



International
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100
1919-2019

TOOLS AND GUIDELINES
for Watershed Management
in the South-Western Region
of **SRI LANKA** for
Increased Climate Resilience

TOOLS AND GUIDELINES FOR WATERSHED MANAGEMENT IN THE SOUTH-WESTERN REGION OF SRI LANKA FOR INCREASED CLIMATE RESILIENCE

**The research and the compilation of this document was
carried out by the Environmental Foundation (Guarantee) Limited.**

ILO Country Office for Sri Lanka and the Maldives

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First published 2019

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Tools and guidelines for watershed management in the South-Western region of Sri Lanka for increased climate resilience with a special focus on tea growing areas

ISBN : 978-92-2-133474-3 (web pdf)

International Labour Office: ILO Country Office for Sri Lanka and the Maldives

Also available in Sinhala: *Tools and guidelines for watershed management in the South-Western region of Sri Lanka for increased climate resilience with a special focus on tea growing areas*

ISBN: 978-92-2-133473-6 (print), Colombo, 2019

ILO Cataloguing in Publication Data

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Printed in Colombo, Sri Lanka

Foreword

The International Labour Organization (ILO) promotes and supports its 187 member states to meet their commitment to ensure decent work for all. The ILO in Sri Lanka has initiated “the creation of sustainable, inclusive and decent employment” as a core programme pillar under its Decent Work Country Programme (DWCP). This resonates with the Sustainable Development Goals (SDGs) commitment to leave no one behind. As Sri Lanka fast approaches upper-middle income status, the need is to ensure that marginalised communities such as workers outside the formal economy and at-risk populations are able to be part of the shared prosperity.

The rural economy and the agriculture sector in particular face challenges due to frequently occurring natural disasters, which Sri Lanka is highly vulnerable to. The segment is negatively impacted by the increasing frequency of flood and drought incidents and needs to be enabled to withstand these shocks.

With the aim to build disaster resilience in a particularly climate vulnerable sector, the study has to focus on rural communities in plantations. Further emphasis is paid to tea growing areas as the sustainability of the tea industry and the livelihoods of its low-income workers greatly depend on the ability of the sector to be buoyant amidst the scale and intensity of natural disasters.

The main effect of disasters in the area of focus were floods and landslides, making it important to identify vulnerable sites in order to reduce risk and better mitigate the effects of natural calamities. The research found that better management of watershed areas and inculcating sustainable land use practices would have a positive impact on reducing the risk flood and landslide.

Strengthening disaster resilience is a key focus under the ILO Sri Lanka flagship “Jobs for Peace and Resilience” programme, under which this manual was developed. The study is a pilot and presents tools and guidelines for watershed management to help guide future work. It provides an effective model in support of improved livelihoods through strengthened disaster resilience of flood and landslide-affected communities.

The manual guides practitioners, specifically targeting local government officers mandated to carry out development work as well as other stakeholders engaged in land use management. It is hoped this knowledge would enable informed decision making and lead to greater engagement of relevant communities for implementation.

Although the publication centres on tea plantations and small holders, certain sections are just as applicable to other agriculture practitioners and land users in watershed areas. Communities should be made aware of how to replicate the success by adopting better water management practices and improved land use techniques.

This would help the creation of more disaster-resilient local economies, in improved rural livelihoods, and aid in achieving a more inclusive and sustainable growth.

Ms Simrin Singh

Country Director

ILO Office for Sri Lanka and the Maldives

PREFACE

Due to rising global surface temperatures, intense storms and increased droughts are more likely to occur. Warmer atmospheric and oceanic temperatures can lead to increased wind speed resulting in tropical storms. Being a tropical country, Sri Lanka too is experiencing changes in weather patterns; floods, landslides and droughts being frequent in the country.

Sri Lanka is on the path towards becoming an upper middle-income country and to progressively achieving the Sustainable Development Goals. However, an estimated one fifth of the population is considered 'poor' and vulnerable to shocks that can push them back into poverty. The need for improved disaster preparedness has arisen as it promotes stronger resilience and helps prevent excessive damage to infrastructure.

Maintaining environment sustainability is a vital consideration for reducing the risks and impacts of climate induced adverse weather events. Flood risks are predominantly influenced by the velocity and volume of runoff within the catchment and by flow attenuation in the floodplain. Reduced infiltration due to loss of forest cover, increased impervious surfaces in the form of roofs, roads, pavements and informal settlements and lack of water storage options increase the flood and drought risks in certain areas more than others.

Integrated catchment management is essential to promote coordinated development and management of water, land and related resources in order to optimize economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems. A catchment is not an isolated unit; it comprises the headwater areas, side slopes, valley floor and water bodies including its abiotic and biotic components. Therefore, catchment management requires the participation of a large number of stakeholders and demands resolving and reconciling foreseeable land use by addressing priorities and conflicts.

Catchment management mainly involves water and soil conservation methods, which could be achieved by proper land use planning, regardless of whether the land is being used for agriculture or for infrastructure. It requires the understanding of watershed structure, its processes and the evaluation and prioritization of selected areas.

Unfortunately, most traditional land use planning teams from national to sub-national levels are not capable of conducting these analyses, for the most part. Planners are generally unaware or uninformed of the importance of integrating watershed management practices into land use planning processes in a systematic manner.

This manual provides tools and guidelines that could be used by the sub-national administrative level to identify vulnerable areas in watersheds and incorporate watershed management practices for land use planning processes that would help minimize impacts from disasters.

EXECUTIVE SUMMARY

The “*Tools and Guidelines for Watershed Management in the South-Western Region of Sri Lanka for Increased Climate Resilience, with a Special Focus on Tea Growing Areas*”, provides guidance and recommendations to accommodate existing land use and planning of land conservation in tea growing areas in a manner that would ensure that natural resources present in watershed areas remain consistent.

A watershed is the land area that channels rainfall through a common point of the drainage system. Watershed management is predominantly relevant for upland areas where different land use practices such as agriculture, forestry, and plantations can be observed. These land use practices and unregulated human activities have created a significant impact on the downstream areas of a watershed. Ratnapura and Kalutara districts are two of the main districts that are prone to frequent floods and intermittent droughts. Tea growing areas in Ratnapura and Kalutara districts were selected as the areas of study.

This publication consists of four chapters. The first chapter provides a brief introduction to the project. It describes the background of the project, key terminologies used and the benefits of applying watershed management practices. Chapter two describes how to identify the vulnerable areas for prioritization and implementation of watershed management practices.

This publication can be used for the identification of intervention areas with a high risk for natural disasters, and the necessary steps that can be applied for managing land use and land use changes. Data collected in relation to this study areas were used to formulate maps depicting the features of the landscape, and intervention areas. These maps include the geographical features of the area, the existing forests, agricultural and plantation areas as well as streams and river networks.

The third chapter describes issues within of Ratnapura and Kalutara districts in the Kalu Ganga basin and the use of several tools to create resilience among the communities to mitigate disasters occurring in the area. The last chapter provides an insight of the legal framework which can be used as a tool in watershed management.

The tools and guidelines in this publication can be used to implement flood, landslide, and drought mitigation methods at the field level, especially in tea growing areas, for watershed management purposes in relation to development activities carried out in the future. The document can also be used to create awareness among national and divisional level government stakeholders on how to create preparedness among tea plantation sector communities in watersheds to face climate related disasters and make them climate resilient.

ACKNOWLEDGEMENTS

The present guide was produced with the support of the project “Jobs for Peace and Resilience: Strengthening disaster resilience of rural communities and micro and small enterprises in the North and South West of Sri Lanka”. The International Labour Organisation (ILO) country office for Sri Lanka and the Maldives collaborated with the Environmental Foundation Limited (EFL) to carry out geospatial analysis of vulnerable and selected sites in the South-Western region of Sri Lanka—with a special focus on tea growing areas in the Rathnapura and Kalutara Districts.

The design and preparation of the tools and guidelines compilation is fully adapted to the national and sub-national context and specificities. It draws from international guides and best practices which for cultural, legal, social or traditional reasons needed adaptation to the Sri Lankan context.

This ILO-commissioned study was undertaken by EFL. A special thanks to Dr Eric Wikramanayake (Chairperson), Dr Chaturangi Wickramaratne (Environmental Scientist), Dr S.P. Chaminda (Senior Lecturer, University of Moratuwa), and Dr Lalitha Dissanayake (Senior Lecturer, University of Peradeniya) for their guidance; Ms Anushka Gunawardena and Ms Lasantha Withanage for their support in compiling the legal framework for this publication, and also Mr Rishan Yaheya and Ms Uvini Senanayake for the considerable effort and enthusiasm shown in seeing this endeavour through.

The valuable support of Ms Chamila Weerathunghe (National Project Coordinator – ILO) in recognizing the necessity for this study and technical inputs in reviewing the content and Mr Prasanth Senarathge for project administration support. The International Union for the Conservation of Nature (IUCN) should be recognized for the steadfast cooperation extended.

The technical services and feedback of Bjorn Johannessen, Senior Engineer, ILO Decent Work Technical Support Team for Asia is also appreciated.

Carrying out this study would not have been possible without the contributions of Ms Malani Lokupothagama (District Secretary, Ratnapura), Mr U.D.C. Jayalal (District Secretary, Kalutara), Mr S.B. Udowita (Additional District Secretary, Ratnapura), Mr D.L.W.D. Samarawickrama (Assistant Director – Planning, Kalutara), Mr Manju Gunawardana and other government officers who assisted by providing technical inputs and coordinating with other technical experts to obtain their responses.

The support received from the Department of Agrarian Development, Department of Agriculture, Disaster Management Centre, Department of Irrigation, Department of Land Use and Policy Planning, Department of Meteorology, Ministry of Plantation Industries, Department of Census and Statistics, Department of Surveys and the National Building Research Organization in providing essential spatial and non-spatial data is gratefully acknowledged.

The study was proof read by Ms Apsara Kapukotuwa while the preliminary pages were contributed by Surani Perera.

The usual disclaimers apply with respect to errors and omissions. The responsibility for views expressed in this study rests solely with the researchers and not their institution of affiliation, and publication does not constitute an endorsement by the International Labour Office.

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THE PROJECT

The International Labour Organization (ILO) under its flagship programme on Jobs for Peace and Resilience has adopted a proactive approach in climate and disaster resilience and development. The pilot project in Ratnapura and Kalutara, addresses flood resilience of tea plantation workers and tea small holders including other Micro Small and Medium Enterprise (MSME) sectors. Therefore, this document provides tools and guidelines for watershed management focusing on tea growing areas in Ratnapura and Kalutara districts. These tools and guidelines focus on improving the land and water management practices in tea growing areas that will ensure the health of the watershed to improve its benefits for upstream and downstream communities.

Furthermore, this document provides guidance on identifying vulnerable sites and prioritizing them for the purpose of implementing the tools and guidelines for management of watersheds in Ratnapura and Kalutara districts. As a part of the project, capacity building workshops will be conducted to create awareness as well as to train national and regional level government officers to integrate watershed management tools and guidelines into their periodic work.

Through visualization, planning and integrating tools and guidelines at watershed level could serve as initial step for addressing the larger concerns of the nation such as reducing the impacts of flooding and building a climate resilient community in the watershed areas.



Project Area: Kalu Ganga Basin in Ratnapura and Kalutara Districts

CHAPTER 1:

INTRODUCTION

1.1 BACKGROUND

Sri Lanka has 103 rivers and tributaries and the Central Highlands contain the major upper watersheds of those rivers and tributaries. The river basin or watershed consists of both natural and manmade resources, such as forests, buildings and so on. With increased erratic rainfalls and changes in rainfall patterns over the years, Sri Lanka has been facing various climate related disasters (or incidents) which resulted in loss of human lives, property damages and displacing many other families (DesInventar, 2011).

When resolving issues caused by disasters such as floods, droughts and landslides, the economy of the country is affected significantly. The frequency of these disasters has also increased over the past few years, where frequent flood events occurred in 2016, 2017, and 2018 (DesInventar, 2011). The severity of these climate related incidents has increased over time where rainfall has become intense causing flash floods in highly populated areas, and absence of rainfall which resulted in severe droughts in northern, eastern areas and some parts of southern and western areas of the country (DesInventar, 2011).

Impacts of disasters are multitudinous, ranging from socio-economic to environmental impacts. To mitigate and adapt to the some of the disasters, stakeholders need to invest funds not only to recover from disasters, but also to decrease the potential recurrence of such calamities. Out of 25 districts in Sri Lanka, 10 districts, namely Kandy, Matale, Nuwara Eliya, Badulla, Kegalle, Ratnapura, Kalutara, Galle, Matara, and Hambantota, have been identified as landslide prone areas by the National Building Research Organization (NBRO) (National Building Research Organization, 2018). Unfortunately, even though these areas have been identified, the precautionary methods taken to counter the effects of these incidents and to reduce the number of lives lost and the families affected are not adequate. The reactive stance taken to incidents by both the responsible, mandated government authorities and the general public results in massive losses each year.

Although floods are a natural phenomenon that has existed for centuries and is important for the functioning of wetlands and floodplains, human interference and human activities in the river basins have caused alterations of flood paths converting floods into a hazardous condition. In order to manage floods, it is important to take the entire river basin into account rather than taking action according to political boundaries ("Best Practices on flood prevention, protection and mitigation", 2003).

Integrated catchment management is essential to promote coordinated development and management of water, land and other related resources in order to optimize economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems and also to create resilience to future environment related incidents.

Having guidelines for watershed management is important as it helps to influence the way by which water resources are managed at each of its contact points. If this occurs in a similar manner at all locations of the watershed it will in turn have a cumulative advantage for the entire watershed and will also allow improvement of food production and environment protection (Pandurang, Kulkarni and Swami, 2012).

The tools and guidelines in this document can be used to implement flood/drought mitigation methods at field level for watershed management purposes in relation to development activities carried out in the future. The document can also be used to create awareness among national and divisional level government stakeholders on how to improve preparedness among watershed communities to face climate related disasters and make them climate resilient.

1.2 DEFINITIONS AND KEY TERMINOLOGY

To understand how to use the tools and guidelines of this document, it is important to understand the underlying terminology and key concepts and definitions used in this document.

1.2.1 WATERSHED

A watershed (drainage basin/ catchment area), is defined as a land area that channels rainfall through a common point of the drainage system. The drainage basin is the fundamental landscape unit concerned with the collection and distribution of water and sediment. Each basin is separated from its neighbor by a divide, or interfluvies. Thus, the basin can be viewed as a geomorphic system or unit. Watershed is not only a hydrological unit, it is an incorporation of socio-economic and political entities (NOAA, n.d).

1.2.2 WATERSHED MANAGEMENT

Watershed management is a technique of managing watershed resources to maximize the benefits that can be derived from them without affecting the ecological sustainability. It seeks to balance healthy ecological, economic, and cultural/social conditions within a watershed by including adaptive, comprehensive, integrated multi-resource management planning processes (Wang et al., 2016).

1.2.3 INTEGRATED WATERSHED MANAGEMENT

Integrated watershed management is the sustainable management of land and water resources within a watershed by local governments and stakeholders in order to control and conserve hydrology, ensure biodiversity, minimize land degradation and optimize economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems (Chifamba, 2011).

1.2.4 EXTREME WEATHER EVENTS

With the warming of earth, many other changes to the Earth's climate have been triggered. Extreme weather events are severe weather conditions that occur unexpectedly or unpredictably. Frequent heat waves, droughts, heavy downpours causing floods, hurricanes are among major extreme weather events. Human induced climate change has already increased the number and strength of some of these extreme events (Balasubramanian, 2018).

1.2.5 CLIMATE RESILIENCE

Climate resilience is the capacity for a socio-ecological system to absorb and withstand stresses and maintain its function upon external stresses imposed by climate change and the ability to adapt, re-organize and evolve to maintain sustainability of the system's basic structure and function and leaving it better prepared for future climate change impacts (Kerner and Thomas, 2014).

1.2.6 VULNERABILITY

From a climate change perspective, according to the IPCC Fifth Assessment Report, vulnerability is defined as "The propensity or predisposition to be adversely affected". Vulnerability encompasses three components i.e. exposure, sensitivity and adaptive capacity (Pachauri and Meyer, 2014).

1.2.7 MITIGATION

Mitigation is defined as the reduction of risk of loss, severity or gravity from the occurrence of any undesirable event such as a disaster (Kelman, 2018).

1.2.8 ADAPTATION

According to the climate change perspective, in human systems adaptation is “the process of adjustment to the actual or expected climate and its effects, in order to moderate harm or exploit beneficial opportunities”. In natural systems, “it is the process of adjustment to the actual climate and its effects” (Pachauri and Meyer, 2014).

1.2.9 SPATIAL DATA

Spatial data (geospatial data) contains locational information of an object which can be represented by numerical values in a geographic coordinate system (IBGE, 2011).

1.3 BENEFITS

The application of watershed management tools and guidelines will be beneficial in many aspects, both ecologically and socio-economically. Watersheds integrate all features of the environment including climate, terrain, land use and land cover, human activities, human communities and biota. Therefore, the condition of the watershed will affect all the integrated entities including humans. Degrading watersheds or poorly managed watersheds could lead to many impacts on both the environment and humans.

A healthy watershed improves both human and ecological health by conserving and maintaining the quality of water, promoting stream flow, supporting groundwater recharge, improving quality of soil for crops and livestock, and also providing habitat for wildlife. Ecosystem services provided by a healthy watershed is difficult to be replaced and very expensive to artificially engineer. A healthy watershed improves the economic health as well. It produces energy and supplies water for agriculture, industry and households. Improved soil quality will increase the amount of yield from crops, reduces the expenditure on fertilizers and increases income generation (“The Economic Benefits of Protecting Healthy Watersheds”, 2012). A healthy watershed also increases resilience towards climate change threats by better adapting for extreme weather events, thus benefitting the economy by reducing expenditure on disasters.

CHAPTER 2:

EXISTING MAJOR ISSUES IN WATERSHED AREAS

2.1 IMPACTS FROM LAND USE CHANGE

2.1.1 SOIL EROSION

Conversion of land from natural vegetation to agricultural land and plantations has been the norm over the years with or without the use of sustainable practices. Vegetation cover provides protection against soil erosion and runoffs. Removing vegetation in montane areas is a known cause of sedimentation, water quality reduction and increased probability of floods (Zhou *et al.*, 2008). Removal of vegetation cover cause direct exposure to sunlight and rain which in turn result in the reduction of soil productivity.

Tea cultivated areas experience higher rates of soil erosion than other plantation areas (such as rubber and coconut) due to the steep topography and management methods that are practiced (Krishnarajah, 1985). Plantation areas are commonly seen in hill areas of Ratnapura and Kalutara. Although, plantations provide more ground or vegetation cover, it is still susceptible to landslides. This is due to the disturbances caused to the top soil during land clearing. According to the NBRO, landslides have been reported in the Divisions of Kalawana, Wewalkandura, Nivithigala Wanniwatha, Eheliyagoda and Maheengoda Grama Niladari divisions causing severe property damages and loss of human lives. The common land use types in those areas have been identified as Tea, Rubber and Cinnamon cultivation. When these plantations are exposed to high intensity rainfall over a long period of time, it could increase soil erosion which could lead to landslides in sloped areas.



Figure 2.1: Soil erosion can occur due to unmanaged tea lands. The above image shows soil erosion and the potential threat of further erosion on tea land (Source: EFL).

In a natural forest, erosion is not a dominant factor due to the presence of the understory, deep rooted vegetation and leaf litter which allows water infiltration and act as a protective barrier to rainfall. But in monoculture land areas such as rubber or tea plantations, soil is depleted resulting in soil erosion and degradation (Baltodano, 2000). Further, mechanized or non-mechanized harvesting methods can lead to soil compaction and can affect the growth of understory where the protective layer of ground vegetation is missing.

Exposed soil in a sloped area can cause sheet and rill erosion. The degree of erosion will depend on the land use. Sheet erosion occurs when the topsoil is removed or loosened, and rill erosion occurs when runoff water forms small channels as it flows down a slope which is known as a rill. Overtime, with erosion and runoff, the soil that is loosened in slopes must be deposited at some point in a lower elevation. This can be either lowlands, water bodies, rivers or streams. If the soil is eroded from the upper catchment and deposited on a lower part of the catchment, this may cause hindrance to the flow of water, thus causing floods. Although, sedimentation and erosion are natural processes, inappropriate land use such as conversion of lands for agricultural purposes can cause direct damage to waterways, channels or banks. Excess sedimentation can be damaging to the ecological health of waterways and increase probability of floods and river overflow (Zhou *et al.*, 2008).

2.1.2 IMPACT ON WATER QUALITY

When alterations to the hydrological balance occur over a large or in a critical area of a watershed, it could lead to significant short-term and long-term impacts both in terms of water quality and quantity, over a range of temporal and spatial scales (Bhaduri *et al.*, 2000; Bochis-Micu and Pitt, 2005).

Changes in land use, specially conversion of permeable surfaces to impermeable surfaces limit infiltration pathways and the capacity which supports the functioning of the hydrological cycle (Cairns, 1995; Hsu *et al.*, 2000) increase the hydraulic efficiency in urban catchments (Johnson and Sayre, 1973) and decrease recharging of the ground water table with a corresponding decline in base flows (Klein, 1979; Smakhtin, 2001). Lowering of the water table can in turn dry up wetlands and produce intermittent or dry streams during low flow periods (Mitsch and Gosselink, 1993).

Increase in the surface runoff and soil erosion directly affect quality of the water. Changes in water quality parameters such as turbidity, salinity, pH, dissolved oxygen level, amount of heavy metals and contaminants in water bodies could affect the health of the watershed, declining aquatic communities, and reducing ecological diversity. Entry of excessive nutrients could cause eutrophication in water bodies which could indirectly increase the surface runoff causing downstream flooding (Shuster *et al.*, 2005). Poor water quality also has a significant impact on human health and welfare.

2.2 HEAVY RAINFALL

With the changing climate, frequency of extreme weather events is increasing. Majority of the tea areas are found in the wet zone where the annual average rainfall is about 2500 mm. However, even though tea has adapted to a relatively high amount of rainfall, extreme weather events such as short intense rainfalls can have a major impact on tea which leads to low productivity and poor quality. This could have a major impact on the livelihoods of the community and the economy of the country.

Heavy rainfalls cause breakage of poor buds and affect the shoot development of tea plants. Soil in tea growing areas are known to be degraded, and the heavy rainfalls could aggravate the soil erosion and degradation, lowering the soil depth. Soil erosion and runoff increase short term and long term production costs. It also displaces soil nutrients, reducing the nutrient availability for the plants and also increase the weed growth in the tea lands. Heavy rainfalls can reduce the water holding capacity of soil. It increases the runoff and reduce the time available for water to infiltrate, creating poor drainage of soil. As a result low lands get flooded quickly.

2.3 MINING IN SLOPE AREAS AND RIVER BANK AREAS

A study done in 1993 showed that nearly 25 per cent of Sri Lanka's land mass is bearing gems (Dissanayake and Rupasinghe, 1994). The Ratnapura district is most renowned for its high concentration of gem deposits (Wickramaarachchi, Jayasinghe and Dharmaratne, 2011). Gem mining is important economy wise as it generates high income and employment opportunities. However, at the same time, it causes adverse effects on the environment (Dissanayake and Rupasinghe, 1994). Gem mining is done in several ways such as open pit mining, river bed mining, traditional pit mining and mechanized mining. Gem mining operations are carried out in hilly areas and around rivers or streams. This has created both environmental and socio-economic impacts.



Figure 2.2: Gem mining in rivers. (Image source: www.gia.edu/ Andrew Lucas)

During mining operations, a large amount of soil, sand and rubble is removed from the deep soil and dumped onto open areas around mining sites. This dumped soil gets washed away with the rainfall and dewatering of mining pits causing sedimentation and pollution in nearby water sources. Sedimentation in upstream water bodies increase the probability for flooding in the lower catchment areas. Unregulated and unsystematic gem mining increase the potential of slope failures during rainfall.

Gem mining is now practiced in lands reserved for agriculture which reduces land extent and production as well as causing environmental issues. Although only a small extent is legally reserved for gem mining, in agricultural lands a much larger extent is illegally reserved (Priyanath, 1999). Due to unclosed yet abandoned gem pits, clay piles, sand and stones are found on agricultural lands. This has resulted in loss of soil fertility of these lands (Priyanath, 1999).

CHAPTER 3:

TOOLS AND GUIDELINES FOR WATERSHED MANAGEMENT IN RATNAPURA AND KALUTARA DISTRICTS

3.1 USING GEOSPATIAL ANALYSIS TOOLS FOR IDENTIFICATION OF VULNERABLE SITES

3.1.1 SPATIAL DATA REQUIRED AND AVAILABILITY

Haphazard development activities in the country not only increase the vulnerability to disasters but also impair the effectiveness of conservation efforts. Unplanned development can change soil structure and hydrologic regime in high risk areas, leading to extreme surface runoff and soil erosion. Given the dynamic nature and complex processes within a watershed, the cumulative impact of localized actions, especially in the upstream region, will have a significant impact on the downstream communities.

Many projects have been conducted by different government agencies and NGOs on watershed management, soil conservation, water conservation and river bank restoration but their success rates are low due to the ad hoc nature of selecting the sites for project implementation. Some restoration activities are conducted in the same area repeatedly while other vulnerable areas are overlooked. Additionally, infrastructure development projects have failed to take into consideration the impacts of land use changes and compaction of soil on these already vulnerable areas. For instance, forest cover clearing for road expansion has vastly increased the susceptibility of these areas to calamities such as landslides and floods (Figure 3.1).



Figure 3.1: Ongoing landslide alongside Ratnapura-Wewalwatta road (Source: EFL)

Several development projects have been proposed for Ratnapura and Kalutara districts under the Western Region Megapolis Planning Project. Proposed projects include infrastructure development activities such as the construction of Ruwanpura Expressway and conservation programmes such as riverine buffer zone development and management of Kelani, Kalu, Attanagalu and Deduru river systems. If these activities are to be sustainable and effective, it is imperative that vulnerable areas in the study regions are identified and prioritized for conservation. This can be achieved through the analysis of spatial data, which can provide insight into the flood prone sites by mainly considering processes that lead to excess runoff and soil erosion.

Prioritization of areas for watershed management can be done after identifying the most vulnerable areas. For that, spatial data can be used to understand the physical and cultural features of the area which gives an overall picture of where the management practices should be implemented. It will also allow the monitoring of individual successes as well as the cumulative success of the projects.

However, in most instances, the ideal data layers are not available and the planners will have to use proxy data sets. Some of the human use and development related spatial data may already be available and used by planning teams but they may require updating. Sometimes, even though spatial data layers are unavailable, spatial data layers can be created using already existing data and technologies. Table 1 contains a list of data / spatial data important for watershed management and the respective agencies/ departments from where the data can be obtained.

Table 1: National spatial databases and available government institutions.

Type of Data/ Spatial Data	Data Source
Rainfall and Temperature	Department of Meteorology
Basins and Sub basins	Department of Irrigation
Hydrology	Department of Surveys and Department of Irrigation
Slope	Developed through DEM
Contour	Department of Surveys
Soil types	Department of Agriculture
Land use	Department of Land use Policy and Planning
Population data	Department of Census and Statistics
Disaster data	Disaster Management Center
Tea plantations and tea grown areas	Department of Land use Policy and Planning

3.1.2 GEOGRAPHICAL INFORMATION SYSTEM (GIS) SOFTWARE

ArcGIS

ArcGIS is a Geographic Information System (GIS) developed by ESRI - Environmental System Research Institute, Inc., which can be used to create, manage, share and analyze spatial data. This system was used for creating data layers used for Maxent. Vector data layers related to the study area of Ratnapura and Kalutara districts were used to create Raster data for running Maxent. ArcGIS can be used for conversion of data layers into required data type layer to run Maxent, and also to display output data from Maxent.

ArcGIS is a premium software which can be purchased from,
<https://www.esri.com/en-us/arcgis/products/arcgis-pro/buy-now>

Note:

- Raster - It is a spatial data type that defines space as an array of equally sized matrix of cells (or pixels) and columns (or a grid) where each cell contains information. Raster data can be digital aerial photographs, imagery from satellites, digital pictures or even scanned maps.

Example formats of Raster: Esri Grid, JPEG, GeoTIFF, Digital Raster Graphic (DRG)

- Vector - It is a data structure which is used to store spatial data. These data layers are comprised of lines or arcs defined by beginning and end points. Vector data can be in the forms of lines, polygons and points (or coordinate points).

Example formats of Vector: Shapefile, Spatialite, Spatial data file, Keyhole Markup Language (KML), Geography Markup Language (GML), Cartesian Coordinate System (XYZ)

QGIS

QGIS or Quantum GIS is a free, open source platform, similar to ArcGIS that can be used for viewing (Raster and Vector), editing and analyzing geospatial data. Data layers required for running Maxent can also be prepared using QGIS if ArcGIS is not available.

QGIS can be downloaded from <https://qgis.org/en/site/forusers/download.html>

MAXENT

Maxent is based on the maximum-entropy approach for modelling species niches and distributions. From a set of environmental (e.g. climatic) grids and georeferenced occurrence localities, the model expresses a probability distribution where each grid cell has a predicted suitability of conditions for the species. Rasterized data (and converted into ASCII format) prepared from ArcGIS or QGIS was used to run Maxent. Instead of species data, soil types, hydrology, flood, elevation (DEM 30 m) and land use data of the study area was used to identify vulnerable sites. Maxent is a standalone software, and the outputs can be viewed using ArcGIS, QGIS or other spatial software. Using the outputs vulnerable sites in a watershed can be identified.

Maxent can be downloaded from https://biodiversityinformatics.amnh.org/open_source/maxent/

3.1.3 IDENTIFICATION OF VULNERABLE SITES

Here, Maxent was used as the key spatial planning software in identifying sites with a high vulnerability for flooding where management and mitigation measures should be adopted. Several spatial data layers were used and created for Maxent model. Initially each layer, both vector and raster were added to either ArcGIS or QGIS and projected under one projection system (WGS-84). Each layer was saved as a raster layer and converted to ASCII format to be used in Maxent.

Using ArcGIS or QGIS, random points (1000 points) were generated for the Kalu Ganga Flood area (Vector) layer. Using the points generated, the coordinates of these points were saved as a comma delimited (.csv) file which was then added to Maxent. The files thus prepared were used to carry out the Maxent model. Using ArcGIS, a flow accumulation layer was also prepared and using the 30 m DEM, a slope map was generated. By overlaying the flow accumulation, slope and Maxent output layers, vulnerable sites were identified (Figure 3.2).

See Annex 1 for the steps for using Maxent to identify vulnerable sites.

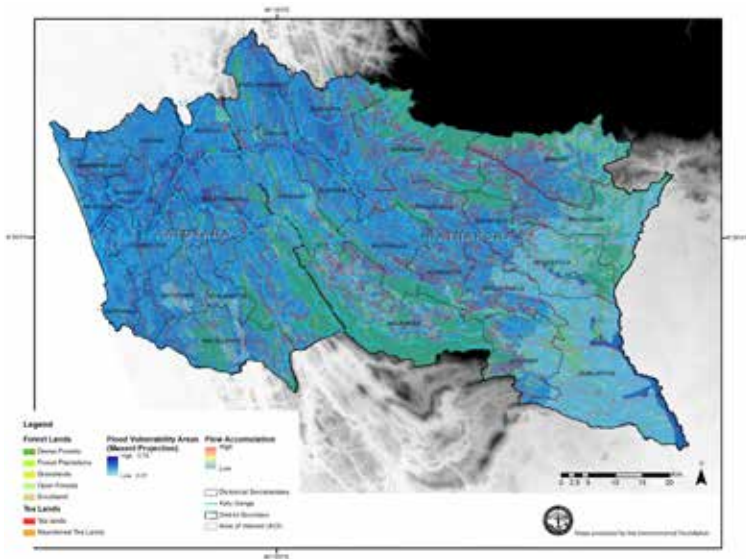


Figure 3.2: Identification of vulnerable sites

3.2 SOIL AND WATER CONSERVATION MEASURES IN CULTIVATED AREAS, ESPECIALLY IN TEA GROWING AREAS

Although agriculture is part of the rural community and holds an important economical aspect, conservation of natural resources in a watershed area is an important factor that supports the survival of a healthy watershed. A healthy watershed can support recharging of the groundwater level and reducing effects from disasters. While replanting or increasing forest cover comes as a suitable option, agricultural lands should also exist. Several activities can be practiced within a farmland or a plantation land to reduce soil erosion and its impacts.

3.2.1 CONTOUR FARMING

Contour farming is based on a series of contour rows that will drain runoff to a waterway and thereby, reduces the steepness of the slope over which overland flow passes (Smith and Wischmeier, 1957). Contour farming is practiced in many areas including where steeper slopes are present. Terracing and strip cropping methods are combined with contour farming to further reduce surface runoff. It has its own advantages when done properly and reduces soil erosion and runoff. Sloping Agricultural Land Technology, otherwise known as SALT is a system which incorporates leguminous tree species as hedgerows along contours at predetermined distances among the cash crops. Several conservation practices when farming in sloped areas can be combined with contour farming;

3.2.1.1 PREPARING DITCHES TO TRAP SOIL DURING RAINFALL

Ditches can stop downslope water movement as the water falls into the ditch. Preparing ditches can be less labour and time consuming compared to terracing. Ditches can either retain or divert water to drainage lines and can be connected to leader drains where the excess water can flow while retaining runoff soil (Figure 3.3). Further, it could increase the groundwater recharge in the upper catchment areas and help to maintain the dry flow during dry seasons.



*Figure 3.3: Drainage ditches to stop downward water movement and trap soil
(Source: www.discoveringtea.com)*

3.2.1.2 PLANTING CROP (LIVE) BARRIERS ACROSS THE SLOPE

Crops can be grown along the contour lines to anchor the soil in their place by the roots of the plants. Crop barriers are planted above ditches to be more effective in controlling soil erosion and runoff (Crozier, 1986). Grasses are commonly used for crop barriers such as Napier grass (*Pennisetum purpureum*) and Guinea grass (*Panicum maximum*). Grass types have a dense foliage as well as a strong root network which helps to hold the soil in place. When planting contour barriers, the spacing from one barrier to the next depends on the slope of the land. Barriers are built close to each other in steep slopes and further apart in less steeper slopes. The SALT system can be applied here where permanent crops are grown in 3 m to 5 m wide belts or bands. Between contoured rows, nitrogen fixing plants such as *Gliricidia maculata* can be planted. Green manure crops can be grown to provide both shade and reduce evaporation. They also act as pest barriers and provide fertilizers from foliage matter (Nitrogen, Phosphorus and Potassium).



Figure 3.4: Use of live plant barriers and stone (dead) barriers on sloped tea lands (Source: EFL)

3.2.1.3 PREPARING (DEAD) BARRIERS USING ROCKS AND OTHER NON-LIVING MATERIAL

Dead barriers are made of mostly non-living materials such as rocks and dead plant matter. Building barriers entirely by using rocks is a common practice and these barriers are also built along the contour lines. Dead barriers are often supplemented with live barriers and organic matter such as plant residue to reinforce the strength of the barriers (Crozier, 1986).

3.2.1.4 ALLEY-CROPPING AND HEDGEROW PLANTING ALONG THE SLOPE

The contour hedgerows have proven to be an effective agronomic practice in controlling soil erosion by creating a barrier to reduce soil movement on the upslope boundary as terraces. Plants such as *Gliricidia maculata* can be planted thickly to make hedgerows using the SALT system. When a hedge is 1.5 to 2 m tall, it is cut down to about 75 cm and the cuttings (tops) are placed in alley-ways to serve as organic fertilizer.



Figure 3.5: Stone barriers along contour lines on tea lands (Source: EFL)



Figure 3.6: Use of stones for barriers on sloped tea lands (Source: EFL)

3.2.2 MULCHING

Mulching is referred to as the use of organic materials such as straw and leaves as a spread to cover exposed soil and growing crops on it (Sharma and Bhardwaj, 2017). The National Agricultural Policy encourages efficiency of rain fed agriculture through mulching as it serves many purposes such as,

- a. Reduction of soil moisture evaporation rate
- b. Reduction of soil erosion (splash erosion)
- c. Providing soil nutrients and improving soil fertility
- d. Regulation of soil microclimate and improving soil environment for micro and macro fauna
- e. Reduction of weed growth

The materials used for mulching depends on availability. Mulching material or mulch can be organic (living or dead plant material) or inorganic such as polythene sheets. Straw is a dead mulch material that is commonly used. For plants which require high soil temperatures for growth (e.g. strawberries), a black film is used (Sharma and Bhardwaj, 2017). During rainfall periods, the mulch acts as a canopy that would reduce soil erosion, and during dry periods the mulch covers the soil from evaporation (Sharma and Bhardwaj, 2017). A mulch can be used to cover an area that is exposed and is not used for planting between the crops or crop lines. Bare soil that is exposed to heat, wind and compaction loses water through evaporation and is less capable of absorbing irrigated water or rain water. Use of a mulch reduces these effects (Telkar *et. al.*, 2017). When using hedgerows in alley-cropping method, the biomass can be used for mulching. Mulching can be done on entire plant beds, or around the plants or applied in strips between plant rows (Figure 3.7).

Green manure crops can be used for mulching as they provide valuable organic matter when incorporated with the soil (Loks *et al.*, 2016). Green manure crops can also act as a wind barrier and provide shade for tea plants. Several types of legumes such as *Clitoria ternatea* known as “Nil Katarolu”, *Canavalia ensiformis* known as “Awara” and other legumes can be used as living mulches.



Figure 3.7: Use of mulch in tea lands in Sri Lanka (Source: IUCN, 2016)

3.2.3 TERRACING

Terracing can be defined as building a mechanical structure of a channel or a bank such as an earthen ridge or a stone wall (Dorren and Rey, 2004). Terracing is used to trap surface runoff, increase infiltration and control soil erosion. It is used to transform landscapes in to steeped agro-systems in many hilly or mountainous regions of the world (Widomski, 2011). Since terracing requires maximum soil disturbance, the land will be extremely susceptible to erosion unless properly measured, compacted and maintained. If the slope is steeper the cut will be deeper, and more land space will be lost. Planting will be done in narrow spaces. Terracing is similar to a cut and fill method where the top part of the land is cut and the soil is moved to the fill section.

Continuous terraces are staircase like structures which would minimize soil erosion caused by planting on inverse lands. Planting can be done on these terraces where each terrace strip can be used as a plant bed. Bench terracing is a type of a continuous terrace system. It is used for rain-fed agriculture and in upland areas where irrigation is only required during dry seasons. Bench terracing can be done on slopes that do not exceed 25 degrees. Grasses are planted on the slope of the terrace or on the risers (sloping banks) to prevent erosion.

Discontinuous terraces provide both a flat platform to plant crops and an inverse slope to serve as a drainage or an infiltration ditch which is also known as a discontinuous narrow terrace. Similar to a bench terrace, the slopes are filled and cut to construct the terraces in this method. In both discontinued and continued terraces, the terrace building depends on the degree of the slope. The distances between canals and platform width depends on the slope.



Figure 3.8: Terraced slope lands for growing tea (Source: EFL)

3.2.4 PLANTING SHADE TREES

Shade trees can be planted along contours or borders or between rows of tea plants. Plants such as *Erythrina* spp., *Gliricidia* sepium, and *Albizia moluccana* can be used for buffer strip as medium and high shade trees (Tea Research Institute, 2003). Maintaining plant shade can also reduce sun scorch and plant damages by acting as a high canopy shade. Tea plants are shade seeking trees and when exposed to high temperatures for longer periods, it can cause high rates of transpiration from the plants. To minimize this, the plants are naturally capable of controlling the rate of water loss and damages to the plant, but shade plants act as a natural canopy which will create a cooling effect under the shaded areas (Lin and Lin, 2009).

Suitable shade trees should be identified for planting and spacing between shade trees and tea rows should be determined. Different species of trees can be used in tea growing lands at different elevations. Shade trees require adequate spaces during the initial growing stage, and later will acquire a maximum spacing where tea rows can be accompanied in between shade trees.



Figure 3.9: Use of high shade trees Albicia (Albizia moluccana) and medium shade nitrogen fixing tree Gliricidia (Gliricidia sepium) in tea lands (Source: EFL)

3.2.5 WEED MANAGEMENT AND IN-FILLING VACANCIES

Weeds are a common problem for many plantations as they compete for water, light and nutrients. Especially, in the tea industry, weeds have the potential to reduce the yield by 70 per cent as they can raise the humidity around the bush, increasing the vulnerability for diseases and can hinder the tea harvesting process (Gianessi and Williams, 2011). While manual weeding or hand pulling is the most ecologically friendly method, the practice of clean weeding with scrapers (“sorandi”) and mamoty exposes the soil surface and increases soil erosion. Studies have shown that manual weeding using tools resulted in severe soil loss of about 30 cm of topsoil per hectare eroding over a century in Sri Lanka and this method leaves behind a layer of loose soil which is easily washed away by runoff water (Ekanayake, 1994). Soil Conservation Regulations of 2009 states that any person for the purpose of weeding a land cultivated for tea shall not use or is not permitted to use any mamoty or any tool with a working edge exceeding 20 cm and an overall length exceeding 50 cm.

It is recommended that ecological techniques are adopted to enable the quick establishment of proper ground cover to suppress the growth of weeds. The areas that get vacant as a result of casualties or plant dieback gets gradually expanded over time leading to soil erosion and heavy weed infestation. Suitable mulching materials such as “Mana” (*Cymbopogen confertiflorus*), “Guatemala” grass (*Tripsicum laxum*) and “Vetiver” grass (*Vetiveria zizanioides*) can be planted in the vacant patches to prevent such areas from becoming breeding grounds for weeds and provide protection against soil erosion (Tea Research Institute, 2013).

3.2.6 DRAINAGE SYSTEMS

The idea of a drainage system is to minimize soil runoff and to prevent water logging in planted areas. There are two types of drainage systems that can be adapted in tea growing lands. Those are lateral drains and main (leader) drains. Lateral drains can be prepared along the contour lines which will be connected to leader drains that are placed along the vertical line of the slope. Lateral drains should not cut open to the leader drain directly opposing each other, but in slightly different elevations to minimize the collapsing of the drainage banks and to prevent erosion. The spacing between two lateral drains depend on the slope and amount of approximate rainfall received. It ranges from 6 m to 12 m. When the slope reduces, and lower rainfall is received, spacing can be made wider (12 m) and vice versa. Edges of the drains should also be cultivated with grasses or smaller plants to prevent erosion along the edges and collapse of the edges. Drains should de-silted and cleaned regularly. Silt removed from drains should always be put in the upper side of the drain, but not in the lower side.

The leader drains can be constructed along naturally occurring drains to carry away water from lateral drains in non-erosive velocities. The width and depth of the main drain or leader drain is dependent on the amount of water that has to be carried away. Leader drains are made in a stepwise structure with a reverse slope with the sides and bottom paved with stones to prevent gullies caused by eroding. Check dams are made in frequent intervals to collect silt carried away with runoff water and sides or banks are planted with Vetiver grass. Leader drains must always be cleaned and de-silted at frequent intervals as done in the lateral drains. Stone paved terrace areas are built along the contour lines to minimize soil erosion and to reduce the slope. The upper brim of the terrace must be above the ground/soil level and sloped towards the hill side.



Figure 3.10: Lack of proper drainage systems observed in tea lands (Source: EFL)

3.2.7 TIME OF PLANTING

Planting should be done prior to the rainy season. Tea plants are planted as cuttings of original propagated seedlings. Tea saplings should also be planted in contour lines to ensure minimum soil erosion since tea plant roots are also capable of binding soil particles together. In this same context, removing weeds need to be taken into consideration as their removal can expose the soil to rain drops which can increase erosion. Only the harmful weeds should be removed which will reduce competition with the tea plants and also reduce topsoil loss.

3.2.8 CROP DIVERSIFICATION (INTERCROPPING)

Intercropping provides a valuable opportunity to fully utilize the available space for production of resources with an economic value. It generally involves cultivation of a mixture of crops grown in a specific spatial pattern (Bavappa and Jacob, 1982) (Figure 3.11). It has numerous benefits including improved soil stability and fertility, weed control, increased productivity, higher net returns, reduced risk of dependence on a single crop and extra employment opportunities. Traditional intercropping in tea plantations included cultivation of export agricultural crops such as pepper, coffee and cloves. Pepper is identified as the most compatible crop with any category of tea in moderate and low elevations, while coffee is more suitable for tea lands with low plant population and cloves should be confined to field boundaries (Ekanayake and Jayasekara, 2003). Fruit trees could be planted as intercrops and these are also suitable for tea lands with low plant populations. Rubber, cinnamon, pepper, mandarin, cloves, cardamom and eucalypt species used for fuel wood are commonly chosen for crop diversification (Gunathilaka, Smart, and Fleming, 2018).



Figure 3.11: Use of different crops as multi cropping method in tea lands (Source: EFL).

3.3 MANAGEMENT STRATEGIES FOR ABANDONED TEA LANDS

Land use conversion from unutilized or underutilized land to economically profitable and environmentally sound ventures provide better results for the farmers as well as the country.

3.3.1 IMPLEMENTING AGROFORESTRY SYSTEMS IN DEGRADED LANDS

Establishment of mixed forest garden holdings and community managed forests are possibilities that could lead to increased land conservation and improved livelihood income. As with intercropping in already existing tea lands, crop diversification can improve forest structure in large areas of degraded and abandoned lands, while providing resources for people. Studies have shown that such degraded plantations, with stocking rates between 0.5-30.2 tree/ha, can be used for fuel wood, fodder and green manure (Palihakkara et al., 2015). Soil characteristics (rockiness, soil depth, drainage status and soil nutrient status) and crop requirements should be assessed prior to implementing such projects to identify suitable areas and plant species. Natural resource extraction should be conducted in a sustainable manner.

3.3.2 CONVERSION OF ABANDONED LANDS TO FORESTS

Converting abandoned and degraded lands into high canopy forest areas can be effective to counter landslide occurrence during heavy rainfalls and also improve soil health by improved vegetation cover. Agroforestry or home gardening systems using woody perennial trees, timber trees, spice crops, fruits and vegetables can reduce the impact on soil loss during heavy rains. Using a mixture of canopy trees, perennials and live fencing trees can act as wind barriers as well as a natural forest area.

3.4 GENERAL PRACTICES FOR WATERSHED MANAGEMENT

3.4.1 RIVER RESERVATION MAINTENANCE AND RIVER BANK RESTORATION

Regulation/ gazette no. 1454/4 dated 17th July of 2006 issued under the National Environment Act prevents mining along public streams and rivers that are essential to prevent river bank erosion and degradation that can also increase flooding in heavily mined areas.

Sand mining and gem mining in river banks should be limited or prohibited in areas that can be identified as flood or landslide prone areas.

River and stream banks could be restored by using bioengineering methods such as re-vegetation of the riparian zones, usage of vegetated erosion control blankets and construction of retaining walls which are both economically and environmentally sustainable technologies (Martin, 1995; MWMO, 2010; Soyza, Ranagalage and Manawadu, 2013). Applying these technologies allows the reduction of soil erosion and siltation, improves water quality, increases resistance to flood damage and increases the green cover along river belts allowing the sustenance of more biodiversity. Using endemic plants such as “Mee” (*Madhuca longifolia*), “Midella” (*Barringtonia acemosa*), “Kumbuk” (*Peminalia arguna*), “Rambuk” (*Erianthus arundinaceus*) and Bamboo tree types on river banks allow the increase of riverine biodiversity as well as improve the cultural value (Soyza, Ranagalage and Manawadu, 2013).

3.4.2 RESTORING FORESTS IN DEGRADED LANDS

Land degradation is defined as a “persistent decline” in the provision of goods and services that an ecosystem provides, including biological and water related goods and services as well as land related socio-economic goods and services (Sabogal *et al.*, 2015). Forests play a key role in improving the well-being and social equity of humans while significantly reducing the environmental risks and ecological scarcities (Gunatilleke, 2015). Forest and land degradation increase competition for scarce resources and creates possible conflicts between those who depend on it. And in return, it will threaten the livelihoods, wellbeing, food, water, energy security and resilience to climate change (Sabogal *et al.*, 2015). Restoration of degraded lands and converting them to forests is therefore an important task.

The purpose of reforestation can vary depending on the scale and the purpose. Reforestation can be carried out to achieve multiple objectives such as mitigating land degradation, establishing sustainable land use practices, enhancing land productivity, supporting livelihoods, supplying forests and agricultural products to local communities, conserving biodiversity and providing environmental services, and creating landscapes that will sequester large quantities of carbon and are resilient to adverse changes. For the management and reforestation of degraded lands, identification of the agents and drivers of degradation should be done before starting reforestation work. Human activities such as deforestation are reasons for degradation of lands which results in loss of biodiversity, infertile lands and carbon stocks. Several Eucalypt species (*Eucalyptus grandis*, *Eucalyptus microcorys*, *Eucalyptus robusta*) can be grown in up country tea areas on degraded lands. Other tree species such as Carribbean Pine (*Pinus caribaea*), African Mahogany (*Khaya senegalensis*) can also be grown in the intermediate zones. Native species such as Hora (*Dipterocarpus zeylenicum*), Halmilla (*Berrya cordifolia*), Burret, Margosa (*Azadirachta indica*), Jak (*Artocarpus integrifolia*) and exotic tree species such as Acacia species (*Acacia mangium*, *Acacia auriculiformis*) can also be considered.

Home gardens can also be implemented in areas with degraded sloping lands with the use of multiple economically valuable trees. These home gardens provide a rich diversity of tree species and can have a dense structure of plants. The most common high density trees are coconut and rubber in some areas. However, in areas where rubber and coconut are present, Teak, Mahogany (*Swietenia macrophylla*) and Jak trees can be planted. Alibizzia (*Albizia molucana*) a tree that is used as a high shade tree in tea plantations can also be used as a tree species for replantation and home gardening in degraded lands.

3.4.3 RAINWATER HARVESTING AND DECREASING SURFACE RUNOFF

Although rainwater harvesting is implemented for areas where availability of freshwater is poor and are affected by long drought periods, rainwater harvesting can also be done to reduce the amount of rainwater reaching exposed surfaces by collecting rainwater and rerouting the water in to either water storage tanks or directly in to streams. This can decrease the chances of water clogging and flooding due to failure of drainages. Setting up rainwater harvesting methods such as water collecting tanks and directing water to canals in developed areas can be used as a supporting measure other than drainage which will prevent excess water reaching impervious lands.

3.5 COMMUNICATION, EDUCATION AND PARTICIPATION

A successful management plan includes community participation. It is important to communicate with the communities and to create awareness among them. Initially, before starting watershed management practices in a vulnerable area, communities in those areas should be brought together and a project briefing should be conducted for them. This will ensure smooth implementation of the plans without building resistance from the communities.

The community should understand the importance of managing the watersheds. They should understand the watershed structure and components and their interconnection. Actions done upstream area of a watershed will not only affect the surrounding areas, it will also affect the downstream area both negatively and positively. Therefore, it is important to educate the communities both upstream and downstream about how the watersheds function, how actions of one area affect the other areas (causing floods for example), how they will benefit and could improve their livelihoods by watershed management. In order to self sustain the management plan, engaging the community on these activities is important.

CHAPTER 4:

SUPPORTING LEGAL FRAMEWORK FOR WATERSHED MANAGEMENT

4.1 SOIL CONSERVATION REGULATIONS NO. 01. OF 2009

- i. Soil Conservation Act No 1951 No 25
- ii. Amendment Act No 24 of 1996
- iii. Regulations under National Environment Act

There are several issues regarding land use for cultivation which cause negative impacts on watersheds, groundwater resources and stability of soil layers. Aquatic habitats could be affected, and watersheds could be contaminated with fertilizers due to cultivation. In addition to that, surface soil runoff from cultivation lands cause soil erosion and fill riverbeds and water streams which leads to floods during rainy seasons.

Soil Conservation Regulations No. 01. of 2009 provides guidelines for cultivations in areas declared as Conservation areas under Sec. 4 of Soil Conservation Act. (Conservation areas has been declared under Extraordinary No. 1550/9 of 22/05/2008).

E.g. : No cultivation of annual crops in land that consists of a slope of more than 60 per cent. As such, in the District of Ratnapura there are conservation areas like Eheliyagoda, Kiriella, Kalawana, Ratnapura, Balangoda, Kolonne, Kuruwita, Weddagala, Rakwana and Palledbedda.

According to Sec. 23 H and 23 M of National Environment Act any act that pollutes inland water or soil is prohibited and according to Sec. 24, the Central Environmental Authority has the power to issue directives to any person who engages in any project which is causing or is likely to cause, damage or detriment to the environment, regarding the measures to be taken in order to prevent or abate such damage or detriment.

4.2 LOCAL AUTHORITIES ACTS, NATIONAL ENVIRONMENT ACT

- i. Urban Development Authority Act- No.41 of 1978
- ii. Municipal Council Ordinance- No. 16 of 1947
- iii. Urban Council Ordinance- No. 61 of 1939
- iv. Pradeshiya Sabha Act- No:15 of 1987

Unorganized constructions and land developments might cause issues such as groundwater drawdown and water leakage which lead to floods and landslides.

Local Authorities are mandated to manage construction activities, land development activities, waste management, town planning, maintaining drainage systems and all thoroughfares other than principal thoroughfares, within the administrative area of the local authority unless the area has been declared as an urban development area under the Urban Development Authority Act. The Local Authorities Acts, the National Environment Act, the Housing and Town Improvement Ordinance, and other enactments have been ratified towards this end.

Further, local authorities act as approving agencies towards granting Environmental Protection Licenses to ensure compliance by the factories and businesses with the environmental standards prescribed by the Central Environmental Authority, located within the relevant area of administration. The Minister of Environment, through gazette notification No. 1159/22 dated 22.11.2000 ordered that all factories and businesses in all Pradeshiya Sabha areas should obtain this license. There are a few other authorities such as the Central Environmental Authority and the National Building Research Organization under the Ministry of Disaster Management that engage in some of the above mentioned activities.

4.3 FELLING OF TREES ACT NO. 09 OF 1951, NATIONAL ENVIRONMENT ACT NO. 47 OF 1980 AND FOREST ORDINANCE

Clearing forest areas and removing trees result in deforestation that in turn lead to soil erosion and issues related to the water cycle and watersheds. There are various legislations and mandatory authorities such as the Central Environmental Authority, Local Authorities and Department of Forests to overlook matters related to this.

- According to regulations under **Felling of Trees Act No.09 of 1951**, Jak, Breadfruit and Female Palmyra trees cannot be felled without a permit
- According to regulations (Gazette No.772/22 dated 24/06/1993) under the **National Environment Act**, an Environmental Impact Assessment (EIA) /Initial Environmental Examination (IEE) is required for
 - i. Extraction of timber covering land area exceeding 5 ha
 - ii. Clearing of land areas exceeding 50 ha
 - iii. Conversion of forests covering an area exceeding 1 ha. into non- forest uses
 - iv. Any project within 100 m from the boundaries of or within area declared under the National Heritage Wilderness Act and Forest Ordinance
- According to **Forest Ordinance**, any business associated with timber should be registered
- Permits need to be obtained to fell trees in a Land (granted by government or any other deed) which does not have clear boundaries or leased by Government

4.4 WATER STREAM RESERVATIONS

Table 2: Reservations according to the manual issued by the Ministry of Lands

Width of the stream	Reservation
up to 15 feet [4.6 m]	66 feet [20 m]
15-50 feet [4.6-17.4 m]	132 feet [40 m]

The common practice is for the Department of Agriculture to allocate two times the width of the stream or reservation.

4.5 CROWN LANDS ORDINANCE NO. 8 OF 1947

This Ordinance provides regulation regarding the use of water in lakes and public streams through permits under PART IX of the ordinance (Sections 70 to 80) including formal rights of the state to use and manage public streams. Part IV states that the Minister has the power to declare any state land as reservation for the protection of public streams, tanks, reservoirs, lakes, ponds, lagoons, protection of the foreshore; prevention of the erosion of the soil; and the preservation of water supplies. Further, the Ordinance defines the terms lake, private lake, private stream, public lake, public stream and stream.

But it has not provided provisions on how to preserve water in a sustainable manner.

4.6 STATE LANDS ORDINANCE NO. 8 – 1947

Section 49 states that the Minister may, by Notification published in the Gazette, declare that any state land is constituted a State reservation for any one or more of the stated public purposes including: the prevention of soil erosion.

4.7 WATER RESOURCES BOARD (AMENDMENT) ACT (NO. 42 OF 1999) – SECTIONS 2 TO 12 OTHER MATTER THAT IS REFERRED TO THE BOARD FOR ADVICE BY THE MINISTER

- a) the control, regulation and development (including the conservation and utilization), of the water resources of the country;
- b) the prevention of the pollution of rivers, streams and other water resources;
- c) the formulation of national policies relating to the control and use of the water resources of the country
- d) the preparation of comprehensive and integrated plans for the conservation, utilization, control and development of the groundwater resources of the country;
- e) the coordination of the activities of government departments, local authorities and public corporations, in regard to surveys of basic data and other investigations, relating to hydrogeology;
- f) the analysis of reports based on investigations, statistical surveys, plans and proposals relating to the ground water resources of the country made by government departments, local authorities and public corporations;

- g) the coordination of projects undertaken by government departments, local authorities and public corporations, relating to the conservation, utilization and development of the subterranean water resources of the country, and the assessment of the possibilities, benefits and economic feasibility of such projects;
 - h) any other suitable measures to be taken by the Government for the proper control and economic use of groundwater.
2. The Board may undertake such investigations and surveys as would enable it to collect the data and information necessary to advise the Minister on the matters specified in subsection (1) of this section.
 3. The Board may carry out such other activities, for payment or otherwise, as would enable it to effectually perform its duties under subsection (1) of this section. The activities which the Board may carry out shall include the following: -
 - a) carrying out of feasibility studies on the availability of ground water resources;
 - b) carrying out of hydrogeological investigations to identify groundwater sites for deep tube wells and agro wells;
 - c) the construction of tube wells in a scientific manner to enable the extraction of groundwater for domestic, agricultural and industrial purposes;
 - d) the drilling of bore holes to investigate the subsurface strata.

4.8 AGRARIAN SERVICES ACT NO.58 – 1979

This Act provides security of tenure to tenant cultivators of paddy lands. According to Section 34(2) the owner, cultivator or occupier of any agricultural land shall, in addition to other such duties as the Commissioner may in his discretion specify, ensure that

- (d) the land is properly maintained in order to ensure the maximum conservation of soil and water

4.9 MAHAWELI AUTHORITY OF SRI LANKA ACT NO.23 OF 1979

Section 13 notwithstanding the provisions of any other law and without prejudice to the generality of the powers conferred on the Authority by this Act, the Authority shall in or in relation to any Special Area have the power:

- (3) to take such measures as may be necessary for watershed management and control of soil erosion

4.10 MINES AND MINERALS ACT NO.33 OF 1992 (AMENDED ACT NO. 66 OF 2009)

There are several issues related to mining in Sri Lanka such as illegal mining, over mining, political influence and improper rehabilitation. A large number of mining sites exist in Ratnapura district due to the gem mining industry. Unregulated sand mining result increased sedimentation, leading to heavy flooding during monsoon seasons. Mining also causes water pollution problems such as increased turbidity in water and toxic or acid contamination.

The Geological Survey and Mines Bureau (GSMB) was established under the Mines and Minerals Act to oversee and manage the mines and minerals sector of the country including issuing licenses and ensuring protection of the environment. GSMB is authorized to carry out research, identify sensitive areas and implement rules and regulations accordingly.

Even though the Act does not directly address environment protection and rehabilitation activities carried out by mines, GSMB has made it a requirement when issuing a license that a rehabilitation programme and deposit for re-filling the site needs to be submitted. All mining and mineral extraction activities gazetted under the National Environment Act should obtain environmental clearance with an Initial Environmental Examination Report or an Environment Impact Assessment Report as applicable.

According to Sec. 30, no license shall be issued to explore or mine upon any land situated within the stipulated distance to a lake, stream, tank, catchment area or national reserve within the meaning of the Crown Land Ordinance without the approval of the Minister. In addition, “Reserved areas and Minerals” can be decided by the Minister under Sec.32 and 33.

When issuing mining or excavation license in sensitive areas like Ratnapura, it is essential to conduct surveys and consider expert opinions as relevant to mitigate natural disasters such as floods, landslides, soil erosion and water pollution and follow regulations by GSMB and other relevant officers. Carrying regular inspections for illegal activities as well as monitoring the progress of rehabilitation processes and taking legal action when necessary are important points to remember.

4.11 POLICIES

4.11.1 NATIONAL POLICY ON WATERSHED MANAGEMENT, 2004

Watersheds contain a number of natural resources. Therefore, its protection, conservation and proper use and management will determine the wellbeing of the vast majority of the country's population. The national watershed management policy aims to conserve, protect, rehabilitate and sustainably use and manage watersheds while maintaining their environmental characteristics by human intervention.

In addition to the above considerations, the policy also sets out a detailed overview on the importance of proper watershed management actions and resource evaluation of services extracted from the watersheds.

Overall, the national watershed management policy aims for a sustainable use of watershed resources, while maintaining the quality of the environment that surrounds it.

4.11.2 NATIONAL POLICY ON PROTECTION AND CONSERVATION OF WATER SOURCES, THEIR CATCHMENTS AND RESERVATIONS IN SRI LANKA, 2014

This policy identifies micro catchments which include rivers and streams, their reservations and their spouts and flood plains of rivers as one of the main components that must be protected and conserved. The policy renews the government's commitment towards identifying borders, demarcating boundaries, protection and conservation of water sources while rehabilitating degraded areas related to water sources. Furthermore, it emphasizes the formulation of new legislation and amendments on existing legislation for the purpose of protecting water sources and its surrounding environment.

4.11.3 NATIONAL POLICY ON WETLANDS – 2005

The National policy on wetland management focuses on the protection, conservation, restoration and sustainable use of wetland resources, while fulfilling international commitments as a signatory to the Ramsar Convention on Wetlands.

Wetlands provide a large number of ecosystem services for the functioning of large scale ecosystems. Therefore, the maintenance of the quality of such components are crucial.

Furthermore, wetlands are an integral component of the lower segments of the watersheds. Therefore, the protection of such habitats is crucial for the maintenance of the overall quality of watersheds.

4.11.4 NATIONAL AGRICULTURE POLICY

This policy aims to implement technically sound, economically viable, environmentally friendly and socially acceptable programmes to promote sustainable agricultural development with efficient and effective utilization of resources. On such a foundation, the policy promotes land conservation within watershed areas in order to ensure water retention, while focusing on the adoption of effective irrigation and water management techniques in order to ensure the conservation of both rain and ground water and safeguarding irrigation reservoirs, rivers, canals and drainage systems.

USEFULNESS AND APPLICABILITY

This publication was prepared by using Ratnapura and Kalutara Districts as the study areas. These two districts are known for increased disaster risk and has a wide distribution of tea plantations and micro, small and medium enterprises (MSMEs).

This document can be used by both the government administrative level and decision makers in the tea plantation industry; it is also applicable for other landscapes in the said region. Land use planning officers, District and Divisional planning officers, officers in District and Divisional Secretariats, Disaster Management Centre officers and respective decision makers can use this document to identify flood vulnerable sites and avoid or consider the risk factors when new development projects are proposed for those areas. Likewise, the same areas can be used to implement conservation and management practices or disaster impact mitigatory projects.

Management level stakeholders (Regional Plantation Companies – RPCs, Tea Smallholders and their societies and other decision makers) in the tea industry can use the guidelines to improve the health of the watershed in tea grown areas which will eventually contribute to mitigate floods in lowland areas. Moreover, it is expected that these guidelines would be used by the local level government authorities for land use planning purposes in these two districts. Finally, all the authorities that can contribute to protect watersheds through policy and legal provisions could also use this document.

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ANNEX 1:

DETAILED INSTRUCTIONS FOR USING MAXENT (DATA PREPARATION AND ANALYSIS)

We used Maxent software to create a spatial flood vulnerability map for Ratnapura and Kalutara districts. These two districts cover most of the Kalu Ganga basin (Figure A.1)

We used the following spatial layers in Maxent to model flood vulnerability areas in Kalutara and Ratnapura districts, the Area of Interest (AOI):

- Land use and land cover (Figure A.2)
- Soil types (Figure A.3)
- Slope map (Figure A.4)

We also generated a flow accumulation model for the two districts using the Hydrology toolbox in ArcGIS. The flow accumulation model shows the direction and accumulation of hydrological flows; i.e., where and how much water (Figure A.5).

We used the 30 m Digital Elevation Model (DEM) (Figure A.6) to generate the raster files for slope and flow accumulation. The DEM for Sri Lanka was clipped to the Area of Interest (AOI) using the boundary map for Kalutara and Ratnapura districts.

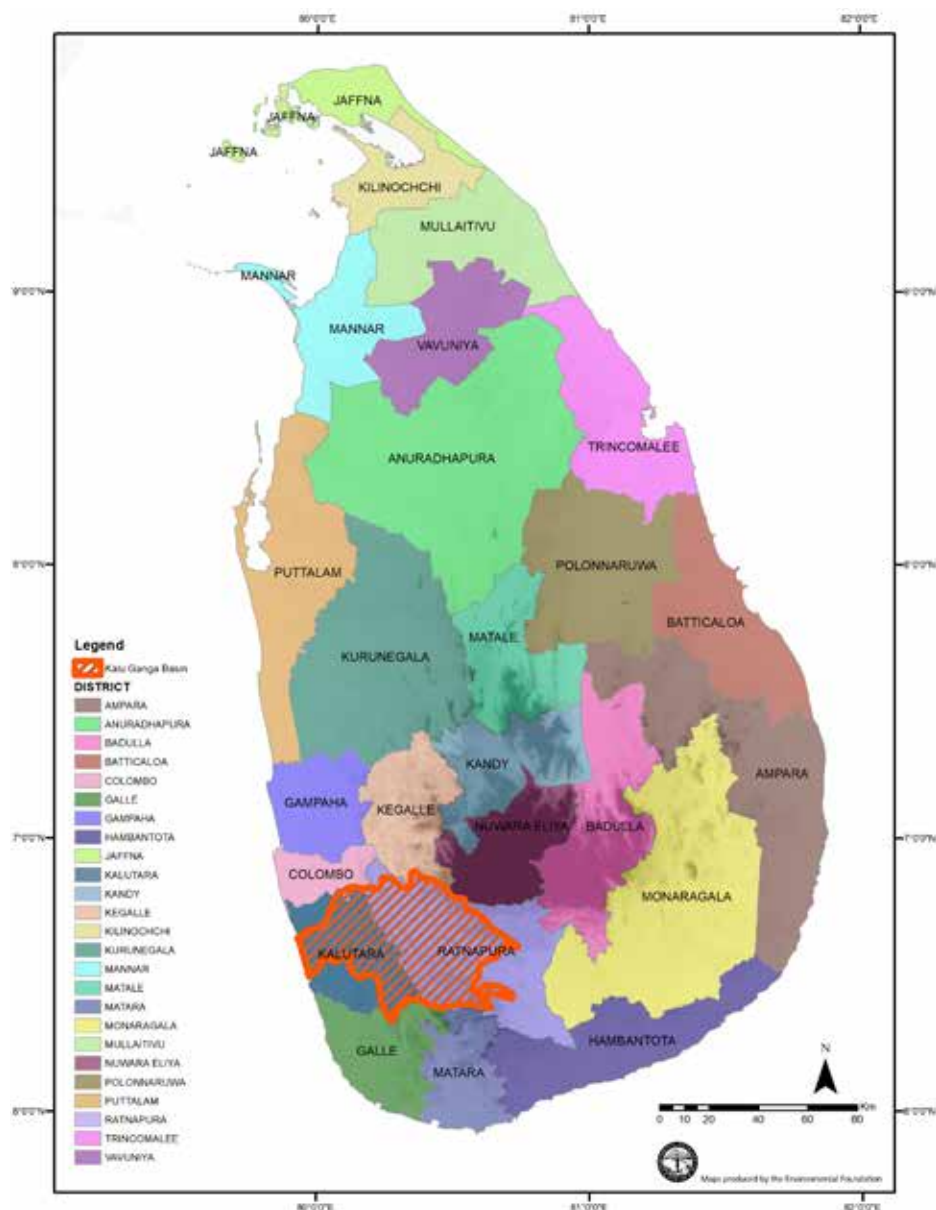


Figure A.1: Map to show location of Kalu Ganga basin in relation to Kalutara and Ratnapura districts. The basin includes most of these two districts.

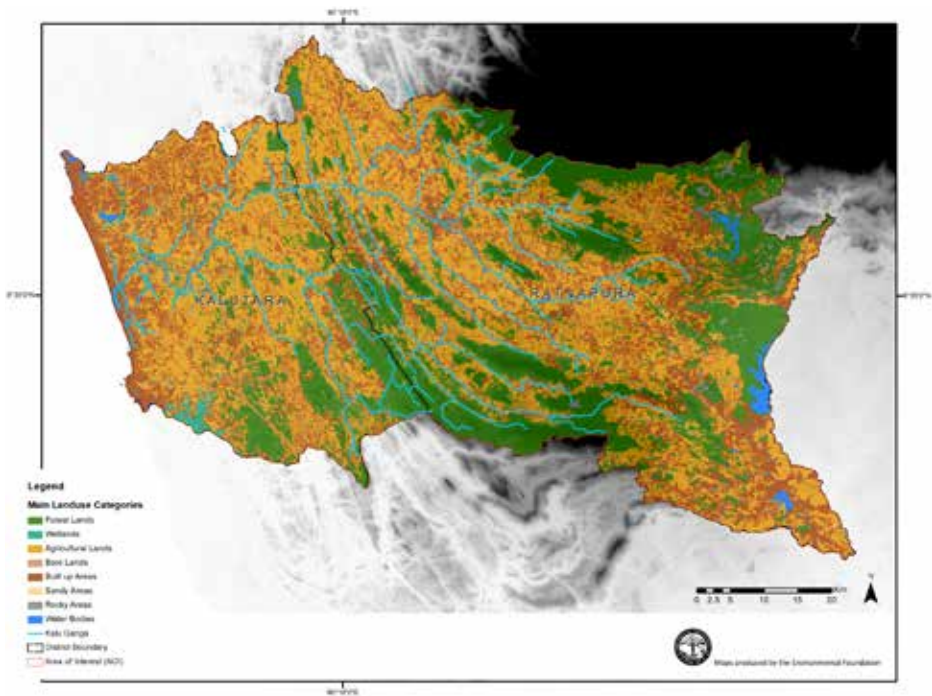


Figure A.2: Major land use and land cover types in the Ratnapura and Kalutara districts, the Area of Interest (AOI). This land use and land cover map was used in Maxent to generate the flood potential areas for Ratnapura and Kalutara districts. The natural ecosystems of both districts have been mostly converted. Some forest lands still remain in the higher elevations. These forests are within protected areas. Sinharaja National Heritage Wilderness Area is an important protected area in the southern part of Ratnapura and western part of Kalutara district.

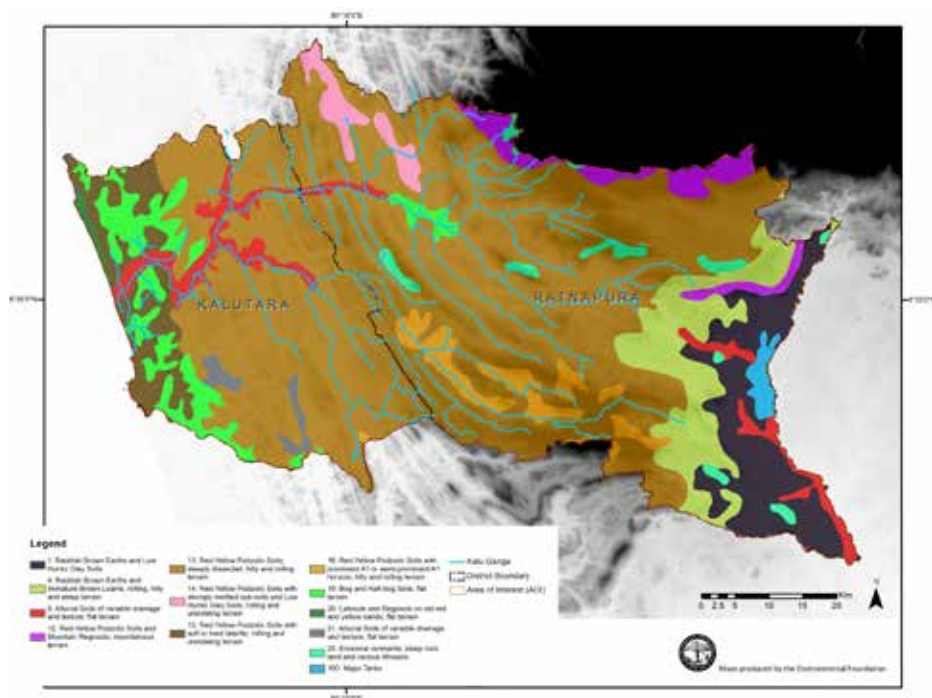


Figure A.3: Major soil types in the Ratnapura and Kalutara districts. The soil map was used in Maxent to generate the flood potential areas for Ratnapura and Kalutara districts.

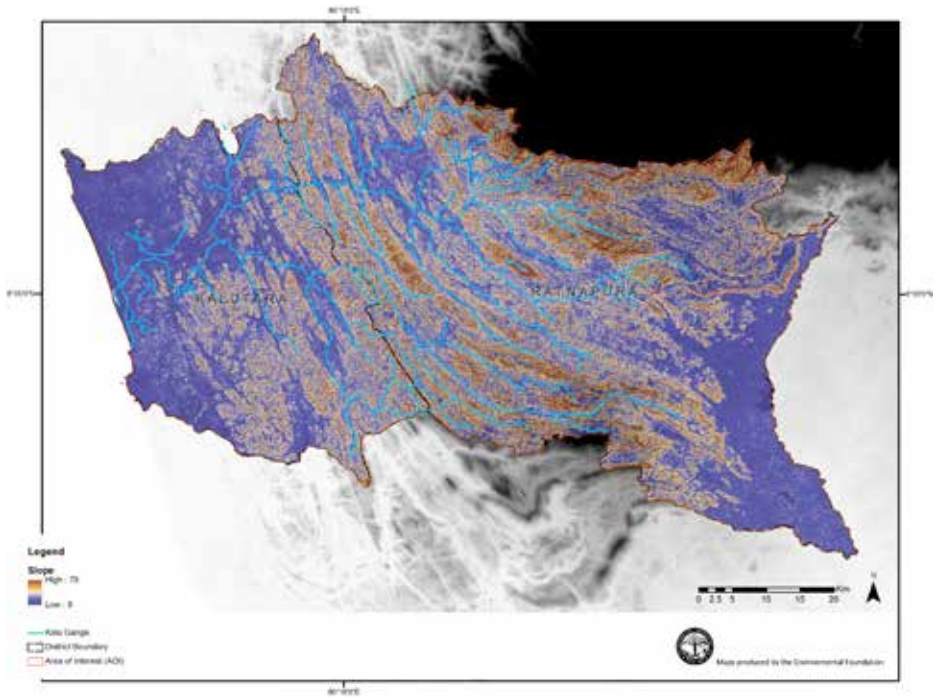


Figure A.4: The slope map generated from the 30m Digital Elevation Model (DEM). The slope map was used in Maxent to generate the flood potential areas for Ratnapura and Kalutara districts.

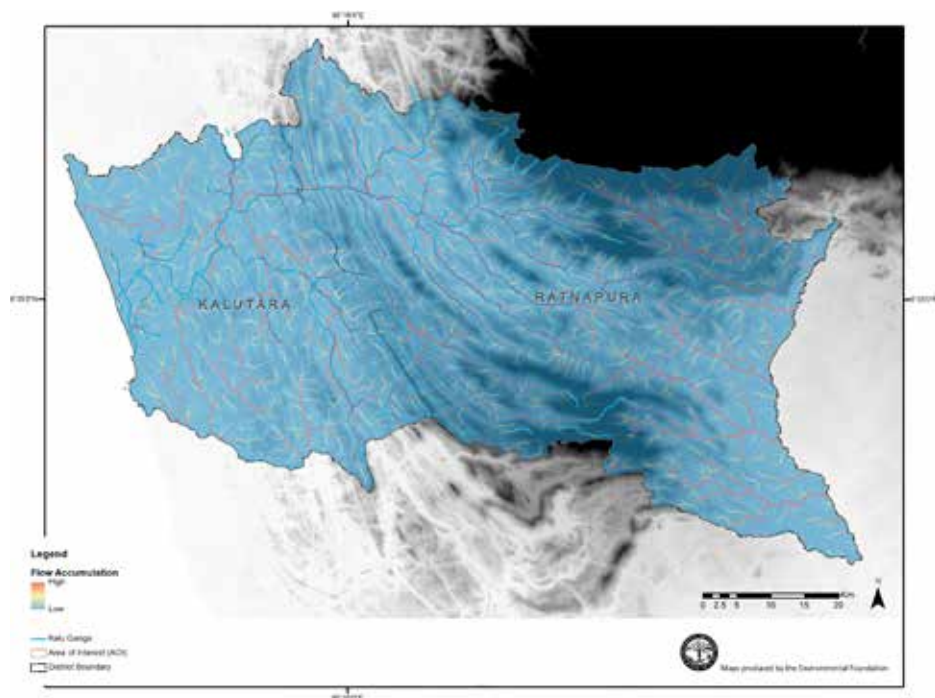


Figure A.5: The flow accumulation coverage for Ratnapura and Kalutara districts. The coverage was generated using the Hydrology function in ArcGIS. The yellow lines indicate low hydrological flows from origins, and the red shades indicate stronger or higher flows due to flow accumulation.

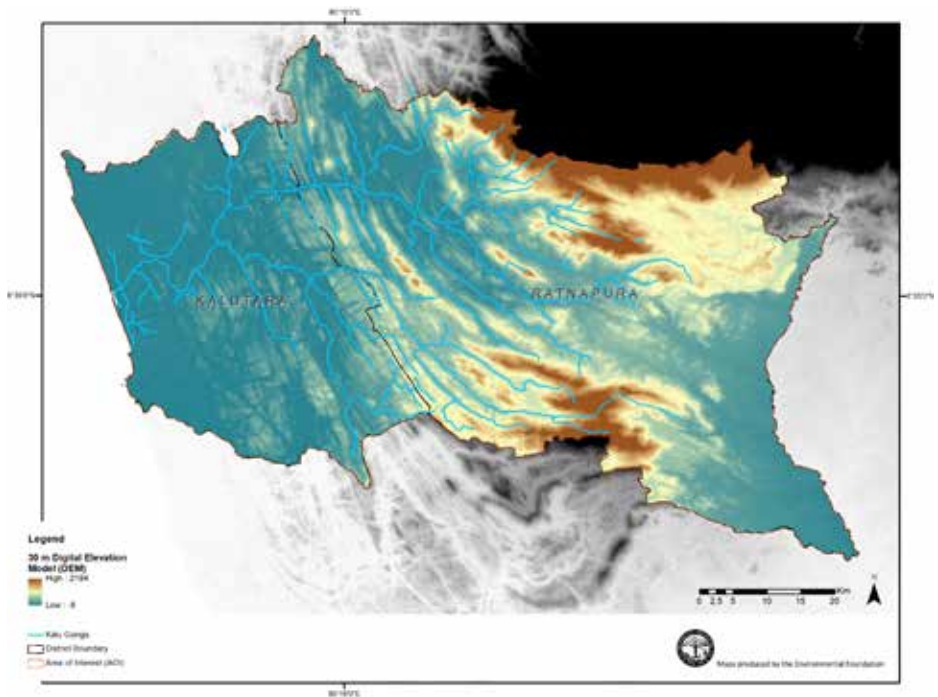


Figure A.6: The 30m Digital Elevation Model (DEM) clipped to Ratnapura and Kalutara districts to show topographical relief and elevation.

The Maxent output for the flood vulnerability areas show that much of the low-lying areas of both districts are vulnerable to flooding (Figure A.7). The outputs from the jackknife analysis (Figure A.8) shows that soil explained most of the environmental contributions to the Maxent model (64.2 per cent), while land use was next with 23.5 per cent, and slope contributed 12.3 per cent (Table 1).

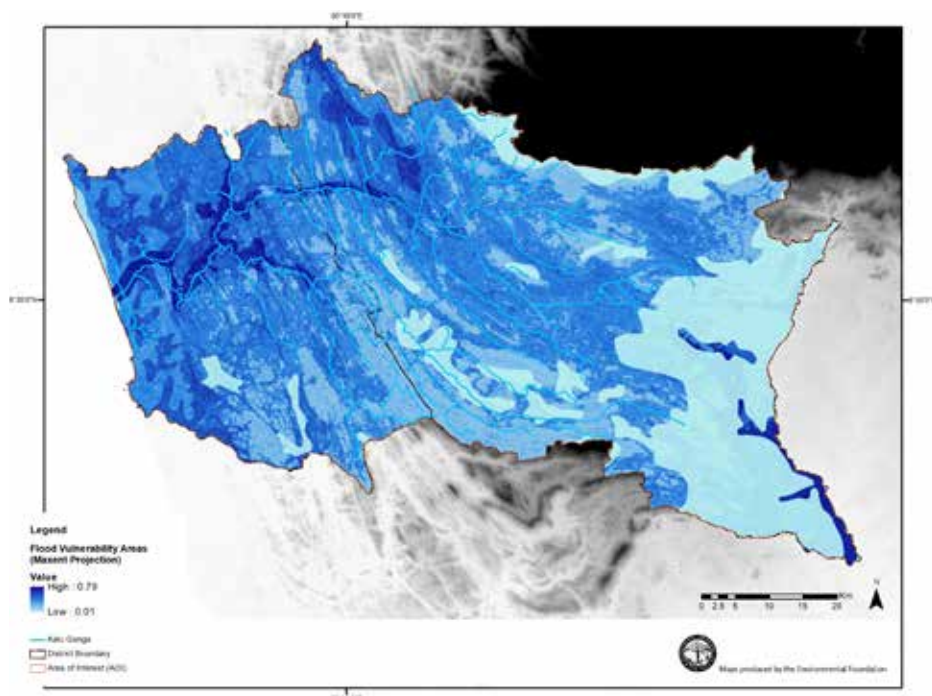


Figure A.7: The Maxent output using land use/land cover, soil types, and slope showing the predicted flood prone areas in Ratnapura and Kalutara districts. The darker blue shades indicate areas that are more prone to floods. The Maxent model was trained using 2000 random points extracted from areas that have been historically flooded following heavy rainfall.

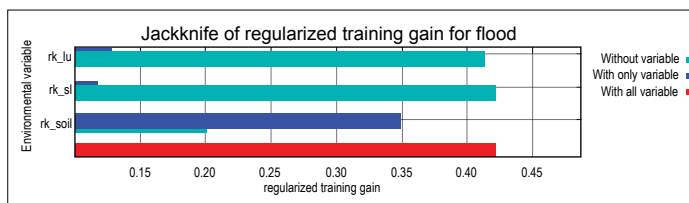


Figure A.8: The jackknife analysis output from Maxent. The output indicates that soil (rk_soil) contributes most to flood proneness, followed by land use and land cover (rk_lu).

We also ran Maxent with two other additional spatial layers; the DEM to represent elevation and the flow accumulation layers to test the contributions of elevation. This output indicated that elevation accounted for almost 84 per cent of the contributions to floods (Table 2), with the low-lying areas accounting for most of the contributions (Figure A.9).

Table A.1: The estimates of relative contributions of the environmental variables to the Maxent model. Soil (rk_soil) contributed 64.2 per cent to the model, while land use-land cover (rk_lu) contributed 23.5 per cent.

Variable	Percent contribution
rk_soil	64.2
rk_lu	23.5
rk_sl	12.3

Table A.2: The estimates of relative contributions of the environmental variables to the Maxent when the DEM is included to represent elevation. Elevation (rk_dem) contributes 83.9 per cent of the variability to the model, while soil contributes the next highest.

Variable	Percent contribution
rk_dem	83.9
rk_soil	14.6
rk_lu	1
rk_flo	0.3
rk_sl	0.1

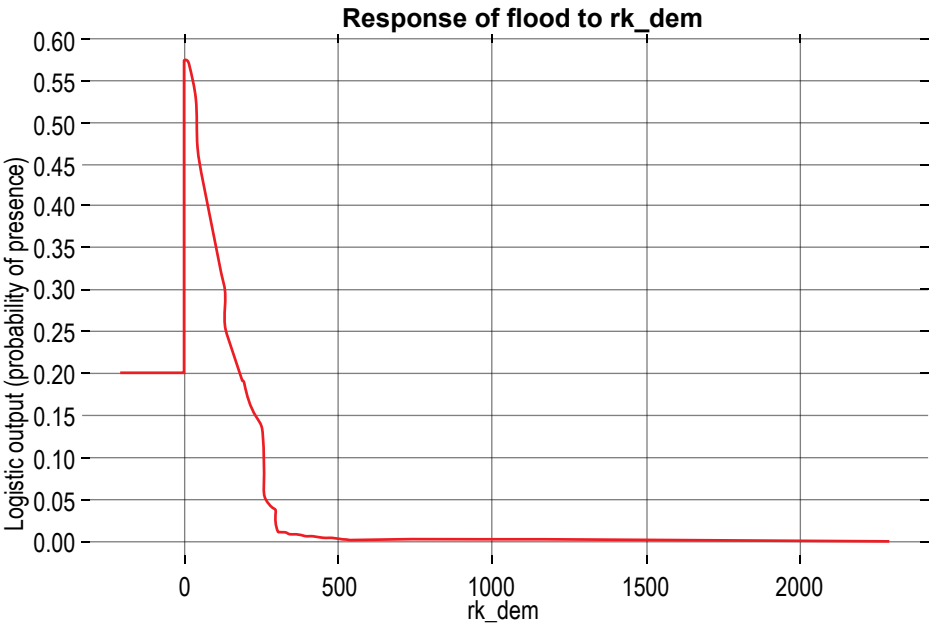


Figure A.9: Maxent response curve for the Digital Elevation Model (DEM) indicates that the low elevation areas contributed most to the output.

extracted the forests and tea lands (Figure A.10) from the land use/land cover and overlaid the coverage on the Maxent output (Figure A.11).

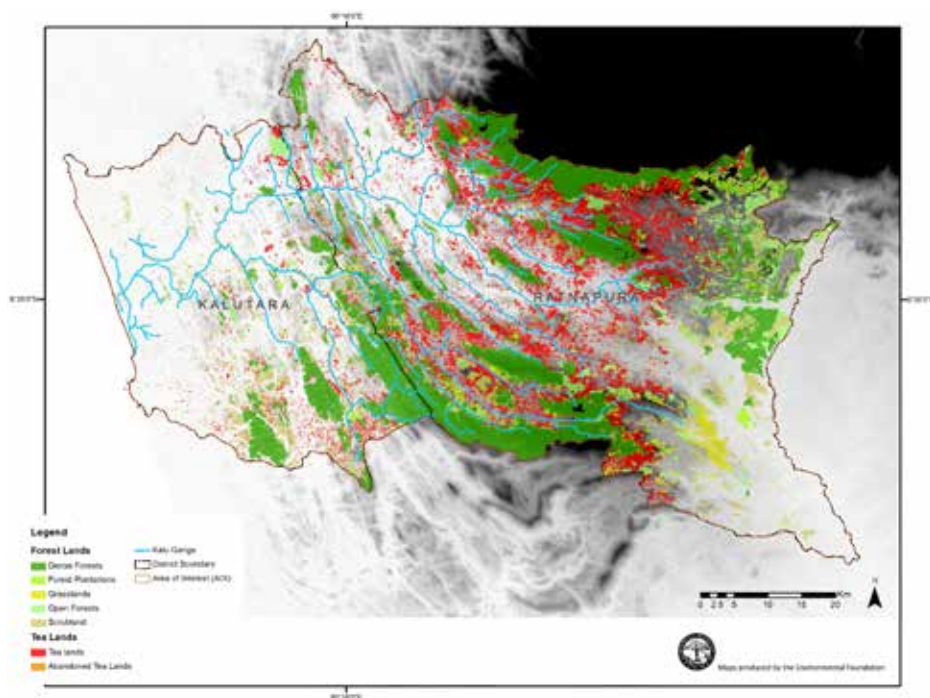


Figure A.10: The forests and tea lands extracted from the land use and land cover database.

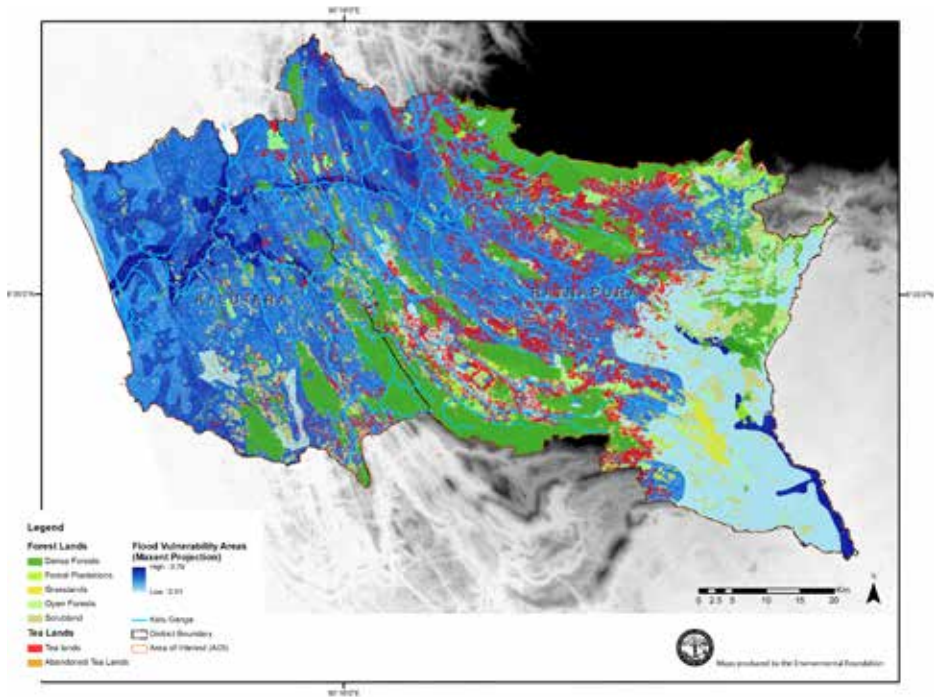


Figure A.11: The forests and tea lands overlaid on the Maxent output of flood prone areas to show relative distributions.

We then overlaid the ‘hydrological conduit’ network (i.e., the rivers and streams generated by the flow accumulation model) to identify the relative contributions and origins of hydrological flows within the basin from the various catchments based on the flow accumulation coverage and their respective land uses (Figure A.12).

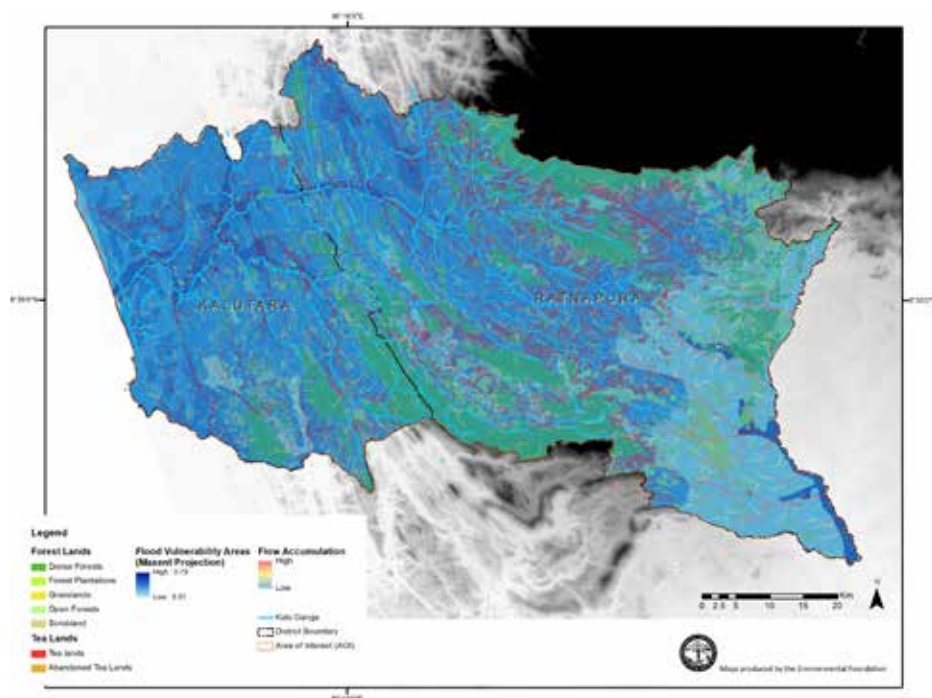


Figure A.12: The flow accumulation model of the 'hydrological conduit' network was overlaid on the forests and tea lands, and the Maxent output of flood prone areas (shown in Figure A.11) to show the relative contributions and origins of hydrological flows within the basin from the various catchment areas and their respective land uses. The streams that originate in the high elevation areas, which are forested, have low flows. However, the flows accumulate as they flow further into the middle, low-lying regions of the districts and are shown as shades of red. These higher flow areas are in tea lands and non-forest land use areas.

Based on the patterns and correlations of this methodology and tools, our results indicate the following:

1. The low-lying areas are most vulnerable to flooding
2. Areas with the following soil types are flood prone: Alluvial Soils of variable texture and drainage in flat terrain (9); Red-Yellow Podzolic Soils with strongly mottled sub-soil and Low Humic Gley Soils; rolling and undulating terrain (14); Red-Yellow Podzolic Soils on steeply dissected, hilly and rolling terrain (13); and Bog and Half-bog soils, flat terrain (19) (Figure A.13- graph)

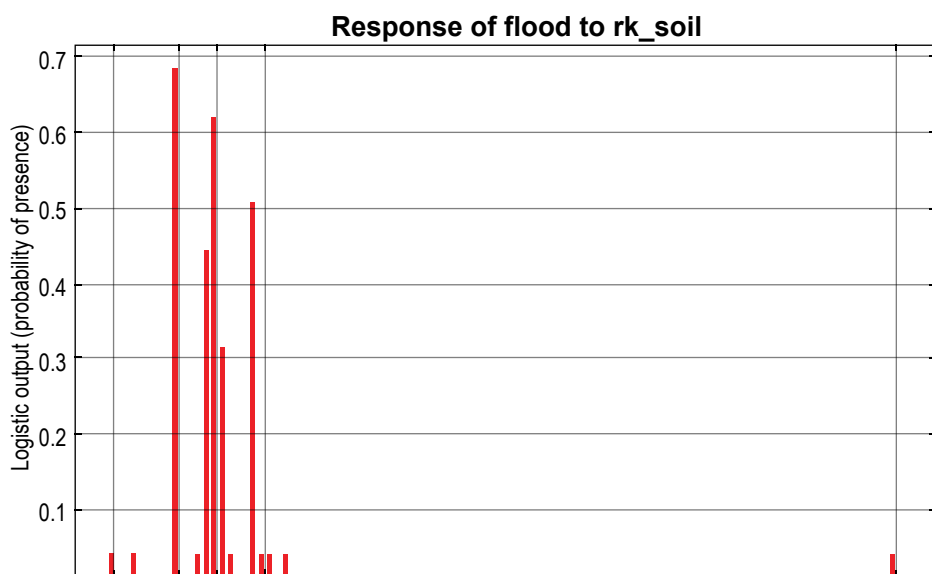


Figure A.13: The Maxent response curve for soils show that the Alluvial Soils of variable texture and drainage in flat terrain (9); Red- Yellow Podzolic Soils with strongly mottled sub-soil and Low Humic Gley Soils (14); Red-Yellow Podzolic Soils on steeply dissected, hilly and rolling terrain (13); and Bog and Half-bog Soils, flat terrain (19) contribute most to flood proneness.

3. All major land use types with the exception of forest lands (6) contributed to floods (Figure A.14– graph). Wetlands (4), agricultural lands (2), built up areas (1), and bare lands (7) contributed most. There were few sandy areas (5) in the AOI. These land uses that contributed to flooding had low permeability, with low capacity for infiltration of rainwater into the ground. Wetlands are boggy areas that are already saturated but do act as sinks for rainwater.

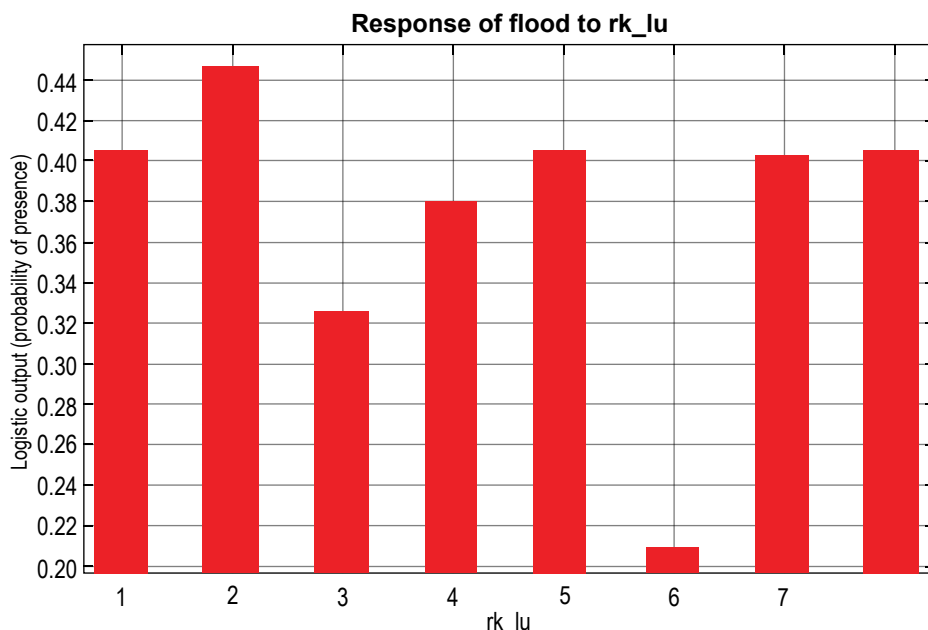


Figure A.14: The Maxent response curve for land use shows that with the exception of forest lands (6), all others contributed substantially to flood proneness. However, agricultural lands (2), built up areas (1) and bare lands (7) contributed more than water bodies (3) and wetlands (4). There are few sandy areas (5) and rock areas (8) in these two districts.

- The flow accumulation patterns indicate that the hills surrounding the low-lying areas in Ratnapura district are origins of water flows and contribute to accumulation in the low-lying, flood-prone areas (Figure A.12).

5. The landuse in the higher elevation areas are a mix of forest lands and tea lands (Figure A.11). The model indicates that the flows become greater in the tea lands, especially in the northern sections of the Ratnapura and Kuruwita DS divisions and southern areas of the Nivitigala and Kahawatte DS divisions (Figure A.15).
6. Because forest lands, with their high rainfall infiltration and percolation capacities, can ameliorate surface flow, managing land use, especially in the tea lands, to allow more surface water percolation, along with surface water management to reduce downslope flows, could help to decrease flooding in the low-lying areas of Ratnapura district, especially in the southern areas of Ratnapura DS division, and Elapatha, Nivitigala, and Kuruwita DS divisions.

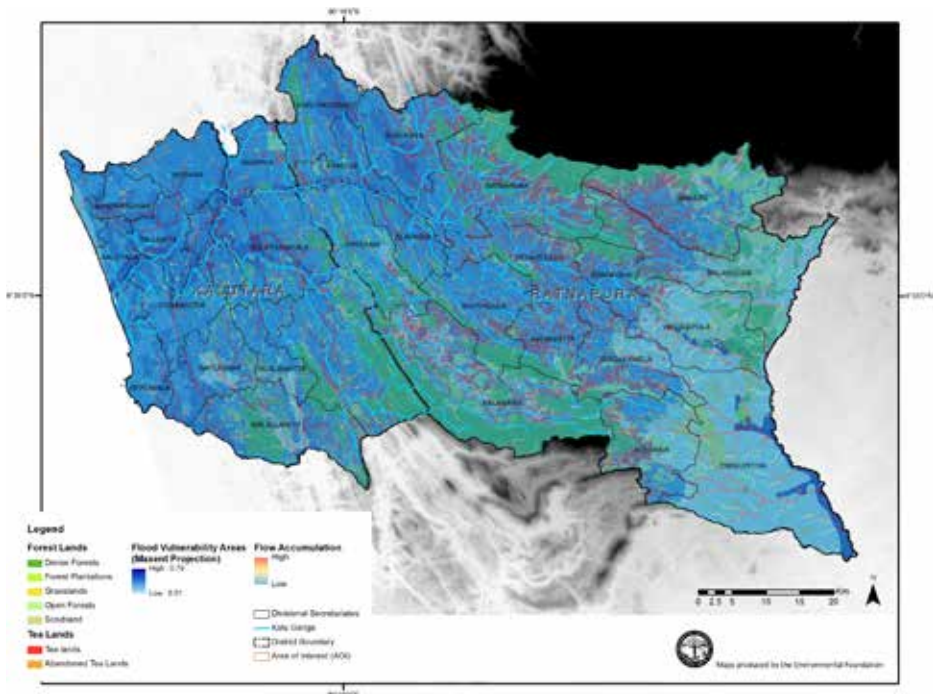


Figure A.15: Areas under the district secretariats overlaid on the flood proneness, land use and flow accumulation model show that the Ratnapura and Kuruwita DS divisions and southern areas of the Nivitigala and Kahawatte DS divisions require attention to restore ground and land cover and restore ground permeability and infiltration capacity to reduce the risks of flooding.



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