Restoration Guidelines- Enhancing Ecosystem and Ecohealth Considerations in Cascade Tank Restoration

Healthy Landscapes Project

2024

Consultancy Service for Undertaking Develop Restoration Guidelines on enhancing ecosystem and eco-health considerations in cascade tank restoration and Conduct awareness workshops for all line agencies towards a shared understanding of Cascade Restoration Guidelines for landscape management

Submitted to
The UNEP-GEF project on Healthy Landscapes: Managing Agricultural Landscapes in Socio-Ecologically Sensitive Areas to Promote Food Security, Wellbeing and Ecosystem Health Project in Sri Lanka

Submitted by

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PROGRESS SUMMARY

Village Tank Cascade Systems (VTCS) in Sri Lanka are sustainable water management model which harmonizing ecosystem components to supports diverse life forms in regions that comprises with one season excess rain and rain deficit second rainy season. VTCS, vital for rural livelihoods, faces threats necessitating restoration. Recognizing its uniqueness and importance, Healthy Landscape Project (Managing Agricultural Landscapes in Socio-ecologically Sensitive Areas to Promote Food Security, Well-being and Ecosystem Health Project; HLP) which was operational as GEF funded project has identified preparation of guidelines on enhancing ecosystem and Eco health considerations in cascade tank restoration with stakeholder awareness enhancing on "Restoration Guidelines" in Key Indicative Activity 4.2.1. Project documents suggest mainstreaming **Land-use-system based approach** for cascade restoration planning.

As indicated in the TOR, this consultancy aim generating following two key deliverables for completion of Key Indicative activity 4.2.1 of the Healthy Landscape Project have been undertaken.

1. Prepare set of sequential guidelines for evaluation of land-use system based / tank component base status assessment targeting comprehensive multidisciplinary multi-stakeholder integration holistic approaches

2. Enhance awareness on related stakeholders on application of sourcebook and guidelines for systematic restoration planning and implementation for cascade integrated landscape restoration

Consequently, agreed to complete following 5. sub activities.

Sub activity 1. Develop and submit action Plan with expected time targets

Sub activity 2. Formulate guideline for restoration planning of VTCS using LUS-based approach by developing all model data for pilot cascade landscape

Sub activity 3. Prepare training materials

Sub activity 4. Conduct training workshops

Sub activity 5. Submission of printable version of all products (with a set of hard copy)

This is the final submission after completion of all the 5 sub activities successfully. Summary of each sub activity is given below:

1 BACKGROUND OF THE CONSULTANCY

The Dry Zone of Sri Lanka serves as the country's food basket, with agriculture and food production systems meeting population growth demands through various means: conversion of natural ecosystems, farming intensification, improved crop and animal breeds, and agronomic practices. However, this process has incurred significant health and environmental costs. Recent unplanned efforts to enhance agriculture in VTCS have led to degradation, deforestation, loss of biodiversity, and deterioration of village tanks, alongside health risks like pesticide overuse. Reliance on fertilizers has depleted soil fertility, increased erosion, and caused pollution. Land use changes and intensified agriculture are major biodiversity loss drivers in cascade landscapes. Simplification and homogenization impact human health by altering natural habitat services crucial for agriculture, reducing wild species habitat, enhancing disease interactions, accelerating medicinal plant loss, and degrading cultural ecosystem services and mental wellbeing. Agricultural expansion into wild habitats escalates human-wildlife conflicts, worsened by invasive species' effects on biodiversity, ecosystems, agricultural production, and human health. Many health impacts of unsustainable land management practices in cascade landscapes remain undocumented and unquantified.

Numerous drivers and threats challenge the restoration, sustainability, and conservation of cascade landscapes in Sri Lanka's dynamic socio-political and economic context. For instance, the water holding capacity of VTCS has diminished over time, impacting irrigation availability and farm productivity. Climate change exacerbates these issues, altering rainfall patterns and cropping cycles. Challenges include reservoir sedimentation, declining farm viability, agricultural expansion, water pollution, invasive species, health concerns like chronic kidney disease (CKDu), migration, lack of landscape appreciation, pesticide reliance, fertilizer dependency, soil degradation, and human-wildlife conflicts.

A major challenge in VTCS is the absence of effective institutional mechanisms for cohesive landscape management, exacerbated by natural boundaries crossing administrative lines. Efforts to integrate environment, agriculture, and health in policy-making are hindered by limited awareness of ecosystem and health linkages. Currently, there is a lack of education and awareness regarding holistic cascade management, with insufficient institutional frameworks for participatory planning. As a result, there are few holistic management plans based on comprehensive cascade ecology understanding, and no supportive models or guidelines for sustainable land management approaches in village tanks.

Most interventions targeting VTCS development, often overlook ecological aspects, focusing on conventional technical approaches instead. This neglect leads to adverse outcomes such as flooding, water scarcity, and salinity. Limited awareness among farmers and communities exacerbates the issue. A key challenge is the lack of understanding of cascade ecology and its links to human health across society. Poor coordination and policy coherence hinder project success, as stakeholders work in isolation. Nationally, there's inadequate capacity building and research partnerships to manage cascade landscapes effectively for multiple benefits, including human health.

Agriculture and sustainable land management rely on healthy ecosystems and biodiversity, impacting human health positively or negatively (WHO and CBD, 2015). In Sri Lanka, poor agricultural practices harm biodiversity and ecosystem services, affecting human health. Overuse of pesticides contributes to health issues like Chronic Kidney Disease, while simplified agricultural landscapes lead to dietary shifts and non-communicable diseases. Unplanned land use, degradation, pollution, invasive species, climate events, and fragmentation further diminish ecosystem services, worsening health outcomes.

Critical among Sri Lanka's ecological challenges is the degradation of cascade wetland landscapes in the Dry Zone, impacting biodiversity and ecosystem services. These landscapes, rich in resources vital for local communities, suffer from overexploitation, leading to species and habitat decline. Village tanks, integral to cascade landscapes, have deteriorated due to development projects and agricultural changes, exacerbating ecosystem degradation. Deforestation, population growth, loss of fertile lands, and increased drought severity further degrade these landscapes, eroding traditional biodiversity conservation knowledge. Climate change exacerbates these issues, particularly in the Dry Zone.

The Healthy Landscapes project is aiming to establish a platform for integrated and holistic sustainable land management in VTCS landscapes based on cascade ecology principles and ecosystem services flow, including human health outcomes. It adopts a holistic approach to VTCS landscape rehabilitation, creating multi-sectoral platforms for sustainable management plans and guidelines. It introduces innovative SLM and agroecology approaches, with a focus on soil health and optimized water use. The project also develops and implements sustainable restoration models with stakeholder and local community involvement.

The project aims to scale up holistic cascade restoration guidelines following evaluation at project test sites to neighbouring cascade landscapes in the Dry Zone and beyond. It leverages national interest through its approaches, practices, and lessons learned.

In line with above the TOR, this assignment is to prepare sequential guidelines for evaluation of land-use system based / tank component base status assessment targeting comprehensive multidisciplinary multi-stakeholder integration holistic approaches and enhance awareness on related stakeholders on application of guidelines for systematic restoration planning and implementation for cascade integrated landscape restoration. Summary of assigned task is given in the table 2.

Table 1: Activities responsible and targeted project components

Component 4: Knowledge, information management and monitoring and evaluation		
Outcome 4: Project implementation based on results-based management and application of project lessons learned in future operations facilitated		
Output 4.2. Project-related best practices, knowledge products and lessons learned systematized and published for a variety of audiences and stakeholder groups		
	Key deliverables	**List of sub activity**
Activity 4.2.1 Develop restoration guidelines on enhancing ecosystem and eco-health considerations in cascade tank restoration with a workshop following that	1. Prepare set of sequential guidelines for evaluation of land-use system based / tank component base status assessment targeting comprehensive multidisciplinary multi-stakeholder integration holistic approaches	1. Develop and submit Action Plan with expected time targets 2. Formulate guideline for restoration planning of VTCS using LADA-WOCAT approach by developing all model data for pilot cascade landscape
	2.) Enhance awareness on related stakeholders on application of	3. Prepare training materials 4. Conduct training workshops

	guidelines for systematic restoration planning and implementation for cascade integrated landscape restoration.	5. Submission of printable version of all products (with a set of hard copy)

The main tasks under taken were 1. Develop and submit Action Plan with expected time targets were already submitted, 2. Formulation of restoration guidelines were completed and final version is attached separately 3. Preparation of training materials for stakeholder training workshops and the following are the main responsibilities of the consultant;

1. Initial planning and preparation of work schedules
2. Formulation of restoration guidelines for cascade landscapes
3. Prepare materials for stakeholder training workshops
4. Conduct training programs enhance line stakeholders

2 FINAL PROGRESS

Progress of Sub activity 1 - Develop and submit action Plan with expected time targets completed and **already submitted** with 1st & 2nd Report.

Progress of Sub activity 2 – "Restoration Guidelines on enhancing ecosystem and eco-health considerations in cascade tank restoration" has been developed and finalized softcopies and hard copy have been submitted to Healthy Landscape project office and a soft **copy is attached separately**.

Progress of Sub activity 3 - Training materials for all the training sessions and practical sessions were prepared. List of training materials and presentations given bellow can be found in the A**nnexure I**

1. PowerPoint presentation - Introduction to Cascade Restoration Guidelines (**section 2.1.1**)
2. PowerPoint presentation - Spatial setting of Village Tank Cascade Systems (VTCS) and anatomy of tank associated components (**Section 2.1.2.**)
3. PowerPoint presentation – Land-use data in Sri Lanka (**section 2.1.3**)
4. PowerPoint presentations - GIS for Land Use System (LUS) mapping (GIS basics, GIS data models, Open-source GIS software & free data sources, GPS & mobile apps) Section 2.1.4 – 2.1.8)
5. Model formats for Questionnaire Manual (QM) approach (QM Code sheets, QM Definition sheet, LUS change assessment, Land degradation assessment, land degradation impact assessment Status of already implemented sustainable land management technologies and approaches (Section 2.2.1 – 2.2.8),
6. . Model formats for local level detailed Land degradation and Sustainable Land Management status assessment (Soil assessment, Water sources assessment, Biodiversity assessment & Livelihood assessment Key-informant data formats, community group discussion data formats) (section 2.3.1-2.3.7)

Progress of Sub activity 4 - Conduct training workshop to Enhance awareness of related stakeholders on application of guidelines for systematic restoration planning and implementation for cascade integrated landscape restoration.

The training on applying cascade restoration guidelines was successfully conducted on 31st May 2024 at CeyBank Rest, Anuradhapura. This training aimed to enhance the understanding and practical application of cascade restoration techniques among the staff of various stakeholder agencies. Main objectives of the training was to familiarize participants with the cascade restoration guidelines, to provide hands-on experience in applying these guidelines and to facilitate the exchange of knowledge and best practices among participants.

The training was attended by over 25 participants from various agencies (Land Use policy Palming Department, Provincial /District Land department, District Secretariate officials, University Academia and subject matter specialists.

Agenda of the training workshop is given bellow.

Healthy Landscape Project

Training Workshop on Cascade Restoration Guidelines

Cey Bank Rest - Anuradhapura

31st May 2024

AGENDA	
08:00 - 08:30	Registration
08:30 - 09:00	Opening Session • Welcome Address – ***Mr. Ajith Silva, Project Manager, Healthy Landscape Project*** • Introduction of participants
09:00 - 10:00	Introduction to Cascade Restoration Guidelines - ***Dr. H.K. Kadupitiya***
10:00 - 10:30	***Tea Break***
09:30 - 12:30	Base Principles • Spatial setting of Village Tank C ascade Systems (VTCS) and anatomy of tank associated components • Land degradation & Ecosystem analysis basics • GIS for Land Use System (LUS) mapping • Questionnisire Manual (QM) approach • LUS-QM linkage development
12:30 - 13:30	***Lunch break***
13:30 - 15:30	Data need & gathering approaches • Field investigation & Visual assessment • Local knowledge integration • Expert judgement Data compilation and degradation mapping
15:00 - 15:30	***Tea Break***
15:30 - 16:00	• Selection of priority landscape (hotspots/bright spots mapping) • Local level detailed assessment of Land degradation (LD) and Sustainable Land Management (SLM) practices
16:00 - 17:00	Closing session • Discussion • Wrap-up

The training was stared with an opening session headed by the Healthy Landscape Project Manager who welcomed all participants and delivered opening remarks for the training workshop.

After the opening session, introduction of cascade restoration guidelines with a PowerPoint presentation was done to provide in-depth understanding principles and tools used for land-use system based QM guided sun-national/ landscape level assessment approaches for hotspot mapping and detailed transect guided local level assessment approaches.

Comprehensive training given to participants on Base Principles details on Spatial setting of Village Tank Cascade Systems (VTCS) and anatomy of tank associated components, Land degradation & Ecosystem analysis basics, GIS for Land Use System (LUS) mapping, Questionnaire Manual (QM) approach, LUS-QM linkage development, Data need & gathering approaches, Field investigation & Visual assessment, Local knowledge integration, Expert judgement, Data compilation and degradation mapping, Selection of priority landscape (hotspots/bright spots mapping), Local level detailed assessment of Land degradation (LD) and Sustainable Land Management (SLM) practices.

During the conduct, participants were allowed to ask questions and up-on request of the participants, detailed clarifications on Land Use System Based approach, cascade related ecosystem services, GIS principles, QM data collection tools were done with more examples.

Headed by the Project Manager, the closing session was conducted with discussion and feed-back components. Some of the comments were given below.

- A professor (watershed management specialist) commented on the approach and sited that, the approach is well aligned with watershed-based approach and with the Land Use System Based approach, some gaps of Watershed based approach can be rectified. He also invited to introduce this approach for university students by conducting similar sessions.

- A professor (Soil Science) commented on the training and stated he has heard on LADA approach and the knowledge gain during the training was much appreciated, holistic approach of the cascade restoration process was valued and willing to link for any collaborative tasks for practical holistic application of cascade restoration guidelines.

- LUPPD staff members responded during the discussion session and mentioned that the land-use mapping approaches can be improved to match the land use system-based mapping system which is a key need of landscape plaining at all levels. They also requested to conduct similar training for the staff of other districts if possible.

- The land officers commented that during the land alienation process the knowledge gained during the training will be much helpful for minimizing environmental damages.

- Staff of divisional secretariate office appreciated the approach and agreed to provide all necessary support for any level of field implementation programs.

Attendance sheet is separately attached.

ANNEXURE I. TRAINING MATERIALS

2.1.1 Presentation 1 - Introduction to Cascade Restoration Guidelines

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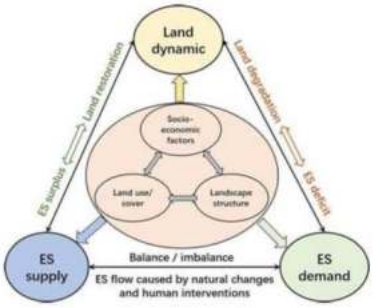
ஆரோக்கியமான நிலப்பரப்பு திட்டம்
The Healthy Landscapes Project

Cascade Restoration Guidelines

Introduction to Cascade Restoration Guidelines

Harsha K Kadupitiya
31st May 2024
Anuradhapura

Land degradation & Ecosystem services



Content

- Land degradation
- Ecosystem functions and land use
- Approaches available for arresting land degradation in central highlands
- Suggest points for open discussion ecosystem optimization

International principles and standards for ecological restoration suggested eight underlying principles

LAND DEGRADATION & IMPACTS

Eight principles for ecological restoration

- **Principle 1.** Ecological Restoration Engages Stakeholders: all details will be collected from different stakeholders at many levels of the assessment (key informant, land users, community focus discussions....)
- **Principle 2.** Ecological Restoration Draws on Many Types of Knowledge: The information on status of each land use system will be collected through questionnaire manual (Land Degradation Assessment– QM Questionnaire by guided brainstorming workshops)
- **Principle 3.** Ecological Restoration Practice is Informed by Native Reference Ecosystems, while Considering Environmental Change: Land use change trends land degradation types and extent, best practices already operational will be evaluated during sub-national or landscape level assessment as well as local level transect assessment
- **Principle 4.** Ecological Restoration Supports Ecosystem Recovery Processes
- **Principle 5.** Ecosystem Recovery is Assessed against Clear Goals and Objectives, Using Measurable Indicators
- **Principle 6.** Ecological Restoration Seeks the Highest Level of Recovery Attainable
- **Principle 7.** Ecological Restoration Gains Cumulative Value when Applied at Large Scales
- **Principle 8.** Ecological Restoration is Part of a Continuum of Restorative Activities

(experts and local communities' collaboration will support to achieve principle 4 – 8 when implementing whole process)

Table 1. Land use system categories used for the ES assessment.

Land Use System (LUS)	Land Use Type (LUT)	Code	Scale	Functions
Agricultural lands	Paddy	P	Macro	Irrigated paddy agro ecosystem.
	Spatially used crop land Shifting cultivation (Chena)	SUCL	Macro	Rain-fed shifting cultivation with very few scattered trees.
	Seasonal crops	SC	Macro	Seasonal crop farming based on climatic seasons.
Forest lands	Dense forest	DF	Micro	Catchment forest (tropical dry mixed evergreen forest – habitat for wild animals).
	Open forest	OF	Micro	Secondary (sparse) forest trees and shrubs. Patches of Dimbula grasslands associated with tree vegetation.
	Scrub land	SL	Micro	Open areas with low vegetation, covered with small trees and shrubs—habitats for small wild species (amphibians, reptiles etc.).
	Forest plantation	FP	Micro	Dominant *Acacia* (*Acacia auriculiformis*) and monoculture Teak (*Tectona grandis*) plantations.
Water bodies	Tank/Minor reservoir	TANK	Micro	Village tanks. Four geomorfical phases of the tank (dead storage, deep phase, shallow phase and high flood phase) provide habitats and support the survival of aquatic flora and fauna.
Rocky areas	Area with exposed rocks	RARE	Micro	Rocks and rock outcrops—habitat for few wild species (amphibians, reptiles, etc.).
Built-up areas	Home garden/Homestead	HG	Micro	Houses, home gardens with horticulture, vegetable and animal husbandry.
Micro land uses (Ecological commons)	Upstream tree belt (Gangommana)	UTB	Micro	Strip of trees found at the periphery of the tank bed. Functioning as a wind barrier, fish breeding habitat, silt filter, habitats for birds and small wild animals.
	Downstream reservation (Kattakaduwa)	DR	Micro	Diverse vegetation function as natural bio-filter to reduce salinity in seepage water before it reaches into the paddy fields. Habitat for many species.
	Upstream soil ridges (Iswetiya)	USR	Micro	Upstream earth ridges to prevent sediment inflow.
	Upstream water hole (Godawala)	UWH	Micro	Human made water hole sizes to trap sediment run-off and provides water to wild animals.
	Deep phase (Diyaglima)	DP	Micro	Central part of the tank bed. Various aquatic plants are grown in this area. Lotus and hydrilla species are dominant. Invasive aquatic plants such as water hyacinth, azolla salvinia and water lettuce are also present.

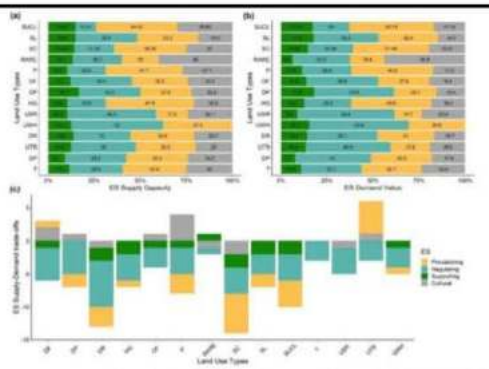


Figure 8. Percentage contributions of current supply (a), demand (b) and trade-offs (c) in four ecosystem service categories of different LUTs in the MVTCS based on community perceived values. T = Tank; DP = Deep-phase (Diyaglima); UTB = Upstream tree belt (Gangommana); DR = Downstream reservation (Kattakaduwa); UWH = Upstream water hole (Godawala); USR = Upstream soil ridge (Iswetiya); HG = House gardens; DF = Dense forests; OF = Open forests; P = Paddy; RARE = Area with exposed rocks; SC = Seasonal crop farming lands; SL = Scrublands; SUCL = Sparsely used crop lands (Chena); ES = Ecosystem service.

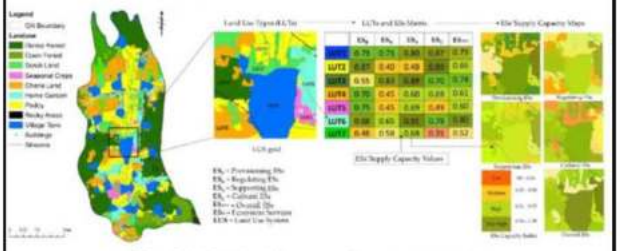


Figure 3. An illustration of the process used to map ecosystem services.

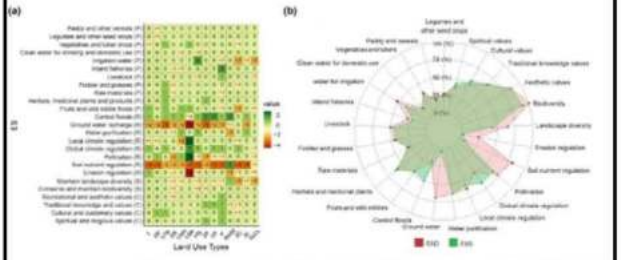


Figure 9. Ecosystem service supply (ESS) and ecosystem service demand (ESD) budget evaluation matrix (a); radar chart of ESS and ESD variations with different LUTs (b). T = Tank; DP = Deep-phase (Diyaglima); UTB = Upstream tree belt (Gangommana); DR = Downstream reservation (Kattakaduwa); UWH = Upstream water hole (Godawala); USR = Upstream soil ridge (Iswetiya); HG = House gardens; DF = Dense forests; OF = Open forests; P = Paddy; RARE = Area with exposed rocks; SC = Seasonal crop farming lands; SL = Scrublands; SUCL = Sparsely used crop lands (Chena); ES = Ecosystem service; P = Provisioning ES; R = Regulating ES; C = Cultural ES; S = Supporting ES.

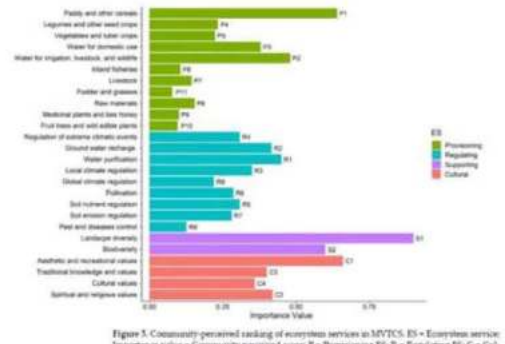


Figure 5. Community-perceived ranking of ecosystem services in MVTCS. ES = Ecosystem service; Importance value = Community perceived score; P = Provisioning ES; R = Regulating ES; C = Cultural ES; S = Supporting ES; Number (P1) = Rank within the ES category.

Knowledge Management and Decision Support for Sustainable Land Management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United Nations
Convention to Combat Desertification
UNCCD recommended SLM Database


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SLM
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Decision Support Framework for mainstreaming and scaling out SLM
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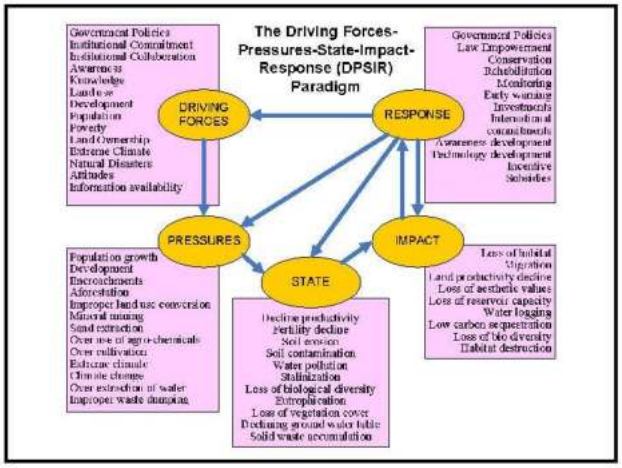
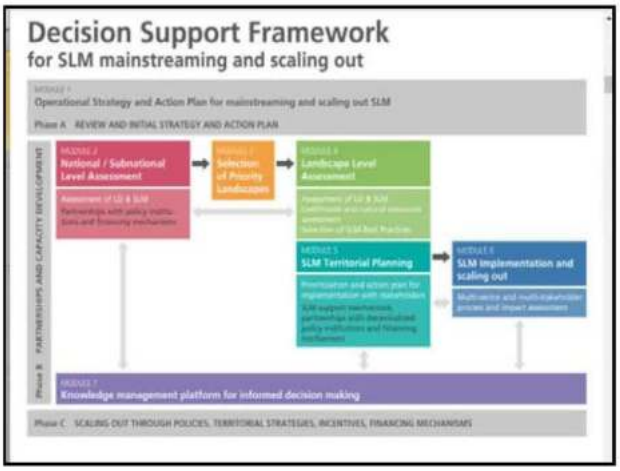
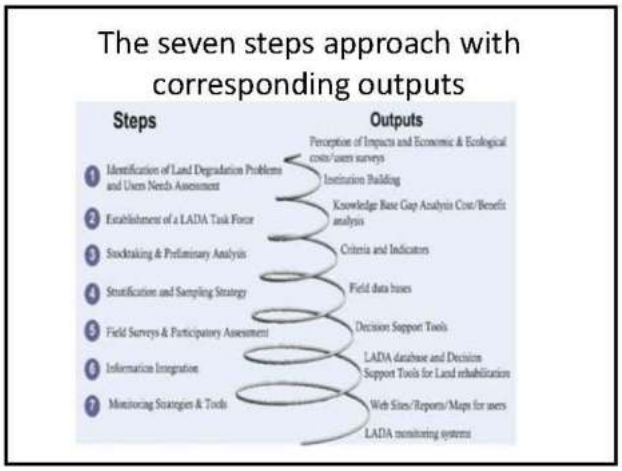
WOCAT


PART 1: Planning and methodological approach, analysis and reporting
PART 2: Field methodology and tools
LANDDEGRADATION ASSESSMENT IN DRYLANDS
LADA
UNEP

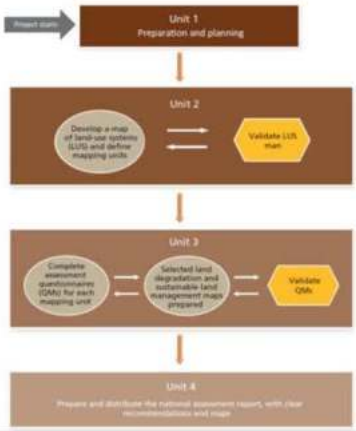

WOCAT
Decision Support for Mainstreaming and Scaling Out Sustainable Land Management (DS-SLM)
About the project


The Driving Forces-Pressures-State-Impact-Response (DPSIR) Paradigm
DRIVING FORCES
PRESSURES
STATE
IMPACT
RESPONSE


Decision Support Framework
for SLM mainstreaming and scaling out
Operational Strategy and Action Plan for mainstreaming and scaling out SLM
Phase A REVIEW AND INITIAL STRATEGY AND ACTION PLAN
National / Subnational Level Assessment
Landscape Level Assessment
SLM Territorial Planning
SLM implementation and scaling out
Knowledge management platform for informed decision making
Phase C SCALING OUT THROUGH POLICIES, TERRITORIAL STRATEGIES, INCENTIVES, FINANCING MECHANISMS


The seven steps approach with corresponding outputs
Steps
Outputs
Identification of Land Degradation Problems and Users Needs Assessment
Establishment of a LADA Task Force
Stocktaking & Preliminary Analysis
Stratification and Sampling Strategy
Field Surveys & Participatory Assessment
Information Integration
Monitoring Strategies & Tools
Perception of Impacts and Economic & Ecological costs/users surveys
Institution Building
Knowledge Base Gap Analysis Cost/Benefit analysis
Criteria and Indicators
Field data bases
Decision Support Tools
LADA database and Decision Support Tools for Land rehabilitation
Web Sites/Reports/Maps for users
LADA monitoring systems

Guiding flow diagram of the landscape restoration planning process



Mapping Land Degradation & Sustainable Land Management

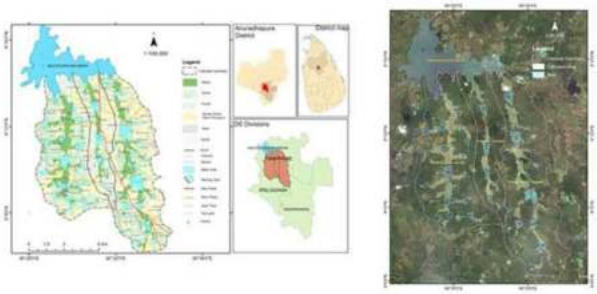
WOCAT

Framework for documentation, evaluation, dissemination of good SLM practices

Degradation & Conservation Map — Local, national, global scale independent (overview)

SLM Technologies & SLM Approaches — Local / field level (Case studies)

Study Area – Nachchaduwa selected VTCS, and Topographic map and bird-eye view

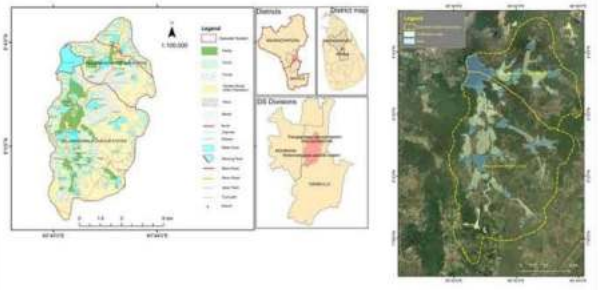


Methodology in brief

1. Develop Land Use System (LUS) maps
2. Establish LUS linked QM Data
3. Form stakeholder – expert group
4. National/ subnational LADA assessment
5. Develop degradation hotspot and bright spot map for three project districts
6. Local level LADA assessment
7. Incorporate country assessment to WOCAT Global network

- *Integrate land use map with other zonal maps in GIS*
- *Link QM to each LUS using MS access & GIS software*
- *Form expert group / LADA team*
- *Train GIS and LADA team (2 international, 5 local)*
- *Complete QM database with LADA team (Brainstorming sessions)*
- *Develop Land degradation maps*
- *Degradation hotspot and bright spot map using GIS*
- *Conduct local level assessment with LADA team*

Study Area – Horiwila selected VTCS, and Topographic map and bird-eye view



Initial planning and expert group and institutional engagement settings

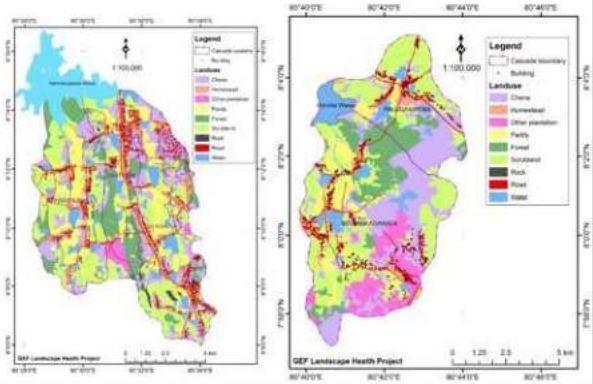
- Obtain necessary authorizations for LD and SLM assessment.
- Determine stakeholder involvement.
- Develop a detailed project plan (stakeholders and key policymakers, including activities, timeline, budget and responsibilities, based on specific country needs).
- Secure budget for implementation.
- Obtain the services of GIS specialists, GIS software.
- Assess data availability and the interinstitutional agreements to ensure data sharing.
- Establish a coordination mechanism.
- Establish a work plan for project implementation.
- Develop a communication strategy to ensure regular feedback and awareness of project activities and achievements among key stakeholders.

Land use mapping

Landscape (Sub-National) level Land Degradation (LD) and Sustainable Land Management (SLM) assessment

1. Land Use System (LUS) mapping & unique ID system for LUS units
2. LD and SLM assessment using the Questionnaire Manuels (QM)
3. Mapping questionnaire results and report development.

Land-use maps of pilot sutes



DATA & SOURCES

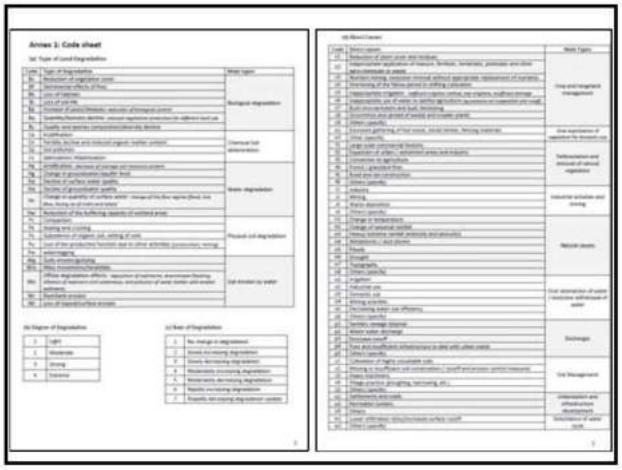
	Data	Description	Source of data
1	Land use data	Extract from land use (1:10000 scale) maps	Land Use Policy Planning Department (LUPPD)
2	Admin boundary map	Admin boundaries for province, District, DSD and GN division	Digital Admin map available at NRMC was used
3	Forest and wildlife reserve of Sri Lanka	The digital map of forest and reservation areas of Sri Lanka	Department of Forest and Department of Wild Life Conservation
4	Agro-ecological map	Digital map used for Degradation assessment	Natural Resources Management Centre, DOA.
5	Soil Series map	Digital map used for Degradation Assessment	Natural Resources Management Centre, DOA.
6	Elevation (30m DEM)	Used for slope map development	Acquired from USGS web site
7	Other layers	Water, Catchment, population, Rural sector maps	NRMC data repository

Coding Land Use

No	Land Use System (LUS)	LUS_ID	Land use Category	Conserved / Protected
1	Forest - Protected	11	Forest	√
2	Forest - Unmanaged	12	Forest	
3	Vegetated areas - protected	14	Scrubland, Uncultivated lands	√
4	Sparsely vegetated areas - unmanaged	15	Scrubland, Abandoned croplands, Uncultivated lands	
5	Grasslands - protected	16	Grass	√
6	Grasslands - unmanaged	17	Grass	
7	Bare areas - protected	18	Barren Land, Sea-Island, Inland-Island, Salter, Sand	√
8	Bare areas - unmanaged	19	Barren Land, Sea-Island, Inland-Island, Salter, Sand	
9	Perennial Agriculture - Coconut	21	Coconut	
10	Perennial Agriculture - Rubber	22	Rubber	
11	Perennial Agriculture - Tea	23	Tea	
12	Woody Perennial Crops	24	Home Garden, Palmyra, Other tree crops	
13	Woody Perennial - protected	24	Abandoned Coconut, Home Garden, Rubber, Tea, Other Perennial	√
14	Crop Lands	25	Chena, Vegetable, Other seasonal crops	
15	Paddy	26	Paddy	
16	Urban	31	Airport, Built-up Area, Runaway	
17	Rock	32	Quarry, Rock	
18	Wetland - Protected	41	Marshy land, Abandoned Paddy	√
19	Wetland - Unmanaged	42	Marshy land	
20	Open Water - protected	43	Bay, Chanel, Lagoon, Lake, Lewaya, Lagoon, Mangroos, Pond, Reservoir, Stream, Tank, Well	√
21	Open Water	44	Open water	

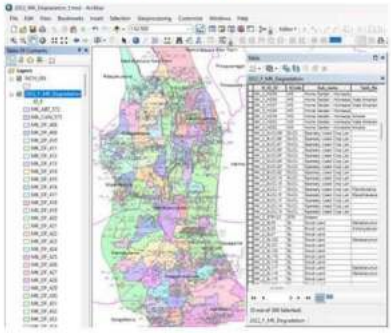
Validation of LU map

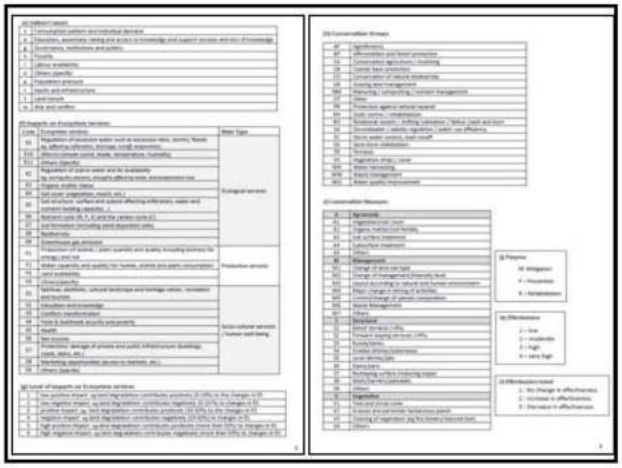
- Checking LUS boundaries for rectification of boundaries for recent changes or to match the ground situation.
- Verification of the land-cover classes used in the LUS map.
- Verification of land uses within each land-cover class to ensure that the LUS map accurately reflects the ground conditions.
- The accuracy of the natural capital inventory (e.g. soil, water and vegetation).



LUS coding & Data Processing

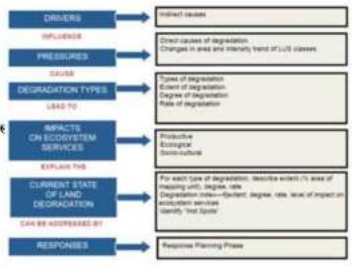
- QMCODE: [Dis_ID][DSD_ID][GN_ID][LUS_ID]
- Eg: [AN][TP][paddy]=1301026



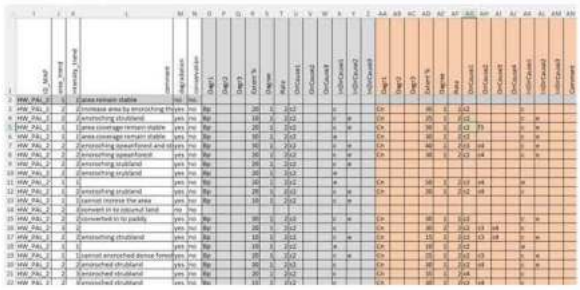


LD and SLM assessment using Questionnaire Manual (QM)

1. Land-use change assessment
2. LD assessment
3. Conservation and SLM assessme
4. Expert recommendations

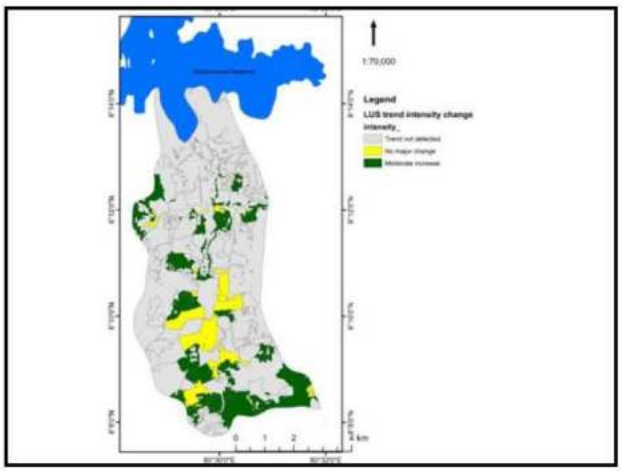


Compilation of QM collected data



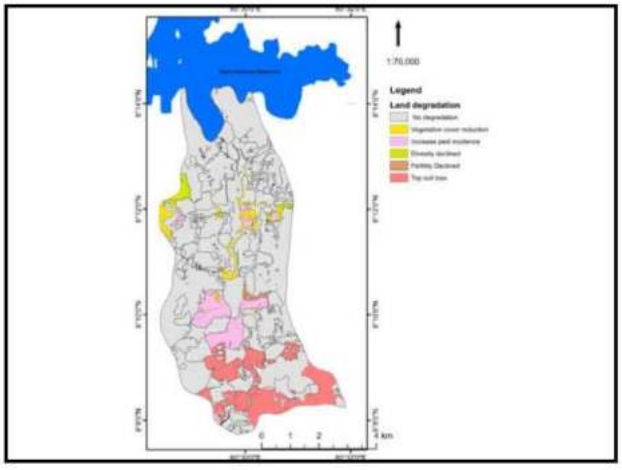
Data processing and linking with GIS

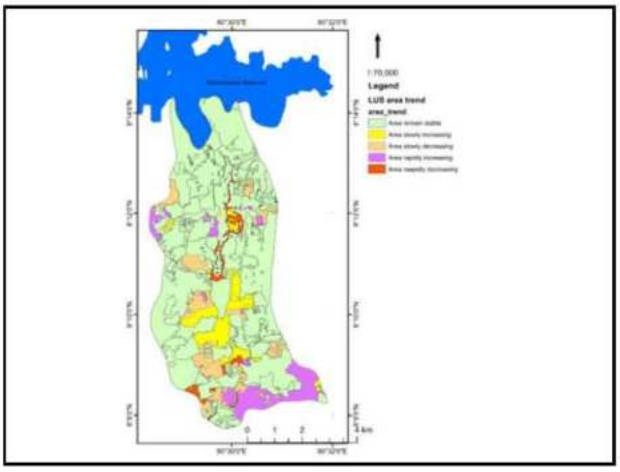
GKCODE	NAFLU	ID_LUS	Name_2	GMCODE	LU_T	LU_T_I	Degradation	D1	D1_ext	D1_Deg	D1_Rate	D2	D2_ext
BLTPA	Buildup Area	31	Urban	1301031	-2	-2	1	Hg	15	2	5	Pw	5
FRSUA	Forest	12	Forest - Un	1301012	-1	-1	1	Bc	10	1	4	Bh	10
HOMSA	Home Garden	24	Woody Per	1301024	1	1	1	Wt	15	2	4	Cn	10
OTHRA	Other plantations	24	Woody Per	1301024	1	1	1	Wt	15	2	4	Cn	10
PDDYA	Paddy	26	Paddy	1301026	-1	-2	1	Cn	10	2	4	Bp	10
PLGDA	Home Garden	24	Woody Per	1301024	1	1	1	Wt	15	2	4	Cn	10
ROCKA	Rock	32	Rock	1301032	0	0	0	Bc	50	1	4		
SCRBA	Scrubland	15	Sparsely Ve	1301015	0	0	1	Bc	10	1	5	Wt	10
TEAA	Tea	23	Perennial A	1301023	0	0	1	Cn	20	1	4	Wt	10
HOMSA	Home Garden	24	Woody Per	1302024	1	1	1	Wt	5	2	4	Cn	10
OTHRA	Other plantations	24	Woody Per	1302024	1	1	1	Wt	5	2	4	Cn	10
PDDYA	Paddy	26	Paddy	1302026	-1	-2	1	Cn	10	2	4	Bp	10
ROCKA	Rock	32	Rock	1302032	0	0	0	Bc	50	1	4		
SCRBA	Scrubland	15	Sparsely Ve	1302015	0	0	1	Bc	10	2	5	Wt	10
TEAA	Tea	23	Perennial A	1302023	0	0	1	Cn	20	1	4	Wt	10
FRSUA	Forest	12	Forest - Un	1303012	-1	-1	1	Bc	10	1	4	Bh	10
HOMSA	Home Garden	24	Woody Per	1303024	1	1	1	Wt	10	2	4	Cn	10
OTHRA	Other plantations	24	Woody Per	1303024	1	1	1	Wt	10	2	4	Cn	10
PDDYA	Paddy	26	Paddy	1303026	-1	-2	1	Cn	10	2	4	Bp	10
RBBRA	Rubber	22	Perennial A	1303022	-2	-2	1	Wt	5	2	4	Cn	5
ROCKA	Rock	32	Rock	1303032	0	0	0	Bc	50	1	4		

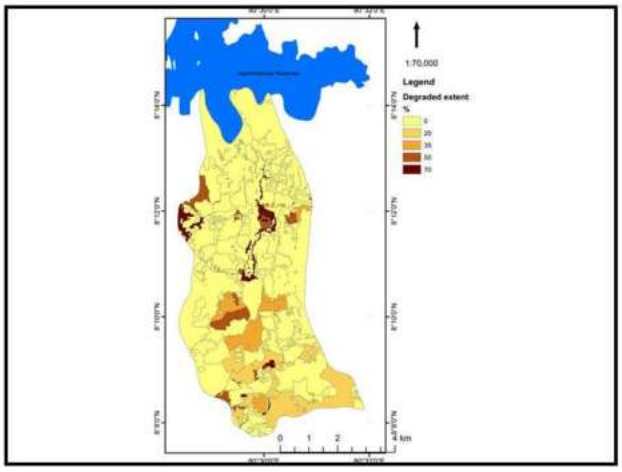


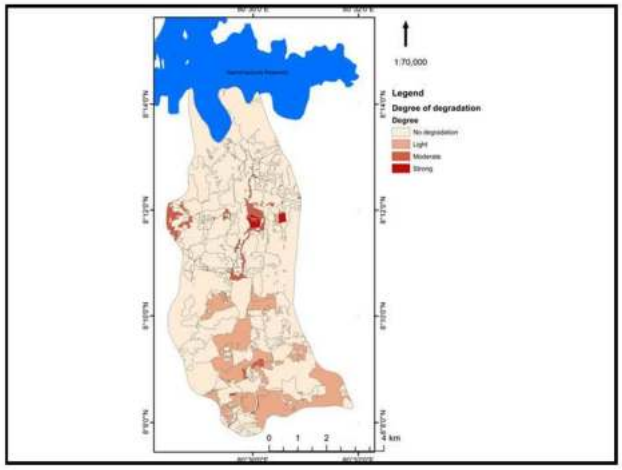
Examples for LADA-Maps

1. Trend of LUS change
2. Trend in LUS change intensity
3. Degradation extent
4. Degree of land degradation
5. Degradation rate
6. Extent of SLM practices
7. Effectiveness of existing SLM practices
8. Degradation with impact: negative high and very high
9. Principal types of land degradation
10. Total degradation index or degradation severity





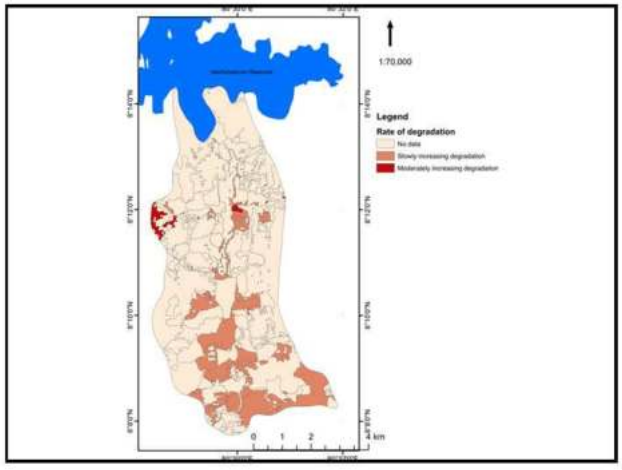




Land Degradation Drivers and Pressures

Human induced factors

- **Direct Drivers & Pressures**
  - Lack of knowledge on SLM
  - Cultivating slopy lands without SLM
  - Over use of agrochemicals and fertilizer
  - Unsystematic use of lands for continuous annual cropping
  - Unplanned development activities
  - Inappropriate land reclamation
  - Mining & other industries
  - Unscientific solid waste management particularly in urban areas
  - Encroachments and land use changes



Land Degradation Drivers and Pressures

Human induced factors

- **Indirect Drivers & Pressures**
  - Population pressure
  - Poverty
  - Inadequate policy enforcement
  - Lack of Land ownership
  - Land fragmentation

$$DI_1 = \sum (Ext_i * Deg_i * Rate_i) \qquad \textit{Equation 1}$$

Where,

DI_1 = Degradation Index 1
Ext_i = Percentage extent of i^{th} degradation type
Deg_i = Degree of i^{th} degradation type
$Rate_i$ = Rate of i^{th} degradation type

$$DI_2 = \frac{\sum (Ext_i * Deg_i * Rate_i)}{\sum Ext_i} \qquad \textit{Equation 2}$$

Where,

DI_2 = Degradation Index 2
Ext_i = Percentage extent of i^{th} degradation type
Deg_i = Degree of i^{th} degradation type
$Rate_i$ = Rate of i^{th} degradation type

Land Degradation Drivers and Pressures

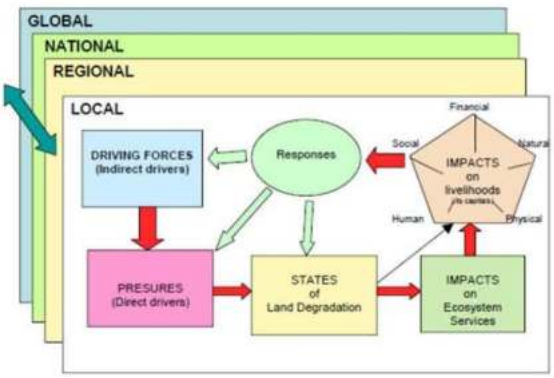
- **Natural factors**
  - Rainfall characteristics, topography and soils (climate change: increase intense rainfall)
  - Surface Erosion, Gully erosion, Loss of Habitats, Fertility Decline, Loss of Soil Life, and Loss of top soil are the degradation types taking place at present

General comments on LADA-WOCAT

- LADA approach is comprehensive, flexible and convenient for national assessment
- Land use base approach provide opportunities for systematic and convenient assessment of land degradation status in a landscape
- Has the ability to incorporate historical trends through QM & field staff expert knowledge
- Degradation types mostly associated with LUS
- Most of the hotspots associated with dynamic LUS (seasonal crop cultivation lands)
- LADA approach can easily be adapted for national SLM planning

Local Level Assessment of Land Degradation and Sustainable Land Management (SLM)

Soil Assessment



Research area

Neelawala

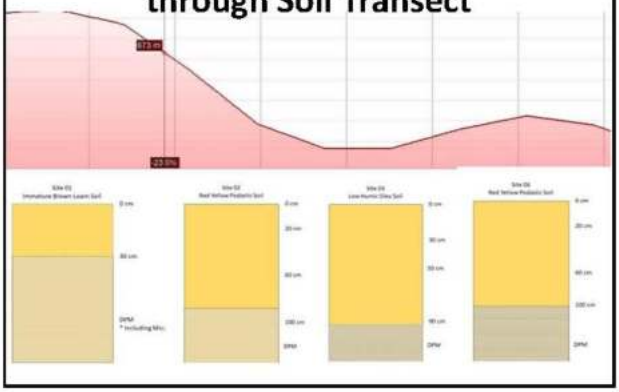
- Crops – cassava, rice, Perennials (Mango, avocado, pineapple, Banana, Manderine) and vegetables
- Physiography - Hilly and Mountainous

Main steps involve in local assessment

1. Assessment group formation
2. Characterization of study area
3. Survey visit and transect walk
4. Vegetation assessment
5. Soil Assessment
6. Water resource assessment
7. Livelihood assessment

Setting of Sample Lines

Distribution of Soil Profile through Soil Transect



Major degraded types

Site 1

Soil Erosion

1.Gully Erosion
2.Rill Erosion
3. Sheet Erosion

Site Description Cont..

Observation	Observe Mica		Mottle colurs	
Tillage pan	0*3=0	2*3=6	2*3=6	2*3=6
Aggregate Size distribution	1*3=3	1*3=3	1*3=3	1*3=3
Soil crusts	2*2=4	2*2=4	2*2=4	2*2=4
Earthworms	0*2=0	2*2=4	2*2=4	2*2=4
Roots	1*3=3	1*3=3	1*3=3	1*3=3
Total (A)	10	20	20	20
Soil visual assessment	Moderate	Good	Good	Good
Slaking and dispersion	1*1.5=1.5	1*1.5=1.5	1*1.5=1.5	1*1.5=1.5
Soil pH	5.4	5.4	5.4	5.4
Water infiltration	1*3=3	1*3=3	1*3=3	1*3=3
OC				
EC	0.014(Normal)	0.014(Normal)	0.014(Normal)	0.014(Normal)
Total B	9.34	9.34	9.34	9.34
Soil measurement	Moderate	Moderate	Moderate	Moderate
A+B	19.34	29.34	29.34	29.34
	Moderate	Good	Good	Good

Major degraded types

Site 2

Soil Erosion

1.Gully Erosion
2.Rill Erosion
3. Sheet Erosion

Analyzing Soil Samples at the Laboratory

Major Degraded Types

Site 4

Soil Erosion
1.Gully Erosion
2.Rill Erosion
3.Sheet Erosion

Recommendations for Controlling Land Degradation

Soil Erosion

1. Contour Cultivation
2. Establishment of drainage system (drenches)
3. Establishment of terraces with back slope
4. Application of stone bunds, SALT method, lock and spill drains
5. Cover crop introduction

Main Suggestions

- Land degradation has close link with land use systems
- Land degradation impact on supply capacity of ecosystem services in particular landscape
  - Degraded forest has low regulatory ES supply capacity
  - Eroded farm land has low Provisioning ES supply capacity
- In-depth analysis of across whole landscape is needed, prior to any type of SLM interventions
- This approach has many appropriate tools for setting up national sustainable land management program
  - Tools available for different spatial scales (National/ landscape/local
  - Flexible to integrate expert judgments and technical assessment tools
  - Provide solutions for consolidate fragmented institutional setup
  - Support of global networks available at WOCAT web portals

Recommendations for Controlling Land Degradation Cont.

Iron Toxicity

1. Improve drainage at water logging area
2. Check PH and apply adequate amount of dolomite
3. Apply 25% more MOP
4. Transplanting paddy instead of sowing
5. Avoid application of green manure

Thank you

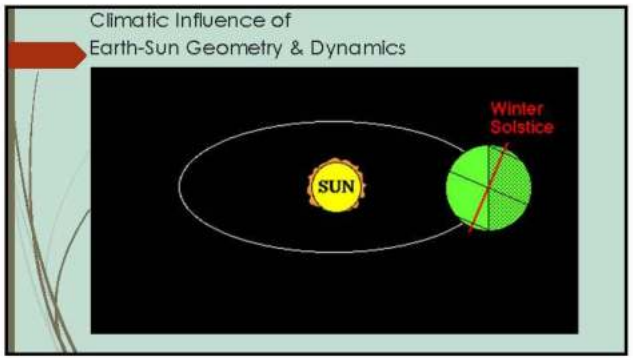
Local assessment Conclusion

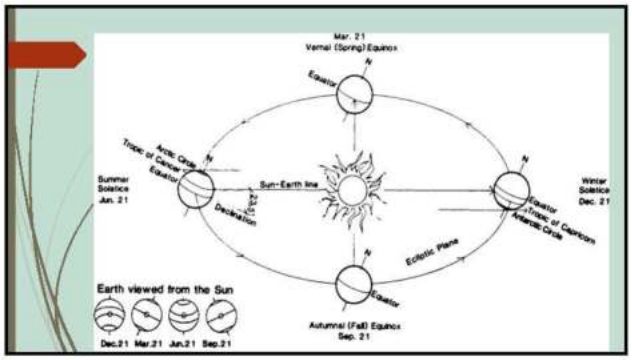
Soil erosion is the major type of degradation observed in transact.

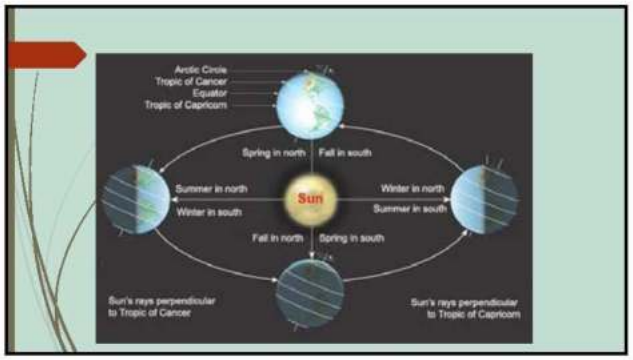
Site 2, 3 and 4 can be considered ideal for agriculture but site 1 is marginal due to shallow soil depth and due to susceptibility for soil erosion.

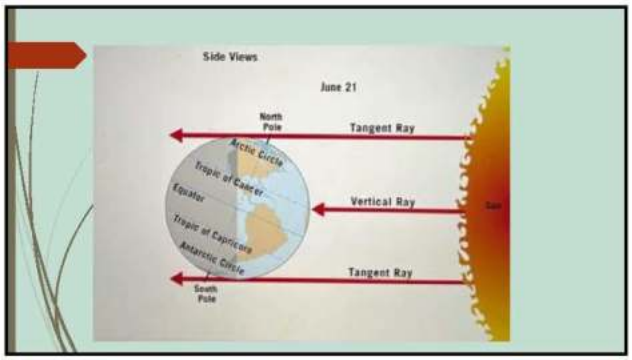
Therefore should apply soil conservation technology into these fields and should maintain existing soil conservation measures.

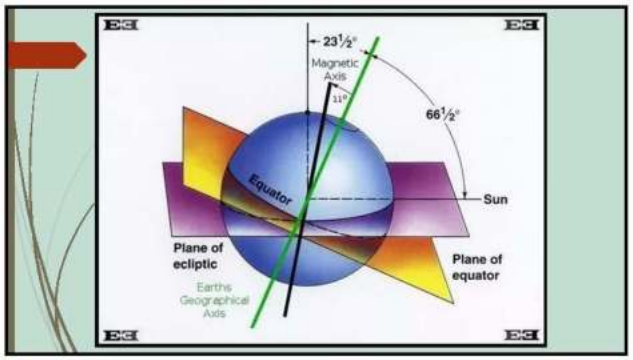
2.1.2 Presentation – "Spatial setting of Village Tank Cascade Systems (VTCS) and anatomy of tank associated components"

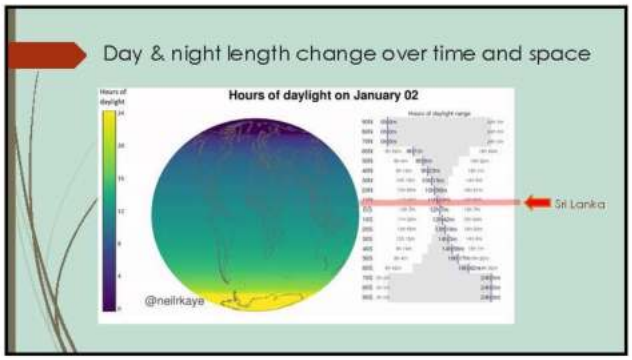


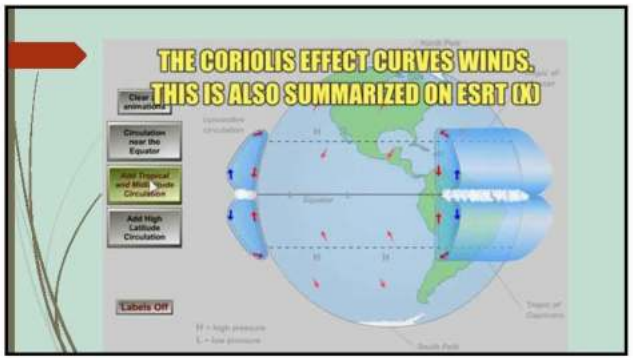


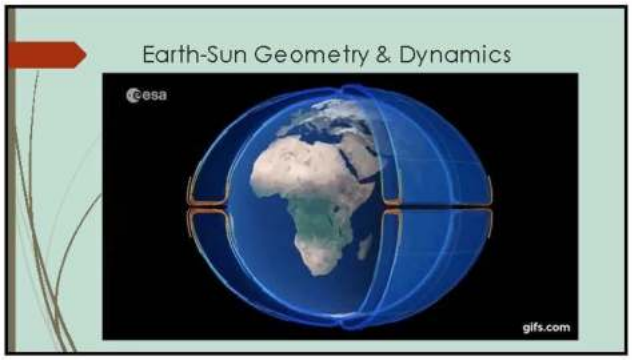


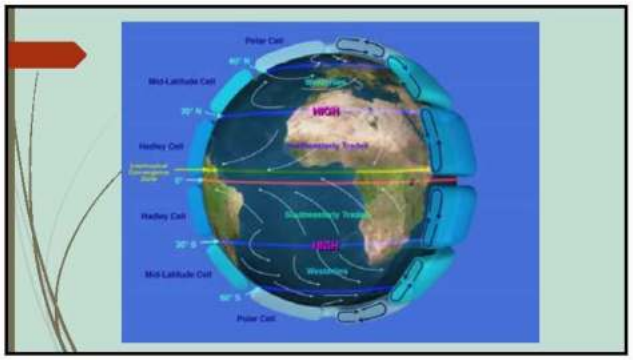


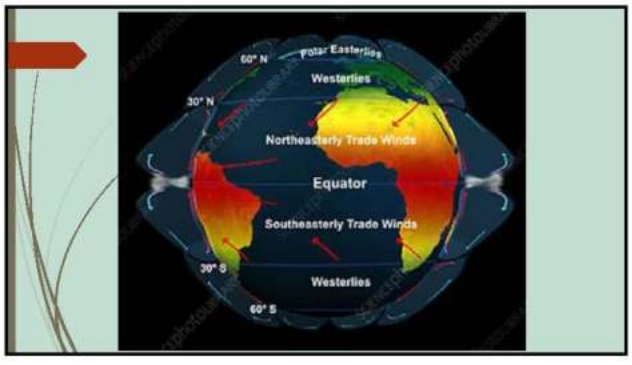


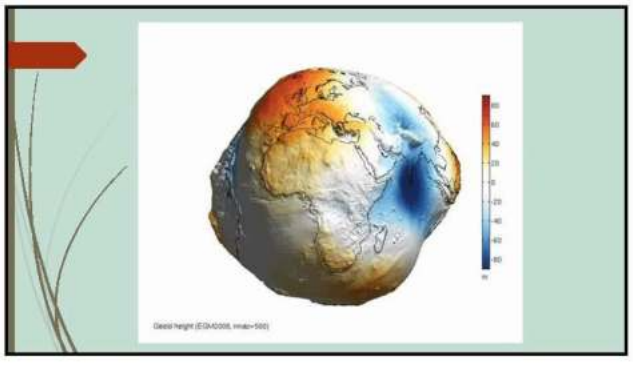

Day & night length change over time and space
Hours of daylight on January 02
Sri Lanka
@neilrkaye

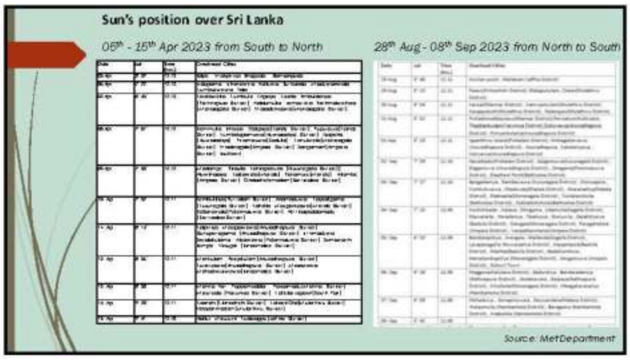

THE CORIOLIS EFFECT CURVES WINDS.
THIS IS ALSO SUMMARIZED ON ESRT (X)
Clear animations
Circulation near the Equator
Add High Latitude Circulation
Labels Off

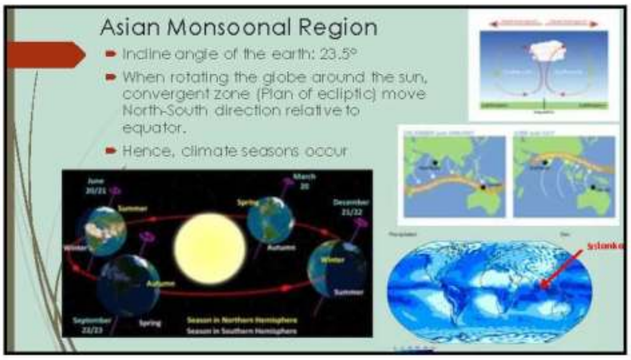

Earth-Sun Geometry & Dynamics
esa
gifs.com

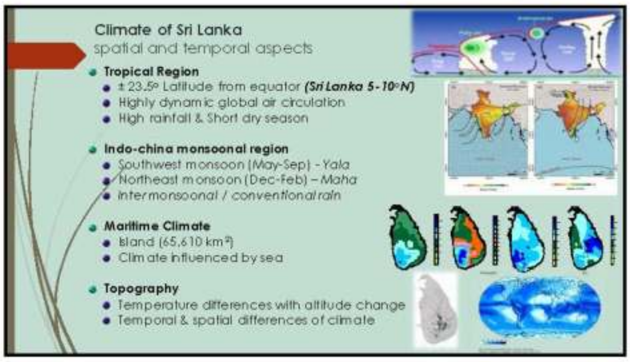

Polar Cell
Mid-Latitude Cell
Hadley Cell
Hadley Cell
Mid-Latitude Cell
Polar Cell

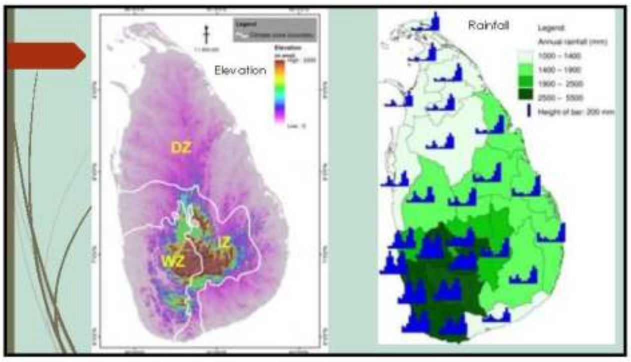

60° N
Polar Easterlies
Westerlies
30° N
Northeasterly Trade Winds
Equator
Southeasterly Trade Winds
30° S
Westerlies
60° S

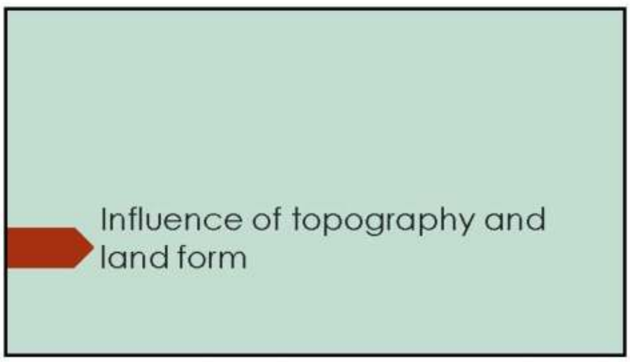


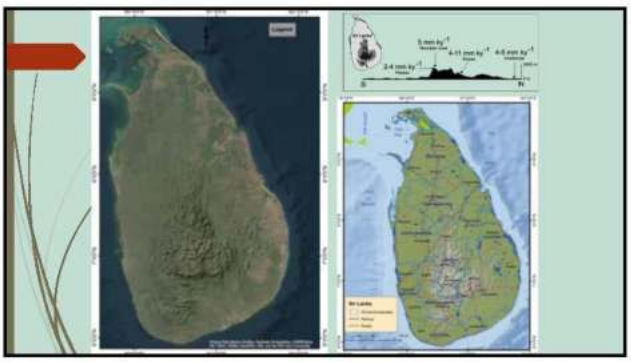

Sun's position over Sri Lanka
05th - 15th Apr 2023 from South to North
28th Aug - 08th Sep 2023 from North to South
Source: MetDepartment

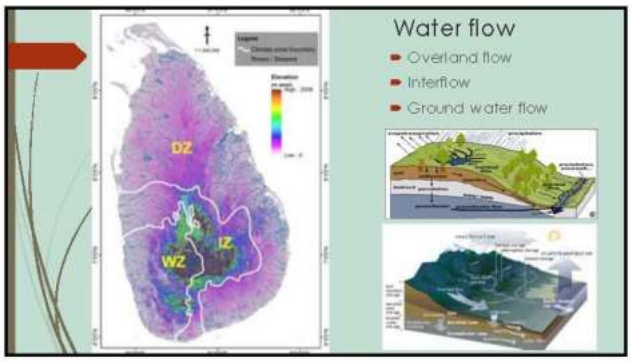

Asian Monsoonal Region
Incline angle of the earth: 23.5°
When rotating the globe around the sun, convergent zone (Plan of ecliptic) move North-South direction relative to equator.
Hence, climate seasons occur
June 20/21
Summer
Winter
Spring
March 20
Autumn
December 21/22
Winter
Summer
Autumn
September 22/23
Spring
Season in Northern Hemisphere
Season in Southern Hemisphere
Srilanka

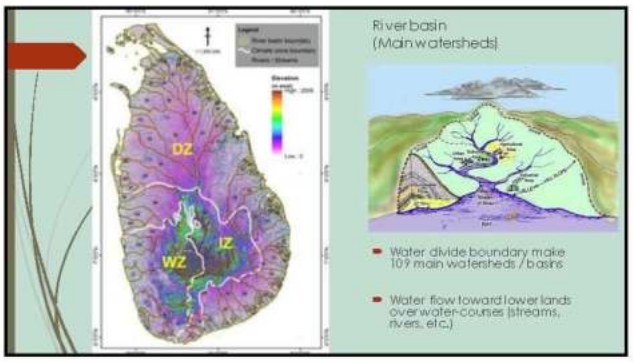

Climate of Sri Lanka
spatial and temporal aspects
Tropical Region
± 23.5º Latitude from equator (Sri Lanka 5-10°N)
Highly dynamic global air circulation
High rainfall & Short dry season
Indo-china monsoonal region
Southwest monsoon (May-Sep) - Yala
Northeast monsoon (Dec-Feb) – Maha
Intermonsoonal / conventional rain
Maritime Climate
Island (65,610 km²)
Climate influenced by sea
Topography
Temperature differences with altitude change
Temporal & spatial differences of climate

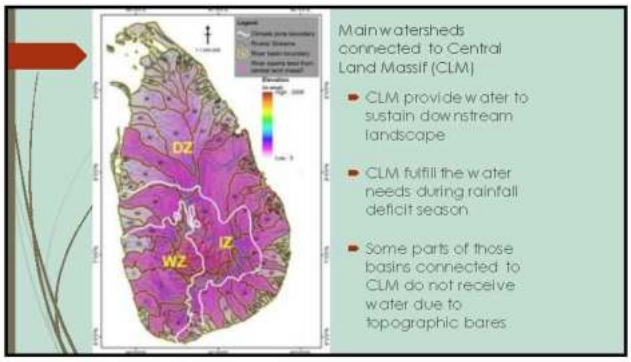

Elevation
DZ
WZ
IZ
Rainfall
Legend
Annual rainfall (mm)
1000 - 1400
1400 - 1900
1900 - 2500
2500 - 5500
Height of bar: 200 mm

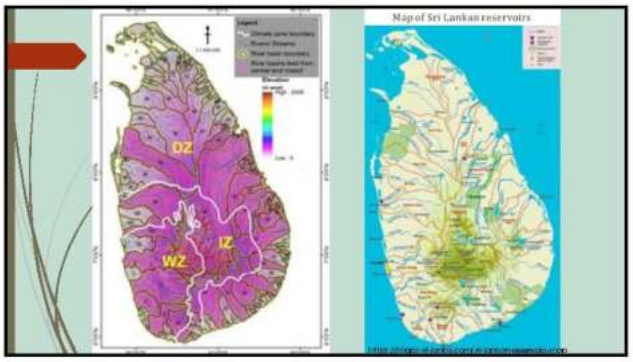

Influence of topography and land form

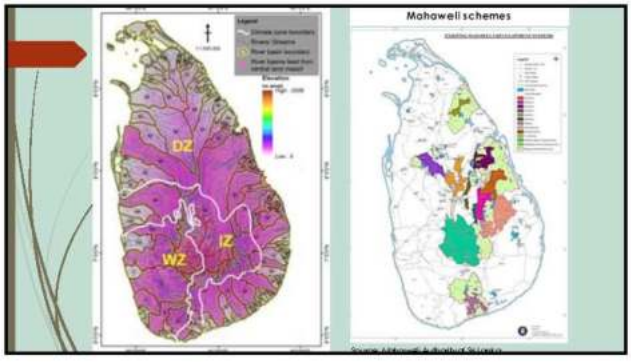


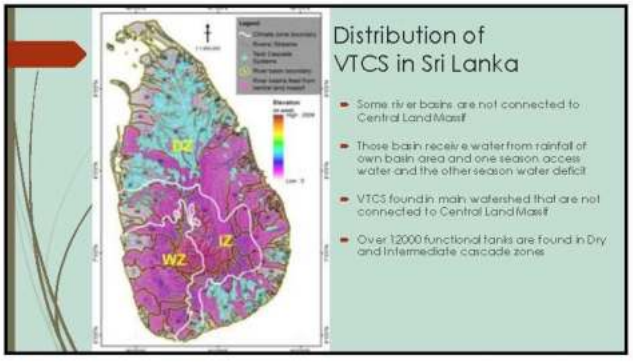

DZ
WZ
IZ
Water flow
Overland flow
Interflow
Ground water flow


DZ
WZ
IZ
River basin
(Main watersheds)
Water divide boundary make 109 main watersheds / basins
Water flow toward lower lands over water-courses (streams, rivers, etc.)


DZ
WZ
IZ
Main watersheds connected to Central Land Massif (CLM)
CLM provide water to sustain downstream landscape
CLM fulfill the water needs during rainfall deficit season
Some parts of those basins connected to CLM do not receive water due to topographic bares


DZ
WZ
IZ
Map of Sri Lankan reservoirs


DZ
WZ
IZ
Mahaweli schemes


DZ
WZ
IZ
Distribution of VTCS in Sri Lanka
Some river basins are not connected to Central Land Massif
Those basin receive water from rainfall of own basin area and one season access water and the other season water deficit
VTCS found in main watershed that are not connected to Central Land Massif
Over 12000 functional tanks are found in Dry and Intermediate cascade zones

Prominent agro-ecosystems

Prominent agro-ecosystems

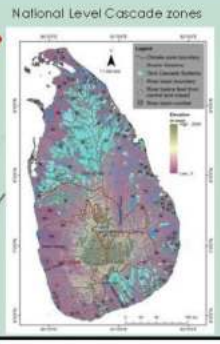
- Geographical diversity based agro-ecosystem
  - Village tank cascade system
  - Anicut based stream fed system
  - Ovitta farming system
  - Kandyan home garden agro-ecosystem
  - Slopping land cultivation system
  - Ground water - dry zone cultivation systems
  - Jaffna groundwater cultivation systems
- Colonial influenced system – plantation sector
- Modern technological advancement
  - Major multi-purpose irrigation systems
  - Lift irrigation systems

Village tank cascade systems

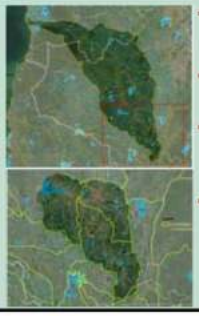
- The Tank Cascade System (VTCS) is an **man-made** irrigation infrastructure in Sri Lanka & represents the **wisdom of ancient hydrologic experts** with deep knowledge of ecological functions.
- VTCS is a **network of small tanks draining into large reservoirs**, designed to store rainwater and surface runoff for future use.
- VTCS was created to harmonize the natural flow of water, supporting both **human and ecological needs** by synchronizing various components of the ecosystem.
- VTCS serves as a model for a unique and sustainable ecological production landscape that **sustains diverse life forms, including flora, fauna, and people**, in the face of various natural and human-induced challenges.
- VTCS In 2017, the **Tank Cascade System was designated as a Globally Important Agricultural Heritage System (GIHAS)** by the United Nations Food and Agriculture Organization.

Spatial settings of VTCS

National Level Cascade zones

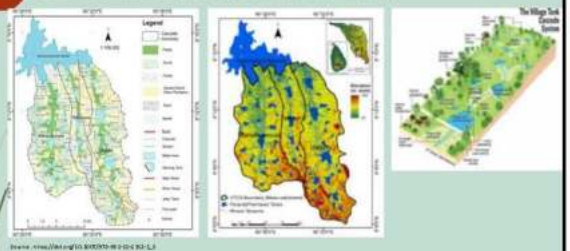


Sub National Level Setting



- VTCS zone consisted with tank cascade complexes (Sub catchments)
- All the water directed to large reservoir (Nachchaduwa)
- Tanks & tank systems are placed to get maximum benefits from upper catchment waterflow
- Basin / Catchment boundary normally consisted with vegetation cover associated forest tanks to sustain natural fauna & flora

Ensemble of the Cascade System and Its Anatomy

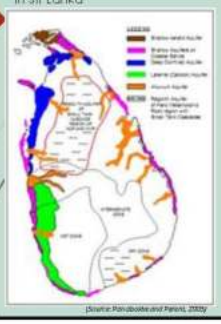


Ensemble of the Cascade System and Its Anatomy

The spatial setting of tank associated micro-land use components within a selected micro-catchment in the Mahakanumulla VTCS

1 = tank bed
2 = tank bund
3 = downstream reservation (kattakaduwa)
4 = upstream treeline (Gasgommana)
5 = upstream shallow-tank bed (Wewa-thatuwa)
6 = upstream immediate catchment (Wewa-imathitha)
7 = shrubland (Lands)
8 = rainfed farmland (Hena)
9 = hamlet (Gangoda)
10 = upper catchment forest
11 = command area paddy-fields
12 = upstream water-hole (Godawela)
13 = soil ridge (Iswetiya)
14 = common drainage (Kiwul-ela)
15 = irrigation canal
16 = theam (Bo)
17 = back yard reservation around hamlet (Te-bamboe)

Different types of aquifers in Sri Lanka



(Source: Panabokke and Perera, 2005)

Groundwater resources in Jaffna Peninsula

(Source: Puvaneswaran, 1988)

Some agro-eco systems

- Slopping land cultivation systems

- Chena

- Plantation/ perennial crops

Tea Rubber Coconut Cinnamon

- Jaffna ground water wells

- Agro-wet

- Ovitacultivation system

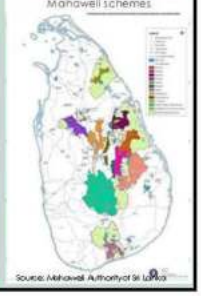
Spatial distribution of agro-ecosystems in Sri Lanka

Village Tank Cascade / Anicut Systems

Source: Department of Agrarian Development

Major Sri Lankan reservoirs

Mahawell schemes



Source: Mahaweli Authority of Sri Lanka

Spatial distribution of agro-ecosystems in Sri Lanka

Spatial distribution of Traditional Agro-ecosystems

Sri Lanka's protected areas sup-erimposed with land use (Source: Land use: Survey Dept. 2007; Protected areas: MoE, 2012

Final notes and Suggestions

- Sri Lanka is endowed with a high degree of natural resources that support a diverse range of agricultural production landscapes.
- The entire country boasts a rich variety of agro-ecosystems strategically located across different spatial zones.
- Sri Lanka has implemented well-designed water utilization zones to efficiently manage its water resources.
- The central land massif of Sri Lanka plays a crucial role in supplying irrigation water to the irrigation regions of the Dry Zone.
- The cascade systems properly in place to prioritize the sustainability of all aspects, including human well-being, the environment, flora and fauna, and overall ecosystem health. This approach is closely aligned with the One Health concept.
- Suggest integrating spatial considerations into development interventions to further enhance the sustainable use of these natural resources.


Thank you very much

2.1.3 Presentation – "Land data in Sri Lanka"

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ஆரோக்கியமான நிலப்பரப்பு திட்டம்
The Healthy Landscapes Project

Cascade Restoration Guidelines

Land Use data in Sri Lanka

Harsha K Kadupitiya
31st May 2024
Anuradhapura

Introduction

- Agriculture related map information in Sri Lanka not well organized
  - Map of seasonal crop land distribution ?
  - Map of Home Garden distribution?
  - Map of Rainfed paddy?
- Land Classification System in Sri Lanka
  - Criteria for differentiation of scrub land ?
  - Criteria for demarcation of Home Gardens ?

GIS Data Availability

Topographic maps of survey department

- 10 major data classes
- Vegetation and agriculture land categories are included in 2 data classes (open space lands and vegetation).
- Open Space Land: 4 data classes & 10 feature types
- Vegetation : 27 feature types
- Northern and central Province 1982-1994
- Data development year range from 1994 to 2017
- Digital data available

Land information

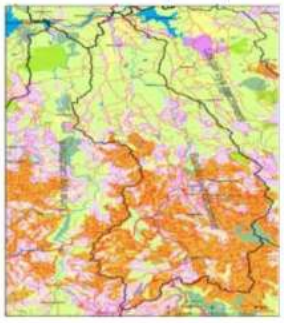
- 1:50,000 & 1:10,000 (Survey Department)

Land Use Maps of Land Use Policy Planning Department

- Land-use map covering whole island at 1:10000 scale
- Developed following 11 stepped procedure with several steps for field checking & accuracy assessment
- Recently updated data (2015 – 2017)
- 8 main land use classes and 264 sub-classes
- 41 sub-classes categorized as agriculture lands
- Some agriculture related land classes grouped into non-agricultural lands
- Available in GIS compatible digital data formats

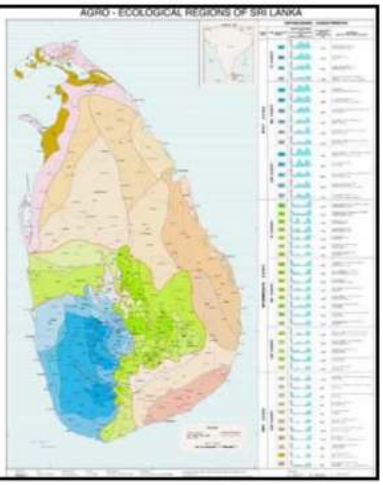
Land related spatial data

LUPPD land use maps 1:10,000



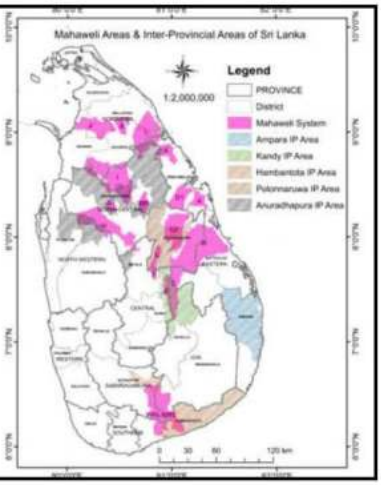
Agro-ecological zone map

B.V.R. Punyawardena 2003



Land related spatial data

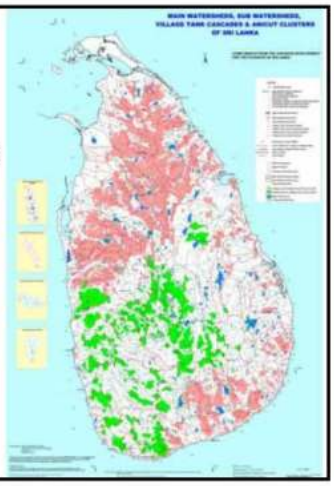
Mahaweli Systems



Land related spatial data

Village tank cascades & Anicut Clusters

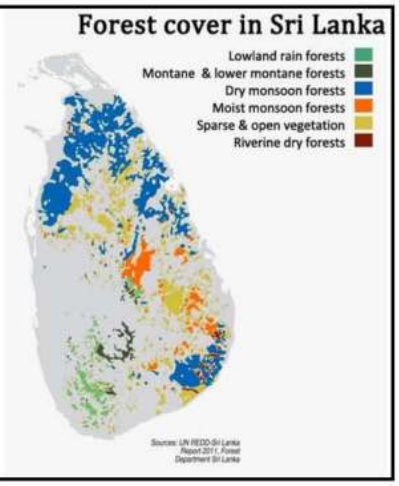
Department of Agrarian Services



Land related spatial data

Forest cover map

Forest Department



literature survey on agro ecosystem classification systems

- Agro-ecosystems in Sri Lanka
  - Traditional
    - Cascade / Anicut Systems
    - Kandyan Home Gardens
    - Ovita System
    - Chena
    - Plantation
    - Rainfed Agriculture
  - Modern
    - Major Irrigation
    - Minor Irrigation
    - Cultivation with ground water (Agro-well)
    - Slopping Land Cultivation
    - Urban & Semi-urban agriculture

literature survey on agro ecosystem classification systems

- Cropping pattern
  - Rice – Rice
  - Rice – Vegetable / OFC
  - Rice – Fallow
  - Vegetable - OFC
  - Mixed cropping
  - Multiple cropping
  - Relay cropping
  - Alley cropping

literature survey on agro ecosystem classification systems

Table 5. ecosystem classification of Ganashan et.al. (1995)

No	Forests	Grasslands	Coastal and marine	Inland wetlands	Agricultural
01	Tropical Thorn Forest (Arid zone)	Wet Montane grasslands (*wet patanas*)	Mangroves	Flood Plains	Irrigated Lowland
02	Dry Evergreen Forest (Dry zone)	Dry Montane grasslands (*dry patanas*)	Salt Marshes	Swamp Forests	Rainfed Lowland
03	Moist Deciduous Forest (Dry zone)	Tamana and Talawa grass lands	Sand Dunes	Streams	Rainfed Upland
04	Moist Semi Evergreen Forest (Intermediate zone)	Wet *Villu* grasslands	Mudflats	Rivers	Rainfed and Spring fed Terraces
05	Wet Semi Evergreen Forest (Intermediate zone)		Sea-grass Beds	Ponds	Home Gardens
06	Tropical Savannah Forest (Dry/Intermediate zone)		Lagoons & Estuaries		Dry Zone Lift Irrigation Systems
07	Tropical Wet Evergreen Forest (Wet zone)		Coral Reefs		Shifting Cultivation
08	Sub Montana Evergreen Forest (Wet zone)		Coastal Seas		
09	Montana Temperate Forest				

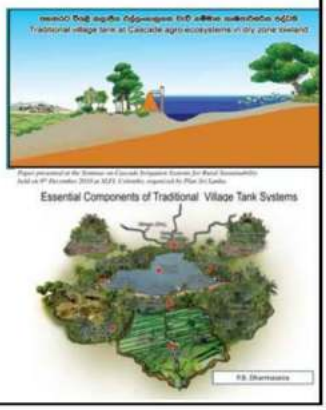
literature survey on agro ecosystem classification systems

Other agriculture land systems found during literature survey

- Cascade agro-ecosystem
- Home Gardens
  - dry zone home gardens
  - wet zone home gardens
  - Jaffna home gardens
  - Kandyan Home Gardens (Kandy, Matale, Kegalle and Rathnapura, Kurunegala)
- Ovita system
- Plantation crops

Traditional

- Tank cascade systems



Traditional

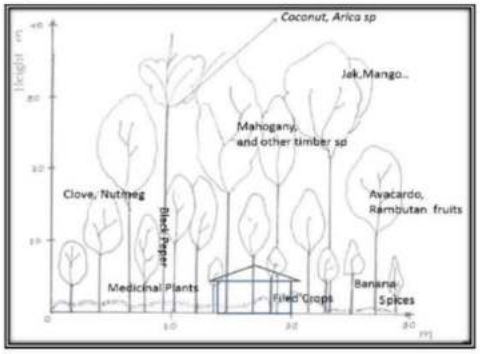
- Kandyan Home Gardens

Traditional

- Kandyan Home Gardens

Traditional

- Kandyan Home Gardens



Traditional

- Ovita

Traditional

- Ovita

Traditional

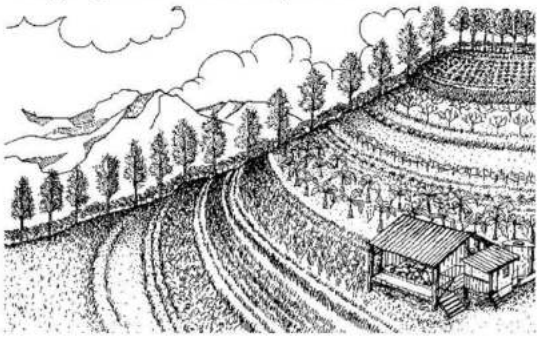
- Chena

Traditional

- Slopping land cultivation systems

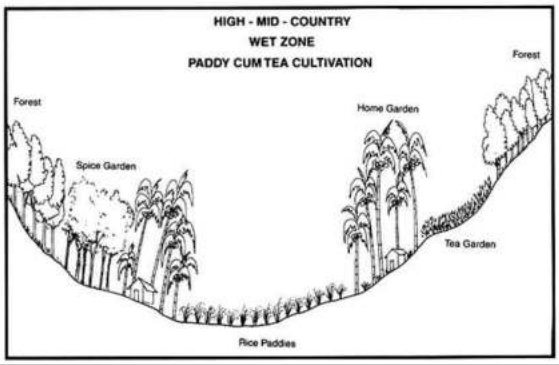
Traditional

- Slopping land cultivation systems



Traditional

- Tea & Paddy



- Plantation crops

Traditional

- Plantation: Rubber

Perennial crops

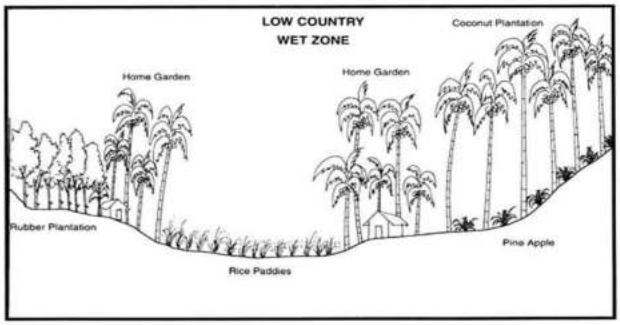
- Cinnamon

Modern ecosystems

Agro-well based dry zone cultivation systems

Traditional

- Low country wet zone ecosystem



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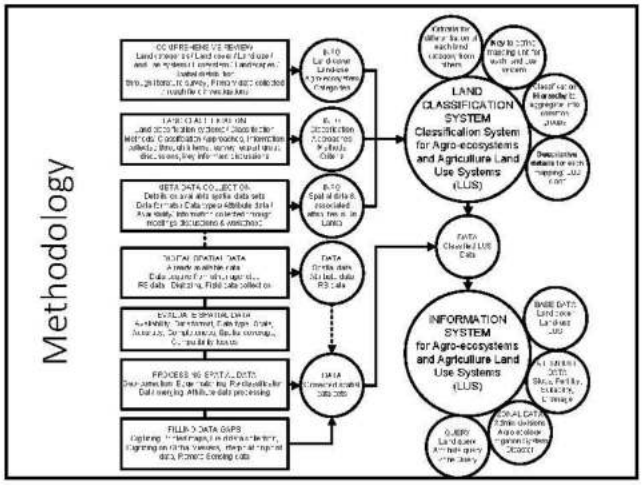
Kuruppu, I. V., Edirisighe, J. C., Herath, H. M. L. K., Jayasinghe-Mudalige, U. K., Wijesuriya, W., Udugama, J. M. M., & Fernando, A. P. S. (2015). Farmers' valuation of agro-biodiversity in home gardens: case study in the Kurunegala district. Journal of Environmental Professionals Sri Lanka, 4(1).

Jacob, V. J., & Alles, W. S. (1987). Kandyan gardens of Sri Lanka. Agroforestry Systems, 5(2), 123-137.

- Land Use Classification system need to be improved

1. Assess agriculture related land types in Sri Lanka
2. Develop land classification system for Sri Lanka
3. Develop data sets for agriculture LUS with base data, attribute data and zone data.
4. Develop spatial information system for agriculture LUS for Sri Lanka



THANK YOU

2.1.4 Presentation – 1 : GIS basics for Land Use System (LUS) mapping

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The Healthy Landscapes Project

Cascade Restoration Guidelines

GIS for Land-use-system mapping

Harsha K Kadupitiya
31st May 2024
Anuradhapura

Spatial tools and application basics

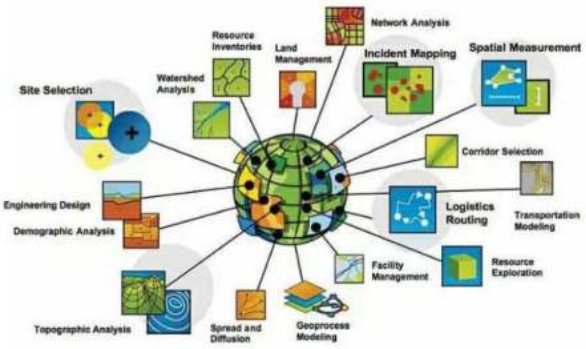
- Introduction to geographic information systems
- Map Projection & coordinates
- GIS data models
- Map production
  - Types of maps
  - Elements of a map
  - GIS software
  - Data collection for Map production
- Uses of maps
  - Available maps
  - Map reading
  - Using map as field guide
  - Limitations of maps
- Mobile phone apps & map browsers

Geographic Information System - GIS

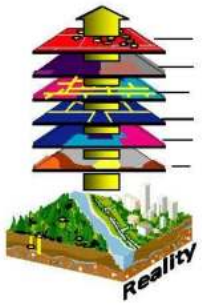
A Geographical information system is a computerized system for integrate spatial and non-spatial data in a referenced space

It is designed to ***acquire, store, retrieve, manipulate, analyze, visualize*** data for generation of information according to user requirements`

Contribution of different Disciplines/ tasks



GIS Integrates All ...to See the Whole!



GIS can hold specific map data as layers

Maps can be produced using only one layer or any group of selected layers as required

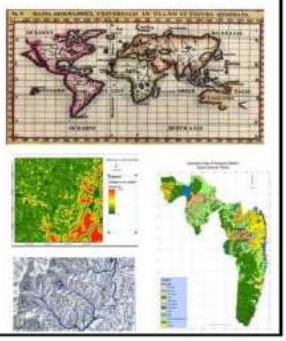
What is a map ?

A map is a symbolic depiction emphasizing relationships between elements of some space, as objects, regions, or themes.

Map

A map is a symbolic representation of selected geographic elements with their relationships

- A generalized / simplified view of an area
- As seen from above
- Usually north oriented
- A two-dimensional representation
- Greatly reduced size
- It has a scale
- Has grid or coordinate
- Features given by symbols, lines, and colors
- Display only selected features



- Need convert 3D Globe into 2D map

3D - GLOBE → 2D - Map

Map Projection & coordinates

- First 3D Globe need to be converted into 2D map

GLOBE

MAP

Map Coordinates

2 Types

- Geographical coordinates given as latitude and longitude
- Grid coordinates given as Easting & Northing

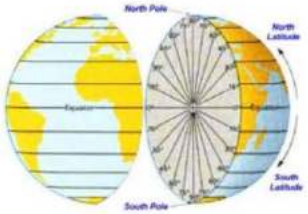
1. Geographical coordinates

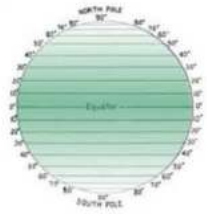
- Uses degrees, minutes, minutes
  - *Each degrees & minutes is divided into 60 graduations*
- Horizontal lines (Parallels of latitude)
  - *Reference to equator*
- Vertical lines (Meridians of longitude)
  - *Reference to Greenwich line*

6° 51' 0" N: 79° 54' 3" E

Coordinates: Latitude and Longitude

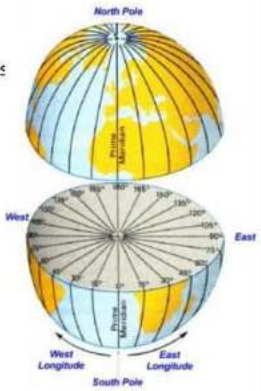
- Latitude
  - Measured in degrees North and South of the Equator.
  - Lines drawn parallel to each other running west to east.



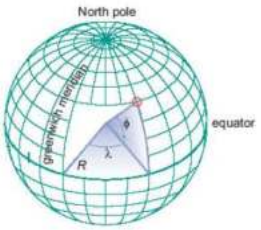


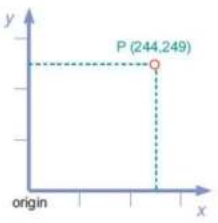
Longitude

- Longitude
  - Measured in degrees East or Wes of the prime meridian.
  - Lines drawn running North and South.



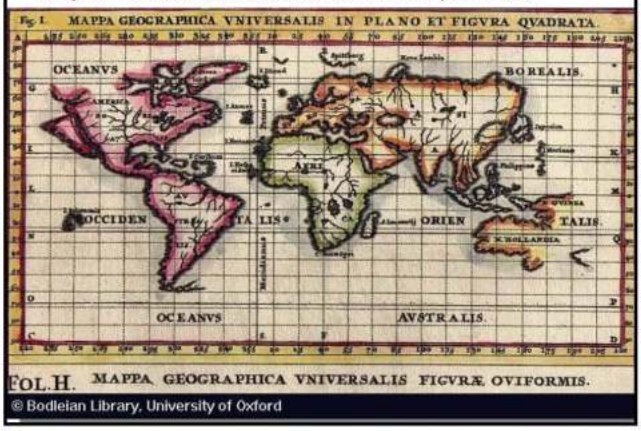
Two-Dimensional spatial referencing approaches



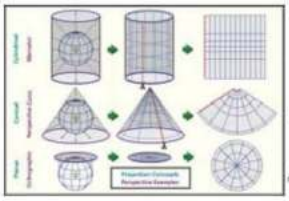


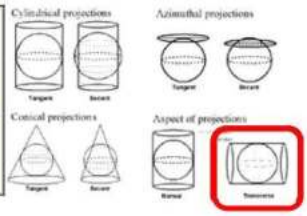
Two dimension spatial referencing approaches
(a) Through geographic coordinates
(b) Through Cartesian plane, rectangular coordinates (x, y)

Map of the world and was drawn in the year 1703



Map Projections





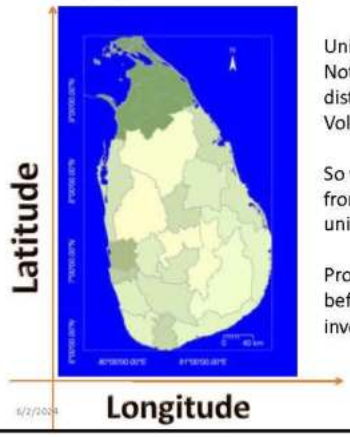
Airy 1830	Fischer 1960
ATS 77	Fischer 1968
Australian National	GRS 80
Bessel 1841	Helmert 1960
Bessel 1841 (Japan by Law)	Hough 1960
Bessel 1841 (Namibia)	Indonesian 1974
Clarke 1866	International 1924
Clarke 1880	Krassovsky 1940
Clarke 1880 (IGN)	Modified Airy
D-PAF (Orbits)	Modified Fischer 1960
Everest (India 1830)	New International 1967
Everest (India 1956)	SGS 85
Everest (Malaysia 1969)	South American 1969
Everest (E. Malaysia and Brunei)	WGS 60
Everest (Malaysia and Singapore 1948)	WGS 66
Everest (Pakistan)	WGS 72
Everest (Sabah Sarawak)	WGS 84

World Geodetic System (WGS)

WGS 84

14

Geographic Coordinates of Sri Lanka – WGS 84



Units are degrees
Not possible to calculate distance, Area, Depth, Volume, etc.

So we need convert map units from degrees into distance units

Projection need to be done before use maps for analysis involve distance or areas

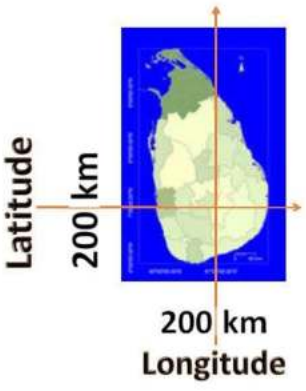
6/2/2024 15

Universal Transverse Mercator (UTM) coordinate system

1- 60 Time Zones (One zone 6° wide)
20 Latitude bands from C to X (omits I & O)
each band 8° wide

UTM zone of Sri Lanka: 44N

6/2/2024 16



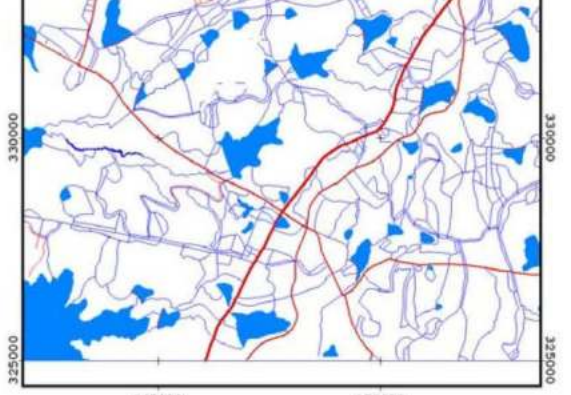
UTM Zone 44

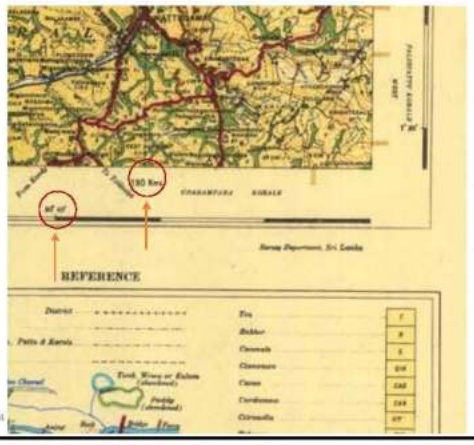
200 km , 200 km
at Piduruthalagala

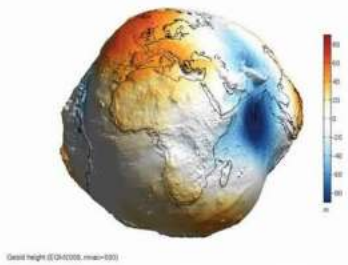
Description = Coordinate System
Projection " SL – UTM 44 "
Class=Coordinate System Projection
Type=CoordSystem

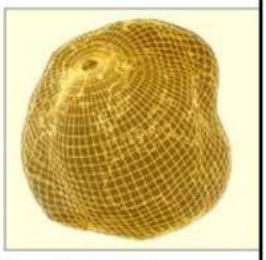
UnitSize=1.000000
Type=Projection
Projection = Transverse Mercator
Datum = Kandawala
Datum Area = [Projection]
False Easting = 200,000 m
False Northing = 200,000 m
Central Meridian: 80.771714 deg
Central Parallel: 7.000481 deg
Scale Factor= 0.9999238000

6/2/2024 17





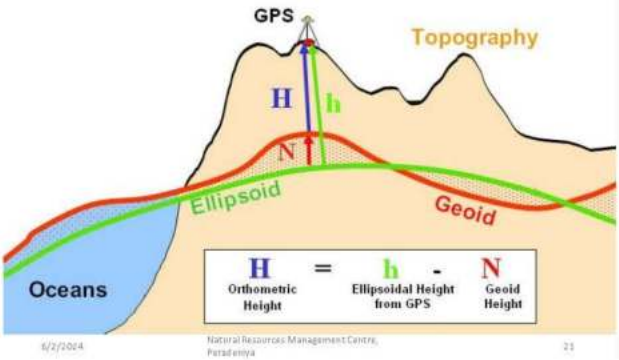




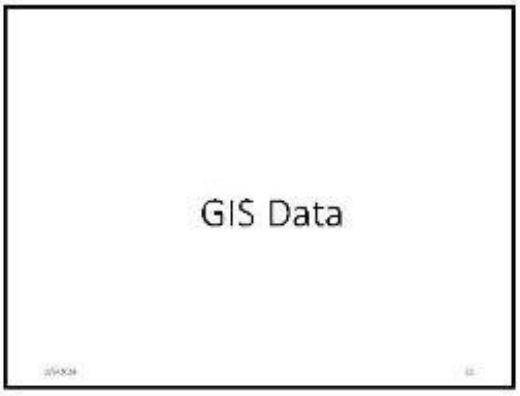
The geoid, exaggerated to illustrate the complexity of its surface.

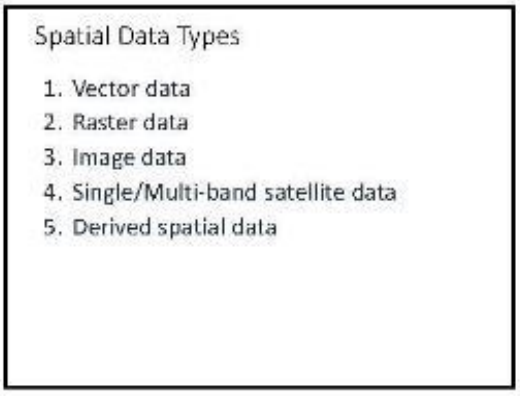
Source: Denise Dettmering, Seminar Notes for Bosch Telekom, Stuttgart, 2000.

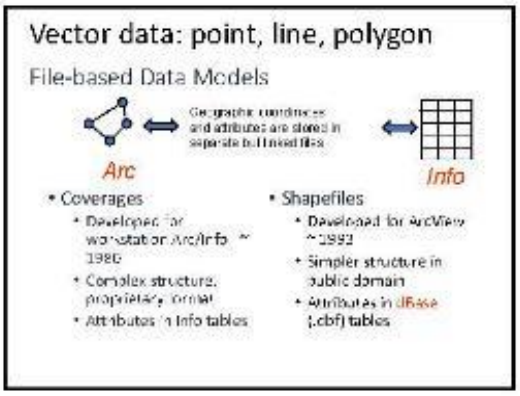
Ellipsoid, Geoid and Datum

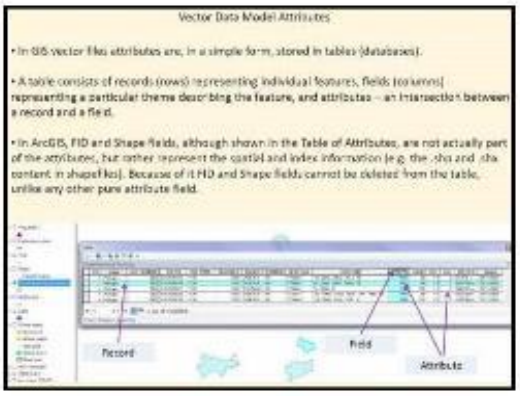


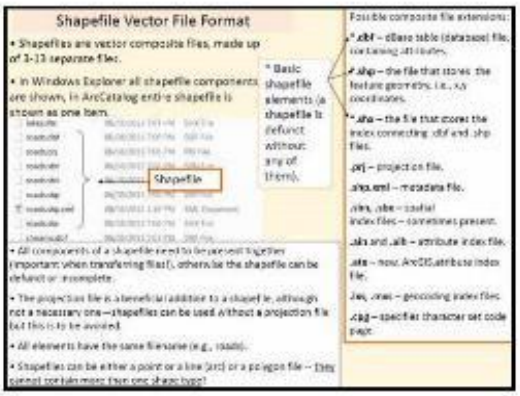
2.1.5 GIS Presentation 2 - GIS Data Models

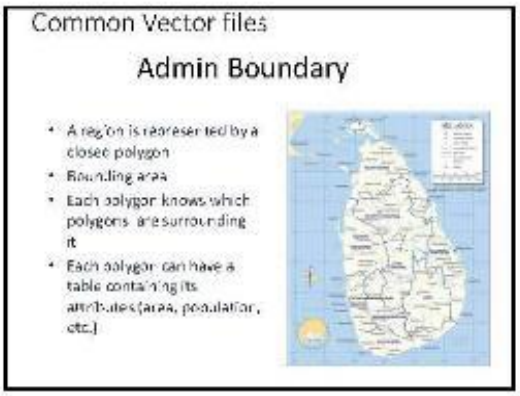












Common Vector files

Network

- A **network** is a set of edges (lines) and junctions (points) that are topologically connected to each other.
- Each edge knows which junctions are at its endpoints.
- Each junction knows which edges it connects to

Common Vector files

Contour

- a contour line joins points of equal elevation or a constant value.
- No crossing or overlapping lines with two values

- Common vector format to represent continues features

Common Vector files

Vector formats

- AutoCAD DXF – common vector file used in AutoCAD DXF format (by Autodesk)
- Extensible coordinate system (XYZ) – simple point data
- Digital line graph (DLG) – a USGS format for vector data
- Esri E00 – proprietary binary format for topologically integrated vector and raster data used by Esri
- Geography Markup Language (GML) – XML-based open standard (by OpenGIS) for GIS data exchange
- GeoMedia – Intergraph's Microsoft Access based format for spatial vector storage
- GPKG – Intergraph's free software based OGC compliant data storage container for a relational Microsoft Access database
- Keyhole Markup Language (KML) – XML based open standard by OpenGIS for GIS data exchange
- MapInfo TAB format – MapInfo vector data format using TAB, DAT, ID, and MAP files
- National Transfer Format (NTF) – National Transfer Format (mostly used by the UK Ordnance Survey)
- SpatiaLite – is a spatial extension to SQLite, providing vector geodatabase functionality. It is similar to PostGIS, Oracle Spatial, and SQL Server with spatial extensions
- Shapefile – a popular vector data GIS format developed by Esri
- Simple Features – Open Geospatial Consortium specification for vector data
- SOSI – a spatial data format used for all public exchange of spatial data in Norway
- Spatial Data File – Autodesk's geodatabase format, native to AutoCAD
- TIGER – Topologically Integrated Geographic Encoding and Referencing
- Vector Product Format (VPF) – National Geospatial-Intelligence Agency (NGA) standard of vectored data for large geographic databases

Raster Data

The raster data model represents the Earth's surface as an array of two-dimensional grid cells, with each cell having an associated value:

1	2	3	5	8	← Cell (x,y)
4	6	8	3	9	← Cell value
3	5	3	3	1	
7	5	4	3	9	
2	2	4	5	2	← Cell size – resolution

rows ↑

columns →

The value is an integer, either actual value OR codes representing an attribute

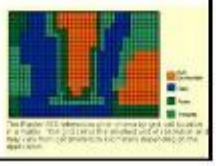
Cell Values

Absolute Values

Cell Value represents the **value** of the phenomenon of interest, e.g. Elevation at that pixel location.

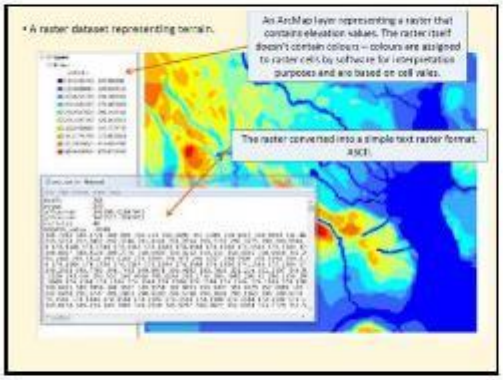
Coded Values

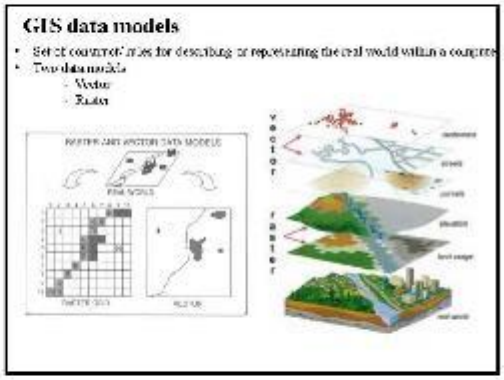
Cell Values stored in each cell are used as **substitutes** for **categorical** data, e.g. Land Cover Classes

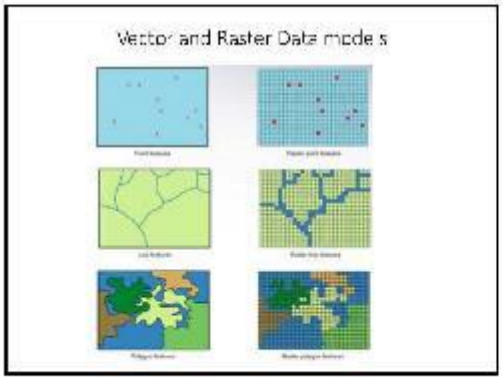


Cell Size & Resolution

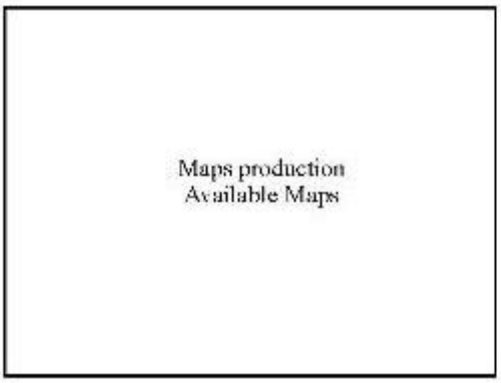
- The **size** of the **cells** in the raster data model determines the **resolution** at which features can be represented
- The resolution can have an effect on which features are represented in what locations:

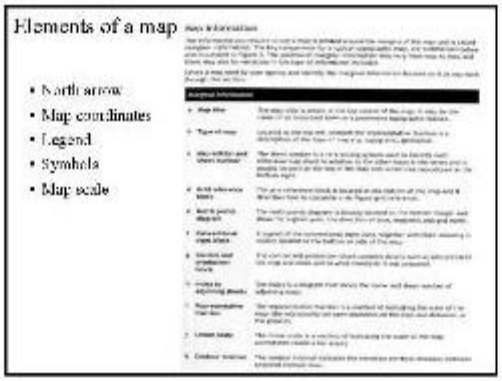

• A raster dataset representing terrain.
An ArcMap layer representing a raster that contains elevation values. The raster itself doesn't contain colours – colours are assigned to raster cells by software for interpretation purposes and are based on cell value.
The raster converted into a simple text raster format, .asci

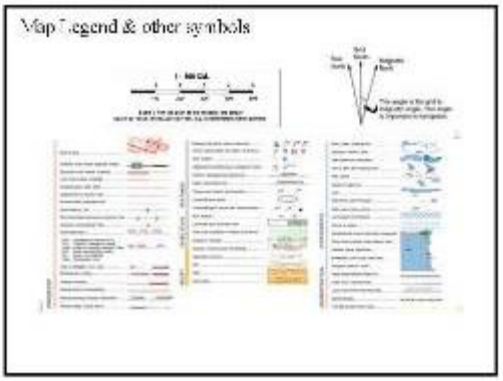

GIS data models
Vector
Raster

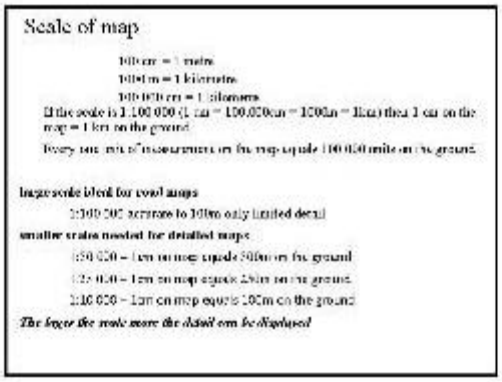

Vector and Raster Data models

2.1.6 GIS Presentation 3 - Map production and Available maps









One Inch Map Index

One mile to one inch or 1:63,360 scale this map series is commonly known as One Inch. This is the first topographical map series published in Sri Lanka and based on surveys commenced on 1897 and completed on 1925.

These maps were revised periodically till 1972 the year metrication of maps were started.

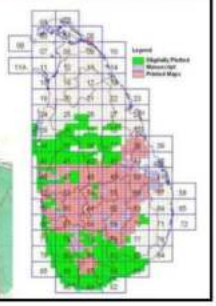
- One Inch to One mile Map (1:63,360)
- 72 Sheets

Index to 1:50,000 Maps

- This map series is a new metric map series published to replace the old One Inch. Commenced in 1979 and completed on 1996 .
- These maps compiled mostly using modern photogrammetric methods and cartographic technologies based on old one inch series.

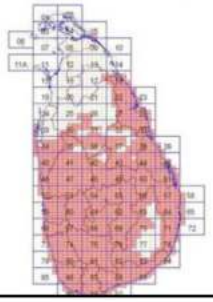
1:10,000 Topographic Maps

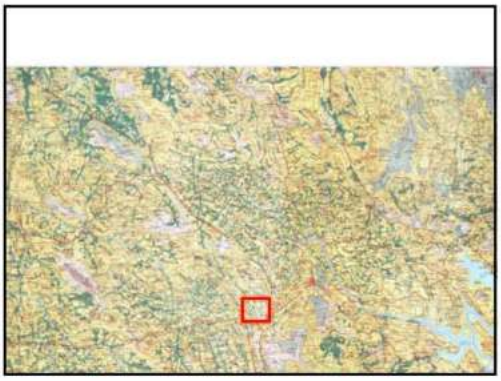
- Out of 1834, 1:10,000 maps, only 488 were printed and another 570 sheets of photogrammetric plots were available at various stages of production.
- 58% of 1:10,000 maps available in the Country.

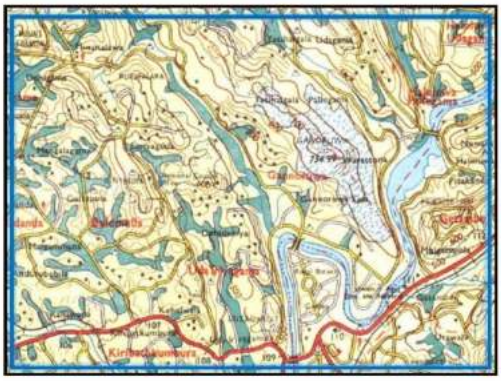


1:10,000 Digital data in 2009

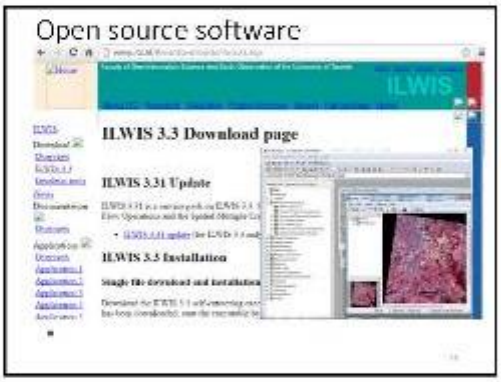
- 70% of the country will be covered with 1:10,000 Digital Topographic Data in 2009.







2.1.7 GIS Presentation 4 - Open source software and resources



GIS data –National Spatial Data (NSDI)

- https://www.nsdi.gov.lk/thematic-maps

Weather forecast

- https://www.weather-forecast.com

Weather forecast

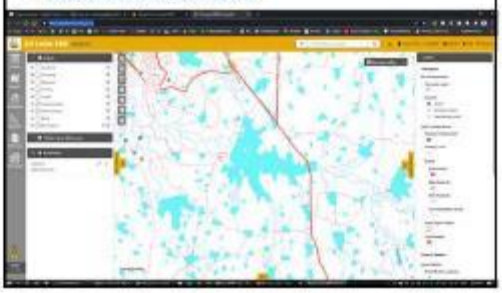
- https://www.accuweather.com

GIS data –Survey Department Website

- https://www.survey.gov.lk/sdweb/home.php

GIS data –National Spatial Data (NSDI)

- https://geoportal.nsdi.gov.lk/

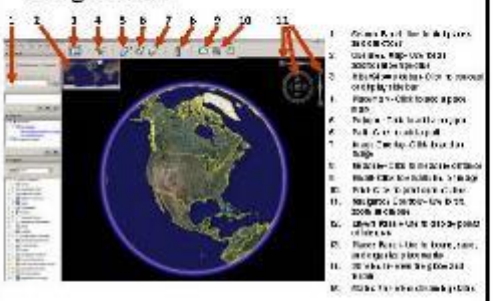


2

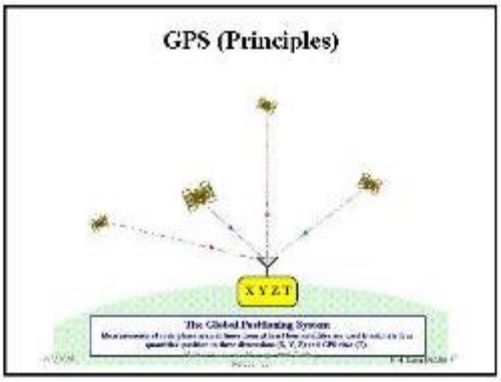
Tools and resources available for LU / C mapping

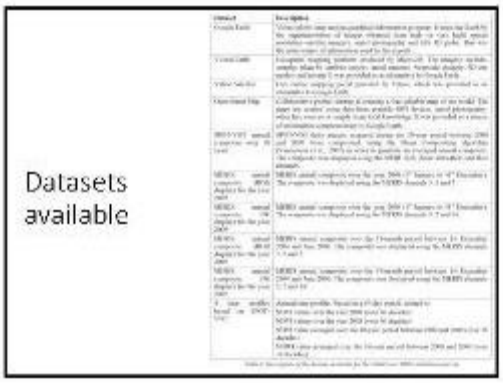
- Free satellite data – USGS website
- Free global datasets – WORLD ClimGrid, Global Soil Grid
- Google earth engine allows online spatial analysis with time series satellite data integration

Google Earth



2.1.8 GIS Presentation 5 - GPS, and Mobile apps





1

Mobile Apps

Mobile Apps

- CTDroid Sri Lanka – by Chanaka Alahakoon, PGIS

Mobile Apps

- Place App

Mobile Apps

- Field Area Measure

Angle meter App
Land slope measurements

1

2.2 Land Degradation Assessment – QM Questionnaire (2024)

1	CP-MT-Dambulla-Siyambalawewa	
2	NCP-AN-Palugaswewa-Demuththewa	
3	NCP-AN-Palugaswewa-Horivila	
4	NCP-AN-Palugaswewa-Keleva	
5	NCP-AN-Palugaswewa-Palugaswewa	
6	NCP-AN-Palugaswewa-Senadhiriyagama	
7	NCP-AN-Palugaswewa-Wayaulpatha	

(GN) ***B. Land Use System*** *(LUS)*

A.1. Administration Unit – Hiriwila site *(GN)*

1	NCP-AN-Ipalogama-Manewa	
2	NCP-AN-Kekirawa-Ihala Puliyankulam	
3	NCP-AN-Kekirawa-Maradankadawela	
4	NCP-AN-Nachchaduwa-Nachchaduwa NT	
5	NCP-AN-Thirappane-Alisthana	
6	NCP-AN-Thirappane-Aluth Punchikulama	
7	NCP-AN-Thirappane-Dayagama	
8	NCP-AN-Thirappane-Ethungama North	
9	NCP-AN-Thirappane-Ethungama South	
10	NCP-AN-Thirappane-Idigahawewa	
11	NCP-AN-Thirappane-Mahakanumulla	
12	NCP-AN-Thirappane-Manakkulama	
13	NCP-AN-Thirappane-Paidikulama	
14	NCP-AN-Thirappane-Sembukulama	
15	NCP-AN-Thirappane-Thirappane Kadawee	
16	NCP-AN-Thirappane-Thirappanegama	
17	NCP-AN-Thirappane-Walagambahuwa	
18	NCP-AN-Thirappane-Wanamal Uyana	
19	NCP-AN-Thirappane-Wannammaduwa	
20	NCP-AN-Thirappane-Wellamudawa	

A.2. Administration Unit – Nachchaduwa site

01_Natural forest	
02_Plantation forest	
03_Protected recreational	
04_Scrub land	
05_Grass land	
06_Sparsely vegetated or bare land	
07_Unmanaged bare land	
08_Annual cropping	
09_Peranial non-woody cropping	
10_Tree and shrub cropping	
11_Tea	
12_Home garden	
13_Mining	
14_Paddy abandoned	
15_Paddy land	
16_Urban	
17_Water_body	
18_Water_stream	
19_Wetlands	

1. Land Use System Trends

1.1 Trend of area coverage changes

1. Area Coverage remains stable	
2. Area coverage slowly increasing	
3. Area coverage slowly decreasing	
4. Area coverage rapidly increasing	
5. Area coverage rapidly decreasing	

1.2 Trend of intensity changes

1. No major changes	
2. Moderate increase	
3. Moderate decrease	
4. Major increase	
5. Major decrease	

1.3 Remarks (eg: reasons for trend)

……

……

……

……

……

2. Important types of Land degradation prevailing within LUS in Admin unit, their causes and impacts (*Refer Annex 1 & Annex 2 for description)*

No	Land degradation types (a) *(One type or combination of types for a particular area)*			Extent %	Degree of degradation (b)	Rate of degradation (c)	Direct Causes (d)	Indirect causes (e)	Impact on ecosystem services (f)	Level of Impact (g)	Remarks
	i	ii	iii								
01											
02											
03											
04											
05											
06											
07											
08											

3. Land Conservation types, measures, purposes, effectiveness and impacts (*Refer Annex 1 for details and Annex 2 for definitions)*

Name of technology	Conservation Group (h)	Conservation Measures (i)			Purpose (j)	Conservation Area %	Degradation Addressed (a)			Effectiveness (k)	Effectiveness Trend (l)	Start Period (yyyy)	End Period (yyyy)	Impact on Ecosystem services (f)	Level of Impact (g)
		i	ii	iii			i	ii	iii						

3.1 Remarks

……

……

……

4. Expert Recommendation (please provide recommendations for degradation issue/s for LUS in the Admin unit in detail

4.1 Recommendation :- ……

A – Adaptation : ……

M – Mitigation : ……

P – Prevention : ……

R – Rehabilitation: ……

4.2 Remarks:-

……

……

……

Contributor Details:

Name/s: - ……

Designation/s: - ……

Institution: - ……

Contact No: - …….. *Date: -* ……..

Signature/s: ……

Office Use: Data computerized by: …….. Date:- ……

2.2.1 QM Code Sheet

(a) Type of Land Degradation

Code	Type of Degradation	Main types
Bc	Reduction of vegetative cover	Biological degradation
Bf	Detrimental effects of fires	
Bh	Loss of habitats	
Bl	Loss of soil life	
Bp	Increase of pests/diseases*: reduction of biological control*	
Bq	Quantity/biomass decline*: reduced vegetative production for different land use*	
Bs	Quality and species composition/diversity decline	
Cn	Fertility decline and reduced organic matter content	Chemical Soil deterioration
Ha	Aridification: *decrease of average soil moisture content*	Water degradation
Hg	Change in groundwater/aquifer level	
Hp	Decline of surface water quality	
Hq	Decline of groundwater quality	
Hs	Change in quantity of surface water: *change of the flow regime (flood, low flow, drying up of rivers and lakes)*	
Hw	Reduction of the buffering capacity of wetland areas	
Wg	Gully erosion/gullying	Soil erosion by water
Wm	Mass movements/landslides	
Wo	Offsite degradation effects : *deposition of sediments, downstream flooding, siltation of reservoirs and waterways, and pollution of water bodies with eroded sediments*	
Wr	Riverbank erosion	
Wt	Loss of topsoil/surface erosion	

(b) Degree of Degradation

1	Light
2	Moderate
3	Strong
4	Extreme

(c) Rate of Degradation

1	No change in degradation
2	Slowly increasing degradation
3	Slowly decreasing degradation
4	Moderately increasing degradation
5	Moderately decreasing degradation
6	Rapidly increasing degradation
7	Rrapidly decreasing degradation update

Degree: intensity of the land degradation process

Light: *there are some indications of degradation, but the process is still in an initial phase. It can be easily stopped and damage repaired with minor efforts.*

Moderate: *degradation is apparent, but its control and full rehabilitation of the land is still possible with considerable efforts.*

(d) Direct Causes

Code	Direct causes	Main Types
c1	Reduction of plant cover and residues	Crop and rangeland management
c2	Inappropriate application of manure, fertilizer, herbicides, pesticides and other agro-chemicals or waste	
c3	Nutrient mining: excessive removal without appropriate replacement of nutrients	
c4	Shortening of the fallow period in shifting cultivation	
c5	Inappropriate irrigation : *inefficient irrigation method, over-irrigation, insufficient drainage*	
c6	Inappropriate use of water in rainfed agriculture *(eg excessive soil evaporation and runoff)*	
c7	Bush encroachment and bush thickening	
c8	Occurrence and spread of weeds and invader plants	
c9	Others (specify)	
e1	Excessive gathering of fuel wood, (local) timber, fencing materials	Over-exploitation of vegetation for domestic use
e3	Other (specify)	
f1	Large-scale commercial forestry	Deforestation and removal of natural vegetation
f2	Expansion of urban / settlement areas and industry	
f3	Conversion to agriculture	
f4	Forest / grassland fires	
f5	Road and rail construction	
f6	Others (specify)	
i1	Industry	Industrial activities and mining
i2	Mining	
i3	Waste deposition	
i4	Others (specify)	
n1	Change in temperature	Natural causes
n2	Change of seasonal rainfall	
n3	Heavy/ extreme rainfall (intensity and amounts)	
n4	Windstorms / dust storms	
n5	Floods	
n6	Drought	
n7	Topography	
n8	Others (specify)	
o1	Irrigation	Over abstraction of water / excessive withdrawal of water
o2	Industrial use	
o3	Domestic use	
o4	Mining activities	
o5	Decreasing water use efficiency	
o6	Others (specify)	
p1	Sanitary sewage disposal	Discharges

p2	Waste water discharge	
p3	Excessive runoff	
p4	Poor and insufficient infrastructure to deal with urban waste	
p5	Others (specify)	
s1	Cultivation of highly unsuitable soils	Soil Management
s2	Missing or insufficient soil conservation / runoff and erosion control measures	
s3	Heavy machinery	
s4	Tillage practice (ploughing, harrowing, etc.)	
s5	Others (specify)	
u1	Settlements and roads	Urbanization and infrastructure development
u2	Recreation (urban)	
u3	Others	
w1	Lower infiltration rates/increased surface runoff	Disturbance of water cycle
w2	Others (specify)	

(e) Indirect Causes

c	Consumption pattern and individual demand
e	Education, awareness raising and access to knowledge and support services and loss of knowledge
g	Governance, institutions and politics
h	Poverty
l	Labour availability
o	Others (specify)
p	Population pressure
r	Inputs and infrastructure
t	Land tenure
w	War and conflict

(f) Impacts on Ecosystem Services

Code	Ecosystem services	Main Type
E1	Regulation of excessive water such as excessive rains, storms, floods *eg :affecting infiltration, drainage, runoff, evaporation,*	Ecological services
E10	(Micro)-climate (wind, shade, temperature, humidity)	
E11	Others (Specify)	
E2	Regulation of scarce water and its availability *eg: during dry seasons, droughts affecting water and evaporation loss*	
E3	Organic matter status	
E4	Soil cover (vegetation, mulch, etc.)	
E5	Soil structure: surface and subsoil affecting infiltration, water and nutrient holding capacity(...)	
E6	Nutrient cycle (N, P, K) and the carbon cycle (C)	
E7	Soil formation (including wind-deposited soils)	
E8	Biodiversity	
E9	Greenhouse gas emission	
P1	Production (of animal / plant quantity and quality including biomass for energy) and risk	Productive services
P2	Water (quantity and quality) for human, animal and plant consumption	
P3	Land availability	

P4	Others(Specify)	
S1	Spiritual, aesthetic, cultural landscape and heritage values, recreation and tourism	Socio-cultural services / human well-being
S2	Education and knowledge	
S3	Conflicts transformation	
S4	Food & livelihood security and poverty	
S5	Health	
S6	Net income	
S7	Protection/ damage of private and public infrastructure (buildings, roads, dams, etc.)	
S8	Marketing opportunities (access to markets, etc.)	
S9	Others (Specify)	

(g) Level of Impacts on Ecosystem services

1	low positive impact: land degradation contributes positively (0-10%) to the changes in ES
2	low negative impact: land degradation contributes negatively (0-10-%) to changes in ES
3	positive impact: land degradation contributes positively (10-50%) to the changes in ES
4	negative impact: land degradation contributes negatively (10-50%) to changes in ES
5	high positive impact: land degradation contributes positively (more than 50%) to changes in ES
6	high negative impact: land degradation contributes negatively (more than 50%) to changes in ES

(h) Conservation Groups

AF	Agroforestry
AP	Afforestation and forest protection
CA	Conservation agriculture / mulching
CB	Coastal bank protection
CO	Conservation of natural biodiversity
GR	Grazing land management
NM	Manuring / composting / nutrient management
OT	Other
PR	Protection against natural hazards
RH	Gully control / rehabilitation
RO	Rotational system / shifting cultivation / fallow /slash and burn
SA	Groundwater / salinity regulation / water use efficiency
SC	Storm water control, road runoff
SD	Sand dune stabilization
TR	Terraces
VS	Vegetative strips / cover
WH	Water harvesting
WM	Waste management
WQ	Water quality improvement

(i) Conservation Measures

A	**Agronomic**
A1	Vegetation/soil cover

A2	Organic matter/soil fertility
A3	Soil surface treatment
A4	Subsurface treatment
A5	Others
M	**Management**
M1	Change of land use type
M2	Change of management/intensity level
M3	Layout according to natural and human environment
M4	Major change in timing of activities
M5	Control/change of species composition
M6	Waste Management
M7	Others
S	**Structural**
S1	Bench terraces (<6%)
S2	Forward sloping terraces (>6%)
S3	Bunds/banks
S4	Graded ditches/waterways
S5	Level ditches/pits
S6	Dams/pans
S7	Reshaping surface (reducing slope)
S8	Walls/barriers/palisades
S9	Others
V	**Vegetative**
V1	Tree and shrub cover
V2	Grasses and perennial herbaceous plants
V3	Clearing of vegetation (eg fire breaks/reduced fuel)
V4	Others

(j) Purpose

M -Mitigation

P – Prevention

R – Rehabilitation

(k) Effectiveness

1 – low

2 – moderate

3 – high

4 – very high

(l) Effectiveness trend

1 - No change in effectiveness

2 - Increase in effectiveness

3 - Decrease in effectiveness

2.2.2 QM Assessment Definition sheet

Land use: *human activities which are directly related to land, making use of its resources or having an impact on it.*
Land cover: *vegetation (natural or planted) or man-made structures (buildings, etc.) that cover the earth's surface.*

Land use types

Main categories	*Subcategories*
Cropland: *land used for cultivation of crops (field crops, orchards)*	• ***Ca: Annual cropping:*** *land under temporary/ annual crops usually harvested within one, maximally two years (e.g. maize, paddy rice, wheat, vegetables, fodder crops).* • ***Cp: Perennial (non-woody) cropping:*** *land under permanent (not woody) crops that may be harvested after 2 or more years, or where only part of the plants are harvested (e.g. sugar cane, banana, sisal, pineapple).* • ***Ct: Tree and shrub cropping:*** *permanent woody plants with crops harvested more than once after planting and usually lasting for more than 5 years (e.g. orchard/ fruit trees, coffee, tea, grapevines, oil palm, cacao, coconut, fodder trees).*

Grazing land: *land used for animal production*	• ***Ge: Extensive grazing land:*** *grazing on natural or semi-natural grasslands, grasslands with trees/ shrubs (savannah vegetation) or open woodlands for livestock and wildlife. Includes the following subcategories:*
	  • ***Nomadism****: people move with animals.*
	  • ***Semi-nomadic pastoralism****: animal owners have a permanent place of residence where supplementary cultivation is practiced. Herds are moved to distant grazing grounds.*
	  • ***Ranching****: grazing within well-defined boundaries, movements cover smaller distances and management inputs are higher compared to semi-nomadism.*
	  • ***Transhumant pastoralism****: regular movements of herds between fixed areas in order to benefit from the seasonal variability of climates and pastures.*
	• ***Gi: Intensive grazing/ fodder production:*** *improved or planted pastures for grazing/ production of fodder (for cutting and carrying: hay, leguminous species, silage etc.) not including fodder crops such as maize, cereals. These are classified as annual crops (see above). Intensive grazing can be subclassified into:*

Forests/ woodlands: *land used mainly for wood production, other forest products, recreation, protection.*	• ***Fn: Natural or semi-natural:*** *forests mainly composed of indigenous trees, not planted by man.*
	  • *Selective felling.*
	  • *Clear felling: felling the whole forest at one time.*
	  • *Shifting cultivation: felling (harvesting) only certain valuable trees within a forest.*
	  • *Dead wood/ prunings removal (no cutting of trees).*
	  • *Non-wood forest use (e.g. fruit, nuts, mushrooms, honey, medicinal plants, etc.) .*
	• ***Fp: Plantations, afforestations:*** *forest stands established by planting or/ and seeding in the process. of afforestation or reforestation.*
	  • *Monoculture local variety.*
	  • *Monoculture exotic variety.*
	  • *Mixed varieties.*
	• ***Fo: Other:*** *e.g. selective cutting of natural forests and incorporating planted species.*

Settlements, infrastructure	• ***Ss:*** *Settlements, buildings* • ***St:*** *Traffic lines: roads, railways* • ***Se****: Energy lines: pipe lines, power lines* • ***So****: Other infrastructure*

2.2.3 SLM measures – the constituents of a Technology

Type of measure	*Subcategories*	*Examples*
Agronomic measures ***Error! Objects cannot be created from editing field codes.*** • *are usually associated with annual crops* • *are repeated routinely each season or in a rotational sequence* • *are of short duration and not permanent* • *do not lead to changes in slope profile* • *are normally independent of slope*	**A1:** Vegetation/ soil cover	*Mixed cropping, intercropping, relay cropping, cover cropping*
	A2: Organic matter/ soil fertility	*Conservation agriculture, production and application of compost/ manure, mulching, trash lines, green manure, crop rotations*
	A3: Soil surface treatment	*Zero tillage (no-till), minimum tillage, contour tillage* *Differentiate tillage systems: No tillage, reduced tillage (>30% soil cover), full tillage (>30% soil cover).*
	A4: Subsurface treatment	*Breaking compacted subsoil (hard pans), deep ripping, double digging*
	A5: Seed management, improved varieties	*Production of seeds and seedlings, seed selection, seed banks, development/ production of improved varieties*
	A6: Residue management **A7:** Others	*Specification required: burned, grazed, collected, retained.*
Vegetative measures **Error! Objects cannot be created from editing field codes.** • *involve the use of perennial grasses, shrubs, or trees* • *are of long duration* • *often lead to a change in slope profile* • *are often aligned along the contour or against the prevailing wind direction* • *are often spaced according to slope*	**V1:** Tree and shrub cover	*Agroforestry, windbreaks, afforestation, hedges, live fences*
	V2: Grasses and perennial herbaceous plants	*Grass strips along the contour, vegetation strips along riverbanks*
	V3: Clearing of vegetation	*Fire breaks, reduced fuel for forest fires*
	V4: Replacement or removal of alien/ invasive species	*Cutting of undesired trees and bushes*
	V5: Others	*Tree nurseries*
Structural measures **Error! Objects cannot be created from editing field codes.** • *are of long duration or permanent* • *often require substantial inputs of labour or money when first installed* • *involve major earth movements and/ or construction with wood, stone, concrete, etc. are often carried out to control runoff, erosion, and wind velocity, and to harvest rainwater* • *often lead to a change in slope profile* • *are often aligned along the contour/ against prevailing wind direction* • *are often spaced according to slope* *If structures are stabilized by means of vegetation, also select relevant vegetative measures!*	**S1:** Terraces	*Bench terraces (slope of terrace bed <6%); Forward-sloping terraces (slope of terrace bed >6%*
	S2: Bunds, banks	*Earth bunds, stone bunds (along the contour or graded), semi-circular bunds ("demi-lunes")*
	S3: Graded ditches, channels, waterways	*Diversion/ drainage ditch, waterways to drain and convey water*
	S4: Level ditches, pits	*Retention / infiltration ditches, planting holes, micro-catchments*
	S5: Dams, pans, ponds	*Dams for flood control, dams for irrigation, sand dams*
	S6: Walls, barriers, palisades, fences	*Sand dune stabilization, rotational grazing (using fences), area closure, gully plugs (check dams)*
	S7: Water harvesting/ supply/ irrigation equipment	*Rooftop water harvesting, water intakes, pipes, tanks, etc.*
	S8: Sanitation/ waste water structures	*Compost toilet, septic tanks, constructed treatment wetlands*
	S9: Shelters for plants and animals	*Greenhouses, stables, shelters for plant nurseries*

	S10: Energy saving measures	*Wood-saving stoves, insulation of buildings, renewable energy sources (solar, biogas, wind, hydropower)*
	S11: Others	*Compost production pits; reshaping of surface (slope reduction)*
Management measures **Error! Objects cannot be created from editing field codes.** • *involve a fundamental change in land use* • *usually involve no agronomic and structural measures* • *often result in improved vegetative cover* • *often reduce the intensity of use*	**M1:** Change of land use type	*Area closure/ resting, protection, change from cropland to grazing land, from forest to agroforestry, afforestation*
	M2: Change of management/ intensity level	*Change from grazing to cutting (for stall feeding), farm enterprise selection (degree of mechanization, inputs, commercialization), vegetable production in greenhouses, irrigation; from mono-cropping to rotational cropping; from continuous cropping to managed fallow; from open access to controlled access (grazing land, forests); from herding to fencing, adjusting stocking rates, rotational grazing*
	M3: Layout according to natural and human environment	*Exclusion of natural waterways and hazardous areas, separation of grazing types, distribution of water points, salt licks, livestock pens, dips (grazing land); increase of landscape diversity, forest aisle*
	M4: Major change in timing of activities	*Land preparation, planting, cutting of vegetation*
	M5: Control/ change of species composition (if annually or in a rotational sequence as done e.g. on cropland → A1)	*Reduction of invasive species, selective clearing, encouragement of desired/ introduction of new species, controlled burning (e.g. prescribed fires in forests/ on grazing land)/ residue burning*
	M6: Waste management (recycling, re-use or reduce)	*Includes both artificial and natural methods for waste management*
	M7: Others	
Other measures • *comprises any measures which do not fit into the above categories*		*Beekeeping, small stock farming (e.g. poultry, rabbits), fish ponds; food storage and processing (including post-harvest loss reduction)*
Combinations • *occur where different measures complement each other and thus enhance each other's effectiveness* • *may comprise any two or more of the above measures*		*Terrace (S1) + Grass strips and trees along riser (V2, V1) + Contour tillage (A3)* *Zero grazing/ stall feeding (M2) + Construction of stables and fence (S10) + Compost/ manure production pits (S12) + Application of manure and compost on cropland (A2)*

2.2.4 The goals of the Technology with regard to land degradation:

Prevention: good land management practices that are already in place on land that may be prone to land degradation. They maintain natural resources and their environmental and productive functions.

Reduction: interventions intended to reduce ongoing degradation and/ or halt further degradation. They start improving natural resources and their functions. Impacts tend to be noticeable in the short to medium term.

Rehabilitation/ restoration: required when the land is already degraded to such an extent that the original use is no longer possible, and land has become practically unproductive. Here, longer-term and more costly investments are needed to show any impact.

Adaptation: applied when rehabilitation/ restoration of the original state of the land is no longer possible or requires resources beyond the means of land users. This means the state of land degradation is "accepted", but land management is adapted to suit land degradation (e.g. adapting to soil salinity by introducing salt-tolerant plants).

2.2.5 Effectiveness of implemented SLM technologies

Effectiveness: how much it reduces the degree of degradation or how well it is preventing degradation

4: Very high: the measures not only control the land degradation problems appropriately, but even improve the situation compared to the situation before degradation occurred.

3: High: the measures control the land degradation problems appropriately. The measures are able to stop further deterioration, but improvements are slow.

2: Moderate: the measures are acceptable for the given situations. However, the measures only slow down the degradation process, but are not sufficient.

1: Low: the measures need local adaptation and improvement in order to reduce land degradation to acceptable limits.

2.2.6 Effectiveness trend

1 - no change in effectiveness

2 - increase in effectiveness: the measures have a growing positive impact on the reduction of degradation

3 - decrease in effectiveness: the measures have less and less effect in reducing degradation, e.g. due to lack of maintenance

2.2.7 Expert recommendation

A - Adaptation: *to the problem: the degradation is either too serious to deal with and is accepted as a fact of life, or it is not worthwhile the effort to invest in.*

P – Prevention: *implies the use of conservation measures that maintain natural resources and their environmental and productive function on land that may be prone to further degradation*

M - Mitigation: *is intervention intended to reduce ongoing degradation.*

R - Rehabilitation: *is intervention when the land is already degraded to such an extent that the original use is only possible with extreme efforts as land has become practically unproductive.*

2.2.8 Example

Table 1: Land use system (Example)

Name: *First name Last name* **Country:** *South Africa*

Mapping Unit Id (LUS + admin. unit): 113 *(Savanna + Ratlou municipality)*

Land Use System (Step2)		
a) LUS area trend	b) LUS intensity trend	c) Remarks (e.g. reasons for trend)
2	*1*	*Increased grazing pressure due to growing numbers of livestock*

Table 2: Land degradation (Example)

Name: *X Y* **Country:** *South Africa*

Mapping Unit Id (LUS + admin. unit): 113 *(Savanna + Ratlou municipality)*

Land degradation (Step 3)									
a) Type (state)			b) Extent	c) Degree	d) Rate	e) Direct causes	f) Indirect causes	g) Impact on ecosystem services	h) Remarks
i	*ii*	*iii*							
Ha	*Pc*		*15%*	*2*	*1*	*g1, e1, f4,*	*p, h, t*	*P1-3, E2-2*	*Degradation is concentrated in NW communal grazing are of District*
Bs			*10%*	*2*	*-3*	*g1, g3*	*e, g*	*P1-2, S3-1*	*g3: change of livestock composition from large to small stock*

Table 3: Conservation (Example)

Name: ___X Y_____ **Country:** __South Africa

Mapping Unit Id (LUS + admin. unit): **113** *(Savanna + Ratlou municipality)*

Conservation (Step 4)													
a) Name	b) Group	c) Measure			d) Pur-pose	e) % of area	f)Degradation ad-dressed			g)Effec-tiveness	h) Eff.. trend	i) Impact on ESS	j)Period	k)Ref to QT	l) Remarks
Controlled grazing + reseeding	*VS*	*V2*	*M 2*		*M*	*20%*	*Wt*	*Pc*	*Pk*	*3*	*0*	*P1+3, E3+3 E2+2, E7+1*	*1985*		*Major efforts were made in the late 80'ies and have been mein-tained*
Dams (with Agrofor-estry)	*WH*	*S6*	*M 1*		*M*	*15%*	*Wt*	*Cn*	*Ha*	*2*	*1*	*P1+2, S2+1 E1+2*	*1980*	*RSA05*	*Great potential for up-scaling*

Table 4: Expert recommendation (Example)

Name: ___X Y_____ **Country:** __South Africa

Mapping Unit Id (LUS + admin. unit): **113** *(Savanna + Ratlou municipality)*

Expert recommendation (Step 5)	
Expert recommendation	**Remarks and additional information**
P	*Maintain good soil cover conditions through agroforestry systems*
M	*Reduce loss of water through runoff and evaporation by the soil surface through mulching and minimum tillage.*

2.3 Local Assessment field data collection formats

2.3.1 Assessing SLM Technologies and Approaches

TABLE 8 Field form – WOCAT Inventory on SLM technologies

WOCAT Inventory on SLM Technologies (page A)

Date: Country/region: Contributor: (Name, institutions, address, email)

ID*	Name of Technology	Land use type	Position	Area	Main types of land degradation addressed	Conservation measures	Climate	Tolerance / sensitivity of technology to climatic extremes			Slope
								tolerant	sensitive	not known	
...1											
...2											
...3											

See Notes below for details of information to provide in each column *Give consecutive numbers for ID.

ID	Short definition/description of SLM Technology (containing key characteristics of the technology)
...1	
...2	
...3	

For more detailed explanations and definitions refer to the basic version of the questionnaire on SLM technologies
http://www.wocat.net/en/methods/case-study-assessment-qtqa/questionnaires.html

TABLE 9 Field form – WOCAT Inventory on SLM approaches

WOCAT Inventory on SLM Approaches (page A)

Date: Country/region: Contributor: (Name, institutions, address, email)

ID*	Name of Approach	For which land use type	Position	Area	Type of Approach	Implementing bodies	Objectives	Land user involvement	
								Initiation phase	Implementation phase
...1									
...2									
...3									

See Notes below for details of required information to provide in each column *Give consecutive numbers for ID

ID	Short definition/description of SLM Approach (containing key characteristics of the approach)
...1	
...2	
...3	

For more detailed explanations and definitions refer to the basic version of the questionnaire on SLM approaches
http://www.wocat.net/en/methods/case-study-assessment-qtqa/questionnaires.html

TABLE 9 Field form – WOCAT Inventory on SLM approaches *(continued)*

WOCAT Inventory on SLM Approaches (page B)

Date: Country/region: Contributor: (Name, institutions, address, email)

ID*	Technical support	External material support	Motivation of land user to implement SLM	Impact	Photo	Ranking	
						World Map	Potential
...1							
...2							
...3							

See Notes below for details of required information to provide in each column *Give consecutive numbers for ID

ID	Strengths of SLM Approach	Weaknesses of SLM Approach
...1		
...2		
...3		

For more detailed explanations and definitions refer to the basic version of the questionnaire on SLM approaches
http://www.wocat.net/en/methods/case-study-assessment-qtqa/questionnaires.html

2.3.2 Soil Assessment data collection format

FIELD SCORE CARD

Soil Condition Assessed using VS-Fast Methodolgy

PART A: SOIL VISUAL DESCRIPTORS

Date:
Land Use (Current and Past):
Site Location:
Recent Weather Conditions:
Soil Type:
Soil Structure:
Soil Texture:
Soil Colour:
"Walk in" Observations (soil / crop residues):

Soil Profile sketch

Visual Indicator of Soil Quality	Visual Score (VS) 0 = Poor Condition 1 = Moderate Condition 2 = Good Condition		Weighting	VS-Fast score
Tillage pan			x 3	
Aggregate Size Distribution			x 3	
Soil Crusts * * *Score for either "negative" or "positive (biological)" crusts*	**(negative)** 2 = no crust 1 = some cracking 0 = continuous crust	**(positive = biological)** 0 = Poor 1=Moderate 2 = Good	x 2	
Earthworms (or other more pertinent soil fauna)			x 2	
Roots			x 3	
Sum of visual VS-Fast scores				

Soil Visual Assessment	Sum of visual VS-Fast Scores
"Poor"	< 7
"Moderate"	7 – 14
"Good"	15 – 26

FIELD SCORE CARD

Soil Condition Assessed using VS-Fast Methodolgy

PART B: FIELD SOIL MEASUREMENTS

Field Measurement	Actual Value	Visual Score (VS)* 0 = Poor Condition 1 = Moderate Condition 2 = Good Condition		Weighting	VS-Fast score
Slaking and Dispersion		(scores: 0-4)		x 1.5	
Soil pH		Not scored		Not scored	
Water Infiltration *"negative" = sands* *"positive" = other soils*		**(negative = sands)** 0 = fast 1 = medium 2 = slow	**(positive = all other soils)** 0 = slow 1 = medium 2 = fast	x 3	
Organic C – labile fraction				x 2	
Soil salinity (EC)				x 3	
Sum of soil measurement VS-Fast scores					

* These scores not applicable to Slake/Dispersion test, where scores range from 0 to 4 (hence ½ weighting value)

Soil Measurement Assessment	Sum of VS-Fast Scores
"Poor"	< 7
"Moderate"	7 – 14
"Good"	15 – 22

Total VS-Fast score (Part A + Part B) scores	
"Poor"	< 14
"Moderate"	14 – 28
"Good"	30 – 48

Other Notes, e.g. Site Photo; Soil Photo or Sketches of soil, pit location...

2.3.3 Vegetation Assessment data collection format

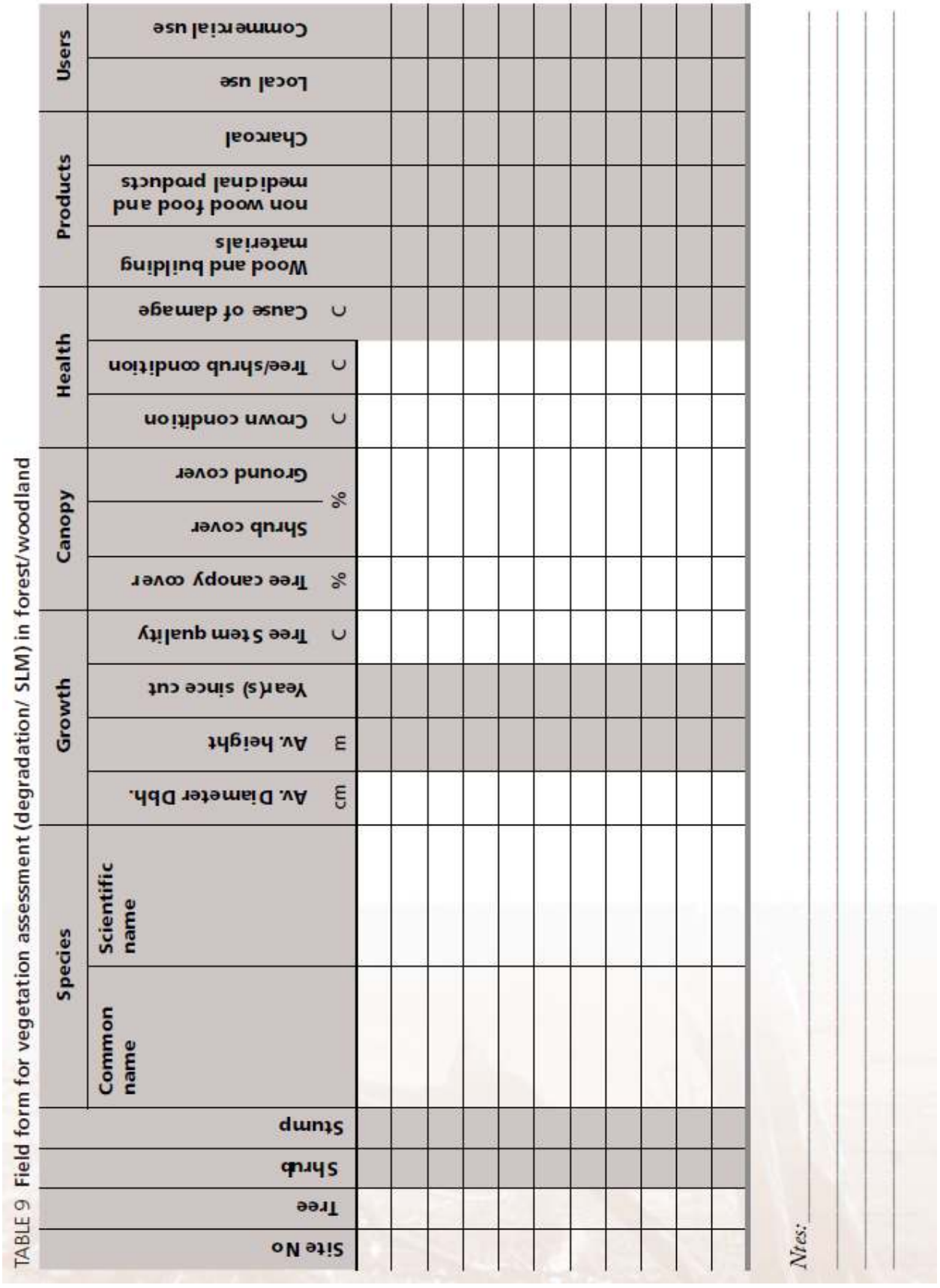


TABLE 9 Field form for vegetation assessment (degradation/ SLM) in forest/woodland

Site No	Species		Growth					Canopy			Health			Products				Users	
	Common name	Scientific name	Av. Diameter Dbh. cm	Av. height m	Year(s) since cut	Tree Stem quality C	Tree canopy cover %	Shrub cover %	Ground cover %	Crown condition C	Tree/shrub condition C	Cause of damage C	Wood and building materials	non wood food and medicinal products	Charcoal	Local use	Commercial use
Tree																			
Shrub																			
Stump																			

Nres:

TABLE 16 **Field form – Assessment of (natural vegetation and crop condition and productivity in croplands**

				Species (natural vegetation and crop)		**Natural vegetation**					**Crop condition**							**Products and Yield**			
Site No	Av. Farm size (ha)	Av field size (ha)	Av. number of parcels	Common name	Scientific name	Distance from cropland	Landscape features	Contribution to household	Use for mulch, soil OM	Ground cover	Crop establishment/ vigour	Crop size	Crop species diversity	Crop varietal diversity	Crop cover	Pest / disease incidence above ground and roots	Leaf colour / signs of nutrient deficiencies	Production costs	Y Yield (1ary and 2ary products)	Users of products (share local users to external)	Harvested product diversity
	ha	ha				km	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C

crop size e.g (e.g. ht; or diameter at maturity)

2.3.4 Water Resource Assessment data collection format

Water resource assessment

Besides review of the secondary information, water resource assessment is conducted in field through key information interview and field measurements of biophysical indicators if no up-to-date secondary information are available.

I. Hydrological regime and Water supply (please tick)

	Increase	Decrease	No change
Hydrological regime and sediment-related processes			
Surface runoff			
Peak flow/floods			
Base flow/ dry season flow			
Ground water recharge			
Soil moisture recharge			
Erosion and sediment load			
Water Quality and their causes			
Pathogens			
Nutrients and Organic matter			
Pesticides and other persistent organic pollutants			
Salinity			

Drought / flood risk and incidence

Do serious droughts / floods occur in the area? /__/ Yes /__/ No

If yes, how frequent are the drought / flood events? ……..

Have they become more or less common in the last 10 years? /__/ Yes /__/ No

Why do local people think this is happening (i.e. such as bare, compacted or crusted soils increasing runoff and hindering infiltration, the use of less drought resilient crop species, the deviation of streams)?

……

What is the period of drying up or flooding (months and interval)?

……

What are the main impacts they have on the different livelihoods activities?

……

Distance and access to water

What is the approximate distance (km) and time (min) taken to reach water for:

i) domestic consumption in the dry and wet seasons …….
ii) livestock watering in the dry and wet seasons? …….
iii) Any changes in the last 10 years? ……..

How far (km) are the main grazing areas from nearest potable water source in:

I) the dry season …… ii) the wet season? …… iii) Has this changed over the last 10 years?.....

II. Water resources management and changes in demand

Demand on water

What changes have there been in demand on water and water withdrawals in the last decade for the different water uses (e.g. number of dried-up wells / boreholes)?

……

How is the water supply managed and by whom? Is the management sustainable and equitable?

……

Do all people in the community / area have equal rights to use water resource?

……

If not what are the differences?

……

Water resources management

Have there been changes in the last 10 years in water conservation, water harvesting activities and irrigation:

a- Soil and water conservation: What techniques are used to optimise moisture and water capture, retention, infiltration and groundwater recharge? Have they been effective?

Soil and water conservation measures	*Effectiveness (Yes/No)*	*Impacts (e.g. increase in productivity, income, health, reduced risk of crop failure)*	*Proportion of people applying these measures (%)*
Bench terraces (level, forward or backward sloping)			
Contour bunds / banks (level, graded, semi-circular, v-shaped, trapezoidal etc.)			
Graded ditches, waterways and cut-off drains;			
Level ditches / pits (infiltration, retention, sediment and sand traps)			

Soil cover and mulching.			
Others……			

b- What are the water harvesting techniques at present

- Dams, tanks, Reservoirs
- Roof catchment and cisterns
- ……..
- ……..

Is water collected used for - /__/Agriculture /__/ domestic use /__/ livestock /__/ other ……

c- What are the types of irrigation systems operational? What is the proportion of each type?

Type	*Proportion of each type (%)*	*Water capture retention*	*Meeting plant water requirement*	*Minimizing drainage and leaching*	*Minimizing runoff*	*Minimizing evaporation from standing water*
		Effectiveness in ensuring water use efficiency (high, moderate, or low)				
Flood/surfaces						
Sprinkler						
Drip						
Pressure hose						
Others_____						

d- What are the constraints to effective water use? Please tick
/__/ Salinity /__/ Shortage/access /__/ Conflict /__/ Cost /__/ _____

e- What are the arrangements for water allocation / water rights and water conflict resolution / byelaws on water resources use and their application? Have there been significant changes in the last 10 years and why?
……
……
……

III. Offsite impacts on water resources (tick)

__ increasing pressure / demand on the water sources, removal of natural vegetation

__ drainage or permanent alteration of the water levels and flows

__ inflow of nutrients in run-off from fertilized farmland

__ inflow of non-selective pesticides or herbicides in run-off from adjacent or upstream farm land

__ changes in the water regime leading to increased floods, or reduced low

__ human activity (e.g. damming, irrigation or recreation and pollution in or close to the water body)

__ other ……..

Does *local land use and management* (vegetation, soil and water) in the study area affect water resources in off-site/ neighbouring areas (Select impacts from Table 36 P. 143 of Part 2 LADA manual)

……
……
……

Does *land use and management outside the study area* affect the water resources in the study area? (Select impacts from Table 36 P. 143 of Part 2 LADA manual)

……
……
……

What are the human and natural causes of off-site impacts? (Identify the relevant causes from Table 37 P 144 of Part 2 LADA manual and rank them in order of importance starting with the most important)

……
……
……

Note: Guidelines of Biophysical assessment of specific water resources, such as rivers, lakes, wetlands, irrigated lands and livestock watering points are given through p144-152 of Part 2 LADA manual. No questionnaires is included for their assessment here.

2.3.5 Livelihood Assessment data collection format

Household Livelihood assessment

1. Natural capital

1.1 Calendar of farming / herding activities by seasons in relation to rainfall

Activity	**Months** (or by seasons in local terms)											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Rainfalls H-High L-Low N-None												

Activity codes: Cropping: 1- Land preparation, 2- Planting, 3- Growing, 4- Harvesting 5-Herding.

1.2 Type of water source available, uses, constraints and changes in the last 10 years

Water Sources	**Use/available during which months?**	**Used for** D- Drinking, I- Irrigation, L- Livestock	**Need access rights or payment** (Yes/No)	**Constraints** P-Price D- Distance S- Safety Q- Quantity	**Changes**
Borehole					
Well					
Dam / Reservoir					
Rivers					
Pipe					
Other:					

1.3 Household land resources, terms of utilisation, and changes in the last 10 years

Household land use types	**Area of land (ha)**	**Terms of utilisation** O- Ownership R- Rental S- Share C- Communal A- Allocation	**Changes**
Cropping 1:			
Cropping 2:			
Cropping 3:			
Pastures			
Natural grazing lands			
Forest / Woodlands			

Who is responsible for forest management (natural and planted trees)?
Natural: _____
Planted: _____

1.4 Household uses of each crop types

Crop types	Crop uses			
	Market	Consumption	Fodder	Other
Hay				
Vegetables				
Fruits				
Other				

1.5 Livestock number by species, details and/or changes in the last 10 years

Animal species	Approximate numbers	Details/Changes
Cattle		
Goats		
Sheep		
Camel		
Other:		

1.6 Vegetation resource(s) used by the household for different activities

Activities	Resources used			
	Land	Water	Trees/Forest	Natural Vegetation
Grow crop				
Fetch water/ water animals				
Wild food				
Fuel wood				
Feed livestock				
Other:				

1.7 Main constraints, problems, changes in vegetation resources in the last 10 years

Constraints	Resources				Changes
	Land	Water	Trees/Forest	Natural Vegetation	
Access					
Use					
Quality					
Other:					

1.8 General changes in activities and practices: Has the household made changes in his/her cultivation practices / rangeland management over the last 10 years?

2. Land degradation

2.1 Quality assessment of the conditions of different land resources and changes

	Cropping lands	Grazing lands	Forested lands	Water resources
Quality				
Changes/Trends				

2.2, 2.3 & 2.4 Types of land degradation, causes, impacts and changes

Land degradation types/problems	Causes (direct pressures)	Root causes (driving forces)	Impacts (I)	Changes in last 10 years (trend)

Examples of land degradation: *soil loss by runoffs or wind, gully, loss of soil fertility, reduced biomass in the grazing lands, reduced quality of the grazing, loss of palatable species, etc*

Example of impacts: *reduction of income, diminution of food production, fewer products to sell, reduction of construction materials, more time spent on farming/grazing/fetching water, need more inputs/fertilisers, out migration, etc*

2.5 Measures / interventions currently used to control land degradation / promote sustainable land management and specific conservation / degradation control measures

SLM / conservation	What for	When	By whom	Obstacles to scale up

Potential conservation / SLM measures / interventions that are known but not currently implemented

Potential conservation/SLM measures	Obstacles to implement

3. Financial capital and production

3.1, 3.2 & 3.3 Sources and importance of each household income, their use and changes in the last 10 years

Income sources	Order of priority	Use for?	Changes
Crop production			
Livestock production			
Remittances			
Fishing			
Forest products			
Off farm employment			
Business			
Processing Food (e.g. honey, cheese, etc.)			
Other:			

3.4 & 3.5 Changes in yield, inputs and practices in the last 10 years

Crop production	Changes (trend)
Yield	
Fertilizers / Inputs	
Practices / Machinery	

Record yields and fertilizer uses per year if available/known by household.

3.6 Forms of aid received to support agricultural activities

Forms of aid	Why	When	By whom	Changes
Subsidies				
Extension services				
Payments				
Food aids				
Micro-credit Project / program				
Cooperative bank loan				
Borrowing money from relatives				

4. Vulnerability context

4.1 Crises faced by the household in the last 10 years, and impacts / effects on natural resources and land management

Crises	When	Impacts on natural resources/Land management
Drought		
Food insecurity		
Crop failure		
Livestock losses		
Natural disaster		
Health problem		
War/conflict		
Migration		
Indebtedness		
Other:		

4.2 Periods of each year with shortage or limited / difficult access to natural resources

Shortage / Limited access	Month(s)
Food	
Grazing	
Fodder	
Water	
Other:	

4.3 Main changes in the landscape and living conditions in the last 10 years (trends)

Changes in landscape

1. _____
2. _____
3. _____

Changes in livelihoods:

1. _____
2. _____
3. _____

4.4 Main problems in the area

1. _____
2. _____
3. _____

5. Physical capital

5.1 Changes in services / infrastructures access in the last 10 years

Services / Infrastructure	Access G- Good M- Medium P- Poor	Distance (or time)	Changes
Market			
Medical centre			
School			
Farming cooperative			
Extension / research			
Water points			
Main town / city			
Other:			

5.2 Services / infrastructures not accessible or missing and explain why

Services / Infrastructure	Not accessible	Missing	Why
Market			
Medical centre			
School			
Farming cooperative			
Extension / research			
Water points			
Main town / city			
Other:			

5.3 Vehicles and farming equipment used by the household and changes in 10 years

Household's goods	Term of access (O-own; R rent; S share)	Changes
Car		
Motorcycle		
Bicycle		
Farm tools		
Tractor		
Donkey / bull / horse		
Other:		

6. Policies, institutions and processes

6.1 Decision makers who control access and use of communal resources and changes in the last 10 years

Communal resources	Decision-makers	Changes
Water		
Grazing lands		
Trees/Forests/woodlands		
Other:		

6.2 Formal and informal laws and rules affecting land/resources management and changes in the last 10 years

Laws, rules, regulations	F- Formal I-Informal	Effects on natural resources and land management	Changes

7. Social capital

7.1, 7.2 & 7.3 Household's membership of associations and benefits

Associations	Since when	Direct benefits[1]	Access to new information[2]
Local group			
Producer associations			
Womens' groups			
NGO			
Social/religious groups			
Water committee/ users association			
Other:			

Codes for Benefits: B- Borrowing money; T- Technical support; S- Share equipment; M- Micro-credit; F- Food processing facilities; T- Transport to market; A- Access to natural resources; C- Community integration; O- Other

Codes for Access to new information: S- Seeds; C- Conservation agriculture; L- Land degradation control measures, R- Rangelands management M- Marketing; O- Other (specify)

8. Human capital and household composition

8.1 Educational level and training of family members

Family	Educational level	Training on conservation / SLM
Head		
Mother		
Children		

8.2 Composition of family members

Family	Number
Total members	
Active workers	
Children	
Migrants	

8.3 Age range of household head

Age of household head	
<20	
20-30	
30-40	
40-50	
50-60	
>60	

2.3.6 Format for Key Informant and land users

Key informant and land user interview

Field form – Sustainable Land Management (SLM) practices

Land degradation problem	SLM practice	Conservation effectiveness (+, neutral, -)	Benefits of SLM practice	Utilization by land users in the area	Constraints to adoption*

* Examples of Constraints: No perception of land degradation
No incentives to adopt SLM practices (e.g. insecurity of tenure, seasonal migration, etc)
No capability to remedy (e.g. land shortage, labour unavailability, lack of capital)

Field form – Plant indicator species

Common name	Scientific name	What does it indicate?	Specific qualities, characteristics	Causes/pressures

Field form – Yield trend analysis

Time (year)	Yield	Events

Summary table of costs and benefits of management practices

Year	Costs (and resources required)					Benefits					
	Labor		Tools	Loss in crop area		Increase in crop yield		Savings on fertilizer		Pole production	
	Min (a)	*Max (b)*	*Actual (c)*	*Min (d)*	*Max (e)*	*Min (f)*	*Max (g)*	*Min (h)*	*Max (i)*	*Min (j)*	*Max (k)*
1											
2											
3											

Calculating net cash flow

Year	Total costs		Total benefits		Net cash flow	
	Min (a+c+d=r)	Max (b+c+e=s)	Min (f+h+j=t)	Max (g+i+k=u)	Min (t – s)	Max (u – r)
1						
2						
3						

Comparing cash flow scenarios

Year	Lower discount rate			Upper discount rate		
	Discount factor	Minimum discounted net cash flow	Maximum discounted net cash flow	Discount factor	Minimum discounted net cash flow	Maximum discounted net cash flow
1						
2						
3						
NPV total						

2.3.7 Form for community focus discussions

Field form for the community focus group discussion

[This form refers to the questionnaire check list (Tool 1.1). The questions have to be reviewed by the team prior to the focus group discussion, in order to adapt the questionnaire to the local context and terminology.]

Study area or community name: _____ Name of record keeper: _____
Date of discussion: _____

1. Population size and number of households: _____

2. History, migration and pattern of settlement:

_____
_____
_____

3. Land units, land use types and water sources in the study area as differentiated by community members

Land Units (biophysical)	**Land use types** (includes management practices)	**Water Sources** (natural and manmade)

4 & 5. Main livelihood / productive activities during rainy and dry seasons, also associated resource uses and products generated.

Livelihood Activities	**Season** R- Rainy D- Dry B- Both	**Resources used** G- Grazing lands M- Medicinal plants W- Wild food W- Water sources F- Forest/tree O- Other	**Products** F- Food W- Wood E- Energy G- other products I– Income
1.			
2.			
3.			
4.			
5.			
6.			

6. Important types of land degradation in the study area, their causes, the impacts, and changes (trends) over the last 10 years.

Land degradation			
Types	**Causes**	**Impacts**	**Changes (trend)**
Erosion by water (splash, rill, gully - specify which)			
Erosion by wind (dust storms, sand blow, sediment deposits, dunes, etc)			
Soil physical degradation (compaction, surface sealing, crusting, pulverisation, etc.)			
Soil biological degradation (loss or soil organic matter or soil life, declining fertility			
Soil chemical degradation (nutrient mining, salinity, acidity pollution, etc)			

Bullet points 7 to 10 below are used to record, as appropriate, relevant details on soil, vegetation, water and / or socio-economic aspects of land degradation:

7. Indicators and causes of soil degradation – including erosion and deterioration of soil properties, as perceived by the community

Locally perceived Soil Indicators	Causes of Soil degradation

8. Indicators and causes of degradation of natural vegetation and biodiversity, as perceived by the community in crop land, in grazing land and in wood/forest land (specify).

Vegetation Indicators	Changes/Trends (Yes/No; L, M, H)	Causes
Deforestation		
Composition of vegetation (structure and species diversity)		
Health and quality of grazing lands Health and quality of forests		
Abundance of useful species (edible, palatable, medicinal, used for energy, building or crafts, etc.)		
Presence of invasive, harmful or less useful species (toxic, pests, less palatable species)		
Bush encroachment		
Evidence of frequent or severe burning		
Extent and vegetation of wetlands		
Diversity of habitats in the area		
Other (specify)...		

9. Livestock management measures and their problems in terms of land degradation or benefits in terms of sustainable land management

Livestock management measure	**Presence** High, Moderate, Few, None	**When and Why? (reasons)**	**What problems do they cause?**	**What are the benefits?**
Range enclosures				
Rotational grazing				
Ranching				
Stall fed (zero grazed) animals				
Seasonal livestock movements (agro-pastoralism)				
Permanent livestock movements (nomadic pastoralism)				
Cattle grazing corridors				
Use of bye laws, other measures, to control livestock numbers, burning, etc.				
Other				

10. Forest management measures

Forest management measure	**Presence** High, Moderate, Few, None	**When and Why? (reasons)**	**What problems do they cause?**	**What are the benefits?**
Clear logging				
Selective felling				
Coppicing or pollarding				
Livestock grazing in forest				
Fire control (fire breaks etc)				
Use of bye laws, other measures, to control forest use and exploitation of products and wildlife				
Other				

11. Changes and causes of water quantity and quality

Water	**Changes** (trends)	**Causes**
Quantity • Rainfall • Drought • Flood • Demand -surface water • Demand - groundwater (wells, boreholes) • Irrigation area/use • Other uses		
Quality • Drinking water • Irrigation • Other uses		

Who practices irrigation in the community? Have the area / crops / seasons changed?

_____

Are community members paying for:

- drinkingwater?_____
- wateringanimals?_____
- irrigation?_____

What are the implications?

Bullet points 12 to 13 below are used to record livelihoods problems and coping mechanisms

12. Main livelihoods problems relating to land use / management and degradation:
    1.
    2.
    3.

Specific issues relating to:

- Occurrenceofconflict(s)_____
- FoodInsecurity_____
- Poverty_____
- Drought/Flood_____
- Access.rights/tenure_____

13. Main coping mechanisms and strategies:
    1.
    2.
    3.

14. Sustainable land management practices for land degradation control or land restoration

SLM practices	Reasons for implementation	When, and by whom	Results

15. Importance of organizations influencing sustainability of land management at local level:

Organizations (specify)	**Influence on sustainability of land management (LD / SLM)**		
	Importance H- High, M-Medium, L-Low	**Influence** + or -	**Remarks**
Informal group			
Cooperative of land users			
NGO local/international			
Private sector			
Local leader			
Government authorities			
Research agencies			
Other			

16. Main informal and formal systems of tenure and rights to access land resources in the community

Land tenure system	**Details**	**Influence on SLM**
• Ownership • Allocation • Share • Rent • Communal		
Access rights system	**Details**	**Influence on SLM**
• Cropping lands • Grazing lands • Forest Lands • Trees • Water		

17. Effects of laws, rules and regulations concerning land resources on land degradation and / or conservation / SLM

Laws, rules and regulations	Effects on land degradation / SLM

18. Major social divisions affecting community members' access and management of natural resources
(e.g. poverty / wealth status, religious or caste groupings, pastoralists or settled farmers, irrigators or rain-fed farmers)

Social divisions	Effects on access and management of natural resources

19. Record any other relevant information arising during the discussion:

2.4 Other training data sets prepared

Following software and training data sets for LADA-WOCAT Assessment have been prepared

1. GIS compatible land-use-system (LUS) maps (1:10000 scale) developed for two pilot sides.
2. Microsoft Access data sets for each GN division were developed
3. GIS database for LUS based assessment and planning has been prepared
4. GIS mapping for two pilot site has been completed for LUS change trends, LUS change severity, Land degradation types, extents of degradation, severity of degradation, hotspot mapping.

Healthy Landscape Project

Managing Agricultural Landscapes in socio-ecologically sensitive Areas to promote Food Security, well -being and Ecosystem Health

Title : Training Workshop on Cascade Restoration Guidelines

Venue : Ceybank Resort

Time : 8.30 am- 5.00 pm

Date : 31.05.2024

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ANNEX 02

Consultancy Service for Undertaking Develop Restoration Guidelines on enhancing ecosystem and eco-health considerations in cascade tank restoration and Conduct awareness workshops for all line agencies towards a shared understanding of Cascade Restoration Guidelines for landscape management

Submitted to
The UNEP-GEF project on Healthy Landscapes: Managing Agricultural Landscapes in Socio-Ecologically Sensitive Areas to Promote Food Security, Wellbeing and Ecosystem Health Project in Sri Lanka

Submitted by

Dr. H.K. Kadupitiya
Geospatial analyst & ecosystem evaluation expert

Restoration Guidelines on enhancing ecosystem and eco-health considerations in cascade tank restoration

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Executive Summary

Village Tank Cascade Systems (VTCS) in Sri Lanka are sustainable water management model which harmonizing ecosystem components to supports diverse life forms in regions that comprises with one season excess rain and rain deficit second rainy season. VTCS, vital for rural livelihoods, faces threats necessitating restoration. Recognizing its uniqueness and importance, **Healthy Landscape Projec**t (Managing Agricultural Landscapes in Socio-ecologically Sensitive Areas to Promote Food Security, Well-being and Ecosystem Health Project; HLP) which was operational as GEF funded project has identified preparation of guidelines on enhancing ecosystem and Eco health considerations in cascade tank restoration with stakeholder awareness enhancing on "Restoration Guidelines" in Key Indicative Activity for mainstreaming **Land-use-system based approach** to cascade restoration planning.

GIS linked Land-Use-System (LUS) based assessment approach is a scientifically-based approach to assessing and mapping land degradation at different spatial scales - small to large - and at various levels - local to national and integrated with widely applicable methods and tools suitable for wide range of ecosystems. This methodological approach follows the DPSIR framework (seven stepped) approach for the application of more flexible methodological framework which consisted with LUS based questionnaire manual (QM) approach for national level assessment & hotspot mapping and detailed local level assessment approach for more informed decision making on sustainable land management (SLM) approaches & technologies providing base for “upscaling” or “downscaling” to any sub-national or national levels. This approach allows integration of all disciplines and all stakeholders; can be adjusted with wide range of spatial variability, scale and diversity; flexible to integrate or drop out any considerations based on requirements and resources availability; globally well tested; and therefore, can mainstreamed confidently for cascade restoration planning in Sri Lanka expecting favourable shift in national SLM ideological paradigm. Main aim of this assignment was to develop and mainstream cascade restoration guidelines for evaluating and mapping hotspot & bright spot through LUS based QM approach with guided expert brainstorming sessions and participatory field investigations.

This guide aims at providing concise guidelines for applying LUS based GIS linked QM approach with descriptive details for each methodical step to guide cascade restoration planning with worked examples pertaining to well representative cascade system in North-Central Province in Sri Lanka.

Background

The Dry Zone of Sri Lanka important as it consisted with variety of irrigated production systems, natural ecosystems and famous for commercialized paddy farming systems. farming intensification, improved crop and animal breeds, and agronomic practices. However, this process has incurred significant health and environmental costs. Recent unplanned efforts to enhance agriculture in VTCS have led to degradation, deforestation, loss of biodiversity, and deterioration of village tanks, potential health risks with overuse of agro-chemicals. Land use changes and intensified agriculture are major biodiversity loss drivers in cascade landscapes. Simplification and homogenization impact human health by altering natural habitat services crucial for agriculture, reducing wild species habitat, enhancing disease interactions, accelerating medicinal plant loss, and degrading cultural ecosystem services and mental wellbeing. Agricultural expansion into wild habitats escalates human-wildlife conflicts, worsened by invasive species' effects on biodiversity, ecosystems, agricultural production, and human health. Many health impacts of unsustainable land management practices in cascade landscapes remain undocumented and unquantified.

Numerous drivers and threats challenge the restoration, sustainability, and conservation of cascade landscapes in Sri Lanka's dynamic socio-political and economic context. For instance, the water holding capacity of VTCS has diminished over time, impacting irrigation availability and farm productivity. Climate change exacerbates these issues, altering rainfall patterns and cropping cycles. Challenges include reservoir sedimentation, declining farm viability, agricultural expansion, water pollution, invasive species, health concerns, migration, lack of landscape appreciation, pesticide reliance, fertilizer dependency, soil degradation, and human-wildlife conflicts.

A major challenge in VTCS is the absence of effective institutional mechanisms for cohesive landscape management, exacerbated by natural boundaries crossing administrative lines. Efforts to integrate environment, agriculture, and health in policy-making are hindered by limited awareness of ecosystem and health linkages. Currently, there is a lack of education and awareness regarding holistic cascade management, with insufficient institutional frameworks for participatory planning. As a result, there are few holistic management plans based on comprehensive cascade ecology understanding, and no supportive models or guidelines for sustainable land management approaches in village tanks.

Most interventions targeting VTCS development, often overlook ecological aspects, focusing on conventional technical approaches instead. This neglect leads to adverse outcomes such as flooding, water scarcity, and salinity. Limited awareness among farmers and communities exacerbates the issue. A key challenge is the lack of understanding of cascade ecology and its links to human health across society. Poor coordination and policy coherence hinder project success, as stakeholders work in isolation. Nationally, there's inadequate capacity building and research partnerships to manage cascade landscapes effectively for multiple benefits, including human health.

Agriculture and sustainable land management rely on healthy ecosystems and biodiversity, impacting human health positively or negatively. In Sri Lanka, poor agricultural practices harm biodiversity reducing capacity of providing ecosystem services, affecting human health. Mis-use of agro-chemicals may lead to health issues. Unplanned land use, degradation, pollution, invasive species, climate events, and fragmentation further diminish ecosystem services, worsening ecosystem health status.

The **Healthy Landscapes project** is aiming to establish a platform for integrated and holistic sustainable land management in VTCS landscapes based on cascade ecology principles and ecosystem services flow, including human health outcomes. It adopts a holistic approach to VTCS landscape rehabilitation, creating multi-sectoral platforms for sustainable management plans and guidelines. It introduces innovative SLM and agroecology approaches, with a focus on soil health and optimized water use. The project also develops and implements sustainable restoration models with stakeholder and local community involvement.

The project aims to scale up holistic cascade restoration guidelines following evaluation at project test sites to neighbouring cascade landscapes in the Dry Zone and beyond. It leverages national interest through its approaches, practices, and lessons learned.

In line with above, this assignment provides sequential guidelines for evaluation of land-use system based / tank component base status assessment targeting comprehensive multidisciplinary multi-stakeholder integration holistic approaches and enhance awareness on related stakeholders on application of guidelines for systematic restoration planning and implementation for cascade integrated landscape restoration.

1 INTRODUCTION

The historically unique Village Tank Cascade Systems (VTCS) of Sri Lanka have been sustainably functioning for generations, providing diverse ecosystem goods and services, from supporting food sources to creating scenic landscapes. Despite their significance, these systems now face imminent threats such as improper land use changes, encroachment on tank-associated components, forest clearance in catchment areas, unplanned urbanization, resource overuse, and residential area expansion. To address these challenges, **the Healthy Landscape Project** has been initiated, focusing on two pilot sites in Sri Lanka. Ecological restoration, aligned with VTCS, is pivotal in this project, aiming to restore ecosystem integrity and uphold personal, cultural, socio-economic, and ecological values. The VTCS landscape comprises various tank-associated components that maintain linkages between tanks from upstream to downstream, enabling efficient water use and sustaining the entire landscape. Thus, integrating VTCS aspects into ecological restoration principles is crucial (Gann, et al., 2019). Ecological restoration is part of broader ecosystem management practices aimed at conserving and sustainably utilizing native ecosystems. International principles and standards for ecological restoration suggest eight underlying principles (Figure 1):

Principle 1. Ecological Restoration Engages Stakeholders: all details will be collected from different stakeholders at many levels of the assessment formal schedules as attached in section **4.3.6 Format for Key Informant and land users, 4.3.7 Form for community focus discussions**

Principle 2. Ecological Restoration Draws on Many Types of Knowledge: The information on status of each land use system will be collected through questionnaire manual as illustrated in the section **4.2. Land Degradation Assessment – QM Questionnaire** by guided brainstorming workshops.

Principle 3. Ecological Restoration Practice is Informed by Native Reference Ecosystems, while Considering Environmental Change: Land use change trends land degradation types and extent, best practices already operational will be evaluated during sub-national or landscape level assessment **(in section 2.3)** as well as local level transect assessment **(in Section 2.4)**

Principle 4. Ecological Restoration Supports Ecosystem Recovery Processes **(experts and local communities' collaboration will support to achieve principle 4 – 8 when implementing whole process)**

Principle 5. Ecosystem Recovery is Assessed against Clear Goals and Objectives, Using Measurable Indicators

Principle 6. Ecological Restoration Seeks the Highest Level of Recovery Attainable

Principle 7. Ecological Restoration Gains Cumulative Value when Applied at Large Scales

Principle 8. Ecological Restoration is Part of a Continuum of Restorative Activities

Figure 1: Eight principles for ecological restoration (sources: Gann et. al., 1999[1]).

Stakeholder engagement is vital in restoration, ensuring ecological integrity and meeting personal, cultural, and economic values. This approach fosters social-ecological resilience, benefiting both individuals and communities. Recognizing stakeholders' roles is key, contributing to improved ecosystem health, nature-based cultures, and local employment opportunities, creating positive ecological and economic impacts.

Any type of external and internal engagement is highly linked to the economic purpose of land or land-use of each unit and its associated ecosystem services. Subdivision of land-use segments based on different criteria allows for the categorization of land-use systems (LUS). Within a LUS, both external and internal interactions are inherent, providing opportunities for separate assessment.

Land-use-system based assessment approach is a scientifically-based approach to assessing and mapping land degradation at different spatial scales - small to large - and at various levels - local to national. It was initiated in drylands, but the methods and tools have been developed so as to be widely applicable in other ecosystems and diverse contexts with minimal required adaptation. The National & Local assessment approach can effectively be applied for cascade landscapes in Sri Lanka.

Assessment methodological approach follows the DPSIR framework as detailed in the figure 2 and seven stepped approach for the application of more flexible methodological framework (figure 3). Approach has been successfully tested in several countries and has well established information sharing platform. Approach consisted with Land Use System based questionnaire manual approach for national level assessment & hotspot mapping and detailed local level assessment approach for more informed decision making on sustainable land management (SLM) approaches & technologies providing base for “upscaling” or “downscaling” to any sub-national or national levels. This approach allows integration of all disciplines

and all stakeholders; can be adjusted with wide range of spatial variability, scale and diversity; flexible to integrate or drop out any considerations based on national requirements; globally well tested; and therefore, can mainstreamed confidently for Sri Lanka expecting favourable shift in national SLM ideological paradigm.

LUS based approach as cascade restoration guide will effectively allow maintaining ecosystem services with wider collaborative participation of all stakeholder institutions and local community linked with Village Tank Cascade Systems (VTCS) Sri Lanka.

This approach has been developed and piloted in many other countries dryland situations as it is originally designed land degradation assessments in drylands. But the approach has been used for other countries, since it can conveniently be customized and adapted for other ecological situations.

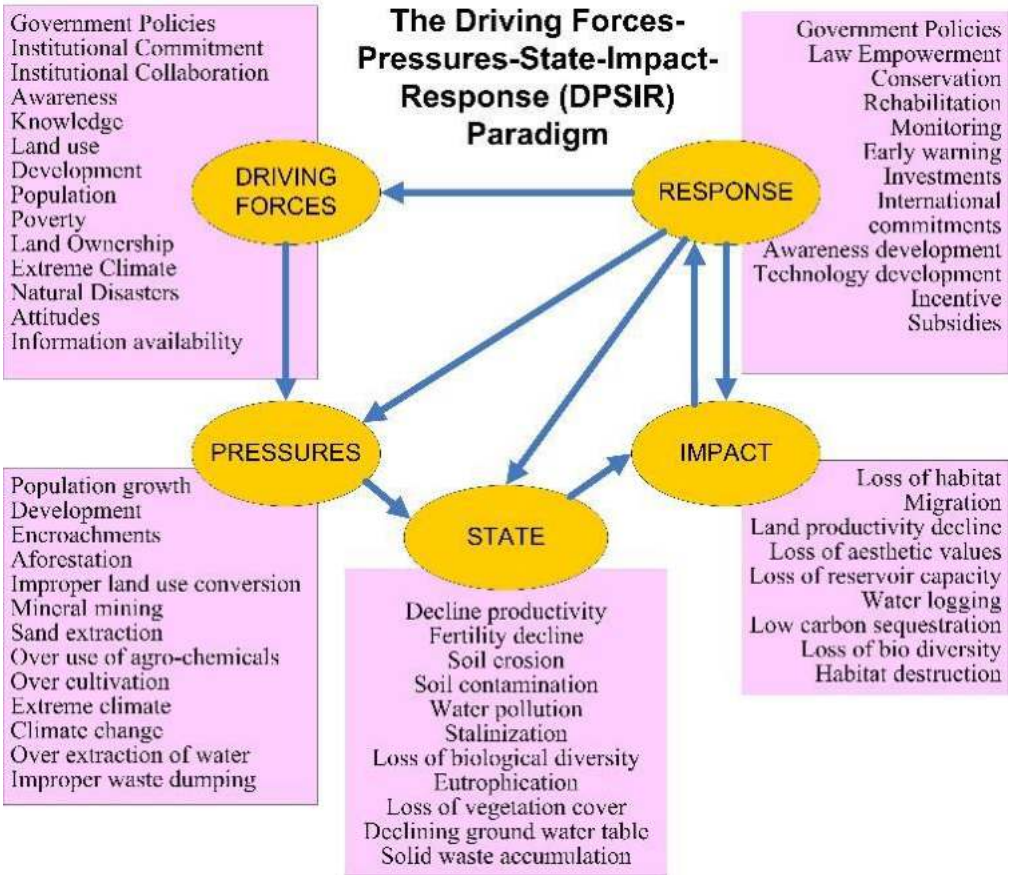


Figure 2:The Driving Forces-Pressures-State-Impact-Response (DPSIR) Paradigm

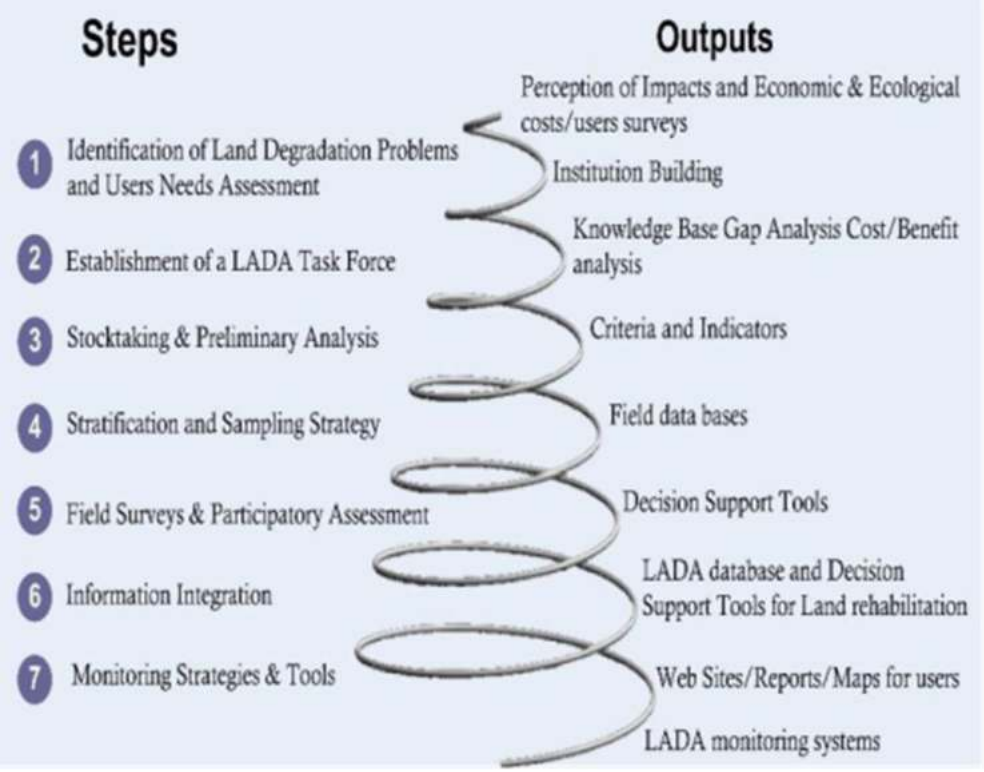


Figure 3: The seven steps approach with corresponding outputs

2 METHODOLOGICAL APPROACH

Land degradation and sustainability of landscapes highly linked with the land utilization patters and management conditions of different land use systems (LUS). Therefore, many suggest LUS based assessment as a tool for systematic land restoration planning. For successful implementation of DPSIR framework, there are several considerations on resource integration, activity sequencing and initial team motivation need to be fulfilled. Initial base GIS data preparation, land-use map generation, land-use-system map generation and linked Questionnaire Manual (QM) data transferring bridge were developed. Systematic training is needed for assessment team on basic concepts and step by step methodological sequencing of activities with intermediate results. Stakeholder knowledge on sub-national or landscape level assessment and detailed local level assessment and planning need to be done systematically in a sequential manner. Sequential approach is given as a guiding flow diagram I figure 4.

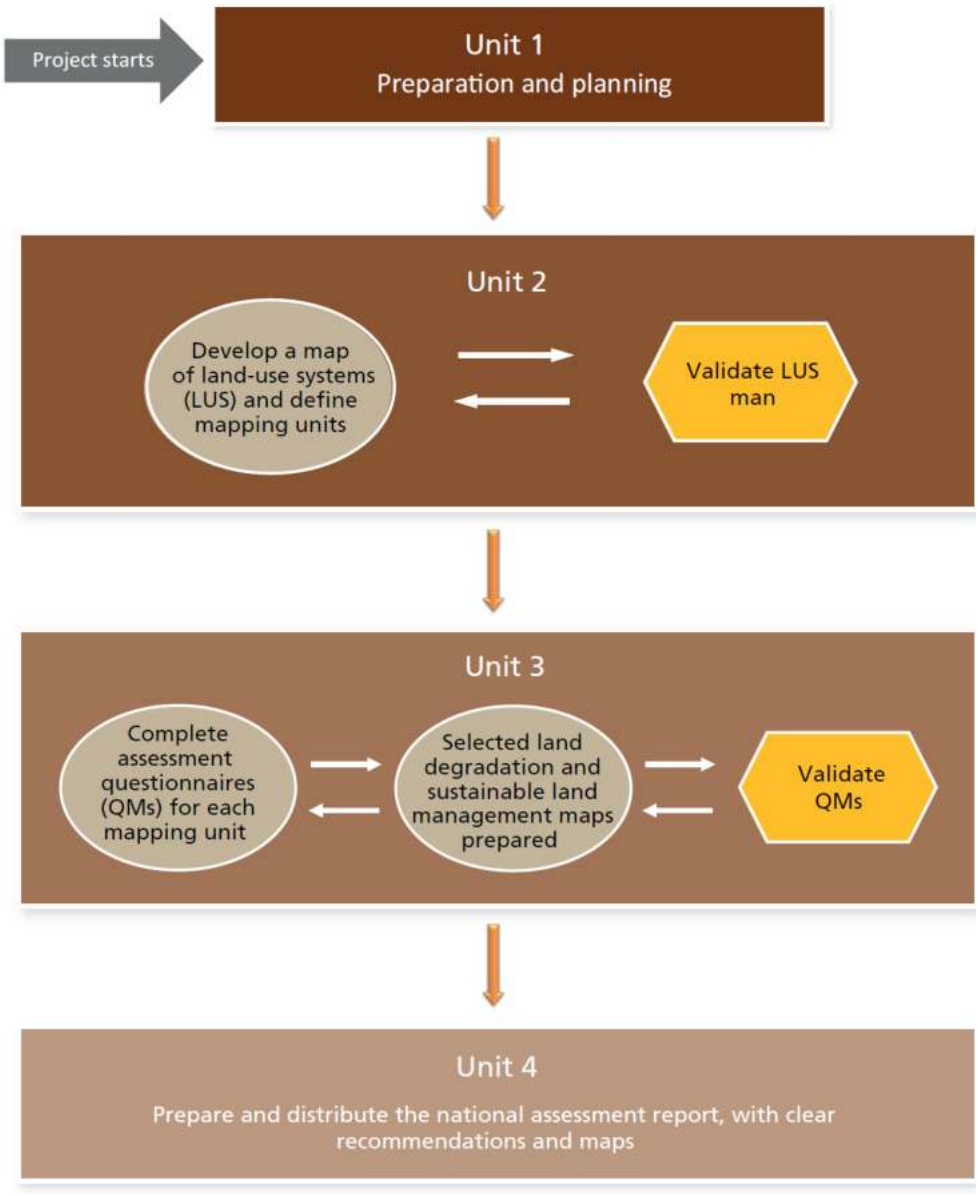


Figure 4: Guiding flow diagram of the landscape restoration planning process

The methodological approaches are discussed in each sub-chapters and sections using data pertaining to pilot project sites (Nachchaduwa and Horiwila cascade complexes).

2.1 Study area

Project site at Nachchaduwa consisted with adjoining three cascade systems (Mahakanumulla, Thirappane and Ulagalle) drained to the Nachchaduwa reservoir via southern bank covering 12,000ha in 4 divisional secretariat divisions (Ipalogama, Thirappane, Ipalogama and Kekirawa) and consisted with 67 different types of tanks. Project site at Horiwila consisted with 2 cascade systems (Palugaswewa and Bellankadawala) drain to Horiwila reservoir and covers 7016 ha in Palugaswewa and Dambulla DS divisions with two cascade systems 42 different types of tanks (figure 5). Preliminary field investigations showed that the two landscapes consisted with many conditions and features allowing generalize the rehabilitation approach for the other cascade areas of almost entire Sri Lanka. The selected sites consisted with rural as well as semi-urban sectors, almost all categories of land uses, vegetation types, land cover types, many types of agriculture lands (plantation crops, seasonal crops, paddy etc.) and topographical variability (terrain features, slope types, land forms, etc.)

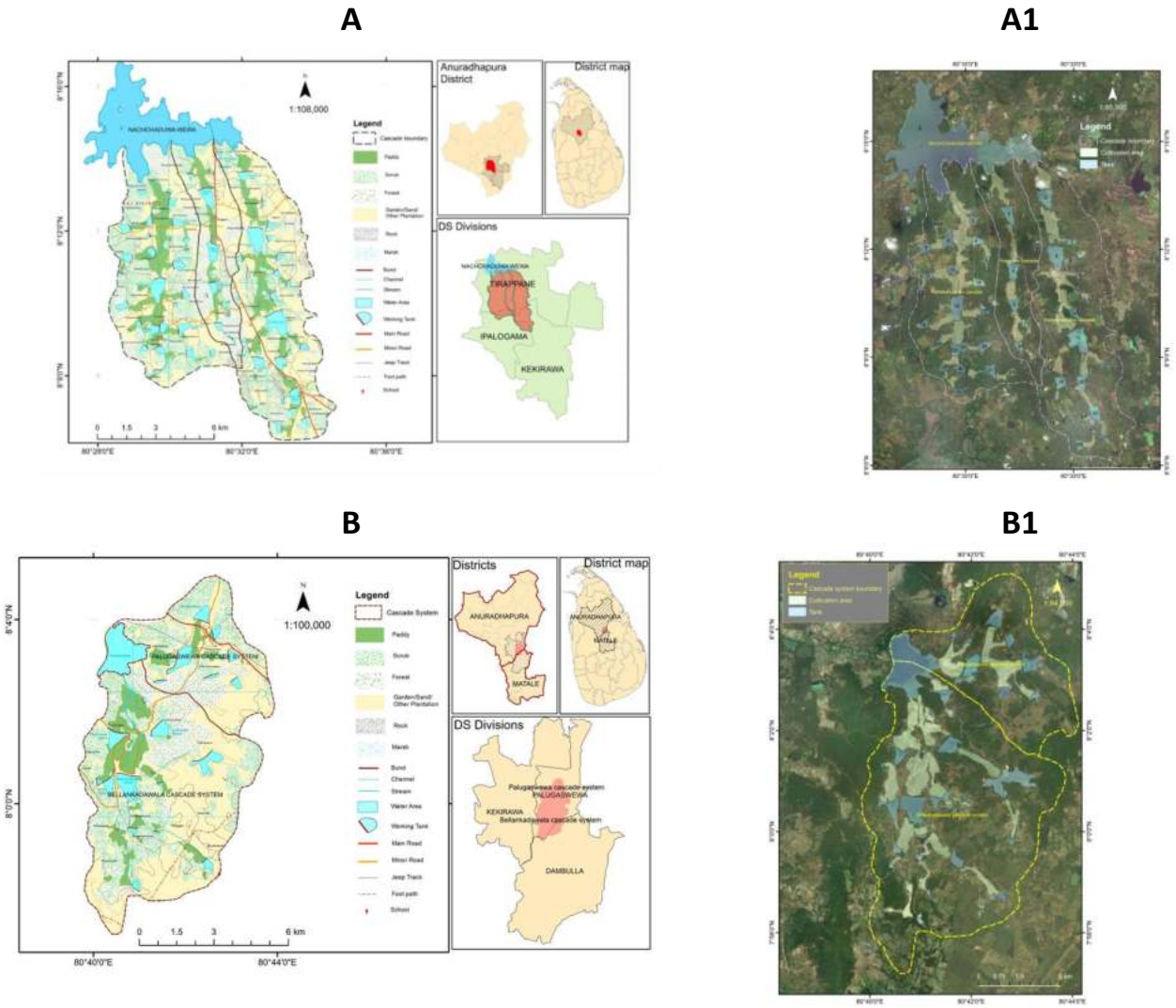


Figure 5: Topographic map (A) and bird-eye view (A1) of Nachchaduwa selected VTCS, and Topographic map (B) and bird-eye view (B1) of Horiwila selected VTCS *(visual effects were used to enhance visibility of water bodies and paddy tracks)*

2.2 Sequential Cascade restoration guidelines

Several sub-steps for restoring planning and main steps in restoration approach are as follows:

1. Initial planning and expert group and institutional engagement settings
2. Landscape (Sub-National) level Land Degradation (LD) and Sustainable Land Management (SLM) assessment
   2.1. Develop Land Use System (LUS) maps in targeted landscapes
   2.2. Questionnaire Manual (QM) based data collection for each LUS for spatial assessment
   2.3. Degradation hotspot and sustainable bright spot mapping at landscape level for vulnerable ranking and prioritization intervention needs
3. Local level detailed assessment in hotspots and more vulnerable ecosystem sections Generated detailed guiding information for restoration planning

2.2.1 Initial planning and expert group and institutional engagement settings

The preparatory and planning step will vary between locations depending on the availability of, for example, resources, capacities and infrastructure. For successful implementation of assessment framework, there are several considerations on resource integration, activity sequencing and initial team motivation need to be fulfilled. Assessment team should be consisted with multidisciplinary experts including GIS experts. Initial base GIS data need to be ready in advance. Systematic training is needed for team on restoration concepts and step by step methodological sequence of activities with intermediate results and final results. It may include some or all of the following activities:

- necessary authorizations need to be obtained for the sub national LD and SLM assessment.
- Stakeholder analysis need to be conducted to determine who should be involved in the assessment.
- Develop a detailed project plan with stakeholders and key policymakers, including activities, timeline, budget and responsibilities, based on specific country needs.
- Secure project budget for implementation, and creating agreements and contracts with stakeholders, contractors and partners involved in project implementation.
- Obtain the services of experienced and capable geographic information system (GIS) specialists, purchasing (or obtaining open-source) GIS software, and setting up GIS infrastructure such as computers, printers and internet access.

- Discuss data availability and the interinstitutional agreements needed to ensure data sharing.
- Hire personnel such as facilitators, GIS experts and other support staff, as required.
- Establish a national project office for coordinating project implementation and appoint a national project coordinator who, as head of the national project office, will have overall responsibility for the effective and efficient implementation of the project.
- Designed and establish a work plan for project implementation.
- Develop a communication strategy to ensure regular feedback and awareness of project activities and achievements among key stakeholders and the wider public.

2.3 Landscape (Sub-National) level Land Degradation (LD) and Sustainable Land Management (SLM) assessment

This approach mainly deals with landscape level LD and SLM assessment and hotspot mapping following a sequential activity schedule. Assessment considers land use systems. Land includes vegetation, physiography, hydrology, climate and infrastructure. Land-use implies economic purpose land allocation and indicates socio-economic, biological and technical aspects. Land Use Systems (LUS) denote sub divisions of land use based on management, locality, topography, climate, or any remarkable attribute that can be used to further divide into different mapping units. This approach considers LUS is as spatial unit for degradation assessment in sub-national level. Landscape level assessment can be done following sequential steps.

1. Land Use System (LUS) mapping & unique ID system for LUS units
2. LD and SLM assessment using the Questionnaire Manuels (QM)
3. Mapping questionnaire results and report development.

2.3.1 Land Use (LU) Mapping

Land includes vegetation, physiography, hydrology, climate and infrastructure. Land-use implies economic purpose land allocation and indicates socio-economic, biological and technical aspects which include VTCS components. Land Use Systems (LUS) denote sub divisions of land use based on management, locality, topography, climate, or any remarkable attribute that can be used to further divide into different mapping units. This approach considers LUS is as spatial unit for LD and SLM assessment in sub-national or landscape level. Landcover/ land use maps developed for pilot sites are given in figure 6 & 7. Land use maps for this assignment were developed using the LU map (Land Use Policy Planning Department, 2020) as base map. Fine verifications and boundary adjustments were done to update present conditions by overlaying the LU map on Google Earth global viewer and field investigations using smartphone-based location tracking approach (Kadupitiya, 2020). All the building locations were mapped by using point creation in GIS using google earth viewer as the base map to facilitate settlement area or home garden differentiation during LU map generation.

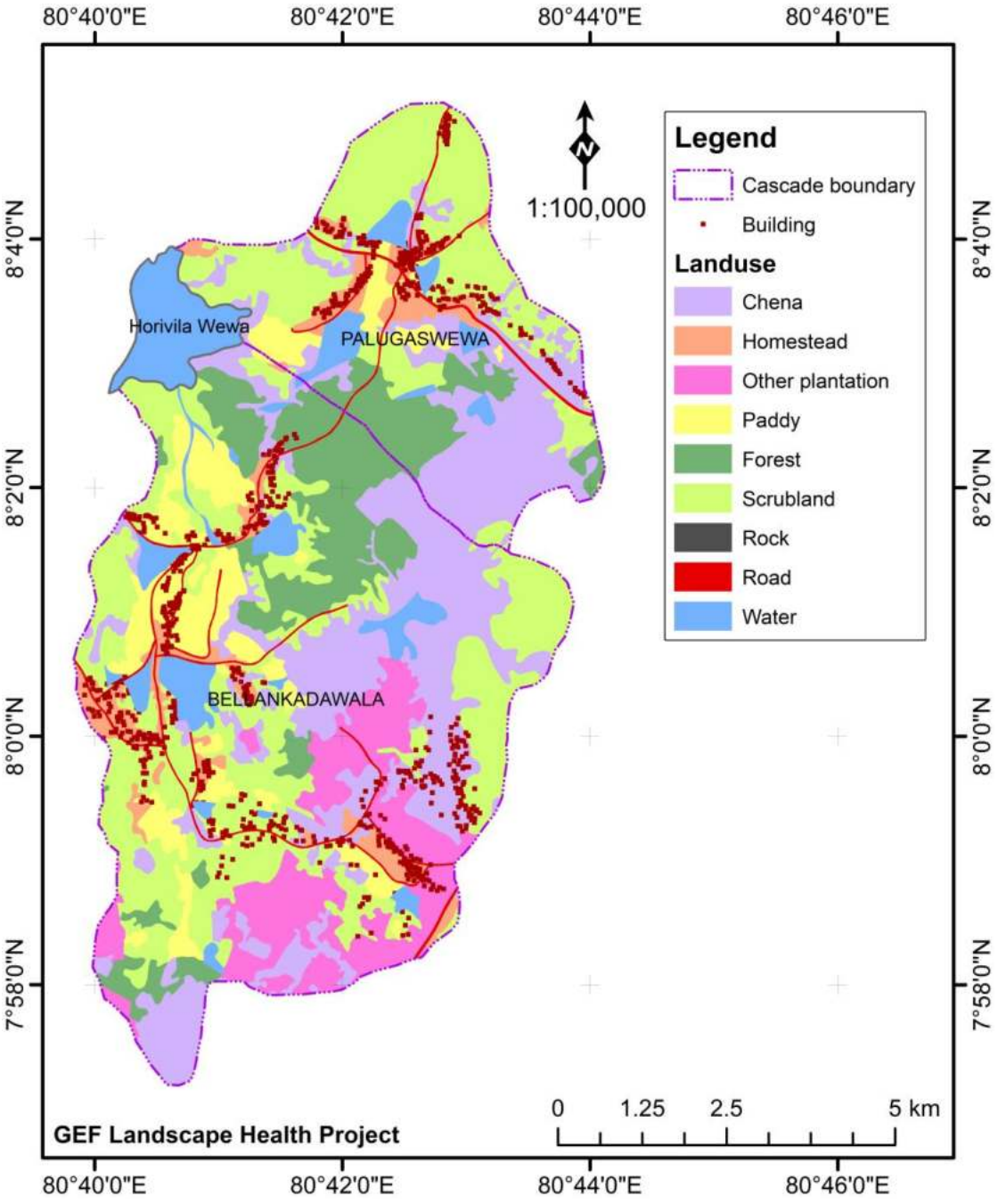


Figure 6: land use of Horiwila Village Tank Cascade Complex (developed by HK Kadupitiya)

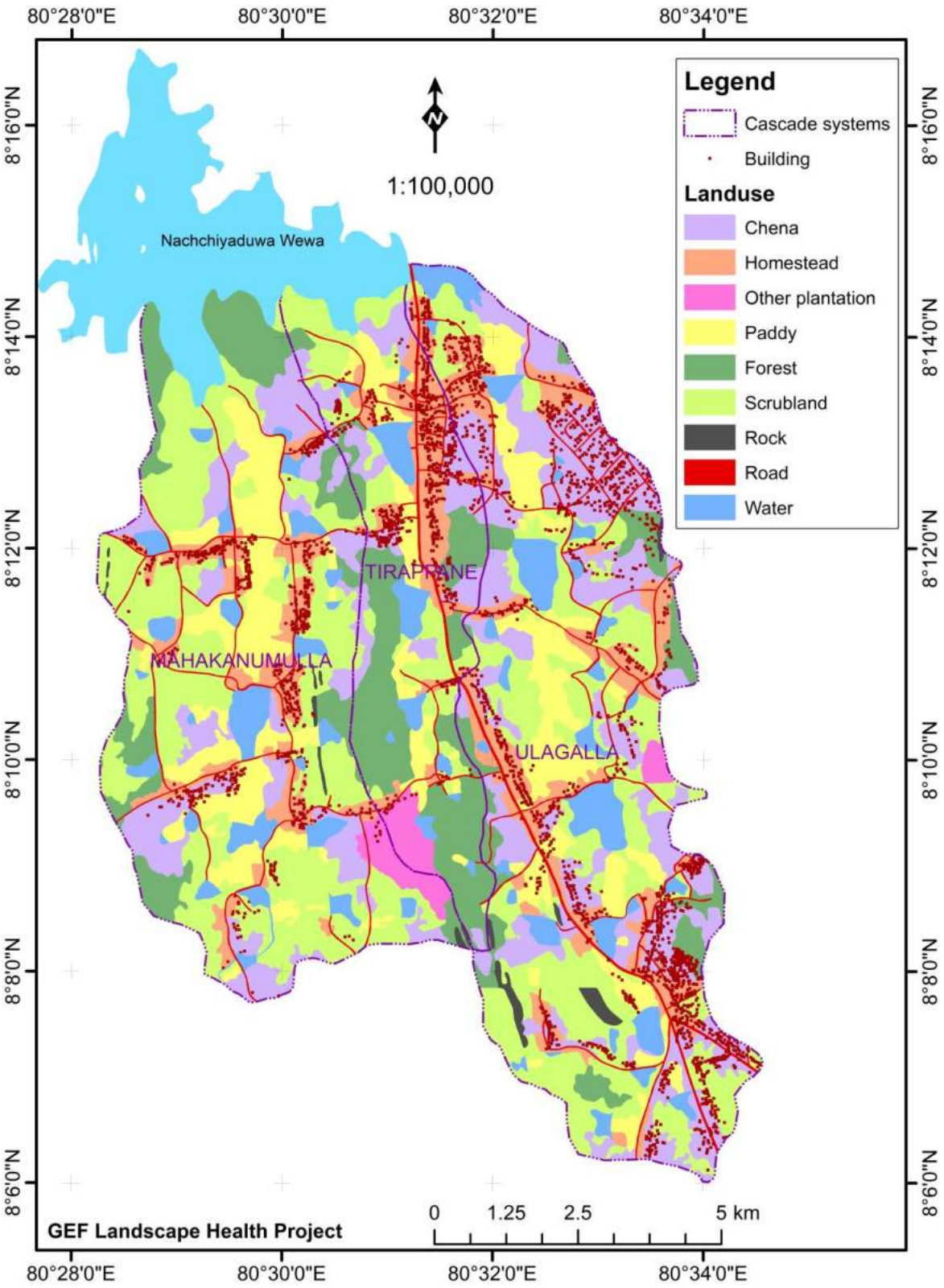


Figure 7: Landuse of Nachchaduwa Village Tank Cascade Complex (developed by HK Kadupitiya)

2.3.2 Land-use system (LUS) map and mapping unit unique ID assignment

Assessment base map, or “land-use systems” (LUS) maps were developed to guide the assessment process. LUS map is an essential part of assessment and provides unique mapping units for assessment of Land Degradation (LD) and Sustainable Land Management (SLM) variables. This step involves various entities including data collection and analysis in a GIS environment, and an iterative field-level validation. The LUS map, with its well-defined ID system linked with mapping units, was used as a basis for conducting LUS based LD assessment and status of Sustainable Land Management (SLM) tracking in step 2. The data used for developing LUS map were: land use map, cascade boundary map and administration division map. Any other variables such as climatic zones, irrigate area and slope classes can also be used for further sub divisions depending on the requirement, extend and data & resource availability.

For this assignment ID assignment for each LUS has been done combining Admin divisions (Grama Niladhari Divisions), LU and cascade systems. Unique mapping unit ID system facilitated LD related attributes and SLM related detail mapping by combining assessment details using Questionnaire Manual (QM) and GIS maps. Part of GIS map and attached attribute table for thirappane cascade system is given in figure 8.

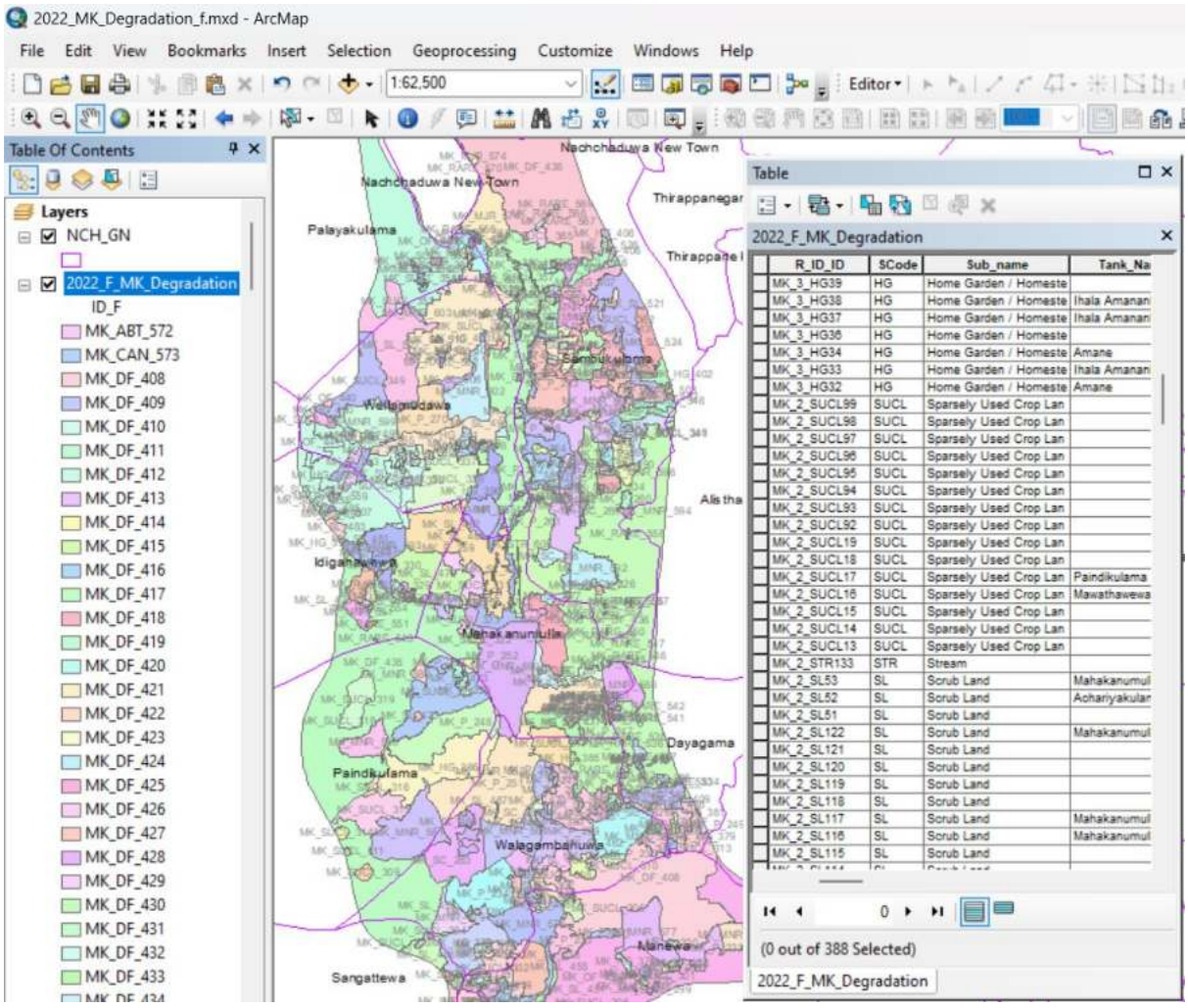


Figure 8: LUS map VTCS - unique ID system for each mapping unit of Thirappane (LUS map & GN map is also visible)

Important to note that there is a relationship between the number of mapping units and the duration of the assessment. The mapping unit is the smallest unique unit identified in the LUS map development process. For example, a mapping unit could be: "Sparsely used crop lands or chena cultivation" for each GN division and for each cascade system. Completion of the QM for each mapping unit is the single most important determinant of the cost and time needed to complete the LD and SLM assessment. The more administrative subdivisions included, the greater the number of mapping units. The more layers used in LUS map preparation, the more divisions or classes and the more mapping units created. The more mapping units, the longer the assessment and the more expensive it will be. Greater detail at the landscape level will increase the accuracy of the assessment's findings, but it is important to find the right balance between, time, cost and reliability. Therefore, it is advisable to limit LU subdivisions considering the time and resource availability and the needed details for cascade restoration planning. It is usually advisable to make a reasonably detailed LUS map and to limit it to 1–2 administrative levels so as not to exceed a total of 500–600 mapping units. Mapping units can also be grouped to simplify the LUS map and shorten the QM procedure. GIS and database expertise is essential for initial map setting and ID system development in GIS environment. Training materials is given in the training material section to provide basic knowledge in use of GIS related tools for spatial data handling and map production principles.

LU map generally contains harmonized data from many different sources and data gathered during time scales. Therefore, updating or fine adjustments are needed prior to QM data collection. Hence, LUS map which was developed from LU map should be validated by field or using global viewers (Google Map) to verify following aspects:

- Checking LUS boundaries for rectification of boundaries for recent changes or to match the ground situation.
- Verification of the land-cover classes used in the LUS map.
- Verification of land uses within each land-cover class to ensure that the LUS map

accurately reflects the ground conditions.

- The accuracy of the natural capital inventory (e.g. soil, water and vegetation).

2.3.3 LD and SLM assessment using the Questionnaire Manuels (QM)

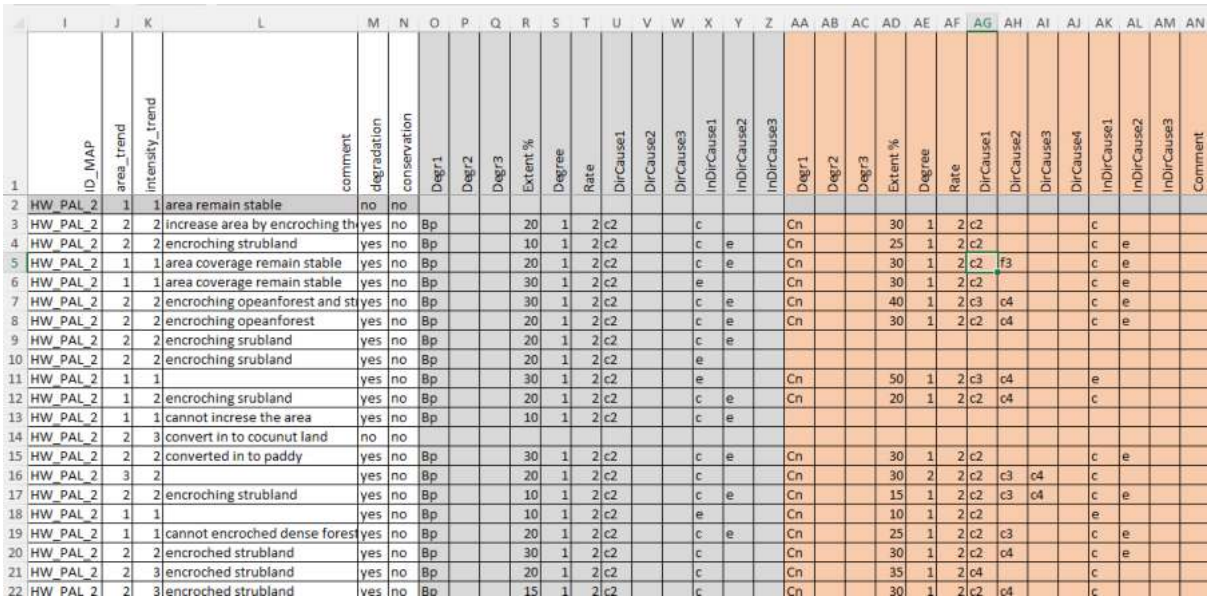
For the purpose of training material development, BSc (Agric) graduates were employed for data collection using QM formats backed with smartphone-based location tracking tools. During the degradation assessment phase Questionnaire Manual (QM), google historical browsing, visual assessment, guided brainstorming session, expert group field visits and key informant interviews were also used for maintaining better accuracy levels. QM forms 488 pertaining to LUS units for Thirappane cascade system and 450 LUS units for Palugaswewa cascade systems were gathered.

Following assessments were conducted using specific sections of QM for each LUS through brainstorming workshops in participation of all stakeholders and subject specialists. (Examples of

Questionnaire Manuals developed for data collection are given in training material section). For illustration of the data and related information collection following collection of following data were completed and used for mapping exercise.

1. Land-use change assessment
2. LD assessment
3. Conservation and SLM assessment
4. Expert recommendations

All the collected data were incorporated into a database format developed in MS excel and the part of the data base has been given in the figure 9.



	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA	AB	AC	AD	AE	AF	AG	AH	AI	AJ	AK	AL	AM	AN
1	ID_MAP	area_trend	intensity_trend	comment	degradation	conservation	Degr1	Degr2	Degr3	Extent %	Degree	Rate	DirCause1	DirCause2	DirCause3	InDirCause1	InDirCause2	InDirCause3	Degr1	Degr2	Degr3	Extent %	Degree	Rate	DirCause1	DirCause2	DirCause3	DirCause4	InDirCause1	InDirCause2	InDirCause3	Comment
2	HW_PAL_2	1	1	area remain stable	no	no																										
3	HW_PAL_2	2	2	increase area by encroching th	yes	no	Bp			20	1	2	c2			c			Cn			30	1	2	c2				c			
4	HW_PAL_2	2	2	encroching strubland	yes	no	Bp			10	1	2	c2			c	e		Cn			25	1	2	c2				c	e		
5	HW_PAL_2	1	1	area coverage remain stable	yes	no	Bp			20	1	2	c2			c	e		Cn			30	1	2	c2	f3			c	e		
6	HW_PAL_2	1	1	area coverage remain stable	yes	no	Bp			30	1	2	c2			e			Cn			30	1	2	c2				c	e		
7	HW_PAL_2	2	2	encroching opeanforest and st	yes	no	Bp			30	1	2	c2			c	e		Cn			40	1	2	c3	c4			c	e		
8	HW_PAL_2	2	2	encroching opeanforest	yes	no	Bp			20	1	2	c2			c	e		Cn			30	1	2	c2	c4			c	e		
9	HW_PAL_2	2	2	encroching srubland	yes	no	Bp			20	1	2	c2			c	e															
10	HW_PAL_2	2	2	encroching srubland	yes	no	Bp			20	1	2	c2			e																
11	HW_PAL_2	1	1		yes	no	Bp			30	1	2	c2			e			Cn			50	1	2	c3	c4			e			
12	HW_PAL_2	1	2	encroching srubland	yes	no	Bp			20	1	2	c2			c	e		Cn			20	1	2	c2	c4			c			
13	HW_PAL_2	1	1	cannot increse the area	yes	no	Bp			10	1	2	c2			c	e															
14	HW_PAL_2	2	3	convert in to cocunut land	no	no																										
15	HW_PAL_2	2	2	converted in to paddy	yes	no	Bp			30	1	2	c2			c	e		Cn			30	1	2	c2				c	e		
16	HW_PAL_2	3	2		yes	no	Bp			20	1	2	c2			c			Cn			30	2	2	c2	c3	c4		c			
17	HW_PAL_2	2	2	encroching strubland	yes	no	Bp			10	1	2	c2			c	e		Cn			15	1	2	c2	c3	c4		c	e		
18	HW_PAL_2	1	1		yes	no	Bp			10	1	2	c2			e			Cn			10	1	2	c2				e			
19	HW_PAL_2	1	1	cannot encroched dense forest	yes	no	Bp			20	1	2	c2			c	e		Cn			25	1	2	c2	c3			c	e		
20	HW_PAL_2	2	2	encroched strubland	yes	no	Bp			30	1	2	c2			c			Cn			30	1	2	c2	c4			c	e		
21	HW_PAL_2	2	3	encroched strubland	yes	no	Bp			20	1	2	c2			c			Cn			35	1	2	c4				c			
22	HW_PAL_2	2	3	encroched strubland	yes	no	Bp			15	1	2	c2			c			Cn			30	1	2	c2	c4			c			

Figure 9: QM data included in to a flat database to facilitate linking with GIS LUS map *(For code description please refer to code sheet attached)*

Mapping ID has been included for each QM format to facilitate linking al the collected data to relevant GIS map and it will facilitate convenient mapping of degradation / conservation related information collected through QM format.

2.3.4 Mapping questionnaire results for report development.

Initially the LD and SLM data collecting through QM need to incorporated in to LUS maps in GIS environment. List of general Maps for each degradation type is given below.

1. Trend of LUS change
2. Trend in LUS change intensity
3. Degradation extent

4. Degree of land degradation

5. Degradation rate

6. Extent of SLM practices

7. Effectiveness of existing SLM practices

8. Degradation with impact: negative high and very high

9. Principal types of land degradation

10. Total degradation index or degradation severity

QM results can be mapped without following particular rules, and each spatial units can be combined, merge or interpolate indicators. Maps based on specific requirements could also be developed by customizing the available options and producing results based on the site needs. Based on communication with policymakers and decision makers at the national / subnational / landscape level maps for specific information needs can also be developed.

Degradation hotspot mapping will prioritize by combining degradation related spatial information after incorporating all the QM-collected data into GIS. Hotspot mapping has been done using degradation indices suggested in this approach (figure 10).

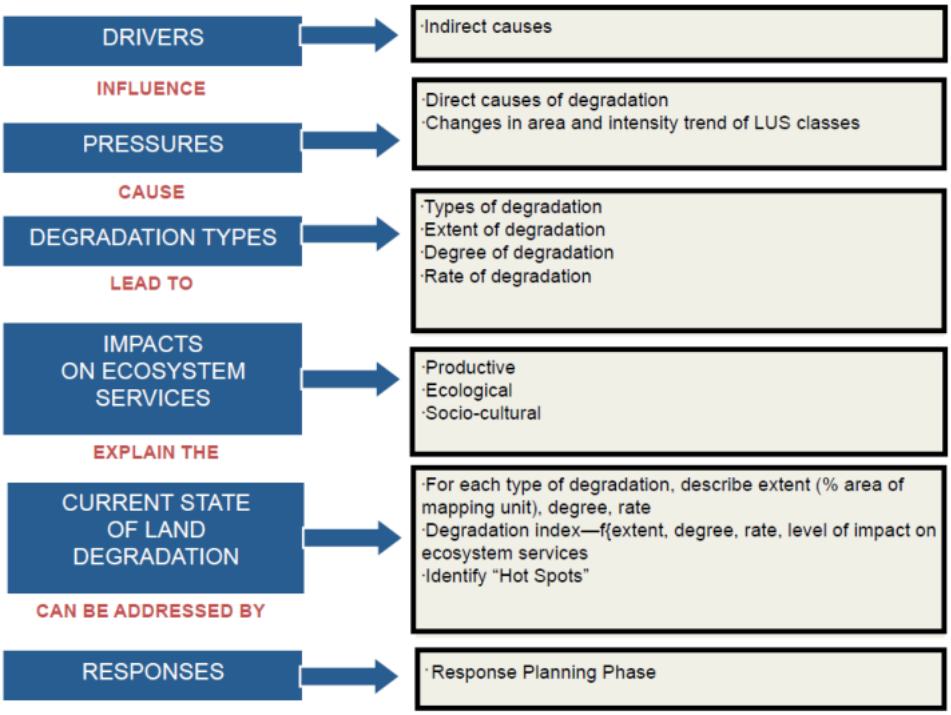


Figure 10: Framework of degradation analysis process

The LUS change and degradation related details that have been included into GIS database could be used for many type of information mapping which can be used for detailed interpretation on spatial

variability and hotspot and successful SLM intervention demarcations. Series of maps produced from information collected through QM manual has been given in figure 11 to figure 16.

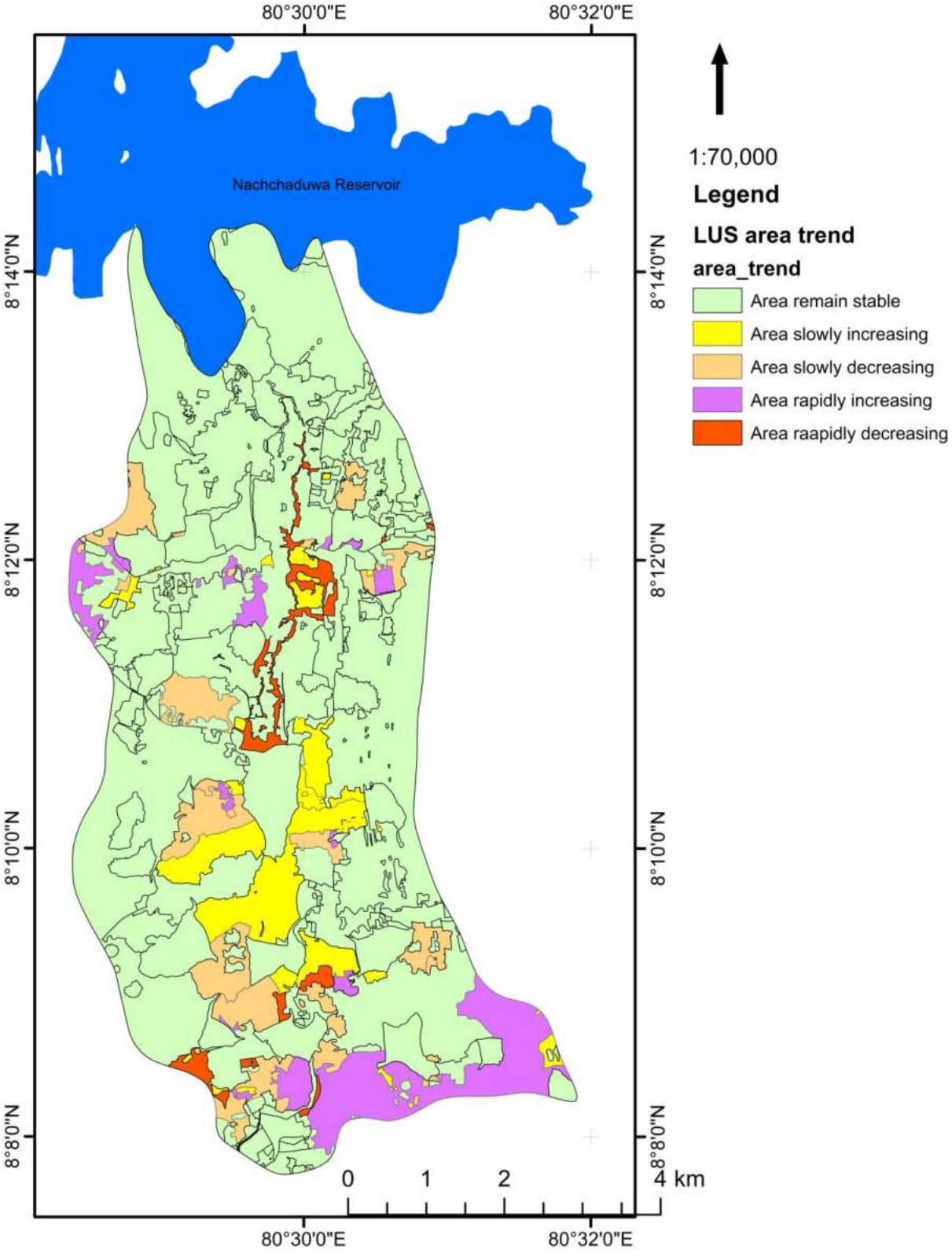


Figure 11: Trend of LUS change

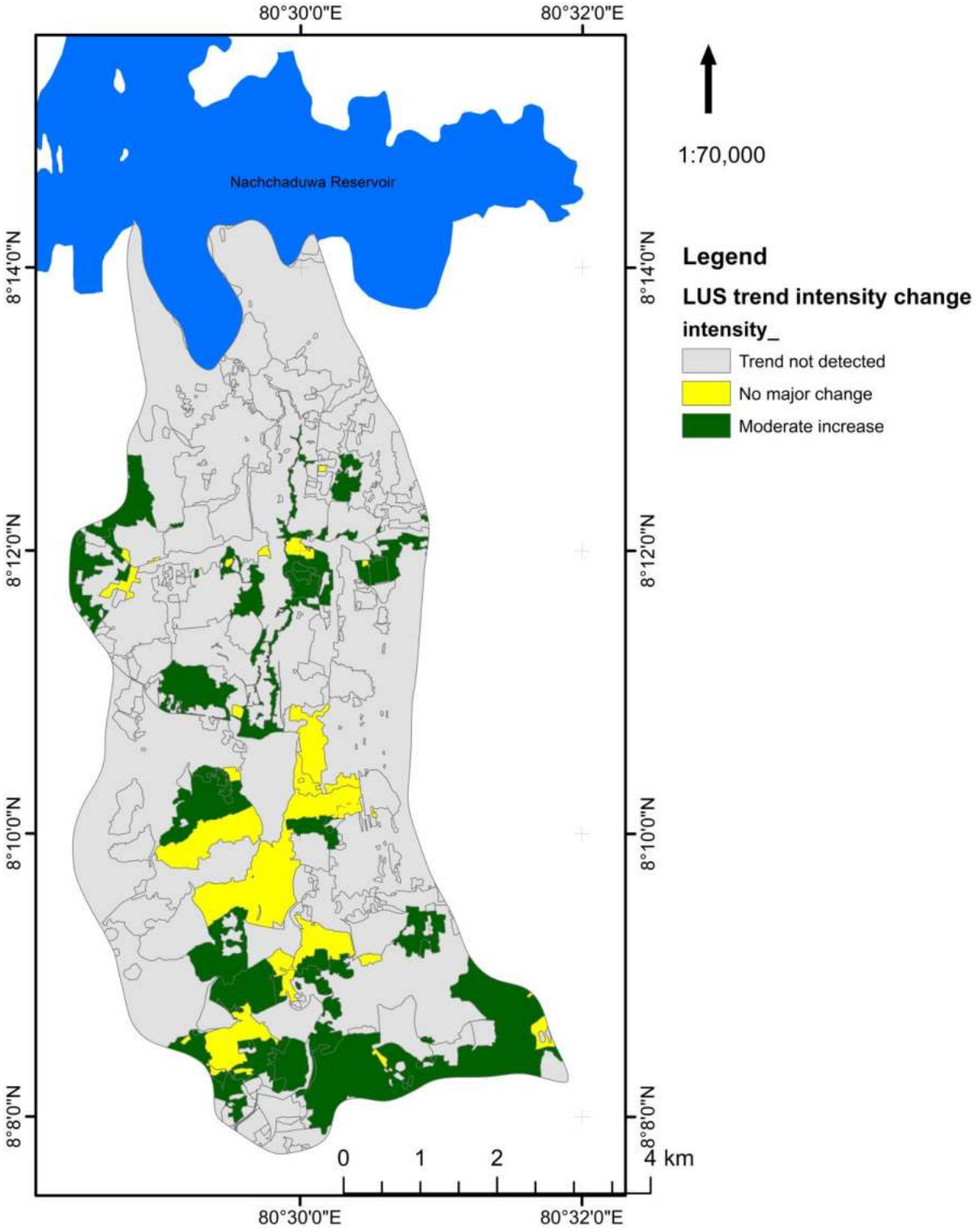


Figure 12: Trend in LUS change intensity

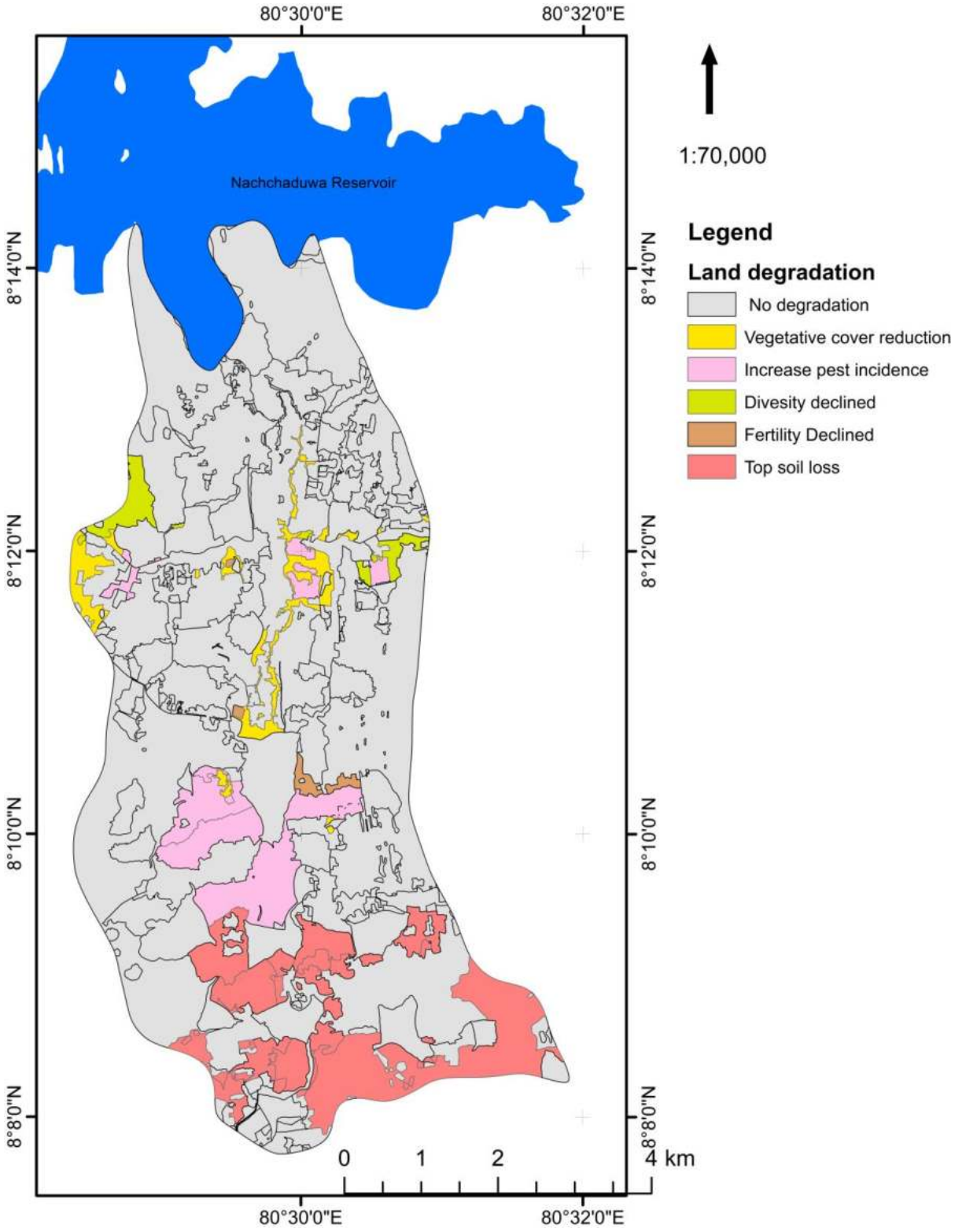


Figure 13: Land degradation detected

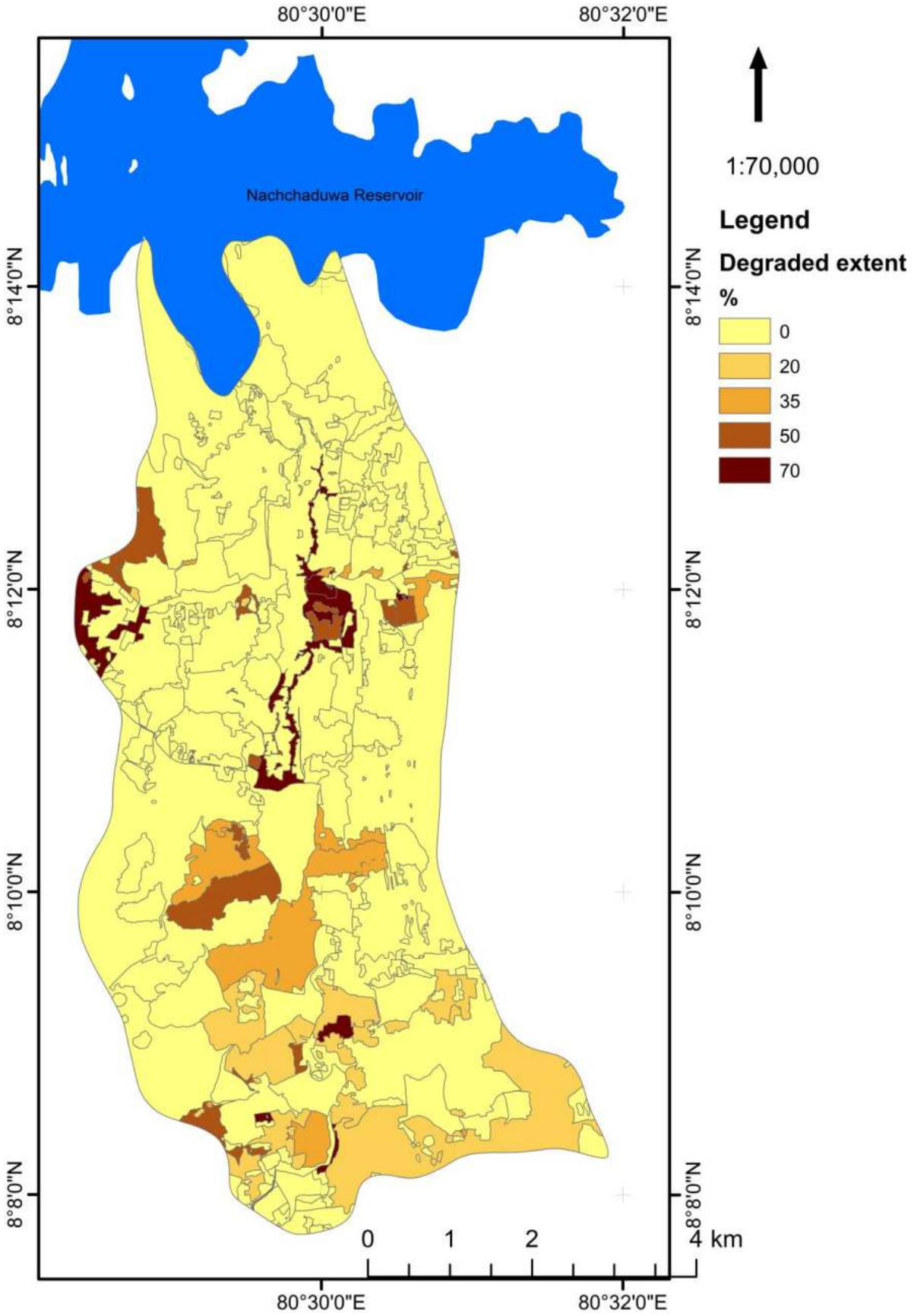


Figure 14: Percentage of degraded area

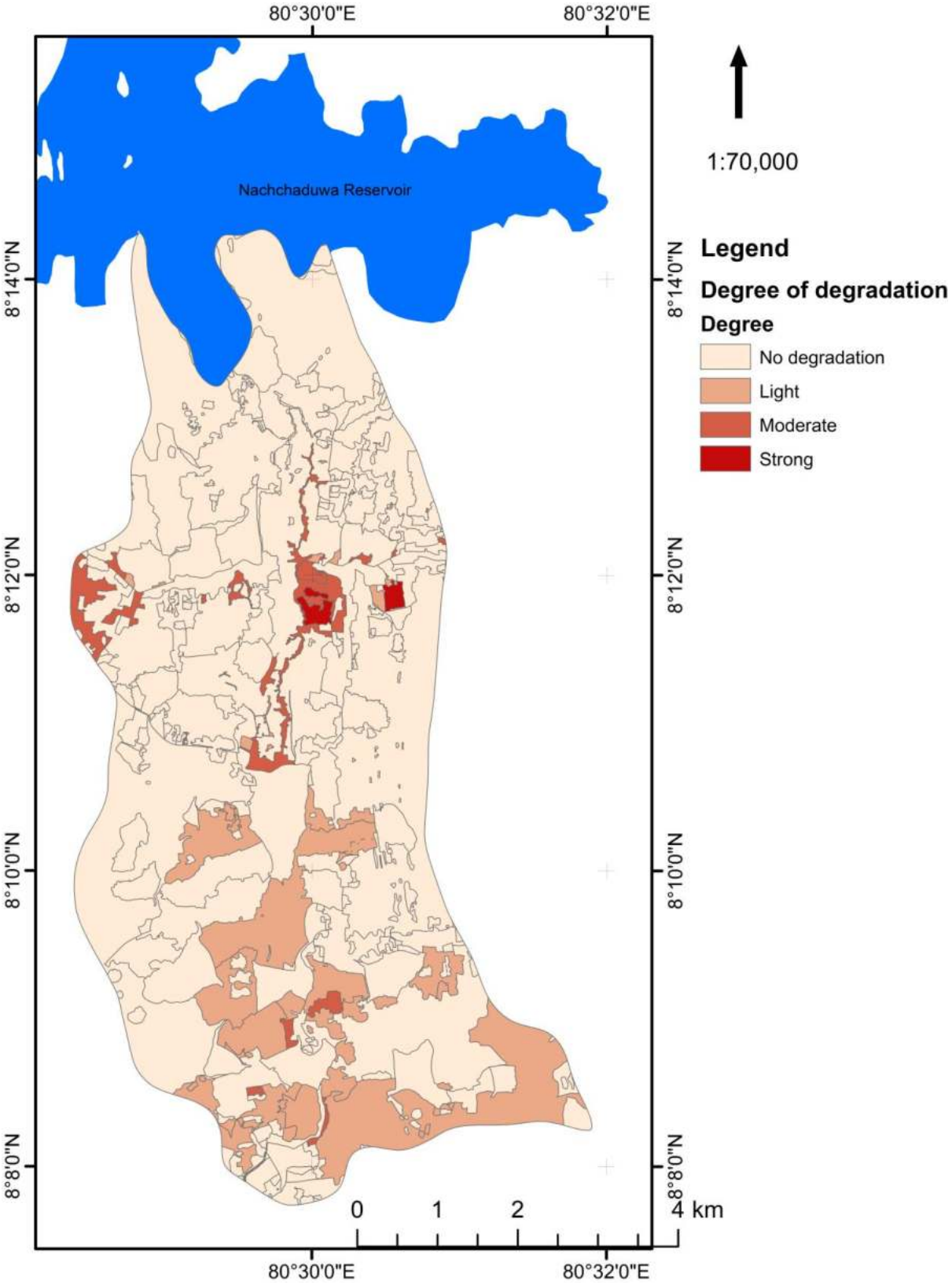


Figure 15: Degree of Degradation

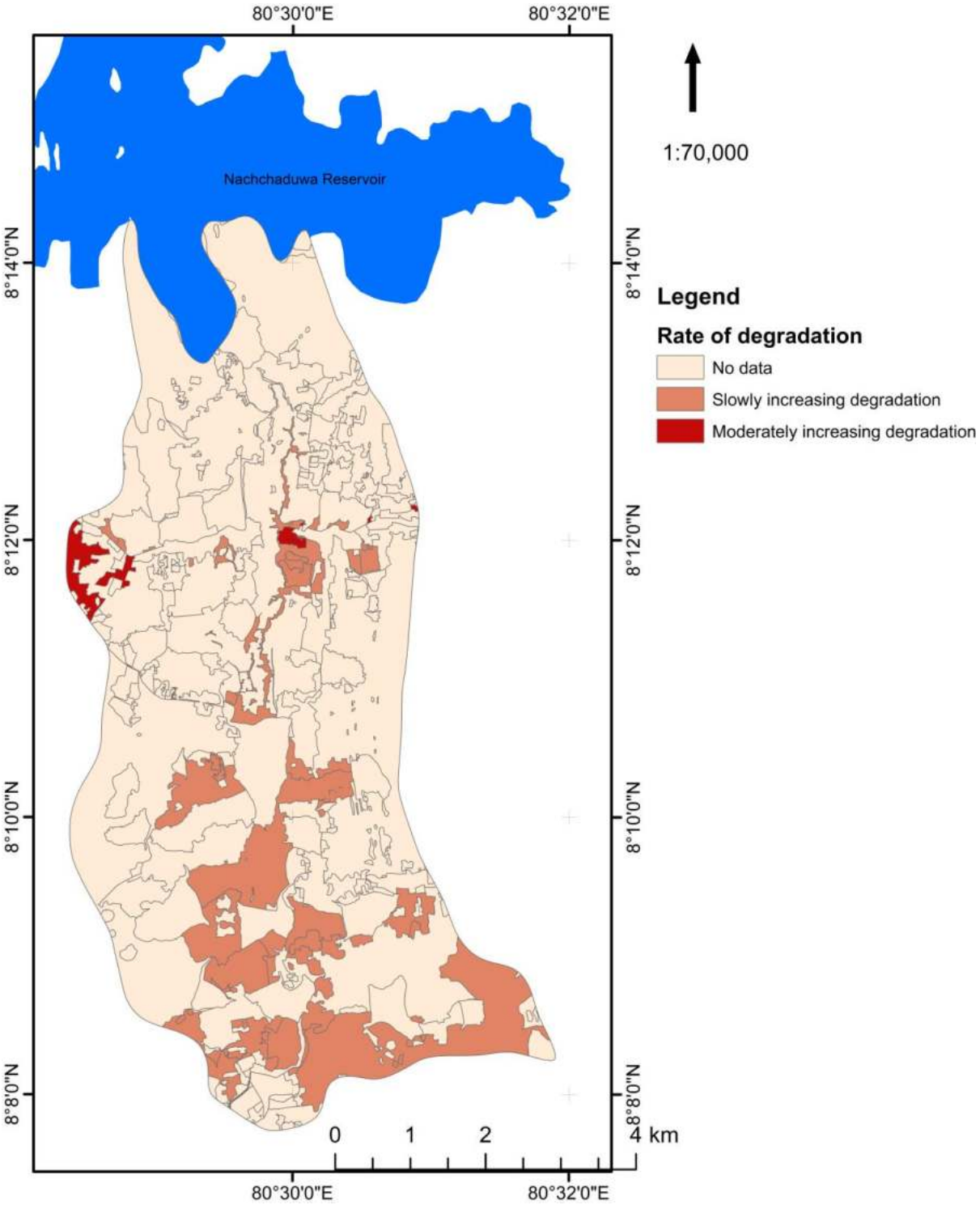


Figure 16: Rate of Degradation

Rank based assessment could be done for degradation mapping in the study are using two versions of Degradation Indices (equation 1 & 2).

$$DI_1 = \sum (Ext_i * Deg_i * Rate_i) \qquad \textit{Equation 1}$$

Where,

DI_1 = Degradation Index 1
Ext_i = Percentage extent of i^{th} degradation type
Deg_i = Degree of i^{th} degradation type
$Rate_i$ = Rate of i^{th} degradation type

$$DI_2 = \frac{\sum (Ext_i * Deg_i * Rate_i)}{\sum Ext_i} \qquad \textit{Equation 2}$$

Where,

DI_2 = Degradation Index 2
Ext_i = Percentage extent of i^{th} degradation type
Deg_i = Degree of i^{th} degradation type
$Rate_i$ = Rate of i^{th} degradation type

Some example maps and other information that can be developed are listed below.

- Maps to compare Degradation extent, Degradation severity
- List most important direct causes due to particular degradation type
- Compare types of impacts of degradation on ecosystem services
- Level of impacts of degradation on ecosystem services
- Negative impact of degradation on ecosystem services
- Comparison of degradation versus conservation
- Compare effectiveness of existing SLM technologies and measures against degradation
- Severity of degradation
- SLM practices against degradation
- Compare effectiveness of existing SLM technologies and measures against degradation
- Effectiveness trend of existing SLM technologies and measures against degradation
- SLM extent and adopted measures against particular degradation types
- Compare extent of SLM technologies against degradation
- Zones where particular degradation type is addressed by SLM
- Degraded areas (with particular degradation type)

- SLM intervention against degradation
- Conservation practices (agronomic, management, structural and vegetative maps)
- Types of conservation impacts and of SLM on particular degradation
- Types of degradation impacts on ecosystem services
- Types of conservation impacts on ecosystem services
- Positive impact of SLM in areas with degradation
- Best practices against particular degradation type

2.4 Local Level Land Degradation Assessment

DPSIR (drivers, pressures, state, impact, and response model of intervention) is a causal framework used to describe the interactions between society and the environment. DPSIR framework is the base of this approach which has been designed to suit harmonizing local level detailed LD and SLM information at different spatial levels from local to global (figure 8). This approach relies on detailed local level assessment and reporting for more effective intervention for restoration planning. Therefore, after completing sub national/ landscape level assessment, local assessment will be focused on details field investigation in hotspots of land degradation based participatory evaluation to assess and understand causes and impacts of land degradation and SLM interventions. Local level assessment methodology aims to deliver in-depth understanding, not only of the state and nature of change in the land resources (soil, water and biological resources) and ecosystems, but also of the drivers of and impacts of land degradation and sustainable land management, the impacts they have on ecosystem services and livelihoods, also the effects of recent response measures adopted by land users and other actors.

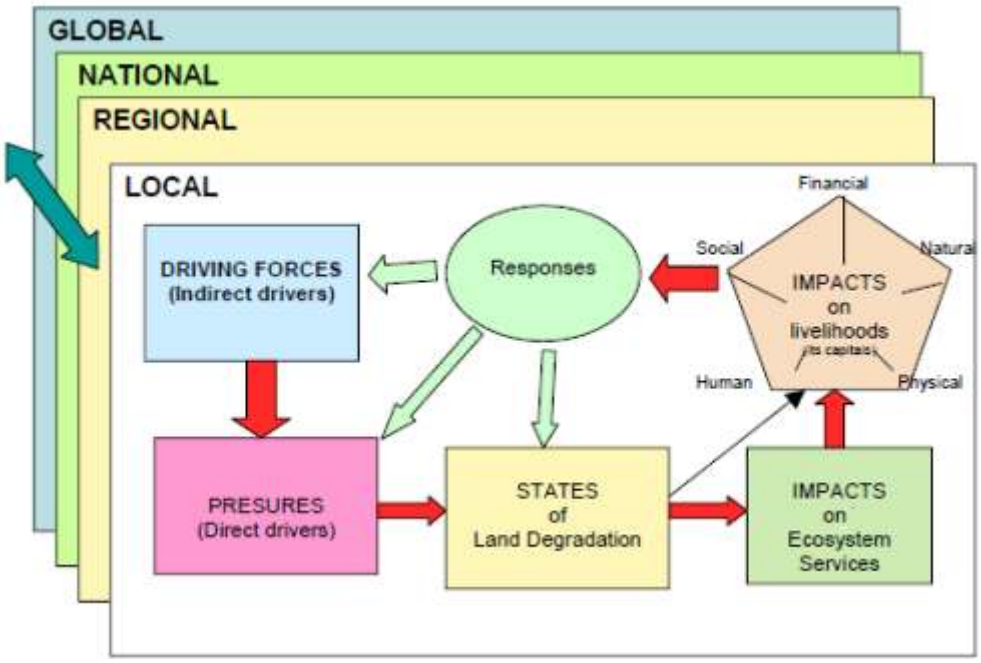


Figure 17: The DPSIR Framework Applied to the multi-level degradation assessment approach

2.4.1 Main steps involve in local assessment

1. Assessment group formation
2. Characterization of study area
3. Survey visit and transect walk
4. Vegetation assessment
5. Soil Assessment

6. Water resource assessment

7. Livelihood assessment

2.4.1.1 Local assessment group formation

Assessment group should consist with people with local knowledge, experts (Soil, Vegetation, Water resources, Livelihood, etc.), institutional representatives.

2.4.1.2 Characterization of study area

The characterization of the study area is organized and conducted using a participatory process with the selected local community/communities and resource people from local/ national technical sectors and local authorities. There are two main objectives:

1. To provide an overview of the study area as the context within which land degradation and sustainable land management (LD / SLM) are occurring. The characterization should enable the team to confirm that the study area is representative of the larger local assessment area and / or one of the national level land use systems (LUS) within.

2. The characterization will provide the team with a rational basis for selecting the location, the required number of representative communities, transects and detailed assessment sites and normally should include the full range of land users.

Characterization provides, community details, history and pattern of settlements, important land use types, water resources, main livelihood, main natural resources, prominent degradation types and details on prominent interventions.

2.4.1.3 Survey visit and transect walk

Field survey visits should be done using a transect path going through hotspots and bright spots and also across a greater number of LUS to get more representative information collection. Local community involvement is important for transect determining.

Detailed assessment of vegetation conditions, soil details, water resource availability and livelihood information in crossing LUS units need to be assess during local level assessment. Focus should be given to degradation, intervention, historical trends, etc.

3 TRAINING MATERIALS FOR SUB-NATIONAL OR LANDSCAPE LEVEL ASSESSMENT

During LUS based Sub-National or Landscape level assessment, Questionnaire Manual (QM) need to be used for data collection for each LUS unit and database needed to get all the QM data to GIS map for Land Status assessment and hotspot/ bright spot mapping. Questionnaire manual was developed and attached in section **1.10 - Land Degradation Assessment – QM Questionnaire (2024),** code sheet was developed and given in **1.10.1 QM Code Sheet** and detailed definitions is given in sub section **1.10.2 QM Assessment Definition sheet.** Code sheet with remedial technology selection during the assessment was developed and given in sub section **1.10.3 SLM measures – the constituents of a Technology.** Guide details for SLM technology assigning were developed and given in sub-section **1.10.4 The goals of the Technology with regard to land degradation, 1.10.5 Effectiveness of implemented SLM technologies, 1.10.6 Effectiveness trend and 1.10.7 Expert recommendation** with examples for easy understanding.

4 TRAINING MATERIALS FOR LOCAL ASSESSMENT

Local level assessment conducts after the sub-national or landscape assessment following standard step by step approach along well represented transect across selected areas with participation of subject specialists, experts, local people and all other stakeholders. During local level assessment, SLM technology assessment, Soil Assessment, Vegetation assessment, Water resource assessment and Livelihood assessment need to be done during field transect visits. Data collection formats were developed for separate groups and field assessment formats developed and given in **1.11 Local Assessment field data collection formats.** Field form for technology inventory is given in sub-section **1.11.1 Assessing SLM Technologies and Approaches** in annexure III, soil assessment format developed and given in **1.11.2 Soil Assessment data collection format**, Vegetation assessment format given in sub-section **1.11.3 Vegetation Assessment data collection format**, water resource assessment sheet is given in sub-section **1.11.4 Water Resource Assessment data collection format** and Livelihood assessment formats is given in sub-section **1.11.5 Livelihood Assessment data collection format.**

References

Kadupitiya HK, Madushan RN, Rathnayake UK, Thilakasiri R, Dissanayaka SB, Ariyaratne M, Marambe B, Nijamudeen MS, Sirisena D, Suriyagoda L (2021) Use of smartphones for rapid location tracking in mega scale soil sampling. Open J Appl Sci 11:239–253. https:// doi. org/ 10. 4236/ ojapps. 2021. 113017

Gann, G.D.; McDonald, T.; Walder, B.; Aronson, J.; Nelson, C.R.; Jonson, J.; Hallett, J.G.; Eisenberg, C.; Guariguata, M.R.; Dixon, K. International principles and standards for the practice of ecological restoration. Restor. Ecol. 2019, 27, S1–S46.

ANNEXURE I. TRAINING MATERIALS

4.1 GIS Presentation

GIS Basics

CONTENT

- Introduction to GIS/ භූගෝලීය තොරතුරු පද්ධතිය හැඳින්වීම
- Map Projection & coordinates
- GIS data models
- Principles of Map production/ සිතියම් සහ සිතියම් නැවතීමේ මූලධර්ම
  - >Types of maps / සිතියම් වර්ග
  - >Elements of a map / සිතියමක මූලිකාංග
    - Map Coordinates / ත්‍රාංශය සහ අක්ෂාංශ (Latitude, Longitude)
    - Map scale / සිතියම් පරිමාණය
  - >GIS software / මෘදුකාංග
  - >Data collection for Map production / සිතියම් සැකසීම් සඳහා දත්ත එකතු කිරීම
- Uses of maps / සිතියම් භාවිතය
  - Available maps / දැනට ලබාගත හැකි සිතියම්
  - Map reading / මනා තොරතුරු සිතියම් මඟින් කියවා ගැනීම
  - Using map as field guide / ක්ෂේත්‍ර මාර්ගෝපදේශ සඳහා සිතියම් භාවිතය කිරීම
  - Limitations of maps / සිතියම් භාවිතයේ සීමාවන්
- Mobile phone apps & map browsers / ජංගම දුරකථන ඇසුරින් සහ අන්තර්ජාලය ඔස්සේ

Geographic Information System
භූගෝලීය තොරතුරු පද්ධතිය

භූගෝලීය තොරතුරු පද්ධතියක් යනු අවකාශීය සහ අවකාශීය නොවන තොරතුරු, ස්ථානීය අගයන් (බණ්ඩාංක) සමඟට අඩංගු කළ හැකි පරිගණකගත තොරතුරු පද්ධතියකි. එය දත්ත ග්‍රහණය, ගබඩා කිරීම, ප්‍රතිසැකීම, හැසිරීම, විශ්ලේෂණය සහ අවසාන ලෙස දත්ත ප්‍රතිදාන ඔබගේ සැකසීම් සඳහා ඒවාවිදහස් කර යැවීම.

A Geographical information system is a computerized information system for spatial and non-spatial data referenced by Geographic coordinates. It is designed to acquire, store, retrieve, manipulate, analyze and display these data according to user defined specifications.

Contribution of different Disciplines
භූගෝලීය තොරතුරු පද්ධතිය සාක්ෂාත්කරගැනීමට විෂයවාර

GIS Integrates All ...to See the Whole!

GIS can hold specific map data as layers

Maps can be produced using only one layer or any group of layers based as required

What is a map ?

A map is a symbolic depiction emphasizing relationships between elements of some space, such as objects, regions, or themes.

Many maps are static, fixed to paper or some other durable medium, while others are dynamic or interactive.

a map.....

- A generalized / simplified view of an area
- As seen from above
- Usually north oriented
- A two-dimensional representation
- Greatly reduced size
- It has a scale
- Has grid or coordinate
- Features given by symbols, lines, and colors
- It has only selected features

සිතියමක් යනු.....

- ගෝලීය පෘෂ්ඨයක කොටසක් සරල කර දැක්වීමක්
- ඉහළින් දෙසට දැකෙන ආකාරය
- උතුර දෙස යොමුවී තබා ඇති බව
- ද්විමාන
- ඉතා කුඩා පරිමාණයකින් යුක්ත
- පරිමාණය සහිත
- ඛණ්ඩාංක සහිත
- සංකේත, රේඛා, වර්ණ සහ වෙනත් සිතියම් ලක්ෂණ දක්වන බව
- තෝරාගත් ලක්ෂණ පමණක් ඇතුළත් වන බව

Map

A map is a symbolic representation of selected geographic elements with their relationships

Map Projection & coordinates

- First 3D Globe need to be converted into 2D map

Map Coordinates

2 Types

- Geographical coordinates given as latitude and longitude
- Grid coordinates given as Easting & Northing

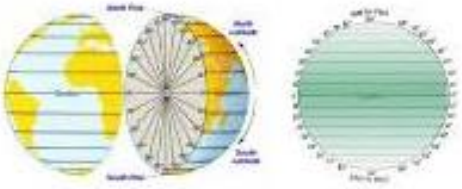
1. Geographical coordinates

- Uses degrees, minutes, minutes / අංශක, මිනිත්තු, විනාඩි
  - *Each degrees & minutes is divided into 60 graduations*
- Horizontal lines (Parallels of latitude) / අක්ෂාංශ
  - *Reference to equator / සමක රේඛාව*
- Vertical lines (Meridians of longitude) / දේශාංශ
  - *Reference to Greenwich line / ග්‍රීන්විච් රේඛාව*

6° 51' 0" N; 79° 54' 3" E

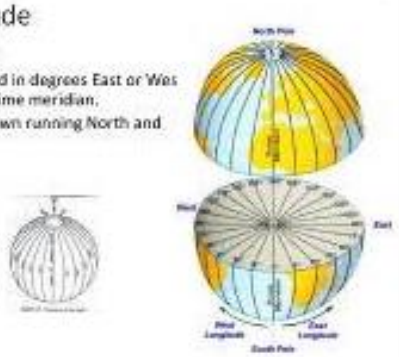
Coordinates: Latitude and Longitude

- Latitude
  - Measured in degrees North and South of the Equator.
  - Lines drawn parallel to each other running west to east.

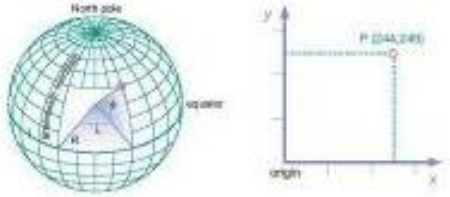


Longitude

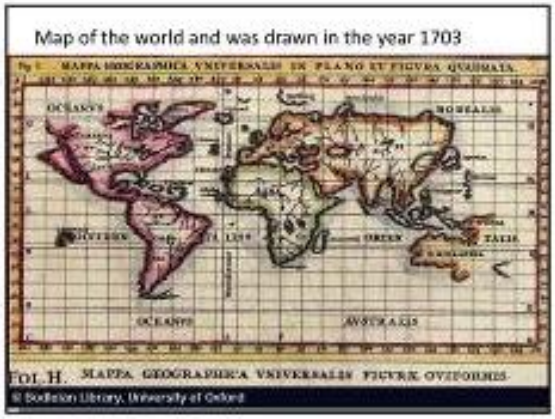
- Longitude
  - Measured in degrees East or West of the prime meridian.
  - Lines drawn running North and South.

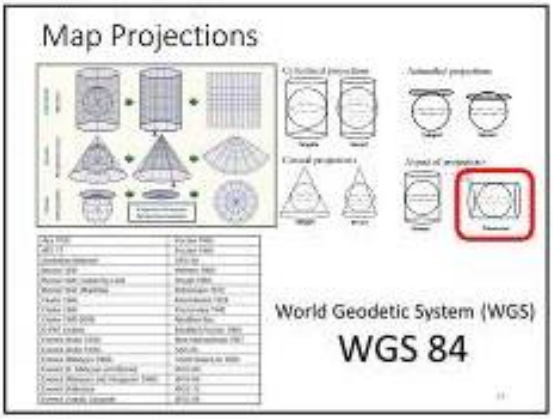


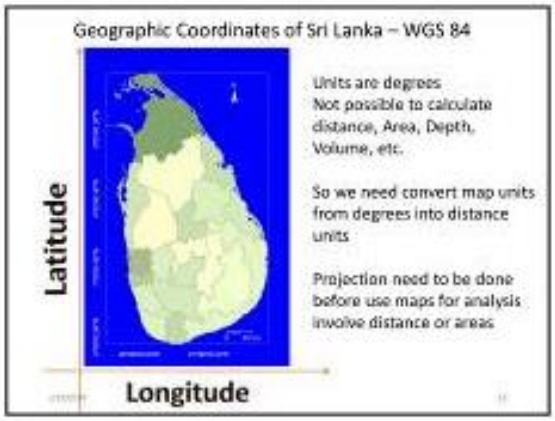
Two-Dimensional spatial referencing approaches

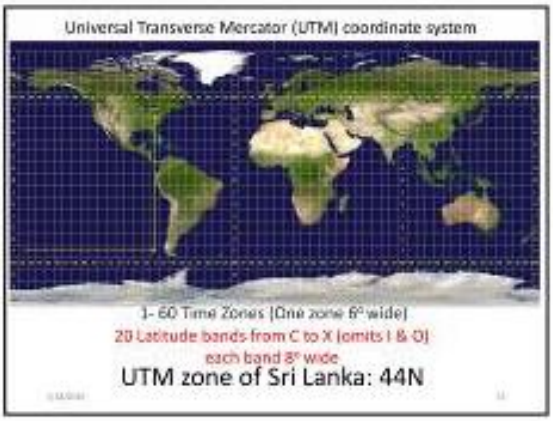


Two dimension spatial referencing approaches
(a) Through geographic coordinates
(b) Through Cartesian plane, rectangular coordinates (x, y)

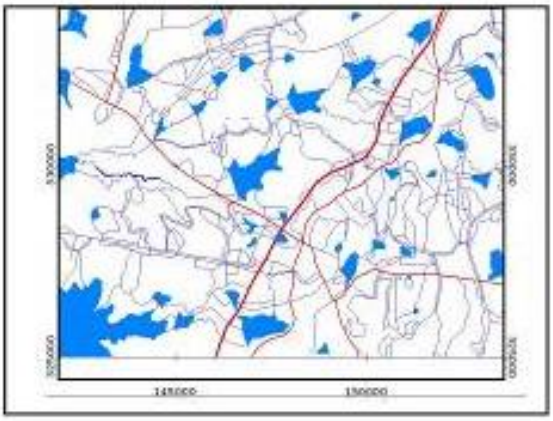

Map of the world and was drawn in the year 1703
TOL. H. MAPPA GEOGRAPHICA VNIVERSALIS FIGVRA OVIFORMIS
© Bodleian Library, University of Oxford

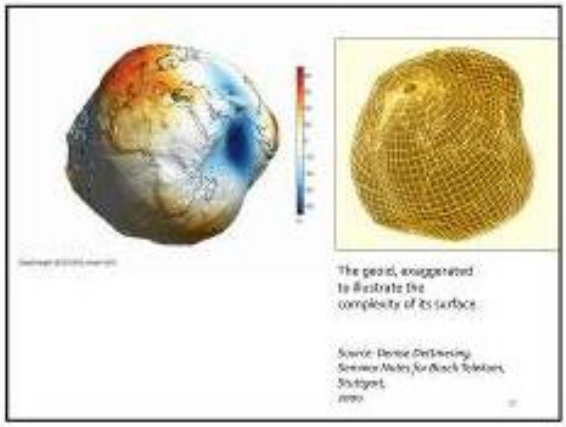

Map Projections
World Geodetic System (WGS)
WGS 84

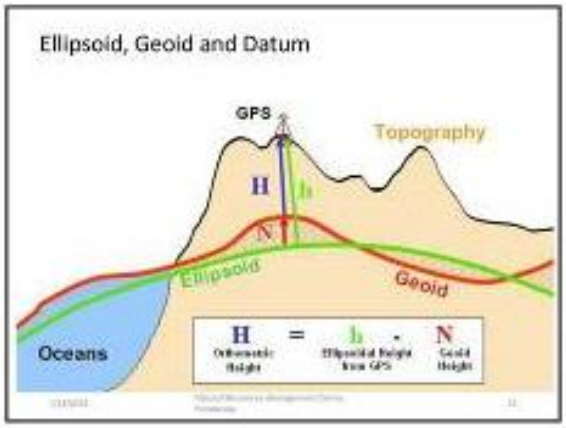

Geographic Coordinates of Sri Lanka – WGS 84
Latitude
Longitude
Units are degrees
Not possible to calculate distance, Area, Depth, Volume, etc.
So we need convert map units from degrees into distance units
Projection need to be done before use maps for analysis involve distance or areas


Universal Transverse Mercator (UTM) coordinate system
1- 60 Time Zones (One zone 6° wide)
20 Latitude bands from C to X (omits I & O)
each band 8° wide
UTM zone of Sri Lanka: 44N


Latitude
200 km
200 km
Longitude
UTM Zone 44
200 km , 200 km
in Palaviththegala
Description = Coordinate System
Projection "SL – UTM 44"
Class=Coordinate System Projection
Type=CoordSystem
UnitSize=1.000000
Type=Projection
Projection = Transverse Mercator
Datum = Kandawala
Datum Area = (Projection)
False Easting = 200,000 m
False Northing = 200,000 m
Central Meridian: 80.771714 deg
Central Parallel: 7.000401 deg
Scale Factor= 0.9999238000


530000
520000
140000
150000





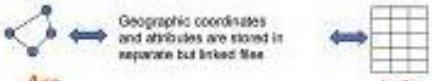
GIS Data

Spatial Data Types

1. Vector data
2. Raster data
3. Image data
4. Single/Multi-band satellite data
5. Derived spatial data

Vector data: point, line, polygon

File-based Data Models



Arc *Info*

- Coverages
  - Developed for workstation Arc/Info ~ 1980
  - Complex structure, proprietary format
  - Attributes in Info tables
- Shapefiles
  - Developed for ArcView ~ 1993
  - Simpler structure in public domain
  - Attributes in dBase (.dbf) tables

Vector Data Model Attributes

- In GIS vector files attributes are, in a simple form, stored in tables (databases).
- A table consists of records (rows) representing individual features, fields (columns) representing a particular theme describing the feature, and attributes – an intersection between a record and a field.
- In ArcGIS, FID and Shape fields, although shown in the Table of Attributes, are not actually part of the attributes, but rather represent the spatial and index information (e.g. the .shp and .shx content in shapefiles). Because of it FID and Shape fields cannot be deleted from the table, unlike any other pure attribute field.

Shapefile Vector File Format

- Shapefiles are vector composite files, made up of 3-15 separate files.
- In Windows Explorer all shapefile components are shown, in ArcCatalog entire shapefile is shown as one item.

- Basic shapefile elements (a shapefile is defunct without any of them).

Possible composite file extensions:

- .dbf – dBase table (database) file, containing attributes.
- .shp – the file that stores the feature geometry, i.e., x,y coordinates.
- .shx – the file that stores the index connecting .dbf and .shp files.
- .prj – projection file.
- .shp.xml – metadata file.
- .sbn, .sbx – spatial index files – sometimes present.
- .aih and .ain – attribute index file.
- .atx – new, ArcGIS attribute index file.
- .fbx, .mxs – geocoding index files.
- .cpg – specifies character set code page.

- All components of a shapefile need to be present together (important when transferring files!), otherwise the shapefile can be defunct or incomplete.
- The projection file is a beneficial addition to a shapefile, although not a necessary one—shapefiles can be used without a projection file but this is to be avoided.
- All elements have the same filename (e.g., roads).
- Shapefiles can be either a point or a line (arc) or a polygon file – they cannot contain more than one shape type!

Common Vector files

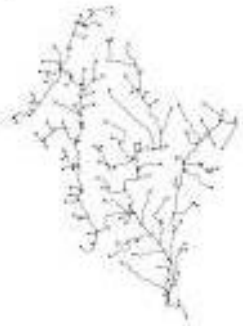
Admin Boundary

- A region is represented by a closed polygon
- Bounding area
- Each polygon knows which polygons are surrounding it
- Each polygon can have a table containing its attributes (area, population, etc.)

Common Vector files

Network

- A **network** is a set of edges (lines) and junctions (points) that are topologically connected to each other.
- Each edge knows which junctions are at its endpoints
- Each junction knows which edges it connects to



Common Vector files

Contour

- a contour line joins points of equal elevation or a constant value.
- No crossing or over lapping lines with two values

- Common vector format to represent continues features

Common Vector files

Vector formats

- **AutoCAD DXF** – communication code in AutoCAD DXF format (by Autodesk)
- **Cartesian coordinate system** (XYZ) – simple point cloud
- **Digital line graph** (DLG) – USGS format for vector data
- **Esri TIN** – proprietary binary format for manipulated irregular network data (used by Esri)
- **Geography Markup Language** (GML) – XML based open standard (by Open GIS) for GIS data exchange
- **GeoJSON** – a lightweight format based on JSON, used by many open source GIS packages
- **GeoMedia** – a geographic information system (GIS) based format for spatial vector storage
- **IGES** – a geographic information system (GIS) based CAD solution allowing vector elements to be imported into a relational Microsoft Access database
- **Keyhole Markup Language** (KML) – XML based open standard (by Open GIS) for GIS data exchange
- **MapInfo TAB format** – MapInfo's vector data format using TAB, DAT, ID and MAP files
- **National Transfer Format** (NTF) – National Transfer Format (mostly used by the UK Ordnance Survey)
- **SpatiaLite** – is a spatial extension to SQLite providing vector geodatabase functionality. It is similar to PostGIS, Oracle Spatial, and IBM DB2, former with spatial extensions
- **Shapefile** – a popular vector data GIS format, developed by Esri
- **Simple Features** – Open Geospatial Consortium specification for vector data
- **SOSI** – a spatial data format used for all public exchange of spatial data in Norway
- **SpatiaLite Data File** – a proprietary high-performance geodatabase format, native to MapGuide
- **TIGER** – Topologically Integrated Geographic Encoding and Referencing
- **Vector Product Format** (VPF) – National Geospatial-Intelligence Agency (NGA)'s format of vector data for large geographic databases

Raster Data

The raster data model represents the Earth's surface as an **array** of two-dimensional grid cells, with each cell having an associated value:

1	2	3	5	8
4	6	8	3	9
3	5	3	3	1
7	5	4	3	9
2	2	4	5	2

Cell (x,y)

Cell value

The values are numbers, either:
actual values OR
codes
representing an attribute

Cell size = resolution

rows

columns

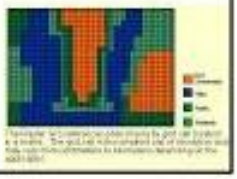
Cell Values

Absolute Values

Cell Value represents the value of the phenomenon of interest, e.g. Elevation at that pixel location.

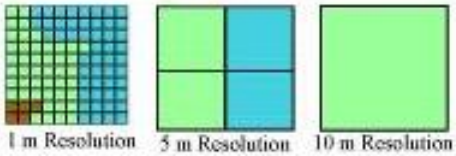
Coded Values

Cell Values stored in each cell are used as substitutes for categorical data, e.g. Land Cover Classes:



Cell Size & Resolution

- The size of the cells in the raster data model determines the resolution at which features can be represented
- The resolution can have an effect on which features are represented in what locations:



1 m Resolution 5 m Resolution 10 m Resolution

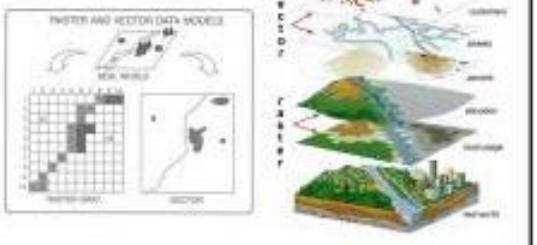
- A raster dataset representing terrain.

An ArcMap layer representing a raster that contains elevation values. The raster itself doesn't contain colours – colours are assigned to raster cells by software for interpretation purposes and are based on cell values.

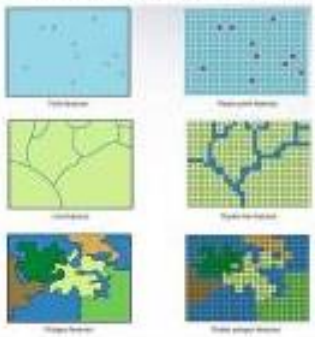
The raster converted into a simple text raster format, ASCII.

GIS data models

- Set of construct rules for describing or representing the real world within a computer
- Two data models
  - Vector
  - Raster



Vector and Raster Data models



Maps and map production
සිතියම් සහ සිතියම් සැකසීම්

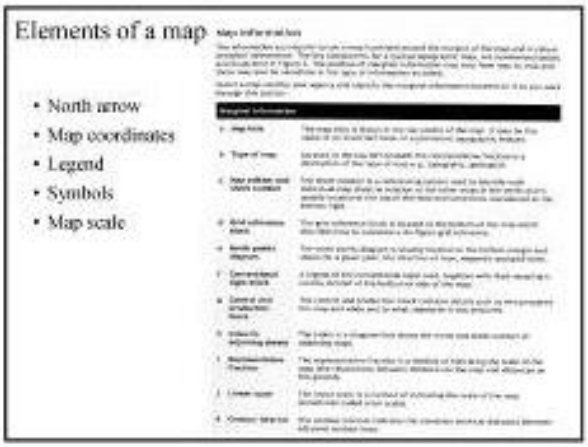
Types of maps

Major two types of map:

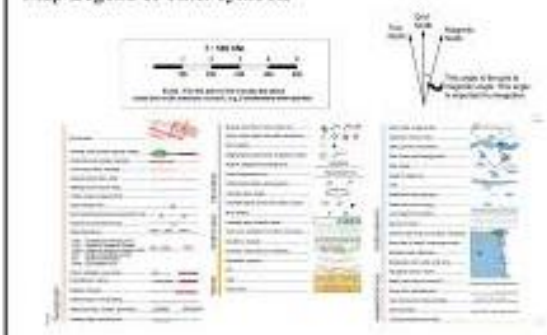
- **topographic map**
  - a reference tool, showing the outlines of selected natural and man-made features of the Earth
  - often acts as a frame for other information
  - "Topographic" refers to the shape of the surface, represented by contours and/or shading
  - And topographic maps often show roads and other prominent features
  - *Elevation contours are the main feature*
  - *Include spot elevations, roads, landuse, buildings, etc*
- **thematic map**
  - a tool to communicate geographical concepts such as the distributions of population densities, climate, movement of goods, land use etc.
  - *Usge pertaining to one theme*
  - *Examples: Soil pH, Elevation, Rainfall, Landuse, slope, ect*

Elements of a map

- North arrow
- Map coordinates
- Legend
- Symbols
- Map scale



Map Legend & other symbols



Scale of map

100 cm = 1 metre
1000 m = 1 kilometre
100 000 cm = 1 kilometre

If the scale is 1: 100 000 (1 cm = 100,000cm = 1000m = 1km) then 1 cm on the map = 1 km on the ground

Every one unit of measurement on the map equals 100 000 units on the ground

large scale ideal for road maps

1: 100 000 accurate to 100m only limited detail

smaller scales needed for detailed maps

1:50 000 – 1cm on map equals 500m on the ground
1:25 000 – 1cm on map equals 250m on the ground
1:10 000 – 1cm on map equals 100m on the ground

The lager the scale more the detail can be displayed

The concept of scale / සිතියම් පරිමාණය

- The scale of a map is the ratio between distances on the map and corresponding distances on the real world
  - For map on a scale of 1:50,000, then 1 cm on the map equals 50,000 cm or 0.5 km on the Earth's surface
- The use of the terms "small scale" and "large scale" is often confused, so it is important to be consistent
  - Large scale map: show great detail, cover few area
  - Represented as fraction or large, e.g. 1:10,000
- A small scale map shows only large features
  - Represented as fraction or small, e.g. 1:250,000
- The scale cannot not only have features are shown, but what features are shown
  - e.g. 1:1,000 maps will show individual houses and fence posts while a 1:50,000 will not

Scale	Scale Type
• 1 inch = 1 mile 1:63,720	Small Scale
• 1:250,000	Small Scale
• 1:50,000	Small Scale
• 1:10,000	Large Scale

One Inch Map Index

One mile to one inch or 1:63,360 scale this map series is commonly known as One Inch. This is the first topographical map series published in Sri Lanka and based on surveys commenced on 1897 and completed on 1925.

These maps were revised periodically till 1972 the year metrication of maps were started.

- One Inch to One mile Map (1:63,360)
- 72 Sheets

Index to 1:50,000 Maps

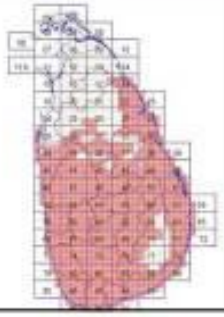
- This map series is a new metric map series published to replace the old One Inch. Commenced in 1979 and completed on 1996.
- These maps compiled mostly using modern photogrammetric methods and cartographic technologies based on old one inch series.

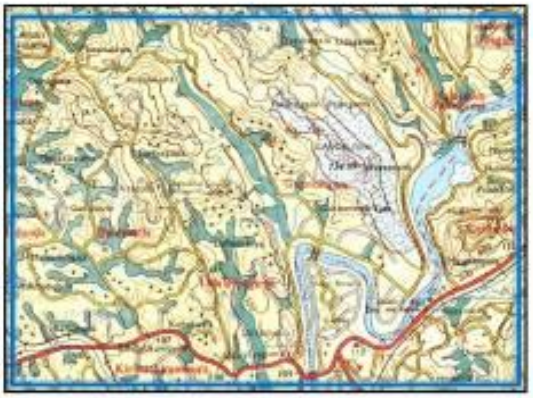
1:10,000 Topographic Maps

- Out of 1834, 1:10,000 maps, only 488 were printed and another 570 sheets of photogrammetric plots were available at various stages of production.
- 58% of 1:10,000 maps available in the Country.

1:10,000 Digital data in 2009

- 70% of the country will be covered with 1:10,000 Digital Topographic Data in 2009.



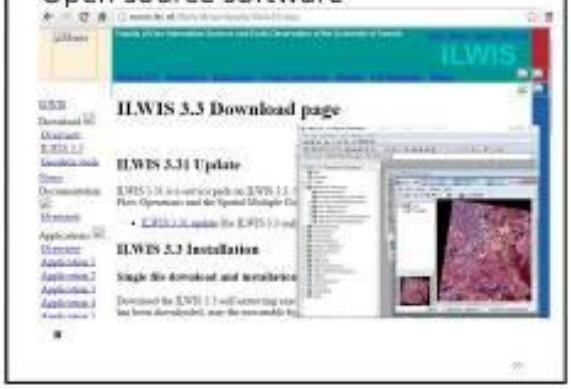


Open source software and resources

Open source software

Quantum GIS: https://www.qgis.org/en/site/forusers/download.html

Open source software



Open source GIS data

GIS layers: http://www.diva-gis.org/gdata

Open Street Map Data

https://www.openstreetmap.org/export#map=7/7.879/80.767

Free satellite data

- USGS web site: http://earthexplorer.usgs.gov/

GIS data –National Spatial Data (NSDI)

- https://www.nsdi.gov.lk/thematic-maps

Weather forecast

- https://www.weather-forecast.com

Weather forecast

- https://www.accuweather.com

GIS data –Survey Department Website

- https://www.survey.gov.lk/sdweb/home.php

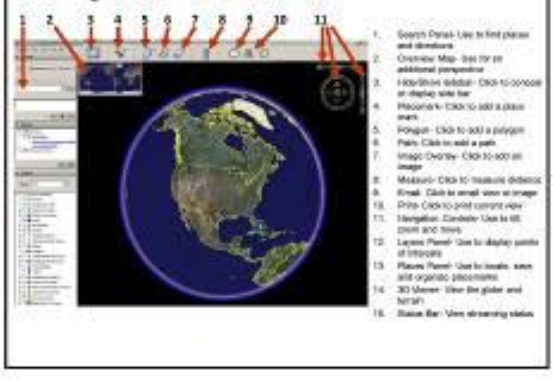
GIS data –National Spatial Data (NSDI)

- https://geoportal.nsdi.gov.lk/

Tools and resources available for LU / LC mapping

- Free satellite data – USGS website
- Free global datasets – WORLD ClimGrid, Global Soil Grid
- Google earth engine – allows online spatial analysis with time series satellite data integration

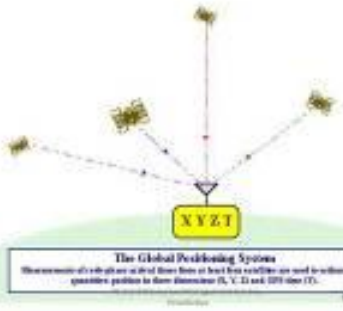
Google Earth



Global Positioning System (GPS) for Recording Location Coordinates

GPS – accuracy depend on the strength of satellite signals

GPS (Principles)



Datasets available

Mobile Apps

Mobile Apps

- CTDroid Sri Lanka – by Chanaka Alahakoon, PGIS

Mobile Apps

- Place App

Mobile Apps

- Field Area Measure

Angle meter App
Land slope measurements

Questions
&
Next – Practical Session

4.2 Land Degradation Assessment – QM Questionnaire (2024)

1	CP-MT-Dambulla-Siyambalawewa	
2	NCP-AN-Palugaswewa-Demuththewa	
3	NCP-AN-Palugaswewa-Horivila	
4	NCP-AN-Palugaswewa-Keleva	
5	NCP-AN-Palugaswewa-Palugaswewa	
6	NCP-AN-Palugaswewa-Senadhiriyagama	
7	NCP-AN-Palugaswewa-Wayaulpatha	

(GN) ***B. Land Use System*** *(LUS)*

A.1. Administration Unit – Hiriwila site *(GN)*

1	NCP-AN-Ipalogama-Manewa	
2	NCP-AN-Kekirawa-Ihala Puliyankulam	
3	NCP-AN-Kekirawa-Maradankadawela	
4	NCP-AN-Nachchaduwa-Nachchaduwa NT	
5	NCP-AN-Thirappane-Alisthana	
6	NCP-AN-Thirappane-Aluth Punchikulama	
7	NCP-AN-Thirappane-Dayagama	
8	NCP-AN-Thirappane-Ethungama North	
9	NCP-AN-Thirappane-Ethungama South	
10	NCP-AN-Thirappane-Idigahawewa	
11	NCP-AN-Thirappane-Mahakanumulla	
12	NCP-AN-Thirappane-Manakkulama	
13	NCP-AN-Thirappane-Paidikulama	
14	NCP-AN-Thirappane-Sembukulama	
15	NCP-AN-Thirappane-Thirappane Kadawee	
16	NCP-AN-Thirappane-Thirappanegama	
17	NCP-AN-Thirappane-Walagambahuwa	
18	NCP-AN-Thirappane-Wanamal Uyana	
19	NCP-AN-Thirappane-Wannammaduwa	
20	NCP-AN-Thirappane-Wellamudawa	

A.2. Administration Unit – Nachchaduwa site

01_Natural forest	
02_Plantation forest	
03_Protected recreational	
04_Scrub land	
05_Grass land	
06_Sparsely vegetated or bare land	
07_Unmanaged bare land	
08_Annual cropping	
09_Peranial non-woody cropping	
10_Tree and shrub cropping	
11_Tea	
12_Home garden	
13_Mining	
14_Paddy abandoned	
15_Paddy land	
16_Urban	
17_Water_body	
18_Water_stream	
19_Wetlands	

1. Land Use System Trends

1.1 Trend of area coverage changes

1. Area Coverage remains stable	
2. Area coverage slowly increasing	
3. Area coverage slowly decreasing	
4. Area coverage rapidly increasing	
5. Area coverage rapidly decreasing	

1.2 Trend of intensity changes

1. No major changes	
2. Moderate increase	
3. Moderate decrease	
4. Major increase	
5. Major decrease	

1.3 Remarks (eg: reasons for trend)

……

……

……

……

……

2. Important types of Land degradation prevailing within LUS in Admin unit, their causes and impacts (*Refer Annex 1 & Annex 2 for description)*

No	Land degradation types (a) *(One type or combination of types for a particular area)*			Extent %	Degree of degradation (b)	Rate of degradation (c)	Direct Causes (d)	Indirect causes (e)	Impact on ecosystem services (f)	Level of Impact (g)	Remarks
	i	ii	iii								
01											
02											
03											
04											
05											
06											
07											
08											

3. Land Conservation types, measures, purposes, effectiveness and impacts (*Refer Annex 1 for details and Annex 2 for definitions)*

Name of technology	Conservation Group (h)	Conservation Measures (i)			Purpose (j)	Conservation Area %	Degradation Addressed (a)			Effectiveness (k)	Effectiveness Trend (l)	Start Period (yyyy)	End Period (yyyy)	Impact on Ecosystem services (f)	Level of Impact (g)
		i	ii	iii			i	ii	iii						

3.1 Remarks

……

……

……

4. Expert Recommendation (please provide recommendations for degradation issue/s for LUS in the Admin unit in detail

4.1 Recommendation :- …….

A – Adaptation : ……

M – Mitigation : ……

P – Prevention : ……

R – Rehabilitation: ……

4.2 Remarks:-

……

……

……

Contributor Details:

Name/s: - ……

Designation/s: - ……

Institution: - ……

Contact No: - …….. *Date: -* ……..

Signature/s: ……

Office Use: Data computerized by: …….. Date:- ……

4.2.1 QM Code Sheet

(a) Type of Land Degradation

Code	Type of Degradation	Main types
Bc	Reduction of vegetative cover	Biological degradation
Bf	Detrimental effects of fires	
Bh	Loss of habitats	
Bl	Loss of soil life	
Bp	Increase of pests/diseases*: reduction of biological control*	
Bq	Quantity/biomass decline*: reduced vegetative production for different land use*	
Bs	Quality and species composition/diversity decline	
Cn	Fertility decline and reduced organic matter content	Chemical Soil deterioration
Ha	Aridification: *decrease of average soil moisture content*	Water degradation
Hg	Change in groundwater/aquifer level	
Hp	Decline of surface water quality	
Hq	Decline of groundwater quality	
Hs	Change in quantity of surface water: *change of the flow regime (flood, low flow, drying up of rivers and lakes)*	
Hw	Reduction of the buffering capacity of wetland areas	
Wg	Gully erosion/gullying	Soil erosion by water
Wm	Mass movements/landslides	
Wo	Offsite degradation effects : *deposition of sediments, downstream flooding, siltation of reservoirs and waterways, and pollution of water bodies with eroded sediments*	
Wr	Riverbank erosion	
Wt	Loss of topsoil/surface erosion	

(b) Degree of Degradation

1	Light
2	Moderate
3	Strong
4	Extreme

(c) Rate of Degradation

1	No change in degradation
2	Slowly increasing degradation
3	Slowly decreasing degradation
4	Moderately increasing degradation
5	Moderately decreasing degradation
6	Rapidly increasing degradation
7	Rrapidly decreasing degradation update

***Degree:** intensity of the land degradation process*

Light: *there are some indications of degradation, but the process is still in an initial phase. It can be easily stopped and damage repaired with minor efforts.*

Moderate: *degradation is apparent, but its control and full rehabilitation of the land is still possible with considerable efforts.*

Strong: *evident signs of degradation. Changes in land properties are significant and very difficult to restore within reasonable time limits.*

Extreme: *degradation beyond restoration.*

(d) Direct Causes

Code	Direct causes	Main Types
c1	Reduction of plant cover and residues	Crop and rangeland management
c2	Inappropriate application of manure, fertilizer, herbicides, pesticides and other agro-chemicals or waste	
c3	Nutrient mining: excessive removal without appropriate replacement of nutrients	
c4	Shortening of the fallow period in shifting cultivation	
c5	Inappropriate irrigation : *inefficient irrigation method, over-irrigation, insufficient drainage*	
c6	Inappropriate use of water in rainfed agriculture *(eg excessive soil evaporation and runoff)*	
c7	Bush encroachment and bush thickening	
c8	Occurrence and spread of weeds and invader plants	
c9	Others (specify)	
e1	Excessive gathering of fuel wood, (local) timber, fencing materials	Over-exploitation of vegetation for domestic use
e3	Other (specify)	
f1	Large-scale commercial forestry	Deforestation and removal of natural vegetation
f2	Expansion of urban / settlement areas and industry	
f3	Conversion to agriculture	
f4	Forest / grassland fires	
f5	Road and rail construction	
f6	Others (specify)	
i1	Industry	Industrial activities and mining
i2	Mining	
i3	Waste deposition	
i4	Others (specify)	
n1	Change in temperature	Natural causes
n2	Change of seasonal rainfall	
n3	Heavy/ extreme rainfall (intensity and amounts)	
n4	Windstorms / dust storms	
n5	Floods	
n6	Drought	
n7	Topography	
n8	Others (specify)	
o1	Irrigation	Over abstraction of water / excessive withdrawal of water
o2	Industrial use	
o3	Domestic use	
o4	Mining activities	
o5	Decreasing water use efficiency	
o6	Others (specify)	

p1	Sanitary sewage disposal	Discharges
p2	Waste water discharge	
p3	Excessive runoff	
p4	Poor and insufficient infrastructure to deal with urban waste	
p5	Others (specify)	
s1	Cultivation of highly unsuitable soils	Soil Management
s2	Missing or insufficient soil conservation / runoff and erosion control measures	
s3	Heavy machinery	
s4	Tillage practice (ploughing, harrowing, etc.)	
s5	Others (specify)	
u1	Settlements and roads	Urbanization and infrastructure development
u2	Recreation (urban)	
u3	Others	
w1	Lower infiltration rates/increased surface runoff	Disturbance of water cycle
w2	Others (specify)	

(e) Indirect Causes

c	Consumption pattern and individual demand
e	Education, awareness raising and access to knowledge and support services and loss of knowledge
g	Governance, institutions and politics
h	Poverty
l	Labour availability
o	Others (specify)
p	Population pressure
r	Inputs and infrastructure
t	Land tenure
w	War and conflict

(f) Impacts on Ecosystem Services

Code	Ecosystem services	Main Type
E1	Regulation of excessive water such as excessive rains, storms, floods *eg :affecting infiltration, drainage, runoff, evaporation,*	Ecological services
E10	(Micro)-climate (wind, shade, temperature, humidity)	
E11	Others (Specify)	
E2	Regulation of scarce water and its availability *eg: during dry seasons, droughts affecting water and evaporation loss*	
E3	Organic matter status	
E4	Soil cover (vegetation, mulch, etc.)	
E5	Soil structure: surface and subsoil affecting infiltration, water and nutrient holding capacity(...)	
E6	Nutrient cycle (N, P, K) and the carbon cycle (C)	
E7	Soil formation (including wind-deposited soils)	
E8	Biodiversity	
E9	Greenhouse gas emission	
P1	Production (of animal / plant quantity and quality including biomass for energy) and risk	Productive services
P2	Water (quantity and quality) for human, animal and plant consumption	

P3	Land availability	
P4	Others(Specify)	
S1	Spiritual, aesthetic, cultural landscape and heritage values, recreation and tourism	Socio-cultural services / human well-being
S2	Education and knowledge	
S3	Conflicts transformation	
S4	Food & livelihood security and poverty	
S5	Health	
S6	Net income	
S7	Protection/ damage of private and public infrastructure (buildings, roads, dams, etc.)	
S8	Marketing opportunities (access to markets, etc.)	
S9	Others (Specify)	

(g) Level of Impacts on Ecosystem services

1	low positive impact: land degradation contributes positively (0-10%) to the changes in ES
2	low negative impact: land degradation contributes negatively (0-10-%) to changes in ES
3	positive impact: land degradation contributes positively (10-50%) to the changes in ES
4	negative impact: land degradation contributes negatively (10-50%) to changes in ES
5	high positive impact: land degradation contributes positively (more than 50%) to changes in ES
6	high negative impact: land degradation contributes negatively (more than 50%) to changes in ES

(h) Conservation Groups

AF	Agroforestry
AP	Afforestation and forest protection
CA	Conservation agriculture / mulching
CB	Coastal bank protection
CO	Conservation of natural biodiversity
GR	Grazing land management
NM	Manuring / composting / nutrient management
OT	Other
PR	Protection against natural hazards
RH	Gully control / rehabilitation
RO	Rotational system / shifting cultivation / fallow /slash and burn
SA	Groundwater / salinity regulation / water use efficiency
SC	Storm water control, road runoff
SD	Sand dune stabilization
TR	Terraces
VS	Vegetative strips / cover
WH	Water harvesting
WM	Waste management
WQ	Water quality improvement

(i) Conservation Measures

A	**Agronomic**
A1	Vegetation/soil cover
A2	Organic matter/soil fertility
A3	Soil surface treatment
A4	Subsurface treatment
A5	Others
M	**Management**
M1	Change of land use type
M2	Change of management/intensity level
M3	Layout according to natural and human environment
M4	Major change in timing of activities
M5	Control/change of species composition
M6	Waste Management
M7	Others
S	**Structural**
S1	Bench terraces (<6%)
S2	Forward sloping terraces (>6%)
S3	Bunds/banks
S4	Graded ditches/waterways
S5	Level ditches/pits
S6	Dams/pans
S7	Reshaping surface (reducing slope)
S8	Walls/barriers/palisades
S9	Others
V	**Vegetative**
V1	Tree and shrub cover
V2	Grasses and perennial herbaceous plants
V3	Clearing of vegetation (eg fire breaks/reduced fuel)
V4	Others

(j) Purpose

M -Mitigation

P – Prevention

R – Rehabilitation

(k) Effectiveness

1 – low
2 – moderate
3 – high
4 – very high

(l) Effectiveness trend

1 - No change in effectiveness
2 - Increase in effectiveness
3 - Decrease in effectiveness

4.2.2 QM Assessment Definition sheet

Land use: *human activities which are directly related to land, making use of its resources or having an impact on it.*
Land cover: *vegetation (natural or planted) or man-made structures (buildings, etc.) that cover the earth's surface.*

Land use types

Main categories	*Subcategories*
Cropland: *land used for cultivation of crops (field crops, orchards)*	• ***Ca: Annual cropping:*** *land under temporary/ annual crops usually harvested within one, maximally two years (e.g. maize, paddy rice, wheat, vegetables, fodder crops).* • ***Cp: Perennial (non-woody) cropping:*** *land under permanent (not woody) crops that may be harvested after 2 or more years, or where only part of the plants are harvested (e.g. sugar cane, banana, sisal, pineapple).* • ***Ct: Tree and shrub cropping:*** *permanent woody plants with crops harvested more than once after planting and usually lasting for more than 5 years (e.g. orchard/ fruit trees, coffee, tea, grapevines, oil palm, cacao, coconut, fodder trees).*

Grazing land: *land used for animal production*	• ***Ge: Extensive grazing land:*** *grazing on natural or semi-natural grasslands, grasslands with trees/ shrubs (savannah vegetation) or open woodlands for livestock and wildlife. Includes the following subcategories:*
	  • ***Nomadism****: people move with animals.*
	  • ***Semi-nomadic pastoralism****: animal owners have a permanent place of residence where supplementary cultivation is practiced. Herds are moved to distant grazing grounds.*
	  • ***Ranching****: grazing within well-defined boundaries, movements cover smaller distances and management inputs are higher compared to semi-nomadism.*
	  • ***Transhumant pastoralism****: regular movements of herds between fixed areas in order to benefit from the seasonal variability of climates and pastures.*
	• ***Gi: Intensive grazing/ fodder production:*** *improved or planted pastures for grazing/ production of fodder (for cutting and carrying: hay, leguminous species, silage etc.) not including fodder crops such as maize, cereals. These are classified as annual crops (see above). Intensive grazing can be subclassified into:*

Forests/ woodlands: *land used mainly for wood production, other forest products, recreation, protection.*	• ***Fn: Natural or semi-natural:*** *forests mainly composed of indigenous trees, not planted by man.*
	  • *Selective felling.*
	  • *Clear felling: felling the whole forest at one time.*
	  • *Shifting cultivation: felling (harvesting) only certain valuable trees within a forest.*
	  • *Dead wood/ prunings removal (no cutting of trees).*
	  • *Non-wood forest use (e.g. fruit, nuts, mushrooms, honey, medicinal plants, etc.) .*
	• ***Fp: Plantations, afforestations:*** *forest stands established by planting or/ and seeding in the process. of afforestation or reforestation.*
	  • *Monoculture local variety.*
	  • *Monoculture exotic variety.*
	  • *Mixed varieties.*
	• ***Fo: Other:*** *e.g. selective cutting of natural forests and incorporating planted species.*

Settlements, infrastructure	• ***Ss:*** *Settlements, buildings* • ***St:*** *Traffic lines: roads, railways* • ***Se****: Energy lines: pipe lines, power lines* • ***So****: Other infrastructure*

4.2.3 SLM measures – the constituents of a Technology

Type of measure	*Subcategories*	*Examples*
Agronomic measures ***Error! Objects cannot be created from editing field codes.*** • *are usually associated with annual crops* • *are repeated routinely each season or in a rotational sequence* • *are of short duration and not permanent* • *do not lead to changes in slope profile* • *are normally independent of slope*	**A1:** Vegetation/ soil cover	*Mixed cropping, intercropping, relay cropping, cover cropping*
	A2: Organic matter/ soil fertility	*Conservation agriculture, production and application of compost/ manure, mulching, trash lines, green manure, crop rotations*
	A3: Soil surface treatment	*Zero tillage (no-till), minimum tillage, contour tillage* *Differentiate tillage systems: No tillage, reduced tillage (>30% soil cover), full tillage (>30% soil cover).*
	A4: Subsurface treatment	*Breaking compacted subsoil (hard pans), deep ripping, double digging*
	A5: Seed management, improved varieties	*Production of seeds and seedlings, seed selection, seed banks, development/ production of improved varieties*
	A6: Residue management	*Specification required: burned, grazed, collected, retained.*
	A7: Others	
Vegetative measures **Error! Objects cannot be created from editing field codes.** • *involve the use of perennial grasses, shrubs, or trees* • *are of long duration* • *often lead to a change in slope profile* • *are often aligned along the contour or against the prevailing wind direction* • *are often spaced according to slope*	**V1:** Tree and shrub cover	*Agroforestry, windbreaks, afforestation, hedges, live fences*
	V2: Grasses and perennial herbaceous plants	*Grass strips along the contour, vegetation strips along riverbanks*
	V3: Clearing of vegetation	*Fire breaks, reduced fuel for forest fires*
	V4: Replacement or removal of alien/ invasive species	*Cutting of undesired trees and bushes*
	V5: Others	*Tree nurseries*
Structural measures **Error! Objects cannot be created from editing field codes.** • *are of long duration or permanent* • *often require substantial inputs of labour or money when first installed* • *involve major earth movements and/ or construction with wood, stone, concrete, etc. are often carried out to control runoff, erosion, and wind velocity, and to harvest rainwater* • *often lead to a change in slope profile* • *are often aligned along the contour/ against prevailing wind direction* • *are often spaced according to slope* *If structures are stabilized by means of vegetation, also select relevant vegetative measures!*	**S1:** Terraces	*Bench terraces (slope of terrace bed <6%); Forward-sloping terraces (slope of terrace bed >6%*
	S2: Bunds, banks	*Earth bunds, stone bunds (along the contour or graded), semi-circular bunds ("demi-lunes")*
	S3: Graded ditches, channels, waterways	*Diversion/ drainage ditch, waterways to drain and convey water*
	S4: Level ditches, pits	*Retention / infiltration ditches, planting holes, micro-catchments*
	S5: Dams, pans, ponds	*Dams for flood control, dams for irrigation, sand dams*
	S6: Walls, barriers, palisades, fences	*Sand dune stabilization, rotational grazing (using fences), area closure, gully plugs (check dams)*
	S7: Water harvesting/ supply/ irrigation equipment	*Rooftop water harvesting, water intakes, pipes, tanks, etc.*
	S8: Sanitation/ waste water structures	*Compost toilet, septic tanks, constructed treatment wetlands*
	S9: Shelters for plants and animals	*Greenhouses, stables, shelters for plant nurseries*

	S10: Energy saving measures	*Wood-saving stoves, insulation of buildings, renewable energy sources (solar, biogas, wind, hydropower)*
	S11: Others	*Compost production pits; reshaping of surface (slope reduction)*
Management measures **Error! Objects cannot be created from editing field codes.** • *involve a fundamental change in land use* • *usually involve no agronomic and structural measures* • *often result in improved vegetative cover* • *often reduce the intensity of use*	**M1:** Change of land use type	*Area closure/ resting, protection, change from cropland to grazing land, from forest to agroforestry, afforestation*
	M2: Change of management/ intensity level	*Change from grazing to cutting (for stall feeding), farm enterprise selection (degree of mechanization, inputs, commercialization), vegetable production in greenhouses, irrigation; from mono-cropping to rotational cropping; from continuous cropping to managed fallow; from open access to controlled access (grazing land, forests); from herding to fencing, adjusting stocking rates, rotational grazing*
	M3: Layout according to natural and human environment	*Exclusion of natural waterways and hazardous areas, separation of grazing types, distribution of water points, salt licks, livestock pens, dips (grazing land); increase of landscape diversity, forest aisle*
	M4: Major change in timing of activities	*Land preparation, planting, cutting of vegetation*
	M5: Control/ change of species composition (if annually or in a rotational sequence as done e.g. on cropland → A1)	*Reduction of invasive species, selective clearing, encouragement of desired/ introduction of new species, controlled burning (e.g. prescribed fires in forests/ on grazing land)/ residue burning*
	M6: Waste management (recycling, re-use or reduce)	*Includes both artificial and natural methods for waste management*
	M7: Others	
Other measures • *comprises any measures which do not fit into the above categories*		*Beekeeping, small stock farming (e.g. poultry, rabbits), fish ponds; food storage and processing (including post-harvest loss reduction)*
Combinations • *occur where different measures complement each other and thus enhance each other's effectiveness* • *may comprise any two or more of the above measures*		*Terrace (S1) + Grass strips and trees along riser (V2, V1) + Contour tillage (A3)* *Zero grazing/ stall feeding (M2) + Construction of stables and fence (S10) + Compost/ manure production pits (S12) + Application of manure and compost on cropland (A2)*

4.2.4 The goals of the Technology with regard to land degradation:

Prevention: good land management practices that are already in place on land that may be prone to land degradation. They maintain natural resources and their environmental and productive functions.

Reduction: interventions intended to reduce ongoing degradation and/ or halt further degradation. They start improving natural resources and their functions. Impacts tend to be noticeable in the short to medium term.

Rehabilitation/ restoration: required when the land is already degraded to such an extent that the original use is no longer possible, and land has become practically unproductive. Here, longer-term and more costly investments are needed to show any impact.

Adaptation: applied when rehabilitation/ restoration of the original state of the land is no longer possible or requires resources beyond the means of land users. This means the state of land degradation is "accepted", but land management is adapted to suit land degradation (e.g. adapting to soil salinity by introducing salt-tolerant plants).

4.2.5 Effectiveness of implemented SLM technologies

Effectiveness: how much it reduces the degree of degradation or how well it is preventing degradation

4: Very high: the measures not only control the land degradation problems appropriately, but even improve the situation compared to the situation before degradation occurred.

3: High: the measures control the land degradation problems appropriately. The measures are able to stop further deterioration, but improvements are slow.

2: Moderate: the measures are acceptable for the given situations. However, the measures only slow down the degradation process, but are not sufficient.

1: Low: the measures need local adaptation and improvement in order to reduce land degradation to acceptable limits.

4.2.6 Effectiveness trend

1 - no change in effectiveness

2 - increase in effectiveness: the measures have a growing positive impact on the reduction of degradation

3 - decrease in effectiveness: the measures have less and less effect in reducing degradation, e.g. due to lack of maintenance

4.2.7 Expert recommendation

A - Adaptation: *to the problem: the degradation is either too serious to deal with and is accepted as a fact of life, or it is not worthwhile the effort to invest in.*

P – Prevention: *implies the use of conservation measures that maintain natural resources and their environmental and productive function on land that may be prone to further degradation*

M - Mitigation: *is intervention intended to reduce ongoing degradation.*

R - Rehabilitation: *is intervention when the land is already degraded to such an extent that the original use is only possible with extreme efforts as land has become practically unproductive.*

4.2.8 Example

Table 1: Land use system (Example)

Name: *First name Last name* **Country:** *South Africa*

Mapping Unit Id (LUS + admin. unit): 113 *(Savanna + Ratlou municipality)*

Land Use System (Step2)		
a) LUS area trend	b) LUS intensity trend	c) Remarks (e.g. reasons for trend)
2	*1*	*Increased grazing pressure due to growing numbers of livestock*

Table 2: Land degradation (Example)

Name: *X Y* **Country:** *South Africa*

Mapping Unit Id (LUS + admin. unit): 113 *(Savanna + Ratlou municipality)*

Land degradation (Step 3)									
a) Type (state)			b) Extent	c) Degree	d) Rate	e) Direct causes	f) Indirect causes	g) Impact on ecosystem services	h) Remarks
i	*ii*	*iii*							
Ha	*Pc*		*15%*	*2*	*1*	*g1, e1, f4,*	*p, h, t*	*P1-3, E2-2*	*Degradation is concentrated in NW communal grazing are of District*
Bs			*10%*	*2*	*-3*	*g1, g3*	*e, g*	*P1-2, S3-1*	*g3: change of livestock composition from large to small stock*

Table 3: Conservation (Example)

Name: ___X Y_____ **Country:** __*South Africa*

Mapping Unit Id (LUS + admin. unit): **113** *(Savanna + Ratlou municipality)*

Conservation (Step 4)													
a) Name	b) Group	c) Measure			d) Purpose	e) % of area	f)Degradation addressed			g)Effectiveness	h) Eff.. trend	i) Impact on ESS	j)Period	k)Ref to QT	l) Remarks
Controlled grazing + reseeding	*VS*	*V2*	*M 2*		*M*	*20%*	*Wt*	*Pc*	*Pk*	*3*	*0*	*P1+3, E3+3 E2+2, E7+1*	*1985*		*Major efforts were made in the late 80'ies and have been maintained*
Dams (with Agroforestry)	*WH*	*S6*	*M 1*		*M*	*15%*	*Wt*	*Cn*	*Ha*	*2*	*1*	*P1+2, S2+1 E1+2*	*1980*	*RSA05*	*Great potential for up-scaling*

Table 4: Expert recommendation (Example)

Name: ___X Y_____ **Country:** __*South Africa*

Mapping Unit Id (LUS + admin. unit): **113** *(Savanna + Ratlou municipality)*

Expert recommendation (Step 5)	
Expert recommendation	**Remarks and additional information**
P	*Maintain good soil cover conditions through agroforestry systems*
M	*Reduce loss of water through runoff and evaporation by the soil surface through mulching and minimum tillage.*

4.3 Local Assessment field data collection formats

4.3.1 Assessing SLM Technologies and Approaches

TABLE 8 Field form – WOCAT Inventory on SLM technologies

WOCAT Inventory on SLM Technologies (page A)

Date: Country/region: Contributor: (Name, institutions, address, email)

ID*	Name of Technology	Land use type	Position	Area	Main types of land degradation addressed	Conservation measures	Climate	Tolerance / sensitivity of technology to climatic extremes			Slope
								tolerant	sensitive	not known	
...1											
...2											
...3											

See Notes below for details of information to provide in each column *Give consecutive numbers for ID.

ID	Short definition/description of SLM Technology (containing key characteristics of the technology)
...1	
...2	
...3	

For more detailed explanations and definitions refer to the basic version of the questionnaire on SLM technologies
http://www.wocat.net/en/methods/case-study-assessment-qtqa/questionnaires.html

TABLE 9 Field form – WOCAT Inventory on SLM approaches

WOCAT Inventory on SLM Approaches (page A)

Date: Country/region: Contributor: (Name, institutions, address, email)

ID*	Name of Approach	For which land use type	Position	Area	Type of Approach	Implementing bodies	Objectives	Land user involvement	
								Initiation phase	Implementation phase
...1									
...2									
...3									

See Notes below for details of required information to provide in each column *Give consecutive numbers for ID

ID	Short definition/description of SLM Approach (containing key characteristics of the approach)
...1	
...2	
...3	

For more detailed explanations and definitions refer to the basic version of the questionnaire on SLM approaches
http://www.wocat.net/en/methods/case-study-assessment-qtqa/questionnaires.html

TABLE 9 Field form – WOCAT Inventory on SLM approaches *(continued)*

WOCAT Inventory on SLM Approaches (page B)

Date: Country/region: Contributor: (Name, institutions, address, email)

ID*	Technical support	External material support	Motivation of land user to implement SLM	Impact	Photo	Ranking	
						World Map	Potential
...1							
...2							
...3							

See Notes below for details of required information to provide in each column *Give consecutive numbers for ID

ID	Strengths of SLM Approach	Weaknesses of SLM Approach
...1		
...2		
...3		

For more detailed explanations and definitions refer to the basic version of the questionnaire on SLM approaches
http://www.wocat.net/en/methods/case-study-assessment-qtqa/questionnaires.html

4.3.2 Soil Assessment data collection format

FIELD SCORE CARD

Soil Condition Assessed using VS-Fast Methodolgy

PART A: SOIL VISUAL DESCRIPTORS

Date:
Land Use (Current and Past):
Site Location:
Recent Weather Conditions:
Soil Type:
Soil Structure:
Soil Texture:
Soil Colour:
"Walk in" Observations (soil / crop residues):

Soil Profile sketch

Visual Indicator of Soil Quality	Visual Score (VS) 0 = Poor Condition 1 = Moderate Condition 2 = Good Condition		Weighting	VS-Fast score
Tillage pan			x 3	
Aggregate Size Distribution			x 3	
Soil Crusts * * *Score for either "negative" or "positive (biological)" crusts*	**(negative)** 2 = no crust 1 = some cracking 0 = continuous crust	**(positive = biological)** 0 = Poor 1=Moderate 2 = Good	x 2	
Earthworms (or other more pertinent soil fauna)			x 2	
Roots			x 3	
Sum of visual VS-Fast scores				

Soil Visual Assessment	Sum of visual VS-Fast Scores
"Poor"	< 7
"Moderate"	7 – 14
"Good"	15 – 26

FIELD SCORE CARD

Soil Condition Assessed using VS-Fast Methodolgy

PART B: FIELD SOIL MEASUREMENTS

Field Measurement	Actual Value	Visual Score (VS)* 0 = Poor Condition 1 = Moderate Condition 2 = Good Condition		Weighting	VS-Fast score
Slaking and Dispersion		(scores: 0-4)		x 1.5	
Soil pH		Not scored		Not scored	
Water Infiltration *"negative" = sands* *"positive" = other soils*		**(negative = sands)** 0 = fast 1 = medium 2 = slow	**(positive = all other soils)** 0 = slow 1 = medium 2 = fast	x 3	
Organic C – labile fraction				x 2	
Soil salinity (EC)				x 3	
Sum of soil measurement VS-Fast scores					

* These scores not applicable to Slake/Dispersion test, where scores range from 0 to 4 (hence ½ weighting value)

Soil Measurement Assessment	Sum of VS-Fast Scores
"Poor"	< 7
"Moderate"	7 – 14
"Good"	15 – 22

Total VS-Fast score (Part A + Part B) scores	
"Poor"	< 14
"Moderate"	14 – 28
"Good"	30 – 48

Other Notes, e.g. Site Photo; Soil Photo or Sketches of soil, pit location...

4.3.3 Vegetation Assessment data collection format

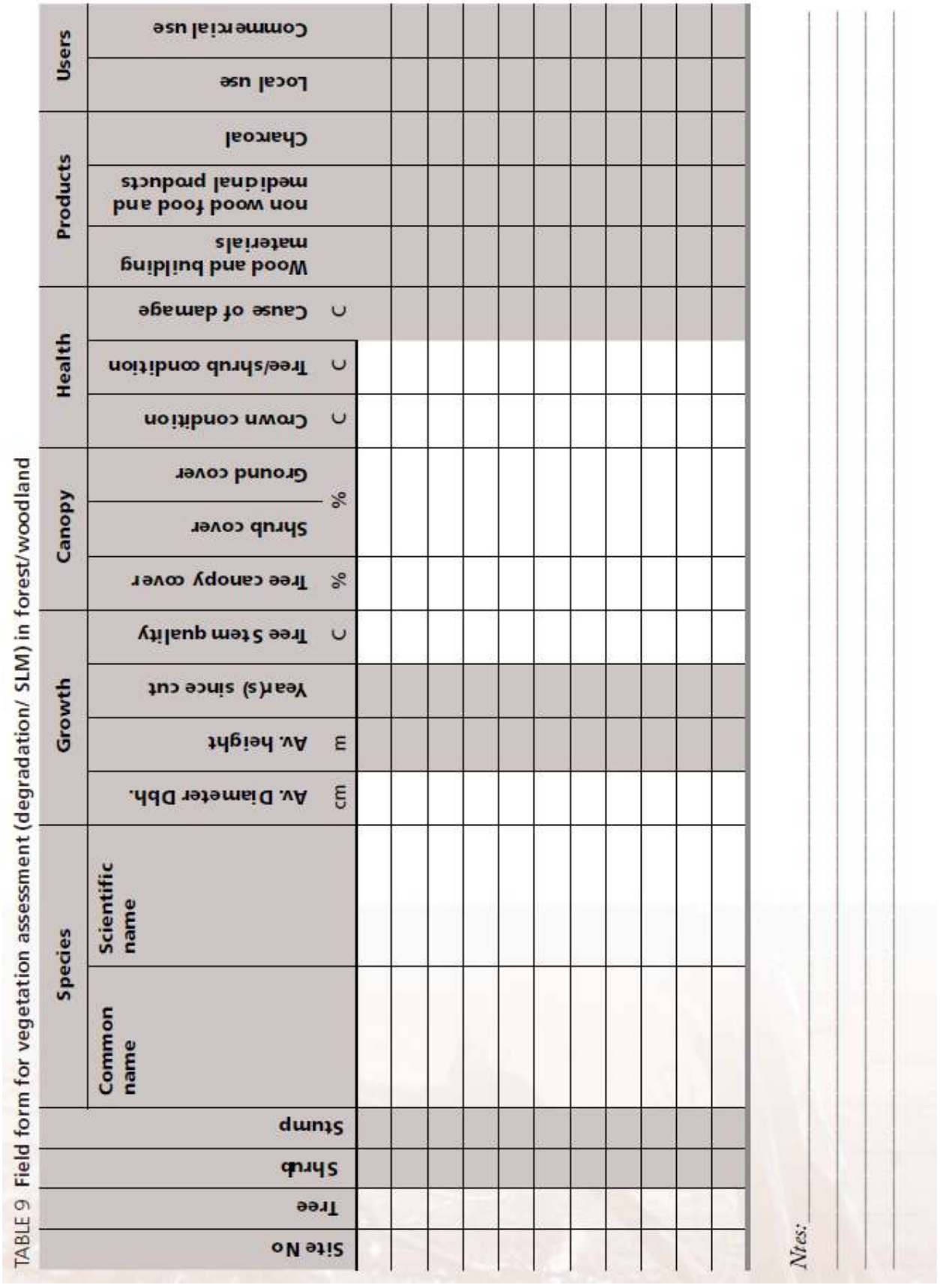


TABLE 9 Field form for vegetation assessment (degradation/ SLM) in forest/woodland

Site No	Species		Growth						Canopy			Health			Products			Users	
	Common name	Scientific name	Av. Diameter Dbh. cm	Av. height m	Year(s) since cut	Tree Stem quality C	Tree canopy cover %	Shrub cover %	Ground cover %	Crown condition C	Tree/shrub condition C	Cause of damage C	Wood and building materials	non wood food and medicinal products	Charcoal	Local use	Commercial use
Tree																	
Shrub																	
Stump																	

Nres:

TABLE 16 **Field form – Assessment of (natural vegetation and crop condition and productivity in croplands**

				Species (natural vegetation and crop)		**Natural vegetation**					**Crop condition**							**Products and Yield**			
Site No	Av. Farm size (ha)	Av field size (ha)	Av. number of parcels	**Common name**	**Scientific name**	Distance from cropland	Landscape features	Contribution to household	Use for mulch, soil OM	Ground cover	Crop establishment/ vigour	Crop size	Crop species diversity	Crop varietal diversity	Crop cover	Pest / disease incidence above ground and roots	Leaf colour / signs of nutrient deficiencies	Production costs	Y Yield (1ary and 2ary products)	Users of products (share local users to external)	Harvested product diversity
	ha	ha				km	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C

crop size e.g (e.g. ht; or diameter at maturity)

4.3.4 Water Resource Assessment data collection format

Water resource assessment

Besides review of the secondary information, water resource assessment is conducted in field through key information interview and field measurements of biophysical indicators if no up-to-date secondary information are available.

I. Hydrological regime and Water supply (please tick)

	Increase	Decrease	No change
Hydrological regime and sediment-related processes			
Surface runoff			
Peak flow/floods			
Base flow/ dry season flow			
Ground water recharge			
Soil moisture recharge			
Erosion and sediment load			
Water Quality and their causes			
Pathogens			
Nutrients and Organic matter			
Pesticides and other persistent organic pollutants			
Salinity			

Drought / flood risk and incidence

Do serious droughts / floods occur in the area? /__/ Yes /__/ No

If yes, how frequent are the drought / flood events? ……..

Have they become more or less common in the last 10 years? /__/ Yes /__/ No

Why do local people think this is happening (i.e. such as bare, compacted or crusted soils increasing runoff and hindering infiltration, the use of less drought resilient crop species, the deviation of streams)?

……

What is the period of drying up or flooding (months and interval)?

……

What are the main impacts they have on the different livelihoods activities?

……

Distance and access to water

What is the approximate distance (km) and time (min) taken to reach water for:

i) domestic consumption in the dry and wet seasons …….
ii) livestock watering in the dry and wet seasons? …….
iii) Any changes in the last 10 years? ……..

How far (km) are the main grazing areas from nearest potable water source in:

I) the dry season …… ii) the wet season? …… iii) Has this changed over the last 10 years?.....

II. Water resources management and changes in demand

Demand on water

What changes have there been in demand on water and water withdrawals in the last decade for the different water uses (e.g. number of dried-up wells / boreholes)?

……

How is the water supply managed and by whom? Is the management sustainable and equitable?

……

Do all people in the community / area have equal rights to use water resource?

……

If not what are the differences?

……

Water resources management

Have there been changes in the last 10 years in water conservation, water harvesting activities and irrigation:

a- Soil and water conservation: What techniques are used to optimise moisture and water capture, retention, infiltration and groundwater recharge? Have they been effective?

Soil and water conservation measures	*Effectiveness (Yes/No)*	*Impacts (e.g. increase in productivity, income, health, reduced risk of crop failure)*	*Proportion of people applying these measures (%)*
Bench terraces (level, forward or backward sloping)			
Contour bunds / banks (level, graded, semi-circular, v-shaped, trapezoidal etc.)			
Graded ditches, waterways and cut-off drains;			
Level ditches / pits (infiltration, retention, sediment and sand traps)			

Soil cover and mulching.			
Others……			

b- What are the water harvesting techniques at present

- Dams, tanks, Reservoirs
- Roof catchment and cisterns
- ……..
- ……..

Is water collected used for - /__/Agriculture /__/ domestic use /__/ livestock /__/ other ……

c- What are the types of irrigation systems operational? What is the proportion of each type?

Type	*Proportion of each type (%)*	*Water capture retention*	*Meeting plant water requirement*	*Minimizing drainage and leaching*	*Minimizing runoff*	*Minimizing evaporation from standing water*
		Effectiveness in ensuring water use efficiency (high, moderate, or low)				
Flood/surfaces						
Sprinkler						
Drip						
Pressure hose						
Others_____						

d- What are the constraints to effective water use? Please tick
/__/ Salinity /__/ Shortage/access /__/ Conflict /__/ Cost /__/ _____

e- What are the arrangements for water allocation / water rights and water conflict resolution / byelaws on water resources use and their application? Have there been significant changes in the last 10 years and why?

……
……
……

III. Offsite impacts on water resources (tick)

__ increasing pressure / demand on the water sources, removal of natural vegetation

__ drainage or permanent alteration of the water levels and flows

__ inflow of nutrients in run-off from fertilized farmland

__ inflow of non-selective pesticides or herbicides in run-off from adjacent or upstream farm land

__ changes in the water regime leading to increased floods, or reduced low

__ human activity (e.g. damming, irrigation or recreation and pollution in or close to the water body)

__ other ……..

Does *local land use and management* (vegetation, soil and water) in the study area affect water resources in off-site/ neighbouring areas (Select impacts from Table 36 P. 143 of Part 2 LADA manual)

……
……
……

Does *land use and management outside the study area* affect the water resources in the study area? (Select impacts from Table 36 P. 143 of Part 2 LADA manual)

……
……
……

What are the human and natural causes of off-site impacts? (Identify the relevant causes from Table 37 P 144 of Part 2 LADA manual and rank them in order of importance starting with the most important)

……
……
……

Note: Guidelines of Biophysical assessment of specific water resources, such as rivers, lakes, wetlands, irrigated lands and livestock watering points are given through p144-152 of Part 2 LADA manual. No questionnaires is included for their assessment here.

4.3.5 Livelihood Assessment data collection format

Household Livelihood assessment

1. Natural capital

1.1 Calendar of farming / herding activities by seasons in relation to rainfall

Activity	**Months** (or by seasons in local terms)											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Rainfalls H-High L-Low N-None												

Activity codes: Cropping: 1- Land preparation, 2- Planting, 3- Growing, 4- Harvesting 5-Herding.

1.2 Type of water source available, uses, constraints and changes in the last 10 years

Water Sources	**Use/available during which months?**	**Used for** D- Drinking, I- Irrigation, L- Livestock	**Need access rights or payment** (Yes/No)	**Constraints** P-Price D- Distance S- Safety Q- Quantity	**Changes**
Borehole					
Well					
Dam / Reservoir					
Rivers					
Pipe					
Other:					

1.3 Household land resources, terms of utilisation, and changes in the last 10 years

Household land use types	**Area of land (ha)**	**Terms of utilisation** O- Ownership R- Rental S- Share C- Communal A- Allocation	**Changes**
Cropping 1:			
Cropping 2:			
Cropping 3:			
Pastures			
Natural grazing lands			
Forest / Woodlands			

Who is responsible for forest management (natural and planted trees)?
Natural: _____
Planted: _____

1.4 Household uses of each crop types

Crop types	Crop uses			
	Market	Consumption	Fodder	Other
Hay				
Vegetables				
Fruits				
Other				

1.5 Livestock number by species, details and/or changes in the last 10 years

Animal species	Approximate numbers	Details/Changes
Cattle		
Goats		
Sheep		
Camel		
Other:		

1.6 Vegetation resource(s) used by the household for different activities

Activities	Resources used			
	Land	Water	Trees/Forest	Natural Vegetation
Grow crop				
Fetch water/ water animals				
Wild food				
Fuel wood				
Feed livestock				
Other:				

1.7 Main constraints, problems, changes in vegetation resources in the last 10 years

Constraints	Resources				Changes
	Land	Water	Trees/Forest	Natural Vegetation	
Access					
Use					
Quality					
Other:					

1.8 General changes in activities and practices: Has the household made changes in his/her cultivation practices / rangeland management over the last 10 years?

2. Land degradation

2.1 Quality assessment of the conditions of different land resources and changes

	Cropping lands	Grazing lands	Forested lands	Water resources
Quality				
Changes/Trends				

2.2, 2.3 & 2.4 Types of land degradation, causes, impacts and changes

Land degradation types/problems	Causes (direct pressures)	Root causes (driving forces)	Impacts (I)	Changes in last 10 years (trend)

Examples of land degradation: *soil loss by runoffs or wind, gully, loss of soil fertility, reduced biomass in the grazing lands, reduced quality of the grazing, loss of palatable species, etc*

Example of impacts: *reduction of income, diminution of food production, fewer products to sell, reduction of construction materials, more time spent on farming/grazing/fetching water, need more inputs/fertilisers, out migration, etc*

2.5 Measures / interventions currently used to control land degradation / promote sustainable land management and specific conservation / degradation control measures

SLM / conservation	What for	When	By whom	Obstacles to scale up

Potential conservation / SLM measures / interventions that are known but not currently implemented

Potential conservation/SLM measures	Obstacles to implement

3. Financial capital and production

3.1, 3.2 & 3.3 Sources and importance of each household income, their use and changes in the last 10 years

Income sources	Order of priority	Use for?	Changes
Crop production			
Livestock production			
Remittances			
Fishing			
Forest products			
Off farm employment			
Business			
Processing Food (e.g. honey, cheese, etc.)			
Other:			

3.4 & 3.5 Changes in yield, inputs and practices in the last 10 years

Crop production	Changes (trend)
Yield	
Fertilizers / Inputs	
Practices / Machinery	

Record yields and fertilizer uses per year if available/known by household.

3.6 Forms of aid received to support agricultural activities

Forms of aid	Why	When	By whom	Changes
Subsidies				
Extension services				
Payments				
Food aids				
Micro-credit Project / program				
Cooperative bank loan				
Borrowing money from relatives				

4. Vulnerability context

4.1 Crises faced by the household in the last 10 years, and impacts / effects on natural resources and land management

Crises	When	Impacts on natural resources/Land management
Drought		
Food insecurity		
Crop failure		
Livestock losses		
Natural disaster		
Health problem		
War/conflict		
Migration		
Indebtedness		
Other:		

4.2 Periods of each year with shortage or limited / difficult access to natural resources

Shortage / Limited access	Month(s)
Food	
Grazing	
Fodder	
Water	
Other:	

4.3 Main changes in the landscape and living conditions in the last 10 years (trends)

Changes in landscape

1. _____
2. _____
3. _____

Changes in livelihoods:

1. _____
2. _____
3. _____

4.4 Main problems in the area

1. _____
2. _____
3. _____

5. Physical capital

5.1 Changes in services / infrastructures access in the last 10 years

Services / Infrastructure	Access G- Good M- Medium P- Poor	Distance (or time)	Changes
Market			
Medical centre			
School			
Farming cooperative			
Extension / research			
Water points			
Main town / city			
Other:			

5.2 Services / infrastructures not accessible or missing and explain why

Services / Infrastructure	Not accessible	Missing	Why
Market			
Medical centre			
School			
Farming cooperative			
Extension / research			
Water points			
Main town / city			
Other:			

5.3 Vehicles and farming equipment used by the household and changes in 10 years

Household's goods	Term of access (O-own; R rent; S share)	Changes
Car		
Motorcycle		
Bicycle		
Farm tools		
Tractor		
Donkey / bull / horse		
Other:		

6. Policies, institutions and processes

6.1 Decision makers who control access and use of communal resources and changes in the last 10 years

Communal resources	Decision-makers	Changes
Water		
Grazing lands		
Trees/Forests/woodlands		
Other:		

6.2 Formal and informal laws and rules affecting land/resources management and changes in the last 10 years

Laws, rules, regulations	F- Formal I-Informal	Effects on natural resources and land management	Changes

7. Social capital

7.1, 7.2 & 7.3 Household's membership of associations and benefits

Associations	Since when	Direct benefits[1]	Access to new information[2]
Local group			
Producer associations			
Womens' groups			
NGO			
Social/religious groups			
Water committee/ users association			
Other:			

Codes for Benefits: B- Borrowing money; T- Technical support; S- Share equipment; M- Micro-credit; F- Food processing facilities; T- Transport to market; A- Access to natural resources; C- Community integration; O- Other

Codes for Access to new information: S- Seeds; C- Conservation agriculture; L- Land degradation control measures, R- Rangelands management M- Marketing; O- Other (specify)

8. Human capital and household composition

8.1 Educational level and training of family members

Family	Educational level	Training on conservation / SLM
Head		
Mother		
Children		

8.2 Composition of family members

Family	Number
Total members	
Active workers	
Children	
Migrants	

8.3 Age range of household head

Age of household head	
<20	
20-30	
30-40	
40-50	
50-60	
>60	

4.3.6 Format for Key Informant and land users

Key informant and land user interview

Field form – Sustainable Land Management (SLM) practices

Land degradation problem	SLM practice	Conservation effectiveness (+, neutral, -)	Benefits of SLM practice	Utilization by land users in the area	Constraints to adoption*

* Examples of Constraints: No perception of land degradation
No incentives to adopt SLM practices (e.g. insecurity of tenure, seasonal migration, etc)
No capability to remedy (e.g. land shortage, labour unavailability, lack of capital)

Field form – Plant indicator species

Common name	Scientific name	What does it indicate?	Specific qualities, characteristics	Causes/pressures

Field form – Yield trend analysis

Time (year)	Yield	Events

Summary table of costs and benefits of management practices

Year	Costs (and resources required)					Benefits					
	Labor		Tools	Loss in crop area		Increase in crop yield		Savings on fertilizer		Pole production	
	Min (a)	*Max (b)*	*Actual (c)*	*Min (d)*	*Max (e)*	*Min (f)*	*Max (g)*	*Min (h)*	*Max (i)*	*Min (j)*	*Max (k)*
1											
2											
3											

Calculating net cash flow

Year	Total costs		Total benefits		Net cash flow	
	Min (a+c+d=r)	Max (b+c+e=s)	Min (f+h+j=t)	Max (g+i+k=u)	Min (t – s)	Max (u – r)
1						
2						

3						

Comparing cash flow scenarios

Year	**Lower discount rate**			**Upper discount rate**		
	Discount factor	Minimum discounted net cash flow	Maximum discounted net cash flow	Discount factor	Minimum discounted net cash flow	Maximum discounted net cash flow
1						
2						
3						
NPV total						

4.3.7 Form for community focus discussions

Field form for the community focus group discussion

[This form refers to the questionnaire check list (Tool 1.1). The questions have to be reviewed by the team prior to the focus group discussion, in order to adapt the questionnaire to the local context and terminology.]

Study area or community name: _____ Name of record keeper: _____
Date of discussion: _____

1. Population size and number of households: _____

2. History, migration and pattern of settlement:

_____
_____
_____

3. Land units, land use types and water sources in the study area as differentiated by community members

Land Units (biophysical)	**Land use types** (includes management practices)	**Water Sources** (natural and manmade)

4 & 5. Main livelihood / productive activities during rainy and dry seasons, also associated resource uses and products generated.

Livelihood Activities	**Season** R- Rainy D- Dry B- Both	**Resources used** G- Grazing lands M- Medicinal plants W- Wild food W- Water sources F- Forest/tree O- Other	**Products** F- Food W- Wood E- Energy G- other products I– Income
1.			
2.			
3.			
4.			
5.			
6.			

6. Important types of land degradation in the study area, their causes, the impacts, and changes (trends) over the last 10 years.

Land degradation			
Types	**Causes**	**Impacts**	**Changes (trend)**
Erosion by water (splash, rill, gully - specify which)			
Erosion by wind (dust storms, sand blow, sediment deposits, dunes, etc)			
Soil physical degradation (compaction, surface sealing, crusting, pulverisation, etc.)			
Soil biological degradation (loss or soil organic matter or soil life, declining fertility			
Soil chemical degradation (nutrient mining, salinity, acidity pollution, etc)			

Bullet points 7 to 10 below are used to record, as appropriate, relevant details on soil, vegetation, water and / or socio-economic aspects of land degradation:

7. Indicators and causes of soil degradation – including erosion and deterioration of soil properties, as perceived by the community

Locally perceived Soil Indicators	Causes of Soil degradation

8. Indicators and causes of degradation of natural vegetation and biodiversity, as perceived by the community in crop land, in grazing land and in wood/forest land (specify).

Vegetation Indicators	Changes/Trends (Yes/No; L, M, H)	Causes
Deforestation		
Composition of vegetation (structure and species diversity)		
Health and quality of grazing lands Health and quality of forests		
Abundance of useful species (edible, palatable, medicinal, used for energy, building or crafts, etc.)		
Presence of invasive, harmful or less useful species (toxic, pests, less palatable species)		
Bush encroachment		
Evidence of frequent or severe burning		
Extent and vegetation of wetlands		
Diversity of habitats in the area		
Other (specify)...		

9. Livestock management measures and their problems in terms of land degradation or benefits in terms of sustainable land management

Livestock management measure	**Presence** High, Moderate, Few, None	**When and Why? (reasons)**	**What problems do they cause?**	**What are the benefits?**
Range enclosures				
Rotational grazing				
Ranching				
Stall fed (zero grazed) animals				
Seasonal livestock movements (agro-pastoralism)				
Permanent livestock movements (nomadic pastoralism)				
Cattle grazing corridors				
Use of bye laws, other measures, to control livestock numbers, burning, etc.				
Other				

10. Forest management measures

Forest management measure	**Presence** High, Moderate, Few, None	**When and Why? (reasons)**	**What problems do they cause?**	**What are the benefits?**
Clear logging				
Selective felling				
Coppicing or pollarding				
Livestock grazing in forest				
Fire control (fire breaks etc)				
Use of bye laws, other measures, to control forest use and exploitation of products and wildlife				
Other				

11. Changes and causes of water quantity and quality

Water	**Changes** (trends)	**Causes**
Quantity • Rainfall • Drought • Flood • Demand -surface water • Demand - groundwater (wells, boreholes) • Irrigation area/use • Other uses		
Quality • Drinking water • Irrigation • Other uses		

Who practices irrigation in the community? Have the area / crops / seasons changed?

_____

Are community members paying for:

- drinkingwater?_____
- wateringanimals?_____
- irrigation?_____

What are the implications?

Bullet points 12 to 13 below are used to record livelihoods problems and coping mechanisms

12. Main livelihoods problems relating to land use / management and degradation:
    1.
    2.
    3.

Specific issues relating to:

- Occurrenceofconflict(s)_____
- FoodInsecurity_____
- Poverty_____
- Drought/Flood_____
- Access.rights/tenure_____

13. Main coping mechanisms and strategies:
    1.
    2.
    3.

14. Sustainable land management practices for land degradation control or land restoration

SLM practices	Reasons for implementation	When, and by whom	Results

15. Importance of organizations influencing sustainability of land management at local level:

Organizations (specify)	**Influence on sustainability of land management (LD / SLM)**		
	Importance H- High, M-Medium, L-Low	**Influence** + or -	**Remarks**
Informal group			
Cooperative of land users			
NGO local/international			
Private sector			
Local leader			
Government authorities			
Research agencies			
Other			

16. Main informal and formal systems of tenure and rights to access land resources in the community

Land tenure system	**Details**	**Influence on SLM**
• Ownership • Allocation • Share • Rent • Communal		
Access rights system	**Details**	**Influence on SLM**
• Cropping lands • Grazing lands • Forest Lands • Trees • Water		

17. Effects of laws, rules and regulations concerning land resources on land degradation and / or conservation / SLM

Laws, rules and regulations	Effects on land degradation / SLM

18. Major social divisions affecting community members' access and management of natural resources
(e.g. poverty / wealth status, religious or caste groupings, pastoralists or settled farmers, irrigators or rain-fed farmers)

Social divisions	Effects on access and management of natural resources

19. Record any other relevant information arising during the discussion:

4.4 Other training data sets

Following software and training data sets available for further training programs.

1. GIS compatible land use maps (1:10000 scale) developed for two pilot sides.
2. LUS system map for pilot sites with unique LUS ID system.
3. Microsoft Access data sets for each GN division were developed.
4. Filled set of MQ formats (hard copies).
5. LUS change and Degradation related maps (soft copy versions)