"Restoration of Himalayan old growth oak forest through science-society interaction".

Phase II Report (September, 2018 to October, 2019).

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1.0 Overall Project Objective:

- Valuation of old growth oak forests for conservation and restoration activities.
- Old growth oak forest understood for long term restoration and sustainable forest management.
- Extend of old growth oak forest distribution mapped and threats docume nted.
- Training and capacity building for local communities through hands on training, meeting and consultation workshop.
- Local income generated through strong engagement in project implementations.

2.0 Summary of 2nd Phase project activity

During the second phase of the project, activities amounting to US$ 30,000 has been implemented starting from October 2018 to September 2019 (as scheduled in project document). In the First phase of the project, we largely focused on the preparatory activities which is crucial for successful implementation of the remaining core project activities. Second phase of the project emphasized on estimating nationwide distribution of brown oak (*Quercus semecarpifolia*) and understanding the physiography/climatic conditions under which the species thrives. As oak forest plays a pivotal role in providing ecosystem services and mitigating climate change, it is imperative to know the extent and status of oak forest across Bhutan's landscape. Another important activity during the second phase of the project was to conduct rapid biodiversity assessment in the old growth oak forest to understand the biodiversity richness of oak forest and to monitor the sustainability of ecosystem services arising from such forests. Ideally conventional forest inventory would have yielded better result in estimating the distribution of oak across the country but using predictive tools such as species distribution model (SDM) provides a cheap alternative. Such tools are necessary for country like Bhutan which has difficult terrain to negotiate and has limited resources for carrying out expensive conventional inventory. In addition, such tool can enable forest managers and policy decision makers in reconstructing past species distribution, assess current status and predict futures changes in the distribution resulting from changes in climatic conditions. Such knowledge can prepare forest managers in taking preemptive action ranging from relocation of a species under threat from climate change or reintroduction of species in new suitable ranges.

For modeling the distribution of the Oak forest in Bhutan, MaxEnt software was used with bioclimatic data as predictive input variables. From the select variables, altitude, annual mean temperature and the precipitation during the driest quarter of the year had the highest influence on the distribution of *Quercus semecarpifolia*. The model predicts that under future climate with more warming, oak species could shift northwards or vertically upwards along the mountain slope as the lowlands get much warmer and unsuitable for the species to survive. It is likely that under such circumstances, oak could lead mass exodus of associated species to new suitable ranges.

Besides, it is also essential to understand assemblage of species associated with oak forest as it can directly influence the establishment and regeneration as interaction

amongst species forms the basis of forest processes such as nutrient cycling and food webs. Biodiversity information in oak forest is also crucial for scientific management of the such forest type and ensure that the flow of ecosystem services is not disrupted. Biodiversity survey generated information on the structure, composition, regeneration and disturbances such as grazing by wild ungulates and domestic cattle. However, during the current biodiversity survey, the focus was mainly on assessing the floral diversity. Altogether, 59 tree species, 33 species of shrubs and 125 species of herbs were recorded in oak forest creating a rich habitat for other faunal species to survive. Grazing by domestic cattle effects successful regeneration in the oak forest as the seedlings are browsed and trampled by herds which are led loose in the forest. Successful establishment of recruits in oak forest is critical for maintaining the dominance of the species or otherwise such forest could be gradually replaced by aggressive pioneer species like blue pine. Through the project, several plantation trials were carried out to test the efficacy of the different seedling shelters. large scale fencing of plantation in forest area is a cheaper option rather than individual seedling protection but such fencing restricts the access to grazing grounds which were traditionally used by the locals. As oak forests are extensively used by the locals mainly as fuel and fodder, it is essential for the community to actively participate in conservation and sustainable management of oak forest in their vicinity. For that reason, awareness program was conducted for Guensa community, khotokha primary school under Wangdiphodrang district and nuns of Hongtsho nunnery under Thimphu district. Through such programs, we expect to highlight the importance of role of communities and individuals in sustainable management and restoration of degraded oak forest. In short, following specific activities were carried out in the second phase of the project:

- Climate in Old growth Oak Forest Restoration Area at Shalley and Chamgang Stations.
- Nationwide mapping of old growth Oak (Quercussemecarpifolia) forest
- Biodiversity assessment in the old growth oak forest dominated by Quercus semecarpifolia.
- Training on plantation techniques and awareness program on the importance of old growth oak forest (Gensa communities, Hongtsho nunnery, Tshaluna Pry. School &Khotokha Pry school).
- Community based Plantation and Installation of seedling shelters.

3.0 Climate in Old growth Oak Forest Restoration Area at Shalley and Chamgang Stations:

Temperature and rainfall plays an important role in determining the existence of particular species in a locality besides other factors such as soil type, aspect and elevation. Himalayan region in particular is sensitive to climate change which can impact vegetation shifts in the future. In addition, warming climate can also impair the flow of ecosystem services resulting from change in phenophase and drought conditions. Climate change can also trigger large scale pest and diseases outbreak which could wipe out entire species. Therefore, it is important to know the climatic requirement of oak forest in determining the future management interventions to retain the ecosystem functionality of such important forest types. Thus, as a part of the project,

to document climatic requirement for the old growth oak forest, two climate stations were set up at Shallay and Chamgang. The climate station recorded three weather parameter: Rainfall, Temperature and relativity humidity.

3.1 Climate recording:

Both the stations are class “C” and equipped with RG3M rain gauge, HOBO Pro V2: thermal temperature, relative humidity and the loggers were housed in the solar radiation shield.

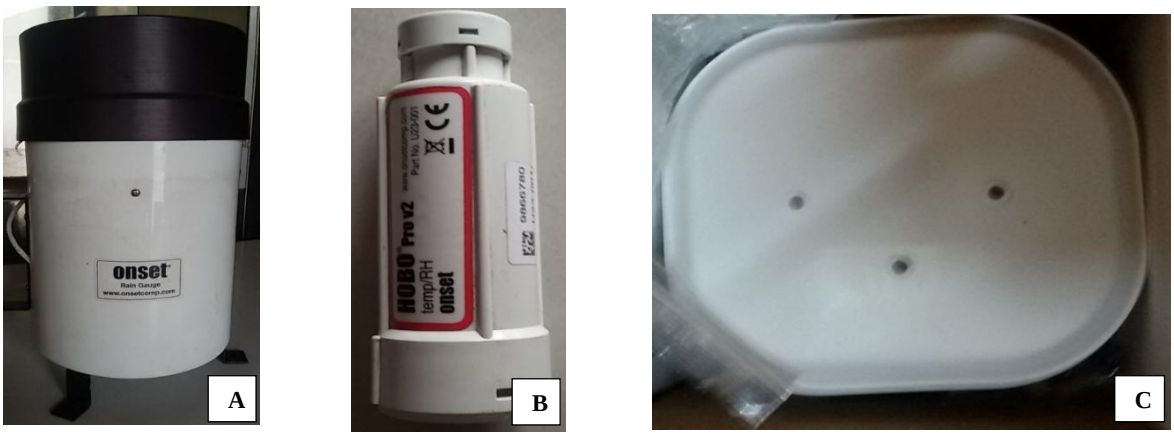


Figure 1.0 Climate instruments: A: RG3M rain gauge; B: HOBO pro v2; C: Solar radiation shield

Two climate stations were set up in study area of the old growth oak forest at Chamgang in Thimphu district at an altitude of 2825 masl (E $89^0$42’ 36.96”, N $27^0$24’ 57.22”), Shalley in Wangdue district at an altitude of 2547 masl (E $89^0$58’ 41.81”,N $27^0$23’ 18.19”).

Figure 2.0 Climate station at Shalley Khotokha Valley.

Figure 3.0 Climate station established at ChamgangHelela Valley

3.2 Climate conditions at study site:

The data logging for the thermal temperature and relative humidity were set at an hour interval and tipping bucket RG3M at the event based. The monitoring and data gathering from the station was conducted quarterly. Following figures represent the climatic conditions (Temperature and rainfall) at the site from June 2018 till August 2019.

3.3 Thermal Temperatures:

Mean temperature at chamgang for the period of June to December 2018 was 10.6^{o}C and Mean temperature from Jan till August 2019 was recorded at 9.4^{o}C . Mean temperature at Shallay for the period of June to December 2018 was 12.1^{o}C and Mean temperature from Jan till August 2019 was recorded at 10.8^{o}C

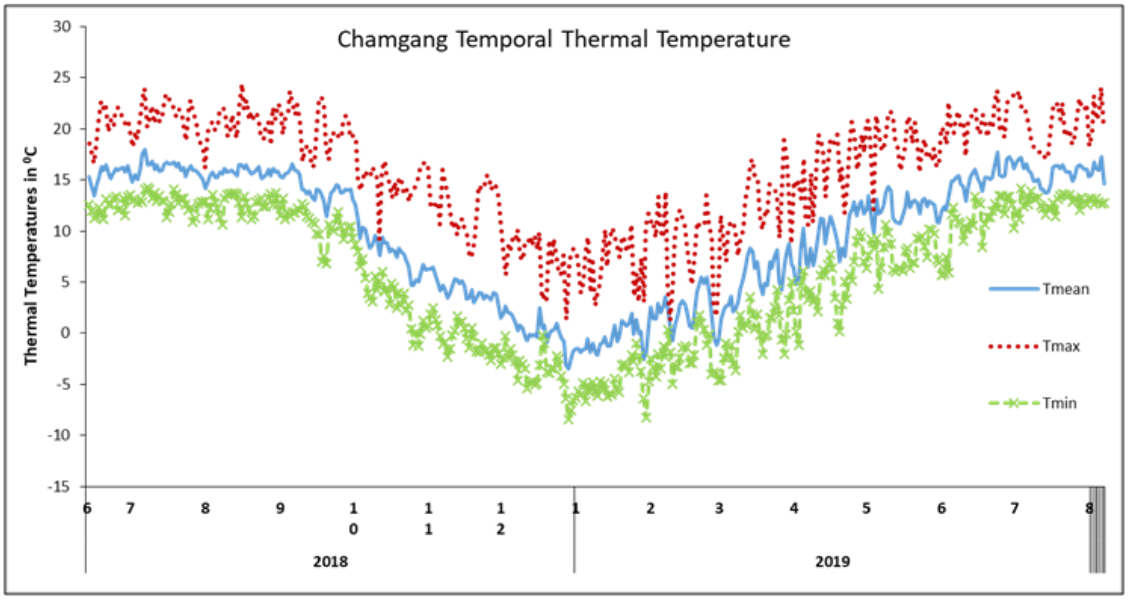


Fig (a)

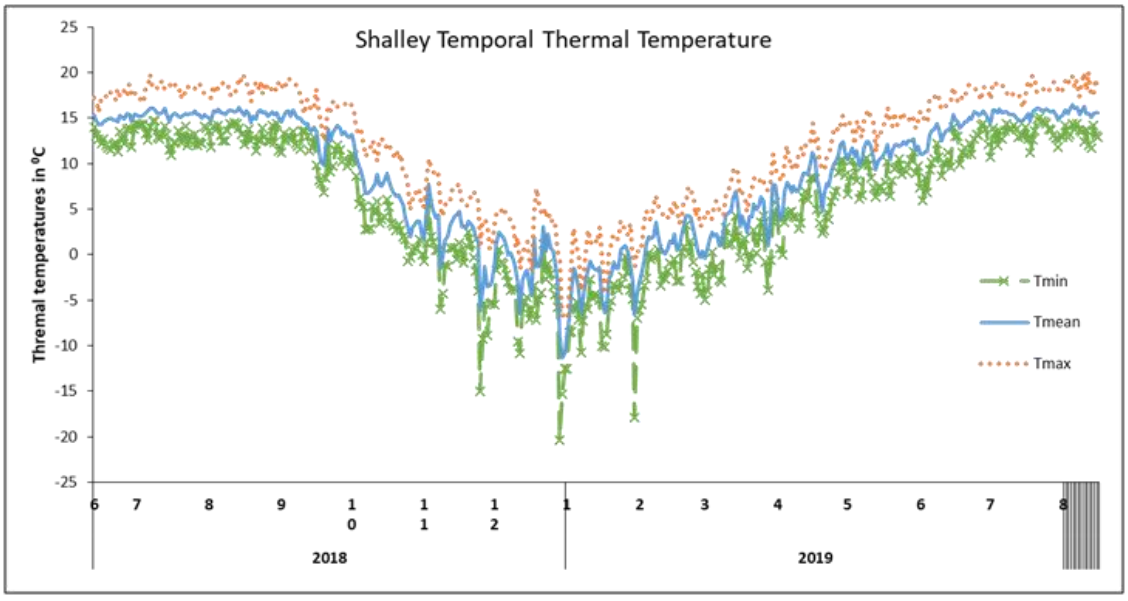


Fig (b)

Figure 4.0 Fig (a) , Chamgang 2825 masl Fig(b), Shellay 2547 masl

3.4 Rainfall:

The total rainfall recorded at chamgang was 651.8 mm for the period of June, 2018 until December, 2018 and 549.8mm for the period from January to August, 2019. At Shalley during the same period in 2018, the study site received 679.6 mm and for the period from January to August in 2019 received 674.2 mm of rainfall (Figure 5.0).

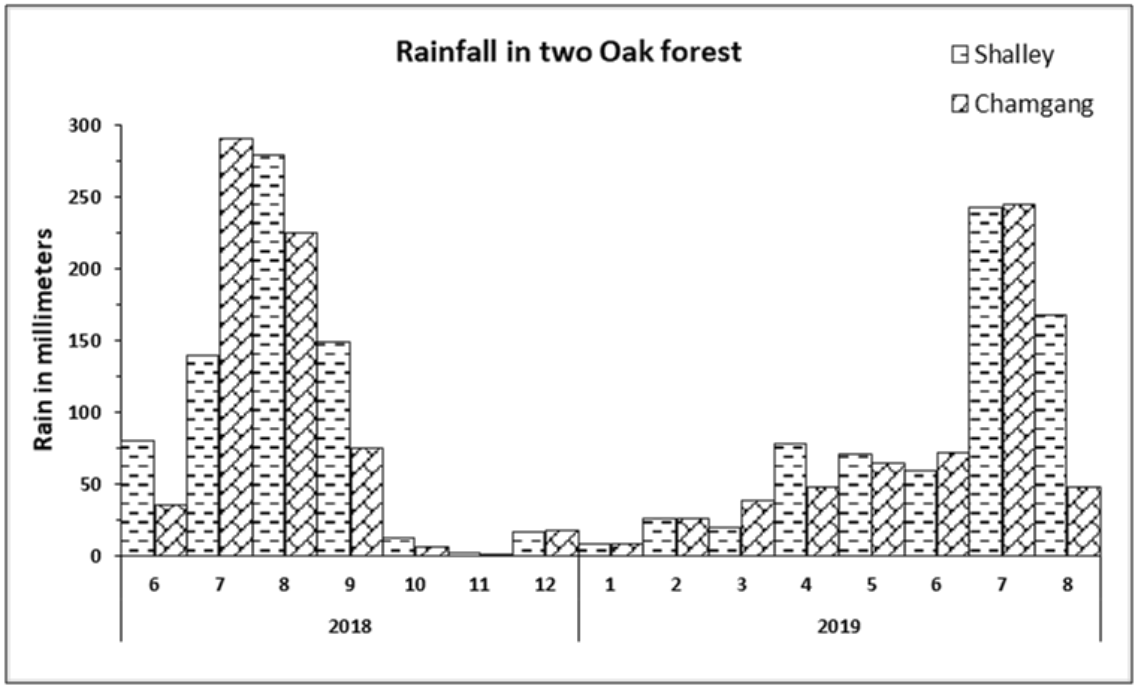


Figure 5.0 Rain record from June 2018 to August 2019

The data logging from the stations is for period of over one year and therefore describing the climatic parameters for oak forest will not be possible. Long term data recording at the study site will be necessary to characterize the climate conditions conducive for the oak forest type and determining the trend of climate condition which might influence processes in the oak forest.

4.0 Nationwide mapping of old growth Oak (*Quercus semecarpifolia*) forest.

Bhutan has a record of eleven oak species and it is considered as a commercially important fuelwood species that grows in a wide range of habitat. Amongst the oak species, brown oak (*Quercus semecarpifolia*) form an integral part of ecosystem services as well as the livelihood of the people. They are also strongly associated with the socio-cultural values of local communities (Dorji et al., 2019). The species is mostly distributed along the cool temperate zone between 2400 and 3000 m elevation.

In the recent past, human intervention in these forests has increased substantially resulting in rapid deterioration of these forests in the entire Himalayan range. For instance, in early 2000s, the demand for firewood by urban centers, domestic and institutional use has escalated the overcutting of mature oak trees in Bhutan (Moktan, 2014) . On the other hand, free-grazing cattle has posed huge threat to regeneration of the species, hence affecting tree species diversity and change in forest composition

over time (Naudiyal & Schmerbeck, 2017). Climate change is also perceived to affect the seed germination and reproduction adversely, thereby limiting its distribution in many parts of the Himalayas (V.K Bisht & Kuniyal, 2013; V. K. Bisht, Kuniyal, Nautiyal, & Prasad, 2013). Although, the species is highly utilized and widely distributed in the Bhutanese forests in the entire belt (2500 -3500 m) from east to west, no studies were conducted to map the extent of its distribution.

Through this project, the aim was to map the extent of *Q. semecarpifolia* distribution using species distribution model (SDM) and come up with estimate of oak forest coverage in Bhutan.

4.1 Methods

For this study, spatial location of *Q.semecarpifolia* from 12 districts across Bhutan was collected (Table 1). The probability of the presence of species was derived based on elevation (2400-3600 meters) and aspect (north, south). All these districts were connected with one or more category of the road (national, district and farm roads) and have people living adjacent to the oak forests. The primary occupation of the communities living at the study sites are subsistence farming where they depend mostly on local forests for tangible and intangible ecosystem services.

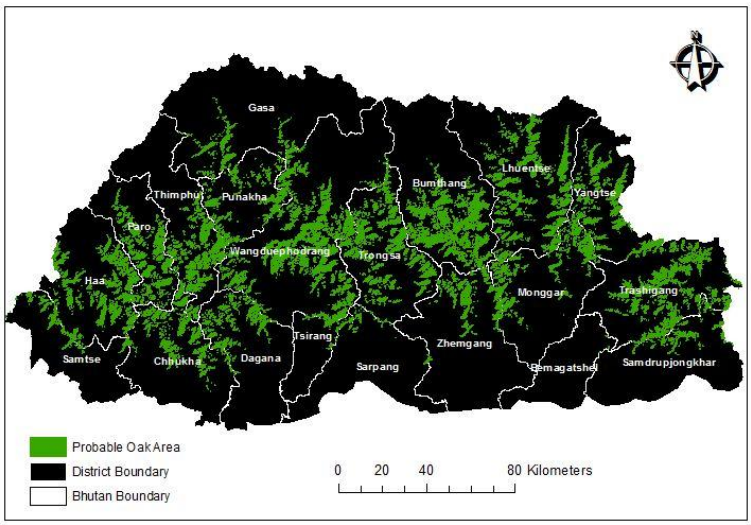


Figure 4.0 Probable brown oak distribution

Prior to the field work, the probable oak area was derived using QGIS (Version 2.18). Three main environmental predictors - forest cover, aspect and elevation were considered in the mapping exercise. The specific benchmark for the prediction includes: area between the elevation range of 2400-3600 meters; cool broadleaved and mix conifer forests; north and south facing locations.

We referred the distribution map derived from three environmental predictors to look for the oak forests in the sampling districts. Field data gathered in consultation with forestry officials and local people on availability of the oak species prior to visiting the place.

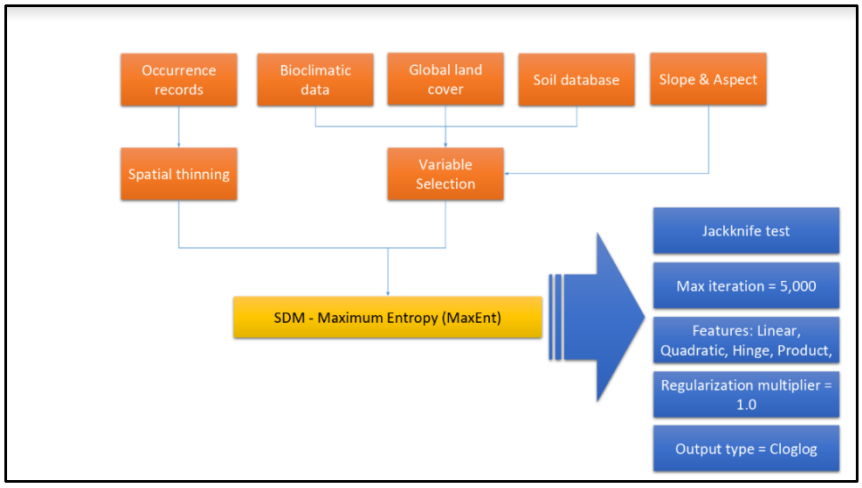


Figure 5.0 Diagrammatic workflow of Maximum Entropy (MaxEnt)

We used maximum entropy methods to model the ecological niche of brown oak species using physiography and climatic conditions as input variables. The Maximum Entropy principle is built in MaxEnt Software v 3.4.1 for quantifying the suitable habitats (Phillips et al., 2017) implemented in Wallace Package in R (JM. Kass et al., 2018). The selection of MaxEnt is based on following reasons. MaxEnt require presence only and background data for modelling ecological niches (i.e. absence data are not required), the performance is robust and relatively better than other modelling algorithms(Elith J et al., 2006) and the model is hardly influenced by small sample sizes and prediction will be relatively robust (Barik et al., 2012, Pearson RG et al., 2007). In this study, we choose all scenario's i.e., RCP2.6 through RCP 8.5 (IPCC, fifth assessment report), to simulate the habitat suitability distribution of the species (Wei *et al*., 2018).

4.2 Preliminary findings

The MaxEnt (Maximum Entropy) predicted brown oak distribution between the elevation ranges of 1500 to 3500 meters. A total area of about 6849.16 km^2 was predicted as brown oak forest in Bhutan out of a total surface area of 38394 km2 (17.83%) and a total forest cover of 26,338 km2 (26%). As per Max Ent model, brown oaks in Bhutan can be found in 17 districts (Bumthang, Chukha, Dagana, Gasa, Haa, Lhuntse, Mongar, Paro, Punakha,Samdrupjongkhar,Thimphu, Trashigang, Trashiyangtse, Trongsa, TsirangWangduePhodrang, and Zhemgang districts). The majority of the species are distributed in Wangdueprodrang (17.59%), Trongsa (13.11%) and Lhuntse (12.73%). The district like Dagana (0.12%), Gasa (0.44%) and Samdrupjonkhar (0.70%) and Chukha (0.71%) has the least area of brown oak forests (Figure).

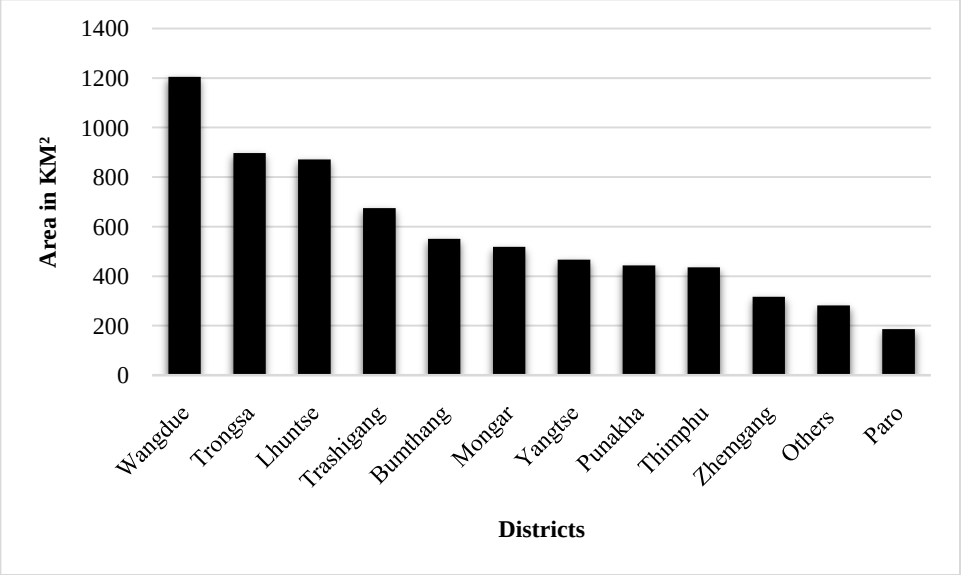


Figure 6.0 As per Max Ent model, brown oaks in Bhutan

4.3 Past, Current and Future Oak Distribution

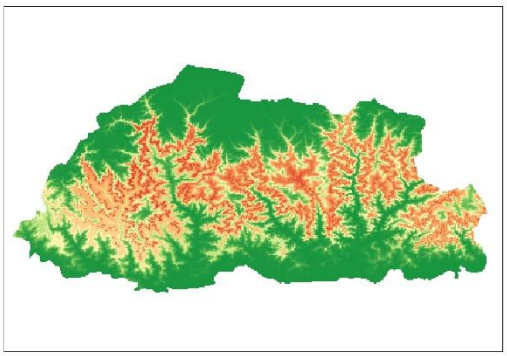
Using occurrence data and suite of environmental variables, we have predicted the distribution of *Quercus semecarpifolia* in the past (Mid- Holocene and Last interglacial), current and future (RCP 2.6, 4.5, 6.0 & 8.5) for 2070. MaxEnt predicted the high, moderate and low suitable areas of brown oak distribution during the Mid-Holocene era were found in Central & southern parts of Haa, Paro, Thimphu, Punakha, Wangduephodrana, Trongsa, Bumthang, Lhuentse, Yagtse and Trashigang. The highly suitable habitats are also found in Northern parts of the Chukha, Dagana, Sarpang, Zhemgang, Monggar and Samdrupjongkhar. During the Last Interglacial (LIG) era the entire areas of Bhutan was either low or not suitable for brown oak habitat.

In the present climatic scenario, the MaxEnt predicted the very high suitable habitats for oak species in northern parts of Paro, Punakha, Dagana, Tsirang, Sarpang, Zhemgang, SamdrupjongkharandTrashigang districts. The highly suitable habitats were found in Central parts of the Haa, Paro, Chhukha, Dagana, Thimphu and Trashigang. The moderately suitable habitat were found in Tsirang, Sarpang, Zhemgang, Pemagatshel, Samdrujongkhar, Trashiyangtse, Lhuentse, Bumthang, Pumakha, Wangduephodrang, Chhuka, Dgana and Samtse. The lower altitudes were found not suitable for the species.

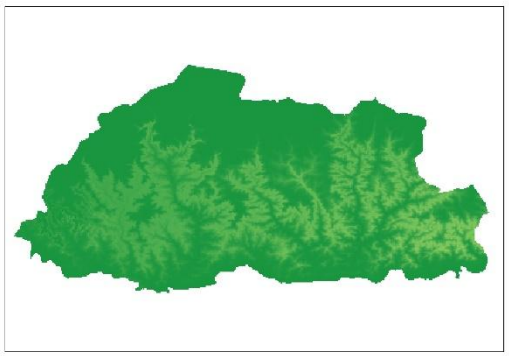
MaxEnt predicted that in case of RCP 2.6 (2070) the highly suitable areas for oak species in future were Punakha, Wangduphodrang, Trongsa, Bumthang, Lhuentse, Yangtse, Dagana, Tsirang, Sarpang, Zhemgang and Samdrupjongkhar. In coming years, due to alteration in weather and climatic condition, northern parts of Lhuentse, Trashiyangtse and Bumthang would become moderately suitable. In case of RCP 4.5 scenario, the highly suitable areas of Punakha, Wangduphodrang, Trongsa, BumthangLhuentse, Yangtse, Dagana, Tsirang, Sarpang, Zhemgang and Samdrupjongkhar may alter due to climate change. However, the moderately suitable areas of Lhuentse, Yangtse, Samdrupjongkhar, Zhemgang, Monggar, Bumthang, Trongsa, Wangduephodrana, Punkha and Dagana would become more suitable.,

In RCP 6.0 scenario, the Very high, high, moderate & low suitable habitats are lost in Punakha, Wangduephodrang, Trongsa, Bumthang, Lhuentse, Yangtse, Monggar, Sarpang, Tsirang, Dagana, ChhukhaThimphu, Samtse and Haa due to climate change.

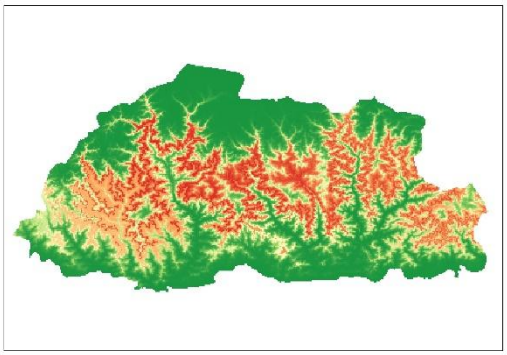
In RCP 8.5, the very high, high, moderate and low suitable areas are lost in all the regions found in present conditions however, the moderately suitable are found towards the northern parts of the Haa, Paro, Thimphu, Punakah, Gasa, Wangduephodrang, Trongsa, Bumthang, Lhuentse and Yangtse. This indicates that the species shift niche towards the Northern parts of the Bhutan whereas, the Central and southern parts of the Bhutan would become unsuitable for the species distribution.



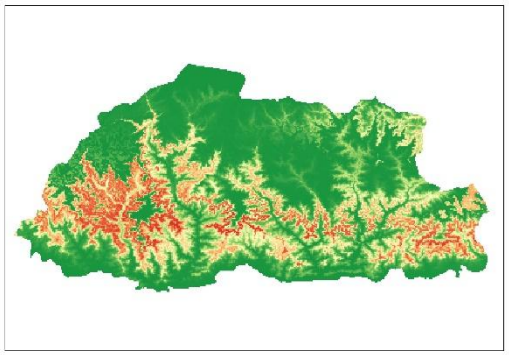
A. Mid-Holocene



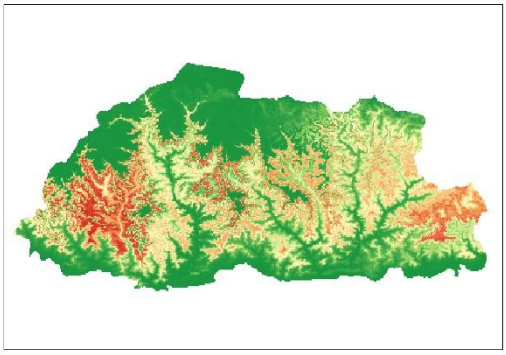
B. Last interglacial



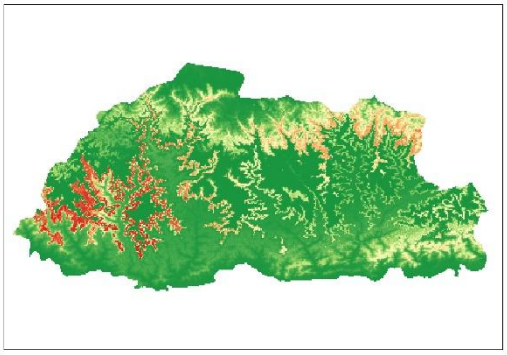
C. Current



D. RCP 2.6 (2070)



E. RCP 4.5 (2070)



F. RCP 6.0 (2070)

5.0 Biodiversity assessment in the old growth oak forest dominated by *Quercus semecarpifolia.*

In the last few decades, human intervention in oak forests have increased tremendously leading to degradation, change in biodiversity and composition. Not much is understood about structural features and biodiversity of the old-growth brown oak forests of Bhutan. Without adequate information, forest management aiming at conserving this important forest type uncertain. It is also difficult to garner support from the partners for the conservation efforts in the absence of these critical information. This study was carried out to assess the forest structure, composition and biodiversity of old-growth oak forests at the national level. The study documents biodiversity richness of brown oak forests in Bhutan.

5.1 Method:

The study was conducted from east to west of Bhutan at an altitude varying from 2300 – 3600 m above sea level.Total of 40 plots surveyed are spread all over Tashigang, Tashiyangtse and Lhuntse in the eastern region, Bumthang and Trongsa in the central region and Wangdi, Thimphu, Paro andHaa in the western regions. The plot at Chelela was recorded at the highest elevation of 3601 masl and plot at Zamling under Lhuntse was at lowest elevation of 2356 masl.

The plot was laid out in a size of 25 m x 25 m where the actual observations/measurements were done. The plot's position were accurately recorded, referring to fixed points available from GPS coordinates and topographical maps. Detailed plot/site information including aspect, altitude, slope, wild animal presence (dung/scat/dropping/foot print) etc. were recorded.

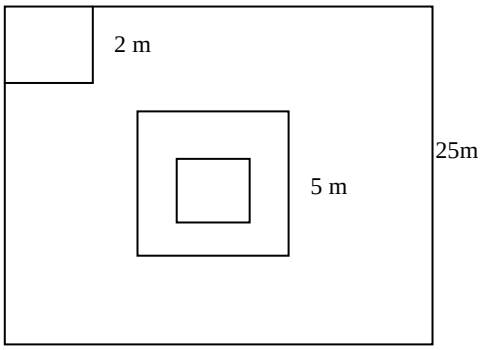


Figure 7.0 Plot layout for the biodiversity survey: Tree layer- 25mX25m, shrub layer 5mx5m, regeneration and herb layer 2mx2m

Vegetation survey were done in 3 categories: 1). Tree layer survey (25m x 25 m), 2). Shrub layer survey (5m x 5 m), 3). Herbs (2m x 2m corner) and regeneration survey (2m x 2m centre plot).

Identification and nomenclature of trees, shrubs and herbs was referred to "Flowers of the Himalaya" (Polunin & Stainton, 1984), "Flowers of the Himalaya: A supplement" (Stainton, 1988), "Flora of Bhutan" (Grierson & Long, 1983-2000; Noltie,1994-2000), "The Orchids of Bhutan" (Pearce &Cribb, 2002), "Weeds of Bhutan" (Parker, 1992), "The plant book" (Mabberley, 1997) and "Wild Rhododendrons of Bhutan" (Pradhan, 1998).

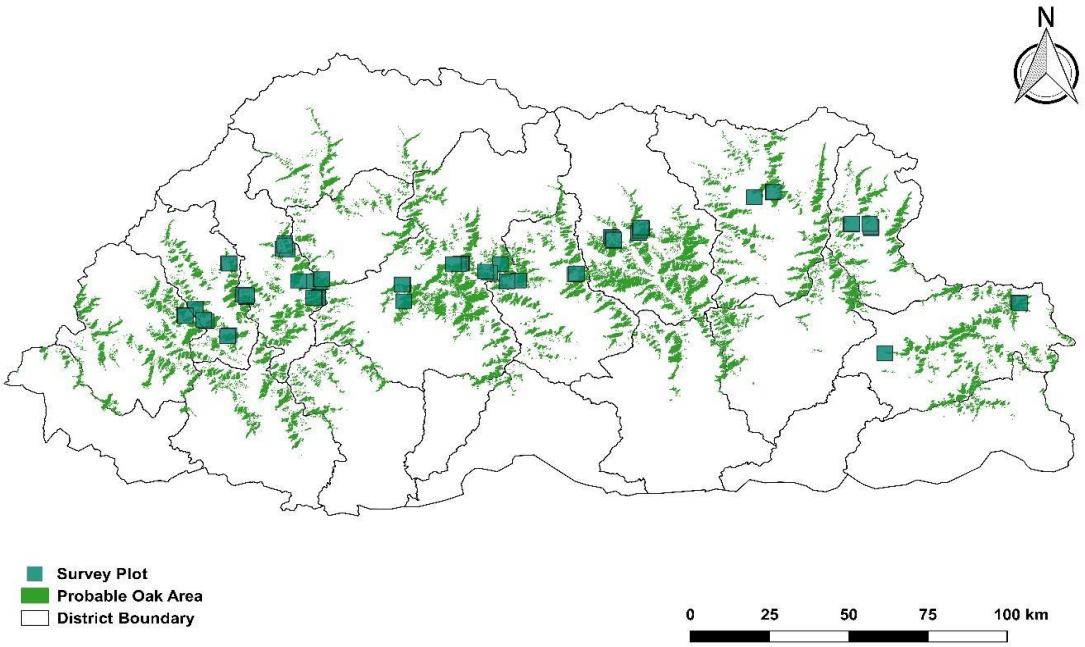


Figure 8.0 showing spatial distribution of biodiversity data sample plots

5.2 Preliminary findings

The oak forests are rich in floral diversity, a total of 59 tree species, 33 shrub species and 125 herb species were recorded. *Quercus semecarpifolia* trees dominated all the plots as the canopy dominants occasionally dotted with few conifers like *Tsuga dumosa*, *Picea spinulosa* and *Pinus wallichiana* in several plots. *Rhododendron arboreum* and *Ilex dipyrena* mostly dominated the middle storey with few species of *Symplocos* and *Eurya* in some plots. The average basal area of the trees was 90.5 m^2 ha^{-1} with a mean of 675 trees ha^{-1}. A maximum DBH of 222 cm and a minimum of 10 cm was both recorded for *Q. semecarpifolia*. The maximum height of 48 m was also recorded for *Q. semecarpifolia*. The shrub layer is mostly dominated by *Daphne bholua* (21.5 %), Berberis spp. (18%) and Rosa sericea (10%). The herb layer was mostly dominated by *Carex* spp. (25 %), *Rubia* spp. (10 %) and ferns (8%). The entire forest showed signs of grazing by domestic and wild animals.

Figure 9.0 Brown oak stand (Quercus semecarpifolia)

Composition of Quercus semecarpifolia forest

Plot layout

Plot layout

Data collection

Data collection

Figure 10.0 Brown forest and biodiversity survey activities

Conifers and other broadleaved trees like Ilex and Rhododendron showed continuous signs of growth. In contrast, oak showed continuous recruitment in the earlier phase but huge absence in the middle phase representing complete recruitment failure. Forest grazing by domestic and wild animals seem to impact the recruitment of oak forests. More grazing resistant species are favored compared to the oaks.

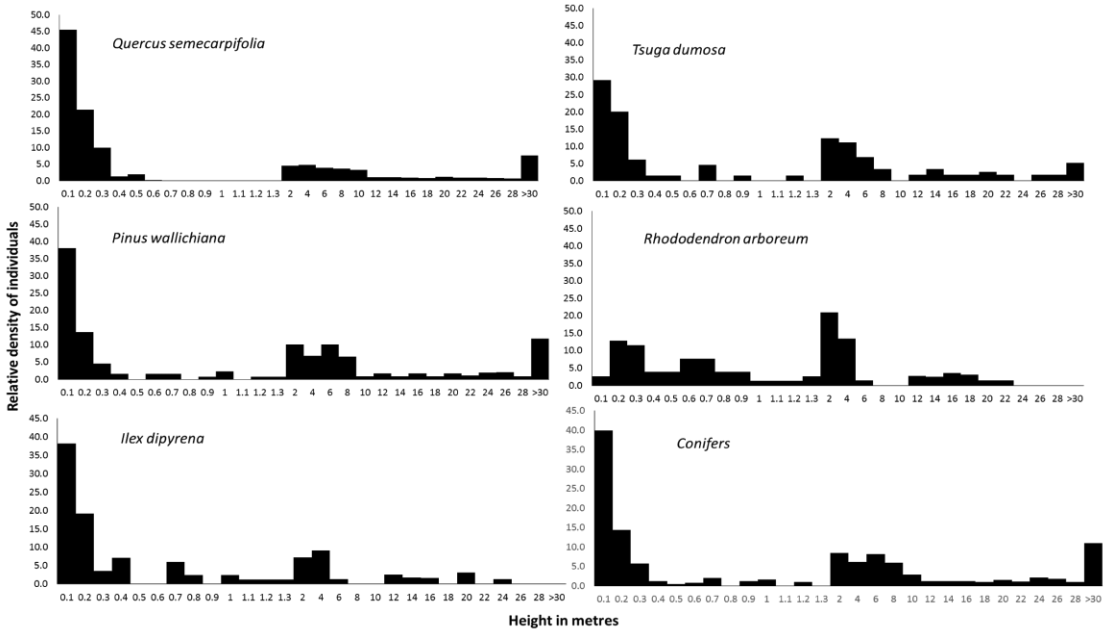


Figure 11.0 Relative density of different major tree species found in the brown oak forest

Figure 12.0 Brown Oak (Quercus semecarpifolia) regeneration

6.0 Training on plantation techniques and awareness program on importance of old growth oak forest.

Target group(s): Local communities, teacher's & student, religious bodies, extension staff and local government officials.

A total of 188 students and 26 local communities and 75 nuns were trained and educated on the importance of oak habitats, need for protection and the types of restoration measures.

6.1 Methods

The awareness campaign was organized with communities through meetings, group discussions, posters and power point presentations. In schools the students were briefed on importance of old growth oak forest focusing on the role of forests, in particular the importance of oak trees to the environment. It was accompanied by interactive educational events like art competition .

6.2 Materials used

The project team members prepared power point presentations, banners and posters which were used to communicate and educate the communities. Charts were also used during the discussion to reflect participants' idea and information.

6.3 Awareness program at Khotokha Primary School and Nunnery at Hongtsho

Art competition was organized on different themes like 'What We Get from the Forest' by Class I and Class II students, 'Save the Forest' to Class III and Class IV students and Importance of Oak Forest by Class V and Class VI. The purpose of competition was to increase children's interest in conservation of forests, increase environmental friendliness and increase knowledge on importance of oak forest. A total of 150 students (79 girls and 71 boys) of 6 years and upward participated in the event including 15 teaching staff and non-teaching staff (4 males and 11 female). The participants showed great interest in the competition and prepared many creative drawings. Competition winners were also awarded the prizes and all participants were given recognition certificate. Same activities were also conducted for 75 nuns at Hongtsho nunnery.

Poster presentation and physical demonstration were made on plantation techniques to the students and nuns. Plantation activity was carried out by participants consisting of teachers ,students, nuns, private individuals, forestry staff of UWICER and forest extension agents.

Figure 14:Awareness Program got Nuns at Hongtsho nunnery

6.4 Awareness to Community

Awareness on importance of old growth oak forest was given to the communities of Guensa village under Rubuesa Geog, WangdueDzongkhag. In total, 26 individuals participated during the awareness program in the villages of which 18 participants were female and 8 participants were male. The awareness program were given through poster presentation and group discussion. The communities were divided into group and asked them to discuss on traditional uses of oak and present their opinions to the floor. The plantation technique were also demonstrated to the communities as the part of awareness campaign using posters.

Figure 15: Awareness program for Goensa comunity at Wangdue district

6.5 Plantation:

A total of 250 nos. trees of different species of *Quercus semecarpifoilia, Quescus griffithi, Benthimedia spp. and prunus* spp. were planted at Sheley, under Rubuesa gewog as a Community based plantation. The plantation was carried out using different seedling shelter methods and micro sites to compare the effectiveness of protection of seedling from grazing animals. The plantation was carried out with an objective to create awareness on importance of Oak trees and also a part of habitat enrichment for wildlife to reduce human wildlife conflict in the locality. The long term data to evaluate the effectiveness of different seedling shelters of plantation at Dochula was also collected.

Figure 18.0 Transportation of seedlings oak forest restoration sites by the community people

Figure 19.0 Different individual seedling shelters built after the plantation with the locally available materials

7.0 Future Activities

Current project has been instrumental in making communities, school children and other stakeholders understand the importance of the oak forest in provision of ecosystem services. Making people understand their role in the conservation and sustainable management of the old growth oak forest is important in reducing deforestation and degradation of existing oak forest. Protection and restoration of forest without the support and understating of those people who depend heavily on the forest resources will be futile .Engagement of community and individuals will not only enhance their knowledge and capacity in conservation and restoration of natural forest but it will also reduce the burden on the government in policing and protection of forest resources from the illegal loggers and forest offenders. Therefore, it is important to scale up the partnership between communities and Department of Forest and Park Services in protecting the oak forest from further deterioration and degradation and improve sustainable management of existing oak forest in the country. Climate change could also intensify loss of oak forest coverage though species range shifting and outbreak of pest and disease which could wipe out the species. In addition, as a result of global warming, most of the oak habitats could be gradually colonized by aggressive species like blue pine and other alien invasive plant species. Therefore, climate data from oak habitats will be critical in determining the future course of action related to reintroduction and rehabilitation of the potential sites. To ensure continuity in the conservation and restoration activities initiated through this project, following activities will carried out in the third phase and after the termination of the project.

- Climate station at study site will be maintained and data used for long term research
- Continue study on the efficacy of different seedling shelters in the plantation established through the support of the project
- Dissemination of finding form the study such as rapid biodiversity assessment and oak distribution modeling to the communities and relevant stakeholders
- Publication of papers in peer reviewed journals
- Prepare policy and technical briefs for policy makers to make them understand the need for conserving old growth oak forest.

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