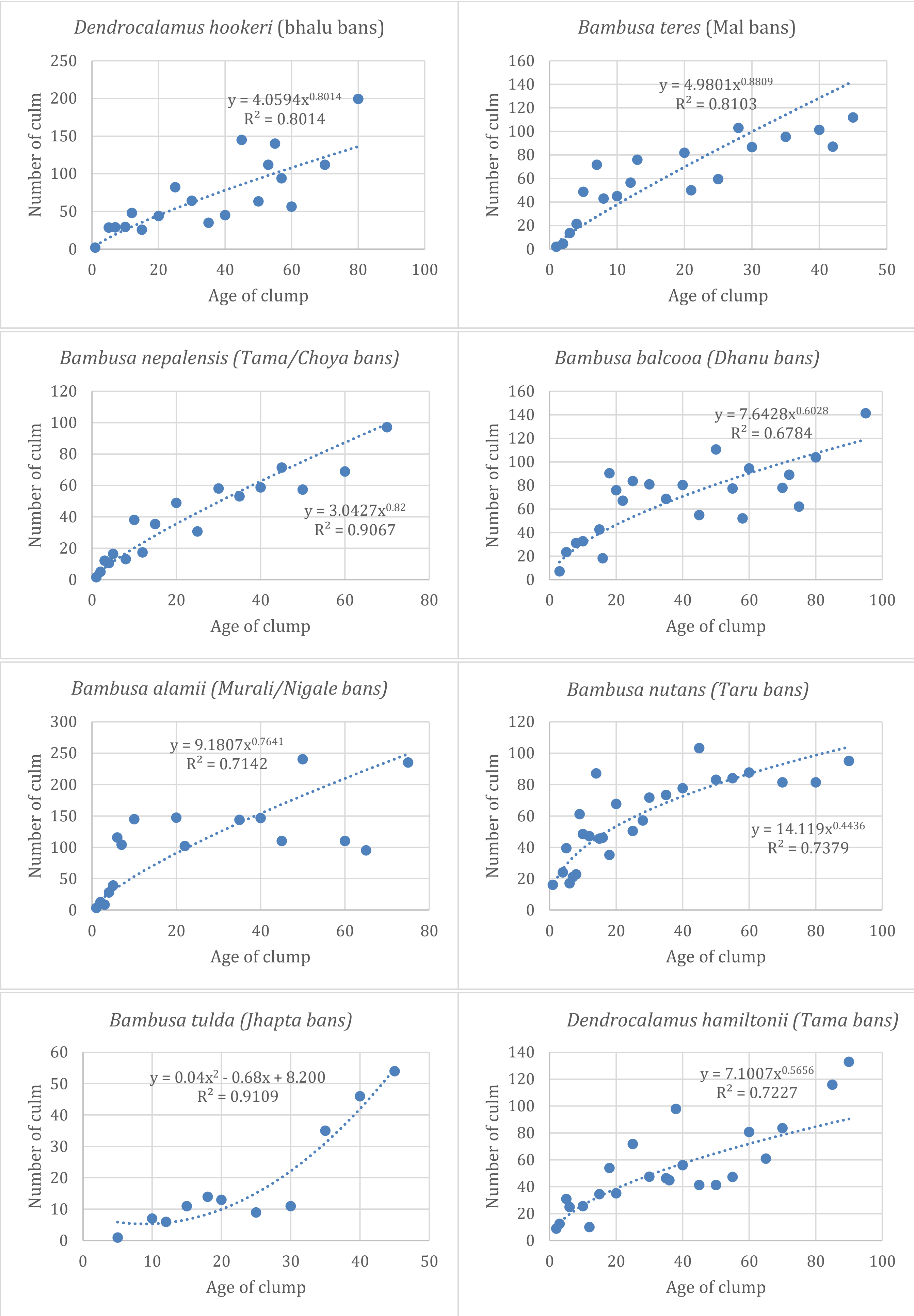

Figure 4: Bamboo culm number and clump age by species

3.2 Taper models for bamboo

The following figure (5) shows the distribution of sample bamboo culms of all species along with their diameters measured at different sectional heights for each bamboo culm.

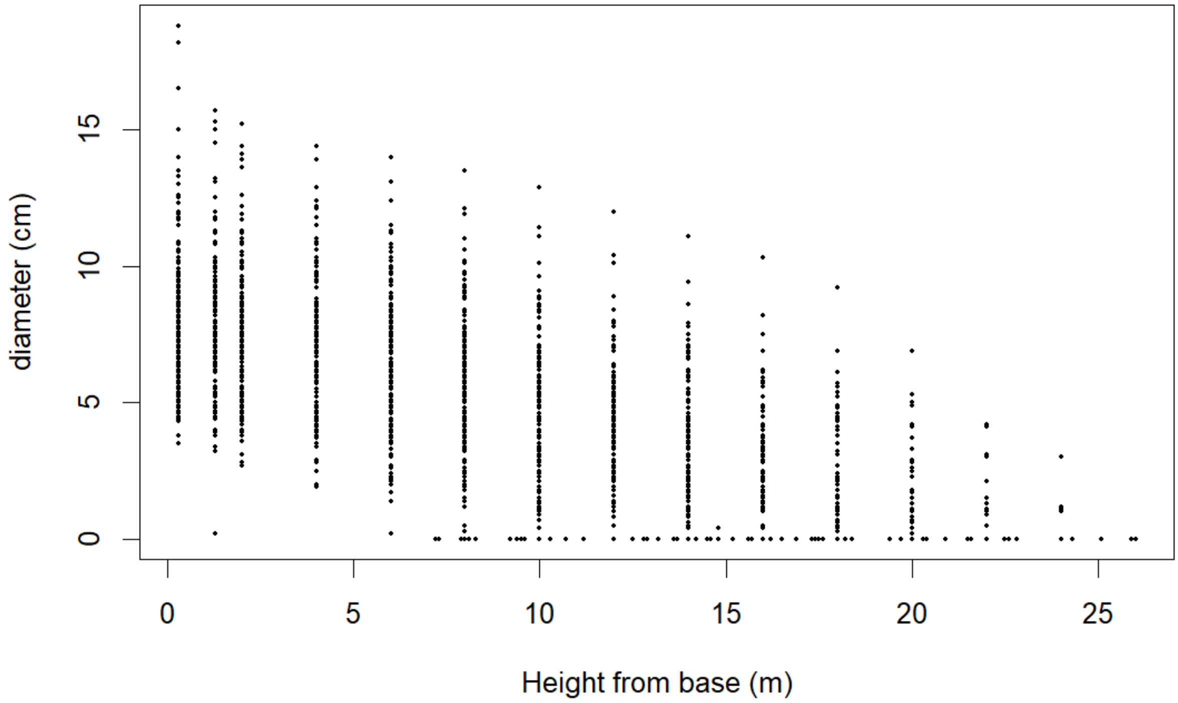

Figure 5: Observation on sectional diameters and heights from base of bamboo culms

The highest number of bamboo culms were from the DBH class 5 to 10 cm figure (6). On the other hand, minimum samples of culms were representing the DBH above 10 cm and below 5 cm.

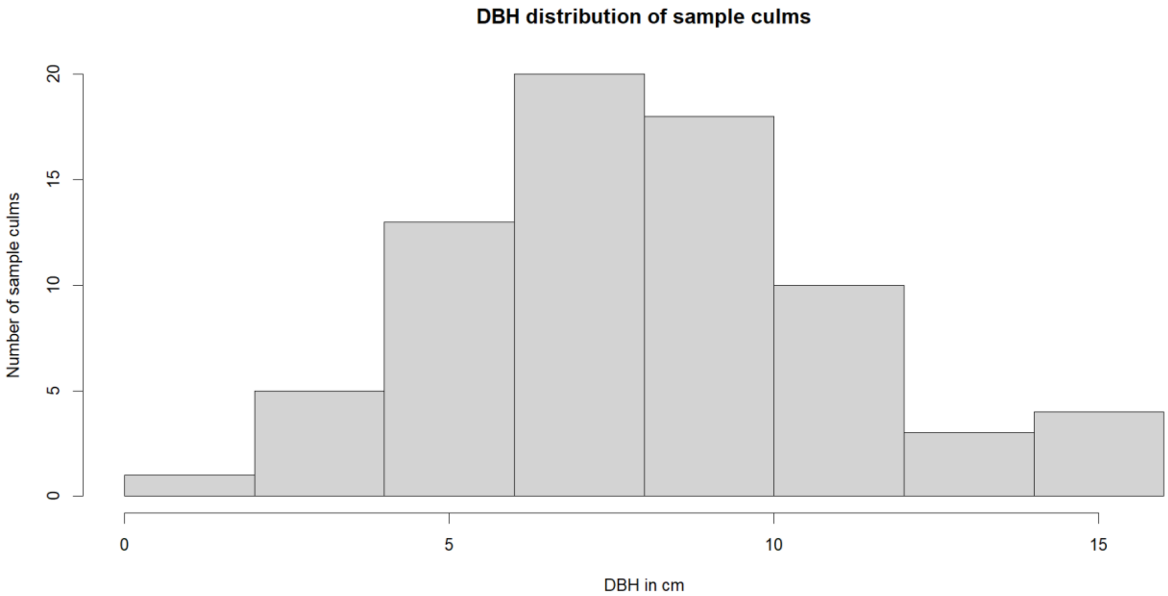

Figure 6: Observation on sectional diameters and heights from base of bamboo culms

The following taper equations (table 14) have been developed.

Table 15: Taper models and model parameters

SN	Model	Model equation	Parameters	Residual standard error	Adj. R^2
1	Linear	Y=a+b(X) Where, Y=predicted diameter for mean DBH X=hi/ht (hi=sectional height and ht= total height)	a= 9.0051 b=- 7.8016	2.01	0.61
2	Polynomial	$Y=a+b(X)+c(X)^2$ Where, Y=predicted diameter for mean DBH X=hi/ht (hi=sectional height and ht= total height)	a= 8.53 b=- 4.4 c=3.41	1.99	0.63
3	BSpline	$Y=a+b(X)+c(X)^2+d(X)^3$ Where, Y=di/DBH (di=upper stem diameter) X=hi/ht (hi=sectional height and ht= total height)	a= 8 b=- 1.08 c=-13.5 d=-8.04	1.93	0.64
4	5th degree polynomial taper model	$Y=a+b(X)+c(X)^2+d(X)^3+e(X)^4+f(X)^5$ Where, Y=di/DBH (di=upper stem diameter) X=hi/ht (hi=sectional height and ht= total height)	a= 8.86 b=- 17.6 c=76.3 d=-158 e=123 f=-31.4	1.92	0.65

3.2.1 Taper equation in a linear model

The following figure (7) illustrates taper model in a linear form.

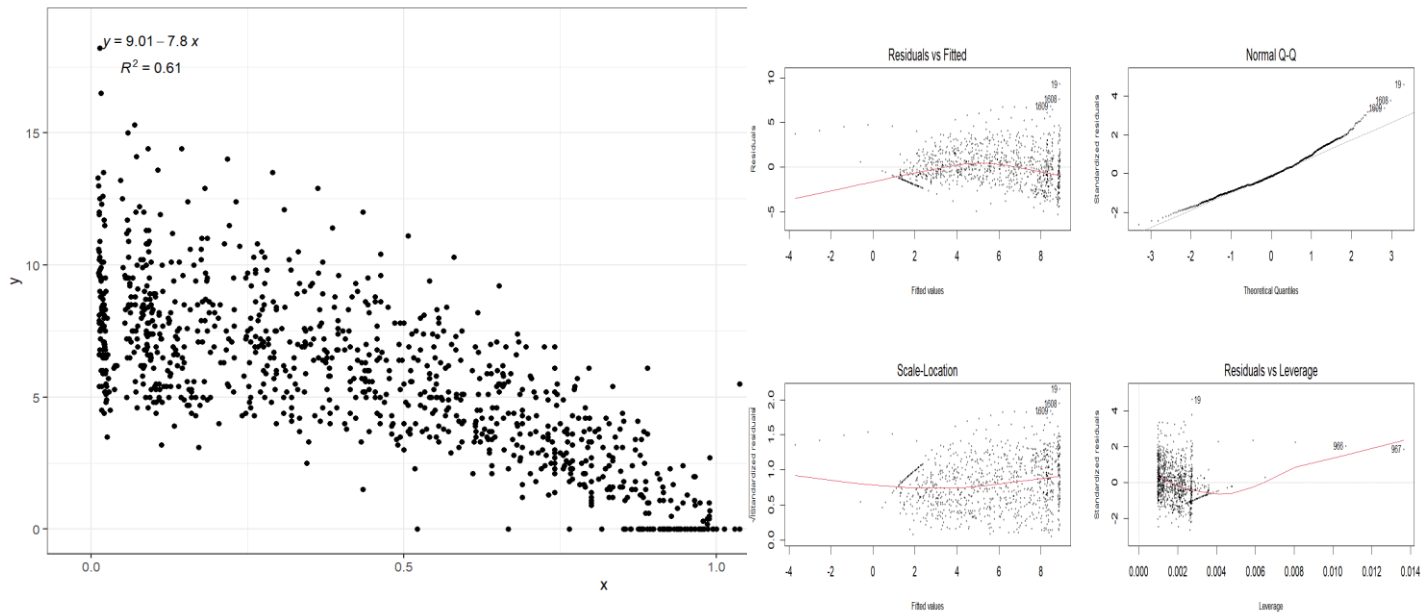

Figure 7: Linear taper model and residuals

3.2.2 Taper equation in a polynomial model

The following figure (8) illustrates taper model in a polynomial form.

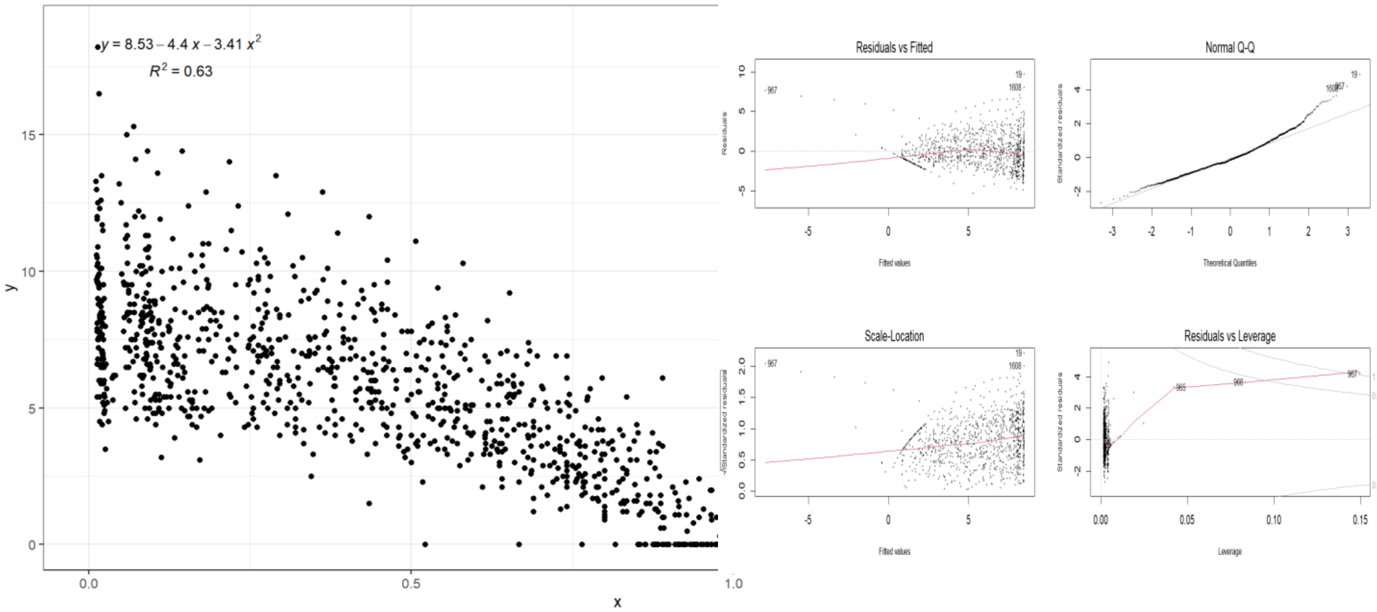

Figure 8: Polynomial taper model and residuals

3.2.3 Taper equation in a BSpline model

The following figure (9) illustrates BSpline taper model.

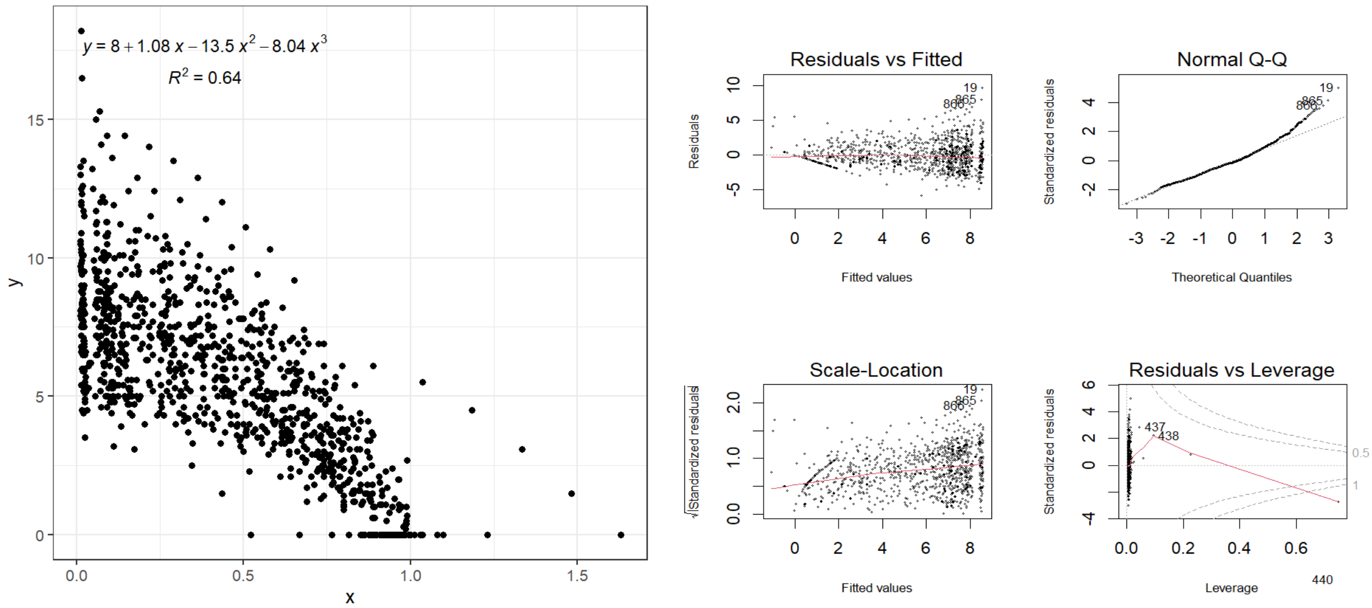

Figure 9: Bspline taper model and residuals

3.2.4 Taper equation in a 5th degree polynomial taper model

The following figure (10) illustrates a 5th degree polynomial taper model.

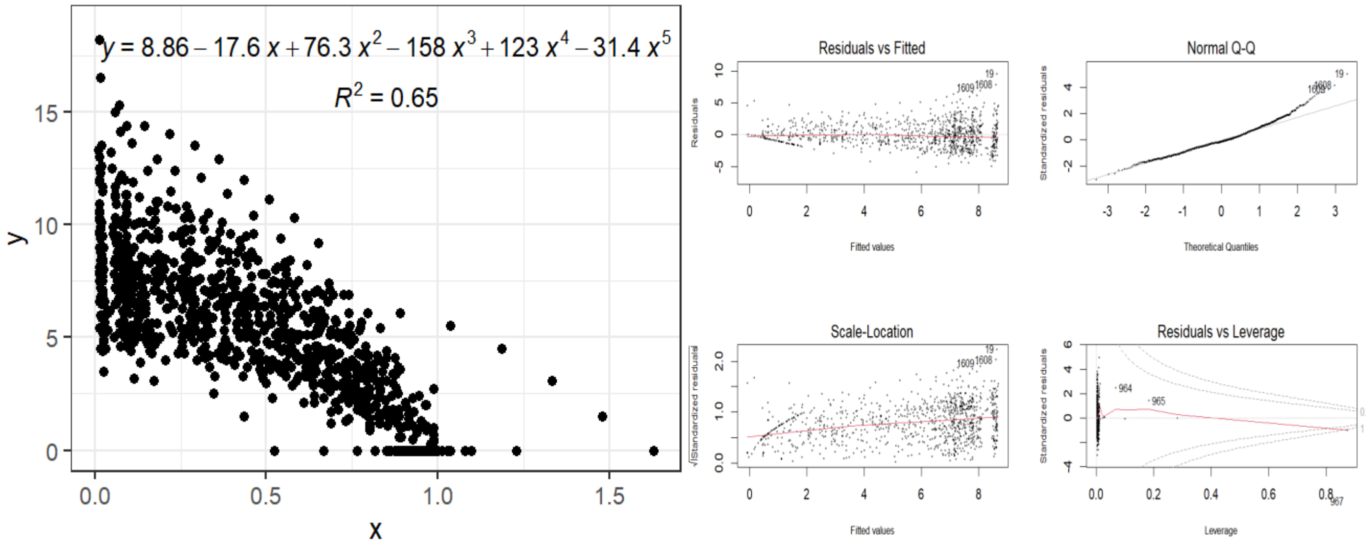

Figure 10: 5th degree polynomial taper model and residuals

3.2.5 Model selection

Taper models were developed in four different equations: linear, polynomial 2nd degree, bSpline (3rd degree) and polynomial 5th degree equations. Nevertheless, all four taper models seemed well performing, however, due to better adjusted R^2 and lesser residual standard errors, the latter two equations namely: (i) bSpline (3rd degree) and (ii) polynomial 5th degree taper models had been found more appropriate for the recommended taper models of bamboo species of Nepal.

3.3 Bamboo green - dry mass and conversion ratio

3.3.1 Total green mass of culms, branches and foliage

The average mass of a bamboo culm is 32.27 kg, of which major proportion 26.06 kg is occupied in culm, and other mass being occupied by branches and foliage 3.88 kg and 2.33 kg respectively. Among all samples in this study, the highest mass (42.69 kg) is found in *Dendrocalamus hookeri* of which culm being 36.04 kg, and branches & foliage being 3.71 kg and 2.95 kg respectively. Similarly, the lowest mass (24.86 kg) is found in *Bambusa teres* of which culm being 20.95 kg, and branches & foliage being 2.48 kg and 1.42 kg respectively (Table 16).

Table 16: Green mass of culms, branches, and foliage by species

Species	Size	Culm	Branch	Foliage	Total
Dendrocalamus hookeri/Bhalu bans		36.04	3.71	2.95	42.69
	L	49.59	4.47	3.27	57.33
	M	26.54	3.03	2.84	32.41
	S	12.45	2.68	2.18	17.31
Bambusa balcooa/Dhanu bans		31.35	5.25	2.21	38.81
	L	48.67	7.24	2.47	58.38
	M	21.61	4.40	2.59	28.61
	S	10.79	2.61	1.35	14.75
Bambusa tulda/Jhapta bans		23.01	6.60	3.55	33.16
	L	38.22	8.75	3.77	50.74
	M	20.39	7.01	4.67	32.07
	S	12.68	4.59	2.60	19.87
Bambusa nepalensis/Khasre/Choya bans		22.47	3.16	2.08	27.72
	L	41.15	4.83	3.34	49.31
	M	22.51	3.25	2.01	27.77
	S	9.98	1.93	1.34	13.25
Bambusa teres/Mal bans		20.95	2.48	1.42	24.86
	L	29.52	3.17	1.79	34.48
	M	18.63	2.49	1.60	22.72
	S	12.57	1.62	0.77	14.96
Dendrocalamus hamiltonii/Tama bans		22.52	2.90	2.11	27.54
	L	42.31	4.11	2.96	49.37
	M	23.40	3.35	2.24	28.99
	S	11.51	1.73	1.53	14.77
Bambusa nutans/Taru bans		25.59	3.38	1.98	30.94
	L	43.56	4.62	2.77	50.95
	M	22.55	3.19	1.68	27.42
	S	10.81	2.34	1.50	14.64
Average of all		26.06	3.88	2.33	32.27

Note: L: Large; M: Medium; S: Small

3.3.2 Green weight to oven dry weight conversion ratio

The average green weight to oven dry weight ratio for bamboo culm was 0.45 with the maximum value of 0.7 for *Dendrocalamus hamiltonii* and minimum value of 0.2 for *Dendrocalamus hookeri.* The details of ratio for culms of various species are presented in table 17.

Table 17: Ratio of green weight to oven dry weight for culms

Species	Local names	Average	Minimum	Maximum	sd
Dendrocalamus hookeri	Bhalu bans	0.43	0.20	0.64	0.10
Bambusa balcooa	Dhanu bans	0.42	0.22	0.65	0.12
Bambusa tulda	Jhapta bans	0.43	0.23	0.67	0.11
Bambusa nepalensis	Khasre/Choya bans	0.43	0.21	0.68	0.12
Bambusa teres	Mal bans	0.50	0.29	0.63	0.08
Dendrocalamus hamiltonii	Tama bans	0.45	0.26	0.70	0.11
Bambusa nutans	Taru bans	0.47	0.24	0.67	0.10
	Grand Total	**0.45**	**0.20**	**0.70**	**0.11**

Similarly, the average green weight to oven dry weight ratio for bamboo branches was 0.45 with the maximum value of 0.79 for *Bambusa tulda* and minimum value of 0.21 for *Dendrocalamus hookeri.* The details of ratio for branches of various species are presented in table 18.

Table 18: Ratio of green weight to oven dry weight for branches

Species	Local names	Average	Minimum	Maximum	sd
Dendrocalamus hookeri	Bhalu bans	0.43	0.21	0.62	0.08
Bambusa balcooa	Dhanu bans	0.47	0.32	0.60	0.08
Bambusa tulda	Jhapta bans	0.43	0.21	0.79	0.09
Bambusa nepalensis	Khasre/Choya bans	0.47	0.24	0.74	0.11
Bambusa teres	Mal bans	0.48	0.33	0.67	0.08
Dendrocalamus hamiltonii	Tama bans	0.43	0.25	0.68	0.08
Bambusa nutans	Taru bans	0.46	0.22	0.66	0.09
	Grand Total	**0.45**	**0.21**	**0.79**	**0.09**

Also, the average green weight to oven dry weight ratio for bamboo foliage was 0.47 with the maximum value of 0.8 for *Bambusa nepalensis* and minimum value of 0.19 for *Bambusa teres.* The details of ratio for foliage of various species are presented in table 19.

Table 19: Ratio of green weight to oven dry weight for foliage

Species	Local names	Average	Minimum	Maximum	sd
Dendrocalamus hookeri	Bhalu bans	0.45	0.33	0.77	0.11
Bambusa balcooa	Dhanu bans	0.49	0.25	0.78	0.15
Bambusa tulda	Jhapta bans	0.42	0.30	0.74	0.11
Bambusa nepalensis	Khasre/Choya bans	0.48	0.22	0.80	0.12
Bambusa teres	Mal bans	0.46	0.19	0.75	0.13
Dendrocalamus hamiltonii	Tama bans	0.46	0.24	0.78	0.14
Bambusa nutans	Taru bans	0.51	0.30	0.78	0.13
	Grand Total	**0.47**	**0.19**	**0.80**	**0.13**

3.4 Allometric models for biomass estimation

Allometric models in **linear**, **exponential** and **power** regression equations were developed for biomass modelling of bamboo species. Initially, allometric models were developed for all bamboo samples irrespective of species and later separate models for seven different species.

3.4.1 Linear regression model

Linear models, based on two (a and b) parameters, were developed to estimate bamboo biomass where independent variables were chosen diameter at breast height and height of bamboo independently (table 20).

Table 20: Model description

Description	Linear model based on DBH	Linear model based on Height
Formula	Y = -15.11 + 7.3 * X	Y = -3.76 + 2.11 * X
Residuals: Min Median Max	-33.28 -1.34 39.55	-34.65 -1.79 42.0
Coefficients a (Intercept) (se) b (slope) (se)	 -15.1127 *(2.54)* 7.2993 *(0.39)*	 -3.7566 *(2.44)* 2.1130 *(0.14)*
Residual standard error	*11.46 on 338 degrees of freedom*	*12.73 on 338 degrees of freedom*
Adjusted R-squared:	0.5093 F-statistic: 352.8 on 1 and 338 DF, p-value: < 2.2e-16	0.3966 F-statistic: 222.1 on 1 and 338 DF, p-value: < 2.2e-16

The fitted models on linear regression equation are illustrated in the following figure (11).

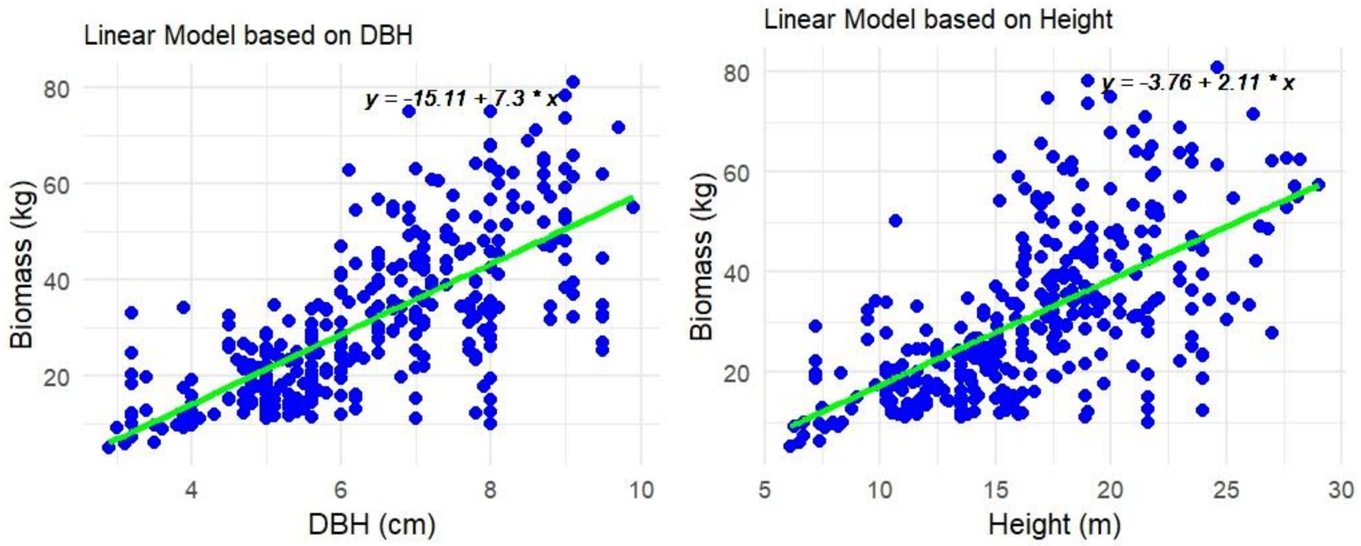

Figure 11: Linear models for bamboo biomass

3.4.2 Exponential regression model

<u>I. Models based on DBH and Height independently</u>

Exponential models, based on two (a and b) parameters, were also developed to estimate bamboo biomass where independent variables were chosen diameter at breast height and height of bamboo independently (table 21).

Table 21: Model description

Description	Exponential model based on DBH	Exponential model based on Height
Formula	Y = a * exp (b *X)	
Residuals: Min Median Max	-33.53 -1.50 41.52	-34.81 -2.25 43.50
Coefficients a (Intercept) (se) b (slope) (se)	 7.4040 *(0.71)* 0. 2178 *(0.01)*	 11.0019 *(0.97)* 0.06060 (*0.004*)
Residual standard error	*11.64 on 338 degrees of freedom*	*12.97 on 338 degrees of freedom*
Adjusted R-squared:	0.492	0.369

The fitted models on exponential regression equation are illustrated in the following figure (12).

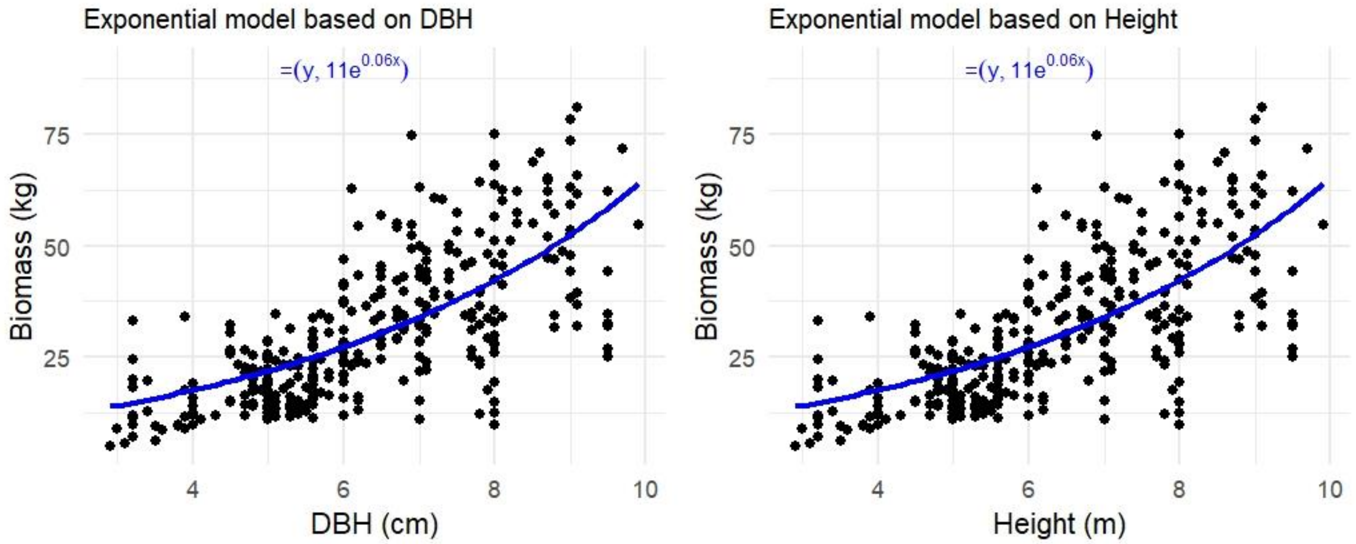

Figure 12: Exponential models for bamboo biomass

II. Models based on both DBH and Height

Exponential model, based on three (a, b, and c) parameters, was also developed to estimate bamboo biomass where both independent variables: diameter at breast height and height of bamboo were taken. The output of this model is illustrated in table (22).

Formula: y ~ a * exp(b * x1 + c * x2)

Table 22: Model description

Parameters	**Estimate**	**Std. Error**	**t value**	**Pr(>|t|)**	**Residual SE**
a	6.912611	0.68	11.033	< 2e-16 ***	11.44, df=337
b	0.172687	0.01	6.911	< 2e-16 ***	
c	0.021178	0.005	5.496	0.0002 ***	
		Adjusted R^2 = 0.51			

Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

The fitted model on exponential regression equation based on both diameter at breast height and total height is illustrated in the following figure (13).

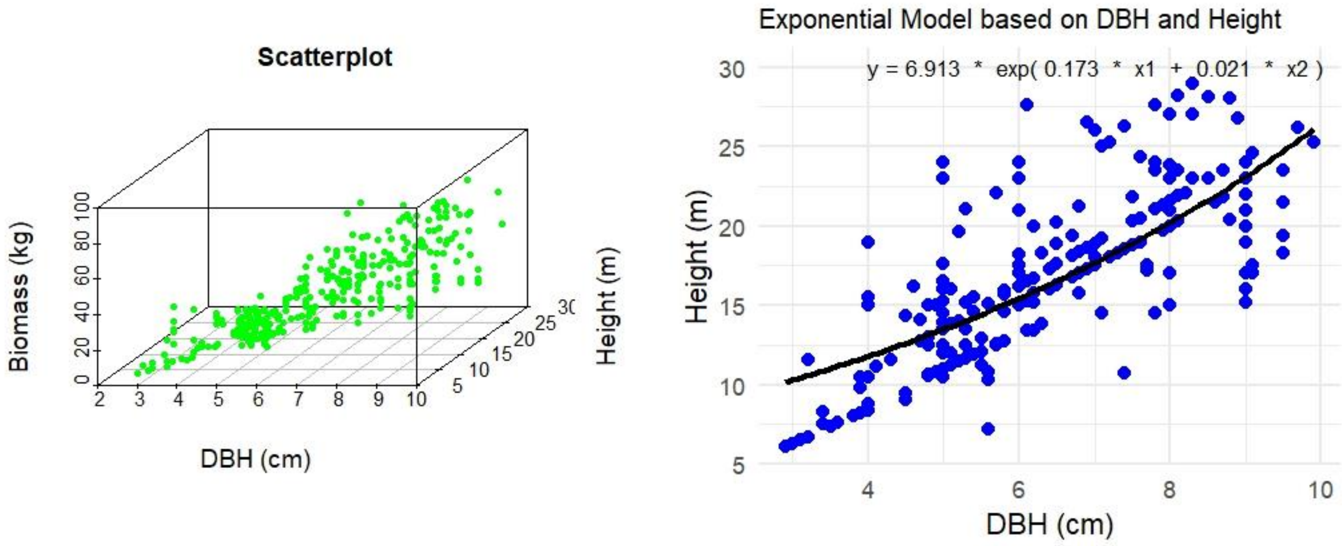

Figure 13: Exponential model based on both DBH and height

3.4.3 Power regression model

I. Models based on DBH and Height independently

Power models, based on two (a and b) parameters, were developed to estimate bamboo biomass where independent variables were chosen diameter at breast height and height of bamboo independently (table 23).

Table 23: Model description

Description	Independent variable = DBH	Independent variable = Height
Formula	(Y = a *X^b)	
	*Biomass = 1.888 * Diameter^ 1.506*	*Biomass = 1.381 * Height^ 1.11*
Residuals: Min	-33.22	-34.66
Median	-1.67	-1.85
Max	40.20	42.14
Coefficients		
a (Intercept) (se)	1.888 *(0.33)*	1.381 *(0.34)*
b (slope) (se)	1.506 *(0.09)*	1.109 (0.08)
Residual standard error	11.45 on 338 degrees of freedom	12.73 on 338 degrees of freedom
Adjusted R-squared:	0.508	0.392

The fitted models on power regression equation based on two different independent varibales are illustrated in the following figure (14).

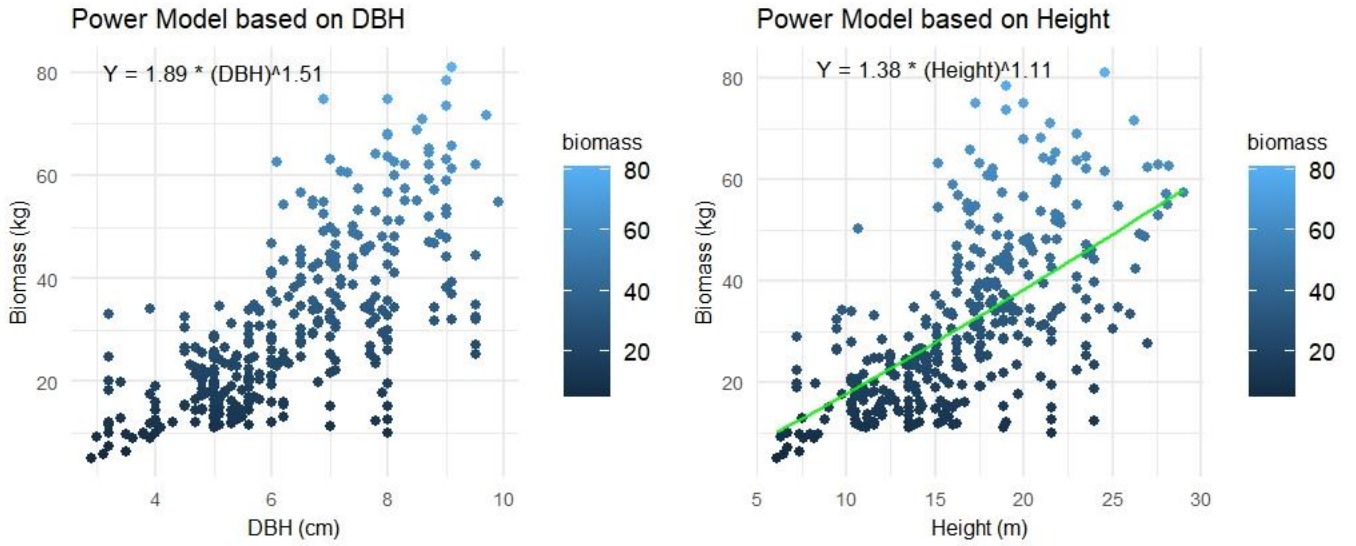

Figure 14: Power models for bamboo biomass

II. Power model based on both DBH and Height

The following power model was developed to estimate bamboo biomass where both independent variables (diameter at breast height and total height) were taken.

Formula: [$Y = a * (DBH)^b * (Height)^c$]

Biomass = 1.258 * Diameter^ 1.203 * Height^ 0.345

Table 24: Model description

Parameters	Estimate	Std. Error	t value	Pr(>|t|)	Residual SE
a	1.2581	0.28	4.510	8.95e-06 ***	11.3, df=337
b	1.2027	0.13	9.469	< e-16 ***	
c	0.3449	0.11	3.232	0.00135***	
	Adjusted R^2 = 0.522				

Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

The fitted model on power regression equation based on both independent varibales (DBH and height) are illustrated in the figure (15).

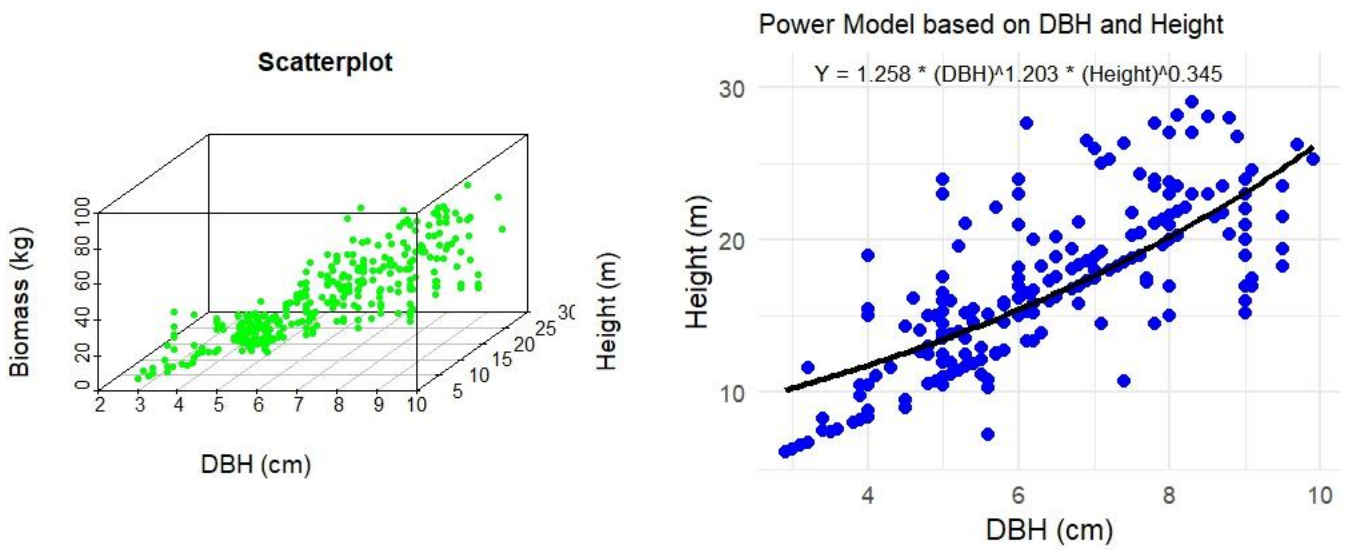

Figure 15: Power biomass model based on DBH and height

3.4.4 Allometric models for seven bamboo species

Allometric models for each seven bamboo species/varieties were also developed independently in power function where both diameters at breast height and heights were taken as independent variables against the dependent variable biomass (table 25).

Table 25: Model description

Species	**Formula: Biomass = a * (dbh^b) * (height^c)**	**Residual summary Min/Median/Max**	**Residual standard error**	**Adjusted R^2**	**RMSE**
Bambusa nepalensis	Biomass = 1.128 * Diameter^ 0.892 * Height^ 0.583	-30.7 -1.58 24.2	9.55 on 49 df	0.950	9.27
Bambusa nutans	Biomass = 0.958 * Diameter^ 0.581 * Height^ 0.854	-24.4 -1.25 26.9	9.22 on 50 df	0.953	8.96
Bambusa teres	Biomass = 4.166 * Diameter^ 0.414 * Height^ 0.384	-20.7 -2.37 21.3	10.11 on 45 df	0.949	9.79
Bambusa balcooa	Biomass = 1.507 * Diameter^ 1.67 * Height^ -0.021	-28.0 -2.03 29.3	12.16 on 44 df	0.928	11.76
Bambusa tulda	Biomass = 1.186 * Diameter^ 1.663 * Height^ 0.09	-24.2 -1.25 36.7	10.92 on 45 df	0.940	10.57
Dendrocalamus hookeri	Biomass = 0.904 * Diameter^ 1.641 * Height^ 0.184	-30.6 -1.87 20.0	11.06 on 44 df	0.940	10.70
Dendrocalamus hamiltonii	Biomass = 3.536 * Diameter^ 0.962 * Height^ 0.09	-24.5 -1.94 29.2	11.72 on 42 df	0.936	11.32

The fitted model on power regression equation, for seven different bamboo species/varieites, based on both independent varibales (DBH and height) are illustrated in the figure (16).

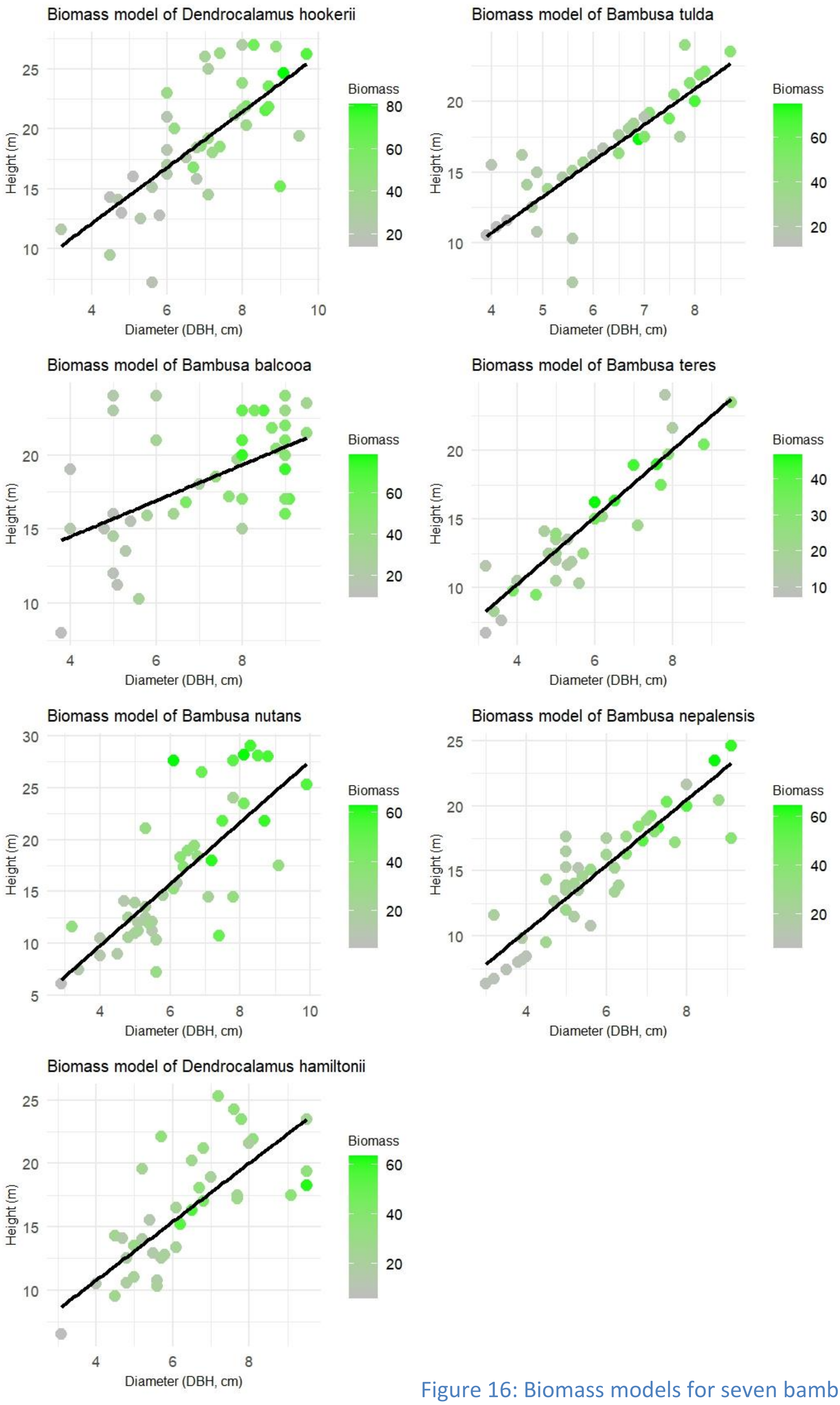

Figure 16: Biomass models for seven bamboo species

3.4.5 Model selection

Biomass allometric models were developed in three different equations: linear, exponential, and power. Biomass models developed in all equations seemed performing well, however, due to better adjusted R^2 and lesser residual standard errors, the models developed in power equations with two independent variables (diameter at breast height and height) were found more appropriate and thus could be recommended as biomass allometric models for bamboo species.

3.5 Bamboo resource mapping

Bamboo resource mapping was conducted for bamboo presence plots outside the forest area in Nepal (Annex 3). Furthermore, maps of seven bamboo species were prepared detailing the density of culms and clumps per hectare.

A higher density of clumps of *Bambusa balcooa* was observed in the Bagmati and Gandaki provinces, with similar trends noted for culms per hectare in these regions. In terms of culms per hectare, higher densities were recorded in Madhesh, Gandaki, and Lumbini provinces. For *Bambusa nepalensis*, lower densities (1–5 clumps per hectare) were predominantly found in Koshi and Bagmati provinces, with densities of 11–15 clumps per hectare identified only in a few locations. Notably, densities exceeding 400 culms per hectare were recorded in Bagmati and Koshi provinces for this species.

Bambusa teres was absent in Karnali province, but higher densities (11–15 clumps per hectare) were found in Koshi province. Conversely, Sudurpaschim province exhibited much lower densities (1–5 clumps per hectare) for this species. Densities exceeding 400 culms per hectare were observed in Koshi and Bagmati provinces.

Bambusa nutans was not observed in the sample plots of Koshi province. The lower clump densities (1–5 clumps per hectare) for this species were found in Bagmati, Gandaki, Lumbini, Karnali, and Sudurpaschim provinces. However, densities exceeding 400 culms per hectare were recorded in Bagmati, Lumbini, Karnali, and Sudurpaschim provinces.

For *Bambusa tulda*, clump densities of 6–10 clumps per hectare and culm densities of 200–400 culms per hectare were found in Madhesh province. For *Dendrocalamus hamiltonii*, clump densities were mostly low (1–5 clumps per hectare), while culm densities exceeding 400 culms per hectare were recorded in Gandaki and Bagmati provinces. However, this species was not observed in Madhesh and Sudurpaschim provinces.

Finally, *Dendrocalamus hookeri* was found as low as 1–5 clumps per hectare in Koshi and Bagmati provinces to as high as 100–200 culms per hectare in Koshi province.

4. Conclusions

Bamboo resource assessment outside the forest area has been carried out for the first time in Nepal. This assessment has revealed some of the very valuable information on bamboo all over Nepal. Detailed information on bamboo species/varieties, culm, clumps, size, number, location in addition to the total biomass, taper and allometric models, etc. have been revealed from this assessment.

Altogether 15 bamboo species were found in sample plots in different districts and physiographic regions. Bamboo distribution was noticed up to the highest altitude (2007 m) in Koshi province to the lowest altitude (57 m) in Madhesh province. The average mass of a bamboo culm was 32.27 kg, of which major proportion being occupied in culm. Out of all species, the highest mass (42.69 kg) was found in *Dendrocalamus hookeri.* The average green weight to oven dry weight ratio for bamboo culm was 0.45.

Two taper models, namely: (i) bSpline and (ii) polynomial 5^{th} degree were found more appropriate as the recommended taper models for bamboo. Biomass allometric models developed in power equations with two independent variables (diameter at breast height and height) were found more appropriate and thus could be recommended as biomass allometric models for bamboo species.

The information generated can be crucial for planners, policy makers, farmers, entrepreneurs, and concerned stakeholders. Out of all visually interpreted bamboo presence sample plots (650) error was found only on 6% out of all. Thus, the present assessment methodology seems promising to further explore information on bamboo resources of Nepal.

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Annexes

Annex-1: Various aspects of bamboos (based on focus group discussion)

Annex 1.1 Ways of identifying bamboos

People have good knowledge on features to be applied for identifying bamboo. Based on their opinion in focus group discussion, the ways of identifying bamboo species are as follows:

Leaf size: Size of leaves varies with bamboo species. For instance, *D. hamiltonii* (Tama bans) and *B. nepalensis* (choya bans) have long leaves and *B. teres* (Mal bans) has short and broad (*chepto*) leaves.

Size of culm (diameter or girth): *D. strictus* (Katha bans) has small sized culms, Mal bans has medium sized smooth culms and *D. hookerii* (Bhalu bans) has large culms. Similarly, malingo and nigalo are small bamboos.

Nodes: Number of nodes are many in Kharaute band.

Height of culm: Mal, *B. balcooa* (Dhanu) and Bhalu bans are taller than other bamboo species

Leaves: Tama bans has heavy (dense) foliage.

Branch and branching pattern: Tama bans has many branches. Some bamboo species have large branches whereas some bamboo species have thin branches. Again the number of main and other branches at the node varies with bamboo species.

Use: Tama bans is famous for shoot as a vegetable. Its shoot is very delicious. Taru bans has bitter shoot. Choya beans are good for making *choya*.

Internode length: It varies with bamboo species. Some bamboo species have short internode length e.g., Bhalu bans and Kharaute bans, whereas some bamboo species have long internode length, e.g., Mal bans.

Thorns: All bamboo species have no thorns but some species have thorns e.g., Kande bans and Taru bans.

Size of shoot: Bhalu bans have large shoots and shape of shoot also varies with bamboo species.

Size of clump: Clump height of Bhalu bans is large.

Culm sheath: Type of culm sheath is different for different bamboo species.

Smoothness of culm: Some bamboo culms are smooth e.g., Mal bans while other bamboo culms are rough.

Annex 1.2 Methods for identifying age of bamboo culm

The methods for identifying age of bamboo culm based on focus group discussion are as follows:

Size of culm: In general, the girth or diameter of first year culm is large. The size of mature culms is small.

Colour of culm: Young culms (first year) are deep green and mature culms are light yellow. The second year is green and dull. Old mature culms become red in colour (from 4 to 5 years but 8-10 years in shading places) in some cases. Similarly, a number of mature culms become yellowish. Black colour is found in some mature culms.

Softness and hardness of culms: Mature culms are strong and start to become yellow. Young culms are soft. Third year club is mature and strong.

Bark thickness of culm: Thickness of culm varies with the age of culms.

Foliage: As the age of culm increases, the foliage in culm gradually decreases. Younger culms have dense foliage but older culms have less foliage. No leaves or very few leaves present in the first year culm, and flushing starts in second year

Size of leaves: With the increase in age of culm, leaves become smaller and less foliage. As the culms become mature, the size of leaves gradually reduces. Young culms have large leaves.

Branch: Very few thin branches arise in first year culm. With the increase in age of culm, branches become thin and small. Branches appear in second year culms.

Culm sheath (Khabata/ patyas/dhyangro): Culm sheath is attached with new culms. Presence of culm sheath (khabata) is found in first year culm.

Spots: In some cases, white spots are found in first year culm.

Annex 1.3 Livelihood support

The bamboo sub-sector has supported livelihood, to some extent. They have used bamboo for their own purpose such as fodder for cattle, fencing, construction of cattle and goat sheds, house construction. Further they have generated income by selling bamboo culms to the traders for the use of scaffolding, tunnel construction and for making bamboo products. But it varied from district to district. The farmers in Jhapa district have been more benefitted than the farmers in Dadeldhura district. In Surunga, Jhapa, some people are involved in making mats in which Kankaimai community forest has made an agreement with Kankaimai Municipality.

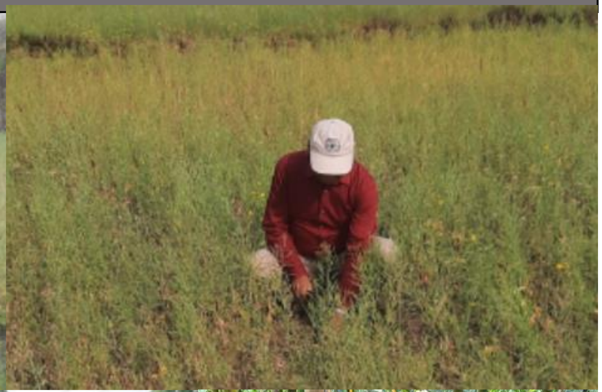
Annex-2: Photo plates

Focus group discussion in Sankhuwasabha district


Felling bamboo samples for biomass measurement in Kaski district

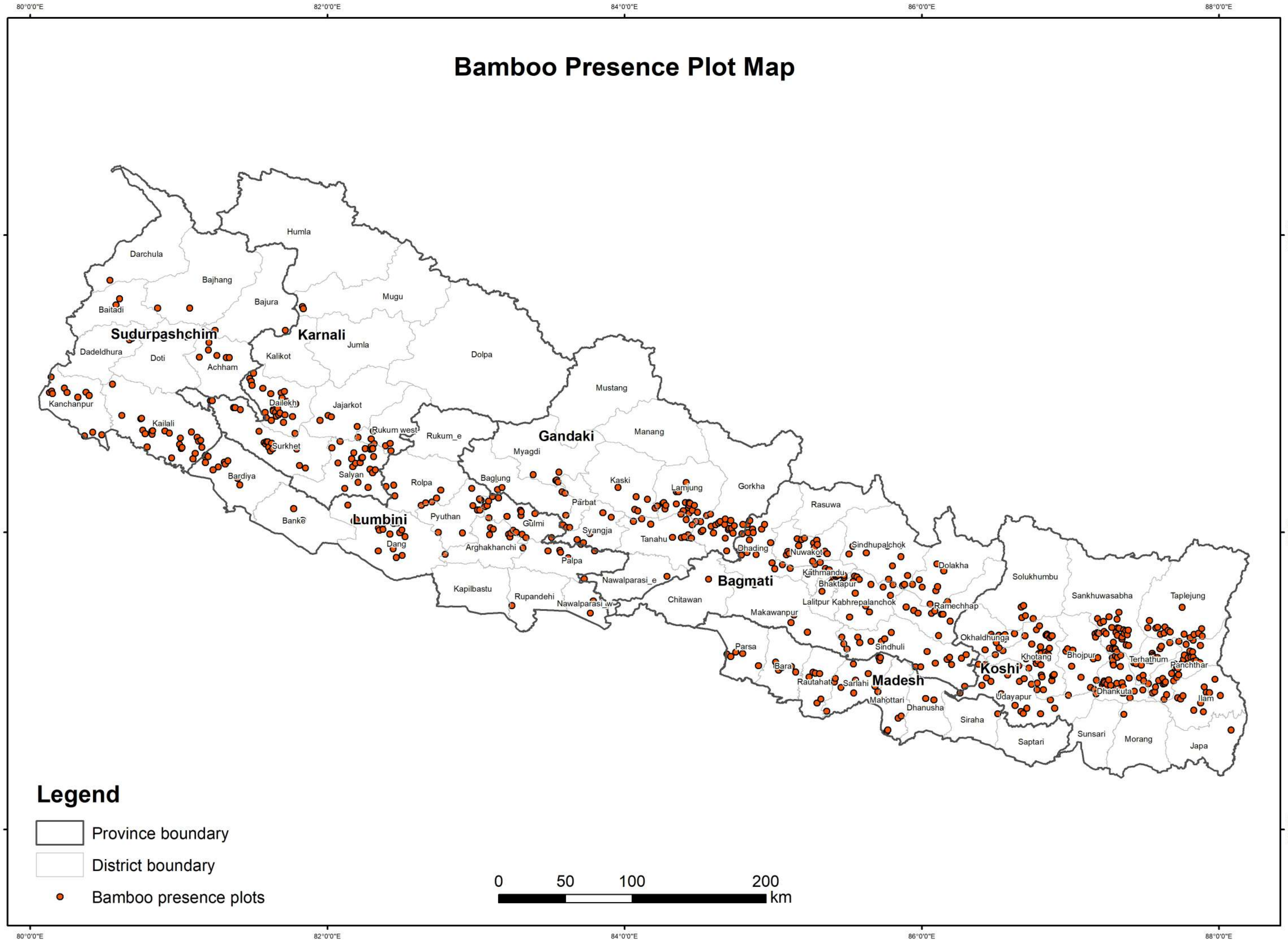

Training Field Crews in Bhaktapur district

Start of Field work in Kaski district

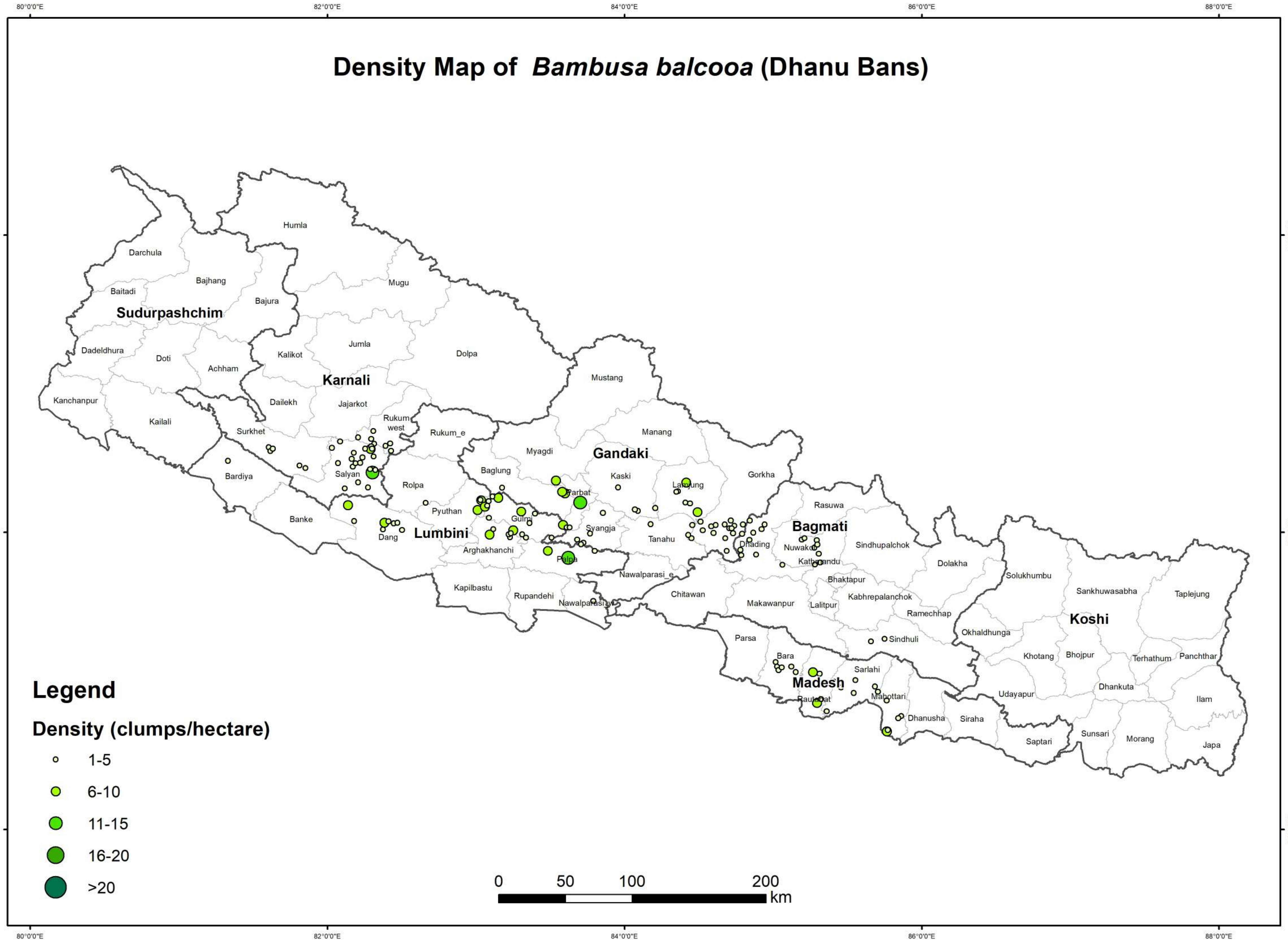


Focus Group discussions

Annex-3: Maps



Bamboo Presence Plot Map
80°0'0"E
82°0'0"E
84°0'0"E
86°0'0"E
88°0'0"E
30°0'0"N
28°0'0"N
26°0'0"N
Sudurpashchim
Karnali
Lumbini
Gandaki
Bagmati
Madesh
Koshi
Humla
Darchula
Bajhang
Bajura
Mugu
Baitadi
Jumla
Dadeldhura
Doti
Achham
Kalikot
Dolpa
Kanchanpur
Kailali
Dailekh
Jajarkot
Mustang
Manang
Surkhet
Rukum west
Rukum_e
Myagdi
Bardiya
Salyan
Rolpa
Baglung
Kaski
Lamjung
Gorkha
Parbat
Rasuwa
Banke
Pyuthan
Gulmi
Syangja
Tanahu
Dang
Arghakhanchi
Dhading
Nuwakot
Sindhupalchok
Palpa
Dolakha
Kathmandu
Bhaktapur
Nawalparasi_e
Kapilbastu
Rupandehi
Nawalparasi_w
Chitawan
Lalitpur
Kabhrepalanchok
Ramechhap
Makawanpur
Solukhumbu
Sankhuwasabha
Taplejung
Okhaldhunga
Sindhuli
Parsa
Bara
Rautahat
Sarlahi
Mahottari
Dhanusha
Siraha
Khotang
Bhojpur
Terhathum
Panchthar
Dhankuta
Udayapur
Ilam
Saptari
Sunsari
Morang
Japa
Legend
Province boundary
District boundary
Bamboo presence plots
0
50
100
200
km


Density Map of Bambusa balcooa (Dhanu Bans)
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82°0'0"E
84°0'0"E
86°0'0"E
88°0'0"E
30°0'0"N
28°0'0"N
26°0'0"N
Sudurpashchim
Karnali
Gandaki
Lumbini
Bagmati
Madesh
Koshi
Humla
Darchula
Bajhang
Baitadi
Bajura
Mugu
Dadeldhura
Doti
Achham
Kalikot
Jumla
Dolpa
Kanchanpur
Kailali
Dailekh
Jajarkot
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Myagdi
Bardiya
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Kaski
Lamjung
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Pyuthan
Parbat
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Syangja
Rasuwa
Dang
Arghakhanchi
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Sindhupalchok
Palpa
Kathmandu
Dolakha
Nawalparasi_e
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Makawanpur
Bhaktapur
Lalitpur
Kabhrepalanchok
Ramechhap
Solukhumbu
Sankhuwasabha
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Okhaldhunga
Sindhuli
Parsa
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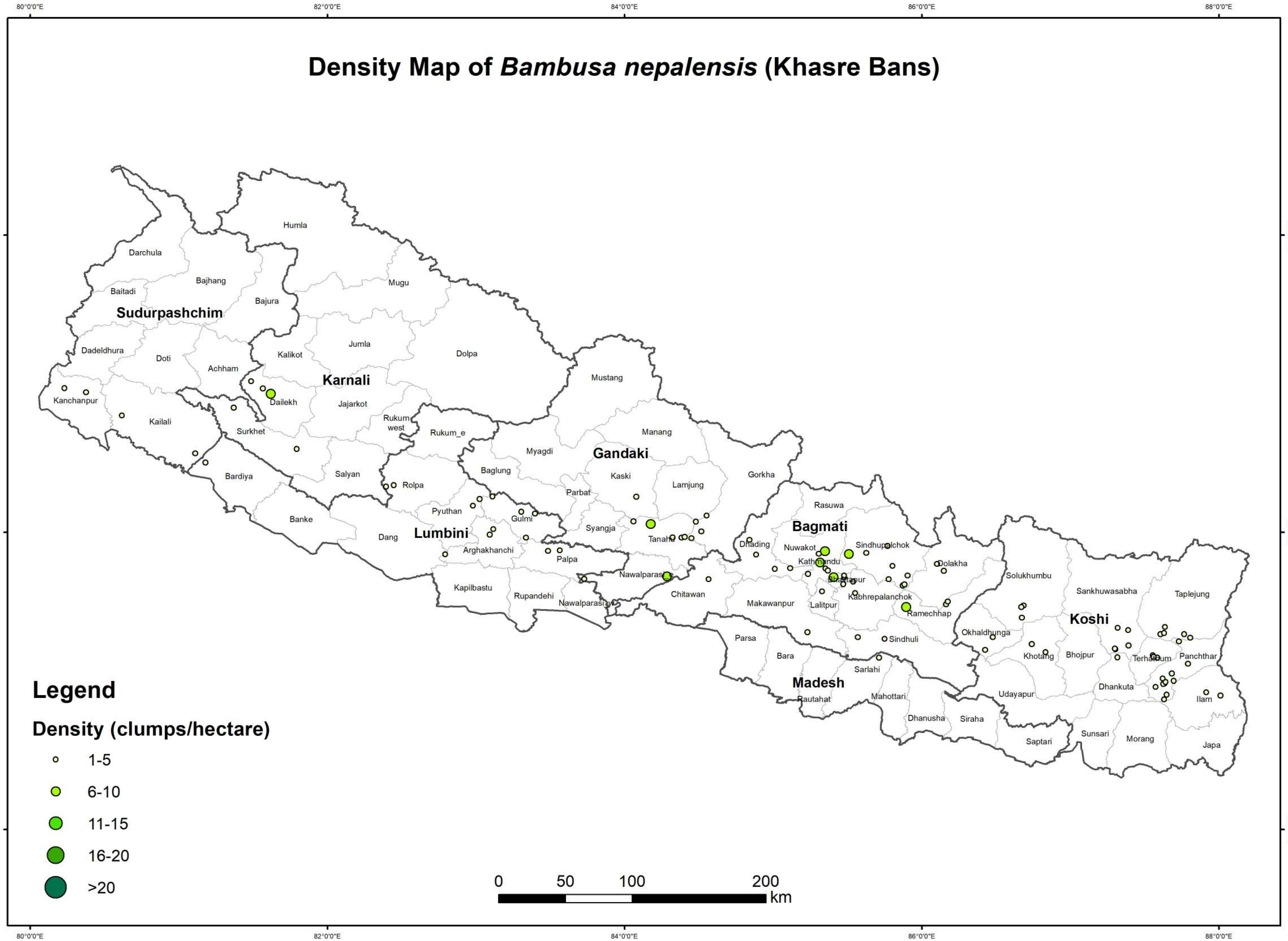
Sarlahi
Rautahat
Mahottari
Dhanusha
Siraha
Khotang
Bhojpur
Terhathum
Panchthar
Udayapur
Dhankuta
Ilam
Saptari
Sunsari
Morang
Japa
Legend
Density (clumps/hectare)
1-5
6-10
11-15
16-20
>20
0
50
100
200
km



Density Map of *Bambusa nepalensis* (Khasre Bans)
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84°0'0"E
86°0'0"E
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30°0'0"N
28°0'0"N
26°0'0"N
Sudurpashchim
Karnali
Gandaki
Lumbini
Bagmati
Madesh
Koshi
Humla
Darchula
Bajhang
Baitadi
Bajura
Mugu
Dadeldhura
Doti
Achham
Kalikot
Jumla
Dolpa
Mustang
Kanchanpur
Kailali
Dailekh
Jajarkot
Surkhet
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Rasuwa
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Arghakhanchi
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Kabhrepalanchok
Ramechhap
Solukhumbu
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Udayapur
Dhankuta
Ilam
Saptari
Sunsari
Morang
Japa
Legend
Density (clumps/hectare)
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16-20
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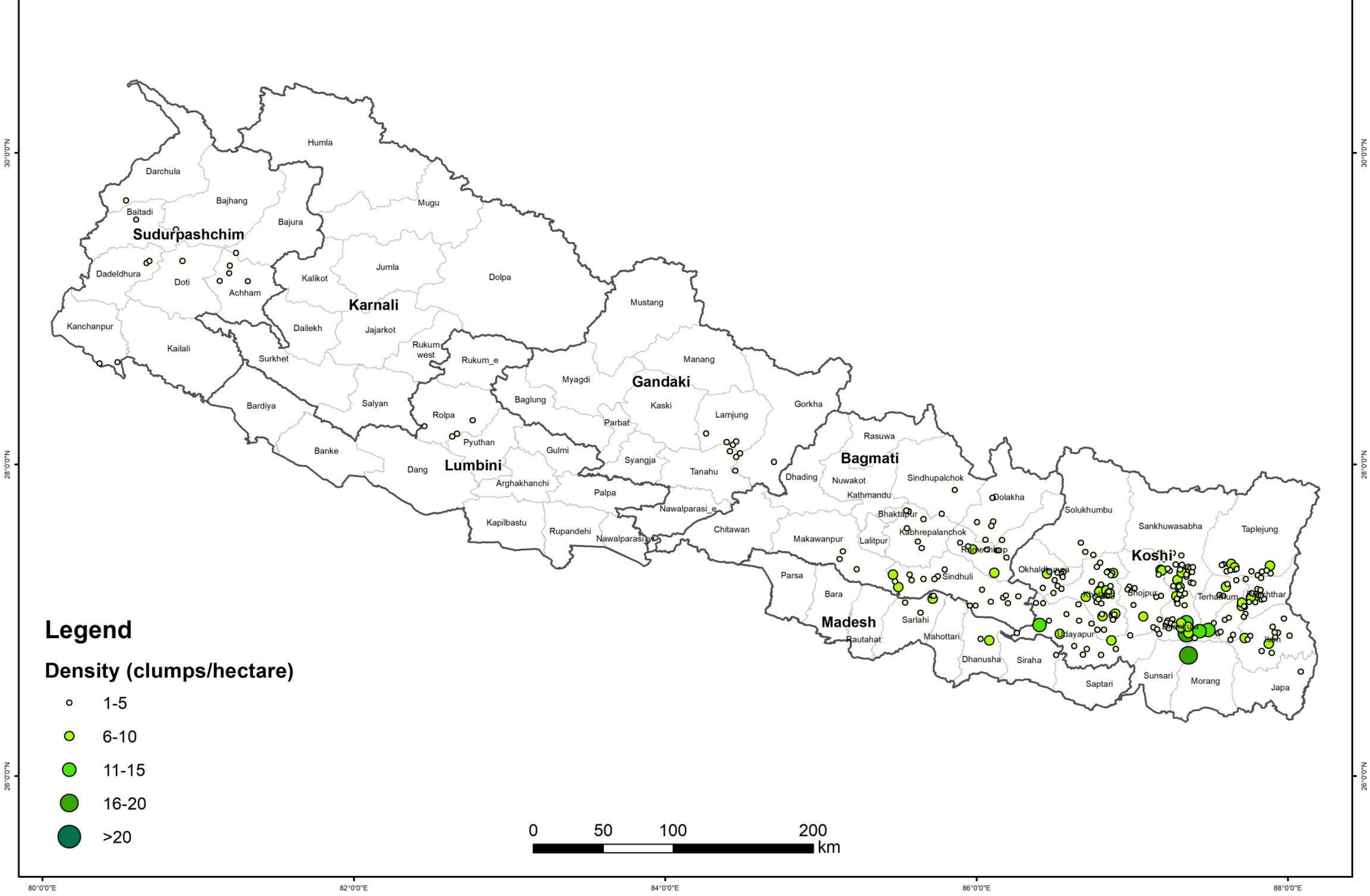
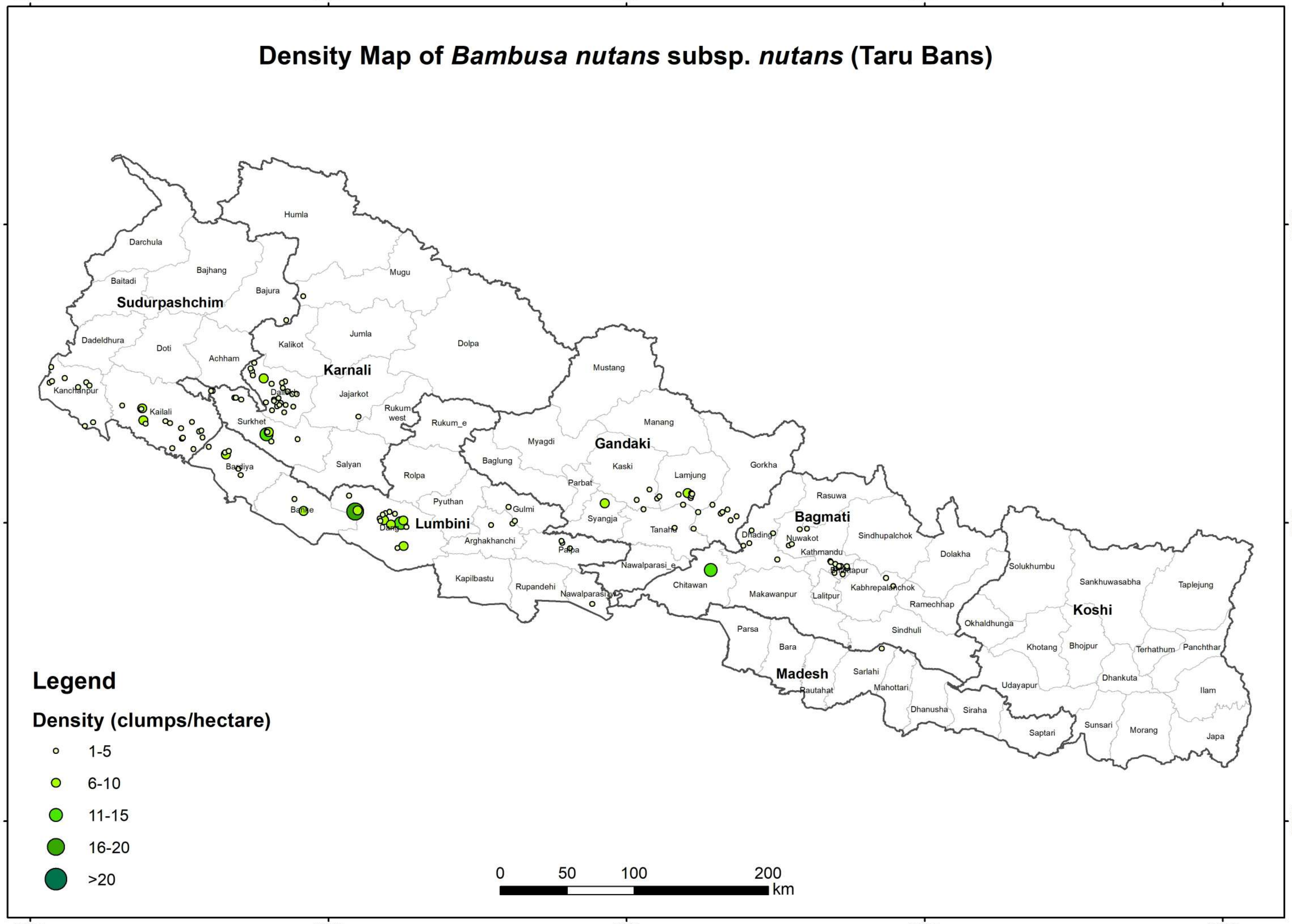
km

Density Map of *Bambusa nutans* subsp. *cupulata* (Mal Bans)




Density Map of *Bambusa nutans* subsp. *nutans* (Taru Bans)
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88°0'0"E
30°0'0"N
28°0'0"N
26°0'0"N
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Karnali
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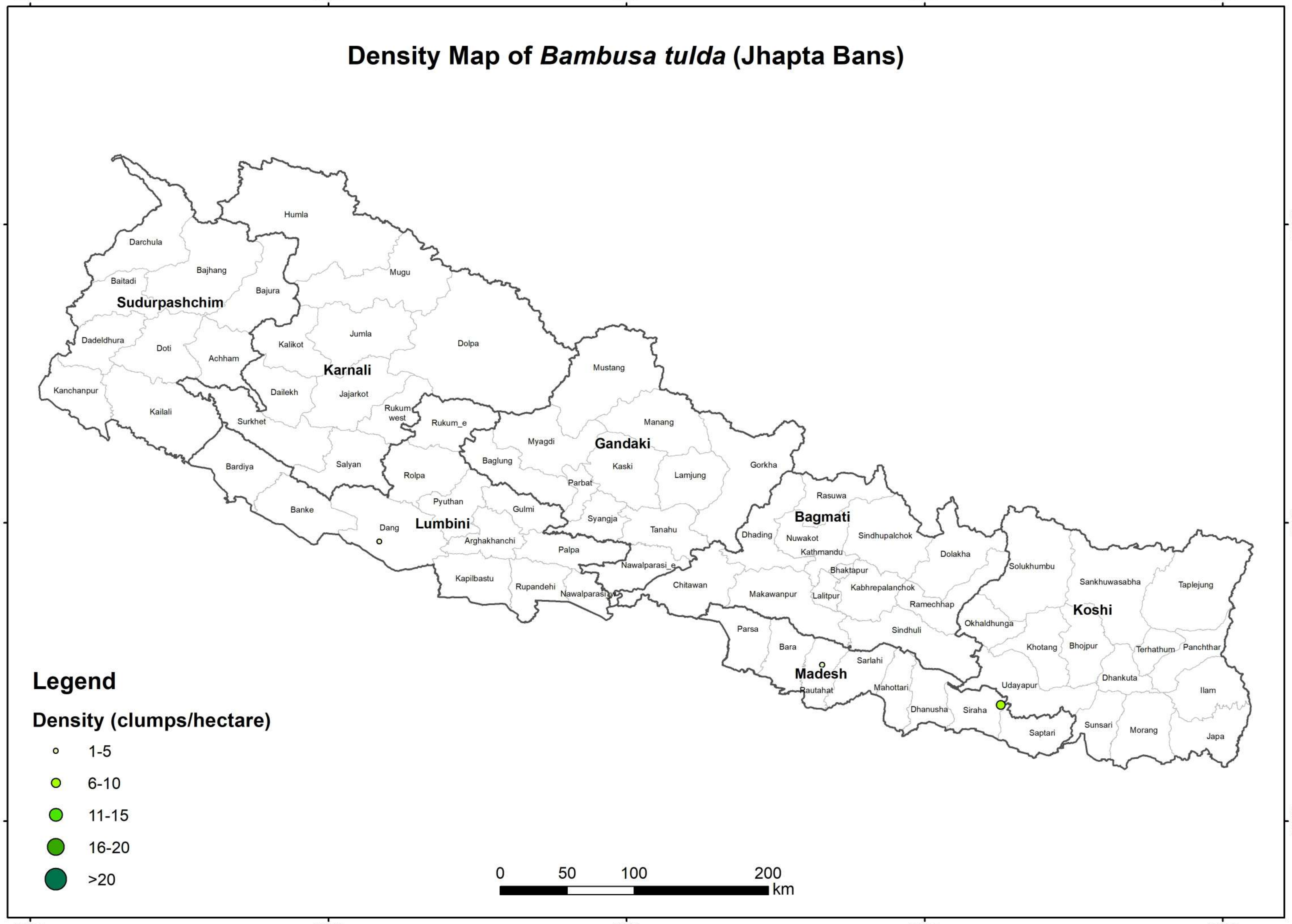
Density Map of Bambusa tulda (Jhapta Bans)
Legend
Density (clumps/hectare)
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Sunsari
Morang
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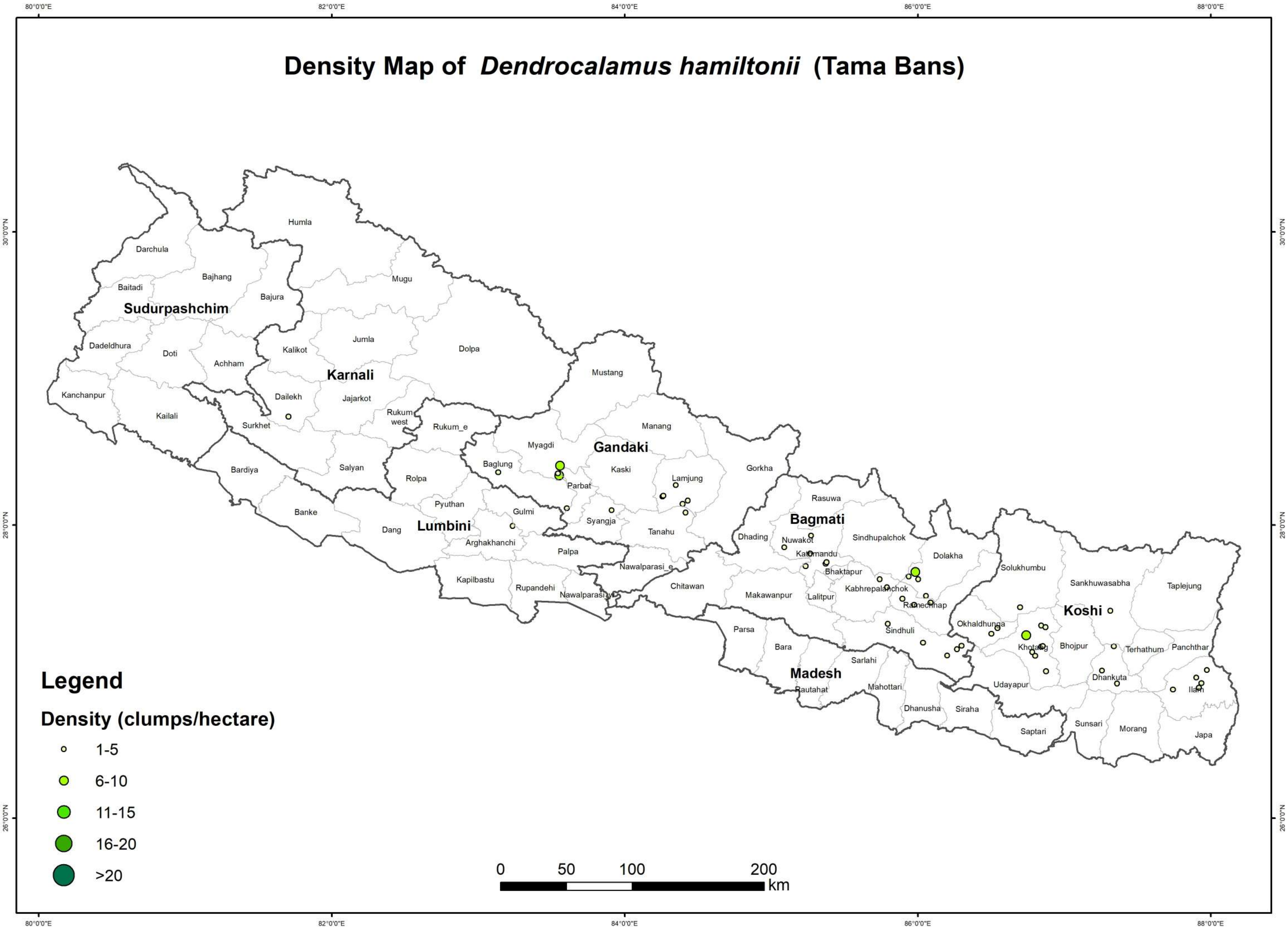
Density Map of *Dendrocalamus hamiltonii* (Tama Bans)
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86°0'0"E
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Sarlahi
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Sunsari
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Legend
Density (clumps/hectare)
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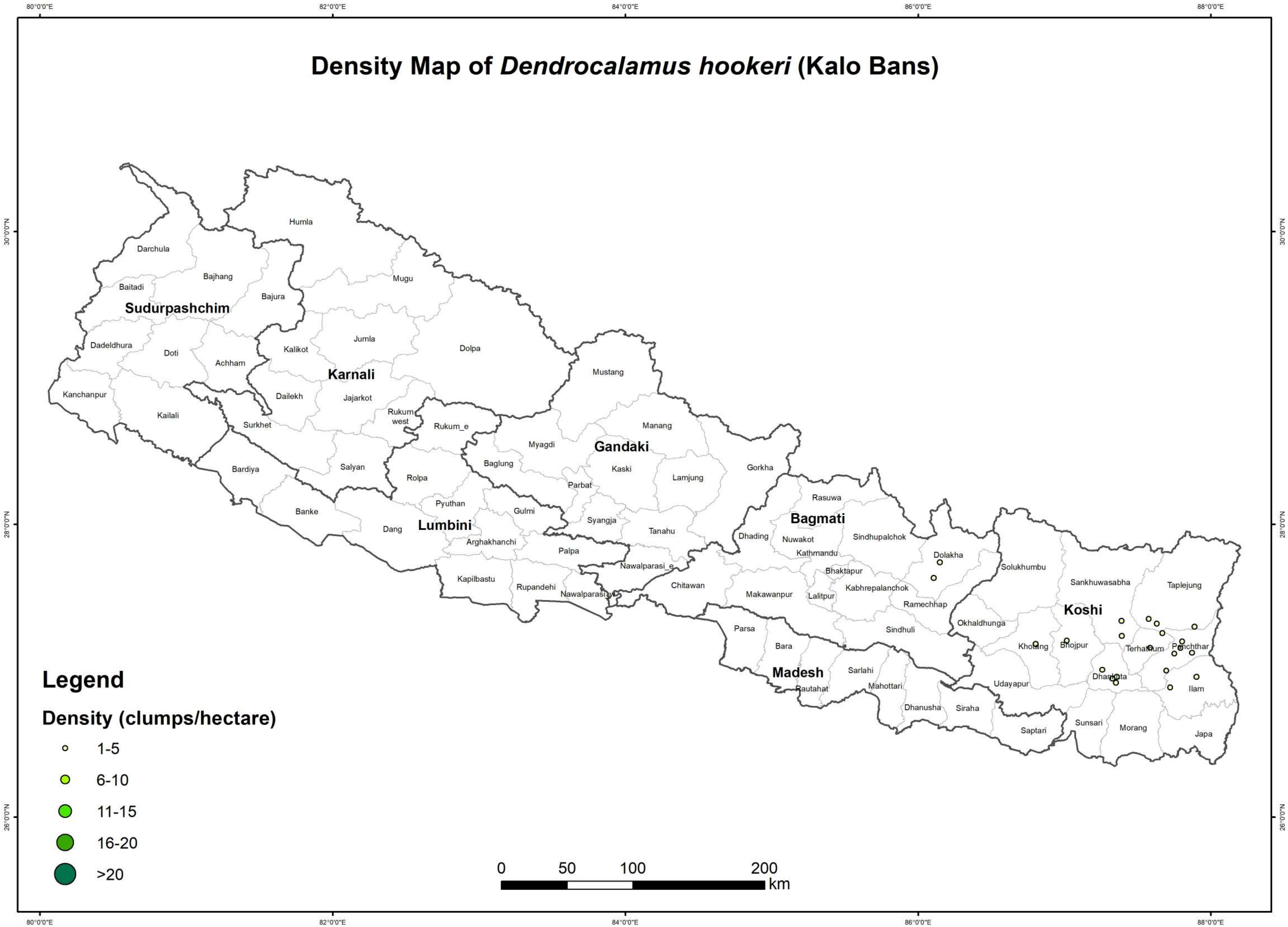
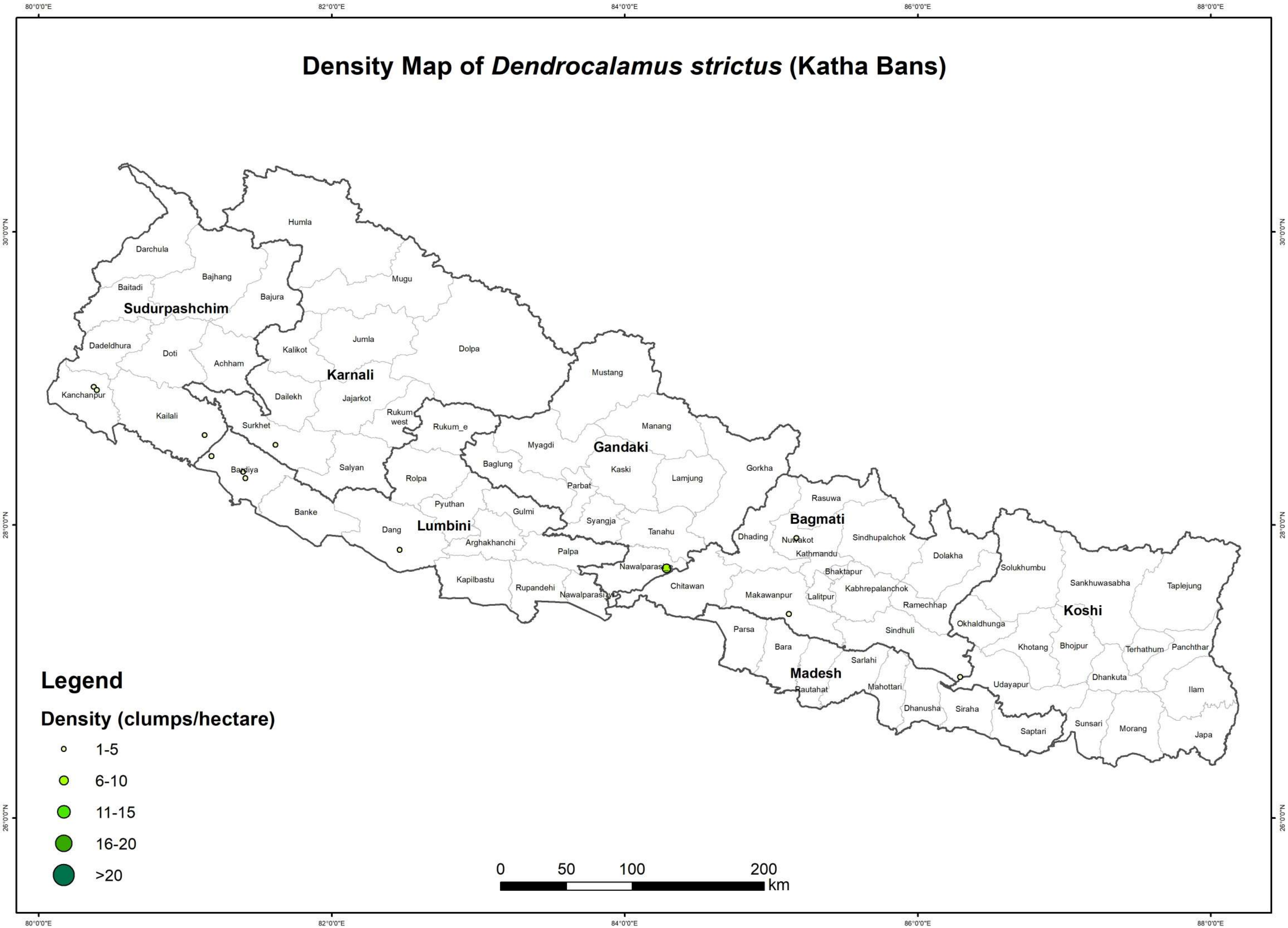


Density Map of *Dendrocalamus hookeri* (Kalo Bans)


Density Map of Dendrocalamus strictus (Katha Bans)
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30°0'0"N
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Rasuwa
Dhading
Nuwakot
Sindhupalchok
Kathmandu
Bhaktapur
Lalitpur
Kabhrepalanchok
Makawanpur
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Sarlahi
Mahottari
Dhanusha
Siraha
Saptari
Solukhumbu
Okhaldhunga
Khotang
Udayapur
Bhojpur
Sankhuwasabha
Taplejung
Terhathum
Panchthar
Dhankuta
Ilam
Sunsari
Morang
Japa
Legend
Density (clumps/hectare)
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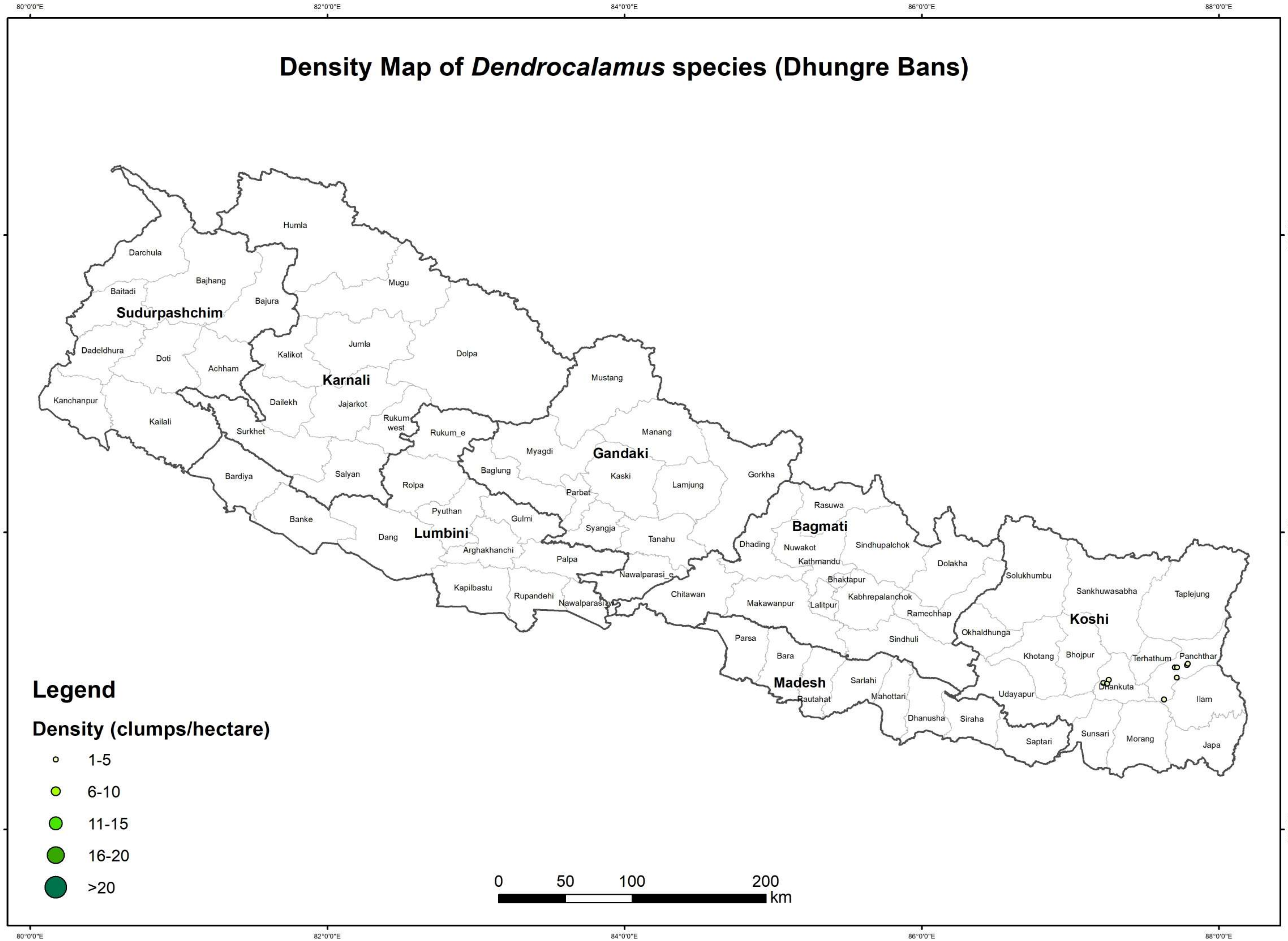
km



Density Map of *Dendrocalamus* species (Dhungre Bans)
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82°0'0"E
84°0'0"E
86°0'0"E
88°0'0"E
30°0'0"N
28°0'0"N
26°0'0"N
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Lumbini
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Dadeldhura
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Kanchanpur
Kailali
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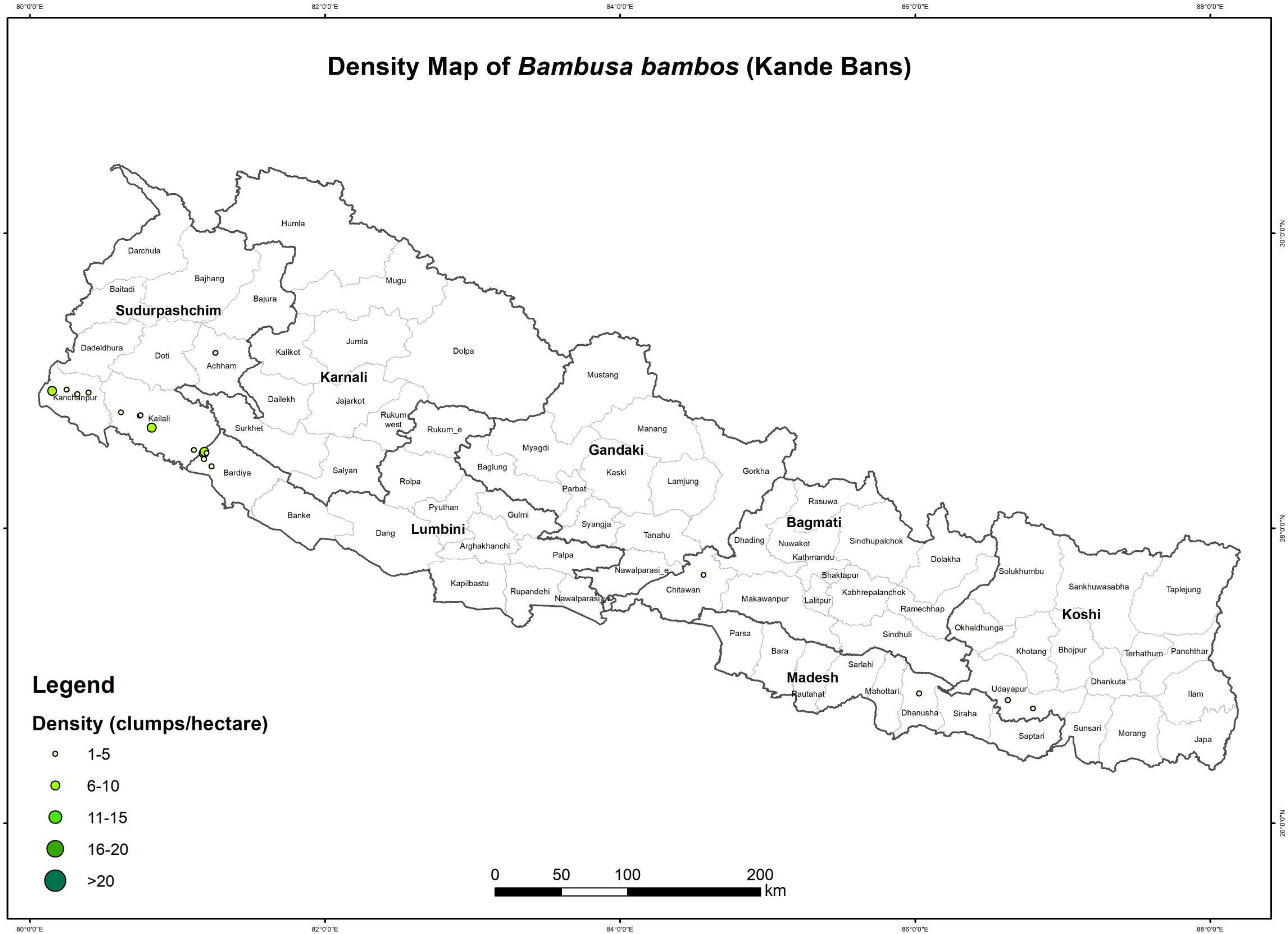
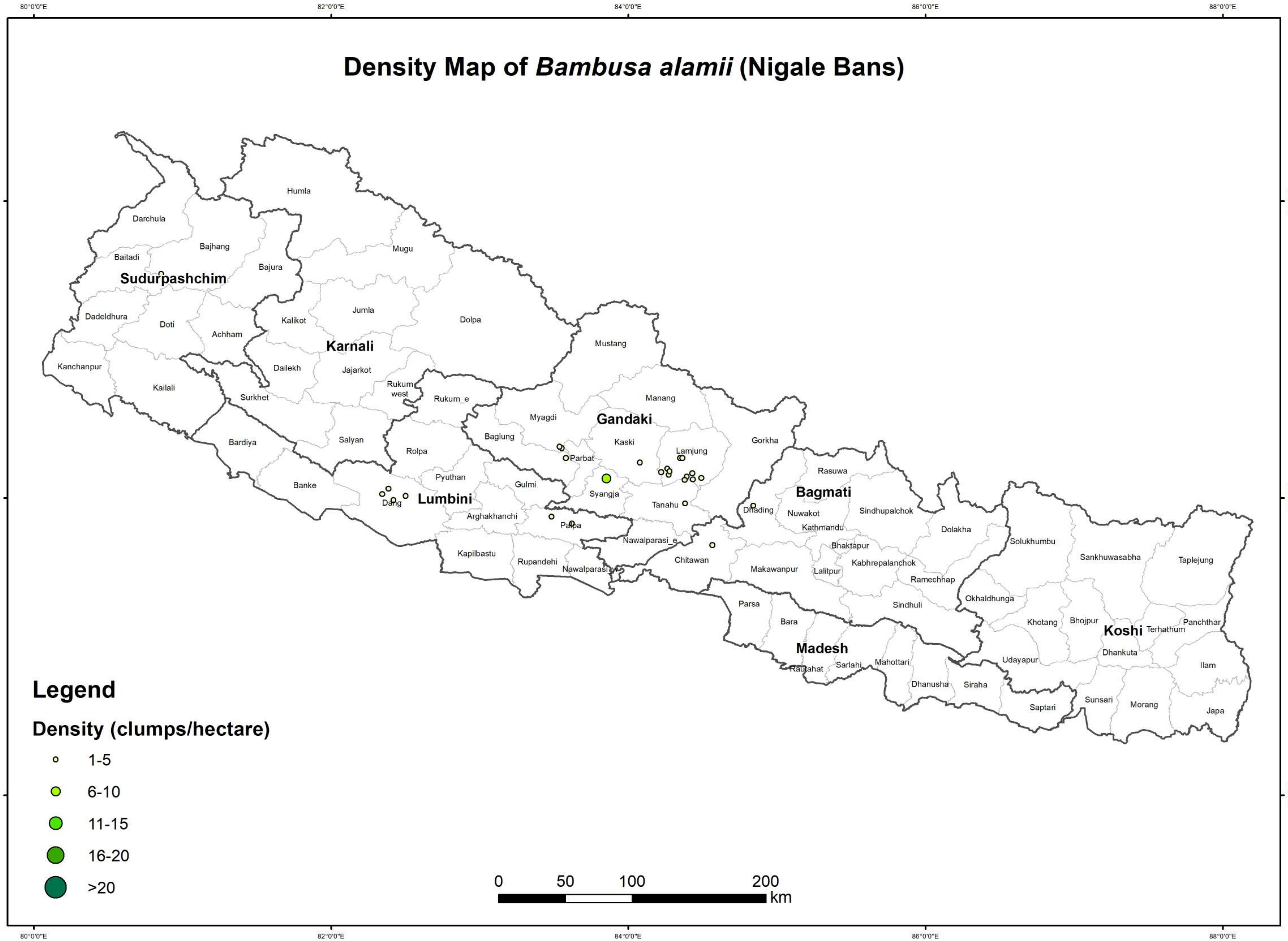
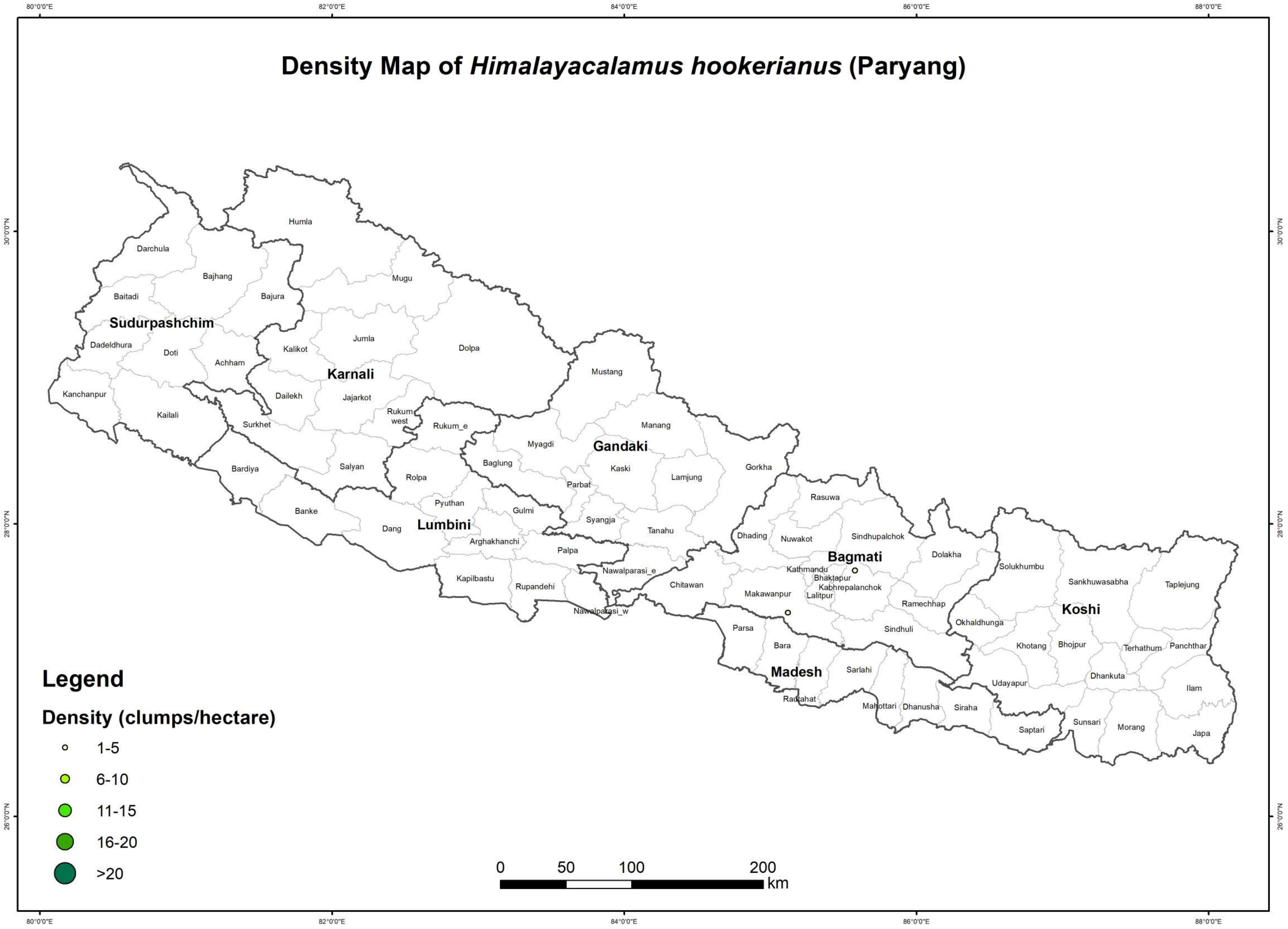
Arghakhanchi
Palpa
Nawalparasi_e
Kapilbastu
Rupandehi
Nawalparasi_w
Chitawan
Rasuwa
Dhading
Nuwakot
Sindhupalchok
Kathmandu
Bhaktapur
Lalitpur
Kabhrepalanchok
Makawanpur
Dolakha
Ramechhap
Sindhuli
Parsa
Bara
Rautahat
Sarlahi
Mahottari
Dhanusha
Siraha
Solukhumbu
Okhaldhunga
Khotang
Udayapur
Saptari
Sankhuwasabha
Taplejung
Bhojpur
Terhathum
Panchthar
Dhankuta
Ilam
Sunsari
Morang
Japa
Legend
Density (clumps/hectare)
1-5
6-10
11-15
16-20
>20
0
50
100
200
km

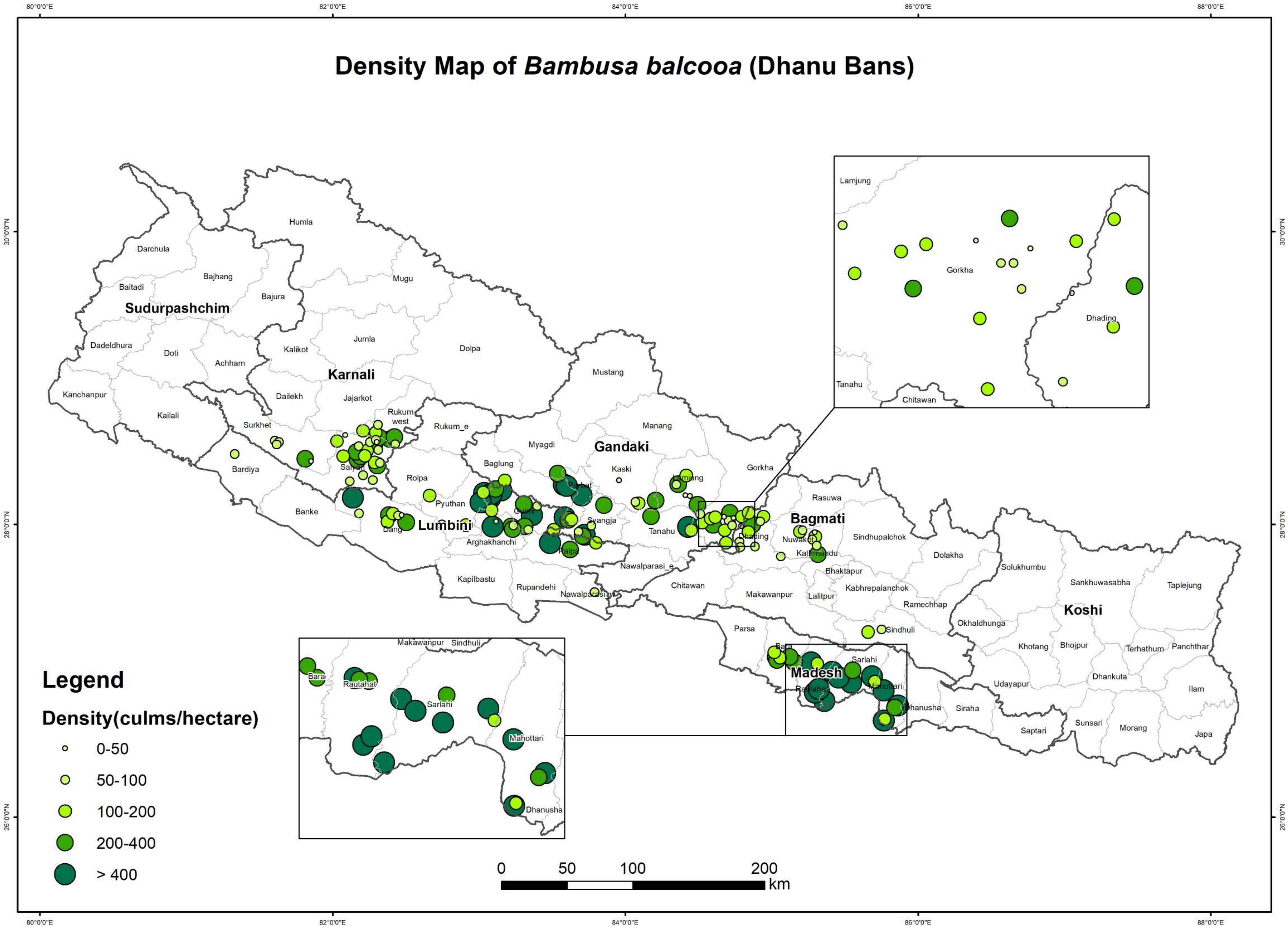


Density Map of *Bambusa bambos* (Kande Bans)
80°0'0"E
82°0'0"E
84°0'0"E
86°0'0"E
88°0'0"E
30°0'0"N
28°0'0"N
26°0'0"N
Sudurpashchim
Karnali
Gandaki
Lumbini
Bagmati
Madesh
Koshi
Darchula
Baitadi
Bajhang
Bajura
Humla
Mugu
Dadeldhura
Doti
Achham
Kalikot
Jumla
Dolpa
Kanchanpur
Kailali
Dailekh
Jajarkot
Surkhet
Rukum west
Rukum_e
Bardiya
Salyan
Rolpa
Banke
Dang
Pyuthan
Mustang
Manang
Myagdi
Baglung
Kaski
Lamjung
Gorkha
Parbat
Gulmi
Syangja
Tanahu
Arghakhanchi
Palpa
Kapilbastu
Rupandehi
Nawalparasi_w
Nawalparasi_e
Chitawan
Rasuwa
Dhading
Nuwakot
Sindhupalchok
Kathmandu
Bhaktapur
Lalitpur
Kabhrepalanchok
Makawanpur
Dolakha
Ramechhap
Sindhuli
Parsa
Bara
Rautahat
Sarlahi
Mahottari
Dhanusha
Siraha
Saptari
Udayapur
Okhaldhunga
Solukhumbu
Khotang
Bhojpur
Sankhuwasabha
Taplejung
Terhathum
Panchthar
Dhankuta
Ilam
Sunsari
Morang
Japa
Legend
Density (clumps/hectare)
1-5
6-10
11-15
16-20
>20
0
50
100
200
km

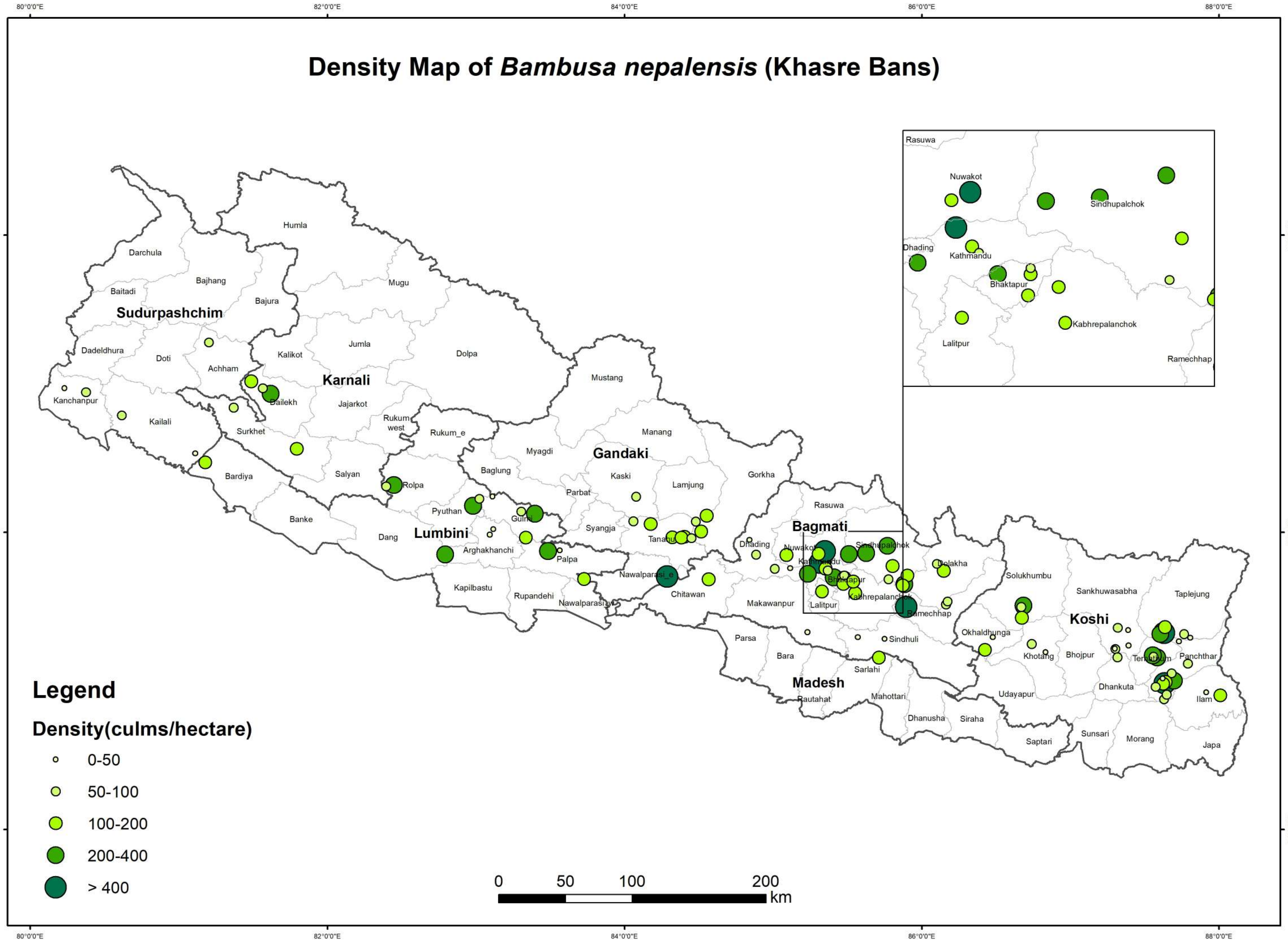

Density Map of *Bambusa alamii* (Nigale Bans)
80°0'0"E
82°0'0"E
84°0'0"E
86°0'0"E
88°0'0"E
30°0'0"N
28°0'0"N
26°0'0"N
Humla
Darchula
Bajhang
Mugu
Baitadi
Bajura
Sudurpashchim
Jumla
Kalikot
Dolpa
Dadeldhura
Doti
Achham
Karnali
Mustang
Kanchanpur
Dailekh
Jajarkot
Kailali
Rukum west
Manang
Surkhet
Rukum_e
Myagdi
Gandaki
Baglung
Kaski
Gorkha
Bardiya
Salyan
Rolpa
Lamjung
Parbat
Rasuwa
Banke
Pyuthan
Gulmi
Syangja
Bagmati
Lumbini
Dang
Tanahu
Dhading
Nuwakot
Sindhupalchok
Arghakhanchi
Palpa
Kathmandu
Dolakha
Nawalparasi_e
Bhaktapur
Solukhumbu
Kapilbastu
Chitawan
Kabhrepalanchok
Sankhuwasabha
Taplejung
Rupandehi
Nawalparasi_w
Makawanpur
Lalitpur
Ramechhap
Okhaldhunga
Parsa
Sindhuli
Bara
Khotang
Bhojpur
Panchthar
Koshi
Terhathum
Madesh
Dhankuta
Mahottari
Udayapur
Rautahat
Sarlahi
Ilam
Dhanusha
Siraha
Sunsari
Morang
Saptari
Japa
Legend
Density (clumps/hectare)
1-5
6-10
11-15
16-20
>20
0
50
100
200
km

Density Map of *Himalayacalamus hookerianus* (Paryang)

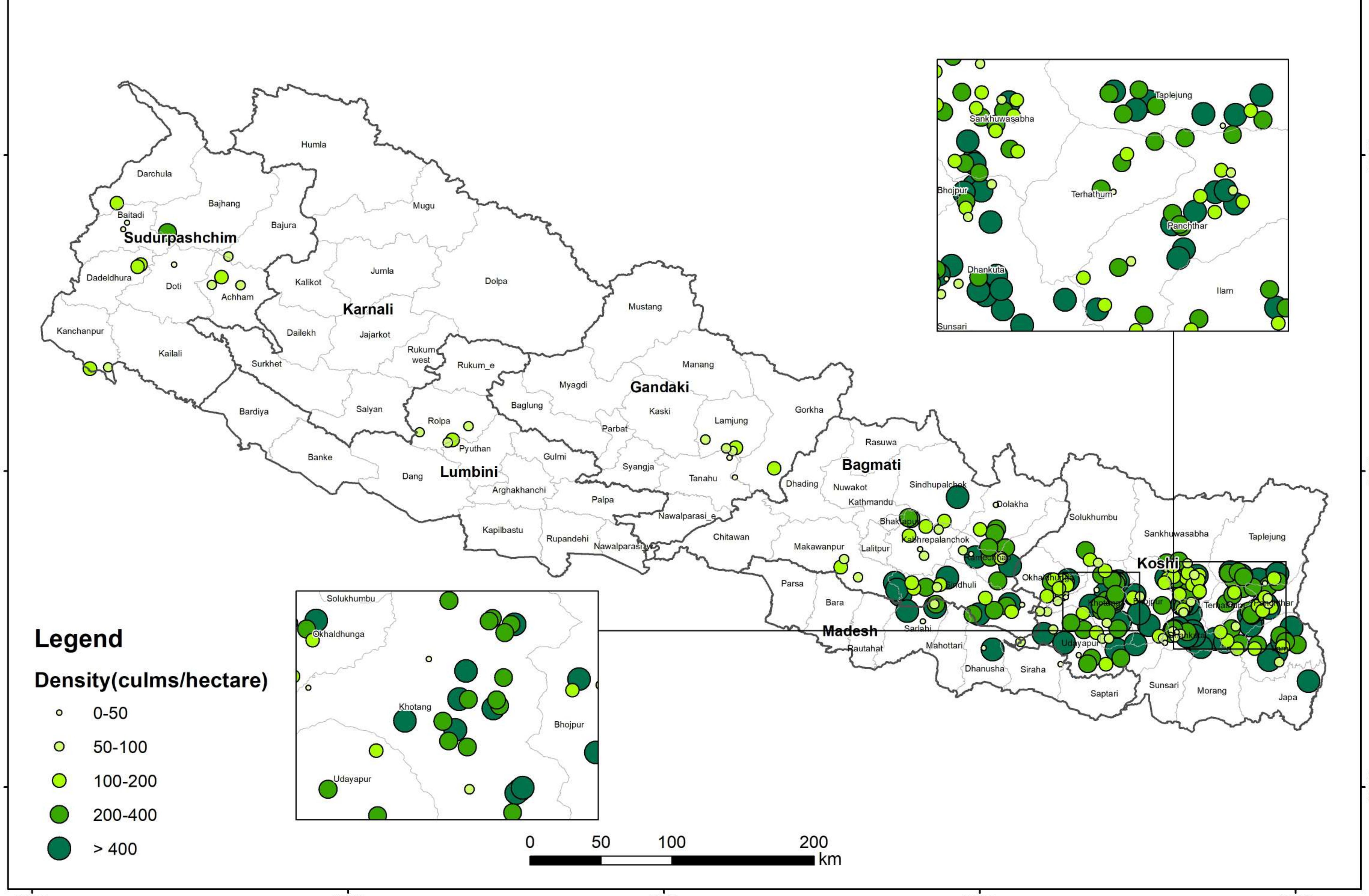


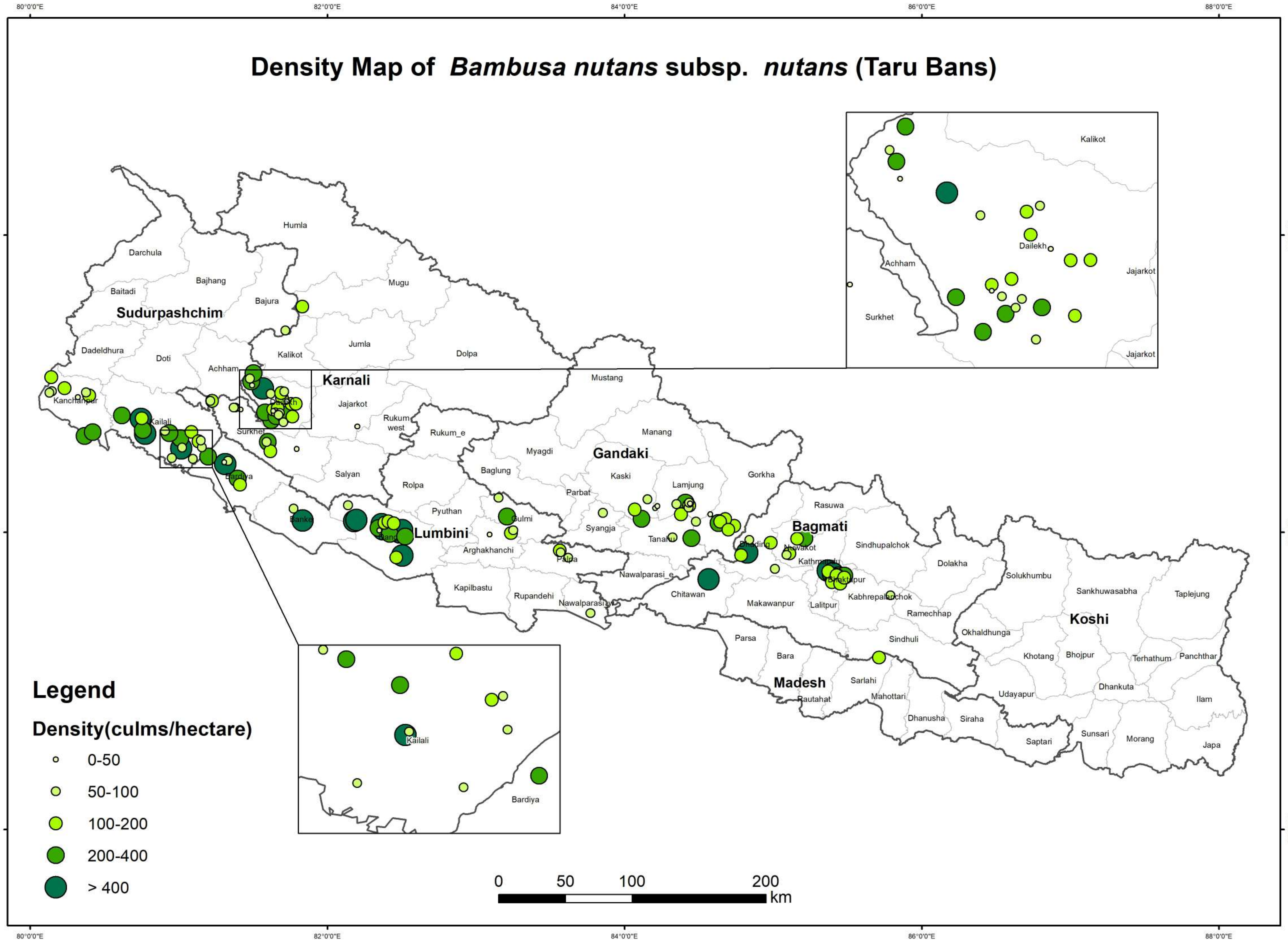


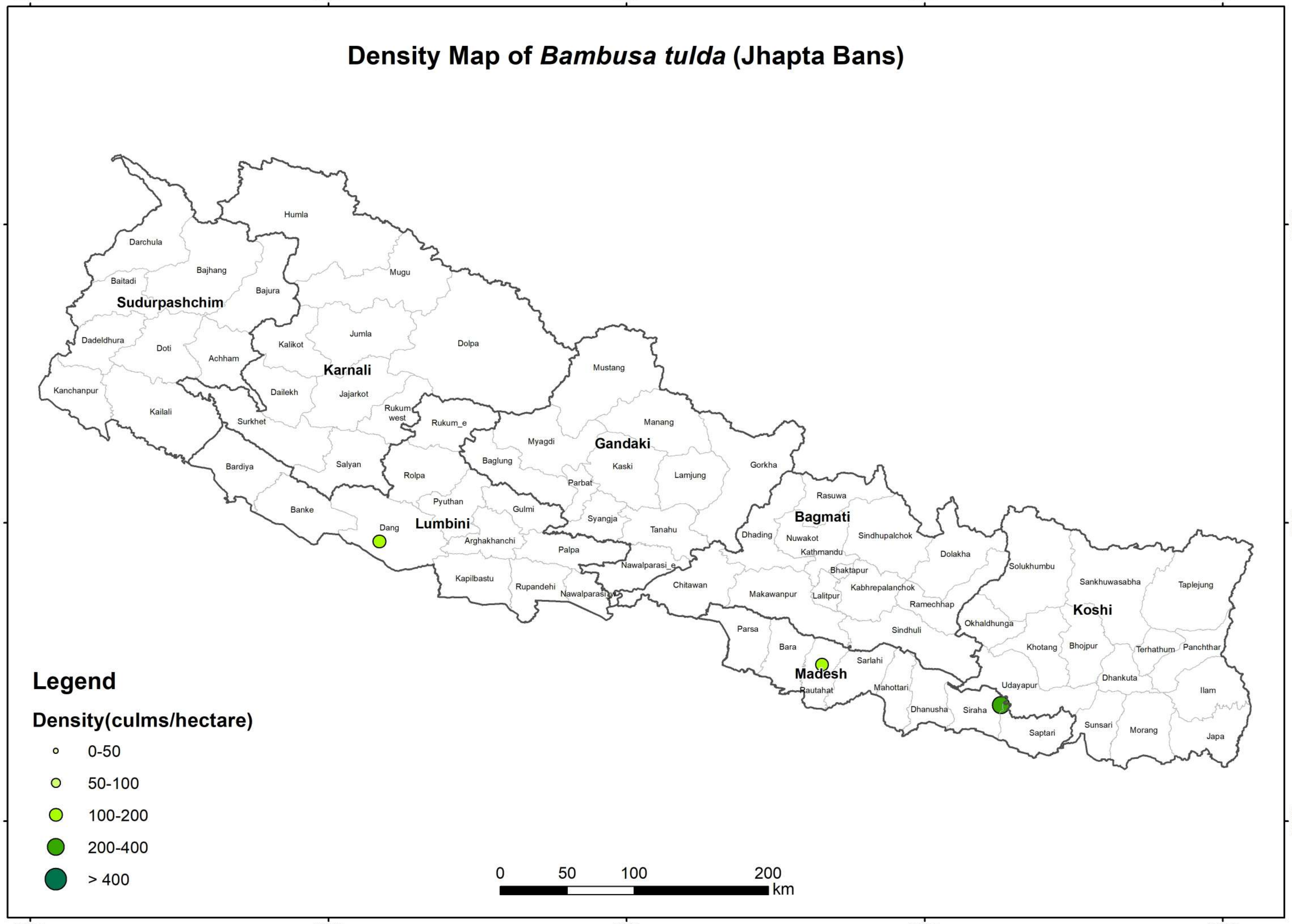
Density Map of *Bambusa balcooa* (Dhanu Bans)
80°0'0"E
82°0'0"E
84°0'0"E
86°0'0"E
88°0'0"E
30°0'0"N
28°0'0"N
26°0'0"N
Sudurpashchim
Karnali
Gandaki
Lumbini
Bagmati
Madesh
Koshi
Humla
Darchula
Bajhang
Baitadi
Bajura
Mugu
Dadeldhura
Doti
Achham
Kalikot
Jumla
Dolpa
Kanchanpur
Kailali
Dailekh
Jajarkot
Surkhet
Rukum west
Rukum_e
Mustang
Manang
Myagdi
Kaski
Lamjung
Gorkha
Bardiya
Salyan
Baglung
Rolpa
Parbat
Banke
Pyuthan
Gulmi
Syangja
Tanahu
Dhading
Nuwakot
Rasuwa
Sindhupalchok
Dang
Arghakhanchi
Palpa
Kathmandu
Dolakha
Bhaktapur
Nawalparasi_e
Kapilbastu
Rupandehi
Nawalparasi_w
Chitawan
Makawanpur
Lalitpur
Kabhrepalanchok
Solukhumbu
Sankhuwasabha
Taplejung
Ramechhap
Okhaldhunga
Sindhuli
Parsa
Bara
Sarlahi
Rautahat
Mahottari
Dhanusha
Siraha
Khotang
Bhojpur
Terhathum
Panchthar
Udayapur
Dhankuta
Ilam
Saptari
Sunsari
Morang
Japa
Legend
Density(culms/hectare)
0-50
50-100
100-200
200-400
> 400
0 50 100 200 km


Density Map of *Bambusa nepalensis* (Khasre Bans)
80°0'0"E
82°0'0"E
84°0'0"E
86°0'0"E
88°0'0"E
30°0'0"N
28°0'0"N
26°0'0"N
Sudurpashchim
Karnali
Gandaki
Lumbini
Bagmati
Madesh
Koshi
Darchula
Baitadi
Bajhang
Bajura
Humla
Mugu
Dadeldhura
Doti
Achham
Kalikot
Jumla
Dolpa
Mustang
Kanchanpur
Kailali
Surkhet
Dailekh
Jajarkot
Rukum west
Rukum_e
Manang
Myagdi
Bardiya
Salyan
Baglung
Kaski
Lamjung
Gorkha
Rolpa
Parbat
Banke
Pyuthan
Gulmi
Syangja
Tanahu
Dang
Arghakhanchi
Palpa
Nawalparasi_e
Kapilbastu
Rupandehi
Nawalparasi_w
Chitawan
Rasuwa
Dhading
Nuwakot
Sindhupalchok
Kathmandu
Bhaktapur
Lalitpur
Kabhrepalanchok
Dolakha
Ramechhap
Makawanpur
Parsa
Bara
Sarlahi
Sindhuli
Rautahat
Mahottari
Dhanusha
Siraha
Saptari
Solukhumbu
Okhaldhunga
Khotang
Udayapur
Sankhuwasabha
Bhojpur
Tehrathum
Taplejung
Panchthar
Dhankuta
Ilam
Sunsari
Morang
Japa
Legend
Density(culms/hectare)
0-50
50-100
100-200
200-400
> 400
0
50
100
200
km

Density Map of *Bambusa nutans* subsp. *cupulata* (Mal Bans)

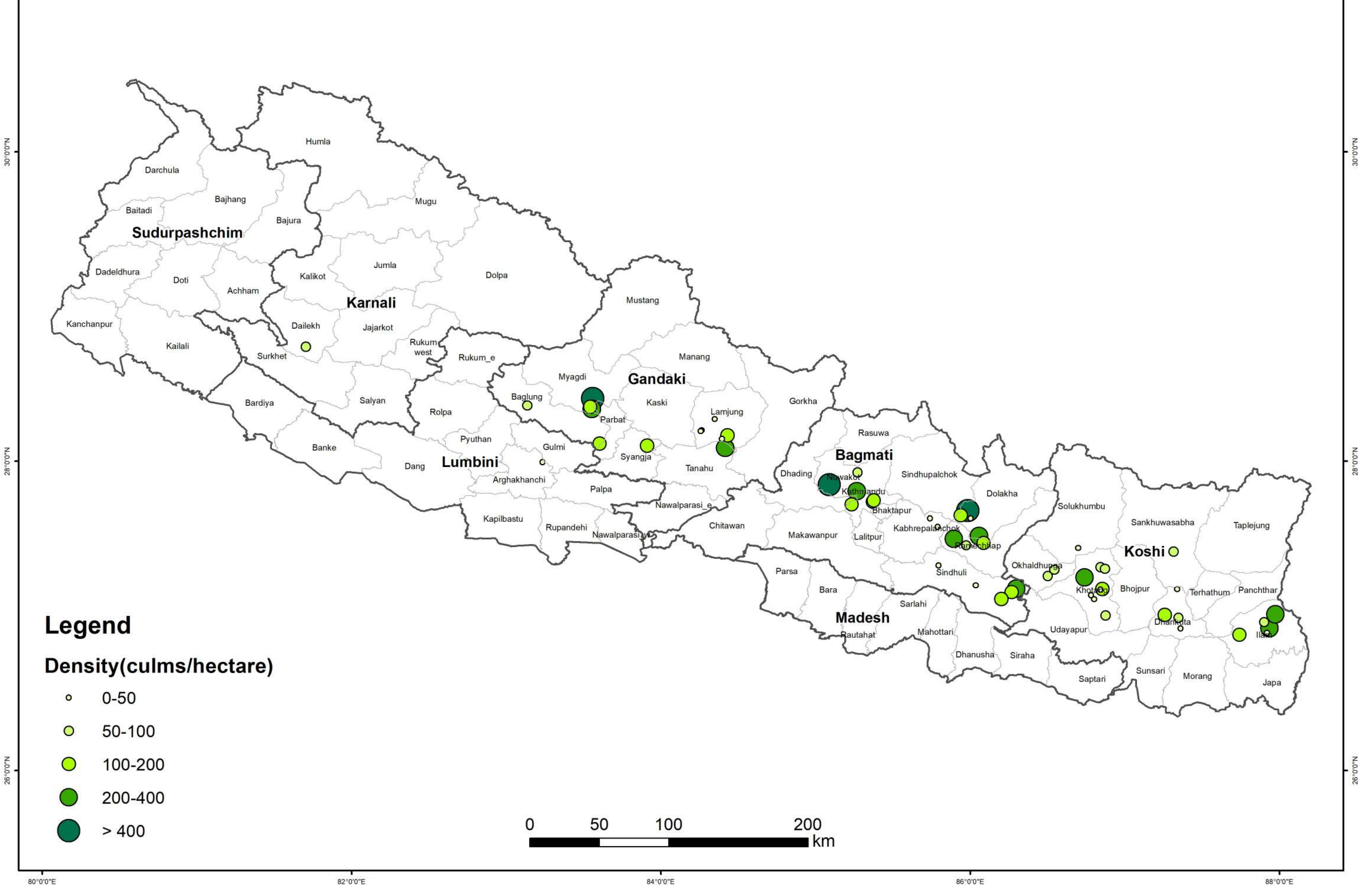


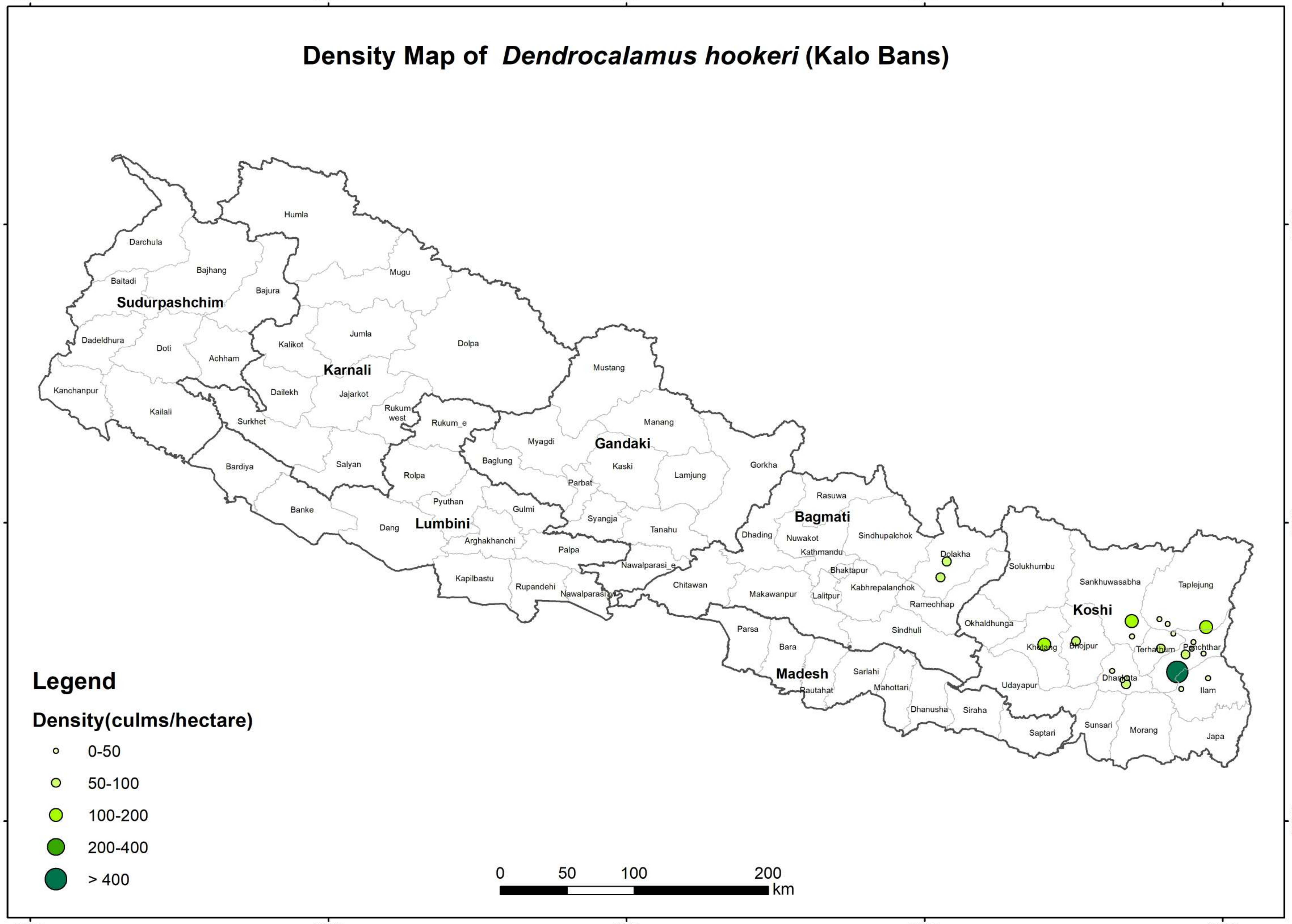

Density Map of Bambusa nutans subsp. nutans (Taru Bans)
80°0'0"E
82°0'0"E
84°0'0"E
86°0'0"E
88°0'0"E
30°0'0"N
28°0'0"N
26°0'0"N
Sudurpashchim
Karnali
Gandaki
Lumbini
Bagmati
Madesh
Koshi
Darchula
Baitadi
Bajhang
Bajura
Humla
Mugu
Dadeldhura
Doti
Achham
Kalikot
Jumla
Dolpa
Kanchanpur
Kailali
Surkhet
Dailekh
Jajarkot
Rukum west
Rukum_e
Bardiya
Salyan
Rolpa
Banke
Pyuthan
Dang
Gulmi
Arghakhanchi
Kapilbastu
Rupandehi
Palpa
Nawalparasi_w
Nawalparasi_e
Baglung
Myagdi
Parbat
Syangja
Kaski
Mustang
Manang
Lamjung
Tanahu
Gorkha
Chitawan
Dhading
Nuwakot
Rasuwa
Sindhupalchok
Kathmandu
Bhaktapur
Lalitpur
Kabhrepalanchok
Makawanpur
Dolakha
Ramechhap
Sindhuli
Parsa
Bara
Rautahat
Sarlahi
Mahottari
Dhanusha
Siraha
Saptari
Solukhumbu
Okhaldhunga
Khotang
Udayapur
Sankhuwasabha
Bhojpur
Dhankuta
Sunsari
Morang
Taplejung
Terhathum
Panchthar
Ilam
Japa
Legend
Density(culms/hectare)
0-50
50-100
100-200
200-400
> 400
0 50 100 200
km



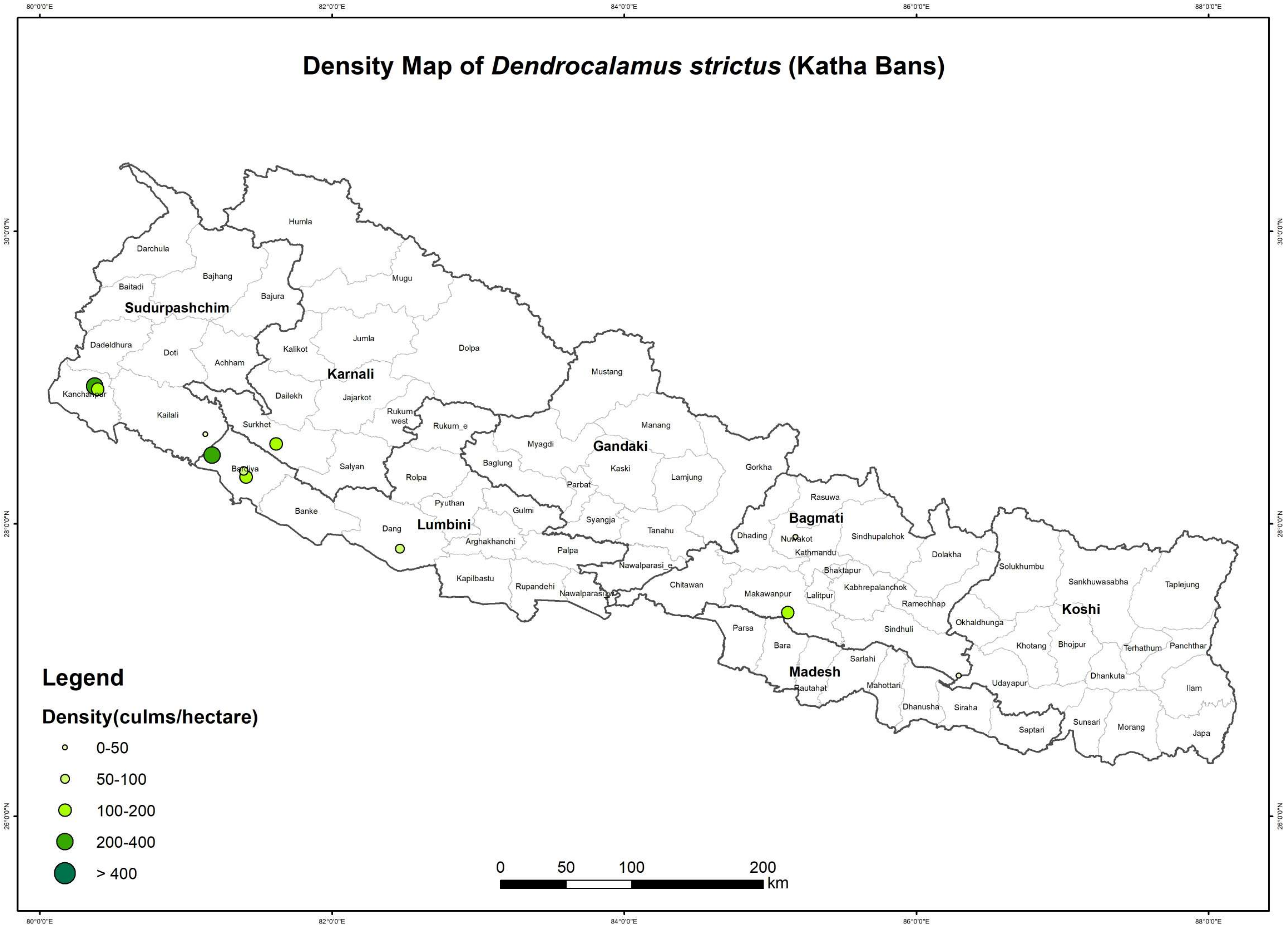
Density Map of *Bambusa tulda* (Jhapta Bans)
80°0'0"E
82°0'0"E
84°0'0"E
86°0'0"E
88°0'0"E
30°0'0"N
28°0'0"N
26°0'0"N
Sudurpashchim
Karnali
Lumbini
Gandaki
Bagmati
Madesh
Koshi
Darchula
Bajhang
Baitadi
Bajura
Humla
Mugu
Dadeldhura
Doti
Achham
Kalikot
Jumla
Dolpa
Kanchanpur
Kailali
Dailekh
Jajarkot
Rukum west
Surkhet
Rukum_e
Mustang
Manang
Myagdi
Bardiya
Salyan
Rolpa
Baglung
Kaski
Lamjung
Gorkha
Parbat
Banke
Pyuthan
Gulmi
Syangja
Tanahu
Rasuwa
Dang
Arghakhanchi
Palpa
Dhading
Nuwakot
Sindhupalchok
Kathmandu
Dolakha
Nawalparasi_e
Bhaktapur
Kapilbastu
Rupandehi
Nawalparasi_w
Chitawan
Makawanpur
Lalitpur
Kabhrepalanchok
Ramechhap
Solukhumbu
Sankhuwasabha
Taplejung
Okhaldhunga
Sindhuli
Parsa
Bara
Sarlahi
Khotang
Bhojpur
Terhathum
Panchthar
Rautahat
Mahottari
Udayapur
Dhankuta
Ilam
Dhanusha
Siraha
Saptari
Sunsari
Morang
Japa
Legend
Density(culms/hectare)
0-50
50-100
100-200
200-400
> 400
0
50
100
200
km

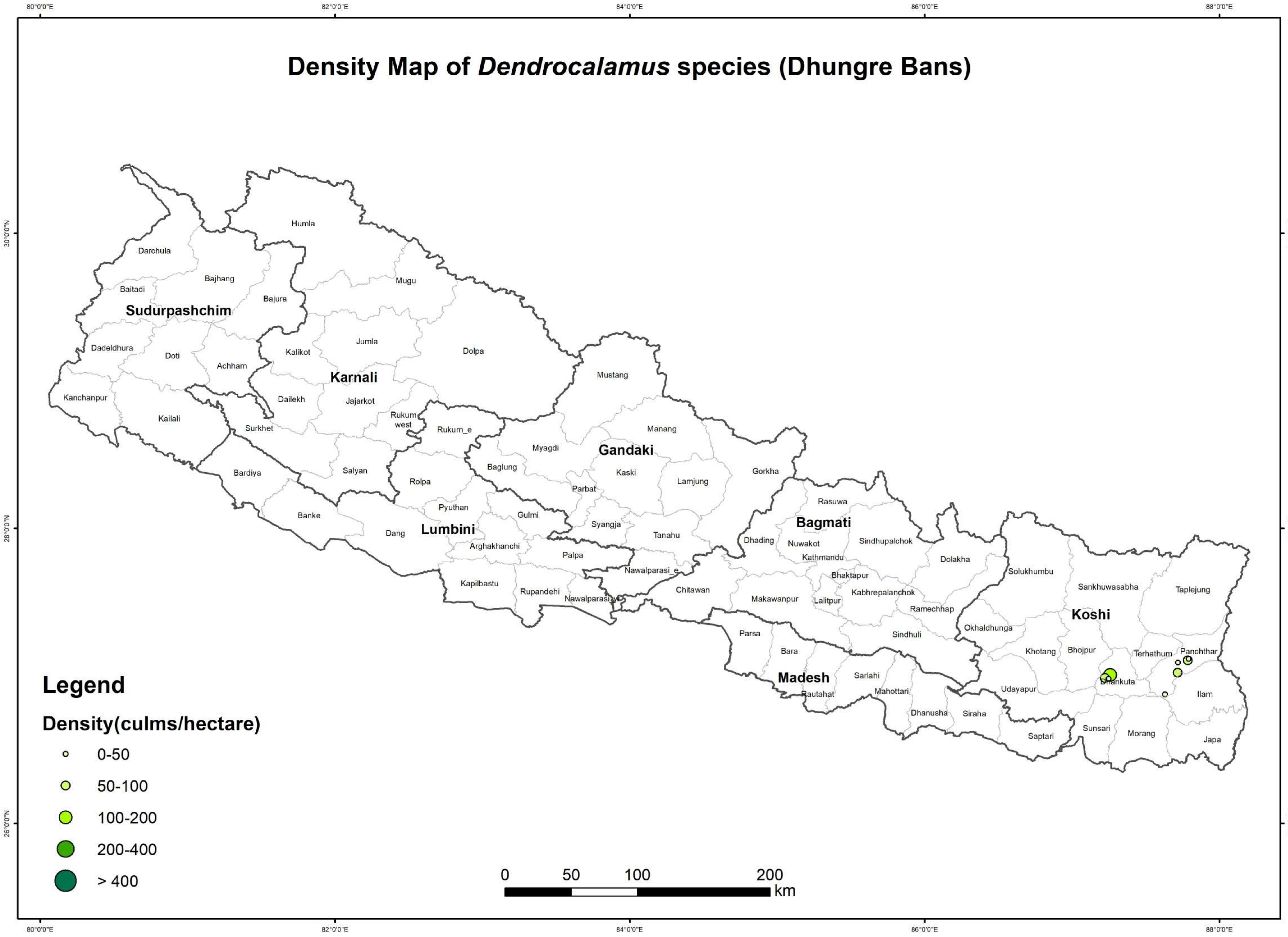
Density Map of *Dendrocalamus hamiltonii* (Tama Bans)



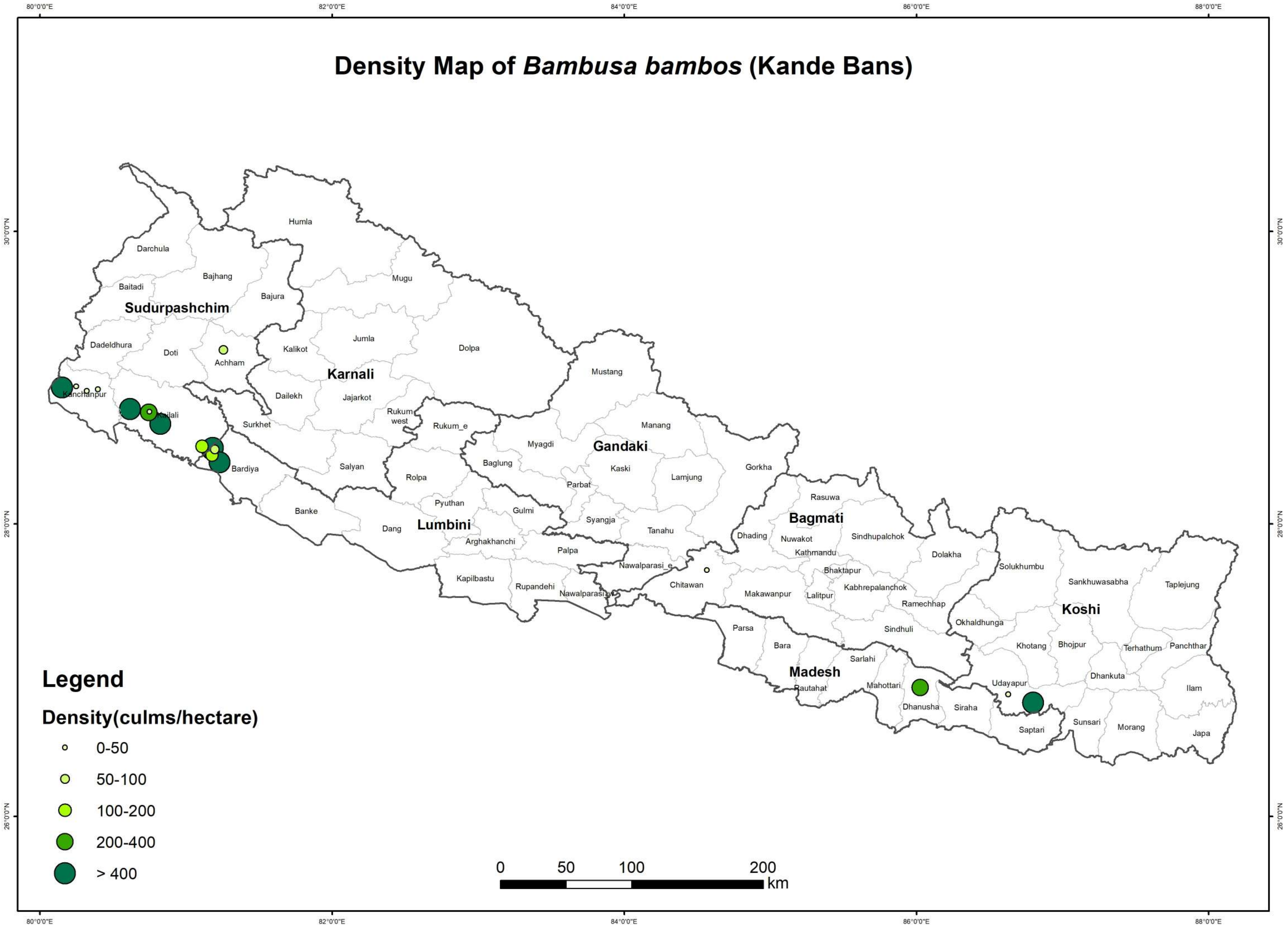

Density Map of *Dendrocalamus hookeri* (Kalo Bans)
80°0'0"E
82°0'0"E
84°0'0"E
86°0'0"E
88°0'0"E
30°0'0"N
28°0'0"N
26°0'0"N
Sudurpashchim
Karnali
Gandaki
Lumbini
Bagmati
Madesh
Koshi
Humla
Darchula
Bajhang
Baitadi
Mugu
Bajura
Dadeldhura
Doti
Achham
Kalikot
Jumla
Dolpa
Kanchanpur
Kailali
Dailekh
Jajarkot
Mustang
Rukum west
Surkhet
Rukum_e
Manang
Myagdi
Baglung
Kaski
Lamjung
Gorkha
Bardiya
Salyan
Rolpa
Parbat
Banke
Pyuthan
Gulmi
Syangja
Tanahu
Rasuwa
Dang
Arghakhanchi
Palpa
Dhading
Nuwakot
Sindhupalchok
Kathmandu
Dolakha
Nawalparasi_e
Kapilbastu
Rupandehi
Nawalparasi_w
Chitawan
Bhaktapur
Makawanpur
Lalitpur
Kabhrepalanchok
Ramechhap
Solukhumbu
Sankhuwasabha
Taplejung
Okhaldhunga
Sindhuli
Parsa
Bara
Sarlahi
Rautahat
Mahottari
Dhanusha
Siraha
Khotang
Bhojpur
Terhathum
Panchthar
Udayapur
Dhankuta
Ilam
Saptari
Sunsari
Morang
Japa
Legend
Density(culms/hectare)
0-50
50-100
100-200
200-400
> 400
0
50
100
200
km

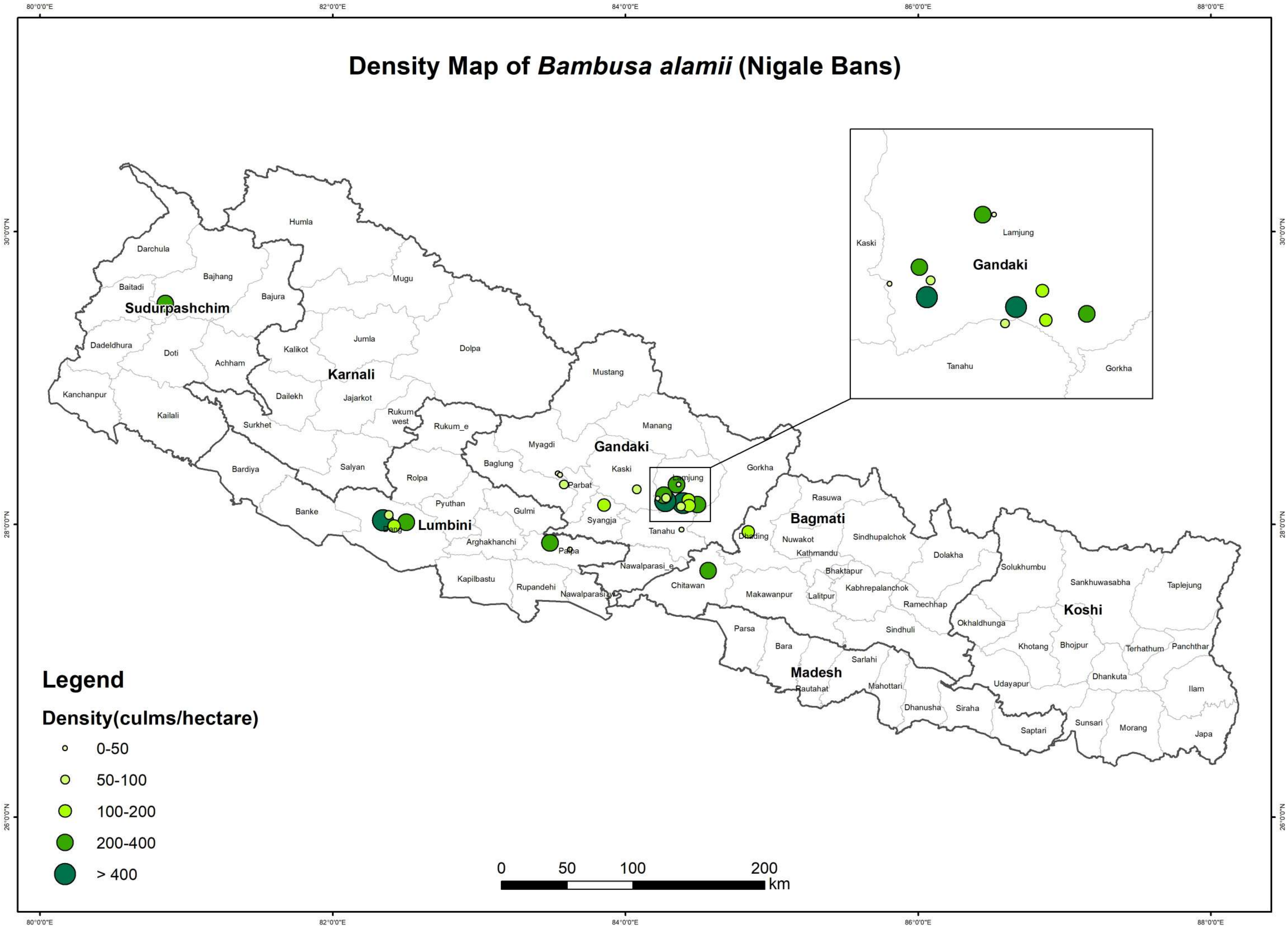
Density Map of *Dendrocalamus strictus* (Katha Bans)





Density Map of Dendrocalamus species (Dhungre Bans)
80°0'0"E
82°0'0"E
84°0'0"E
86°0'0"E
88°0'0"E
30°0'0"N
28°0'0"N
26°0'0"N
Sudurpashchim
Karnali
Lumbini
Gandaki
Bagmati
Madesh
Koshi
Darchula
Baitadi
Bajhang
Bajura
Humla
Mugu
Dadeldhura
Doti
Achham
Kalikot
Jumla
Dolpa
Kanchanpur
Kailali
Dailekh
Jajarkot
Surkhet
Rukum west
Rukum_e
Mustang
Manang
Myagdi
Baglung
Kaski
Lamjung
Gorkha
Bardiya
Salyan
Rolpa
Parbat
Banke
Pyuthan
Gulmi
Syangja
Tanahu
Rasuwa
Dang
Arghakhanchi
Palpa
Nawalparasi_e
Dhading
Nuwakot
Sindhupalchok
Kathmandu
Dolakha
Bhaktapur
Kapilbastu
Rupandehi
Nawalparasi_w
Chitawan
Makawanpur
Lalitpur
Kabhrepalanchok
Ramechhap
Solukhumbu
Sankhuwasabha
Taplejung
Okhaldhunga
Parsa
Bara
Sindhuli
Khotang
Bhojpur
Terhathum
Panchthar
Sarlahi
Rautahat
Mahottari
Dhanusha
Siraha
Udayapur
Dhankuta
Ilam
Saptari
Sunsari
Morang
Japa
Legend
Density(culms/hectare)
0-50
50-100
100-200
200-400
> 400
0
50
100
200
km


Density Map of *Bambusa bambos* (Kande Bans)
80°0'0"E
82°0'0"E
84°0'0"E
86°0'0"E
88°0'0"E
30°0'0"N
28°0'0"N
26°0'0"N
Sudurpashchim
Karnali
Gandaki
Lumbini
Bagmati
Madesh
Koshi
Darchula
Baitadi
Bajhang
Bajura
Humla
Mugu
Dadeldhura
Doti
Achham
Kalikot
Jumla
Dolpa
Kanchanpur
Kailali
Dailekh
Jajarkot
Rukum west
Rukum_e
Surkhet
Bardiya
Salyan
Rolpa
Banke
Dang
Pyuthan
Gulmi
Arghakhanchi
Palpa
Kapilbastu
Rupandehi
Nawalparasi_w
Mustang
Manang
Myagdi
Baglung
Kaski
Lamjung
Gorkha
Parbat
Syangja
Tanahu
Nawalparasi_e
Chitawan
Rasuwa
Dhading
Nuwakot
Sindhupalchok
Kathmandu
Bhaktapur
Lalitpur
Kabhrepalanchok
Dolakha
Makawanpur
Ramechhap
Sindhuli
Parsa
Bara
Rautahat
Sarlahi
Mahottari
Dhanusha
Siraha
Solukhumbu
Okhaldhunga
Khotang
Udayapur
Saptari
Sankhuwasabha
Taplejung
Bhojpur
Terhathum
Panchthar
Dhankuta
Ilam
Sunsari
Morang
Japa
Legend
Density(culms/hectare)
0-50
50-100
100-200
200-400
> 400
0
50
100
200
km


Density Map of Bambusa alamii (Nigale Bans)
80°0'0"E
82°0'0"E
84°0'0"E
86°0'0"E
88°0'0"E
30°0'0"N
28°0'0"N
26°0'0"N
Sudurpashchim
Karnali
Gandaki
Lumbini
Bagmati
Madesh
Koshi
Darchula
Baitadi
Bajhang
Bajura
Humla
Mugu
Dadeldhura
Doti
Achham
Kalikot
Jumla
Dolpa
Kanchanpur
Kailali
Dailekh
Jajarkot
Surkhet
Rukum west
Rukum_e
Mustang
Manang
Myagdi
Baglung
Bardiya
Salyan
Rolpa
Kaski
Lamjung
Gorkha
Parbat
Banke
Pyuthan
Gulmi
Syangja
Tanahu
Dang
Arghakhanchi
Palpa
Dhading
Nuwakot
Rasuwa
Sindhupalchok
Kathmandu
Dolakha
Nawalparasi_e
Chitawan
Kapilbastu
Rupandehi
Nawalparasi_w
Bhaktapur
Lalitpur
Kabhrepalanchok
Makawanpur
Ramechhap
Solukhumbu
Sankhuwasabha
Taplejung
Okhaldhunga
Parsa
Bara
Sindhuli
Khotang
Bhojpur
Terhathum
Panchthar
Sarlahi
Rautahat
Mahottari
Dhanusha
Siraha
Udayapur
Dhankuta
Ilam
Saptari
Sunsari
Morang
Japa
Legend
Density(culms/hectare)
0-50
50-100
100-200
200-400
> 400
0
50
100
200
km