Assessment of distribution, abundance, threats, challenges and possible conservation of Tree Ferns in Chitwan-Annapurna Landscape

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Background

Tree fern (Cyatheales)

Dicksonia antarctica

Scientific classification

Kingdom: Plantae

Division: Pteridophyta

Class: Polypodiopsida/Pteridopsida (disputed)

Order: **Cyatheales** A.B.Frank in Leunis

Families

- Thyrsopteridaceae
- Loxsomataceae
- Culcitaceae
- Plagiogyriaceae
- Cibotiaceae
- Metaxyaceae
- Dicksoniaceae
- Cyatheaceae

The tree fern (here after referred as fern) 'sensu lato' is a vascular plant (with xylem and phloem) that grow with a trunk elevating the fronds and reproduce via spores, and therefore is a member of Pteridophyte. All tree ferns are belonging to the families Dicksoniaceae, Metaxyaceae, Cytheaceae and Cibotiaceae in the order Cyatheales. However, in Nepal, there are tree ferns which are belonging to family Cytheaceae alone. The family Cyatheaceae has a wide pan-tropical geographical distribution combined with pronounced local endemism (Tryon and Gastony 1975). The tree ferns produce neither flowers nor seeds, they are also referred to as Pteridophyte under the cryptogams. A Pteridophyte is a plant group that include the ferns, horsetails, and the lycophytes (clubmosses, spikemosses, and quillworts). These pteridophytes are free-sporing plants that share a unique life cycle with independent gametophyte and sporophyte phase. Historically both lycophytes and ferns were grouped together as pteridophytes (ferns and fern allies) on the basis of being a spore-bearing feature. The pteridophytes have considered as a group of the ancient plant since they formed the dominant part of the earth during Paleozoic and Mesozoic periods. During the recent era, the majority of the Pteridophytes became extinct. They are preserved in the form of fossils or coal deposits. Only a few Pteridophytes are left at the living stage. At present, of the Pteridophytes, the ferns including tree ferns account for nearly 90% of the extant diversity (Smith et al. 2006). Fossil evidence shows that the tree ferns originated in the Late Jurassic period.

The tree ferns are considered as a living fossil due to their long historical importance (Bystriakova, 2011). However, little is know about their ecology. For instance how they became successful to cross such a long period of time and at what condition their sporophyte established, what strategy of tree ferns help to survive from Carboniferous to present era? Thus, globally the assessment of tree ferns is necessary for their natural habitats to elucidate the relationship between their surviving strategy and ecological preference. In the local context, the tree ferns have been considered as one of the key species in its natural range of subtropical range of Nepal.Thus Nepal also should prepare its inventory and determine the present status in Nepal in general and Chitwan Annapurna Landscape in particular.

The tree ferns play a peculiar role in the dynamics of forests by filtering which trees can regenerate. Seedlings are often observed to grow epiphytically on the fibrous trunks of tree ferns, and these seedlings can eventually over-top and kill their hosts. There is no much information regarding their status, distribution and abundance. However, some available literatures suggest that they are under threat by various anthropogenic activities, such as reckless cutting, grazing and fire. Recent study shows that communities have little knowledge on the species and recommended to raise awareness among local communities for its conservation (Thapa 2017). The tree fern is an indicator species of moist and humid climate, provide shelter for germination to many species. Beside its ecological and historical importance, it is one of the beautiful foliage tree in the Plant Kingdom. Therefore, oweing to it cultural, ecological and historical importance, this study intends to undertake the assessment of tree fern in CHAL region.

Objective

The main objective is to conduct the detail assessment of treeree ferns with respect to its ecology, best practices, and and its prevailing threats in Chitwan Annapurna Conservation Landscape.

The specific objectives includes:

- To assess the ecological status and geographical distribution, abundance and hot spots of tree ferns in CHAL,
- To assess the key threats to the tree ferns in its natural range in CHAL,
- To document the existing knowledges, practices and usage of tree ferns by the local community, and
- To recommend effective conservation measures.

Study Area

The CHAL is located in central Nepal, covering an area of 32,057 km^2, with elevation ranging from 200 m to 8091 m. This landscape covers all or part of 19 districts and seven PAs. The CHAL is rich in biodiversity and culture. The CHAL has eight major rivers and tributaries, draining to Narayani River forming the major part of river basin (Gandak). CHAL is a harbors many endangered species including tiger, rhino, elephant, red panda, gharial and Snow leopard. Approximatgely four millions people lives along the CHAL.

Methods and Materials

The methodology includes following:

1. Desktop study

The team collected printed publish and unpublished literature in library and search relevant literative/ database online. Bibliography is present along with this report in the reference section. We have reviewed published literatures till date and studied the herbarium specimens of National Herbarium and Plant Laboratories, Godawari.

2. Consultations

We consulted with relevant person at Department of Forests, Department of Plant Resources, IUCN, Ministry of Industry, Environment and Forests of state no 4. Pokhara, District Forests Office Kaski, Panchase Conservation Forest Office, and Biodiversity Park, Raniban, Pokhara (Annex: Name list of person consulted). We gathered relevant information relating to tree fern distribution, abundance, threats, challenges, and conservation in CHAL.

3. Sampling techniques

Intesive field survey was conducted in winter season between Dec, 2017- Jan, 2018 in the CHAL (Fig below). From the literative review and field consultations, tentative distribution range was deliniated and which aided in planning the fieldwork. Geographically, the field survey covered four major districts: Tanahun, Lamjung, Kaski, and Parbat districts. Along the four districts, we have focused the survey along the Marsyandi river basin and its adjoining areas, Madi river basin and its adjoining areas, Kaligandaki river basin and its adjoining areas, Seti river basin and its adjoining areas. We collected the spatial information such as coverage area of each population of tree ferns was estimated using hand held GPS. During the survey at each plot, we collected reference information relating to latitude and longitude of each plot, elevation, aspect, geological data (presence of rocks, most forest type, dominant tree species etc), hydrological data (site inundation, surface flow, etc), tree fern condition (visible

signs of disturbance or anthropogenic or natural), and distance to river/stream, nearest settlement-fire history-grazing, etc.

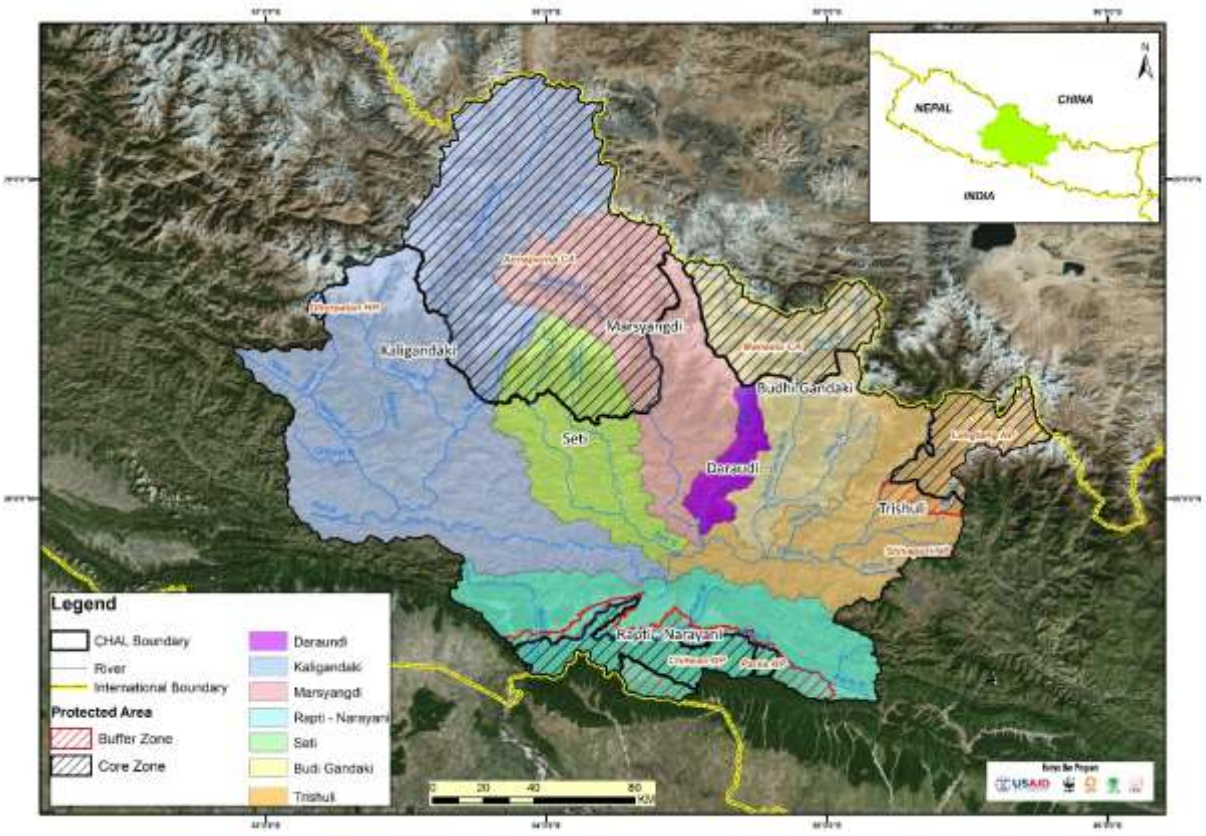

Figure 1: Map showing Chitwan Annapurna Landscape

The morphology of tree fern was observed in the natural habitat to assess the variation within the species and variation between the population. The distribution patterns of tree fern was assessed by sampling techniques after Kent & Coker, 1992. The tree ferns normally grow in the habitats such as damp, sheltered, woodland slopes, and moist gullies. Thus stratified random sampling techniques was applied. The tree ferns population was divided into strata and random sample was taken in stratum. The main goal of the stratification is to organise the population into homogeneous subsets.

Plot size was 20 m x 20 m. Selected size was selected based on topography, tree morphology and standard sampling protocol (Kent & Coker, 1992). At each plot, we recorded for the

presence-absence of tree fern species, while we also recorded the presence of other associated species. We counted and measured the height of each tree species. The forest types were observed based on visual observation. The plots were made across the tree fern's communities. The change in vegetation and environmental gradient were also recorded as a proxy to a relationship between environmental factors and tree fern. We used various equipment during the field survey and descripted is provided in the annex.

The threats to tree fern were assessed based on the individual personal observation and in discussion with local villagers, conservation managers and forest officers. Discussion among various key stakeholders also helped in trangulating the information generated for verification. Traditional and conventional threats were documented using local and expert opinion.

Analysis

Hotspot division: In the study design, we termed 'biodiversity hotspot' specifically referring to biologically rich areas which may have been deeply threaten. To alliance with this term, the **tree ferns-hot spot** is considered as an area/habitat which has highest tree ferns density. Based on the survey and observation from the field in CHAL region, we have categorised tree ferns's hot spot as follows: Hotspot A: if the density > 25 tree ferns per plot; Hotspot B: if the density > 10 tree ferns per plot; Hotspot C: if the density > 5 tree ferns per plot; and Normal D: if the density < 5 tree ferns per plot. This categorization is site specific in nature and related to the local context thus division proposed may not have universal application.

Density: We calculated the density as number of individual of tree ferns found per unit area. Density = Number of tree fern per unit area. Here, area refers to 20 m x 20 m plot and the number of tree ferns indicate total number of tree ferns encounter within each plot.

Distribution of tree fern: We used the field collected data on the presence of tree fern for assessing the distribution of tree fern. We extracted GIS-based landscape level characteristics (slope, elevation, temperature and ruggedness) from the tree fern spatial data for assessing potential tree fern habitat and mapped its refined distribution across the CHAL using maximum entropy modeling algorithm MaxEnt version 3.3.1 (Phillips et al., 2006).

Results

Six species of tree ferns are reported in Nepal and which includes: *Cyathea spinulosa, Cyathea sollyana, Cyathea khasyana, Cyathea henryi, Cyathea gigantean, and Cyathea brunoniana (*Fraser-Jenkins, et al. 2015). The most common species of tree ferns in Nepal is *Cyathea spinulosa.* However, only one species *Cyhea spinulosa* is found in the CHAL region.

We assessed a total of 89 plots with ~ 64 plots were located along the north facing slope, while rest facing various aspects (Table A1). Altitudinal variation in tree fren presence was recorded between 695 and 1,738 m. Tree fern occurrences were recorded primarily in northern slope, shaded area with humid condition, and standing close or near to permanent water source. The recorded habitats were damp, sheltered woodland, sloppy areas and moist gullies with north facing slopes.

Generally, the tree ferns do not make 100 % pure stands along its natural range. In CHAL, no pure stands of tree ferns were observed. It was mostly found under the shade of forest tree. The common forest tree species associated with tree ferns were *Schima wallichii* and *Castanosis indica.* In 70 % of plots two tree species were dominant which is regarded as the major association among the subtropical forests of Nepal. Beside, other species found associated with tree ferns are: *Myrica esculenta, Albizia procera, Rubus ellipticus, Mallotus Nepalensis, Alnus nepalensis, Daphniphyllum himalense, Choerospondias axillaris, Bambusa nepalensis, Ficus*

semicordata, Eurya acuminate, Madhuca butyracea, Rhododendron arboretum, Macularia cochinensis, Walsura trijuga, and *Ficus glaberrima.* Eventhough, tree fern is also found growing in the natural range of *Shorea robosta* upto 100 m asl, it is generally not associated with tree fern as *Shorea robasta* is sun loving species but tree fern is not.

The frequency distribution (number of individual tree fern) varies between 1 to 60 per plot. Maximum of sixty tree ferns per plot were recorded in the forest of Bhujrungkhola, Kaski district (Photo below). The mean density of tree fern was 9.00 (SD 10.4). The detail about the plots and their occurrence of tree ferns is given in Table A2.

The tree ferns are not homogeneously distributed in CHAL region. The mean density was 30.64 and recorded as highest tree ferns density in the forests of Bhujrungkhola so, it falls under the Hotspot-A category. Similarly, the Marsyangdi river gorge of Lumjung has second highest density of tree ferns in CHAL region. The number of individual tree ferns per plot varies between 2-41 individual trees along the Marsyangdi river gorge in Lamjung district (see Table

A1). The mean density was 12.3. Similarly, Machhapuchhre Gaunpalika has a high density of tree ferns recoreded and ranges between 6-20 tree ferns per plot. Average mean density was 11.66. The average tree fern density was 7.64 in the northern side of Kaskiko (Hemaja forest). Thus, Marsyangdi river gorge and Seti river basin in Machhapuchhre Gaunpalika and Kakiko Hemha forest falls under the hotspot B-category. Similarly, the Lumle and Dhital area contains mean density of 5.77 and 5.66 and fall under the hotspot rategory- C. The eastern part of Kaski district, raniban of Pokhara valley, and the population in Tanahun district falls under the hotspot D category in terms of distribution. Thus tree fern potential habitat were recorded across 2639 km^2 (Prime: 659 km^2; Moderate: 959 km^2; Fair: 1021 km^2) along the elevational ranges along the CHAL using the presence data modeled with bioclimatic variables in MaxEnt (Fig below).

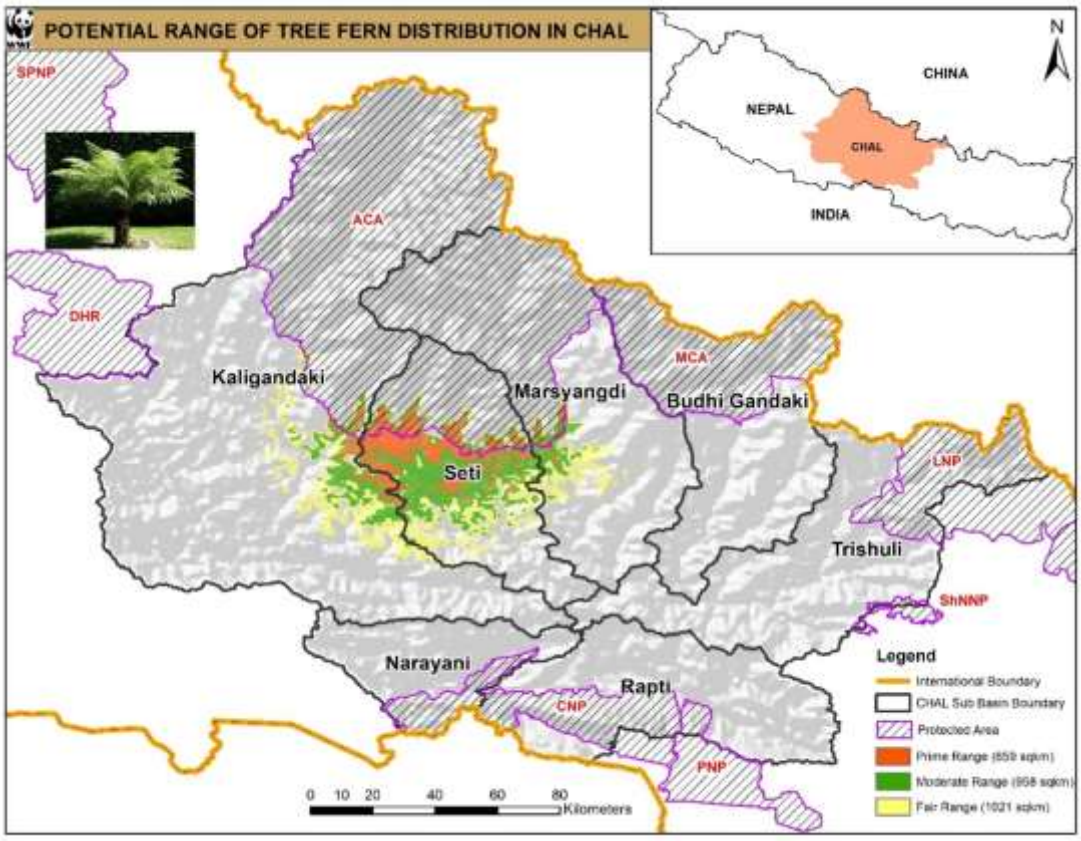

Figure 2: Map showing potential range of tree fern distribution in CHAL

Asssement of threats of tree ferns: We have categorised and listed the identified threats as conventional (C) and modern (M) based on contextual agreement after intensive discussion with key stakeholders as identified under method section.

Use of trunk for entrance gate (C): A tree fern trunk forms an upright accumulation of rhizomes and are usually tightly packed to form a solid rigid support for the fronds and embedded in a dense mantle of modified roots. This structure is water resistant and serves a purpose similar to that of normal tree trunk. Traditionally, it is used in making gate (Tagaro). This conventional practice is still prevalent but get replaced with other means in recent times. The traditional gates were found in Deurali of Kaskikot, Sidane in the Panchase, Chineswara in Dhital and Lumle. In the past, the trunk used to cut haphazardly just to make the gate leaving rest of tree to die. We have found several cut stumps of tree trunk in the Dandapari forest of Kaskikot, Sandhikhola of Dhital (Photo below).

However, such unsustainable practice has been stopped few areas in Panchase as community are aware of the potential repercussion. Communities have set up the tree fern conservation

display (Photo below) to sensitize local communities on conservation issues such as unsustainable harvesting.

Use of fronds for fodder cattle (C): Tree fern fronds as fodder for sheep and goat has been a common practice in CHALas observed in Hemaja, Kaskikot, and Dhital. The young and tender fronds are more palatable by cattles as the thrones are not matured and easy to forage. As a result, demand for the young fronds as fodder often hinders tree fern toward their full

Road and bridge construction (M): In the recent time, infrastructure development is is development issue in CHAL. Large infrastructure such as road construction causes a direct and indirect impact on the terrestrial ecosystem including forest. Potential direct impact such as reduction in forest area will have affect tree fern habitat. Current road construction projects in CHAL have no mitigation measures in place specific for protecting tree fern habitat. Tree ferns

were recorded along the edges and/or along the side of under construction road as observed in Deuarali-Hemaja road, Thulakhet-Panchase road, and Pokhara-Dhital road in Kaski district, Madhya Pahadi Lokmarga located in Kaski and Lamjung district, Besisahar-Manang road in Lamjung districts (Photo below).

Hydropower development project (M): The magnitude and extent of dam construction and associated water diversion, exploitation of groundwater aquifers, stream channelization, and interbasin water transfer in the CHAL region are major threats tree ferns habitat. Tree fern is transitional between aquatic and terrestrial life stage. Thus it is semi aquatic plant that needs water medium for fertilisation. In CHAL, it is often found near permanent water sources. Thus any disturbance of the natural bodies such large dams and river diversions may be directly impact of its habitat and at the extreme may lead to its local extirpation if no mitigation measures is practiced in the future.

Practical on use of tree ferns: The tree ferns are also used as important commodities by the communities in CHAL. It is often used as food, thatching material, fodder, medium for nursery development and used as pillar for making the gate during auspicious ceremonies. Perception on use of tree fern varies among the communities. Few communities have very little knowledge about its use as in risti village in Tanahun district. Few sporadic trees were recorded and local people unaware about its use and importance. The young fronds of tree ferns are commonly used in making prickle as observed among the communities in Damdame, Sidane, Dhampus, Dhital, Hemaja, Lumle, and Lwang of Kaski district, and Sange village of Lamjung district. They also use fronds as fodder for livestock, making thatching material, and used it as litter.

Tree ferns is also used as medicine for pain relief. It was observed as a remedy for relieving back pain among the communities in Dhital, Dhampus, Lwang, and Kaskikot in Kaski district. They often harvest immature and tender fronds and crush it and let it sun dry for 2-3 days which they mix it with rice flour and prepare special food "Puwa" which is spread across affected region for relieving pain. However, no communities in Lamjung district were found using tree ferns as medicine.

Ecological Importance of tree ferns: Tree ferns are keystone, slow-growing and long-lived plant species. Species is very sensitive to physical disturbance. Tree ferns plays an important role as a host to the wide range of epiphytic ferns, bryophytes, climbers, and orchids. The trunk of tree ferns facilitates to germinate the seeds of many forest tree species (see Photo below). Recent studies shows that positive relationship between species abundance and the occurrence of arboreal mammal such as Mountain Brutail Possum *Trchosurus cunningham* (Lindenmayer et al. 1993). No any studies have been reported so far to infer similar relationship between species abundance and occurrence of mammal in Nepal. However

there is a indirect positive role aniticipated between forest formation and providing shelter for birds and mammals.

Economic importance of tree fern: No direct economic use of tree ferns were reported in CHAL. This tree fern has significant economic importance in Australia, Britain, and Europe due to its historical and ornamental value. Plant looks very beautiful from asthetic point of view. It looks more aesthetic than a palm tree. Irony is palm tree have huge market value while tree fern not. Thus tree fern may potential to develop into high market value through its development in the nursery for wider propogation from economic point of view.

Tree fern's habitat potential sector for ecotourism: Occurrence of pure stand of tree ferns forest in Bhujrung Khola, Kaski offer potential to promote site from ecotourism perspective. Bhujrung Khola lies with very close proximity to Pokhara valley thus can contribute in developing surrounding area as ecotourism potential site. Unfortunately, local communities or community's leaders are unaware of its importance of tree fern and development of the site from ecotourism perspective. its beautiful nature and,

Historical importance as a living fossil: The tree fern represent an ancient group of plants which evolved before all modern vascular plant and animals. Record shows that tree ferns evolved even earlier than the evolution of dinosaur. In prehistoric era, it is believed that dinasaur used to forage on tree ferns and cycad-like plants since there was no other flora at that time. After dinosaur extirpation from Earth, existence of tree ferns shows species connotation as a living fossil. Such evolutionary and historical importance needs to be communicated broadly to garner the local and international support for tourism.

Recommendation

- Awareness: Majority of local communities surrounding the portential site of tree fern are un aware of its tree fern importance. Conservation aspect of tree fern is widely overlooked. Thus conservation support from all walk of life including government, conservation partner, donors, local communities and individuals is anticipated.
- Department of the forest: The department and its districts offices include conservation awareness program in their annual plan so that communities are aware and motivated toward the conservation. There is an urgent need to keep vigilance on unsustainable harvest of tree fern' trunck and possible ban on its harvesting as well.
- Department of Plant Resources: Department should also initiate a research on tree fern focusing on the adaptation and resilience. There is also a need on spore culture and develop seedling on a mass scale.
- Local authorities seem unaware of tree fern importance so awareness program needs to be designed.
- Develop a practice of tree fern cultivation as an ornamental plant in the nursery.
- Developing Bhujrung Khola as a tree fern sanctuary: The tree ferns forest of Bhujrung Khola is unique so, its conservation needs attention from the government.

Potential site can be developed as a popular tourism site. The local government in the *Machhapuchhre Gaunpalika* should take the initiative for the development of site as ecotourism site.

- Encourage the farmer for exsite cultivation of tree fern in their farmland and home gardern wherever there is a possibility.
- Infrastructure development project should be oriented in protecting the tree ferns during construction phase. Local conservation authority should inform development project not to harm plant during the construction phase. This can be done by preparation of phamplets and/or flyers about the importance of tree ferns and posting at the construction site.

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Annex 1: Lifecycle, morphology and ecology of tree ferns:

The life cycle of tree ferns involves alternation of generations as found in the other cryptogamic flora (Fig.1). This means a diploid generation (the sporophyte, which produces spores) is followed by a haploid generation (the gametophyte or prothallus, which produces gametes). The tree ferns differ from mosses and seed plants in that both generations are independent and free-living, although the sporophyte is generally much larger and more conspicuous. The vegetative plant body is a sporophyte in tree ferns. It is the asexual stage of the life cycle. The sporophyte forms the dominant stage (see photo 1).

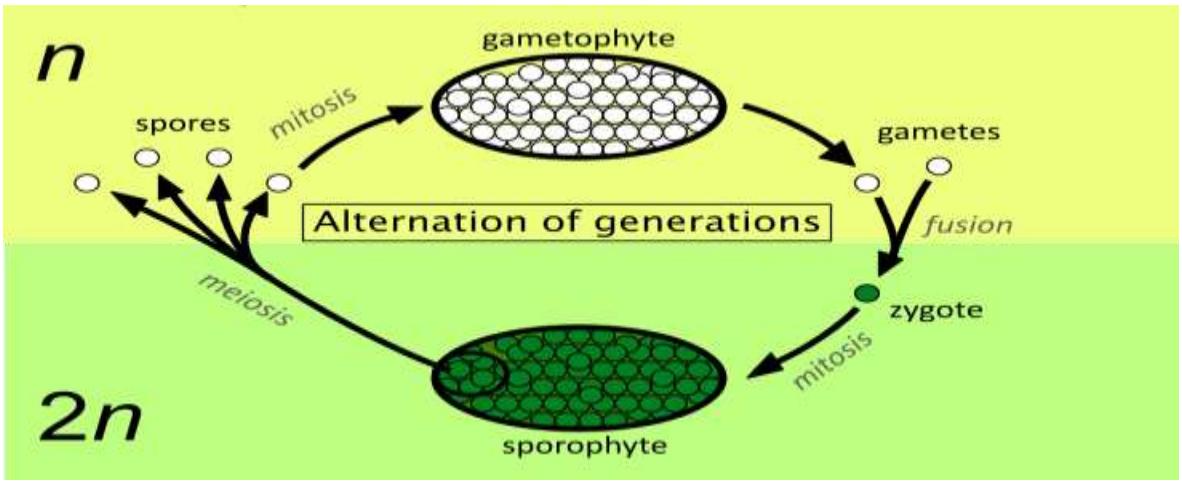


Fig. 1. Life cyscle of tree ferns involve the alternation of generation between gametophyte and sporophyte, (source: https://en.wikipedia.org/wiki/Alternation_of_generations)

Photo: Morphology of tree ferns, a mature tree ferns attain about 12-15 m height (Sporophyte)

The sporophyte is differentiated into stem, leaves and roots (Photo 1). This sporoophyte is an independent plant. The sporophyte of tree ferns possesses well-developed vascular tissue consisting of both xylem and phloem. The vascular tissue is confined to the central region of the stem forming the stele. It is clearly demarcated from the cortex by a well-developed endodermis. The plants produce spores and these spores germinate to form gametophyte or prothallus. The gametophyte is small, insignificant and short lived. It forms a simple thallus called prothallus. Sex organs are embedded in the tissue of the prothallus near the surface. The male sex organ is called antheridia and female sex organ is called archegonia. The antheridia produces flagellate antherozoids and archegonia produce egg. The antherozoids travel through the medium of water for fertilisation. So that, fertilization depends on water, thus ferns including tree ferns rarely found in arid and semi arid climate (Bhattarai, 2005). The tree ferns have a thick trunk that can grow up to 12-15 meters and the leaves/fronds grow out from the top.

According to the Hanbury-Tenison (1972), there are 10,000 species of ferns in the whole world. Among them there are 500 species of tree ferns (Tryon and Gastony, 1975) are found globally. In Nepal, there are 580 taxa of fern and fern allies from Terai to the high Himalayan mountain (Fraser-Jenkins et al. 2015). However, there are only six species of tree ferns. The fern's diversity is relatively high in the cloud forests of Nepal (Bhattarai et al. 2004). The Pokhara valley which lies in the Annapurna region comprises 26 species of ferns and their allies (Bhattarai, 1997); however, little is known about tree ferns.

The family Cyatheaceae is one of the most interesting families among the pteridophytes due to their striking morphology and wide geographical distribution combined with pronounced local endemism (Tryon and Gastony, 1975). It is represented in Nepal by what is often treated nowadays as a single genus, Cyathea (http://www.floraofnepal.org/countryinformation). While many ferns are able to achieve a broad distribution because of their spore reproduction, tree fern species tend to be very local. This makes their species much more susceptible to the effects of local deforestation.

Tree fern (*Cyathea* species) is one of the endangered plant species listed in IUCN Red list and Appendix II of CITES. The tree ferns grow in moist and partially shade areas rich in humus (Bhattarai 2005). Tree Ferns in Nepal are reported from an altitude of 600-1800 meters in hilly areas of eastern, center and western region of Nepal. Generally Annapurna region, here we called CHAL receive relatively more rainfalls in Nepal, so it may have a hot spot of tree ferns. However, the distribution range along the elevation gradient in CHAL is not known.Thus, this study was proposed to generate baseline information about tree ferns.

Annex 2: List of Equipments used in the Survey

The following equipments were used in the field:

- 50 metre tape: Required to establish the transect,
- 20 metre tape: Required to establish the plot,
- Compass: Required to determine transects and to establish the plot,
- GPS device: Required to record start, point latitude and longitude,
- Alimeter: Required to measue the elevation of each plot,
- 45° set square or clinometers: To determine tree height,
- Flagging tape: Required to help identify boundaries of the plot,
- Seven marker pegs, per transect/plot and a hammer,
- Sampling ruler: Required for detection of exotic fauna evidence and measuring native and exotic ground cover,
- Sighting tube (roughly 10 cm long and 4 cm diameter): Required to measure crown type,
- Field sheets.

Table 1: A1: Aspect and number of sampling plots in the study area

Aspect	Number of sampling plots
West	3
East	9
South	13
North	64

Table 2: A1: Range of tree ferns abundance along the plots

S. No	Total number of plots	Total number of tree ferns	S. No	Total number of plots	Total number of tree ferns
1	8	1	12	2	12
2	10	2	13	1	13
3	8	3	14	1	14
4	3	4	15	1	15
5	7	5	16	2	16
6	6	6	17	1	18
7	9	7	18	4	20
8	10	8	19	1	32
9	5	9	20	1	44
10	3	10	21	1	52
11	2	11	22	1	60

Table 3: A2 Location of plots and number of individual tree ferns per plot

Plot No.	Longitude	Lattitde	Alt. masl	Local name	District	Number of tree ferns
1	83.898380	28.283478	1074	Danadapari, Hemaja	Kaski	1
2	83.897570	28.298000	1092	Danadapari, Hemaja	Kaski	1
3	83.897570	28.282460	1109	Danadapari, Hemaja	Kaski	12
4	83.897160	28.282010	1135	Danadapari, Hemaja	Kaski	18
5	83.897150	28.281750	1162	Danadapari, Hemaja	Kaski	7
6	83.896680	28.281790	1158	Danadapari, Hemaja	Kaski	11
7	83.896180	28.282420	1137	Danadapari, Hemaja	Kaski	1
8	83.895880	28.283460	1104	Danadapari, Hemaja	Kaski	9
9	83.902700	28.280320	1229	Danadapari, Hemaja	Kaski	5
10	83.902120	28.278710	1273	Danadapari, Hemaja	Kaski	8
11	83.901590	28.276890	1326	Danadapari, Hemaja	Kaski	8
12	83.901350	28.276800	1335	Danadapari, Hemaja	Kaski	4
13	83.900340	28.276690	1369	Danadapari, Hemaja	Kaski	7
14	83.899790	28.276260	1397	Danadapari, Hemaja	Kaski	8
15	83.899790	28.276260	1163	Danadapari, Hemaja	Kaski	8
16	83.827680	28.236560	1327	Danadapari, Hemaja	Kaski	10
17	83.827540	28.236260	1326	Damdame	Kaski	8
18	83.827850	28.236270	1326	Damdame	Kaski	5
19	83.825840	28.236090	1321	Damdame	Kaski	2
20	83.825630	28.234960	1313	Damdame	Kaski	10
21	83.825940	28.234930	1305	Sidane	Kaski	3
22	83.826130	28.234100	1326	Sidane	kaski	5
23	83.826500	28.234540	1322	Sidane	kaski	5
24	83.826840	28.234620	1314	Sidane	kaski	8
25	83.827060	28.233200	1342	Sidane	kaski	7
26	83.827160	28.233300	1342	Sidane	kaski	7
27	83.827530	28.227710	1543	Sidane	kaski	2
28	83.827000	28.225320	1600	Sidane	kaski	2
29	83.826550	28.224020	1615	Upper Sidane	Kaski	1
30	83.887050	28.301530	1338	Hemajakot, Dhital	Kaski	3
31	83.886750	28.301350	1399	Chinneswara, Dhital	kaski	3
32	83.870110	28.313550	1346	Sandikhola, Dhital	kaski	8
33	83.869910	28.313790	1343	Sandikhola, Dhital	kaski	9
34	83.869760	28.314140	1337	Sandikhola, Dhital	kaski	8
35	83.909490	28.298710	1449	Astam, Dhital	Kaski	3
36	83.913440	28.293970	1415	Astam, Dhital	Kaski	2
37	83.923450	28.293360	1342	Jhijhirka, Dhital	Kaski	3
38	83.928120	28.290690	1285	Hemja	Kaski	5
39	83.972070	28.328690	1230	Bhujrung Khola	Kaski	8
40	83.973520	28.328490	1230	Bhujrung Khola	Kaski	4
41	83.975980	28.328280	1227	Bhujrung Khola	Kaski	13
42	83.988270	28.328090	1294	Bhujrung Khola	Kaski	32

Plot No.	Longitude	Lattitde	Alt. masl	Local name	District	Number of tree ferns
43	83.989200	28.328250	1300	Bhujrung Khola	Kaski	52
44	83.989540	28.328650	1301	Bhujrung Khola	Kaski	60
45	83.990140	28.329360	1308	Bhujrung Khola	Kaski	44
46	84.093780	28.165790	695	Lakeshore, Begnaslake	Kaski	3
47	84.094452	28.166480	699	Lakeshore, Begnaslake	Kaski	2
48	84.094240	28.165780	693	Lakeshore, Begnaslake	Kaski	7
49	84.158010	28.172570	806	Rupakot-7	Kaski	3
50	84.170620	28.165890	892	Souryabas	Kaski	2
51	84.178620	28.167410	721	Souryabas	Kaski	1
52	84.179030	28.167080	722	Kalikathan	Kaski	14
53	84.179140	28.166610	719	Kalikathan	Kaski	2
54	84.184780	28.165160	719	Kalikathan	Kaski	2
55	84.191120	28.164870	670	Thumki-5	Kaski	1
56	84.330365	28.124052	630	Byans Municipality, Risti	Tanahun	1
57	84.401200	28.354800	1068	Mana-Lamjun roard	Lamjung	4
58	84.402050	28.361680	1089	Kavrednada	Lamjung	20
59	84.402550	28.363040	1080	Marsyndi george	Lamjung	5
60	84.402720	28.364240	1092	Rambazar, Marsyandi george	Lamjung	2
61	84.399460	28.376350	1086	Rambazar, Marsyandi george	Lamjung	6
62	84.398740	28.376400	1090	Ridhikhola/ Marsyandi river	Lamjung	20
63	84.400380	28.382100	1099	Syange	Lamjung	41
64	84.400620	28.383000	1116	Syange	Lamjung	5
65	84.400380	28.382100	1121	Syange	Lamjung	9
66	84.400620	28.383000	1120	Syange	Lamjung	11
67	83.882030	28.328990	1273	Machhapuchhre-8	Kaski	3
68	83.880530	28.330130	1254	Machhapuchhre-8	Kaski	6
69	83.880600	28.330060	1256	Ghichekhola, Machhapuchhre-8	Kaski	8
70	83.888052	28.330020	1258	Ghichekhola, Machhapuchhre-8	Kaski	9
71	83.880280	28.333024	1248	Ghichekhola, Machhapuchhre-8	Kaski	16
72	83.883800	28.330440	1239	Ghichekhola, Machhapuchhre-8	Kaski	16
73	83.880300	28.330350	1243	Ghichekhola, Machhapuchhre-8	Kaski	6
74	83.878060	28.329530	1322	Pathlekholsa Machhapuchhre -8	Kaski	7
75	83.876560	28.329000	1340	Pathlekholsa Machhapuchhre -9	Kaski	7
76	83.863056	28.319444	1175	Indhikhola, Machhapuchhre-8	Kaski	20

Plot No.	Longitude	Lattitde	Alt. masl	Local name	District	Number of tree ferns
77	83.870278	28.341944	1154	Sandhikhola, Dhital, Machhapuchhre-6	Kaski	20
78	83.873333	28.323611	1258	Lwang,Machhapuchhre-8	Kaski	10
79	83.881389	28.331667	1199	Lwang, Magarikhola, Machhapuchhre-8	Kaski	15
80	83.813889	28.295833	1672	Lumle, Annapurna- 6	Kaski	4
81	83.813889	28.303889	1689	Lumle, Annapurna- 6	Kaski	7
82	83.815000	28.296111	1700	Lumle, Annapurna- 6	Kaski	8
83	83.813333	28.297778	1743	Lumle, Annapurna- 6	Kaski	9
84	83.815556	28.297778	1712	Lumle, Annapurna- 6	Kaski	1
85	83.813611	28.298333	1738	Lumle, Annapurna- 6	Kaski	6
86	83.804722	28.296111	1565	Lumle, Annapurna- 6	Kaski	7
87	83.804167	28.293333	1466	Lumle, Annapurna- 4	Kaski	8
88	83.970629	28.246803	1137	Sarankot	Kaski	2
89	83.966289	28.197855	871	Raniban	kaski	1

Figure 3: A1: *Location of sample plots of tree ferns in the CHAL region*

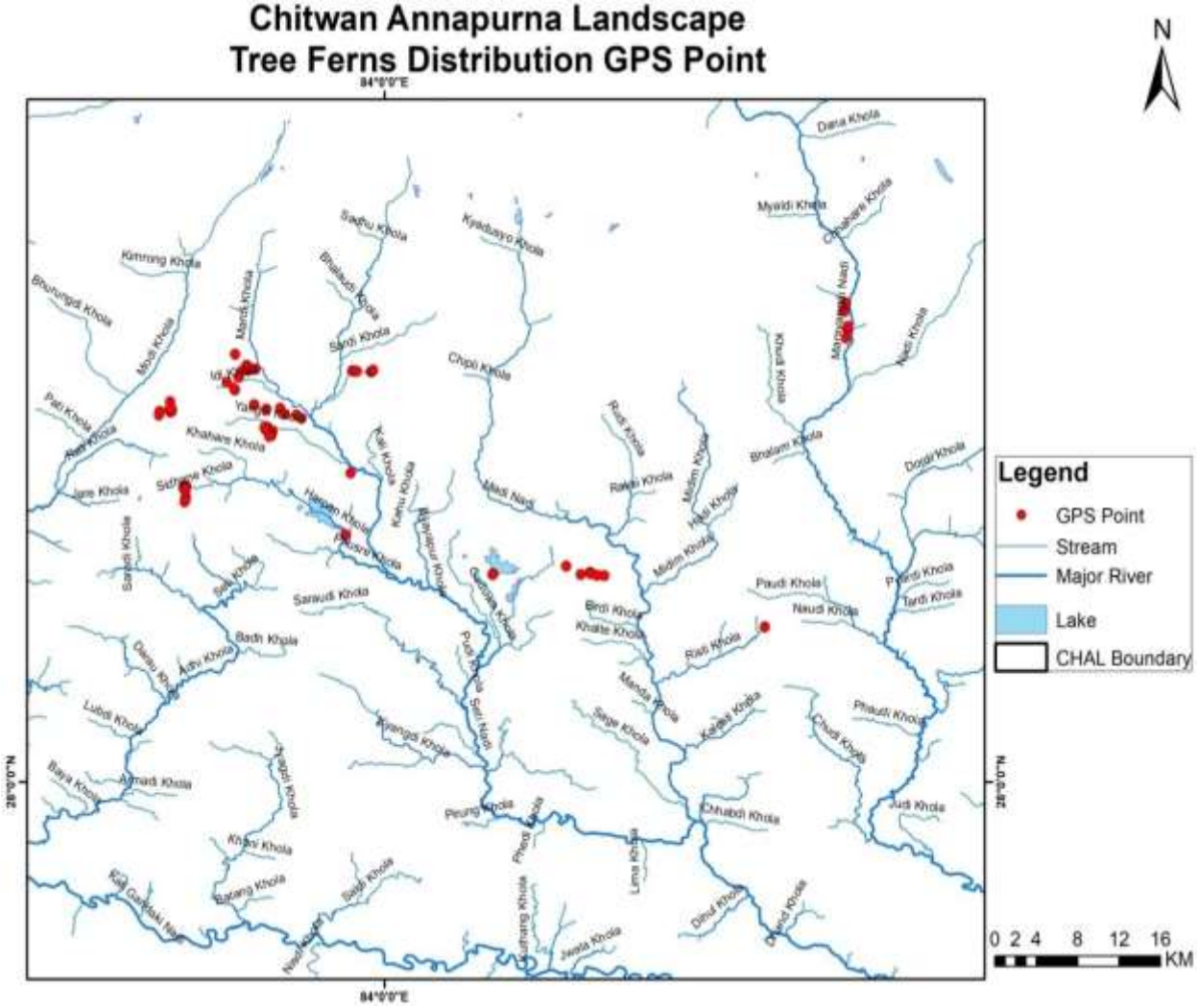
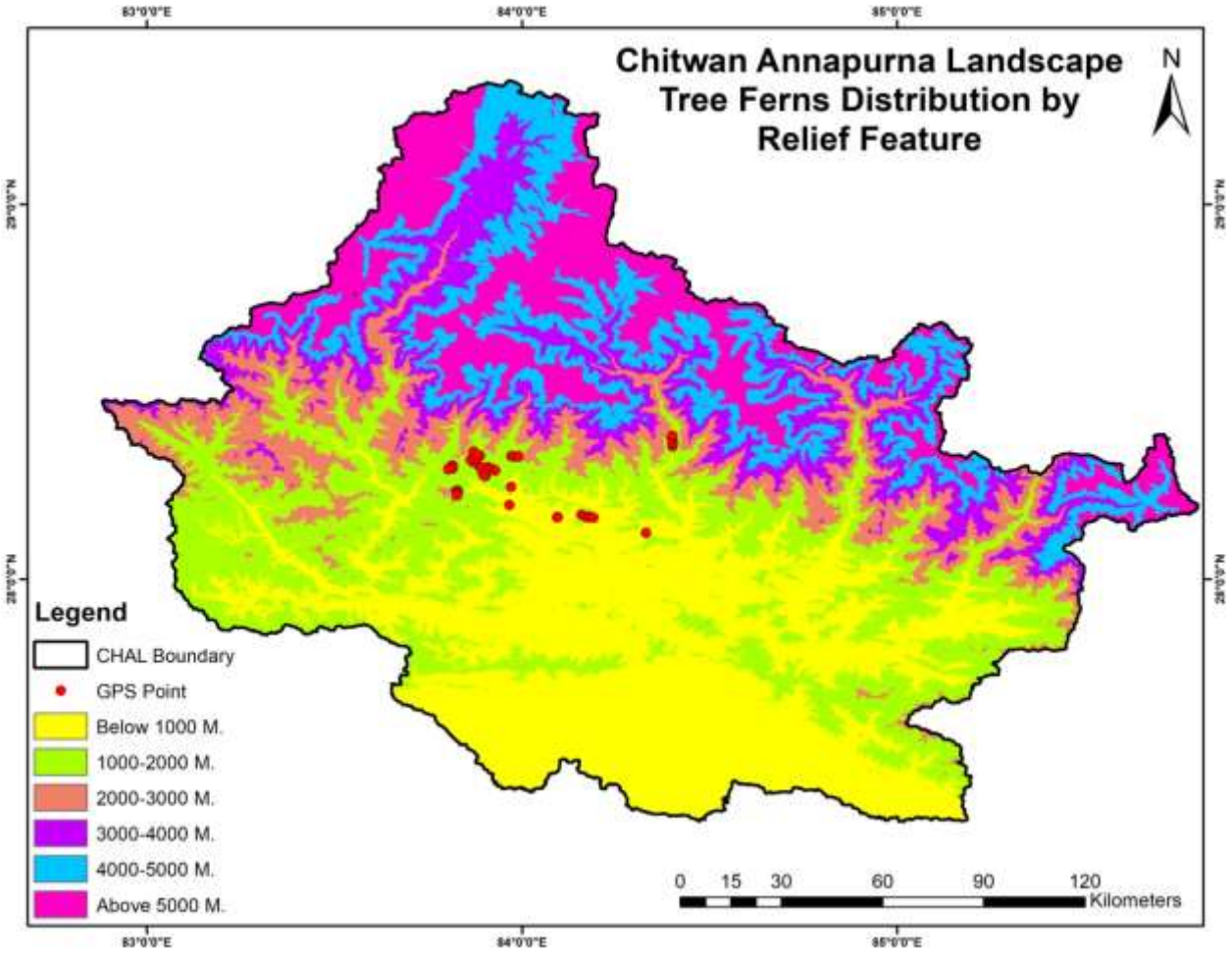


Figure 4: (A2) Distribution tree ferns along the altitudinal gradient in the CHAL region



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