Government of Nepal
Ministry of Forests and Environment
Forest Research and Training Centre
Ecosystem and Forest Types Mapping Program

Inception Report

February 2021

(Revised, July 2021)

(Approved by the second meeting of the Program Coordination Committee, 27/08/2021)

Program summary

Name of the Program	Ecosystem and Forest Types Mapping Program (EFTMP)
Implementing Entity	Forest Research and Training Centre (FRTC), Ministry of Forests and Environment (MoFE)
Technical Assistance	UKAID's Policy and Institutions Facility (PIF), Oxford Policy Management (OPM), USAID's Hariyo Ban Program, WWF Nepal
Budget	NRs. 109,640,000 (equivalent to USD 920,880)
Duration	2.5 years
Starting Date	28 Oct, 2020
End Date	27 March, 2023
Expected Outputs	1. Forest, grassland, wetland, and agriculture types and ecosystems' typologies defined, maps produced, and made available through open data sources. 2. Ecosystems' threats and vulnerabilities assessed, and management interventions prescribed. 3. Institutional capacity for the future monitoring of ecosystems improved.
Expected Outcomes	1. Enhanced understanding and improved decision making regarding sustainable management of Nepal's ecosystems. 2. Improved national capacity to update information to meet national and international requirements.

Executive summary

Characterization, classification and mapping of ecosystems are the key to the sustainable management of biological diversity. In Nepal, several attempts have been made in this regard time and again. However, the vegetation maps prepared by Dobremez and his colleagues in the 1970s and 1980s have been the basis of all those efforts. The Ecosystem and Forest Types Mapping (EFTM) Program, implemented by the Forest Research and Training Centre (FRTC) under the Ministry of Forests and Environment (MoFE) with the technical assistance from the UKAID's Policy and Institutions Facility (PIF) and USAID's Hariyo Ban Program, intends to update Nepal's ecosystem and forest type maps and assess vulnerability of ecosystems. This inception report presents the methodology being adopted to map the forest, grassland, wetland and agriculture types and ecosystems and assess their vulnerabilities, program implementation strategies, implementation plan, and required budget. The report will provide a basis for progress monitoring of the program's implementation.

A geo-spatial approach, which uses satellite image and field data, will be adopted to map ecosystems. In each thematic component, a typology of the land cover has been defined based on review of literature and expert knowledge. Each type of land cover units, based on the defined typology, will be mapped first, and then ecosystems will be delineated using other environmental parameters like landform, lithology and macro-climate. Consultation with experts and stakeholders will be carried out throughout the process, more specifically during designing methodologies and product verification.

An institutional arrangement with three tiers of governing structures has been set up for the Program. The Program Advisory Committee, chaired by the Secretary, MoFE, is in place to provide strategic direction, guidance and policy support. The maps produced by the Program will be approved by this body. The Program Coordination Committee, chaired by the Director General of the FRTC, is there to facilitate coordination and communication with stakeholders, monitor progress and provide support for fieldwork. The Ecosystem Mapping Unit, coordinated by an Under Secretary, FRTC, acts as a technical working group to implement the program.

The Program was originally scheduled to run for two years, starting from 28th Oct, 2020. The preparatory activities, including detailed design of methodology and hiring of and training to field crew, were accomplished before March 2021. The first field survey mission was completed in April 2021. However, the field survey has been paused for five months due to the COVID-19 pandemic; it is expected to resume in October 2021 and complete by November 2022. This has led to a situation that the final products, i.e. maps and reports, will be prepared only by March 2023. The Program budget is estimated to be NRs. 10,96,40,000 (equivalent to USD 920,880).

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Acronyms

AEZ	Agro-ecological Zone
BRDF	Bidirectional Reflection Distribution Function
CART	Classification and Regression Tree
DDG	Deputy Director General
DG	Director General
EFTMP	Ecosystem and Forest Types Mapping Program
EMU	Ecosystem Mapping Unit
EVI	Enhanced Vegetation Index
F&GL	Forest and Grassland
FRA	Forest Resource Assessment
FRTC	Forest Research and Training Centre
GEE	Google Earth Engine
GEOSS	Global Earth Observation System of Systems
GIS	Geographic Information System
ICIMOD	International Centre for Integrated Mountain Development
IUCN	International Union for Conservation of Nature
MoFE	Ministry of Forests and Environment
NDVI	Normalised Difference Vegetation Index
NDWI	Normalised Difference Water Index
NLCMS	National Land Cover Monitoring System
OPM	Oxford Policy Management
PAC	Program Advisory Committee
PCC	Program Coordination Committee
PET	Potential Evapotranspiration
PIF	Policy and Institutions Facility
QA/QC	Quality Assurance/Quality Control
RF	Random Forest
RS	Remote Sensing
SAR	Synthetic Aperture Radar
SAVI	Soil Adjusted Vegetation Index
SMI	Soil Moisture Index
SOP	Standard Operating Procedure
SRTM-DEM	Shuttle Radar Topography Mission - Digital Elevation Model
SVM	Support Vector Machine
TA	Technical Advisor
TPI	Topographic Position Index
TWI	Topographic Wetness Index

1. Introduction

Characterization, classification and mapping of ecosystems are the key to the sustainable management of biological diversity. In Nepal, several attempts have been made in this regard time and again. However, the vegetation maps prepared by Dobremez and his colleagues in the 1970s and 1980s have been the basis of all those efforts. The existing classifications of ecosystem are based on limited field studies of vegetation composition and structure, and analysis of bioclimatic and ecological conditions. In this context, Forest Research and Training Centre (FRTC) has initiated the Ecosystem and Forest Type Mapping Program (EFTMP) to standardize the classification of Nepal's ecosystems and forest types, and update the related maps based on a comprehensive and systematic study. The program aims to inform decision making regarding management and conservation of diverse ecosystems in Nepal.

This inception report of the EFTM Program presents the methodology to be adopted to map the forest and grassland, wetland and agriculture types and corresponding ecosystems and assess their vulnerabilities, program implementation strategies, implementation plan, and required budget. The report will provide a basis for progress monitoring of the program's implementation.

2. Objectives of the Program

The general objective of the EFTM Program is to inform decision making regarding sustainable management of terrestrial and wetland ecosystems of Nepal, and thereby support local as well as national economies. In addition, it is expected to generate information required to fulfill international obligations, such as reporting on the Aichi target # 14 of the Convention on Biological Diversity (CBD). The specific objectives of the Program are to:

a) Review the existing knowledge, data and maps relevant to terrestrial and wetland ecosystems of Nepal;

b) Reclassify and delineate forest, grassland, agriculture and wetland types and ecosystems, and produce appropriate maps;

c) Assess key threats and vulnerabilities to ecosystems and provide management prescriptions; and

d) Strengthen institutional capacity for monitoring of ecosystems and updating ecosystem maps of Nepal.

3. Methodology

This section details the methodologies proposed to achieve the objectives of the EFTM Program. Sub-section 3.1 presents the standardized methodology for ecosystem mapping; it is equally applicable to all thematic components, i.e. forest and grassland, wetland, and agriculture. Sub-sections 3.2, 3.3 and 3.4 outline step-by-step processes and methods applied in ecosystem mapping in the forest and grassland, wetland, and agriculture components, respectively, followed by methodology used for ecosystem vulnerability assessment in sub-section 3.5. Finally, processes and methods for establishing a system for ecosystem monitoring in future is described in sub-section 3.6.

3.1 Standardized methodology for ecosystem mapping

The standardized methodology for ecosystem mapping involves the creation of a composite map of biological community and non-living environmental parameters. The vegetation type is considered to be a proxy for a specific biological community, whereas macroclimate, lithology and landforms are the commonly used spatial parameters for the non-living environment. The homogeneity of environmental parameters with a relatively stable condition delineates the iso-potential zone with a unique habitat, and represents an ecological facet. Each ecological facet is considered as a distinct ecosystem type (Figure 1). This standardized methodology will be adopted for mapping of ecosystems in all components; however, the specific indicators may vary from one component to the other.

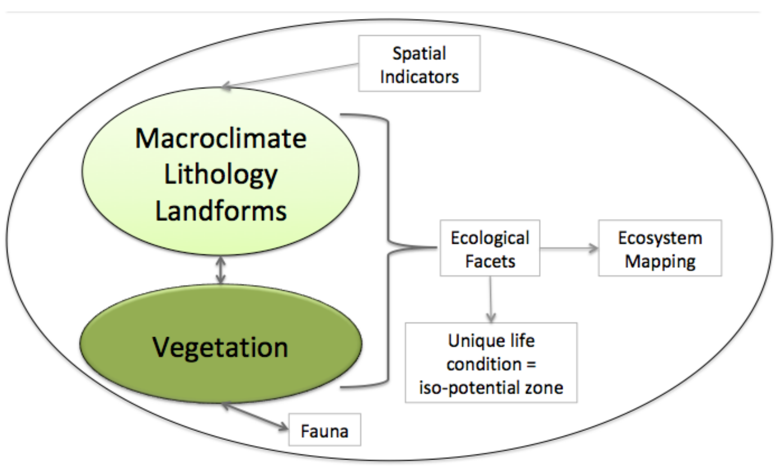

Figure 1: Standardized methodology for ecosystem mapping as developed by global earth observation system of systems

3.2 Mapping of forest and grassland types and ecosystems

3.2.1 Defining forest and grassland ecosystems

As the first step the "forest ecosystem" and "grassland ecosystem" has been defined for the purpose of this assignment. An ecosystem is defined as “a dynamic complex of plant, animal and micro-organism communities and their non-living environment interacting as a functional unit” (CBD 1992). Thus, a forest ecosystem is characterized by the presence of tree community as an important component, whereas a grassland ecosystem is characterized by the presence of grasses and other herbaceous plants. Kimmins (2003) defines forest ecosystems as "areas of the landscape that are dominated by trees and consist of biologically integrated communities of plants, animals and microbes, together with the local soils (substrates) and atmospheres (climates) with which they interact". For the purpose of mapping Nepal's ecosystems, a forest ecosystem is defined as an ecosystem in which plant community is dominated by woody perennials, including trees and shrubs. Thus, it includes land covers classified as 'forest' and 'other wooded land' as defined by FAO (2000) and adopted by the national land cover monitoring system developed by FRTC (2021). Similarly, a grassland ecosystem is defined as an ecosystem in which plant community is dominated by grasses and other herbaceous vegetation; thus it includes the land cover classified as 'grassland' by FRTC (2021). Definitions of 'forest', 'other wooded land' and 'grassland' are presented in Table 1.

Table 1: Definitions of land covers to be included in forest and grassland ecosystems

Land cover	Definition	Remarks
Forest	*Land spanning more than 0.5 hectares with trees higher than 5 meters and a canopy cover of more than 10 percent, or trees able to reach these thresholds in situ. It does not include land that is predominantly under agricultural or urban land use* [such as fruit orchards and agroforestry systems] (FAO 2000, adopted by FRTC 2021)	To be included in forest ecosystem
Other Wooded Land (OWL)	*Land not classified as 'Forest', spanning more than 0.5 hectares; with trees higher than 5 meters and a canopy cover of 5-10 percent, or trees able to reach these thresholds in situ; or with a combined cover of shrubs, bushes and trees above 10 percent. It does not include land that is predominantly under agricultural or urban land use* (FAO 2000, adopted by FRTC 2021).	To be included in forest ecosystem
Grassland	*Areas covered by herbaceous vegetation with cover ranging from Closed to Open (15-100%). It includes*	To be included in grassland ecosystem

	rangeland and pasture that is not considered cropland (FRTC 2021).	

3.2.2 Defining vegetation (forest and grassland) typology of Nepal

The vegetation type is one of the major indicators defining a terrestrial ecosystem. Therefore, it is necessary to delineate/map vegetation types before delineating/mapping forest and grassland ecosystems. Defining vegetation typology is helpful to map forest and grassland types using geospatial approach. Different assessments in the past have variously defined Nepal's vegetation types. Therefore, a new vegetation typology has been proposed (Table 2). It has been developed based on an extensive review of the past assessments, such as Stainton (1972), Dobremez (1976), Jackson (1994), BPP (1996), TISC (2002), DFRS (2014, 2015) and Miehe (2015), analysis of the FRA data (1436 plots), and consultation with experts. The vegetation type mapping will be initiated using this typology. Various attributes of forest and grassland types, given in their definitions, will be used for stratification for sampling. The vegetation types that might be missing from this list but identified later during mapping exercise or field survey will be added later. Also, two or more vegetation types will be merged together if required.

Table 2: Proposed vegetation typology for the forest and grassland type mapping

SN	EFTMP Vegetation Type	Operational definition	Altitude range (m)	Symbol
Forest types				
1	*Tectona grandis* Forest	A plantation forest predominated by *Tectona grandis,* found in the tropical zone [such as Chiliya (Rupandehi) Tamagadhi (Bara), Sagarnath (Sarlahi) and Ratuwamai (Jhapa)]	Below 300	Te.gr
2	*Eucalyptus* Forest	A plantation forest predominated by *Eucalyptus species,* found in the tropical zone [such as Ratuwamai and Sagarnath area)	Below 300	Eu.sp
3	Tropical Mixed Broadleaved Forest	A tropical mixed broadleaved forest having common species like *Shorea robusta, Terminalia species, Butea frondosa, Anogeissus latifolia, Adina cordifolia, Aegle marmelos, Lannea grandis, Duabanga grandiflora, Dilenia pentagyna, and Lagerstroemia parviflora*, but without predominance of a particular species (no single species having equal to or above 60% of the total basal area)	Below 1000	TMBF
4	Tropical Evergreen Riverine Forest	A tropical mixed evergreen forest having common species like *Michelia champaca, Eugenia jambolana, Phoebe lanceolata, Mangifera sylvatica, Diospyros species, Machillus villosa, Acer oblongum, Bassia buryraceae, Acer oblungum, Xylosma longifolium, Ormosia glauca,* with some deciduous trees like *Cedrela toona, Albizzia species, Acrocarpus fraxinifolius, Garuga pinnata and Duabanga sonneratioides,* found along water courses in the Tarai, Bhabar, Dun valleys and Churia hills.	Below 1000	TERF

		Castanopsis tribuloides, C. indica, Quercus glauca can occur above 2000 ft.		
5	*Shorea robusta* Forest	A tropical deciduous broadleaved forest predominated by *Shorea robusta* (with its basal area equal to or above 60%).	Below 1200	Sh.ro
6	*Dalbergia sissoo-Senegalia catechu* Forest	A tropical deciduous broadleaved forest co-dominated by *Acacia catechu* and *Dalbergia sissoo* (both combinedly having equal or over 60% of the total basal area), found in the riverine habitats, specifically on the relatively new floodplains along the large rivers	Below 1200	Ds-Sc
7	*Terminalia* Forest	A tropical to subtropical deciduous broadleaved forest pre-dominated by *Terminalia species*, i.e. *T. tomentosa, T. chebula, T. belerica, T. myriocarpa*) (with its basal area equal to or above 60%), common associates being *Eugenia jambolana, Lagerstroemia parviflora, Dillenia pentagyna, Adina cordifolia and Cedrela toona, common in the Churia and Duns.*	Below 1200	Term
8	*Anogeissus latifolia* Forest	A tropical to subtropical deciduous broadleaved forest pre-dominated by *Anogeissus latifolia*		An.la
9	Tropical Deciduous Riverine Forest	A tropical deciduous mixed broadleaved forest having common species like *Bombax ceiba, Holoptelea integrifolia, Schleichera trijuga, Ehretia laevis, Trewia nudiflora* and *Garuga pinnata*, found on the old river terraces.	Below 1400	TDRF
10	*Pinus roxburghii* Forest	A subtropical evergreen conifer forest predominated by *Pinus roxburghii* (with its basal area equal to or above 60%), found mostly on the south-facing slopes.	500-2000	Pi.Ro
11	*Albizia julibrissin-Toona ciliata* Forest	A tropical to subtropical, partly deciduous and dominantly evergreen broadleaved forest co-dominated by *Albizia jilibrissin* and *Toona ciliata* (both combinedly having equal to or above 60% of the total basal area), found in the riverine habitats in the eastern and central regions	600-1700	Al-To
12	Subtropical Mixed Evergreen Forest	A subtropical evergreen broadleaved forest having common species like *Eugenia tetragona, E. ramosissima, Ostodes paniculata, Drimycarpus racemosus, Lithocarpus spicata, Acer thomsonii, A. oblungum, Machilus species, Castanopsis indica, C. tribuloides, Phoebe lanceolata, Cryptocarya amygdalina, Cinnamomum species, Turpinia nepalensis, Bassia butyraceae, Helicia erratica, Macaranga pustulata, Alnus nepalensis, Erythrina suberosa, Cedrela toona, Albizzia lebbek, A. chinensis, Schima wallichii, Leucosceptrum canum, Eurya acuminata, Talauma hodgsonii, Symplocos spicata, Laportea sinuata, Miliusa macrocarpa, Mahonia napaulensis, Caseria graveolens, Amoora decandra,* found east of the Tamur valley	900-1700	SMEF
13	*Castanopsis-Schima Forest* (also*, Castanopsis* Forest*, Schima* Forest separately if any)	A subtropical evergreen broadleaved forest co-dominated by *Castanopsis species* and *Schima wallichii* (both combinedly having equal to or above 60% of the total basal area). [Pure forests of Castanopsis or Schima will be considered if any of them predominates the forest]	1000-2000	Ca-Sc
14	*Pinus roxburghii-Shorea robusta* Forest	A subtropical mixed broadleaved-conifer forest co-dominated by *Shorea robusta* (broadleaved) and *Pinus roxburghii* (conifer)		Pr-Sr

		(each having 33-60% of the total basal area), found specifically in the Churia region.		
15	*Pinus roxburghii*-Mixed Broadleaved Forest	A subtropical mixed broadleaved-conifer forest dominated by *Pinus roxburghii* (*Pinus roxburghii* having 33-60% of the total basal area), common associates being *Quercus incana, Q. lanata, Rhododendron arboreum, Lyonia ovalifolia* (in the west), *Schima wallichii* (in the central and eastern region), *Engelhardtia spicata* and *Erythrina stricta.*	1000-2000	Pr-MBF
16	*Olea* Forest	A subtropical evergreen broadleaved forest predominated by *Olea species* (with its basal area equal to or above 60%), found in the dry valley bottoms and lower slopes in the Bheri valley	1000-2100	Olea
17	*Alnus* Forest (*Alnus nepalensis* forest, *Alnus nitida* forest, if the latter has large enough area to be delineated separately)	A subtropical deciduous broadleaved forest predominated by *Alnus species* (with its basal area equal to or above 60%), found along streams and moist mudflows (*Alnus nitida* in Mugu Karnali and *Alnus nepalensis* elsewhere)	1000-2450	Alnus
18	*Quercus incana* Forest	A subtropical evergreen broadleaved forest predominated by *Quercus incana* (with its basal area equal to or above 60%), found specifically west of the Karnali river	1200-2400	Qu.in
19	*Rhododendron arboreum* Forest	A temperate evergreen broadleaved forest predominated by *Rhododendron arboreum* (with its basal area equal to or above 60%), commonly found as a single-storeyed, mono-specific, even-aged and closed forest, mostly on southern exposure.	1200-4000	Rh.ar
20	*Quercus lanata* Forest	A subtropical evergreen broadleaved forest predominated by *Quercus lanata* (with its basal area above 60%), found in the central and eastern mountains	1500-2400	Qu.ln
21	*Quercus incana - Quercus lanata* Forest	A mixed evergreen forest co-dominated by Quercus incana and Q. lanata (each having 33-60% of the total basal area)	1650-2400	Qi-Ql
22	*Pinus patula* Forest	A plantation forest dominated by *Pinus patula*, found in the subtropical and temperate zones (specifically in Kavre Palanchok and Sindhupalchok districts)	1500-2500	Pi.pa
23	Warm Temperate Mixed Broadleaved Forest	A temperate mixed, mostly evergreen, broadleaved forest having common species like *Machilus duthiei, M. odoratissima, M. sericea, Phoebe lanceolata, P. pollida, Cinnamomum tamala, Actinodaphne reticulata, Lindera bifaria, L. neesiana, Litsea oblonga, L. citrata, Neolitsea umbrosa, N. lanuginosa , Michelia kisopa, Lithocarpus spicata, Quercus glauca, Castanopsis tribuloides, Betula alnoides, Alnus nepalensis, Dalbergia hircina, Albizzia mollis, Acer oblongum, Cedrela toona, Juglans regia, Ehretia macrophylla, Engelhardtia spicata, Schima wallichii, Michelia doltsopa, Cucklandia populnea, Carpinus viminea, Acer thomsonii.* **The second canopy consists of** *Lindera pulcherrima, Neolitsea umbrosa, Dodecadenia grandiflora, Eriobotrya elliptica, Sapium insigne, Daphnephyllum himalayense, Macaranga denticulata, M. pustulata, Myrsine semiserrata, Symplocos theaefolia, S,*	1500-2200	LTMB

		ramosissima, Prunus undulata, Rhododendron arboreum, Sarauja napaulensis etc.		
24	*Quercus lamellosa* Forest	A temperate evergreen broadleaved forest predominated by *Quercus lamellosa* (with its basal area above 60%), found in the eastern mountains	1600-2800	Qu.lm
25	*Pinus wallichiana* Forest	A temperate to subalpine evergreen conifer forest, predominated by *Pinus wallichiana* (with its basal area above 60%), found mostly on sunny slopes	1600-3600	Pi.wa
26	*Pinus wallichiana-Quercus Species* Forest	A mixed broadleaved-conifer forest co-dominated by *Pinus wallichiana* and *Quercus species*.		Pw-Qs
27	*Juglans regia* Forest	A temperate deciduous broadleaved forest predominated by *Juglans regia* (with its basal area above 60%), found on moist sites, specifically in Jagadulla Municipality, Dolpa district	1800-2800	Ju.re
28	*Cedrus deodara* Forest	A temperate evergreen conifer forest predominated by *Cedrus deodara* (with its basal area above 60%), found on rocky slopes of inner valleys in western mountains	1800-3000	Ce.de
29	*Acer-Aesculus* Forest	A temperate deciduous broadleaved forest co-dominated by *Acer species* and *Aesculus indica* (both combinedly having equal to or above 60% of the total basal area), found on shady slopes along streams in the western mountains	1800-3100	Ac-Ae
30	*Quercus floribunda* Forest	A subalpine deciduous broadleaved forest predominated by *Quercus floribunda* (with its basal area above 60%), found on shady slopes	1900-2900	Qu.fl
31	*Hippophae salicifolia* Forest	A temperate to subalpine deciduous broadleaved forest predominated by *Hippophae salicifolia* (with its basal area above 60%), found mainly on river gravels of the rain-shadowed inner valleys	2000-3400	Hi.sa
32	*Pinus wallichiana-Abies species* Forest	A mixed conifer forest co-dominated by *Pinus wallichiana* and *Abies species*		Pw-As
33	*Abies pindrow* Forest	A temperate to subalpine evergreen conifer forest predominated by *Abies pindrow* (with its basal area above 60%), found in the western mountains	2000-3500	Ab.pi
34	*Abies-Quercus-Tsuga* Forest	A mixed broadleaved-conifer forest having *Abies species, Quercus species* and *Tsuga dumosa*.		Ab-Qu-Ts
35	*Abies-Quercus-Rhododendron* Forest	A mixed broadleaved-conifer forest having *Abies species, Quercus species* and *Rhododendron species*.		Ab-Qu-Rh
36	*Tsuga dumosa* Forest	A temperate evergreen conifer forest predominated by *Tsuga dumosa* (with its basal area above 60%), found generally on the southern slope in the west and northern slopes of the inner valleys in the eastern region	2100-3000	Ts.du
37	*Picea smithiana Forest*	A temperate evergreen conifer forest predominated by *Picea smithiana* (with its basal area above 60%), found on the shady slopes in the central and western mountains	2100-3600	Pi.sm
38	*Populus ciliata* Forest	A temperate to subalpine deciduous broadleaved forest predominated by *Populus ciliata* (with its basal area above 60%), found in the riverine habitats of the inner valleys west of the Trishuli river	2100-3600	Po.ci

39	*Quercus semecarpifolia* Forest	A temperate evergreen broadleaved forest predominated by *Quercus semecarpifolia* (with its basal area above 60%), found mostly on southern slopes	2200-3500	Qu.se
40	*Quercus semecarpifolia-Rhododendron species* Forest	A mixed forest co-dominated by *Quercus semecarpifolia* and *Rhododendron species*		Qs-Rs
41	*Lithocarpus pachyphylla* Forest	A temperate evergreen broadleaved forest predominated by *Lithocarpus pachyphylla* (with its basal area above 60%), found on the south-facing slope in the eastern mountains	2400-2900	Li.pa
42	*Acer-Magnolia* Forest	An upper temperate deciduous broadleaved forest co-dominated by *Acer species* and *Magnolia campbelli* (each having 33-60% of the total basal area), found on steep humid slopes in the eastern mountains	2500-3000	Ac-Ma
43	Cool Temperate Mixed Broadleaved Forest	A mixed forest if not co-dominated by *Acer* and *Magnolia species* or *Acer* and *Rhododendron species* between 2500 and 3000 m.		UTMB
44	*Cupressus torulosa* Forest	A temperate evergreen conifer forest predominated by *Cupressus torulosa* (with its basal area above 60%), found in western mountains	2500-3200	Cu.to
45	*Acer-Rhododendron* Forest	An upper temperate mixed broadleaved forest co-dominated by *Acer species* and *Rhododendron arboreum* (each having 33-60% of the total basal area), found in the eastern region, specifically in the Arun and Tamor valleys	2600-3000	Ac-Rh
46	*Rhododendron hodgsonii* Forest	A subalpine evergreen broadleaved forest predominated by *Rhododendron hodgsonii* (with its basal area above 60%), found as a low to dwarf, gnarled, single-storeyed forest rich in bryophytes or lichen epiphytes on the wet slopes in the eastern region	3000-4000	Rh.ho
47	*Abies pindrow-Abies spectabilis* Forest	A mixed forest *co-dominated by Abies pindrow* and *Abies spectabilis.*		Ap-As
48	*Abies spectabilis* Forest	A subalpine evergreen conifer forest predominated by *Abies spectabilis* (with its basal area above 60%)	3000-4200	Ab.sp
49	*Juniperus recurva* Forest	A subalpine evergreen conifer forest predominated by *Juniperus recurva* (with its basal area above 60%), found on the south-facing rocky cliffs	3000-4300	Ju.re
50	*Abies densa* forest	A subalpine evergreen conifer forest predominated by *Abies densa* (with its basal area above 60%), found particularly in Tamor valley	3000-4350	Ab.de
51	*Larix* Forest (*Larix himalica* forest and *Larix griffithiana* forest, separately if possible)	A subalpine deciduous conifer forest predominated by *Larix species* (with its basal area above 60%), found on rocky slopes of deep valleys in the eastern mountains (*Larix himalica* in Shiar Khola, Langtang, upper Trisuli, and *Larix griffithiana* from Rolwaling to the southeastern inner valleys)	3000-4100	Larix
52	*Juniperus indica* Forest	A subalpine evergreen conifer forest predominated by *Juniperus indica* (with its basal area above 60%), found on the rocky slopes of inner valleys	3000-4500	Ju.in

53	*Betula-Rhododendron* Forest	A mixed forest co-dominated by *Betula utilis* and *Rhododendron species*		Be-Rh
54	*Betula utilis* Forest	A subalpine deciduous broadleaved forest predominated by *Betula utilis* (with its basal area above 60%), found around tree line	3600-4200	Be.ut
Shrubland types				
55	*Caragana sukiensis* Scrub	A temperate to subalpine shrubby vegetation formation dominated by *Caragana sukiensis* (with its crown coverage above 60% of the total vegetation cover), found on southern exposures of the inner valleys west of Langtang (largest stand in the upper Langtang Valley)	2400-3700	Csuk
56	*Caragana gerardiana* Scrub	A temperate to subalpine spiny cushion vegetation formation dominated by *Caragana gerardiana* (with its crown coverage above 60% of the total vegetation cover), found on gravel terraces in the lower range of the Trans-Himalayan region	2600-3900	Cger
57	*Hippophae tibetana* Scrub	A subalpine to alpine shrubby vegetation dominated by *Hippophae tibetana* (with its crown coverage above 60% of the total vegetation cover), found in the riverine habitats of the Trans-Himalayan region	3500-5000	Htib
58	*Rhododendron* Scrub	An alpine vegetation dominated by *Rhododendron species* in their shrubby and dwarf forms (with its crown coverage above 60% of the total vegetation cover), found on moist slopes	3700-4400	RS
59	*Juniperus* Scrub	An alpine vegetation dominated by *Juniperus species* in their dwarf forms (with its crown coverage above 60% of the total vegetation cover), found on dry slopes	3700-5000	JS
60	*Caragana versicolor* Scrub	A subalpine to alpine spiny cushion vegetation formation dominated by *Caragana versicolor* (with its crown coverage above 60% of the total vegetation cover), found on the sandy and silt-rich mineral soils of gentle slopes in the upper range of the Trans-Himalayan region	4400-5000	Cver
Grassland types				
61	Tropical Savannah	A tropical grassland dominated by *Saccharum-Phragmatis* association, in which trees such as *Bombax ceiba, Albizia chinensis* and *Trewia nudiflora* are often present, found on the old, consolidated flood plains (For example, in parts of Koshi Tappu, Shuklaphanta, and Chitwan National Park)	Below 300	TS
62	Tropical Riverine Grassland	A tropical tall dense grassland dominated by *Saccharum spontaneum, Narenga porphyrocoma* and *Themeda arundinacea,* found on the recent flood plains (seasonally flooded area) along the large rivers in the Tarai, Bhabar and Duns. *Phragmites karka, Narenga porphyrocoma* and *Arundo donax* prevail in year-round waterlogged sites.	Below 400	TRG
63	Tropical Hill Grasslands	Grasslands found in Churia hills (specific types to be identified through field survey)	400-1000	THG
64	Subtropical Grasslands	Grasslands found in sub-tropical region (specific types to be identified through field survey)	1000-2000	SG

65	Temperate Grasslands	Grasslands found in temperate region (specific types to be identified through field survey)	2000-3000	TG
66	Pioneer plant successions in glacial forelands	The recently exposed fluvo-glacial sands, gravels and boulders colonized by alpine vegetation, such as carpets of mosses (*Bryum* spp), Lichens (*Gyalidea scutellaris*, *Stereocaulon* spp), Rosettes of *Epilobium* spp, *Senecio albopurpureus*, carpets of *Stellaria decumbens,* and the creeping mat-forming dwarf shrubs of *Myricaria species* and *Oxyria digyna*	3520-4000	PPSG
67	*Kobresia nepalensis* Grasslands	An alpine land covered by *Kobresia nepalensis*, found on humid southern exposure, specifically in the eastern region	3600-5000	Ko.ne
68	Upper Alpine Grasslands (meadows)	A high alpine herbaceous vegetation formation dominated by grass species like *Carex species, Calamogrostis species, Agrotis micantha* and *Festuca leptogonum*, found mostly on the south faces of the main Himalaya	4500-5000	UAM
69	*Kobresia pygmaea* Grasslands	A high alpine land covered by smooth mats of *Kobresia pygmaea* (the smallest of the High Asian Cyperaceae), forming a uniform lawns with up to 95% plant cover, found on the moraine slopes in the headwaters of the inner valleys and the rolling hills in the arid zone	4700-5100	Ko.py

Note: "Inner valleys" are the valleys in the rain shadowed area that drain southwards, mostly between 2500 and 4500m.

Source: Stainton (1972), Jackson (1994), BPP (1996), TISC (2002), DFRS (2014, 2015), Miehe et al. (2015), FRA data (FRTC, nd)

3.2.3 Step-by-step methods of forest and grassland (F&GL) ecosystem mapping

Described below are the methodological steps that will be followed for mapping forest and grassland (F&GL) types and their corresponding ecosystems in Nepal, with the methodological frameworks shown in Figures 2 and 4.

Forest and Grassland Types Mapping

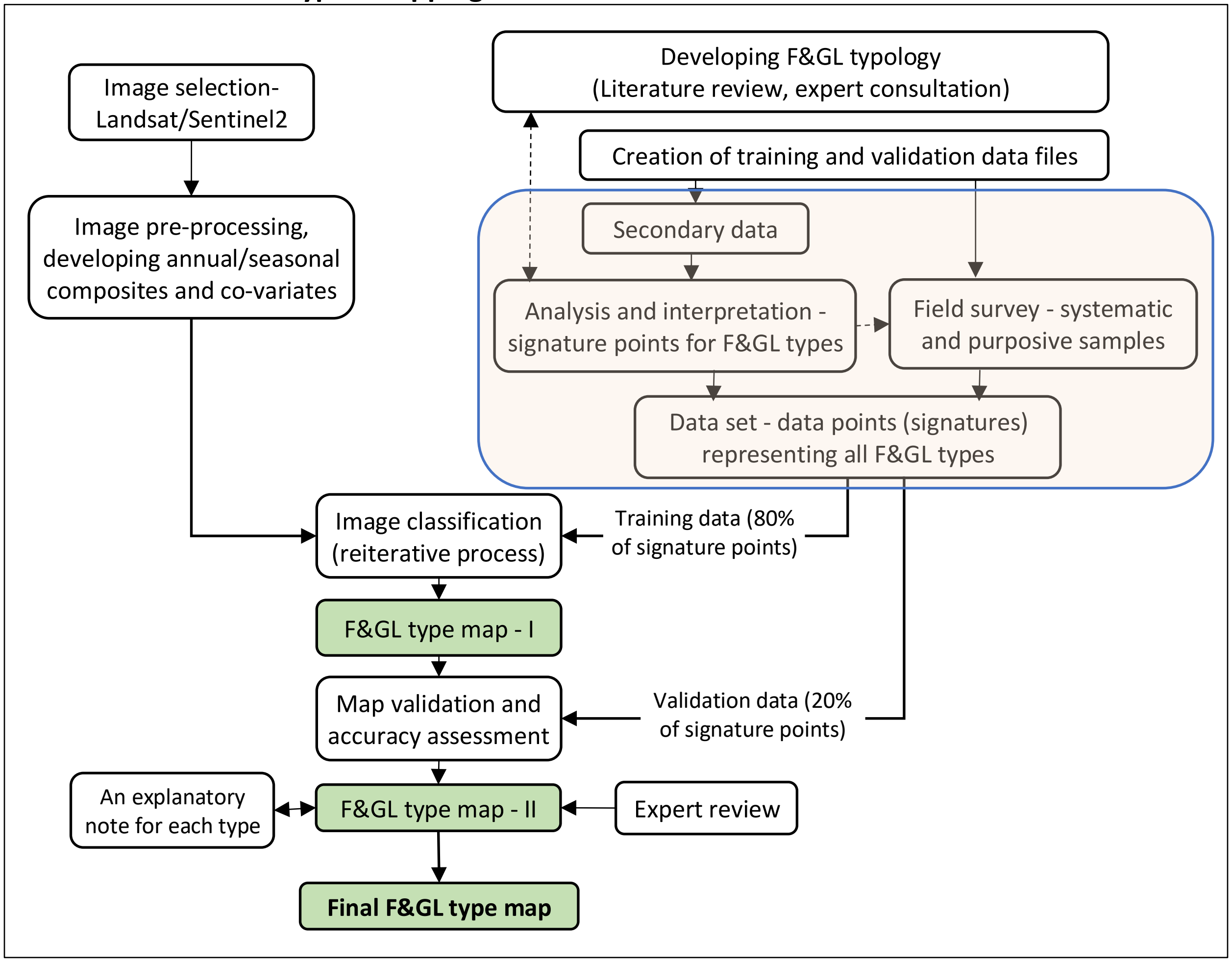

Figure 2: Methodological framework for forest and grassland type mapping

Step 1. Developing forest and grassland typology

The forest and grassland typology of Nepal has been developed based on a review of past assessments, analysis and interpretation of secondary data, specifically FRA plot-level data, and consultation with experts, as described earlier in Section 3.2.2. Thus, a total of 69 types of forest and grassland (60 and 9, respectively) have been identified (Table 2). This typology will help ensure the collection of sufficient signatures for each potential type of forest and grassland and their mapping. The typology, however, may need to be revised (i.e. some types may need merging while some new types may emerge) based on field data.

Step 2. Selection of satellite images

LANDSAT 8 OLI images are chosen for this mapping as they are freely available from the United States Geological Survey website with a reasonable spatial resolution of 30m, and are widely used for ecosystems and forest type mapping by many countries. Thus, these imageries ensure compatibility and consistency with national, regional and global forest area mapping and change analysis. In addition, Sentinel2 images (with 10m resolution) will also be used to

improve forest and grassland type classification through increasing image details.
The annual and seasonal composites of images will be prepared as required in the Google Earth Engine (GEE), a cloud-based platform.

Step 3. Pre-processing of images and developing co-variates
Image pre-processing will be carried out in GEE using the already established algorithm. It includes geometric correction, topographic correction, BRDF correction, radiometric correction, and cloud masking process.

Co-variates will be developed from the available bands of Landsat and Sentinel2 using band combination, band ratio, band indices (e.g. NDVI, EVI, ENVI), terrain indices (e.g. elevation, slope, aspect), and statistical matrices (e.g. standard deviation, percentile). Those co-variates will be developed from either individual image (Landsat or Sentinel2) or their combination.

These processes will be performed separately in three physiographic strata, i.e. Terai and Chure, Middle Mountains, and High Mountains and High Himalaya.

Step 4. Creation of reference data set
A set of reference data points sufficiently representing all F&GL typologies will be prepared for image classification and validation. The data will be collected from the secondary (e.g. FRA data) and primary (field survey) sources. The following activities will be carried out for this purpose.

4.1 Analysis and interpretation of the secondary data
The latest data from the FRA's permanent sample plots have been/will be analyzed and interpreted to assign a F&GL type to each sample point. With the help of F&GL typology (Table 2), each of the 1,436 plots have been defined as an F&GL type considering the species composition or dominance, particularly species-specific basal area. The data from additional sample plots being assessed by FRA will also be analyzed and included in the data set.

In addition, the signature points from other credible sources, such as that from various surveys by the FRTC, will also be collected. Similarly, signatures will be derived from known points using high resolution image or Google Earth, such as that of pure pine forests, Eucalyptus plantations etc. that are known to experts.

4.2 Field survey (collection and analysis of primary data)
The secondary data, including those of the FRA's permanent sample plots, are not sufficient for classification of satellite image to map forest and grassland types of Nepal. Therefore, additional field data are necessary for using them as training data for image classification as well as to check mapping accuracy. Thus, field survey will go hand in hand with the above image classification-related steps.

a) Sampling Design

An intensive and efficient sample distribution is planned for field data collection covering all F&GL types in five physiographic regions as well as in east-west direction. Unlike the quantitative parameters, no method is available to assess the sampling intensity for vegetation's structural and floristic composition. However, the sampling design considers Nepal's vegetation diversity that is more associated with altitude (North-South) and less with longitude (East-West).

Thus, for the Middle Mountains and upper regions, a multi-stage systematic sampling design has been adopted. At the first stage, South-North strips in each km (starting from the West) were laid throughout the country. At the second stage, a strip was randomly selected from among the first 50 strips (in the West) and then every 50th strip was selected. This maintained a total of 16 strips throughout the country. At the third stage, reference points were assigned on the land cover map (FRTC's NLCMS map, excluding glacier, snow cover and rocks and bare soil) at each 2 km along the selected strips, and those falling in the Tarai and Chure physiographic regions were omitted (Figure 3).

A different sampling design have been adopted for the Tarai and Chure. Since a large data set for forest is available in the case of Tarai and Chure regions (from FRA), the sampling is planned to capture data related to grasslands, and the forest types that are poorly represented by the FRA data (e.g. some riverine forests and plantations). Therefore, reference points for grasslands have been randomly identified using NLCMS map, whereas riverine forests will be surveyed following the major river buffers. However, samples will also be selected purposively using secondary information (e.g. literature) and discussion with local stakeholders (e.g. DFOs, NPs, WRs).

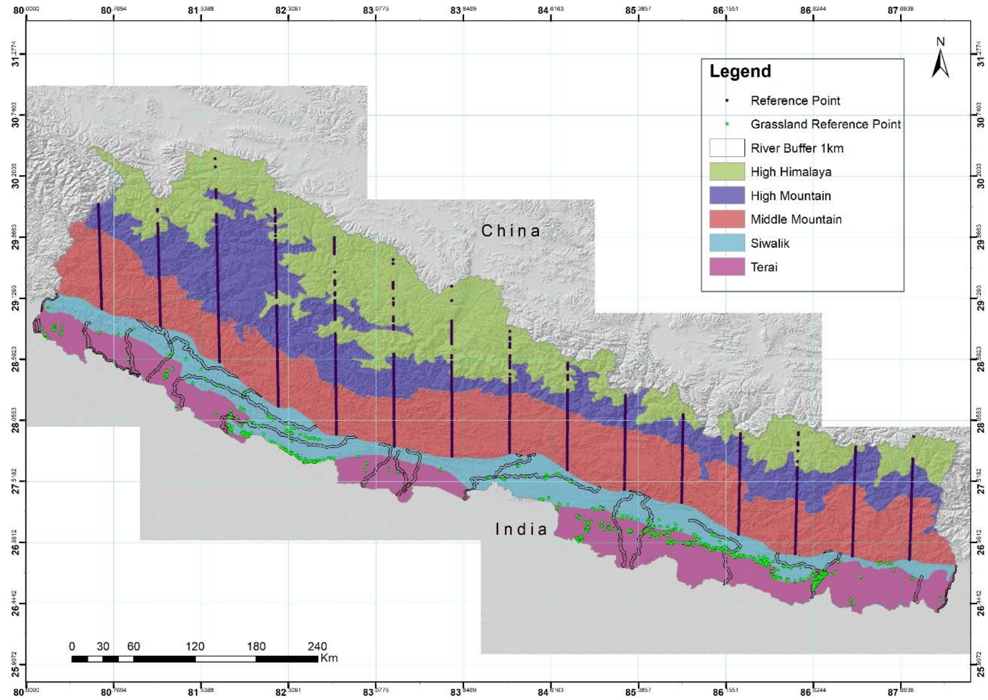

Figure 3: Forest and grassland sample distribution in and above the Middle Mountains

Note: Strip 1 (the westernmost) is missing from the map as it ends within the Tarai/Chure physiographic region.

Each grid point will be treated as a reference point, rather than a fixed sample point, for data collection. Thus,

- If the grid point truly reflects a particular F&GL type (for example, the point falls on the core area of a forest/grassland), the signature/information will be collected from that point (as a **main sample**);
- If the grid point does not truly reflect a particular F&GL type (for example, when it falls on agriculture, wetland, a transitional zone between two land cover type, two F&GL types, or a marginal land near a F&GL type), the signature/information will be collected from one or more points from around the grid point (but not from exactly the grid point) in such a way that each of those points truly represents a F&GL type (as a **main sample**);
- The signature/information of any unique F&GL types observed along the route from one grid point to the other will be collected (as a **main sample**).
- At least three F&GL signatures/information will be collected from along the route from one grid point to the other (at about every 500m) even if the F&GL type is similar to that already collected (as a **sub-sample**).

Apart from the above, a separate purposive survey may need to be carried out. For example, systematic and purposive samples along the defined transects as discussed above may not be sufficient to represent some F&GL types, specifically those which are confined to a particular area (e.g. *Juglans regia* forest). Therefore, the locations of those F&GL types will be identified through a review of literature and data and consultation with experts and stakeholders (e.g. DFOs), and they will be surveyed separately. Also, once data from all the above sampling methods are gathered, some purposive sample points may need to be surveyed in case the data set does not sufficiently represent any F&GL types.

b) Field data collection

The field data collection includes general plot information, environmental parameters, structural and floristic composition of the vegetation – tree and shrubs height and diameter, stem density, and vulnerability related parameters. The field crew will collect data and information from the systematic as well as purposive sample points representing all F&GL types, including the types which are not well documented. Field forms for data collection from the forest and grassland sampling points have been developed accordingly. A standard operating procedure (SOP) for field data collection has also been developed to assist the field crew to collect data accurately and consistently.

Five regular field crews will be mobilized for data collection for 15 months. Each crew involves a technical team consisting of a Field Crew Leader (FCL) (forestry), a Field Technical Assistant (FTA) (forestry), and a Botanist/Taxonomist. In addition, a Local Resource Person (LRP) will be hired in the field to assist the technical team. A local forestry staff will also be involved if available. The TA/Forest Specialist and Rangeland/Grassland Specialist will coordinate the fieldwork and assign and oversee the field crews providing the sample plot with geographic coordinates and a travel plan for undertaking the fieldwork.

Apart from the five regular crews, some additional teams will be mobilized for data collection from purposive samples and reassessing sample points for quality assurance and quality control (QA/QC).

c) Analysis and interpretation of the field data

The data collected from the sampling points will be entered into the database. For Quality Assurance and Quality Control (QA/QC) purposes, the Technical Advisor and other assigned professionals will validate the entered data against the original field documents. The data will be analyzed and interpreted as follows to obtain the following three types of information:

- Each sample is defined as a particular F&GL type, considering the species composition/dominance (specifically basal area), relevant notes from the field, such as F&GL type defined by the field crew, and other information like altitude, aspect etc. This information will be used as signature for image classification to generate F&GL type map.
- The data characterizing a F&GL type, such as species composition (tree/shrub/herb), vertical structure, altitude, aspect, microclimate, soil etc. will be consolidated from all sampling points of the same F&GL type. This information will serve to prepare an explanatory note for each F&GL type mapped.
- The data related to vulnerability, such as disturbances, will be consolidated from all sampling points of the same F&GL type. This information, with other relevant information from secondary sources, will be used to assess the state of vulnerability of a F&GL type.

4.3 Preparation of the training and validation data set
Sampling point data from both secondary sources (e.g. FRA plots) and the field survey will be compiled to prepare a complete data set. Each sampling point data (with a geographic location) will indicate an F&GL type, along with other relevant data like altitude and aspect. The data set will include at least 50 samples for each of the F&GL types as far as possible.

From the complete data set, 80% of samples from each type will be randomly selected to prepare a training data set, which is used for image classification. The remaining 20% of the samples will be used to validate the resulting F&GL map.

Step 5. Image classification (generating F&GL type map - I)
The annual and seasonal composites will be classified applying the machine-learning algorithm using training data set and co-variates. Various algorithms, such as Classification and Regression Tree (CART), Random Forest (RF), Support Vector Machine (SVM), and primitive-based approach will be used for classification.

For the F&GL types that are confined to a small geographic location and are represented by a small number of samples will be digitized as far as possible.

This step will produce the first draft of the F&GL type map.

Step 6. Accuracy assessment and revision of the draft map (generating F&GL map - II)
Accuracy assessment of the draft map will be carried out using the validation data sets. Area-based estimation will be generated to calculate the uncertainty of the map.

The same process will be repeated for all maps prepared by using different algorithms. The algorithm which gives the highest accuracy will be selected for the final map preparation.

The map is considered an acceptable quality with the mapping accuracy above 80% threshold. Where the map accuracy is below 80%, the error areas will be revisited, and corrected and additional data will be used to prepare the final F&GL map until the map achieves the accuracy above 80%. Training data will also be re-interpreted (e.g. two or more similar F&GL types will be merged) and applied to reclassify the map again.

This step will generate the second draft of the F&GL map with accuracy above the threshold of 80%.

Step 7. Preparation of explanatory notes
An explanatory note for each F&GL type (classified in the F&GL map - II) will be prepared based on the map attributes and the relevant field data. The note will assign an appropriate name to each F&GL type and describe it in terms of physical and floristic characters, distribution, area coverage etc.

Step 8. Expert review and generating final F&GL map

The Ecosystem and Forest Type Mapping Program (EFTMP) will engage an independent expert panel, comprising foresters, botanists, ecologists and taxonomists. They will examine the classification of F&GL types (F&GL type map - II produced in Step 6) and the corresponding explanatory notes (prepared in Step 7) and provide feedback to improve the map for a wider acceptance. The TA/Forest Specialist and Rangeland/Grassland Specialist will address the relevant feedback; and the final F&GL type map of Nepal will be produced.

Forest and grassland ecosystem mapping

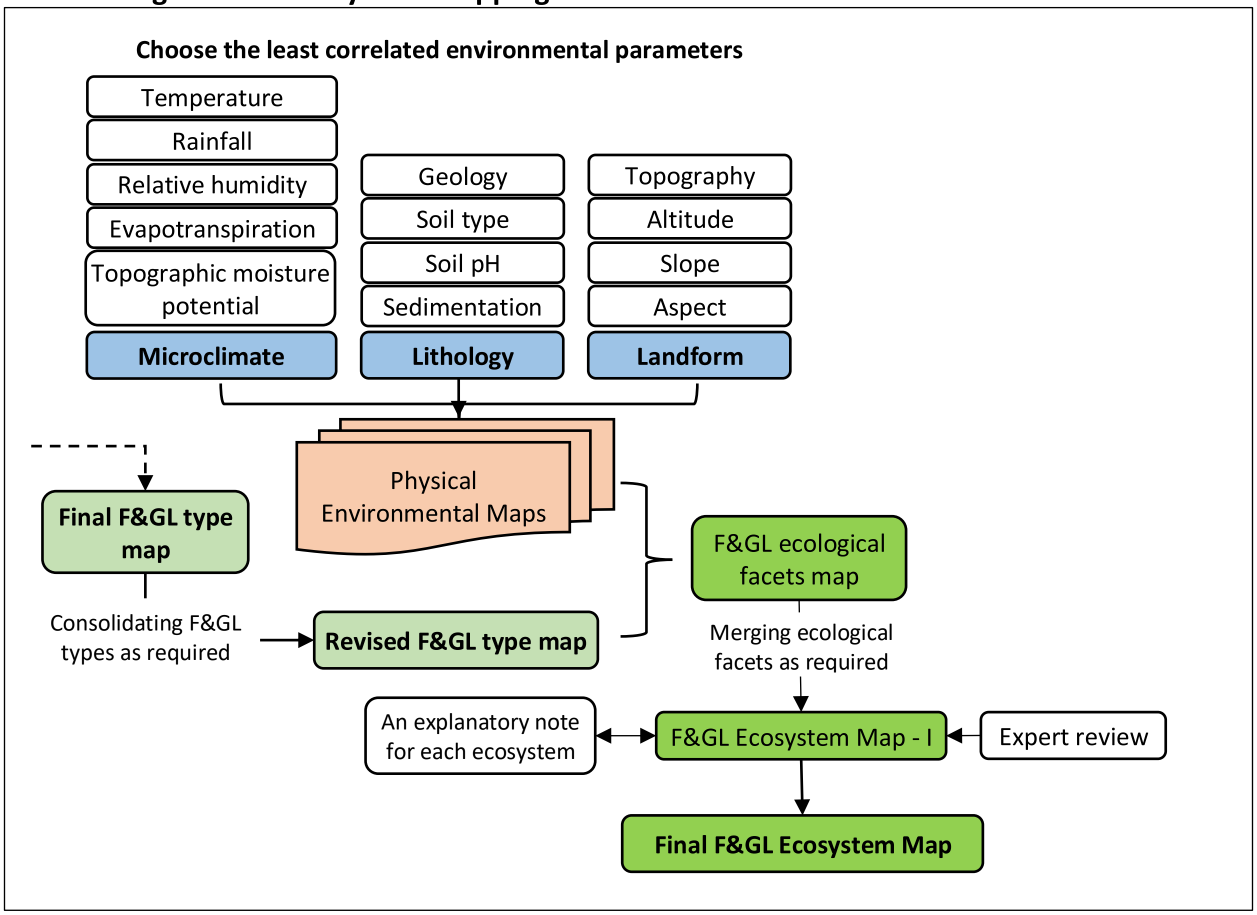

Figure 4: Methodological framework for forest and grassland ecosystem mapping

Step 9. Analysis of environmental parameters and preparation of a consolidated physical-environmental map

A standardized ecosystem mapping method will be used that considers the spatial parameters of three primary environmental variables: macroclimate, lithology and landform (Sayre et al. 2009, Sayre et al. 2014; Clarke and Lewis 2017). Extensive literature reviews have identified relevant parameters of these primary variables to determine the ecosystem formation. Table 3 lists the environmental variables and relevant parameters and the data sources for Nepal's ecosystem mapping.

Table 3: Environmental variables and parameters for ecosystem mapping of Nepal

Major variable	Parameters	Source
Macroclimate or Bioclimatic	Temperature	Department of Hydrology and Meteorology
	Rainfall	Department of Hydrology and Meteorology
	Relative Humidity	Global dataset
	Evapotranspiration	Global dataset
	Solar Radiation	Global dataset
	Topographic Moisture Potential	Derived from SRTM-DEM data
Lithology	Geology	Central Department of Geology, Department of Mines and Geology (DMG)
	Soil Types	NARC, field data
	Soil pH	ICIMOD, field data
	Soil moisture	Global dataset, field data
	Soil Erosion	ICIMOD, field data
Landform	Topography	FRTC/Survey Department, field data
	Altitude	Derived from SRTM-DEM data, field data
	Slope	Derived from SRTM-DEM data, field data
	Aspect	Derived from SRTM-DEM data, field data

An extensive set of bioclimatic parameters will be generated by modelling monthly mean maximum and minimum temperatures, and monthly mean precipitation data (refer to Sayre et al. 2009). Parameters with a correlation coefficient greater than 0.9 will be identified as used in Clarke and Lewis (2017), and only the un-correlated variables will be selected as significant parameters for ecosystem formation.

A geological dataset, commonly used for the surficial lithology or substrate type as a primary indicator, will be used to determine the distribution of natural vegetation. Soil erosion or weathering is significant in Nepal, as this process affects the substrate's chemical and physical properties and thereby influences the formation and function of ecosystems. Soil type and soil pH will be added as parameters for ecosystem mapping. Soil texture, soil pH and soil moisture data will also be collected from the field sample plots, which will be useful in preparing spatial layers as well as characterizing specific forest or grassland types.

Modelling slope and relief from a Shuttle Radar Topography Mission Digital Elevation Model (SRTM-DEM) dataset with 30m spatial resolution for Nepal will derive the land surface form. A drainage channels dataset and Topographic Position Index (TPI) will also be generated from the SRTM-DEM dataset. Topographic moisture potential or the Topographic Wetness Index (TWI) will provide each point's relative wetness and is calculated using a slope and flow accumulation derived from the SRTM-DEM dataset. High TWI areas may indicate wetlands or flood plain areas, which influences vegetation types and structure. In summary, classification of parameters will follow the same approach recommended by the GEOSS to ensure mapping is comparable and consistent with globally standardized methods.

In this step, a consolidated physical-environmental map of macroclimate, lithology and landforms will be generated by combining the selected parameters for each environmental variable.

Step 10. Consolidating the number of F&GL types

The high number of F&GL types will result in an exceptionally high number of ecosystem types, which may not be appropriate for management purposes. One of the strategies to reduce the number of ecosystem types to the manageable numbers is to consolidate two or more F&GL types (from the final F&GL type map produced in Step 8) based on their similarities in vegetation structural formation and key ecosystem services (e.g. habitat of same wild lives) they provide. The assessment of similarities between two or more forest types will be guided by the field data and secondary information.

This step will produce a revised F&GL type map for using it in ecosystem mapping.

Step 11. Generating F&GL ecological facets

The physical-environmental maps (Step 9) and the revised F&GL type map (Step 10) will be combined to produce the ecological facets map for forest and grassland covers. Each ecological facet represents an ecosystem type with a unique combination of environmental variables and associated F&GL type or vegetation structure.

Step 12. Generating an F&GL ecosystem map (draft)

The number of ecological facets produced in Step 11 will be practically too high for any effective management and decision-making. Consequently, the ecological facets will be aggregated by merging the less significant classes of some of the parameters, which generates an F&GL Ecosystem map of Nepal.

Step 13. Preparation of explanatory notes

An explanatory note for each F&GL ecosystem type (classified in the F&GL ecosystem map in Step 12) will be prepared based on the map attributes and the relevant field data. In the note, an appropriate name will be given to each ecosystem type based on the environmental, climatic and vegetation characteristics, and their general features will be described.

Step 14. Expert review and generating final F&GL ecosystem map

The independent expert panel (identified in Step 8) will review the F&GL ecosystem map of Nepal (produced in Step 12) and the corresponding explanatory notes (prepared in Step 13). They will specifically examine naming of ecosystems and their distribution in the map. The map and the explanatory note will be revised based on feedback from the expert panel, and the final F&GL ecosystem map of Nepal and the related report will be produced.

3.3 Mapping of wetland types and ecosystems

3.3.1 Defining wetlands

Defining the boundary of a wetland ecosystem simply means to outline the wetland from the non-wetland area on a landscape, for which it is necessary to define wetlands. The National Wetlands Policy 2003, the spirit of which is followed by the National Wetlands Policy 2012 and the National Ramsar Strategic Plan and Actions (2018-2024), defines wetlands as "*the perennial water bodies that originate from underground sources of water or rains. It means swampy areas with flowing or stagnant fresh or salt water that are natural or man-made, or permanent or temporary. Wetlands also mean marshy lands, riverine floodplains, lakes, ponds, water storage areas and agricultural lands*" (HMG 2003). Following this definition, but with a slight modification to incorporate contemporary themes and their issues, the following spatial entities will be incorporated while mapping wetlands.

a) Water bodies, defined as areas covered by [perennial or seasonal] water; e.g. rivers, lakes and ponds (FRTC 2021). These may be natural or artificial with a construction history of at least 15 years.
b) Riverbed, defined as a tract of land without vegetation surrounded by the waters of a lake or river/stream; it usually includes any accretion in a river course (FRTC 2021),
c) Riverine floodplains, defined as flat areas of the river valleys that become flooded by the waters of a river when its flow exceeds the drainage capacity of its channel, usually containing a distinct river channel and a plain stretching to terraces which limit the flood (Bhandari 1998, citing Howard 1992),
d) Glacial lakes, defined as a body of water with origins from the glacial activities by filling the water in the depression created by the glaciers [Whereas glacier, defined as a perennial ice in movement (FRTC 2021)],
e) Inundated agricultural land, defined as the land used for agricultural activities that remains inundated from six to nine months, and soil remains wet even in the dry period (e.g. some paddy fields).
f) Marshy lands, defined as the land with mineral soils and poor drainage where mostly the non-woody plants like grasses and sedges grow with their lower stem in the water, and plant life is dominated by the grasses.
g) Swampy land, defined as the land with mineral soil and poor drainage where mostly the trees and shrubs dominates the plant life.

Although narrow streams/creeks, irrigation channels, waterfalls and hot springs are also considered wetlands, they will not be delineated in the map because of the data limitation, i.e. the Landsat image (30m resolution) to be used for this mapping initiative can adopt a minimum mapping unit of 0.5 ha.

3.3.2 Defining wetland typology in Nepal

As shown in Table 6, Nepal's wetlands can be broadly classified into natural and human-made categories. Further classification of those classes makes a total of 18 types, which are defined in Table 4.

Table 4: Classification of Nepal's wetlands

Level 1 types	Level 2 types	Level 3 types	Level 4 types
Natural	Fresh Water Wetlands	Riverine	1. Perennial River and Stream
			2. Creek
			3. Waterfall
			4. Seasonal River and Stream Rivers
			5. Riverine Floodplain
		Lacustrine	6. Permanent Lake
			7. Permanent Pond
			8. Seasonal Floodplain Lake
			9. Glacial lake
			10. Hot Spring
		Palustrine	11. Swamps
			12. Marshes
	Saline Wetlands	Saline Wetlands	13. Saline Wetlands
Human-made	Water Storage Area	Reservoir	14. Reservoir
		Urban Wetlands	15. Urban Wetlands
	Agriculture Wetlands	Inundated Paddy Field	16. Inundated Paddy Field
		Canals and Drainage Channel	17. Canals and Drainage Channel
		Irrigation and Aquaculture Ponds	18. Irrigation and Aquaculture Ponds

Table 5: Typology of wetlands in Nepal

SN	Wetland type	Definition	Ramsar Type	Abbr.
1	Perennial River and Stream	A natural flowing body of surface water, usually freshwater through a deep and wide channel, with a constant stream over the parts of its streambed of 3rd and 4th orders throughout the year; e.g., Koshi, Karnali, Kankai, Rapti. Its channel width is 20m at minimum.	**M**	**PRS**
2	Creek	A natural flowing body of surface water, usually the freshwater through a relatively shallow and narrow channel, with a constant stream of 1st and 2nd orders throughout the year; this includes small streams, i.e. with width less than 20m.	**M**	**CRK**
3.	Waterfall	An area where water flows over a vertical drop or a series of steep drops along the course of a river/stream; e.g., Hyatrung (Terhathum), Satashidham (Jhapa), Rupse chhahara (Myagdi)		**WF**
4	Seasonal River and Stream	A flowing body of water with its flow limited to the certain seasons or when there has been a lot of rain; e.g. many rivers and streams in the Churia and Bhavar range	**N**	**SSR**
5	Riverine Floodplain	Flat areas of the river valleys that become flooded by the waters of a river when its flow exceeds the drainage capacity of its channel, usually containing a distinct river channel and a plain stretching to terraces which limit the flood (Bhandari 1998 citing Howard 1992)		**RFP**

6	Permanent Lake	A natural, permanent, stagnant water body with a minimum average depth of 6 meters and water coverage area above 8 ha (NLDC 2019); e.g., Fewa and Begnas (Pokhara), Rara (Mugu), Phoksundo (Dolpa)	**O**	**PL**
7	Permanent Pond	A natural, permanent, stagnant water body with water coverage area of less than 8 ha (Bhandari 1998) and a minimum average depth of 2.5 meter or even less, also called shallow lake; e.g., Gufapokhari (Terhathum), Gonaha Tal (Bardiya).	**TP**	**PP**
8	Seasonal Floodplain Lake	A natural, stagnant water body usually in the flood plains of large rivers, having an average depth of more than 2.5 meters, that is periodically flooded due to the over and outward flow of water from the river; for example one of the lakes in river channel of Buddi Tal Complex (Rupandehi), outside the west embankment of the Koshi river.	**P**	**SFL**
9	Swamp	A perennial wetlands with a poor drainage and mineral soils, and with more than 30% of the aerial coverage (by vegetation crown) by trees, shrubs, persistent emergent, emergent mosses or lichens (FGDC 2013), usually found in the adjoining areas of the river and lakes; e.g Salbari and Jamunkhadi (Jhapa), Betana and Betini (Morang), Zakhoriya and Jhilmila,(Kanchanpur), Rajarani Tal and Dhampalghadi Simsar (Morang).	**W, Xf**	**SMP**
10	Marsh	A permanent or seasonal shallow wetlands that receives water from rain and watershed, surface water and groundwater, and is characterized by the wet, spongy, poorly drained peaty soil, dominated by the growth of bog mosses, Sphagnum and emergent species like reeds, cattails and thatcher adapting to nutrient poor and acidic environment [Also called bog] or peaty soil and alkaline environment with dominated grasses, sedges, and reeds [also called fen]; e.g., Gunde and Maidi (Pokhara), Ghol (Royal Chitwan National Park), Upper area of Talltaliya (Sunsari)	**Tp**	**MRS**
11	Saline wetlands	The area in the plains of salt creek and rock creek, characterized by higher concentration of salt (0.5 to 30 parts per thousand) and low-growing vegetation, with most plants barely emerging above the water line or are knee-high at most; e.g. Tetang (Upper Mustang)	**Sp**	**SW**
12	Hot Spring	A water spring produced by the geo-thermally heated groundwater that ranges in flow rate from 'seeps' to creek and rivers; e.g., Tatopani (Kavrepalanchok), Singa (Myagdi), Tatopani (Jumla).	**Zg**	**HS**
13	Glacial Lake	A body of water with origins from the glacier activities by filling the water in the depression created by the glaciers above 3000 m; e.g. Imja Tsho, Tsho Rolpa, Gokyo lake system	**Va**	**GL**
14	Reservoir	A reservoir is the constructed large storage space to contain water to meet water shortage for human uses and for the generation of power. After construction, reservoirs may gradually gain ecological functions, and gets naturalized in certain period of time. At the present purpose of mapping of wetlands, a construction history period of at least 15 years is considered a threshold. For example, Sundari Jal (Kathmandu),	**6**	**WTR**

		Jagadishpur Reservoir (Kapilvastu), Gaidahawa Reservoir (Rupandehi), Indra Sarobar (Makawanpur), Marsyangdi Reservoir (Tanahun) etc.		
15	Urban Wetlands	The constructed stagnant water bodies in and around urban settlements, especially for the recreational and cultural purposes and to decorate different kinds of gardens in a landscape which gains the salient properties of ecological functioning in the construction history of at least 15 years; e.g., Rani Tal (Nepalgunj), Water park (Jhapa)	**7**	**UW**
16	Inundated Paddy Field	A paddy field is considered wetlands when the field is wet in all seasons, either naturally or through irrigation; e.g., paddy field around Tulsi-di-hawa (Kapilvastu), paddy field in east and west banks of the Koshi river	**3**	**IPF**
17	Canals and Drainage Channel	A water body flowing through a shallow and narrow channel constructed for irrigation purpose with the construction history of at least 15 years; e.g. Babai irrigation canal	**9**	**CDC**
18	Irrigation and Aquaculture Pond	A stagnant water body, constructed for irrigation and aquaculture, with its water surface coverage more than 0.5 ha and with a construction history of at least 15 years e.g., fish ponds and irrigation ponds of the Tarai	**1, 2, 3**	**IA**

The definition and typology of wetlands was initially prepared based on review of literature and limited expert knowledge, and then revised as above based on feedback from a consultation meeting with experts.

3.3.3 Step-by-step methods of mapping wetland types and ecosystems

This sub-section describes the methodological steps required to map wetland types and ecosystems in Nepal with the methodological frameworks in Figure 5 and 6.

Wetland Types Mapping

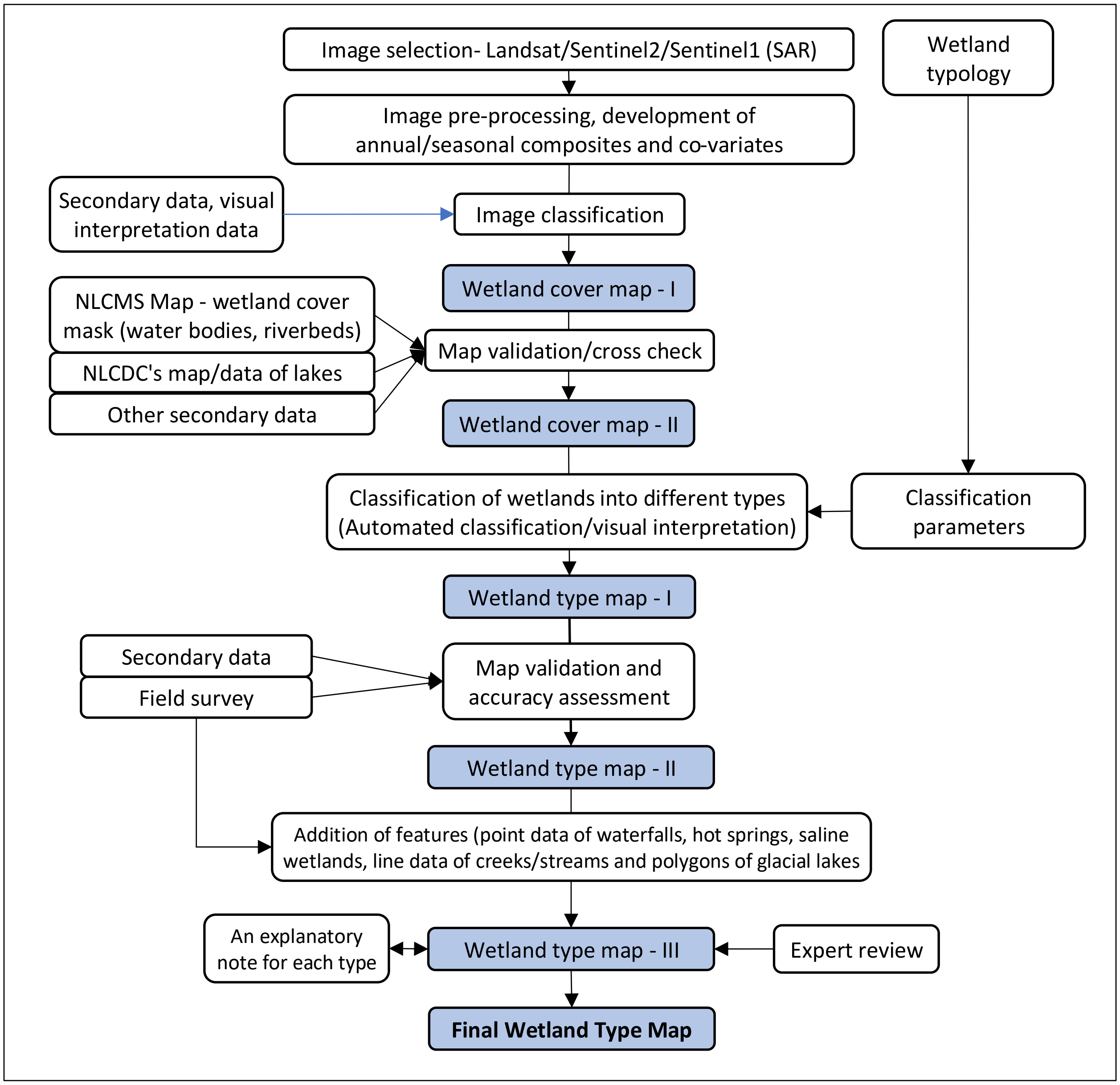

Figure 5: Methodological framework for wetland type mapping

Step 1. Developing wetland typology

The wetland typology of Nepal has been developed based on a review of literature, analysis and interpretation of the secondary data and consultation with experts, as described earlier in Section 3.3.2. A total of 18 types of wetlands has been identified and each of them has been defined (Table 4, 5). This typology will help initial classification of Nepal's wetlands and their mapping; however, it may be revised in course of mapping.

Notably, all 18 wetland types may not be mapped. Also, mapping of different wetland types needs different methodologies. Table 6 presents in brief the methods that will be applied for mapping different types of wetlands to produce an integrated wetlands type map.

Table 6: A summary of methodologies for mapping different wetland types

SN	Types of wetlands	Mapping methods
1	Creeks	These features will not be mapped, but once the wetlands map is generated, these can be shown as line features adopting river feature layer.
2	Canals and drainage channels	These features will not be mapped.
3	Glacial lakes	These features will be mapped using spatial layer from secondary sources (i.e. ICIMOD)
4	Waterfall	Significant waterfalls, hot springs, and saline wetlands will be identified through discussion with local stakeholders; their spatial locations will be collected, and they will be mapped as points. Secondary information will also be used.
5	Hot Spring	
6	Saline Wetlands	
7	Swamp	These features will be mapped through classifying Landsat/Sentinel images, specifically SAR, and validated using the secondary as well as primary data from the field.
8	Marsh	
9	Inundated Paddy Field	
10	Perennial River and Stream	These features will be mapped using annual composites of Landsat/Sentinel imageries. Secondary information, including NLCMS map (FRTC, 2021) and map of Nepal's lake (NLCDC, 2021), will be used to validate the resulting map. Physical parameters will be used to distinguish some specific features, e.g. reservoir and permanent lake. Similarly, for constructed wetlands, e.g. urban wetlands, reservoir, irrigation and aquaculture ponds, construction history (15 years) will be assessed through analyzing 15 year-old Landsat imageries. Visual interpretation of Google Earth images will also be carried out for classification of specific types.
11	Riverine Floodplain	
12	Permanent Lake	
13	Permanent Pond	
14	Reservoir	
15	Urban Wetlands	
16	Irrigation and Aquaculture Ponds	
17	Seasonal River and Stream	These features will be mapped using seasonal composites of Landsat/Sentinel imageries.
18	Seasonal Floodplain Lake	

Step 2. Selection and pre-processing of images and developing co-variates

Sentinel1 (SAR) and Sentinel2 imageries will be used for wetland cover mapping. Pre-processing and development of covariates will be carried out using different algorithms in GEE platform. For example, geometric correction, topographic correction, BRDF correction, radiometric correction, and cloud masking process will be applied for Sentinel2, and thermal noise removal, radiometric calibration and terrain correction will be applied for Sentinel1 (SAR) imageries. In addition, Landsat imageries will also be used as required.

Step 3. Image classification (generating wetland cover map - I)

The annual and seasonal composites will be classified applying the machine-learning algorithm using training data set and co-variates. Training data sets will be collected from secondary sources (e.g., data from National Lake Conservation Development Committee - NLCDC) and visual interpretation of high-resolution imageries (e.g., Google Earth).

Various algorithms, such as Classification and Regression Tree (CART), Random Forest (RF), Support Vector Machine (SVM), and primitive-based approach will be used for classification. Wetlands may also be digitized as required.

In this step, the first draft of the wetland cover map (consisting of types 7-18 in Table 6) will be generated.

Step 4. Map validation/cross-checking (generating wetland cover map - II)
The wetland cover map generated in Step 3 will be collated with the relevant secondary information, such as the wetland mask (comprising Riverbed and Water Bodies) from the National Land Cover Monitoring System's (NLCMS) map (FRTC, 2021), the map of Nepal's lakes prepared by the National Lake Conservation Development Committee (NLCDC, 2021) and the geospatial wetland maps, including river networks and water bodies, from IUCN and ICIMOD.

The wetland cover map will also be cross-checked/combined with the F&GL and agriculture maps. The areas on the F&GL and agriculture maps overlapped by wetlands, if any, will be removed from the respective maps.

With this, the second draft of the wetland cover map will be generated.

Step 5. Classification of wetlands into different types (generating wetland type map - I)
The wetland cover map generated in Step 4 will be further classified into different wetland types (i.e. types 7-18 in Table 6). For this, the classification parameters or interpretation keys (training data) will be developed following the definitions of different wetland types (Table 5). Both automated classification and visual interpretation will be applied as required.

The first draft of wetland type map will be generated in this step.

Step 6. Creation of validation data set
The wetland type map (draft I) will be validated using a set of field-based data from both the secondary as well as primary sources. The following activities will be carried out for preparing the data set.

6.1 Collection, analysis and interpretation of the secondary data
The geo-reference points of several wetlands with details of information are available from different sources, for example, ICIMOD, IUCN and NLCDC. These data will be collected, analyzed and interpreted as required, specifically to identify the type of each wetland.

Similarly, the geo-reference points of different wetland types that are known to experts (e.g. Phewa lake, Rara lake, Karnali river etc.) will be derived through visual interpretation of the high resolution image or Google Earth.

6.2 Field survey (collection and analysis of primary data)

The secondary data (prepared in Step 6.1) may not be sufficient for the validation of the wetland type map. Specifically, adequate signature points for swamps, marshes and inundated paddy fields may not be available from the secondary sources. Further, the data related to characterization of each wetland type may be limited in the database compiled from the secondary sources.

Therefore, additional field data may be necessary not only to validate the map and assess its accuracy but also for describing features of each type. Thus, field surveys are planned once the draft wetland type map is prepared.

a) Sampling Design

Samples of wetland types for field data collection will be selected using different approaches as follows.

I. The forest and grassland (F&GL) field crews will collect wetland-related data from all wetlands (types 7-18 of Table 6) that fall along their survey transects.
II. The F&GL crews will consult with local stakeholders (e.g. DFO, local communities) on whether any saline wetlands, significant waterfalls and hot springs are there in the districts being surveyed, and they will collect their geo-reference points and other information using Google Earth or going to the spot.
III. At least 10 wetlands of each type (as mapped in Step 5) will be randomly selected and surveyed by the dedicated wetland field crew led by the Wetland Specialist.

b) Field data collection

The field data collection includes general information of the wetlands and their physical and environmental parameters. Field forms for data collection from wetland samples have been developed accordingly. A standard operating procedure (SOP) for field data collection has also been developed to assist the field crew to collect data accurately and consistently.

Apart from the five regular and the additional F&GL field crews as described earlier in the F&GL data collection section, a dedicated wetland field crew will be mobilized for data collection. This crew, led by the Wetland Specialist, will consist of a botanist/taxonomist and a local resource person.

c) Analysis and interpretation of the field data

The data collected from the field samples will be entered into the database, and they will be analyzed and interpreted as follows to obtain the following three types of information:

- Each sample is defined as a particular wetland type; this information, along with secondary data, will be used to assess the mapping accuracy.
- The data characterizing a wetland type will be consolidated from all samples of the same type. This information will serve to prepare an explanatory note for each wetland type mapped.
- The vulnerability-related data will be consolidated from all samples of the same wetland

type. This information, with other relevant information from secondary sources, will be used to assess the state of vulnerability of a wetland type.

6.3 Preparation of the validation data set

Data from the field samples and secondary sources will be compiled to prepare a validation data set. Each sample data (with a geographic location) will indicate a wetland type, along with other relevant data like altitude and aspect.

Step 7. Accuracy assessment and revision of the draft map (generating wetland type map - II)

The accuracy of the draft wetland type map (generated in Step 5) will be assessed using the validation data set prepared in Step 6. The map is considered an acceptable quality with the mapping accuracy above 80% threshold. When the accuracy is below 80%, the classification parameters will be re-examined, and the images will be reclassified.

Step 8. Addition of features

The wetland types that have not been considered during the above mapping processes, such as waterfalls, hot springs, saline wetlands, creeks and narrow streams, and glacial lakes, will be added into the wetland type map - II in this step. The identified waterfalls, hot springs and saline wetlands will be inserted in the map as points using the geo-reference point-based data from the field survey and secondary sources. Similarly, the river network data layer from IUCN and ICIMOD will be adopted for the creeks and narrow streams. The glacial lakes will be delineated using the spatial information from ICIMOD.

The third draft of the wetland type map, showing all types, will be generated in this step.

Step 9. Preparation of explanatory notes

An explanatory note for each wetland type (classified in the wetland type map - III, generated in Step 8) will be prepared based on the map attributes and the relevant field data. The note will assign an appropriate name to each wetland type and describe it in terms of physical and environmental characteristics, distribution, area coverage etc.

Step 10. Expert review and generating final F&GL map

The Ecosystem and Forest Type Mapping Program (EFTMP) will engage an independent expert panel, comprising wetland ecologists, wetland specialists, botanists and taxonomists. They will examine the classification of wetland types (wetland type map - III produced in Step 8) and the corresponding explanatory notes (prepared in Step 9) and provide feedback to improve the map for a wider acceptance. The Wetland Specialist will address the relevant feedback; and the final wetland type map of Nepal will be produced.

Wetland ecosystem mapping

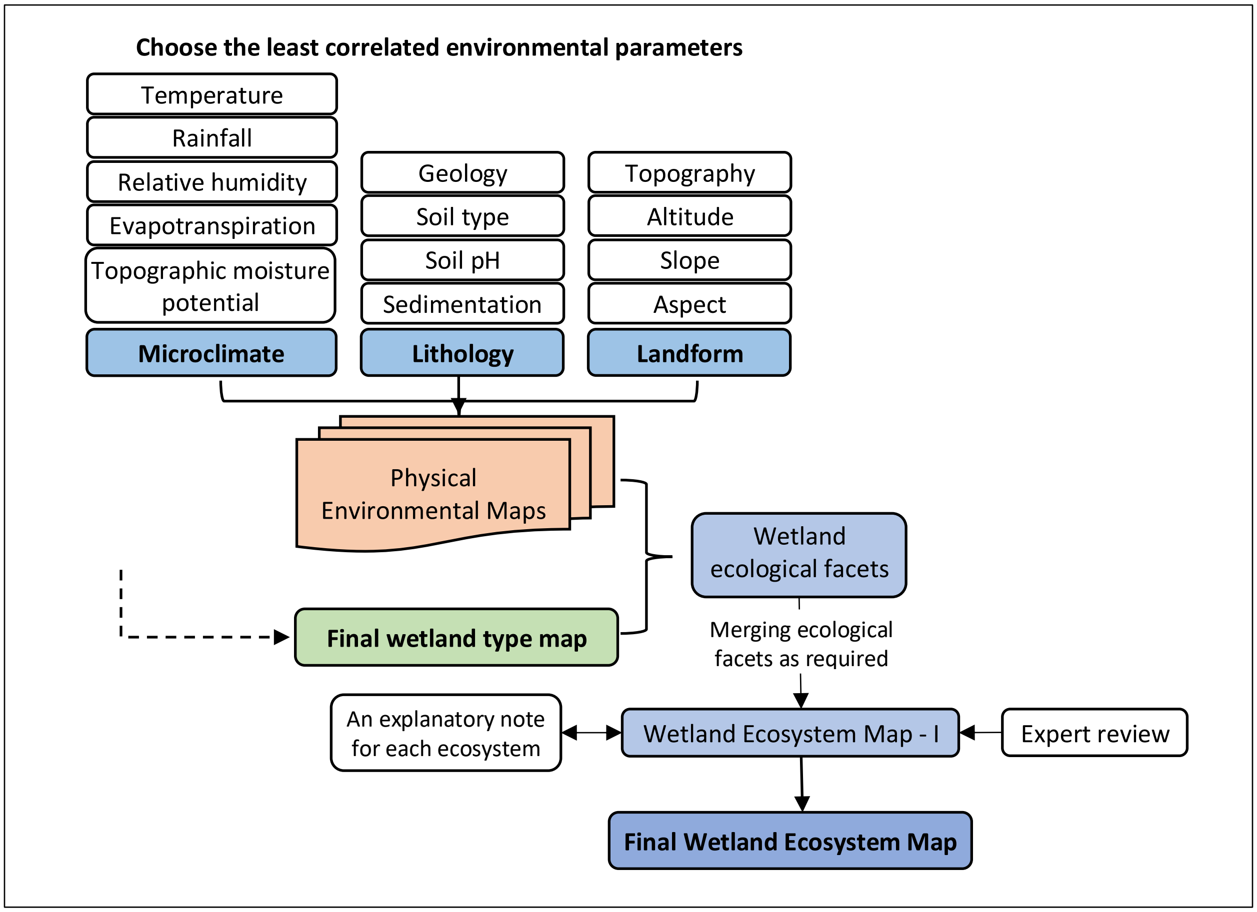

Figure 6: Methodological framework for forest and grassland ecosystem mapping

Step 11. Analysis of environmental parameters and preparation of a consolidated physical-environmental map

Based on the standardized ecosystem mapping method, the environmental variables for macroclimate, lithology and landform are applied to wetland ecosystem mapping of Nepal. The variables compiled in Table 3 are assessed, and the most relevant parameters are selected for wetland ecosystem mapping. The same procedure for integrating the environmental parameters for F&GL ecosystem mapping will be applied to generate a physical environmental map for wetland ecosystem mapping of Nepal.

Thus, a consolidated physical-environmental map of macroclimate, lithology and landforms will be generated by combining the selected parameters for each environmental variable in this step.

Step 12. Generating wetland ecological facets

The physical-environmental maps (Step 11) and the final wetland type map (Step 10) will be combined to produce the ecological facets map for wetlands. Each ecological facet represents an ecosystem type with a unique combination of environmental variables and associated wetland type.

Step 13. Generating a wetland ecosystem map (draft)
The number of ecological facets produced in Step 12 will be practically too high for any effective management and decision-making. Consequently, the ecological facets will be aggregated by merging the less significant classes of some of the parameters, which generates a wetland ecosystem map of Nepal.

Step 14. Preparation of explanatory notes
An explanatory note for each wetland ecosystem type (classified in the wetland ecosystem map in Step 13) will be prepared based on the map attributes and the relevant field data. In the note, an appropriate name will be given to each ecosystem type based on the physical, environmental, climatic and vegetation characteristics, and their general features will be described.

Step 15. Expert review and generating final wetland ecosystem map
The independent expert panel (identified in Step 10) will review the wetland ecosystem map of Nepal (produced in Step 13) and the corresponding explanatory notes (prepared in Step 14). They will specifically examine naming of ecosystems and their distribution in the map. The map and the explanatory note will be revised based on feedback from the expert panel, and the final wetland ecosystem map of Nepal and the related report will be produced.

3.4 Mapping of agro-ecosystems

3.4.1 Defining agro-ecosystem

Wood et al. (2000) defines an agro-ecosystem as *"a biological and natural resource system managed by humans for the primary purpose of producing food as well as other socially valuable nonfood goods and environmental services"*. Following this definition, an agro-ecosystem is defined here as a human-managed ecosystem in which plant community is dominated by agricultural and horticultural crops. Thus, it includes the land cover classified as 'cropland' by the National Land Cover Monitoring System; it has been defined as "the arable and tillage land, and agroforestry systems where vegetation falls below the thresholds used for the forest land category …" (FRTC, 2021). For the classification of world's agro-ecosystems, the Pilot Assessment of Global Ecosystems (PAGE) has derived agro-ecosystem characterization schema by combining data themes of agro-climate, slope, and irrigation area. The resultant types are like *Temperate rainfed humid sloping* and *Moderate cool irrigated flat* agro-ecosystems (Wood et al. 2000). However, many countries have adopted the agro-ecological zoning approach in classifying agro-ecosystems.

An agro-ecological zone is a land resource mapping unit defined in terms of climate, landform and soils and/or land cover and having a specific range of potentials and constraints for land use. Different countries have adopted parameters of physiography, bio-climatic features, and soil characteristics in identification and classification of agro-ecological zones. India has identified 20 agro-ecological zones using the parameters of physiographic features, soil characteristics, bio-climatic features and length of growing period. These 20 agro-ecological zones have been further grouped into 60 agricultural eco-regions. Some examples of these 20 agro-ecological zones in India are: *Western Himalaya cold arid eco-region, Deccan plateau hot arid eco-region, Northern Plain hot subhumid eco-region, Eastern Plain hot Subhumid eco-region etc.* (Balasubramanian 2013).

Similarly, in Pakistan, physiography, climate, land use and water availability have been used to classify the agro-ecological zones into 10 types. Examples of agro-ecological zones of Pakistan are *Indus Delta, Southern Irrigated Plain, Sandy Desert, Wet Mountains, and Northern Dry Mountains.* Agro-ecological zonation in Sri Lanka has used Major criteria of elevation and rainfall pattern. Based on elevation, the country has been demarcated into Low-country, Mid country, Up-country, and coastal plains; and based on rainfall pattern the country has been demarcated into wet zone, intermediate zone, and dry zone. Combining these two demarcations and further classification, 24 agro-ecological zones have been identified in Sri Lanka.

Before classifying and mapping Nepal's agro-ecosystems, agro-ecological zones will be delineated using physiographic and climatic parameters. This is a deskwork, and uses available spatial data layers; and will be verified later through field data.

3.4.2 Defining Agro-ecological zones in Nepal

The tectonic formation shapes the Characterization of Agro ecological zones in Nepal. The Southern face of the Himalayas is composed of four tectonic units: Tarai and Bhabar, the outer foothills or Siwaliks, the Midlands (Midhills or Lesser Himalayas) and the southern slopes of the High Himalayas (Miehe 2015). The tectonic formation underlies the physiographic zonation. The Land Resource Mapping Project has grouped the country into 5 physiographic regions as Tarai, Siwalik, Middle Mountains, High Mountains, and High Himalayas with corresponding climatic zones as sub tropical, warm temperate, cool temperate, sub alpine and arctic (LRMP 1986). These climatic features, soil types and slope ranges were used in characterizing agricultural patterns. Some markers were identified in characterizing agriculture as follows:

1000 m: upper limit of successful double rice cropping
2200 m: upper limit of successful rice cultivation
2500 m: upper limit of maize cultivation
3800 m: upper limit of arable agriculture (buckwheat, potatoes)

Bohner et al. (2015) have broadly classified physiographic climatic zones as Tarai Bhabar, East Midlands, Cenral Midlands, West Midlands, Dry River Valleys, Humla Jumla Area, Western Inner Valleys, Eastern Inner Valleys and Arid zone. Corresponding to these physiographic-climatic zones, Schmidt-Vogt and Miehe (2015) identified five broader agricultural zones as Tarai, Duns, and Siwaliks; Intramontane basins; The Midlands and Southern Slopes of Himalayas; Eastern Inner Valleys; and Western Inner Valleys, Arid Zone and Humla Jumla region.

The National Land Use Project (2016) of the Ministry of Land Reform and Management has developed/used a methodology for classification of the agricultural landuse. The classification follows different hierarchy of classification. At the level 1, it followed general physiographic divisions and termed the agriculture types as Tarai Cultivation, Hill cultivation, Mountain Cultivation, and Valley cultivation. At the second level, these classes have been further classified based on parameters of slope and soil moisture, and have been termed as wet land cultivation, dry land cultivation, leveled terraces, and sloping terraces. The next level follows the cropping pattern.

The Ministry of Agriculture Development (2017) has characterized eight agro-ecosystems in Nepal as Rainfed High Hill, Irrigated High Hill, Rainfed Mid Hill, Irrigated Mid Hill, Rainfed Tarai, Irrigated Tarai, wetland Agriculture, and Rangeland Agriculture. It is widely recognized that these broader classes do not capture and reflect the diversity of agro-ecosystems in Nepal.

Considering these physiographic regions and agro-climatic ranges, 18 agro-ecological zones have been identified (Table 7). The humidity range (humid/subhumid, semi-arid, and arid) is defined based on the soil moisture index. Soil moisture index (SMI) is calculated as 100 (P-PET)/PET, where P is precipitation and PET is potential evapotranspiration; its value in Nepal ranges from -60 in Upper Mustang to 600 in Lumle of Kaski district (DHM 2013). The elevation range broadly reflects the physiographic region.

Table 7: Agro-ecological zones of Nepal and their features

SN	Physiographic region	Elevation sub class	Humidity/Soil Moisture content	Agro-ecological zones	Major identifying features
1	Tarai	unclassified	humid	**Humid Tarai eco-region**	Elevation range of less than 300m, SMI between 200 to 600, gentle slope (e.g. Jhapa, Morang)
2			sub humid/semi-arid	**Sub humid/Semi-arid Tarai eco-region**	Elevation range of less than 300m, SMI between 0 and 200, gentle slope (eg. Banke, Bardiya)
4	Chure	Unclassified	humid/subhumid	**Humid/sub humid Chure eco-region**	Elevation range between 300 up to 1500 m, SMI of 50 and above moderate slope (eg. Chure range of Jhapa, Ilam, Morang)
5			semi arid	**Semi-arid Chure eco-region**	Elevation range between 300 up to 1500 m, SMI range of 0 to 50, moderate slope (eg. Sindhuli, Dang, Surkhet valley)
6	Hill	Lower hills (bensi, river valleys)	humid/subhumid	**Humid river valleys, Tars in Low hills**	Elevation range from 700 to 1000 m, close to river course, SMI of 50 and above, moderate slope (eg. *Bensis* in eastern hills)
7			semi arid	**Semi-arid river valleys, Tars in Low hills**	Elevation range of 700 to 1000 m, SMI of 0 to 50, moderate slope, generally close to river courses (eg. Trisuli, River valleys in Dailekh, Baitadi)

8		Upper hills/Tars	humid/subhumid	**Humid/sub humid Valleys and *upper* Hills**	Elevation range from 1000 to 1500 m, SMI of 50 and above, gentle to moderate slope in valleys and strong slopes upper hills (eg. Kathmandu, Pokhara)
9			semi arid	**Semi-arid valleys and upper hills**	Elevation range from 1000 to 1500 m, SMI of 0 to 50, gentle to moderate slope in valleys and strong slopes upper hills (eg. Tumlingtar, Chainpur (Bajhang)
10	Middle Mountain	Lower region	humid/subhumid	**Humid Lower Middle Mountain eco region**	Elevation range from 1500 to 2000 m, SMI of 50 and above, moderate to strong slope (Arun Tamor Basin)
11			semi arid	**Semi-arid Lower Middle Mountain eco region**	Elevation range from 1500 to 2000 m, SMI of 0 to 50, moderate to slope (eg. Bheri Babai Basin)
12		Upper region	humid/subhumid	**Humid Upper Middle Mountain eco-region**	Elevation range from 2000 to 2500 m, SMI of 50 and above, moderate to strong slope (eg. Lower Solukhumbu, Okhaldhunga, Myagdi)
13			Semi-arid	**Semi-arid Upper Middle Mountain**	Elevation range from 2000 to 2500 m, SMI between 0 and 50, moderate to strong slope (eg. Rukum, lower parts of Humla, Jumla, Bajura)
14	High Mountain	Lower region of southern slopes	humid/subhumid	**Humid high mountain eco region**	Elevation range from 2500 to 3500 m, SMI above 50, moderate to steep slope (upper parts of Taplejung, Solukhumbu, Dolakha)
15			Semi-arid	**Semi-arid Mountain eco region**	Elevation range from 2500 to 3500 m, SMI of 0 to 50, strong to slope (Humla Jumla)
16		Valleys of Southern slopes	humid/subhumid	**Humid Inner valleys of Eastern and Central Himalaya**	Elevation range from 2500 to 3500 m, SMI of 50 and above, gentle to Moderate slope (Khumjung, Olangchunggola, Kyanjing, Beding)
17			Semi-arid	**Semi-arid Inner valleys of Western Himalaya**	Elevation range from 2500 to 3500 m, SMI of 0to 50, gentle to Moderate slope (Dunai, Simikot, Limi valley)
18		Trans-Himalayan	arid	**Trans Himalayan Cold Arid eco region**	Above 3000 m in elevation, SMI value of -60 to 0, moderate slope, north of Himalaya in Mustang and Dolpa (eg.Upper Mustang, Upper Dolpa)

The preliminary agro-ecological zones have generally taken into account the traditionally identified agro-ecological classes as Tarai, hill, and Mountain. This zonation also took into account the elevation range of crops. For example, the upper range of maize (2,500 m) has been taken as boundary elevation for middle mountain and high mountain; upper range of citrus (1,500 m) as boundary elevation of hill and mountain. The elevation range differs from the West to East. Agro-ecosystems in these agro ecological zones are shaped by the availability of irrigation facilities. The general agriculture types in irrigated and rainfed agro-ecosystems in these agricultural zones are listed in Table 8.

Table 8: Agro-ecosystems and major agriculture types

SN	Physiographic region	Agro ecological zones	Irrigation facility	Major agriculture type
1	Tarai	Humid Tarai eco-region	irrigated	Rice-based double and triple cropping, pulses, mustard sugarcane plantation, banana, areca/coconut plantation, mango plantation, tea plantation, warm water fishery
2			rainfed	maize and rice based double cropping, mango plantation, pulses
3		Sub Humid/semi-arid Tarai eco-region	irrigated	Rice-based double and triple cropping, sugarcane plantation, banana, mango
4			rainfed	maize and rice-based double cropping, mango plantation, pulses
5	Chure	Humid/subhumid Chure eco-region	irrigated	Rice-based double/ triple cropping
6			rainfed	Maize, millet-based single, double cropping
7		Semi-arid Chure eco-region	irrigated	Rice-based double and triple cropping
8			rainfed	Maize/millet-based double cropping
9	Hill	Humid river valleys and Tars in Low hills	irrigated	Rice-based double and triple cropping, vegetables
10			rainfed	Maize, millet-based double cropping, vegetables
11		Semi-arid river valleys and Tars in Low hills	irrigated	Rice-based double cropping, vegetables, citrus
12			rainfed	Maize, millet, pulses, vegetables, citrus
13		Humid/sub humid Valleys and upper Hills	irrigated	Rice-based double cropping, mixed cropping, citrus, tea plantation, coffee plantation
14			rainfed	Maize, millet-based single/double cropping, citrus
15		Semi-arid valleys and upper hills	irrigated	Rice-based single/double cropping, pulses, vegetables, citrus
16			rainfed	Maize, millet-based single crop, citrus, vegetables
17	Middle Mountain	Humid Lower Middle Mountain eco-region	irrigated	Irrigated rice-based double cropping, potato-based double cropping, cardamom plantation, tea plantation, coffee plantation, cold water fishery
18			rainfed	maize millet, potato

19		Semi-arid Lower Middle Mountain eco-region	irrigated	Rice-based single/double cropping, pulses, vegetables, citrus
20			rainfed	Maize, millet-based cropping, citrus
21		Humid Upper Middle Mountain eco-region	irrigated	Rice-based single double cropping, peaches, pears
22			rainfed	Maize-based double cropping, peaches, pears
23		Semi-arid Upper Middle Mountain eco-region	irrigated	Rice-based single/double cropping, vegetables,
24			rainfed	Maize, millet-based cropping, peaches, pears, plums
25	High Mountain	Humid High Mountain eco-region	irrigated	Maize, millet-based double cropping, buckwheat-barley double cropping, cardamom plantation, cold water fishery
26			rainfed	Potato-based system, naked barley/wheat-based system
27		Semi-arid High Mountain eco-region	irrigated	Buckwheat, barley double cropping
28			rainfed	Wheat, millet double cropping, maize-based double cropping
29		Humid Inner Valleys of Eastern and Central Himalaya	rainfed	Maize, millet, potato, barley, wheat, apple orchard
30		Semi-arid Inner Valleys of Western Himalaya	irrigated	Millet, barley, wheat, potato-based single, double cropping, apple orchard
31			Rainfed	Barley, wheat, buckwheat
32		Trans Himalayan Cold Arid eco region	irrigated	Wheat/naked barley/buckwheat, potato double cropping in lower region and single crop in upper section
33			rainfed	Wheat/naked barley/buckwheat single cropping, apple plantation

3.4.3 Step-by-step methods of mapping agro-ecosystems

This sub-section describes the methodological steps that will be followed for mapping agriculture types and ecosystems in Nepal with the methodological frameworks in Figures 7.

Agriculture Types Mapping

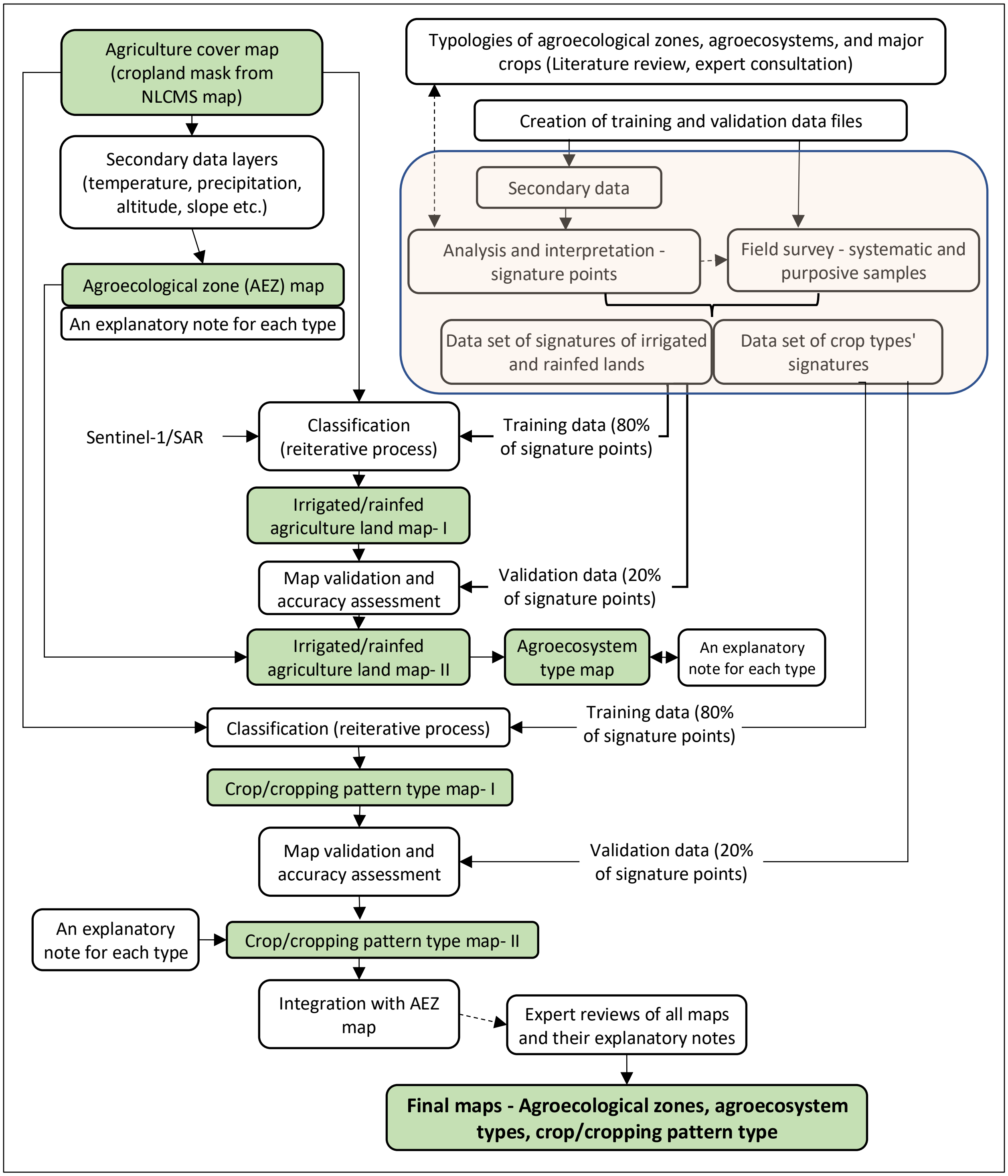

Figure 7: Methodological framework for mapping of agroecosystems

Step 1: Developing typologies of agroecological zones, agroecosystems, and crop/cropping patterns

The typologies of Nepal's agroecological zones and agroecosystems have been developed based on a review of past assessments, analysis and interpretation of secondary data and consultation with experts, as described earlier in Section 3.4.2. A total of 18 agroecological zones (Table 7) and 33 agroecosystem types (Table 8) have been identified (Table 2). The agroecological zones are classified based on physical and environmental parameters, and each agroecological zone is further classified into agroecosystem types based on whether the land is irrigated or rainfed. Dominant crop types/combinations (13 types, Table 9) have also been identified. Thus, this initiative will produce three types of maps relating to agriculture, i.e. agroecological zone map, agroecosystem map, and that showing key crop types or cropping patterns.

Mapping will take place at different levels, in which crop/cropping pattern type map will be prepared at the last level (Table 9).

Table 9: Levels of agriculture types for classification

Level 1 **(Land use category)**	**Level 2** **Physical features (elevation, soil moisture index, and slope category)**	**Level 3** **(Irrigation availability)**	**Level 4** **(Crop/cropping pattern type)**
Agriculture	Humid Tarai eco-region	Rainfed	1. Rice-based cropping (khet)
	Sub humid/ semi-arid Tarai eco-region	Irrigated	2. Maize/millet-based cropping (Bari)
	Humid/sub humid Chure eco-region		3. Sugarcane plantation
	Semi-arid Chure eco-region		4. Tea plantation
	Humid river valleys and Tars in low hill		5. Mango/Litchi orchards
	Semi-arid river valleys and Tars in low hill		6. Banana orchard
	Humid/Sub humid valleys and upper hills		7. Citrus orchard
	Semi-arid valleys upper hills		8. Cardamom plantation
	Humid Lower Middle Mountain eco region		9. Barley/buckwheat/potato-based system
	Semi-arid Lower Middle Mountain eco region		10. Apple orchard
	Humid Upper Middle Mountain eco region		11. Warm water fishery
	Semi-arid Upper Middle Mountain eco-region		12. Cold water fishery
	Humid High Mountain eco-region		13. others
	Semi-arid High Mountain eco-region		
	Humid Inner Valleys of Eastern Himalaya		
	Semi-arid Inner valleys of Western Himalaya		
	Trans-Himalayan Cold Arid eco-region		

Step 2: Preparing an agriculture cover map
Among the 11 land cover classes in the NLCMS Map (FRTC 2021), "cropland" will be extracted to delineate Nepal's agriculture area's spatial boundary. This will serve as a base map for further analysis. Other available maps and spatial information, such as that on fisheries, will be collated from credible sources. The agriculture area missing from this map but identified during the forest and grassland mapping, if any, will be integrated later.

Step 3: Agroecological zone (AEZ) mapping
Agroecological zones is mapped based on the multi-criteria analysis (MCA), using temperature, rainfall, moisture zones, elevation zones, physiography, soil texture, slope and LULC (Patel et al., 2002). Global agroecological zones (GAEZ) are more linked with climatic, edaphic, biomass, yield, crop statistics, land resource etc. (IIASA/FAO, 2012). Agroecological Zones are the function of climatic trend, PET trend, moisture trend, productivity trend, and soil trend (Singh and Aggarwal, 2018).

The NDVI, slope, aspect, texture, SAVI, BAI, seasonal composite (March to October or June to October), Soil moisture index (SMI), NDWI support the interpretation of satellite imageries for agriculture type mapping.

SMI = 100(P-PET)/PET
P=precipitation, PET = Potential evapotranspiration

Using agriculture cover mask from Step 2, Nepal's agroecological zones (as defined in Table 7) will be classified based on satellite imageries (Landsat and Sentinel), Digital Elevation Model, Climatic data (Soil Moisture Index), and Slope. An explanatory note for each agroecological zone will also be prepared.

Step 4: Creation of training and validation data sets for agroecosystem and crop type mapping
Among three types of agriculture-related maps to be generated, the first (i.e. agroecological zones - AEZ) will be prepared using secondary data sets/layers as described earlier. However, the training and validation data sets are required for the classification of agroecosystem types (i.e. irrigated vs rainfed agriculture within each AEZ) and crop/cropping pattern types. These data sets comprise sufficient signatures of each agroecosystem and major crop/cropping pattern type. Such data will be obtained from the secondary (e.g. data points of known types) and primary (field survey) sources. The following activities will be carried out to create the data sets.

4.1 Analysis and interpretation of the secondary data
The signature points representing irrigated and rainfed agricultural lands in different AEZs and different crop/crop pattern types from credible sources (e.g. information published from the District Agriculture Office/Agriculture Knowledge Center, and Ministry of Agriculture and Livestock Development) will be compiled. Similarly, signatures will be derived from known points using high resolution image or Google Earth, such as that of irrigated paddy field or

rainfed maize field etc., that are known to experts and practitioners.

4.2. Field survey (collection and analysis of primary data)

The secondary data are not sufficient for the classification of agroecosystems and crop/cropping pattern types. Therefore, additional field data are necessary for using them as training data as well as for accuracy assessment. Thus, field surveys will be carried out for data collection.

a) Sampling design

Samples of agroecosystem and crop types for field data collection will be selected using two approaches as follows.

I. The forest and grassland (F&GL) field crews will collect agriculture-related data (i.e. irrigated or rainfed, and crop type/cropping pattern at a point) from along or around their survey transects.

II. A dedicated agriculture field crew (consisting of an Agroecologist as the crew leader, a local agriculture staff and a local resource person) will collect data from seven north-south road stretches distributed from east to west (Figure 8). The stretches have been drawn following river courses and major road corridors, considering the need to reach settlements for data collection and its efficiency. This design is expected to capture variations in agriculture with the ecological zones characterized by altitude, aspect, and slope.

    For this, 5 KM (East)*5 KM (North) gridded sample points have been overlaid on the agriculture cover mask (cropland) from NLCMS map (FRTC, 2021) in the 10 Km buffer area of the seven road stretches to cover variations in the agro-ecological zones (AEZ) (Figure 8, Table 10). Such systematic sample points have been identified up to 3,500 m elevation. Above this elevation, where the agriculture is sparse, and in the areas where such systematic sampling could not be done (for example Humla and Dolpa), sample points will be identified purposively.

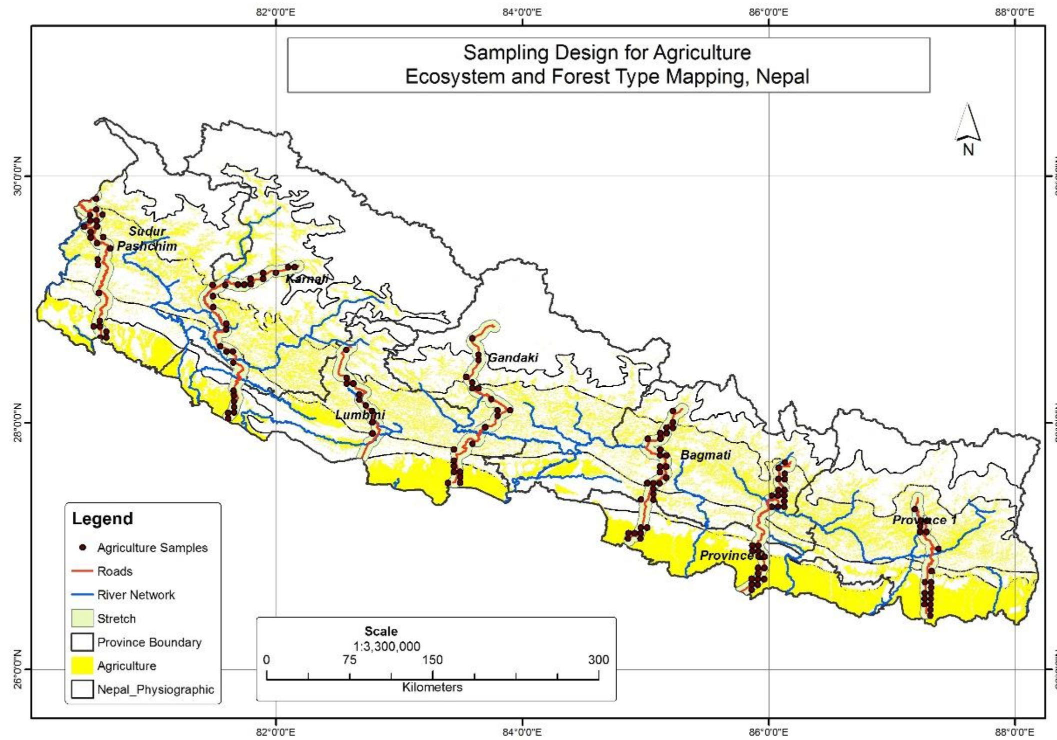

Figure 8: Sampling design for agriculture type mapping

Table 10: Distribution of systematic sample points in different physiographic regions and elevation ranges

Stretch No.	Road Stretch Name	Tarai	Chure			Middle Mountains				High Mountains and Himalaya			Total
		<500	<500	500-1000	>1000	<1000	1000-1500	1500-2000	2000-2500	2000-2500	2500-3000	3000-3500	
1	Dhangadhi to Darchula	6	0	0	1	3	8	1	2	1	0	0	**22**
2	Nepalgunj to Jumla	7	0	3	0	2	3	0	0	4	5	2	**26**
3	Bhalubang to Musikot	0	0	0	0	5	2	2	0	1	0	0	**10**
4	Bhairahawa to Jomsom	6	1	0	1	3	3	1	1	4	1	0	**21**
5	Birgunj to Dhunche, Rasuwa	7	0	4	0	7	3	4	2	2	0	0	**29**
6	Dhanusha to Jugu	14	1	0	0	6	5	2	1	0	0	0	**29**
7	Biratnagar to Khandbari	12	0	0	0	6	1	0	0	0	0	0	**19**
Total		**52**	**2**	**7**	**2**	**32**	**25**	**10**	**6**	**12**	**6**	**2**	**156**

b) Data collection from sample points

Field data collection includes the information on crop land location, environmental parameters (such as elevation, gradient, aspect, slope, soil features etc.), dominant crop, crop rotation/sequence, irrigation/rainfed, and management information related to vulnerability assessment. Field forms for data collection have been developed accordingly. A standard operating procedure (SOP) for field data collection has also been developed to assist the field crew to collect data accurately and consistently.

The agriculture crew will also conduct group meeting with agriculture offices and local communities to list the agriculture types in the area, do participatory mapping on google earth where possible, and visit field to collect data following the SOP. In a given sample point, different agricultural types around it will be identified and information will be collected taking into account of variations in slope, elevation and aspects among others.

c) Analysis and interpretation of the field data

The data collected from the field samples will be entered into the database, and they will be analyzed and interpreted as follows to obtain the following three types of information:

- Each sample point is defined as whether it is irrigated or rainfed (used to delineate agroecosystem types, along with AEZ data).
- Each sample point is defined as a crop type or a type of cropping pattern (used to map major crop types or cropping patterns).
- The data characterizing an AEZ, an agroecosystem or a crop type/crop pattern will be consolidated from all samples of the same type. This information will serve to prepare an explanatory note for each AEZ, agroecosystem and crop/cropping pattern mapped.
- The vulnerability-related data will be consolidated from all samples of the same agroecosystem or crop/cropping pattern type. This information, with other relevant information from secondary sources, will be used to assess the state of vulnerability of each agroecosystem or crop/cropping pattern type.

4.3 Preparation of the training and validation data set

Sampling point data from both secondary sources and the field survey will be compiled to prepare two complete data sets of irrigated/rainfed agriculture types and crop/cropping pattern types. In the first set, each sampling point data (with a geographic location) will indicate whether the agriculture is irrigated or rainfed, and in the second set, each point data will indicate a crop/cropping pattern type, along with other relevant data like altitude and aspect.

From the complete data set of each class (i.e. irrigated/rainfed and crop/cropping pattern type), 80% of samples from each type will be randomly selected to prepare a training data set, which is used to develop interpretation keys for the respective classifications. The remaining 20% of the samples will be used to create a validation data set.

The training and validation data sets will also be separated according to the altitudinal strata as required. Since a crop/crop pattern type is generally confined to a particular altitudinal range, strata-wide (altitudinal) classification can give a better result in terms of accuracy and efficiency.

Step 5. Classification of irrigated and rainfed agricultural lands (generating irrigated/rainfed agriculture map - I)
Using the training data set of irrigated/rainfed agriculture (prepared in Step 4), the agriculture cover map (prepared in Step 2) will be classified into irrigated and rainfed agriculture lands. This will be aided by the Sentinel-1 (SAR image) data.

This step will produce the first draft of the irrigated/rainfed agriculture map.

Step 6. Accuracy assessment and revision of the draft map (generating irrigated/rainfed agriculture map - II)
The draft map's accuracy will be assessed using the validation data set as prepared in Step 4 (i.e. 20% of the relevant data). The map is considered an acceptable quality with the mapping accuracy above 80% threshold. Where the map accuracy is below 80%, the training data will be re-interpreted and applied to reclassify the map again. Additional field data may be collected for training and validation data until the map achieves the accuracy above 80%. This step will generate the second draft of the irrigated/rainfed agriculture map with accuracy above the threshold of 80%.

Step 7. Integration of irrigated/rainfed agriculture map with the agroecological zone (AEZ) map (generating agroecosystem type map)
The irrigated/rainfed agriculture map (prepared in Step 6) will be integrated with the AEZ map (prepared in Step 3) to generate an agroecosystem map. An explanatory note for each agroecosystem type will also be prepared based on the map attributes and the relevant field data. The note will assign an appropriate name to each agroecosystem type and describe it in terms of physical characteristics, dominant crop composition/pattern, distribution, area coverage etc.

Step 8. Crop/cropping pattern classification (generating crop/cropping pattern map - I)
Using the training data set of crop/cropping patterns (prepared in Step 4), the agriculture cover map (prepared in Step 2) will be classified into various crop/cropping pattern types. A reiterative process will be applied in the classification so that the one producing the best results can be adopted. For example, both country-wide and altitudinal strata-wide classification will be run using the respective data sets. This step will produce the first draft of the crop/cropping pattern map.

Step 9. Accuracy assessment and revision of the draft map (generating crop/cropping pattern type map -II)
The draft map's accuracy will be assessed using the validation data set as prepared in Step 4 (i.e. 20% of the relevant data). Area-based estimation will be used for accuracy assessment. The map is considered an acceptable quality with the mapping accuracy above 80% threshold. Where the map accuracy is below 80%, the training data will be re-interpreted and applied to reclassify the map again. Additional field data may be collected for training and validation data until the map achieves the accuracy above 80%. This step will generate the second draft of the crop/cropping pattern type map with accuracy above the threshold of 80%.

Step 10. Integration of crop/cropping pattern map with the AEZ map (generating crop/cropping pattern in each AEZ type map)
The crop/cropping pattern type map (prepared in Step 9) will be integrated with the AEZ type map (prepared in Step 3) to generate a map showing crop/cropping pattern types in each agroecological zone.

Step 11. Expert review and generating final agriculture-related maps
The independent expert panel, comprising of agriculturists, agro-botanist, horticulturists, agronomists, livestock and fisheries experts and agroecologists, will review all the three maps and the corresponding explanatory notes. They will specifically examine naming of agroecological zones, agroecosystem types and major crops/cropping patterns and their distribution in the map. The maps and explanatory notes will be revised based on feedback from the expert panel, and the final maps and the related reports will be produced.

3.5 Vulnerability and risk assessment of ecosystems

Ecosystems are under constant pressure due to natural and anthropogenic causes. The biota, including animals, plants, and microorganisms, interact between themselves and with environmental variables to create a unique system within the energy flow regime. Different natural and anthropogenic processes have been negatively impacting these interactions and the environment by altering one or more elements of the system significantly. An ecosystem is considered vulnerable when the natural composition and function of the system is at risk at varying degrees. Some of the apparent causes are deforestation and degradation of natural vegetation, forest fires, incursion by exotic invasive species, land-use changes and practices, water regime change and climate change.

Nepal’s ecosystems are no exception, and are experiencing significant threats from the above factors. Hence, this mapping exercise also aims to assess their vulnerability and risks. Vulnerability is simply defined as the potential for loss (Weiβhuhn 2018, Adger 2006, IPCC 2014). Since the vulnerability assessment of an ecosystem generates information on its weaknesses and capacity to cope with an impact (Weiβhuhn 2018), it can be used to prioritize ecosystems for management. For better communication to policy makers and other stakeholders, distribution of ecosystem vulnerability will be mapped, indicating vulnerable hotspots. Necessary conservation and management interventions for ecosystems, with special focus on the hotspots, will also be identified.

Ecosystem vulnerability and risk assessment is an emerging concept, and various methods have been used for this. However, IPCC's (2014) framework will be adapted in this initiative. According to this framework, the **risk** of impacts to an ecosystem results from an interaction of **hazard** with the **vulnerability** and **exposure** of the ecosystem, whereas changes in climate system and socioeconomic processes drive the hazard, vulnerability, and exposure.

Hazard is "the potential occurrence of a natural or human-induced physical event or trend or physical impact that may cause loss of … ecosystems …" (IPCC 2014, p. 5). **Exposure** is " the presence of … ecosystems … in places and settings that could be adversely affected" (IPCC 2014, p. 5). This denotes the "location of the system at a place where a hazard occurs and causes adverse impact" (Sharma and Nijavalli 2019, p. 3). Thus, the analysis of an ecosystem's exposure can be guided by the probability of disturbances (abrupt) and stress (continuous) or the spatial proximity to the source of disturbance or stress (Frazier et al. 2014; Weiβhuhn 2018), and the proportion of the area of the ecosystem under threat (Dong et al. 2015).

Vulnerability is "the propensity or predisposition to be adversely affected"; it includes various concepts like sensitivity to harm and lack of adaptive capacity of the ecosystem (IPCC 2014). The '**sensitivity**' is a measure of an ecosystem's susceptibility to a hazard; it indicates the expected severity of impacts due to a given disturbance or stress (Weiβhuhn 2018). Sensitivity of an ecosystem to a particular disturbance or stress is generally dependent on its inherent properties. Therefore, the measure of an ecosystem's sensitivity is generally derived from the inherent characteristics of species (NWF 2011); for example, a coniferous forest may be less sensitive to grazing as compared to a broadleaved forest. The **'adaptive capacity'** is the ecosystem's ability to cope with the hazard and its consequences. It, also denoted by the term 'resilience' by many, means the self-organized adaptation by an ecosystem "as a sum of responses of its biophysical entities", dominantly by biotic components rather than non-biotic ones (Weiβhuhn 2018, p.909). Although measuring 'adaptive capacity' is a key to vulnerability assessment, it's characterization regarding natural systems is rare (Okey et al. 2015). However, indicators like the connectivity between ecosystems of the same type (Peng et al. 2015), adaptation by a single species, a single population, or even individuals in times of stresses, genetic differentiation within and between populations (Weiβhuhn 2018), and regeneration and seed dispersal capacities (Van Looy et al. 2016) have been considered to show an ecosystem's adaptive capacity. The measure of sensitivity is positively correlated with an ecosystem's vulnerability, whereas the measure of adaptive capacity is negatively correlated.

Although many vulnerability assessments evaluate a system's vulnerability and risk to climate change (e.g. USDA 2020), this assessment will evaluate an ecosystem's vulnerability and risk in terms of a combined effects of a range of natural and anthropogenic factors. Based on literature review, including the draft report of the vulnerability and risk assessment (VRA) being conducted by the MoFE with the support from PIF, and consultation with experts, a list of specific indicators to be analyzed for ecosystem vulnerability assessment in each of the forest and grassland, wetland, and agriculture ecosystems have been prepared (Table 11 – a, b, c). The weightages to each of these indicators, to derive their combined effects, will be assigned using experts' opinions.

Table 11: Indicators for assessing vulnerability and risk of ecosystems

a) Forest and grassland

SN	Key indicators	Description	Data source
1	**Hazard**		
1.1	Level/frequency/trend of different kinds of disturbances	The higher level of occurrence of disturbances like forest fire, soil erosion, landslide, disease/pest, grazing, tree cutting, firewood collection, infestation of invasive species etc. may cause loss of ecosystem	Soil Erodibility Index (ICIMOD), Field data

1.2	Change in temperature scenario	Higher rate of change in temperature may cause loss of ecosystem faster	DHM – Point data LST/WorldCLIM - Raster
1.3	Change in precipitation scenario	Higher rate of change in precipitation may cause loss of ecosystem faster	DHM – Point data WorldCLIM - raster
2	**Exposure**		
2.1	The distance from the boundary of the ecosystem to the nearest settlement	The longer the distance, the lower is the exposure to anthropogenic disturbances	Urban - NLCMS, Settlement – Survey Dept.
2.2	The population of the probable users of the ecosystem	The higher the users' population, the higher is the exposure to anthropogenic disturbances	Population GRID CBS
2.3	Aspect	Ecosystems on drier aspects are more exposed to the impacts of temperature rise (climate change) than those on the moist aspects	SRTM-DEM
2.4	Slope	The higher the slope, the higher is the exposure to erosion-related stresses	SRTM-DEM
2.5	Forest management regime	One regime may be more exposed to a disturbance than others (e.g. protected areas are less exposed to anthropogenic disturbances than government-managed forests)	FRTC, DOFSC
3	**Vulnerability**		
3.1	**Sensitivity**		
3.1.1	Species diversity	The higher the species diversity, the lower is the sensitivity	Field data
3.1.2	Species composition/types	One species may be more sensitive to a given disturbance or stress than the other	Field data; literature review
3.1.3	Successional stage of the vegetation	Ecosystems with climax vegetation is less sensitive to climate-related stresses than that with early/mid successional stages	Vegetation type map (EFTMP); literature review
3.1.4	Forest stock	The higher the stock (low level of degradation), the lower is the sensitivity to both natural and anthropogenic stresses or disturbances	Field data FRA/FRTC data
3.1.5	Total area of the ecosystem	The larger the area, the lower is the sensitivity to stresses or disturbances	EFTMP map
3.1.6	Average size of the ecosystem	The larger the size, the lower is the sensitivity to stresses or disturbances	EFTMP map
3.2	**Adaptive capacity**		
3.2.1	Age structure of vegetation	Forest with multiple age gradations is more adaptive than that with single age	Field data
3.2.2	Regeneration potential/status	The higher the regeneration potential, the higher is the adaptive capacity	Field data; literature review
3.2.3	Seed dispersion potential of the key species	The wider is the seed dispersion area, the higher is the adaptive capacity of a species	Literature review
3.2.4	Seed viability of the key species	The longer the seed viability, the higher is the adaptive capacity of the species	Literature review

b) Wetlands

SN	Indicators	Description	Data sources
1	**Hazard**		
1.1	Trend of annual rainfall (average pre-monsoon, monsoon and winter) in a wetland and its basin area	Higher rainfall trend increases stresses and risks of flood and breach of dam and other structures	DHM/LANDSAT imagery, rainfall data from the nearest meteorological stations of DHM
1.2	Trend of temperature (pre-monsoon, monsoon, post-monsoon, winter) in a wetland and its basin area	Higher temperature trend increases stresses and risks of drought and increases evapotranspiration that cause wetlands to dry and increases plant succession in lentic wetlands	DHM/LANDSAT imagery, rainfall data from the nearest meteorological stations of DHM
1.3	Encroachment trend (trend of conversion of wetlands to other land uses)	Higher the trend of encroachment, the greater is the stress on reduction of wetlands area	LANDSAT
1.4	Invasion of weeds and aquatic species (both flora and fauna)	Higher the number of invasive species and their pollution, the greater is the probability of loss of indigenous and native species of wetlands' flora and fauna	Field + Secondary sources
1.5	Number of landslide patches in the basin area	Higher number of landslide patches in the basin area of wetlands, higher the risk of wetlands degradation	LANDSAT imagery
1.6	Soil erodibility index	The higher the erosion potential of the basin, the higher is the exposure to siltation	ICIMOD
1.7	Level of pollution (e.g. solid waste and industrial discharges in rivers and lakes)	Higher the pollution, the higher is the risk of alteration of chemical properties of wetlands ecosystem, so the wetlands degradation. Higher the number of settlements, agriculture fields and industrial network in the basin area and perimeter of wetlands, the greater is the risk of water pollution	Field + Secondary sources
2	**Exposure**		
2.1	Population density around wetlands	Higher the population density, higher is the stress on wetlands.	CBS/Profile of local government unit
2.2	Human Poverty Index (HPI) (of the community living around wetlands)	Higher the HPI, lower the longevity, knowledge and a decent standard of living of communities living around wetlands, which tend to overharvest wetlands resources so increasing stress on wetlands.	Human Development Report/UNDP
2.3	Proximity to Protected Area (PA)	Wetlands inside or in the nearby distance of PAs are less exposed to anthropogenic disturbances	DNPWC
2.4	Forest Area Coverage in the basin area	Higher coverage of forest in the basin area (compared to other land uses, such as agriculture) means that the wetland is less exposed to soil erosion-related stresses (siltation)	
2.5	Forest canopy cover in the basin area	Higher the canopy cover (i.e. dense forest), the lower is the wetland's exposure to erosion-related stresses (siltation)	

SN	Indicators	Description	Data sources
2.6	Topography (Slope)	Lower the slope of the basin, lower is the exposure to erosion-related stresses (siltation)	LANDSAT imagery
3	**Vulnerability**		
3.1	**Sensitivity**		
3.1.1	Area of the wetlands	Larger the area of wetlands, lower is the sensitivity of wetland to respond against the stresses	LANDSAT imagery
3.1.2	Species diversity (A total number of species of aquatic microphyte and invertibrate, and plants and wild animals in the basin area of wetlands)	Higher the species diversity in terms of number and population, lower the sensitivity of wetlands to respond against habitat destruction	Field + Secondary sources
3.1.3	Water quality (Physical, chemical and biological properties of water of the wetlands)	Better the water quality, the lower the sensitivity to respond against stress viabilities	Field + Secondary sources
3.2	**Adaptive Capacity**		
3.2.1	Perennial sources of water	The presence of perennial sources of water flowing to the wetlands increases the adaptive capacity of the wetland (such as to cope with prolonged drought)	
3.2.2	Presence of wetland management institutions	Management institutions (such as CFUGs) play positive role to cope with stresses on wetlands	CFUG database + Field

c) Agro-ecosystems

SN	Key indicators	Description	Data source
1	**Hazard**		
1.1	Trend of precipitation change	More intense and erratic precipitation increase the impacts on agroecosystem	DHM data
1.2	Trend of temperature change	The higher the temperature change (as in Inner valleys), the more is the impacts on agroecosystem	DHM data
1.3	Trend of immigration/ agricultural land conversion into building areas (Plotting)	Trend of immigration (as in the Tarai and river valleys) leading to conversion of agricultural areas causes loss of agroecosystem	RS, field data
1.4	Trend of outmigration/ agricultural land abandonment	Trend of outmigration leading to abandonment of agricultural land causes loss of agroecosystem	Field data
1.5	Level of chemicals use	The higher level of dependency on agricultural chemicals (fertilizers, pesticides) deteriorates an agroecosystem	Agri-stat, field data
2	**Exposure**		
2.1	Proximity to urban area	The less the distance of an agroecosystem to the urban area, the higher is the potential of being converted into built-up area	RS, Field data
2.2	Total population dependent on given	The higher the population size dependent on an agro-ecosystem, the more exposed is the agro-ecosystem to	CBS

	agroecosystem	overexploitation of the land	
2.3	Drought prone area	The agroecosystem in a drought prone area is likely to be affected more.	RS, field data
2.4	Area prone to landslide, flooding	The agroecosystem in an area prone to landslide and flooding (e.g. in a river bank, steep slope) is likely to be affected more	RS, field data
3	**Vulnerability**		
3.1	**Sensitivity**		
3.1.1	Level of diversification	The higher the agricultural diversity, the lower the sensitivity of the agroecosystem	Field data
3.1.2	Proximity to market centers	Closer to the market centers, better opportunities for income improvement and thereby sustaining the ecosystem	RS, field data
3.2	**Adaptive capacity**		
3.2.1	Average ecosystem patch size (ha)	Larger size of the patch increases the adaptive capacity	RS
3.2.2	Degree of availability and reliability of irrigation facility	Higher the availability and reliability of irrigation facility more adaptive is the agroecosystem to hazards like drought	RS, field data
3.2.3	Proximity to forest/communal resources	Forest and communal resources (pastureland, ponds) provides ecosystem services to sustain the agricultural system	RS, field data
3.2.4	Proportion of economically active population	Higher the proportion of economically active population the more resilient will be the agroecosystem	CBS

3.6 Monitoring of ecosystems in future

The EFTM Program will produce maps showing ecosystem types in each of the forest, grassland, wetland, and agriculture components across the country, describing a general characterization of each ecosystem for the base year 2020. Similarly, the ecosystem threat/vulnerability map will show the level of threats to and vulnerability of each ecosystem. In this context, the monitoring of ecosystems means to periodically assess whether an ecosystem type has changed to other type (e.g. change in land cover, change in forest type), the general characteristics of an ecosystem have changed (e.g. enhancement or degradation of forest condition, change in species diversity), and the level of threat/vulnerability has changed (e.g. shift of threat/vulnerability level downwards or upwards).

Therefore, for the future monitoring of ecosystems, key monitoring indicators for each of the forest, grassland, wetland and agriculture components will be identified, monitoring techniques will be defined, and monitoring plan will be prepared. Table 12 summarizes activities to be carried out and methods to be applied for the establishment of ecosystem monitoring system.

Table 12: Activities and methods for establishing ecosystem monitoring plan

Activity	Method	Remarks/time
1. Identify key ecosystem monitoring indicators for each component (i.e. forest, grassland, wetland, and agriculture), and ensure that relevant indicators are included in the field data collection form	Review of literature and existing data from credible sources (e.g. FRA), and consultation with experts and stakeholders	Before the start of fieldwork (these will be reflected in the data collection forms)
2. Defining monitoring techniques/methods	Review of literature, analysis of field data, consultation with experts and stakeholders	Once the ecosystem and ecosystem threat/vulnerability maps are prepared
3. Preparing monitoring schedule		

4. Program Implementation Arrangement

The EFTM Program is being implemented by the Forest Research and Training Centre (FRTC) under the Ministry of Forests and Environment (MoFE). The Program is supported by UKAID's Policy and Institutions Facility (PIF) through Oxford Policy Management (OPM) and USAID's Hariyo Ban Program through WWF Nepal. This section presents the implementation arrangements of the Program, including organizational structure, human resources and budget.

4.1 Organizational structure

The implementation mechanism of the Program consists of three tiers of implementing bodies – the Program Advisory Committee (PAC), Program Coordination Committee (PCC), and Ecosystem Mapping Unit (EMU) (Figure 9).

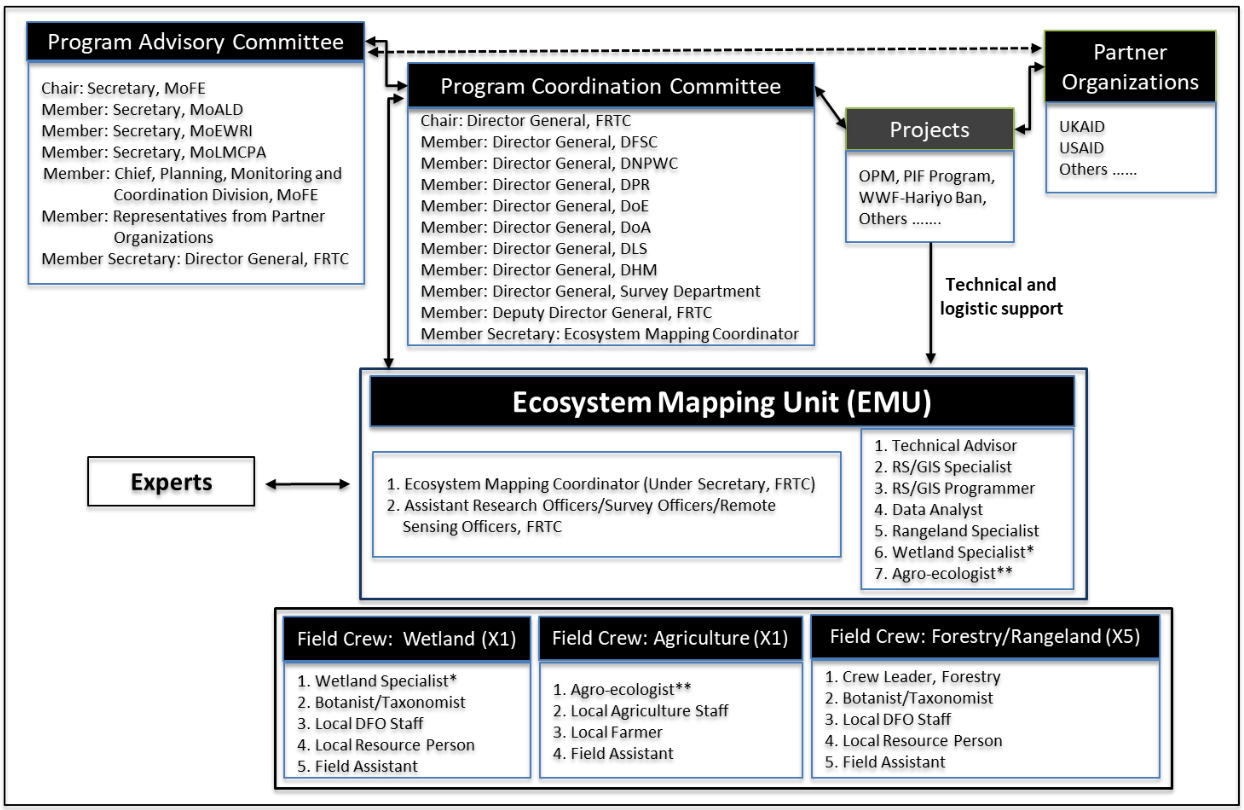

Figure 9: Organizational structure of the Ecosystem and Forest Type Mapping Program

4.1.1 Program Advisory Committee (PAC)

The PAC is the supreme body of the Program. It provides strategic direction, guidance and policy support for the program implementation, and grants approval to the mapping products. It ensures inter-ministerial communication and coordination, and that with the partner organizations. The Secretary of the MoFE chairs this committee, whereas the Director General

(DG) of the FRTC acts as its member secretary. The PAC members include secretaries of the Ministry of Agriculture and Livestock Development (MoALD), the Ministry of Energy, Water Resources and Irrigation (MoEWRI) and the Ministry of Land Management Cooperatives and Poverty Alleviation (MoLMCPA), the Chief of the Planning, Monitoring and Coordination Division, MoFE, and the representatives from the partner organizations. The Chairperson may invite representatives from other organizations as members to the committee. The PAC first meets within three months of the program inception, and later as and when required.

4.1.2 Program Coordination Committee (PCC)

The PCC functions at the department level to ensure effective coordination and communication horizontally and vertically. The DG of the FRTC chairs this committee, whereas the Ecosystem Mapping Coordinator acts as its member secretary. The PCC members include the Director Generals of the Department of Forest and Soil Conservation (DFSC), the Department of National Parks and Wildlife Conservation (DNPWC), the Department of Plant Resources (DPR), the Department of Environment (DoE), the Department of Agriculture (DoA), the Department of Livestock Services (DLS), the Department of Hydrology and Meteorology (DHM), and the Survey Department. The Deputy Director General (DDG) of the FRTC is also a member of this committee. The Chairperson may invite individuals or organizations to join the committee as required. The PCC meets at least once every four months to review the Program's progress and provide necessary guidance and support for the fieldwork. The Chair of the PCC reports to the PAC as and when required.

4.1.3 Ecosystem Mapping Unit (EMU)

The EMU acts as a technical working group of the Program. The Ecosystem Mapping Coordinator (EMC), an Under Secretary (Technical) assigned by the FRTC, coordinates the EMU. The EMU members include four to six Assistant Research Officers/Survey Officers/Remote Sensing Officers assigned by the FRTC to work for the Program and all specialists hired by the Program. It mobilizes all kinds of resources, including field crews, to deliver the Program outputs. It also consults with experts as and when required.

The specific roles of the EMU are as follows:

1. To ensure that the thematic area specialists, experts and field staff are hired at appropriate times in line with the implementation schedule.

2. To ensure that the thematic area specialists, experts and field staff are provided with the necessary logistic support to undertake their specific roles as per their Terms of Reference.
3. To facilitate the coordination and communication with authorities and relevant stakeholders at the province and local levels for fieldwork.
4. To provide technical support to field crews during their fieldwork, for example, to find the location of sample points.
5. To organize capacity building training for the field crews to ensure that field data and relevant information will be collected as per the SOPs.
6. To resolve any conflicts that may arise during the Program's implementation to ensure timely implementation of the Program's activities.
7. To undertake validation of the field data and relevant information.
8. To monitor the Program's progress and report it to the PCC.

The regular meeting of the EMU will be organized every month to review the Program progress. However, it may be organized more than once in a month if required. The DG, DDGs and Under Secretaries of the FRTC and the representatives from partner organizations, such as Hariyo Ban Program of WWF Nepal funded by USAID and Policy and Institutions Facility (PIF) of Oxford Policy Management funded by UKAID, will be invited to the regular meetings.

4.2 Human resources

The human resources for the Program include the technical officers assigned by the FRTC and the specialists and other staff hired by the Program. The FRTC has assigned one Under Secretary as the Ecosystem Mapping Coordinator, who oversees the overall management of the Ecosystem Mapping Unit and coordinates with the PCC. Similarly, the FRTC will deploy four to six officers/forest technicians to the EMU, of which one officer has already been on board. Besides, additional human resources from FRTC shall be deployed whenever required. The FRTC will also allocate internship students to work in the Program. The Department of Plant Resources (DPR) is expected to deploy two botanists/taxonomists for the fieldwork.

Table 13 presents human resources needed for the Program and the status of their engagement.

Table 13: Human resources of the Program

SN	Position	No.	Effective duration (Months)
	Technical team		
1	Technical Advisor	1	29
2	RS/GIS Specialist	1	24
3	RS/GIS Programmer	1	4
4	Data Analyst	1	4
5	Wetland Specialist	1	10
6	Agro-ecologist	1	10
7	Rangeland/Grassland Specialist	1	4
8	International Expert	1	3
	Office Management		
9	Office Assistant	1	24
	Field Crew (regular)		
10	Field Crew Leader - F&GL crew	5	16
11	Forest Technician - F&GL crew	5	14
12	Botanist/Taxonomist - F&GL crew	5	16
13	Botanist/Taxonomist - WL crew	1	4
	Local support team in the field		
14	Local Technical Staff - F&GL crew	5	15
15	Local Technical Staff - WL crew	1	4
16	Local Technical Staff - AG crew	1	4
17	Local Resource Person - F&GL crew	5	15
18	Local Resource Person - WL crew	1	4
19	Local Resource Person - AG crew	1	4
20	Local Assistant - F&GL crew	5	15
21	Local Assistant - WL crew	1	4
22	Local Assistant - AG crew	1	4
	Expert Reviewer		
23	Expert - forest ecosystem	1	1
24	Expert - grassland ecosystem	1	0.5
25	Expert - wetland ecosystem	1	0.5
26	Expert - agro-ecosystem	1	0.5

Note: AG = Agriculture, F&GL = Forest and Grassland, RS/GIS = Remote Sensing/Geographic Information System, WL = Wetland

The Program also requires an IT Professional to set up and maintain a Linux based server system and the database management system. These services will be outsourced from an Information Technology (IT) Company.

4.3 Program budget

As per the Program Design Document, the total budget for the EFTMP implementation was estimated to be NRs. 10,52,30,000 (Nepalese Rupees Ten Crore, Fifty-Two Lakh and Thirty Thousand only), equivalent to USD 857,480 (USD Eight Hundred Fifty Seven Thousand, Four Hundred and Eighty only). However, it has been revised due to the need of additional human resources, i.e. a Forest Technician in each Forest and Grassland field crew, identified during the preparation of detailed methodology. Thus, the total cost has been re-estimated to be NRs. 109,640,000 (equivalent to USD 920,880, as of June 30, 2021), an increase by NRs. 4,410,000 in the original estimate (Annex 1).

A total of NRs. 25,841,396 (NRs. 2,756,843 by GoN/FRTC, NRs. 8,235,453 by USAID/Hariyo Ban Program, and NRs. 14,849,100 by FCDO/PIF) has been spent in the program implementation until June 2021.

5. Program Implementation Plan

5.1 Work Schedule

The EFTM Program was initially designed to be implemented in two years. Thus, started in October 2020, it was expected to complete in October 2022. However, since the fieldwork and other related activities have been paused for about five months (from May to September 2021) due to the COVID-19 pandemic, it is assumed to complete in March 2023. A general schedule of the program implementation is presented in Table 14.

Table 14: Work plan of the EFTM Program

SN	Activities	2020		2021												2022												2023			Remarks/ Deliverables
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	
		N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	
1	**Review program design document, prepare work plan**																														A work plan consisting of all components
2	**Review existing knowledge, data and maps; and define the forest, grassland, wetland and agriculture typologies**																														Review report of each component (draft prepared)
3	**Review and finalize methodology for the forest, grassland, wetland and agriculture type and ecosystem mapping, and assessment of ecosystem threats and vulnerabilities for each component**																														Inception report (prepared in Feb 2021 and revised in July 2021 in the context of the COVID-19's disturbance to the original work schedule)
4	**Collect the forest, grassland, wetland and agriculture type signatures from secondary sources (e.g. FRA)**																														Data set of forest signatures has been prepared from FRA data, data have been collected for other cover types too.

5	**Define sampling design; locate assessment plots/points; and prepare Standard Operating Procedures (SOPs) and field data collection forms relating to mapping and threat/vulnerability assessment**	SOPs and field data collection forms (separate for each component) have been prepared.
6	**Develop training package for the field data collection, hire field crew members, and deliver training to them, including field piloting**	Field crews hired, data collection training delivered, pilot surveys accomplished.
7	**Prepare fieldwork plan, and arrange field accessories**	Fieldwork plan prepared, being revised; field accessories have been arranged.
8	**Carry out field data collection, entry into database, and analysis**	The first field survey mission (20 day-long) completed
9	**Map the forest and grassland types, wetland types, agriculture types and ecosystems, including ecosystem vulnerabilities** (a detailed plan of mapping exercise attached separately)	Cover type, ecosystem, and ecosystem vulnerability maps of each component
10	**Review existing knowledge and conduct consultations on ecosystem monitoring**	Ecosystem monitoring plan for forest and grassland, wetlands, and agriculture ecosystems
11	**Prepare thematic reports**	Reports on cover types, ecosystems, and vulnerability of

																															each component
12	**Compile thematic reports and prepare a consolidated report**																														Report on ecosystems of Nepal

5.2 Consultation schedule

Individual and group consultation with experts and stakeholders is an integral part in the whole processes of this assignment, for assuring both quality and ownership of the Program's products. A roster of experts and stakeholders (individuals and organizations) has been/will be created and updated for each thematic component, and they have been/will be consulted if required during the Program operation. In addition, a plan for key consultation events has been proposed as given in Table 15.

Table 15: Plan for key consultation events

SN	Activity	Time
1	Individual and small group consultation with thematic experts to discuss methodologies for ecosystem mapping and threat/vulnerability assessment	Dec 2020-Feb 2021 (completed)
2	National workshop of experts and stakeholders to discuss methodologies for ecosystem mapping and threat/vulnerability assessment	Feb 2021 (completed)
3	Expert group consultation to discuss forest and grassland ecosystem, agro-ecosystem, wetland ecosystem, and their vulnerability maps	Feb 2023
4	National workshop of experts and stakeholders to discuss the final products of the Program, including the ecosystem maps of Nepal	Feb 2023

5.3 Implementation schedule for capacity building activities

One of the four objectives of the EFTM Program is to improve institutional capacity for the future monitoring and updating of the ecosystem map of Nepal. Capacity building is a continued process, and it involves human resources and technical infrastructure of the respective institutions. Capacity building activities will be targeted to improve the quality of the ongoing ecosystem mapping as well as to develop a sustained system of ecosystem monitoring and updating ecosystem maps in the future. The schedule of capacity building activities is presented in Table 16.

Table 16: Schedule of capacity building activities

SN	Activity	Time
1	Field data collection orientation training; review and refreshment training	Mar (completed), Sep 2021
2	Server installation and operation (FRTC officials will be involved in server operation)	Jul 2021 - Mar 2023

3	Upgrading the RS/GIS laboratory at FRTC (installation of computers, networking etc.)	Feb-Apr 2021 (completed)
4	Maintenance of physical infrastructure to improve working environment	Feb 2023
5	Expert and stakeholder engagement (consultation workshops/meetings)	Dec 2020-Feb 2021, Feb 2023

5.4 Reporting schedule

The reporting schedule of key deliverables of the Program is presented in Table 17.

Table 17: Reporting schedule

SN	Deliverable	Time
1	**EFTM Program inception report**	Feb 2021, the revised report in July 2021
2	**Review reports** (intended to assist sampling design, data collection, and mapping)	March, 2021 (draft), Oct 2021 (Final)
2.1	Vegetation (forest and grassland) types in Nepal	
2.2	Wetland types in Nepal	
2.3	Agro-ecological types in Nepal	
2.4	Methodologies used in ecosystem and vegetation type mapping	
3	**Maps (final products)**	
3.1	Wetland types of Nepal	Feb 2023
3.2	Wetland ecosystems of Nepal	Feb 2023
3.3	Wetland ecosystem vulnerability of Nepal	Feb 2023
3.4	Agro-ecological zones of Nepal	Feb 2023
3.5	Agro-ecosystems of Nepal	Feb 2023
3.6	Agro-ecosystem vulnerability of Nepal	Feb 2023
3.7	Vegetation (forest and grassland) types of Nepal	Feb 2023
3.8	Forest and grassland ecosystems of Nepal	Feb 2023
3.9	Forest and grassland ecosystem vulnerability of Nepal	Feb 2023
4	**Assessment reports**	
4.1	Wetland ecosystems of Nepal (with characterization, vulnerability status, and recommended interventions for each type)	Feb 2023
4.2	Agro-ecosystems of Nepal (with characterization, vulnerability status, and recommended interventions for each type)	Feb 2023
4.3	Forest and grassland ecosystems of Nepal (with characterization, vulnerability status, and recommended interventions for each type)	Feb 2023
4.4	Methods and processes used in the ecosystem mapping of Nepal	Mar 2023
4.4	Ecosystems of Nepal (a summary report based on all thematic reports)	Mar 2023
5	**Ecosystem monitoring plan for Nepal**	Mar 2023
6	**Progress reports**	
6.1	Update reports	July (2021, 2022)
6.2	Annual progress report	Oct 2021, Oct 2022
6.3	Final progress report	Mar 2023

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Annex 1: **Detailed cost estimates for the program implementation**

Position/Roles		Duration	Unit	Rates (NRs)	Total Cost (NRs)	Cost in %
Technical Team Renumeration	**No**				**32,920,000**	**31.28%**
1. Technical Advisor	1	**24**	**Months**	300000	7,200,000	
2. RS/GIS Specialist	1	**24**	**Months**	200000	4,800,000	
3. GIS/RS Programmer	1	**4**	**Months**	200000	800,000	
4.Data Analyst	1	**4**	**Months**	150000	600,000	
5. Wetland Specialist	1	**10**	**Months**	150000	1,500,000	
6. Agri-ecologist	1	**10**	**Months**	150000	1,500,000	
7. Rangeland Specialist	1	**4**	**Months**	150000	600,000	
8.International Expert (Review, Mentoring & Capacity building)	1	**60**	**days**	60000	3,600,000	
Field Team Renumeration						
1. Crew Leader - Forestry	5	**15**	**Months**	80000	6,000,000	
2. Botanist/Taxonomist for forestry team	5	**15**	**Months**	80000	6,000,000	
3. Botanist/Taxonomist for wetland team	1	**4**	**Months**	80000	320,000	
Local Support Crew Renumeration					0	**0.00%**
1. Local Staff for forestry team	5	**15**	**Months**		0	
2. Local Res. Person for forestry team	5	**15**	**Months**		0	
3. Local Assistant for forestry team	5	**15**	**Months**		0	
4. Local Staff for Agri and wetland field team	2	**4**	**Months**		0	
5. Local Res. Person Agri and wetland field team	2	**4**	**Months**		0	
6. Local Assistant Agri and wetland field team	2	**4**	**Months**		0	
Expert Reviewer Renumeration					**660,000**	**0.63%**
1.Expert-Forest types and Ecosystem	1	**1**	**Months**	200000	200,000	
2.Expert-Agro-Ecosystem	1	**0.5**	**Months**	200000	100,000	
3.Expert-Wetland Ecosystem	1	**0.5**	**Months**	200000	100,000	
4.Expert-Rangeland Ecosystem	1	**0.5**	**Months**	200000	100,000	
5.Expert Panel Engagement	20	20	Days	8000	160,000	
Field Work (DSA Accomodation and hardship allowance)					**35,255,000**	**33.50%**
1. Technical Advisor	1	40	Days	5000	200,000	
2. RS/GIS Specialist	1	36	Days	5000	180,000	
3. Wetland Specialist	1	84	Days	5000	420,000	
4. Agro-ecologist	1	84	Days	5000	420,000	
5. Rangeland specialist	1	30	Days	5000	150,000	
6. Crew Leader - Forestry	5	1575	Days	5000	7,875,000	
7. Botanist/Taxonomist for forestry team	5	1575	Days	5000	7,875,000	
8. Botanist/Taxonomist for wetland team	1	84	Days	5000	420,000	
9. Local Staff for forestry team	5	1575	Days	2000	3,150,000	
10. Local Res. Person for forestry team	5	1575	Days	1500	2,362,500	
11. Local Assistant for forestry team (Labor/Porter)	5	1575	Days	1500	2,362,500	
12. Local Staff for Agri and wetland field team	2	168	Days	2000	336,000	
13. Local Res. Person Agri and wetland field team	2	168	Days	1500	252,000	
14. Local Assistant Agri and wetland field team (Labor/Porter)	2	168	Days	1500	252,000	
15.E&FT Mapping Coordinator	1	360	Days	5000	1,800,000	
16.Asst Survey Officer	2	360	Days	5000	3,600,000	
17.Asst Remote Sensing Officer	2	360	Days	5000	3,600,000	
Travel					**20,375,000**	**19.36%**
1.Air travel (national)		1	LS	400000	400,000	
2.Vehicle hire + fuel		2350	Days	8500	19,975,000	

Training, Workshops and Meetings					**3,560,000**	**3.38%**
1.Field data and information collection Training (2 days 20 people field based)		1	Times	400000	400,000	
2.Team building and field Experience sharing workshop (30 people, 1 day)		3	Times	300000	900,000	
3.Expert Panel Meetings (10 people, 1 day)		4	Times	35000	140,000	
4.Program Coordination Committee		6	Times	50000	300,000	
5.Program Advisory Meeting		4	Times	75000	300,000	
6.Threat, Risk and Vulnurability Assessment, Consultation & Workshop		LS		500000	500,000	
7.TWG Meeting		24	Times	30000	720,000	
8.Dissimination Workshop		1	Times	300000	300,000	
Equipment					**2,180,000**	**2.07%**
1.Camera with GPS		7	unit	50000	350,000	
2.D-Tape		14	unit	5000	70,000	
3.Sunnto-clinometer		7	unit	35000	245,000	
4.Measuring Tape		14	unit	2500	35,000	
5.Basic laptop		7	unit	140000	980,000	
6.Inventory Forms Printing		1	unit	150000	150,000	
7.A set of Vegetation Identification book and field manual		7	unit	50000	350,000	
Field Gear					**1,390,000**	**1.32%**
1.Field Gear to each crew member		23	set	30000	690,000	
2. Tents,Torch, cooking utensils		LS	LS	7000000	700000	
Publication					**500,000**	**0.48%**
Report publication			LS	500000	500,000	
Infrastructure					**8,390,000**	**7.97%**
1.Cloud server set and maintenance			LS	200000	200,000	
2.Mapping unit management cost (Communication, Internet,Toner,Paper etc.)		1	unit	1190000	1,190,000	
3.Developing cloud based database system and maintenance				5000000	5,000,000	
4. Software,hardware and it's accessories			LS	2000000	2000000	
		Total			**105,230,000**	NRs
		Exchange Rate 22 April 2020		122.72	857,480	US$

Note: The above details is from the Program Design Document. During the development of detailed methodology, it was realized that a 'Forest Technician' is to be included in each forest and grassland field crew (total 5 persons) and thus included in the SOP for field survey. It was not considered by the Program Design Document. Therefore, the total estimate is increased by the estimated cost associated with this (5 persons*14 months*21 days/month*NRs.3000 per day = NRs. 4,410,000), making the revised total estimate to be NRs. 109,640,000 (equivalent to USD 920,880, as of June 30, 2021).