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CHURE-TARAI MADHESH LANDSCAPE, NEPAL FROM BIODIVERSITY RESEARCH PERSPECTIVE

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Abstract

Chure-Tarai Madhesh Landscape (CTML) that extends from east to west touching upon all seven states of Nepal is considered a hotspot of biological diversity and recharge ground water for Tarai part of Nepal. Biodiversity research is pivotal for proper management and planning to conserve the landscape. Secondary information, interaction with experts and authors own experience in the field of biodiversity has incorporated to provide information on status of biodiversity, its importance and ecosystem services in the landscape. The CTML represents 3 ecoregions; 9 forest types; 8 Important Plant Areas (IPAs); 14 Important Bird Areas (IBAs); 4 Ramsar sites; and 7 protected areas. Four protected forests of the landscape provide important corridor and connectivity to wildlife. However a comprehensive inventory of flora and fauna is lacking, the landscape houses 10 endemic and 6 legally protected by government of Nepal and 3 vulnerable (IUCN category) plant species. It also provide habitat for 8 endangered and 15 protected mammals. Biodiversity in the CTML contribute to deliver different types of ecosystem goods and services (provisioning, regulating, cultural and supporting services). Natural ecosystems and species that comprise within natural ecosystem sustain and fulfill human life. Deforestation, habitat loss, forest degradation, livestock grazing, illegal hunting and poaching, illegal trade across the border are the major threats to biodiversity. The proposed research priority areas in the landscape include: inventory of flora and fauna, ecological study, ethnobiological study, economic botany, mycology, microbiology, plant pathology, biotechnology, tissue culture and genetic diversity, environmental degradation, nature/biodiversity/culture based tourism, long-term socioecological and environmental monitoring, economic valuation of ecosystems, and regional cooperation. The landscape is linked with mountain landscape in the north, and across the Indian border in the south; hence, it should be addressed in a holistic way. There should be trade off in conservation of biodiversity and development of the landscape in sustainable way. There is need to generate new scientific multidisciplinary data and initiate knowledge management.

***Key words*:** Anthropogenic effect, biodiversity, Chure, conservation, landscape, human impact

Introduction

Chure-Tarai Madhesh Landscape (CTML), Nepal is considered a hotspot of biological diversity and provides most important and significant natural habitat for *in-situ* conservation of biodiversity. Altogether seven protected areas in CTML play an important role for conservation of fauna and flora. The landscape also serves to recharge the ground water for the lower plains in the Tarai part of Nepal (FRA/DFRS, 2014), and across the Nepal-India Border.

Extending from east to west and touching upon all seven provinces of Nepal, CTML covers an area of 3,925,204 ha which is about 26.67 % of the total area of the country. Chure (also called Churia) Mountain (Siwalik Hills) is a young mountain range situated between the Mahabharat Range in the north and the Tarai plains in the south. This range is formed by sediments deposited during the origination of the Himalayas about 40 million years ago. It is made up of geologically young sedimentary rocks such as mudstones, shale, sandstones, siltstones and conglomerates (FRA/DFRS, 2014). The landscape has become vulnerable due to abrupt high unpredictable rainfall as well as land-use changes in Nepal in recent decades. Further, deforestation, unplanned road construction and cultivation on steep slopes, among others, have further made the region fragile (SAWTEE, 2016). Year after year Tarai suffers from flash floods, loss of agricultural land, sediment deposition, and channel-shifting by rivers, flooding of agricultural land for months, inundation of villages for weeks together and such other miseries.

Most of the Churia problems are human centered besides geological one. The construction and operation of the East-West Highway that mostly traverses through the Bhavar zone and passes through the Tarai and Churia hills at places, is seen as an important event in Nepal. One of its impacts has been considerable movement and settlement of people along the highway and rapid urbanization along and south of the highway. This has put tremendous pressure on the diminishing and degrading of natural resources in the Churia area. The denudation of natural forests of Tarai, Bhavar and Churia started in 1980s (FRA/DFRS, 2014). It further gained momentum during political change in 1990s, and again during the insurgency period of 10 years between 1996 to 2006. The deforestation further accelerated after there was increased migration of people from the hills following the eradication of malaria in the region (Bhatta *et al.*, 2007). In-migration has been a regular phenomenon in the Chure for many decades. So, both population and development activities have been increasing there causing rapid urbanization of the region.

The CTML has been facing population growth and human encroachment in forest and river areas; unscientific land-use; existence of a large number of landless people; and rapid construction and excessive extraction of sand, gravels and stones (SGS) have resulted in a grave situation in the Chure. These factors are responsible for the erosion of biological diversity, desertification of the Chure and lower areas and increasing threats to people's access to food and water in particular downstream (SAWTEE, 2016).

The CTML is ecologically linked with the Bhavar and the Tarai-Madhesh regions that it cannot be separated from the conservation and management perspectives. For the conservation of the Chure region, the consideration of the

"Chure-Tarai Madhesh Landscape" is imperative. Thus, it is necessary to consider the Chure-Tarai Madhesh as a vast important landscape, and manage it through proper planning for the mitigation of the erosion of the Chure region and the damage owing to the floods in the Tarai Madhesh region.

Overall Aim and Objectives

The discussion paper, in general, will discuss about importance of biodiversity and ecosystem services, and provide information on status of biodiversity in the Chure-Tarai Madhesh landscape. The paper will specifically cover, as far as possible, with quantitative data, status of different levels of biodiversity pertaining to the landscape; major problems and their impacts with focus on biodiversity conservation; biodiversity research priority areas; and way forward.

Materials and Methods

The paper is based on review of published articles, reports and interaction with experts. Our own experience working in the area of biodiversity conservation and landscape management have also been incorporated.

Physical Features

The CTML comprises one climatic region that encompasses five physiographic units *viz.* Chure hills (covering 34.4% of the landscape); Chure narrow gorges (2.2%); Dun/Inner Tarai (8.4%); Bhavar region (14.9%); and Tarai Madhesh (40%) (Fig.1). Approximately, 48.19% of the total area of the Chure-Tarai Madhesh Landscape is covered by agriculture and settlement; 47.16% by forest, shrub-land and grassland; and the rest 4.65% by river and riverbed (GoN-RCTM, 2017). There are altogether 164 river systems with different origin that flow along the landscape and cross the Nepal-India Border. The climate of Churia in general is subtropical. The average maximum temperature is found to be between 28.2^0 – 31.8^0C and the average minimum between 15.8 – 20.4°C. Mean annual precipitation of the area varies between 1,400 and 2,000 millimetres (mm) (GoN-RCTM, 2017).

Socio-economic features

The CTML comprising whole or part of 36 districts extends from east to west in the southern part of Nepal. The total population of CTML is 147,48,672 which is more than half of the total population of the country (CBS, 2011). Three distinct ethnic groups *viz.* Baji groups in the south; Hill migrants in the north; and the Tharus in between resided in CTML. People of the landscape practice farm and off farm based livelihood activities. The highest portion of the population (60.17%) is engaged as skillful and semi skillful worker in agriculture, forestry and fisheries (GoN-RCTM, 2017).

Biodiversity and Ecosystem Services

Biodiversity is the integral part in CTML. Altogether, 26 of the Nepal's total 118 ecosystems lie in the landscape. Of these 26 ecosystems, 23 lie in the forest and 3 in the agriculture. The CTML represents 3 ecoregions; 8 Important Plant Areas (IPAs); 14 Important Bird Areas (IBAs); 4 Ramsar sites; and 7 protected areas (Hamilton and Radford, 2007; MoFSC, 2014).

(i) Ecoregions:

An ecoregion is an ecologically and geographically defined area with distinct assemblages of natural communities and species. Out of total 12 in Nepal, The CTML comprises three ecoregions.

- **Himalayan Subtropical broadleaf forest:** It extends between 500 to 1,000 masl across Siwaliks.*Shorearobusta*and moist mixed deciduous forest are the dominant vegetation of this ecoregion. It provides habitat for threatened species of mammals including tiger (*Panthera tigris*), Asian elephant (*Elephas maximus*), smooth-coated otter (*Lutrogaleper spicillata*), and gaur (*Bos gaurus*).
- **Upper Gangetic plains moist deciduous forest and Lower Gangetic plains moist deciduous forest:** These ecoregions occur in the *Tarai*region. It is dominated by tropical moistdeciduous forests of sal*(Shorea robusta)* and populations of several largemammals including tiger (*Panthera tigris*), rhino (*Rhinoceros unicornis*), Asian elephants (*Elephas maximus*), and gaur (*Bos gaurus*).
- **Tarai-Duar Savanas and grasslands:** It is characterized by a mosaic of tall riverside grasslands (*Saccharum* sp.), savannas and evergreen and deciduous forests. *Eugenia jambolana*, *Bombax ceiba*, *Acacia catechu*, *Trewia nudiflora*, and *Mallotus philippensis* are some of the common tree species that grow in association with the grass species. This ecoregion is habitat for several endangered species of mammals and reptiles, including the Bengal Tiger (*Panthera tigris*), Rhino (*Rhinoceros unicornis*), and Gharial crocodile (*Gavialis gangeticus*), etc.

(ii) Forest Types

Forest type in the Chure-Tarai Madhesh Landscape belongs to tropical and subtropical climatic zones. Out of 55 forests in Nepal 9 types of forests are distributed in CTML (Miehe *et al*., 2015).

- ***Shorea robusta* forest**. It is a drought-deciduous, broadleaved, fire-dominated forest distributed in tropical, and semi-humid area of lowlands to hills in the CTML. The Sal (*Shorea robusta*) is the dominated tree species associated *Terminalia alata*, *T. bellirica*, *Dillenia pentagyna*, *Mallotus philippensis*, *Lagerstroemia parviflora*, *Buchanania latifolia*, *Bauhinia vahlii*, *B. variegata*, *Semecarpus anacardium*, *Adina cordifolia*, and *Spatholobus parviflorus.*
- ***Terminalia* and *Anogeissus* forest**. It is a drought-deciduous forest of the tropical, semi-humid area of Hill, Duns and Siwaliks dominated by *Terminalia tomentosa*, *Anogeissus latifolia.* Besides these two species *T. chebula*, *T. bellirica*, *T. myriocarpa*, *Glochidionvelutinum*, *Croton oblongifolius*, *Garugapinnata*, *Ehretia laevis*, *Syzygium cumini*, *Lagerstroemia parviflora*, *Dillenia pentagyna*, *Engelhardia spicata*, *Bauhinia variegata*, *Flacourtia indica*a nd *Lanneacoro mandelica* are other associated tree species of upper storey and *Rhu sparviflora*, *Butea minor*, *Alangium salviifolium*, *Bauhinia variegata*, *Mallotus philippensis*, *Phoenix humilis*, *Woodfordia fruticosa*, *Dodonea angustifolium*, *Desmodium oojeinense*, *Asparagus racemosus*, *Randia* sp.,

*Euphorbia royleana, g*rassses mainly *Heteropogon contortus*and *Ischaemum angustifolium* are found in under storey.

- **Riverine grassland.** It is characterized by dense tall grasses in the tropical semi humid flood plains along the rivers of Dun, Bhavar and Tarai. It is dominated by *Saccharum spontaneum*, *Narenga porphyrocoma, Themeda arundinacea, Imperata cylindrica, Phragmites karka*, and *Arundo donax.*
- ***Dalbergia sissoo-Acacia catechu* riverine forest**. It is a tropical, semi-humid, drought-deciduous, lowland, pioneer riverine forest. Besides, *Dalbergia sissoo* and *Acacia catechu*, the common associates of this forest are *Tamarix dioica*, *Zizyphus* spp., *Murraya koenigii*, *Callicarpam acrophylla, Holeoptelia integrifolia*, *Lagerstroemia parviflora*, *Bauhinia malabarica*, *Mallotus philippensis* and *Garuga pinnata.*
- ***Bombax* riverine forest**. It is a tropical, semi-humid, drought-deciduous, climax, riverine forest along the great rivers in the Gangetic plain, Duns, Bhavar and Tarai. *Bombaxceiba* is the dominant tree species in this forest. *Holoptelea integrifolia*, *Lannea grandis*, *Ehretia laevis*, *Lagerstroemia parviflora*, *Dillenia pentagyna*, *Sapium insigne*, *Stereospermum chelonoides*, *Garuga pinnata*, *Careya arborea*, *Trewia nudiflora*, *Bridelia retusa*, *Cedrela toona*, *Schleicherao leosa*, *Ficus racemosa*, *Syzygium cumini*, *Acacia catechu*, *Mallotus philippensis*, and *Alangium salviifolium*are the other associated species in this forest.
- ***Schima* forest**. It is subtropical, sub-humid to semi-humid, hill, evergreen, broadleaved forest in the Central to Eastern Midlands. It is found in patches or mixed with *Magnolia velutina*, *M. champaca*, *M. hodgsonii, Podocarpus neriifolius*, *Exbucklandiapopulnea, Engelhartdia spicata,* etc.
- ***Pinus roxburghii* forest**. It is a subtropical, sub-humid to semi-arid, submontane, single-storeyed conifer forest. It is dominated by *Pinus roxburghii.* Limited number of ground layer is poorly represented by limited number of species such as *Woodfordia fruticosa, Anaphalis busua* etc.
- ***Toona ciliata-Albizia julibrissin* riverine forest**. This is a tropical to subtropical, humid, hill to submontane, deciduous to evergreen forests along streams in the central and eastern parts. It is dominated by *Toona ciliata* and *Albizia julibrissin. Podocarpus neriifolius*, *Magnolia hodgsonii*, *Saurauia napaulensis* are other tree species associated with this forest.
- ***Alnus nepalensis* riverine forest**. It is found in subtropical, semi-humid to humid, deciduous forest along the streams. The other plant species found in association are *Boehmeria platyphylla*, *B. rugulosa*, *B. macrophylla*, *Pilea* spp., *Pouzolzia sanguinea*, *Oreocnide frutescens*, *Debregeasia salicifolia*, etc.

(iii) Important Plant Areas (IPAs).

The IPAs are the sites exhibiting exceptional botanical richness and /or supporting an outstanding assemblage of rare, threatened and/or endemic plant species and/or vegetation of high botanical value. Darbyshire *et al*. (2017) revised global IPA selection criteria. They considered threatened species, botanical richness and threatened habitat are the major criteria to designate IPA globally or country level. There are altogether 19 IPA complexes comprising 54 sites in Nepal; out of which 8 IPA complexes and 19 sites have been identified in Chure-Tarai Madhesh Landscape (Table 1).

(iv) Important Bird Areas (IBAs)

The Important Bird Areas (IBAs) are the places of international significance for the conservation of birds, mammals, and other biodiversity. They are identified using standardized and internationally agreed criteria. IBAs apply for terrestrial, freshwater and marine realms. There are altogether 27* Important Bird Areas (IBAs) in Nepal out of which 13 IBAs are found in this landscape (Table 2).

(v) Wildlife corridor and connectivity

Wildlife corridor is a conservation tool that maintains connectivity with other reserves within a country and /or across boarder developing a network of corridors. They provide additional resources for food and space to wildlife species and also an opportunity of exchanging genes among several populations within the network. Protected forests such as Barandabhar (Chitwan), Laljhandi-Mohana (Kailali and Kanchanpur), Basanata (Kailali), and Khata (Bardia) are also important corridor and connectivity in the CTML (MoFE, 2018).

(vi) Floral diversity

A comprehensive inventory of plant diversity in the Chure-Tarai Madhesh Landscape is lacking. However, approximately 900 plant species of different life form have reported from Chure region. It includes 281 tree species which constitute about 40% of total tree species recorded in Nepal (based on plant list by Press et al. 2000), 186 shrub, 322 herbs including pteridophytes, 100 climbers and 11 epiphytes. In the forests of the Bhavar and TaraiMadhesh region, 164 tree, 72 shrub, 109 herbs, 30 climber and 5 epiphyte species have been recorded (FRA/DFRS, 2014).

(vii) Endemic plant species

There are 312 species of endemic flowering plants reported from Nepal (Rajbhandari *et al*., 2017). A few endemic plant species that have been reported from the Chure-TaraiMadhesh Landscape include *Begonia minicarpa* H. Hara (Locality-Sunsari, 630 m); *B. tribenensis* C.R. Rao (Sunsari, 130 m); *Eriocaulonex sertum*Satake (Jhapa, 200-300 m); *E. obclavatum* Satake (Jhapa, 200-300 m); *Isodondhan kutanus* Murata (Dhankuta, 1200 m); *Jasminum amabile* H. Hara (Sunsari, 80 m); *Eria nepalensis* D.M. Bajracharya & K.K. Shrestha (Chitwan, 200 m); *Malaxistamurensis*Tuyama (Dhankuta, 1200 m); *Ophiorrhiza nepalensis* Deb &Mondal (Ilam, 45 0m); *Salix plectiles* Kimura (E. Nepal, 200 m).

(viii) Protected plant species

In the landscape *Rauvolfia serpentina*, *Acacia catechu*, *Bombax ceiba*, *Dalbergia latifolia*, *Pterocarpus marsupium* and *Shorea robusta* are the plant species which are legally protected by Government of Nepal. The three plant species, such as *Dalbergia latifolia, Cycas pectinata* and *Pterocarpus marsupium* found in the landscape are classified as vulnerable in the IUCN red list.

(ix) Invasive alien species.

Invasive and alien plant species are also problematic in the landscape (Siwakoti and Chaudhary, 2011). The invasion by such species can be observed throughout in landscape. They include*Colebrookea oppositifolia*, *Eupatorium odoratum*, *Mikania micrantha*, *Lantana camara*, *Parthenium hysterophorus*, *Ageratum conyzoides*, *Ipomoea carnea*, *Solanum aculeatissimum*, *Urena lobata*, *Tridax procumbens*, *Cassia tora*, *C. occidentalis*, *Mimosa pudica*, *Amaranthus spinosus, Xanthium strumarium*, etc.

(x) Faunal diversity

The CTM holds a high number of important faunal species. So far 325 species of butterflies, 154 species of fishes, 22 species of amphibians, 68 reptiles, 648 Avi-fauna and 91 species of mammals have been reported (BPP, 1995). Higher groups of faunal diversity have been relatively well worked out as compared to lower faunal group. Of the 65 species of mammal species recorded from this region, 8 are recorded as the "endangered" in the IUCN Red List and the 15 are incorporated in the Protected List under the National Parks and Wildlife Conservation Act, 2029 BS (FRA/DFRS, 2014).

(xi) Protected Area System (PAs)

The landscape hosts seven protected areas: Chitwan National park; Bardia National Park; Banke National park; Shuklaphanta National Park; Parsa Wildlife Reserve; Koshi Tappu Wildlife Reserve; and Blackbuck Conservation Area, out of total 20 PAs in Nepal. Total area of the PAs including buffer zone is 5,886 sq. km which is about 4% of the total area of the country. The protected area harbor endangered wildlife and plant species.

(xii) Agrobiodiversity

The Tarai part of the landscape is very important part of the country from agrobiodiversiy and crop productivity perspectives. Agriculture patterns vary in the landscape. Two land type of cropping pattern exist the landscape (MoFSC, 2014). In irrigated type, rice-wheat; rice-rice-wheat; rice-rice/legumes; rice-maize; rice-vegetables in Tarai, and rice-wheat; rice-maize; rice- vegetables; rice-potato-potato in the Siwalik regions. In the rain-fed type rice/legumes; maize/finger millet-wheat; rice-fallow; rice grain/legumes in Tarai, and maize+soyabean-mustard/fallow; maize/millet-wheat; maize+upland rice-fallow occur in the Siwalik region.

Local breeds and transboundary breeds that are found in Tarai and Siwaliks include cattle, buffaloo, goats, sheeps, pigs and poultry.

(xiii) Wetlands

There are altogether 438 wetlands reported from Chure-Tarai Madhesh Landscape (GoN-RCTM, 2017). Out of which 101 wetlands are of high importance from environmental services. Wetlands in landscape play a significant role in conservation of biodiversity, support irrigation system and provide habitat of birds and aquatic flora and fauna. They also hold several species of wild cultivars and wild relatives of cultivated crops including five species of wild rice, namely *Oryza nivara, Oryza granulata, Oryza officinalis*, *Oryza sativa f. spontanea* and *Oryza rufipogon,* and include two species of wild relatives of rice, namely *Hygrorhyza aristata* and *Leersia hexandra* (CSUWN, 2010). Some common wetland dependent flora include *Nelumbo nucifera*, *Nymphaea nauchali, N. stellata, Trapa quadrispinosa, Eichhornea crassipes, Euryale ferox* etc.

(xiv) Ramsar sites

The Ramsar sites are the sites of internationally importance especially at water fall habitat. There are ten Ramsar sites designated in Nepal out of which four Ramsar sites are located in CTML (Table 3) comprising 39% of the total areas of the Ramsar sites of Nepal.

(xv) Grasslands

Grassland are important component of the CTML. Grasslands in the landscape are dominated by S*accharum spotaneum* and *Imperata cylindrica.* They are associated with evergreen and deciduous tree species such as *Eugenia jambolana, Bombax ceiba* and *Trewia nudiflora.* The grasslands are excellent habitat for Rhino and Pre-base for Bengal tiger. They are also home to several globally threatned bird species such as Bengal Florican and Rufous-rumped grassbird.

(xvi) Non-Timber Forest Products

A total of 305 species of NTFP are recorded from the Chure region. They are mainly used for medicinal purpose, religious purpose, fibre, resin, seed oil, agricultural implements etc. The most used NTFPs include Khair (*Acacia catechu*), Bans (*Bambusa* spp.), Amariso (*Thysanolaena maxima*), Amala (*Phyllanthus emblica*), Tejpat (*Cinnamomum tamala*), Nigalo (*Himalayacalamus* Sp.), Bet (*Calamus* Sp.), Kaulo (*Machilus odoratissima*), etc. (GoN-RCTM, 2017). There are also excessively exploited NTFPs that are collected from the landscape and traded to India; these include medicinal plants such as *Rauvolfia serpentina, Asparagus racemosus, Piper longum, Dioscorea bulbifera,* and several Orchid species, etc.

(xvii) Ecosystem services

Biodiversity in the CTML contribute to deliver different types of ecosystem goods and services. Natural ecosystems and species that comprise within natural ecosystem sustain and fulfill human life. Ecosystem goods and services obtained from the CTML has been briefly described into four categories following MEA (2005).

- **Provisioning services.** The provisioning services, i.e. the raw materials obtained from biodiversity in the CTML include goods and services such as food and vegetables, fodder, biomass, fuel-wood, natural fiber, timber, natural medicines for household and commercial uses. A few examples include *Dioscorea* species (Vyakur/Tarul/Githa) used mainly by Tamang communities as staple food; *Terminalia bellerica* (Barro), *T. chebula* (Harro), *Phyllanthus emblica* (Amala), *Rauvolfia serpentina* (Sarpagandha), etc. are important medicinal plant species used for domestic purpose as well as for pharmaceutical and industrial products. Thus, provisioning goods and services from biodiversity/ecosystems of the landscape have enabled people to settle around their periphery and maintain the areas as cultural landscape. In addition to goods and services derived from biological resources, huge amount of boulders and sand are collected for construction purposes in Nepal and beyond (across the boundary), often in a rampant way.

- **Regulating services.** The protected areas play an important role in providing regulating services in terms of climate regulation, water purification, mitigate threats to biodiversity, and improving livelihoods to local communitiesin Koshi Tappu Wildlife Reserve (ICIMOD and MoFSC, 2014; Chaudhary and Sah, 2016). Plant species such as *Oryza rufipogon* (wild rice) and animal species such as *Bubalus arnee* (Arna) are the important genetic resources for plant and animal breeding. However, quantitative information regarding regulating services are lacking, and needs a long-term research.
- **Cultural services**. People obtain the non-materials benefits from ecosystem/biodiversity, such as spiritual enrichment, intellectual development, religious experience, and recreation. Biodiversity provide opportunities for outdoor recreation; and nature-based tourism are becoming an important means of economic source for benefit sharing and enterprise development. Five important protected areas including a natural heritage site, i.e. Chitwan National Park, A World Heritage Site, attract huge number of tourists each year from Nepal and abroad. Sacred natural sitespreserve open landscape, support all forms of life, regulate local atmosphere, provide medicinal plants, and promote cultural integrity (Bhagwat, 2009). There are several important sacred sites, such as Bikram Baba Temple (Chitwan), Salhesh Phulbari (Siraha), etc. in the landscape.
- **Supporting services**. The supporting services are necessary for the production of all other ecosystem services. Honeybee (*Apis cerana)* provide important supporting service by increasing the productivity of large cardamom (*Amomum subulatum*), the main cash crop and important livelihood option for farming communities in the Himalayas. *Apis cerana* is an effective pollinator of large cardamom, and has increased the yield upto 45% in the plots that is maintained by the honeybee than natural pollination (Partap *et al*., 2017).

Major Problems and Their Impacts

Despite the tremendous importance, the Chure Region has been facing severe problems of degradation and overexploitation of biological and natural resources. Frequent forest fires, encroachment and uncontrolled grazing, natural disasters (such as flood, erosion), anthropogenic changes (population growth, encroachment of forest habitats, uncontrolled grazing, and other vagaries) cause damage to the ecosystem at large scale.

Major problems occurring in the upstream of the CTML include soil erosion; landslides; low agricultural productivity; poor arable land; low water table; difficult terrain; forest fires; non-registered land; shifting cultivation; over-grazing; deforestation; smuggling of timber and other forest products (Rai and Dutta, 2010). Whereas, major problems occurring in the downstream of Tarai include flooding, expansion of stream beds, sedimentation, river bank cutting, rising river beds, inundation of villages, reduced agricultural productivity, lowering of water table, drying of water sources, loss of land and property, unemployment, seasonal migration of agricultural labourers, etc.

A prediction has been made in Nepalese perspective that if Nepal were to lose its remaining humid tropical forest, there would be loss of ten species of highly valuable timber, six species of fibre, six species of edible fruit trees, four species of traditional medicinal herbs, and some 50 species of little known trees and shrubs; and this would severely alter the habitat for 200 species of birds, 40 species of mammals and 20 species of reptiles and amphibians (HMG/IUCN, 1988).

Major problems and their impacts in the CTML are as follows;

(i) Deforestation, Habitat loss and Forest degradation leading threat to biodiversity

Deforestation in Nepal has a long history. Intensive deforestation started during the unification phase of Nepal (before 1768), where forests were converted into agriculture land to feed the huge number of militants in different states (Chaudhary *et al*., 2016). Their strength was their army, and military endeavors were typically rewarded with land grants, which often led to further deforestation (Soussan *et al*., 1995). It was further intensified with initiation of the system of selling timber to foreign contractors during the Rana regime in 1846. The extensive Tarai forests were little disturbed until the late 1920s, when the government initiated expansion of cultivated areas by clearing some forests and extracting timber in other forests for export to India to collect revenue (Joshi, 1993). The government hired an experienced British forester (Mr J.V. Collier) who had a long working experience in India from 1925 to 1930 to supervise and improve timber felling in the Tarai. Mr Collier of the Indian Forest Service, whom Rana Prime Minister Chandra Shamsher Jung Bahadur Rana entrusted with the direction of the forest department in Nepal, came in 1923 to Nepal as an adviser who recommended the bulk removal of Sal from the virgin forests of the Tarai, such as Morang District in the east and Kailali-Kanchanpur Districts in the west. Mr. Collier was entrusted with the task of extracting from Nepal 200,000 railway sleepers offered by the Government of Nepal to British Government as a war gift. This also brought tremendous wealth to Rana rulers but also paved the way to reckless destruction of forests in Nepal, and the situation is being continued with an increasing trend of overexploitation in more accessible parts of Tarai belt, where easy transportation helps removal of timber logs across the border to India (Bhatt, 1977).

In the CTML, the greatest threat to the conservation of biodiversity comes from the activities of man, which has led to habitat loss, forest destruction and degradation. In between 1978 to 1991, about 99,000 ha of tropical sal forest in the Tarai was cleared (FRISP, 1994).

Deforestation in the Tarai has been caused mainly by the clearing of forestland for agricultural purposes. From 1963 to 1979, the proportion of cropland in the Tarai increased from 38.5% to 49.8% (Gurung, 1988). Rampant forest fire in the Chure-Tarai Madhesh are also leading to forest degradation and destruction. Population growth (annual rate 1.40% in 2011 compared to 2.25% in 2001) appears to be the most important factor behind decreasing forest cover in Nepal. The number of people dependent on agriculture is rising; and as a result, agricultural land has increased, mostly by encroaching upon forest areas (UNEP, 2001; CBS, 2011).

(ii) Free livestock grazing causing damage to forest degradation

Much forest area in the country is used as open grazing land for livestock. This has led to further degradation of the forest area, in particular damage to ground vegetation cover.

(iii) Over-exploitation of biological resources leading to decline of wildlife population.

People to a large extent depend on biological resources for their sustenance. Several valuable species, in particular timber and medicinal plants are in threat.

(iv) Illegal hunting and poaching leading to biodiversity threat

Illegal hunting is a practice in CTML also. Mammals and birds are killed and Dolphins are trapped for meat, carnivores are hunted for their pelts and bones. Similarly, cases of poaching of Rhino and Bengal tigers are often recorded. These activities have led threat to biodiversity.

(v) Illegal trade across the border leading to deforestation

To a larger extent, timber smuggling along the Nepal-India Border is also responsible for deforestation in Nepal. Such timber smuggling is usually done in an organized manner, often regulated by influential people (Regmi, 1994). Owing to the higher prices of timber in India, smugglers are motivated to export timber from Nepal. The activity intensifies when the price of timber is higher in India than in Nepal. However, in recent years the smuggling has declined probably due to improved monitoring and also decline of forest area in the Tarai.

Other cross-cutting problems and their impacts include, population growth and poverty; perverse incentive by elite group/politically influential people; lack of governance, and weak implementation of laws, policy and acts, shortage of water availability, etc. The migrants from the hilly region cleared the forests legally and illegally and have settled down. The trend is still continuing. They prevented the Tharus and Baji groups from entering the forests but could not prevent its use/misuse by the hilly people, who have been using the forests to meet their fodder, firewood, timber, and NTFP needs despite of whatever be the legal provision.

Therefore, the major problem of conservation of biodiversity lie not only in the biology of the species concerned, but rather in the social, economic and political areas within which people operate (McNeely, 1992). These problems can be solved in part by making the biological diversity a source of economic growth.

Research Priorities Focusing on Biodiversity

Several necessary information identified during the course of the preparation of Master Plan of President Chure-TaraiMadhesh Landscape 2017 are felt to be lacking (GoN-RCTM, 2017). This requires scientific data generation in consistent way over a period of time. Following areas have been proposed for research priority in biodiversity.

(i) **Documentation of flora and fauna**: Higher groups of plants and animals have been fairly documented from the landscape. Inventory of flora and fauna from different protected areas have also been done (MoFSC, 2014). However lower groups of plants and animal have not been seriously considered. Therefore, comprehensive taxonomic study of plants and animals including lower groups should be undertaken.

(ii) **Ecological study**: Study of ecosystem such as forest, grassland, wetlands have been fairly undertaken. A few example includes, soil characteristic (Bhattarai and Mandal, 2016); forest biomass, carbon dynamics (Gautam and Mandal, 2016a), litter dynamics (Gautam and Mandal, 2016b), Nitrogen mineralization (Mandal, 2011), restoration of soil in landslide damaged forest (Mandal, 2012) etc. Similar type of studies needs to be extended in other parts of the landscape.

Status and movement of higher mammals have been undertaken using radio-collar and camera trap (Shrestha and Lapeyre, 2018). It is also extremely important to understand animal behaviour such as monkeys, Asiatic elephant to address issues related to human wildlife conflict.

(iii) **Ethnobiological study and economic botany**: The landscape is rich in cultural diversity and associated traditional knowledge. Ethnoecological study of Tharus, Mooshar, Danuwars, Tamangs, etc. have been undertaken (Manandhar, 2002). In the current perspective of 'Access to Genetic Resources and Benefit Sharing' traditional ecological knowledge of the community based on biological resources need to be conducted and mainstreaming to national process. There are many wild products that are collected and traded in the market. Value addition of those biological resources need to be seriously considered before entering to trade.

(iv) **Mycology, microbiology and plant pathology**: Study of the pathogens and microorganisms that are harmful to plant and animal species are often overlooked.

(v) **Biotechnology, tissue culture and genetic diversity**: Biotechnological tools have been used to propagate commercially valuable plants, orchids and medicinal plants. Study at the genetic level need to be applied to understand the genetic diversity of rare, endangered, threatened biodiversity.

(vi) **Environmental degradation**: Urbanization process is expanding in landscape that has adding pollution to the environment. Regular monitoring of pollution (water, air, soil etc) at the landscape should be given a priority. Forest fire is also rampant in the landscape causing loss of biodiversity. A multistakeholders' management practice can mitigate forest fire in the landscape.

(vii) **Nature/biodiversity/culture based tourism**: The nature/biodiversity/culture based tourism particularly focusing on protected areas system provide opportunities for income generation, however, there is also a threat to sustainably manage the resources. Priority should be given to equity in benefit sharing from the tourism sector as well as inclusiveness of indigenous and local communities in programme initiation, development, implementation and monitoring.

(viii) **Long-term Socioecological and Environmental monitoring**: Lack of social, ecological, and environmental data, rapidly changing land-use pattern, data gap on climate change and related issues, emerging problem of food security, health issues, solid

waste management, etc. need to be addressed in the landscape. Systematic long term socio-ecological and environmental monitoring is necessary to be undertaken to achieve the goal of sustainable development.

(ix) Economic valuation of ecosystems: Economic valuation of ecosystem is important to understand the issues of ecosystem services, as well as to formulate long-term strategy for resilience of ecosystems. Such type of studies are very meager. A good example includes economic valuation of ecosystem services of the Koshi Tappu which is estimated around 1.4 billion NPR per year; this is around NPR 78,840 per hectare (ICIMOD and MoFSC, 2014).

(x) Regional cooperation: Regional cooperation in particular with India is important to address transboundary issues in the CTML such as illegal wildlife trade, wildlife movement, transboundary grazing, etc.

Conclusions and Way forward

The Chure-TaraiMadhesh Landscape is environmentally dynamic, socially complex, and economically poor. The landscape holds rich biodiversity comprising big opportunities for sustainable development. The landscape is linked with mountain landscape in the north, and across the Indian border in the south; hence, it should be addressed in a holistic way. There should be trade off in conservation of biodiversity and development of the landscape in sustainable way. There is need to generate new scientific multidisciplinary data and initiate knowledge management. A few way forward proposed are, strengthening capacity of academic institutions and stakeholders; establishing database centre for knowledge management in the landscape; prioritize research thematic areas for scientific research; undertake economic valuation of biological and other resources; raise awareness about upstream-downstream linkages and consequences of biodiversity and ecosystem services loss at the local and national levels, and land-use and climate change. Regional cooperation with India could be meaningful to address common issues of conservation such as human-wildlife conflict, illegal timber and non-timber trade, sustainable tourism, and including generation of biodiversity and socio-economic data through research collaboration with relevant institutions of the two countries. A multidisciplinary approach is essential to address complex issues in the landscape.

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Table 1: Important plant areas in Chure-Tarai Madhesh Landscape

IPA complex	Number of site	District(s)
Lower Mahakali-Seti	1	Dadeldhura
Lower Bheri (Veri)-Rapti	2	Salyan and Surkhet
Tarai Arc Landscape- Nepal	8	Kailali, Bardia, Banke, Dang, Palpa, Nawalparasi, Chitwan, Parsa
Rapti- Lumbini	2	Pyuthan and Argahkhanchi
Narayani	2	Makwanpur and Bara
Lower Janakpur	2	Sarlahi and Sindhuli
Udayapur	1	Udayapur
Lower Kangchenjungha	1	Ilam

(Source: Hamilton and Radford, 2007)

Table 2: IBAs and Globally threatened category and number of birds in the landscape

S.N.	Name of IBAs	Globally Threatened category (Number of bird species)
1	Barandabhar Forest and wetlands	Near-threatened (10); Vulnerable (4); Critical (2)
2	Bardia National park	Near-threatened (12); Vulnerable (7); Critical (2); Endangered (2)
3	Chitwan National Park	Near-threatened (15); Vulnerable (15); Critical (2); Endangered (3)
4	Dang-Deukhuri Foothills Forest and West Rapti Wetlands	Near-threatened (2); Vulnerable (1); Critical (2)
5	Ghodaghodi Lake Area	Near-threatened (2); Vulnerable (2); Critical (2)
6	Jagdishpurreservior	Near-threatened (3); Vulnerable (3); Critical (2)
7	KoshiTappu Wildlife Reserve	Near-threatened (13); Vulnerable (15); Critical (2); Endangered (3)
8	Farmlands in Lumbini Area	Near-threatened (4); Vulnerable (6); Critical (2)
9	Mai Valley Forests	Near-threatened (7); Vulnerable (4); Critical (2)
10	Nawalparasi Forests	Near-threatened (3); Vulnerable (2); Critical (2)
11	Parsa National Park	Near-threatened (1); Vulnerable (2); Critical (2)
12	Shukla Phanta National Park	Near-threatened (11); Vulnerable (11); Critical (2);Endangered (2)
13	Urlabari Forest Grooves	Vulnerable (1)

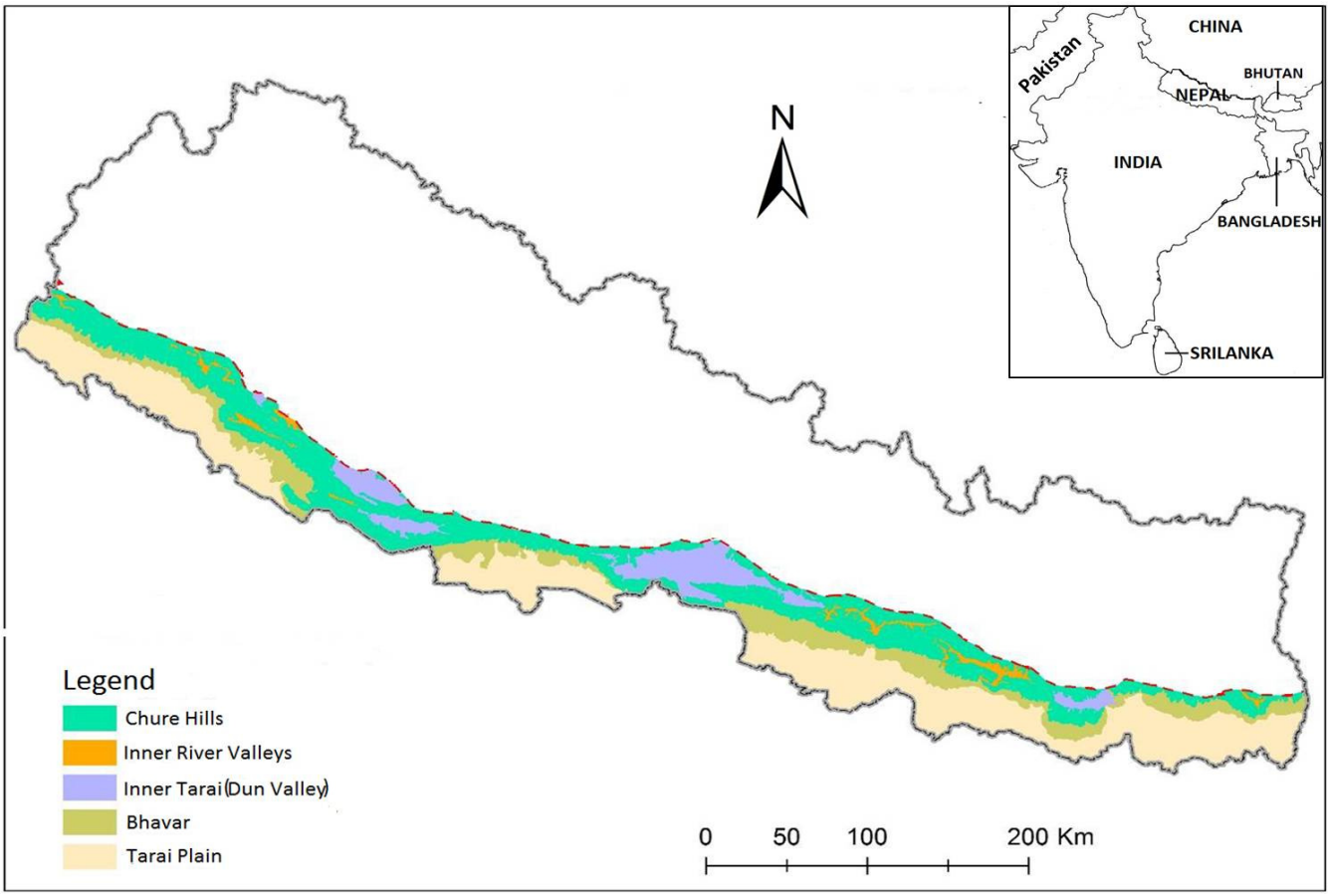
(Source: Baral and Inskipp, 2005)

*Recently 37 IBAs has been identified in Nepal (BCN, 2018, cf MOFE, 2018)

Table 3: Ramsar sites in CTM Landscape

S.N.	Name	Area (ha)	Elevation	District
1.	KoshiTappu	17,500	80	Sunsari & Saptari
2.	Bishazari Lake	3,200	286	Chitwan
3.	Jagadishpur Lake	225	197	Kapilvastu
4.	Ghodaghodi Lake	2,563	205	Kailai

(Source: GoN-RCTM, 2017)



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