Training Manual for Integrating Biodiversity Conservation and Sustainable Use into Land Use Planning in Environmentally Sensitive Areas

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June 2017

Biodiversity Secretariat
Ministry of Mahaweli Development and Environment

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MESSAGE OF THE SECRETARY/ MINISTRY OF MAHAWELI DEVELOPMENT & ENVIRONMENT

Sri Lanka is a small island with rich biological diversity and high level of endemism. Biodiversity of the country is unique and hence it has universal value. Nevertheless, it is currently under threat from ever increasing human interferences. Due to this extraordinary endemism and also high level of threat the country is considered as one of the global biodiversity hotspots.

Sri Lanka has signed the "**Convention on Biodiversity"** in 1992, ratified it in 1994 and is obliged to implement the relevant provision of the Convention. As per the Article 6 of the CBD, This Ministry has developed the National Biodiversity Strategic Action Plan (NBSAP) to mainstream biodiversity into national development policies and activities of their key national economic sectors. The Strategic Action Plan has proposed working solutions and actions after in depth studies on causes of degradation of biodiversity of our country.

Sri Lanka has instituted a national system of Protected Areas (PAs), but not withstanding actions underway to identify gaps in PAs and to expand the PA estate, many of the globally important ecosystems and habitats of globally significant species will continue to remain outside protected areas and will face accelerating pressures. Unless strong measures are undertaken to put development on a more conservation- friendly trajectory by mainstreaming biodiversity into production activities, biodiversity outside and inside protected areas cannot be safeguarded, especially under the current context of rapid urbanization and high rate of economic development in the country. Environmentally Sensitive Areas (ESA) project have been developed to introduce a new land use governance frame work for Sri Lanka to safeguard biodiversity in the multiple land use areas with high biodiversity value.

I believe we as the Ministry of Mahaweli Development & Environment has the responsibility in strengthening the country's ability to safeguard biodiversity inside and outside protected areas in special Environmentally Sensitive areas, through a new land use governance framework. ESA project has developed this training manual to be guide the land use planners, especially at sub-national administrative units to integrate biodiversity priorities into land-use plans. I wish these guidelines and tools will be instrumental to integrate biodiversity conservation into landscape level land use planning process.

Udaya R. Senevirathna
Secretary
Ministry of Mahaweli Development and Environment

MESSAGE OF THE DIRECTOR/ BIODIVERSITY SECRETARIAT

Enhancing Biodiversity Conservation and Sustenance of Ecosystem services in Environmentally Sensitive Areas (ESA Project), is a GEF funded project implemented by the Ministry of Mahaweli Development and Environment with the assistance of UNDP for mainstreaming biodiversity management into development in areas of high conservation significance.

The National Biodiversity Strategic Action Plan (NBSAP) is the main policy instrument we have for guiding us on conserving biodiversity of the island and using it for sustainable development as well as sharing benefits generated by it among the general public in a justifiable manner. It contains recommendations for mainstreaming biodiversity in a sustainable manner into the national economy.

The concept of developing the ESA project is to conserve the biodiversity of the country and the objective of this project is aligned with the following national targets of NBSAP.

1. By 2022, habitat loss, degradation and fragmentation are significantly reduced.
2. By 2022, the loss of species is significantly reduced
3. By 2022, mechanisms are established to ensure sustainable use of biodiversity
4. By 2022, sustainable agriculture practices are promoted and established.
5. By 2022, traditional sustainable uses of biodiversity are promoted and established
6. By 2022, the capacity of ecosystems to deliver goods and services and provide protection from hazards is enhanced

Whilst the BDS has the overall policy advisory role on biodiversity conservation nationally, specific conservation actions on the ground are implemented by a number of Departments/ Agencies under the Ministry of Mahaweli Development & Environment and other Ministries.

I hope this document will be taken as an important tool in future to build the capacities of land use planning teams to integrate biodiversity conservation into land use planning.

R.H.M.P. Abeykoon
Director (Biodiversity)
Biodiversity Secretariat

MESSAGE OF THE DIRECTOR/ ENVIRONMENT PLANNING & ECONOMICS DIVISION

The Project "Enhancing Biodiversity Conservation and Sustenance of Ecosystems services in Environmentally Sensitive Areas (ESAs)" is funded by GEF, implemented by the Ministry of Mahaweli Development and Environment (MoMDE) and supported by UNDP. The Project would contribute to safeguarding globally significant biodiversity on production lands of high interest for conservation. Project activities will provide a vehicle for safeguarding globally significant biodiversity on multiple-use lands of high conservation values.

The national policy, strategy and national scale up plan for ESAs and national institutional capacities to foster inter-sectoral partnerships to be developed to support ESA identification, management and monitoring. The Project proposes to use land use planning and management frame work as the key entry point to optimize land management in ESAs to ensure conservation of biodiversity and other natural resources while allowing the ESAs for sustainable economic activities under proper management. These guideline is expected to build capacity of the national and divisional level planning teams and provide overall guidance to undertake the integrated, cross-sectoral participatory planning exercise to develop a spatial land use management plan for each site of the Kala Oya Project area.

I hope this document will be used among intersectoral partners as an important tool in mainstreaming biodiversity conservation into land use planning.

Deepal C. Siribaddana
Director, Environment Planning & Economics/ Project Director -ESA
Environment Planning & Economics Division

PREFACE

Biodiversity is a natural heritage that most countries on Earth are now bound by various international covenants to conserve and protect. Sri Lanka, as a signatory to the Convention on Biodiversity, the RAMSAR convention on wetlands, and the more recent Paris Agreement on Global Climate Change, has obligations to conserve its biodiversity.

Landscape-scale conservation is now the widely accepted paradigm for biodiversity conservation. However, conservation at these scales go beyond protected area boundaries, which were the traditional scale at which biodiversity conservation was viewed and all planning and management was conducted. Taking conservation beyond the boundaries of protected areas requires a much more involved process of conceptualization, visualization, planning, and implementation. The process also has to engage a larger number of stakeholders and entails resolving and reconciling inevitable land use priorities and conflicts.

Landscape-scale conservation planning is basically an exercise in land-use planning. But it requires an understanding of biodiversity priorities and ecological processes, and how to evaluate and prioritize them. Unfortunately, most traditional land-use planning teams from national to sub-national levels are not capacitated to conduct these analyses. Planners are generally unaware or uninformed about the importance of integrating biodiversity conservation into land-use planning processes in a systematic manner. This manual is meant to be a guide for land-use planners, especially at sub-national administrative units, to integrate biodiversity priorities into land-use plans. It is intended to build awareness and understanding of the importance of including biodiversity conservation priorities into planning processes, the contributions that biodiversity and functioning ecosystems make towards sustaining ecosystem services and human wellbeing, the underlying principles of selecting biodiversity priorities, and introduce some of the spatial planning tools available to identify biodiversity conservation priorities and integrate them into land-use plans. The manual neither assumes, nor is it intended to build in-situ biodiversity expert capacity within the planning units. Instead, it is meant to build an understanding of basic principles that planners can bring to an essential consultative workshop with biodiversity experts in academic and other relevant institutions as an early step in the planning process.

The Project

"Enhancing Biodiversity Conservation and Sustenance of Ecosystems Services in Environmentally Sensitive Areas" is a GEF funded project, implemented by the **Ministry of Mahaweli Development and Environment** (MoMDE) and supported by UNDP with the objective of streamlining biodiversity management in the course of development in the areas with conservation value."

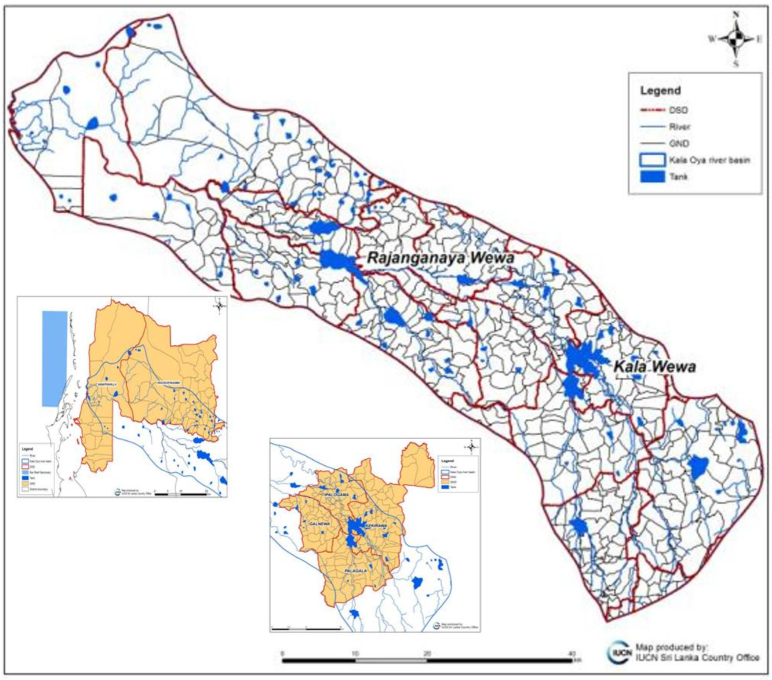
The project focuses integrating biodiversity conservation into the mix of diverse land use patterns in Environmentally Sensitive Areas (ESA) across Sri Lanka, especially in areas outside the Protected Areas. The ESA's will act as the structure upon which a landscape-scale land use management framework will be established.

Under this project, Outcome Two includes a Land Use Planning and Capacity Building Assignment (RFP-ESDR/ESA/2016/01) which will involve the initial implementation of an ESA identified in two sites within the Kala Oya basin. The aim of the assignment is to foster inter- sectoral partnerships and conserve the biodiversity and ecosystem services of the land area.

This training manual is an instrument in detailing key data-needs, methods and analytical approaches for prioritizing biodiversity conservation targets, including steps and approaches for multi-criteria spatial planning to integrate conservation into multi-sectoral (i.e., agriculture, irrigation, roads, etc.) land-use planning. Through the visualization, planning and integration of guidelines at a local level it will serve as the cornerstone in addressing the larger concerns of the nation.

Project Area

Kala Oya Basin in Puttalam and Anuradhapura Districts



Project area, the Kala Oya basin and the two priority sites within the basin (inset maps) that that have been identified as Environmentally Sensitive Areas (ESAs).

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EXECUTIVE SUMMARY

Biodiversity is not evenly distributed; some ecosystems are more diverse and species-rich, some have high spatial turnover of species while others have more homogeneity. Many ecosystems have very high levels of endemism, which make them irreplaceable and even un-restorable if they are degraded or converted. Certain ecosystems support critical ecosystem processes and services based on their location; e.g., watersheds of river headwaters.

Most ecological processes - from animal migrations and dispersal to pollination and seed dispersal, and hydrological processes - occur at spatial scales that are larger than can be contained within small sites-scaled areas. Large species generally roam across large areas in search of food, water, and mates. Some large animals roam across large area ,,.. food and water. Loss of ecological links in ecosystem processes or species' life histories due to lack of adequate spatially distributed resources or access to the resources can have cascading impacts that affect entire ecosystems and long-term survival of species.

Because of this variability in distribution of biodiversity and the need for larger spatial areas than provided by the relatively small protected areas, successful, long term conservation of biodiversity requires landscape-scale approaches and strategies.

Landscape-scale conservation planning is essentially an exercise in land-use planning where biodiversity conservation priorities are identified, spatially mapped, and targets set for conservation using large-scale spatial analysis. The spatially explicit conservation areas are then integrated into land-use plans at national and sub-national levels.

The five-step process begins by defining the landscape boundary. In Step 1, the planners will convene an expert workshop to identify the representative biodiversity—including species and their habitats, ecosystems, and ecosystem processes and services—in the landscape and map their distribution. Because distribution data are usually not available for all biodiversity, a set of proxy species will be selected to represent overall biodiversity.

In Step 2, planners will set quantitative conservation targets for the selected priorities. These targets will indicate how much and where the biodiversity can be conserved. The outputs will be spatially depicted through GIS analyses. Both steps will require expert consultation. Information should also be sourced from the NBSAP, which should be used as a touchstone during planning.

In Step 3 the biodiversity targets will be prioritized for conservation; in most cases, lack of resources, time, funds, and even land-use conflicts may require that some biodiversity targets require more attention, and sooner. However, it is important to note that every effort should be made to conserve all biodiversity represented in the landscape; prioritization does not imply that some species or ecosystem processes should be allowed to disappear or degrade, or become completely converted throughout the landscape. The prioritization will be guided by several principles and criteria that are widely used in conservation planning.

Step 4 will be a gap analysis to identify where additional conservation protection and conservation interventions are needed to ensure representative and priority biodiversity targets are covered. The gap analysis should also refer to the NBSAP.

Step 5 is a critical step where the conservation areas are integrated and mainstreamed into national and sub-national land-use plans. It is essential that the conservation areas that have been identified and prioritized are given due recognition for their high biodiversity values that also support and sustain human livelihoods and economic development by providing important ecosystem goods and services. By integrating these biodiversity conservation areas into landscape-scale land-use plans, the conservation areas are assigned a land-use function, and not perceived as being 'undeveloped areas' that can be allocated for other uses. Integrating the conservation areas into land-use plans in an explicit way can also reduce conflicts between environmentalists and developers, facilitating economic development. However, because development invariably has larger impact footprints that go beyond the immediate development area, proper IEEs and EIAs are necessary.

Photo credits: Gayan Pradeep

CHAPTER 1 – INTRODUCTION

Why landscape-scales for conservation?

Most ecological processes that sustain biodiversity occur at spatial scales that are larger than can be contained within small sites-scaled areas, such as national parks, sanctuaries, reserves and other protected areas (Margules and Pressey 2000, Noss 1983, Wilson 2016). These processes can include animal migrations or other life history related movements, pollination and seed dispersal, and hydrological processes such as river flows, to name a few. Loss of ecological links in ecosystem processes can have cascading impacts that can affect entire ecosystems, including in places far away from the source of the threats (Estes *et al*. 2011). For example, removal of forest cover in the headwaters of a river or stream can impact ecosystems and communities far downriver through floods, siltation, and loss of sustained water supplies. Offshore coral reefs can become silted. In Sri Lanka, large, wide-ranging species like the elephant usually require more habitat areas than can be included within a single protected area. Therefore, successful conservation must happen at the larger spatial scales necessary to include these processes, and in most cases, this can only be provided through landscape-scale conservation planning and plans.

Biodiversity is also not evenly distributed across a landscape. Some ecosystems are more diverse and species-rich, some have a high spatial turnover in species while others have more homogeneity. Many ecosystems have very high levels of endemism, which make them irreplaceable and even un-restorable if they are degraded or converted. Certain ecosystems support critical ecosystem processes and services based on their location; e.g., watersheds of river headwaters.

Because of this variability in distribution of biodiversity, a few protected areas cannot adequately capture all biodiversity. Landscapes have better spatial thresholds and capacities than small sites to include the species turnover (i.e., β and μ -diversity[1]), and more ecosystem processes and links than small sites (Pressey and Bottrill 2009). This is especially true in ecosystems such as tropical moist forests which have very high α biodiversity (i.e., site-scale biodiversity), but are also high in β - and μ -diversity.

Landscapes can also increase the persistence and long term viability of species populations, and provide more habitats to conserve the ecological, demographic, behavioural, and genetic characteristics of a species (Hanski and Ovaskainen 2000). Managing a number of small, connected populations can increase the viability and persistence of even small populations through 'metapopulation dynamics' than when compared to a small, isolated population.

Global climate change has now emerged as a significant driver of ecosystem change (IPCC 2007, Parmesan 2006). The changing climatic conditions are expected to cause shifts in range distributions of species, local extinctions, and changes to ecosystems and ecological communities (Hansen *et al*. 2001). Ecosystem process and service delivery will also become affected (Mooney *et al*. 2009). Larger, more intact ecosystems, especially at landscape scales, are more resilient to climate change (Thompson *et al*. 2009), justifying the need for conservation at large spatial scales.

Since landscape-scaled approaches are now the widely accepted paradigm for conservation planning, it is also important that such planning is based on a process that ensures

[1]Very simply, β diversity quantifies the number of different communities in the region and μ diversity represents the biodiversity of an entire landscape, or the regional species pool

representation of all biodiversity and relevant conservation units, with quantitative and measurable conservation targets, where possible (Grumbine 1994, Margules and Pressey 2000, Pierce *et al*. 2005, Tear *et al*. 2005). The targets should be set to ensure persistence of focal species populations and their ecological characteristics (i.e., the roles of the species in the ecosystems), and the ecological processes that sustain biodiversity and ecological communities and systems.

The planning process will include identifying appropriate and adequate habitat, protecting key areas, and connecting core areas to enable species movements, and connecting source areas with sink areas to facilitate environmental flows (SANBI & UNEP-WCMC 2016). It will include an analysis to make sure that the representative ecosystems are included within the conservation system. The identified conservation areas, including habitats and ecosystems, should then be prioritized so that the high priority areas and conservation targets will receive most attention.

Landscape-scale biodiversity conservation plans are also important to support people's livelihoods and lives, and national and sub-national economic development aspirations and goals because much of the biodiversity also includes forest products that are used by people, and many ecosystem processes are also ecosystem services that support local communities and economic development plans (Balmford *et al*. 2002, Kaimowitz and Sheil 2007, Sachs and Reid 2006). Loss of these services due to environmental and ecosystem degradation can result in natural disasters that can lead to loss of livelihoods, lives, infrastructure, agricultural productivity, and eventually result in social upheaval and chaos.

Therefore, the biodiversity conservation plans must be integrated into regional and local land-use plans so that when lands are identified for allocation for various land uses, the priority conservation areas are not given away for other conflicting uses. Moreover, when the conservation priorities are explicitly identified and integrated into land-use plans, and recognized for their functions, conservation and development can both be supported with less conflict and disagreements over land allocations.

Photo credits: Sampath de Alwis Goonatilake @ IUCN

CHAPTER 2 – THE PLANNING PROCESS

First, it is important to define the extent of the landscape. There is no fixed definition or spatial extent that determines what a landscape is. Some accepted criteria are that a landscape should consist of a heterogeneous mix of land-uses and land cover types, and should be large enough to include ecosystem processes that maintain the ecosystems and species populations (SANBI & UNEP-WCMC. 2016). The land uses can include protected areas, corridors that link these protected areas, representative ecosystems that define the region, as well as human use areas in the matrix. It should also include spatial extents large enough to be resilient to threats. River basins represent good landscape boundaries because: a) ecologically, the hydrological flows—an important ecosystem process and service—are contained within a basin or sub-basin and it's easy to follow the course of environmental flows; and b) the geographic boundaries of a basin are clearly defined, topographically.

The landscape scale conservation plans also have to be linked to national level distribution of biodiversity and conservation priorities. For example, the landscape of interest may have some species that are found only in that landscape and nowhere else; i.e., endemic to the landscape. Therefore, these species become high priorities for conservation within that landscape. But, other species or ecosystems that can be better conserved in a different landscape may be a relatively lesser priority within the landscape of interest. A species that is very common in the landscape, but is highly threatened elsewhere in the country may become a conservation priority because of the conservation opportunity for that species presented in the landscape.

When the landscape has been identified, planners will select biodiversity conservation units; the focal species and their habitats, ecosystems, ecosystem processes, and ecosystem services that should be considered for conservation planning. Selection of these units requires asking and answering some key questions. Biodiversity experts must be consulted during this process to help identify priorities, and to develop the initial database for the landscape. Many of these biodiversity conservation units and priorities are presented in the National Biodiversity Conservation Strategy and Action Plan, and this plan should become the source for all initial planning information. It should be noted, however, that in many cases complete data and information for comprehensive landscape-scale planning, including populations and ecosystems may not be available. In such events, 'proxy' species that represent overall biodiversity can be used.

Step 1. Identify Representative Biodiversity in the Landscape and its Distribution.

'Biodiversity' (see Chapter 3 for a definition) for this planning process includes the holistic definition of the variety of life on Earth, from genetic and species diversity to ecosystems and the processes that maintain and sustain these ecosystems.

This conservation planning process should consult biodiversity experts where needed. The planning team will not be expected to become biodiversity experts. The planning team can also review the literature, including the National Biodiversity Strategic and Action Plan (NBSAP). Experts that should be consulted can include landscape ecologists, biogeographers, experts with knowledge on distribution of various taxonomic groups (mammals, birds, reptiles and amphibians, fishes, insects, plants, etc.), and soil scientists. Experts can be drawn from academic institutions, government and non-government organizations, etc.

Species Priorities. Identify the important species in the landscape and how they are distributed in the landscape, and create a spatial database.

These species can be selected from biodiversity survey outputs. But, biodiversity experts from the universities or other institutions should be consulted for their knowledge. Reports, publications should also be consulted.

Note that complete information about the presence and/or distribution of biodiversity in the landscape will not be available in most landscapes. In such cases, planners will have to work with whatever information is available for the moment. Since conservation planning, implementation and monitoring is an adaptive management process, the conservation plan can be updated as additional information becomes available. Waiting for a complete database will result in further delays and greater loss of habitat, species and conservation opportunities. Consult with experts during the workshop to help compile this database.

Use the NBSAP, the national Red List, and expert input to identify the species of concern in the landscape that require conservation attention and interventions. This should include both fauna and flora.

It is usually not necessary to map all species. Instead, some species can be used as ‘proxy’ species; i.e., they can be used to represent other biodiversity, especially species communities, habitats, or even ecosystems in some cases (see Chapter 3 for details). These are usually the ‘Landscape species’, ‘Umbrella species’, or ‘Habitat specialists’. The characteristics of these species are described below. However, deciding what these species are usually required some research and knowledge of ecology. It is strongly suggested that planners with no previous experience consult biodiversity experts to get advice on species selections. The National Biodiversity Secretariat also has a database of threatened and endangered species that should be accessed. The primary reason for compiling and maintaining a Red Data List is to help with recovery plans, including in-situ plans to provide adequate habitat for threatened and endangered species. Landscape-scale conservation should therefore include these species and consider the habitat and ecological conditions necessary for their recovery.

For some species, it is also important to understand how they are distributed outside the landscape, and even have information on priorities set at national levels. For example, a species that is rare in the landscape may be widely distributed elsewhere in the country, making it a lower priority for the landscape. Similarly, a species relatively widely distributed in the landscape may be rare at national scales, which makes it a high conservation priority for the landscape and nationally. This broader perspective will also assess the extent of the population and ecological links within the landscape and outside the landscape boundary. For example, if most of the population of a species falls outside the landscape, and the landscape does not present critically important habitat (e.g., key breeding areas or waterholes), then that species need not be considered a high priority for conservation in the landscape of interest.

From the species lists available for the landscape, the following should become conservation priorities:

- Endemic species.
- Threatened and endangered species.
- “Landscape species”
- Habitat specialist species

- "Keystone Species"
- Migratory species
- "Flagship species"

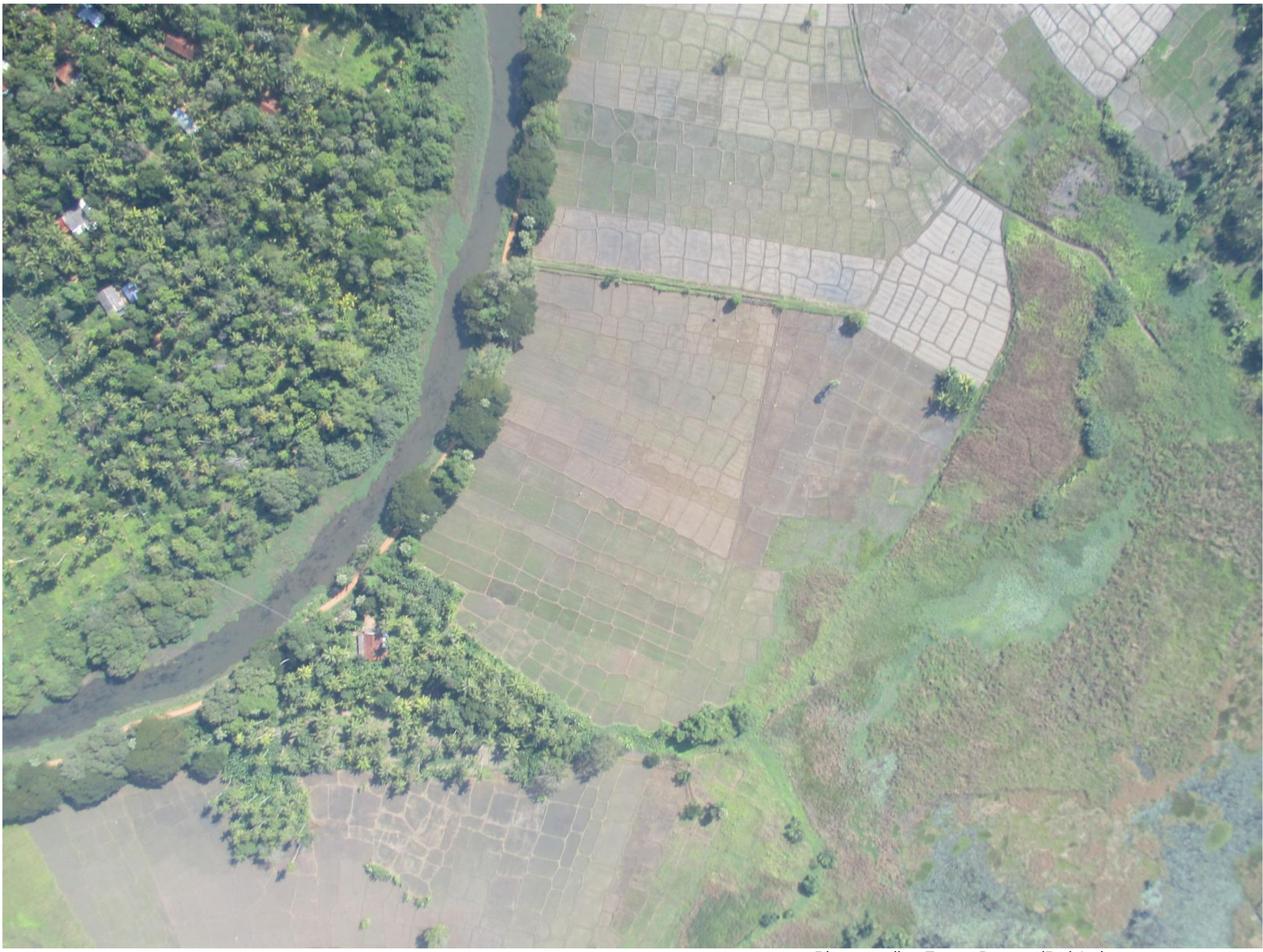


Photo credits: Future Drones (Pvt) Ltd.

These species are important conservation targets for the following reasons (also see Table 3). It is important to note that some species may qualify for several of these categories.

Endemic species: Because the distributions of endemic species are restricted to Sri Lanka, or even a small area within Sri Lanka. These species should be high priorities because they can only be conserved in Sri Lanka. Therefore, if endemic species are found in the landscape, their habitats must be protected from conversion and degradation.

Threatened and endangered species: These can be endemic or other species that are more widely distributed. These species are listed in the national Red List, available from the National Biodiversity Secretariat. Any endemic species that are also threatened or endangered should receive the highest priority for conservation. Species that are more widely distributed but are also threatened or endangered should become conservation priorities anywhere in the range; whether in Sri Lanka or outside Sri Lanka.

Landscape species: These are species that need large areas of habitat to survive. They usually tend to be large mammals. Because habitat fragmentation and loss are severe threats to their survival, any large areas of continuous habitat should be set aside for their conservation. Usually, because these are large mammals, habitat fragmentation and loss can also escalate human-wildlife conflict, resulting in socio-economic and governance problems. In Sri Lanka, elephants and leopards are good examples of landscape species. Usually these landscape species also make good ‘Umbrella species’ because if enough habitat is conserved and protected for these species, they will also provide conservation cover for other biodiversity.

Habitat specialist species: These are species with a very narrow niche, and require a specific type of habitat to survive. Any change in habitat composition or structure can result in local extinction of these species. A good example of a habitat specialist is the fishing cat, which requires wetland or riparian habitat.

Keystone species: These are species that usually help to maintain ecosystem integrity. Loss of these species can cause the ecosystems to change from the current state into a different ecosystem. Therefore, conservation of these species should be a priority. Keystone species need not be large mammals. Even smaller animals can help to maintain ecosystem integrity. Fruit bats and fruit-eating birds (hornbills, barbets, and pigeons) are examples of keystone species because they disperse seeds across the landscape. If seed dispersal stops, the forest ecosystem can change. Top predators (e.g., leopard) are also keystone species because they help to keep the populations of herbivores under control. If the top predators are lost and the herbivore populations increase rapidly, they can degrade the forest or grassland ecosystems

Migratory species: There are several migratory species that arrive in Sri Lanka to spend winter months. The best known are the birds; however, several insects such as butterflies and dragonflies also undertake long distance migrations. If the winter habitats of these migratory species are destroyed, these species will not survive. Therefore, winter habitats of migratory species should be conservation priorities. A good example of migratory habitat are the wetlands in Mannar.

Flagship species: These are usually socially and culturally important species that attract a lot of attention. These species can draw attention to conservation issues and attract people’s attention to wildlife. Species such as the elephant, leopard, bears, dolphins, and whales are good examples of Flagship species.

Photo credits: Sampath de Alwis Goonatilake @ IUCN

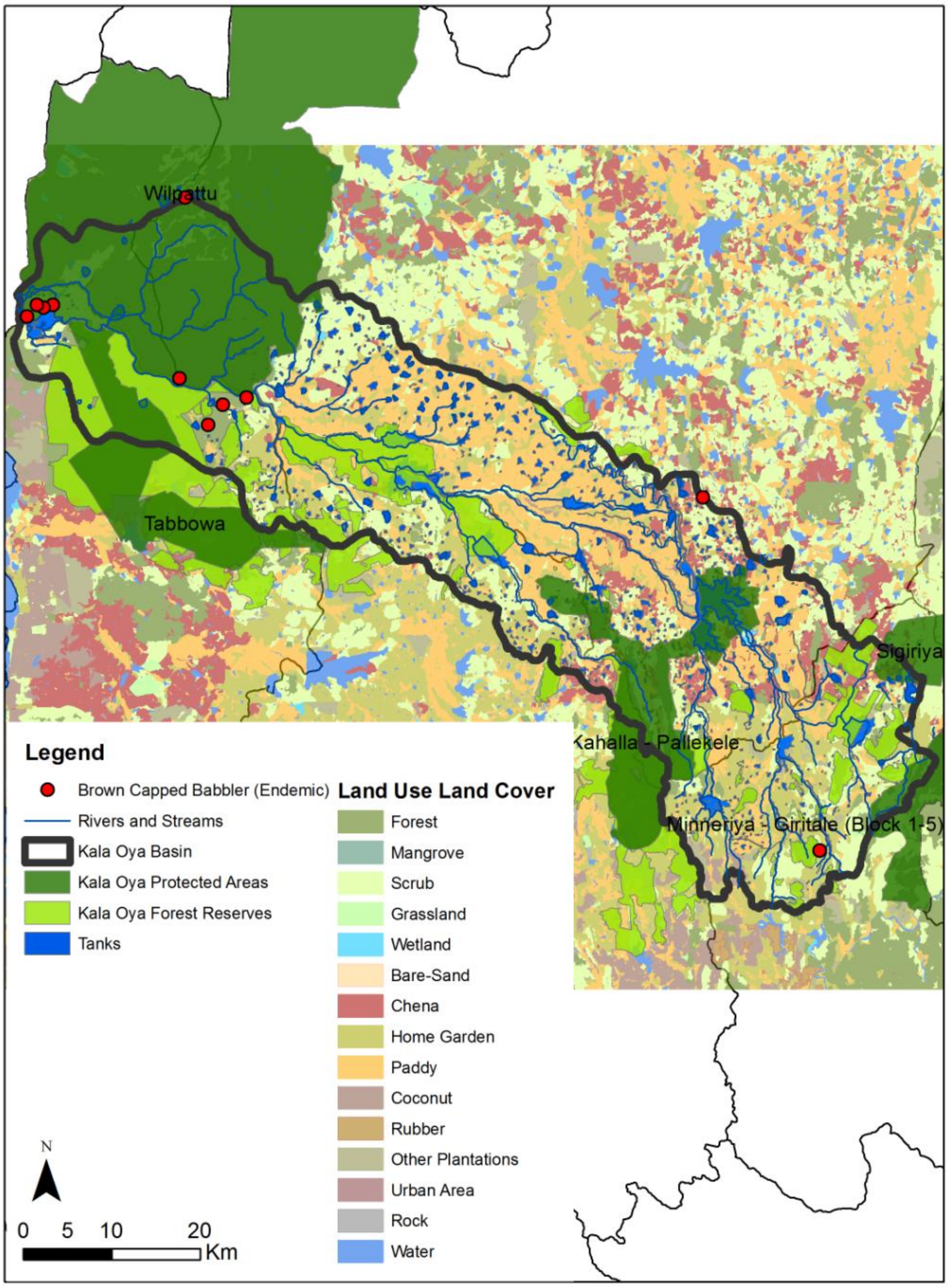


Figure 1. Distribution data of the Brown capped Babbler, based on a biodiversity survey in the Kala Oya Basin. The Brown capped Babbler is an endemic bird species, and the distribution data shows that it prefers forested habitats because most location data are from protected areas that usually contains relatively undisturbed and un-degraded forest habitats.

These species can be selected from surveys that provide location data and from experts who can provide information on species distributions. The information can be in the form of point locations (if they have collected field data) or polygons drawn on maps, based on their field knowledge. All data should be entered into a GIS, and data layers prepared as shown in Figures 1-3).

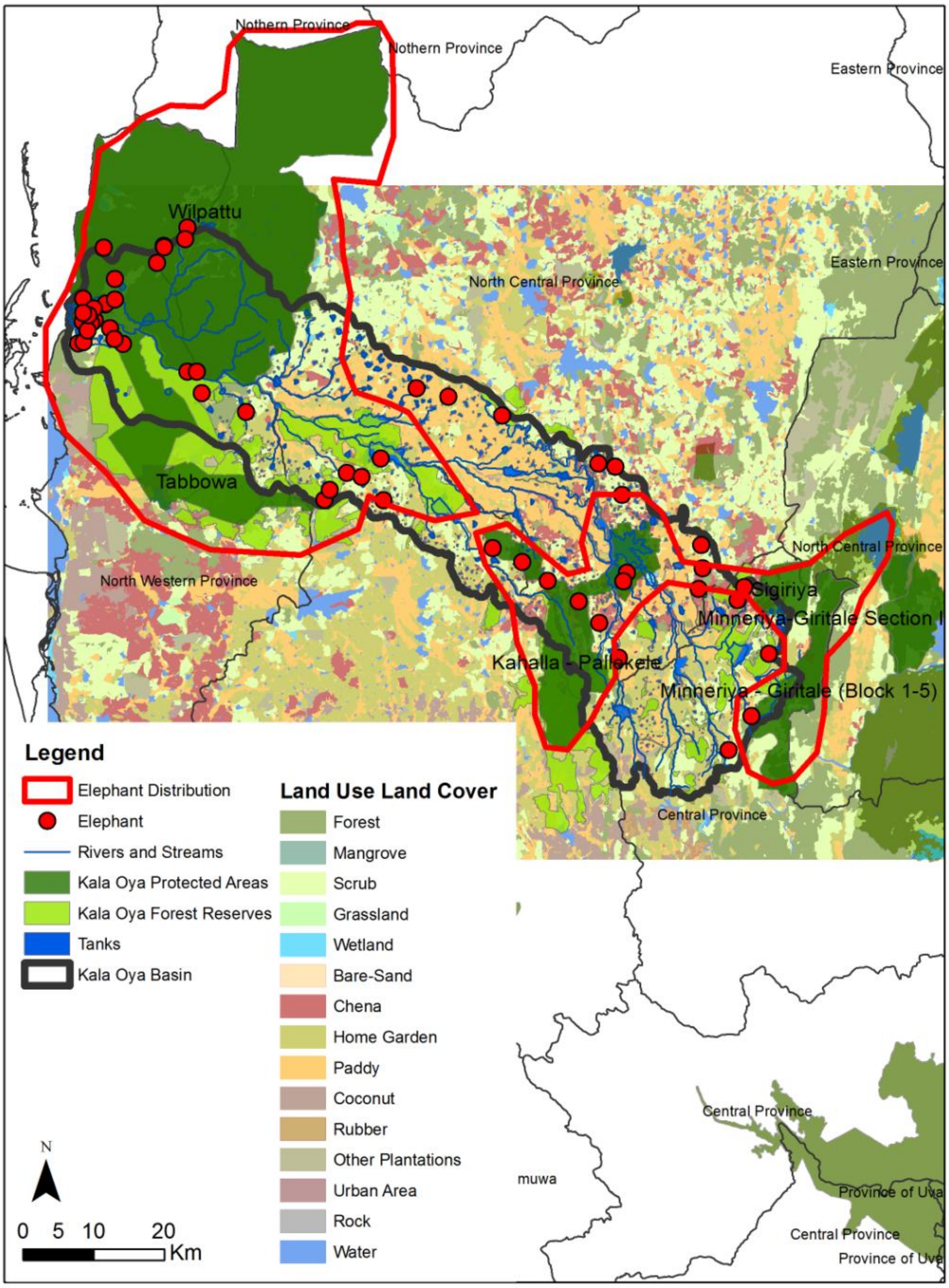


Figure 2. Elephant locations in the Kala Oya basin. The point locations are based on a biodiversity survey in the Kala Oya Basin. However, expert opinion can also be obtained to identify distribution data. Experts can be asked to draw polygons to indicate distributions. This is useful when point locations from surveys and unavailable, or the survey data are inadequate. The Elephant is an endangered species, as well as a Landscape Species, Umbrella Species, and a Flagship Species.

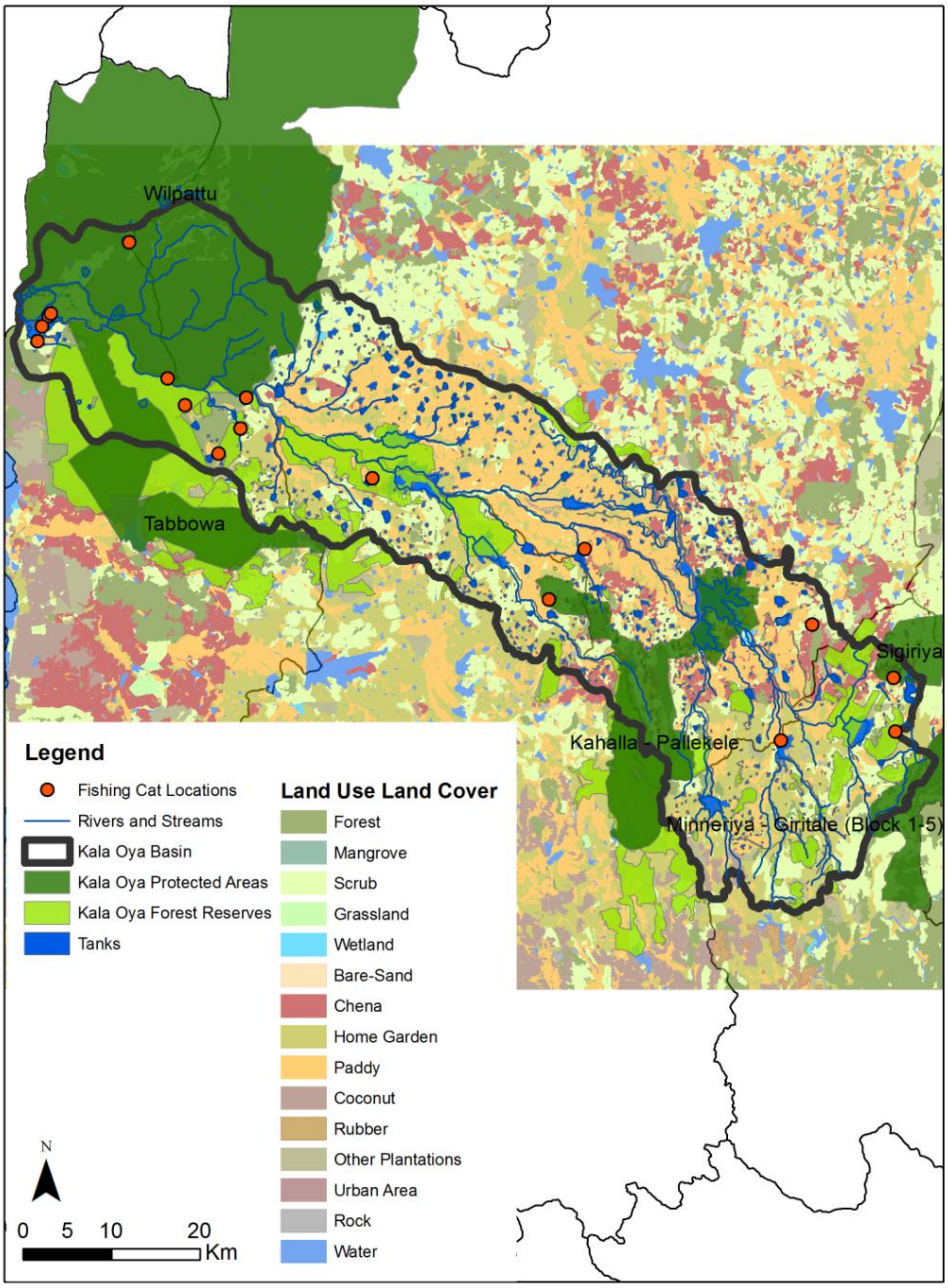


Figure 3. Distribution data for Fishing Cats, based on a biodiversity survey in the Kala Oya Basin. The Fishing Cat is a habitat specialist species that requires wetlands and waterways. The location data indicate that Fishing Cats are distributed throughout the landscape. This is probably because the numerous tanks, reservoirs, and other wetlands (including paddy fields) provide habitat for this species.

Biodiversity survey data can also be used to identify 'Hotspots' of endemism (Figure 4), species richness (Figure 5), important migratory sites (Figure 6), and even where there are concentrations of threatened and endangered species (Figure 7).

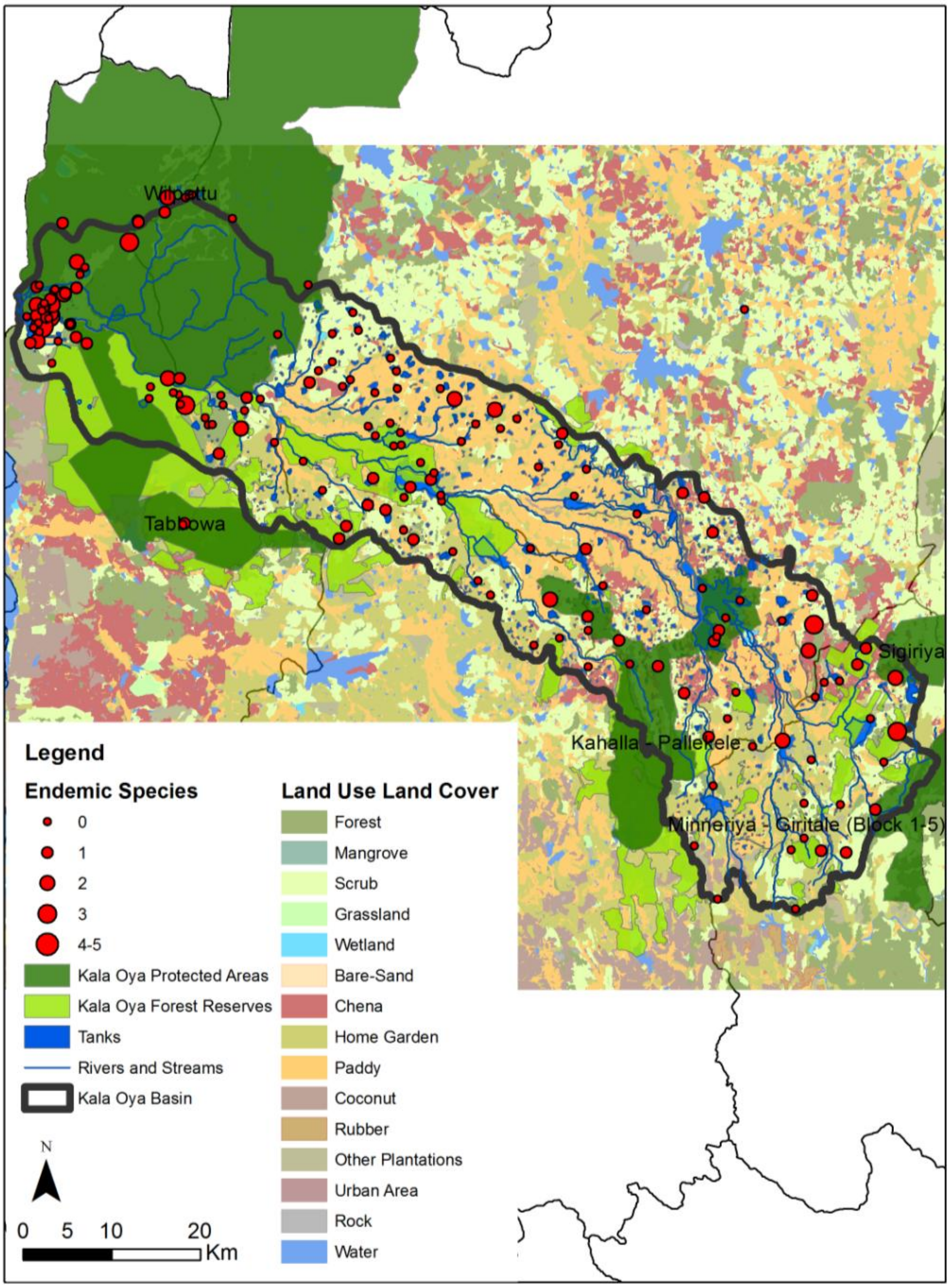


Figure 4. Endemism 'Hotspots' in the Kala Oya Basin, based on biodiversity surveys. These areas were identified by calculating the highest numbers of endemic species represented in the surveys sites.

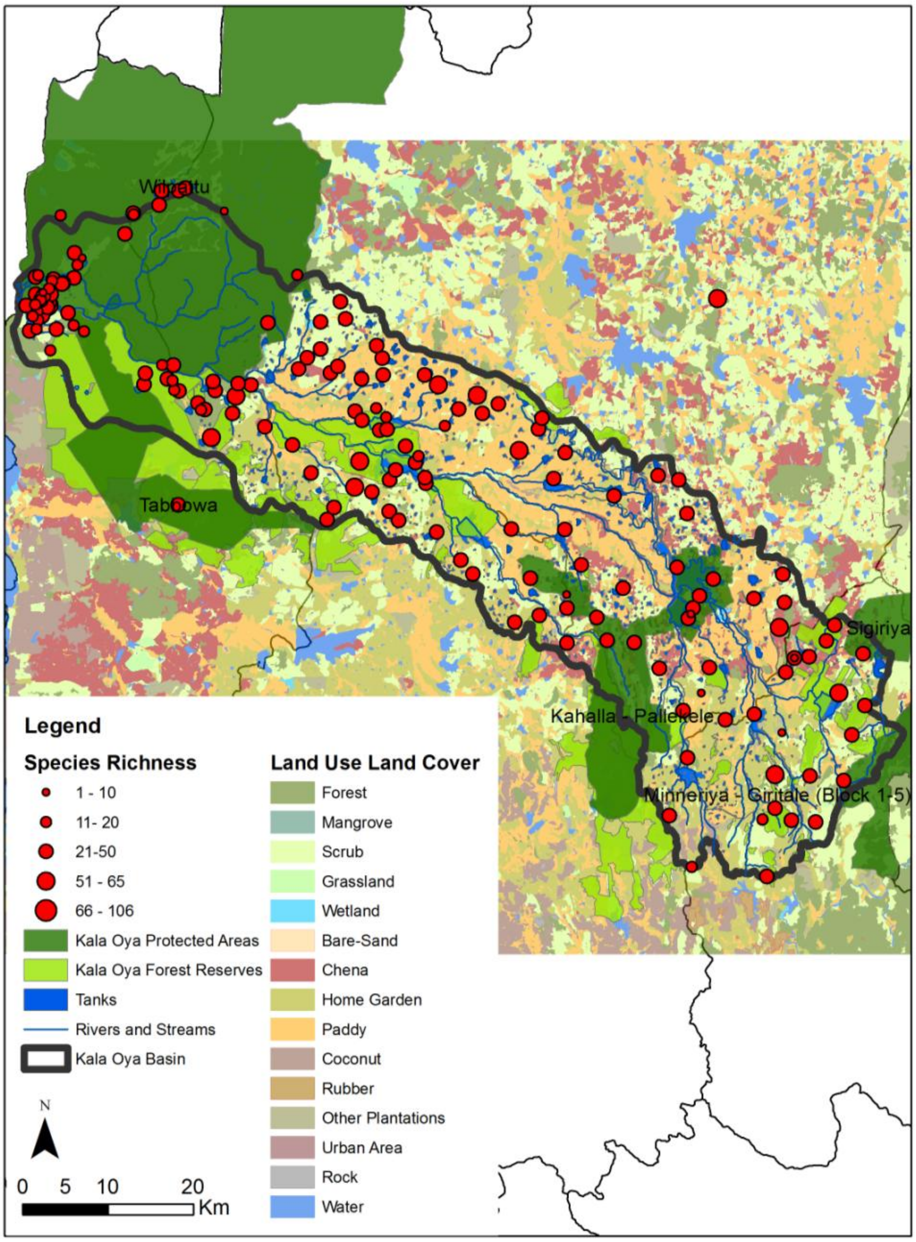


Figure 5. Species Richness 'Hotspots' in the Kala Oya Basin, based on biodiversity surveys. These areas were identified by calculating the total numbers of species represented in the surveys sites.

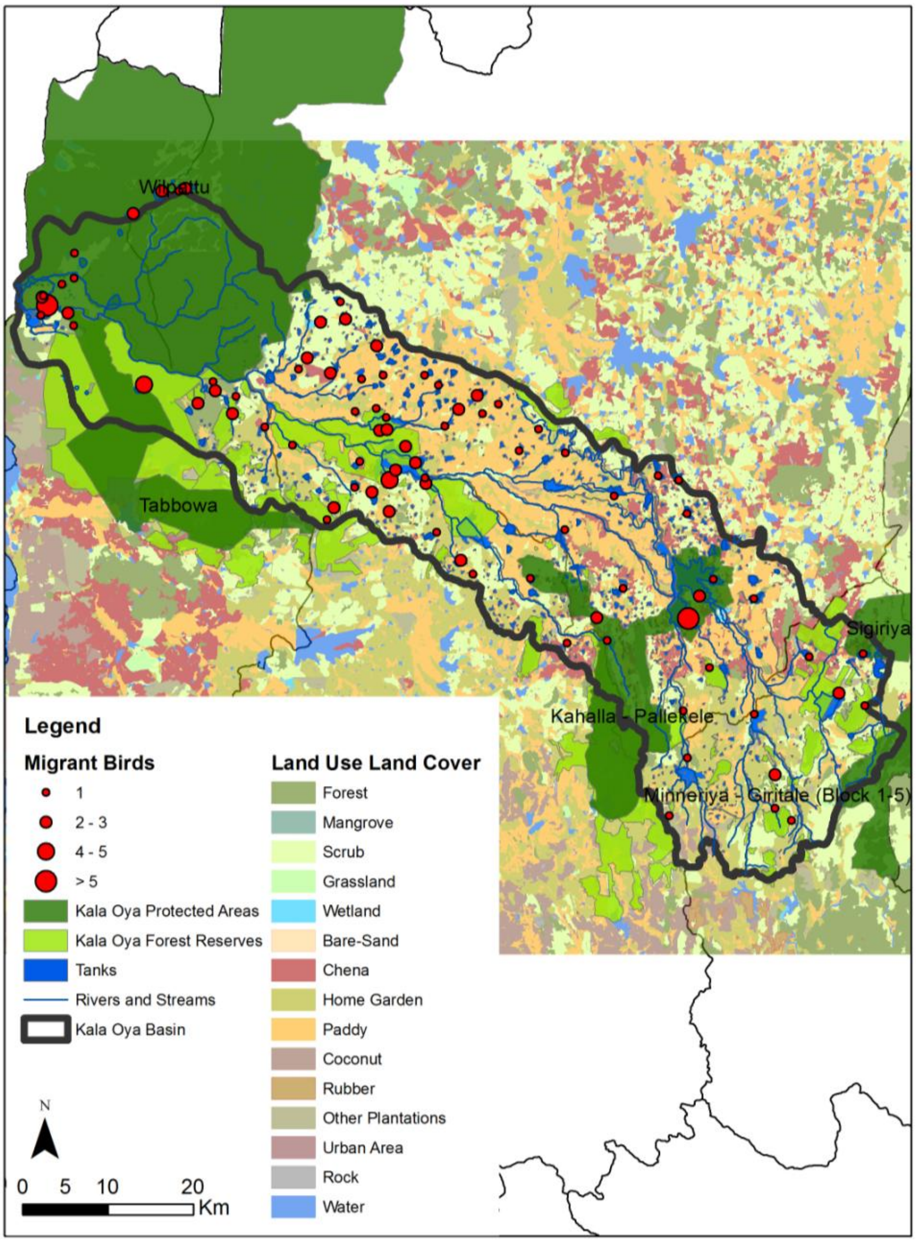


Figure 6. Important sites for migrant birds in the Kala Oya Basin, based on biodiversity surveys. These areas were identified by calculating the highest numbers of migrant bird species represented in the surveys sites.

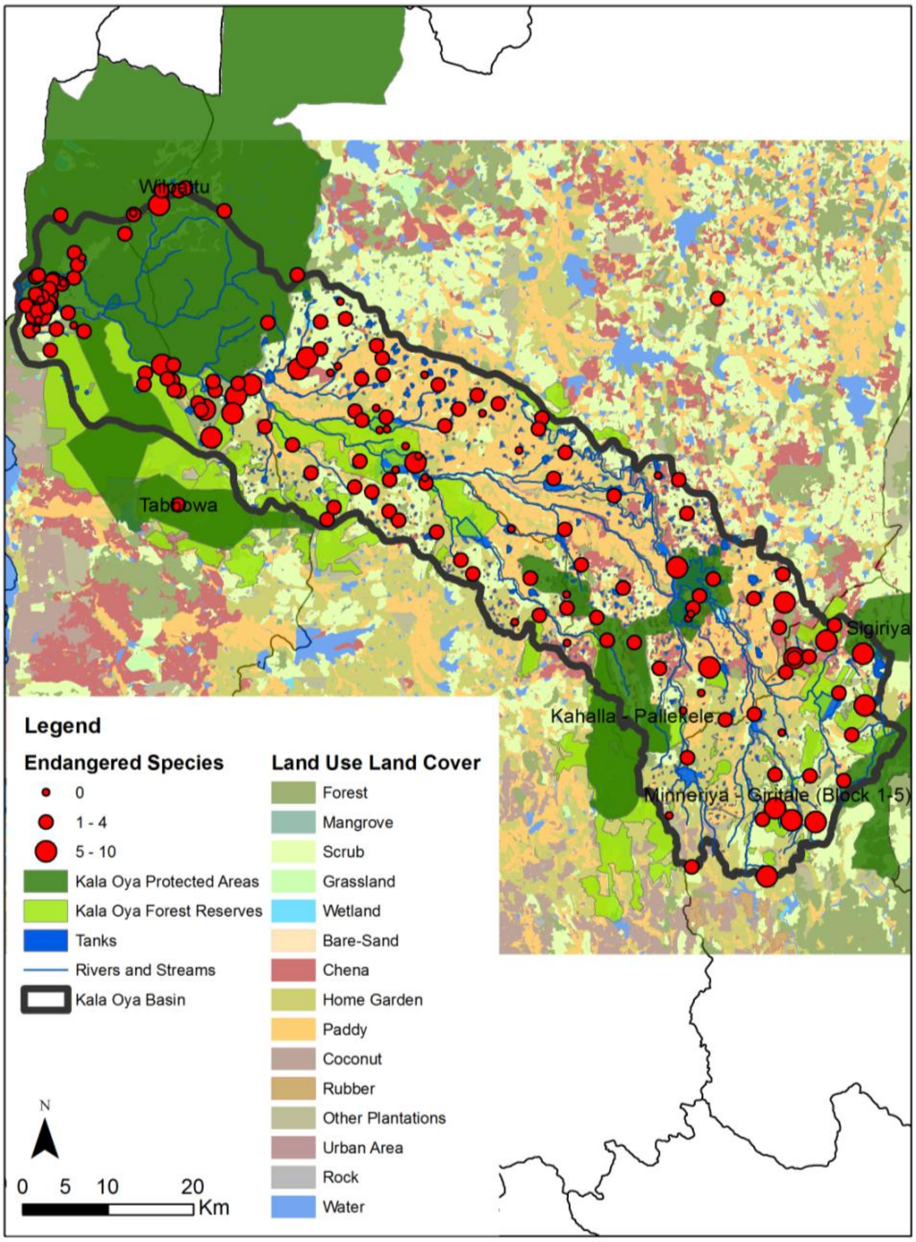


Figure 7. Concentrations of threatened and endangered species in the Kala Oya Basin, based on biodiversity surveys. These areas were identified by calculating the highest numbers of threatened and endangered species represented in the surveys sites. These areas should be identified for conservation.

Mapping these species distributions will show where these focal species have to be conserved. Overlaying the protected areas (both Department of Wildlife Conservation areas and Forest Department's forest reserves) on the distribution map will show how much protection these species already have.

The point locations can be used in a program such as Maxent (See Chapter 4 for details) to predict and create a map of the potential distribution of a species based on habitat parametres of some known locations, for instance, collected through field surveys (Figure 8). But note that Maxent provides a predictive output map that does not necessarily confirm that the species is found there. Maxent outputs are, however, also useful to aid in planning surveys for a specific species or group of species.

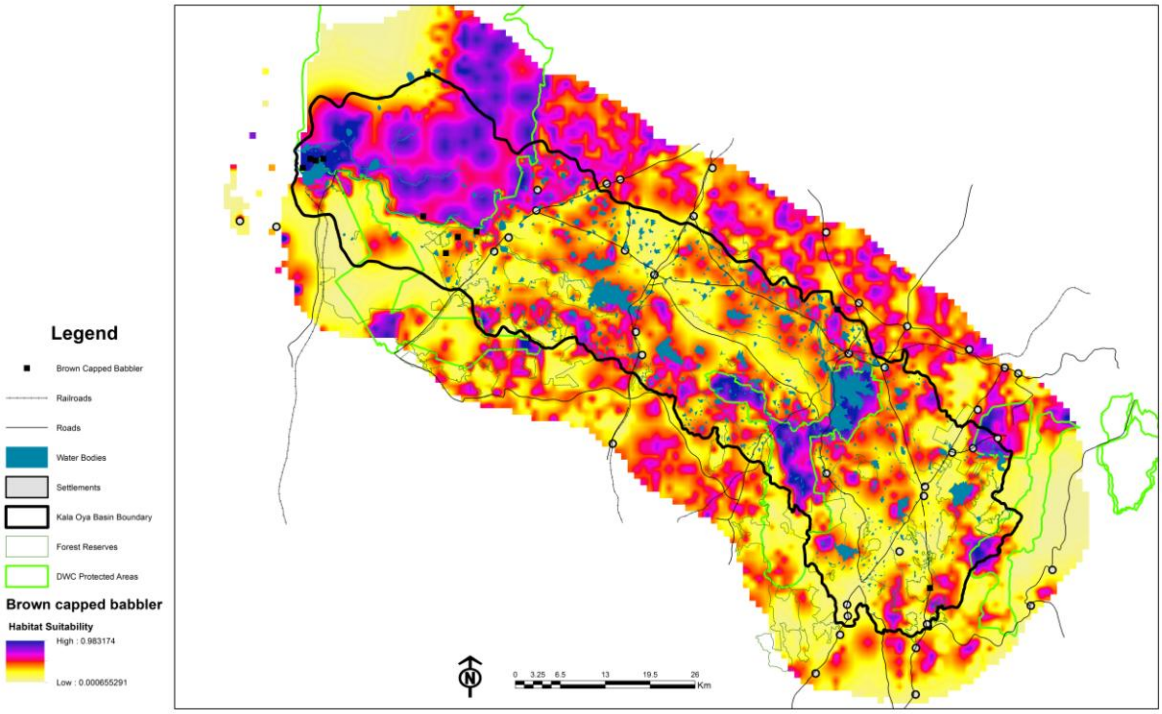


Figure 8. Maxent output of habitat suitability for the endemic bird, Brown capped Babbler. The output is based on known locations from field surveys. Conservation plans should ensure that habitat in the blue and pink areas are conserved, since these habitats are most suitable for this species.

Maxent is widely used to map species' habitats at landscape scales, but can also be used to predict and map the distributions of ecosystems. It is also scalable, from landscapes to national and regional scales.

When the data for all focal species have been compiled into a spatial database, these distributions can be overlayed to identify where the greatest overlap of species richness, highest numbers of threatened and endangered species, etc. are. The protected areas data base can then be overlayed to assess whether all important biodiversity is included within the protected areas. Usually, several of the wide ranging species will also occur outside protected areas. If most of their distribution is within the protected areas, it should achieve conservation goals.

All endemic species must be included within protected areas. If the distribution of an endemic species falls entirely outside the protected areas system in the landscape, conservation measures to ensure its protection (including protecting necessary habitat and ecological conditions) should be undertaken to ensure that habitat is managed to prevent change or degradation.

Software such as Marxan can be used to systematically ensure that all conservation targets identified through the species mapping are included within the protected areas system (See Chapter 4 for details). This software uses a decision support algorithm to optimize the protected areas system by selecting reserves to achieve the most efficient and parsimonious system when identifying new protected areas to fill in gaps in conservation. Planners can either learn to use this software to identify new protected areas, or use a less systematic approach of using maps of species distribution data to identify what species or groups of species require additional protection. Studies have shown that both approaches provide similar results.

However, in a highly fragmented landscape such as the Kala Oya Basin, the potential to create more large protected areas are limited, especially since the landscape already has several relatively large protected areas and the matrix is already under extensive anthropogenic use. Thus, the priority should be to protect and conserve the existing reserves well.

Large or mid-sized landscape species, especially those that roam across the landscape, generally require habitat connectivity to enable them to move between protected areas. GIS applications and tools such as cost-distance models can be used to identify these ecological corridors, and Circuitscape can be used to identify corridor bottlenecks (see Chapter 4 for more details). The ecological knowledge to parameterize these models will have to be acquired through research, or by consulting biodiversity experts. There are no general guidelines that can be provided.

Hands-on training on use of these models can be provided by GIS trainers during training programs. But usually GIS analysts should be able to navigate through the instruction manuals that come with the software (available for free download on the internet) and learn how to use them.

While conservation planning at landscape scales use coarse-resolution data (1;20,000 to 1:50,000), conservation action plans within the landscapes should identify meso- and micro-habitats for species that require very specialized habitats (e.g., spray zones of waterfalls). But this step will be a second analysis at smaller scales than at landscapes, and is more relevant for management. For example, conserving an important river for its ecological connectivity will, by default, include the waterfalls, spray zones, and other micro habitats. Therefore, landscape-scale planning can take place at larger spatial scales, using coarser data. But management planning will require consideration of the meso- and micro-scale habitats and species distributions.

Ecosystem Priorities. Identify the ecosystems in the landscape that have to be, or can be conserved.

As with the species, the representative ecosystems in the landscape should be identified using land cover maps. At landscape scales, these can include the different forest types, grasslands, different wetlands (swamps, marshes, ponds, large lakes, streams, rivers, etc.) (Figure 9).

A standardized classification of ecosystems of Sri Lanka is available in the NBSAP (also see Table 1 in Chapter 3). However, not all land cover maps will map all these ecosystems; most will have fewer, broader ecosystems (e.g., Figure 9). Therefore, additional classification of the land cover maps will be necessary to ensure that all ecosystems that are represented in the landscape are also represented in the protected areas or other conservation areas. Biodiversity experts should be consulted to aid with this classification.

As part of the mapping process, the planners and GIS analysists should:

1. Compile a list of all representative ecosystems in the landscape and map these.
2. Identify any meso- or micro-scale ecosystems that are ‘endemic’ to the landscape (i.e., found only in the landscape), or are now restricted to the landscape because they have been converted elsewhere, and map these areas.

3. Identify the conservation values (i.e., unique species compositions, functions, services, etc.) and create a database and spatial layer in GIS.
4. Develop a conservation strategy to address conservation gaps.

Photo credits: Sampath de Alwis Goonatilake @ IUCN

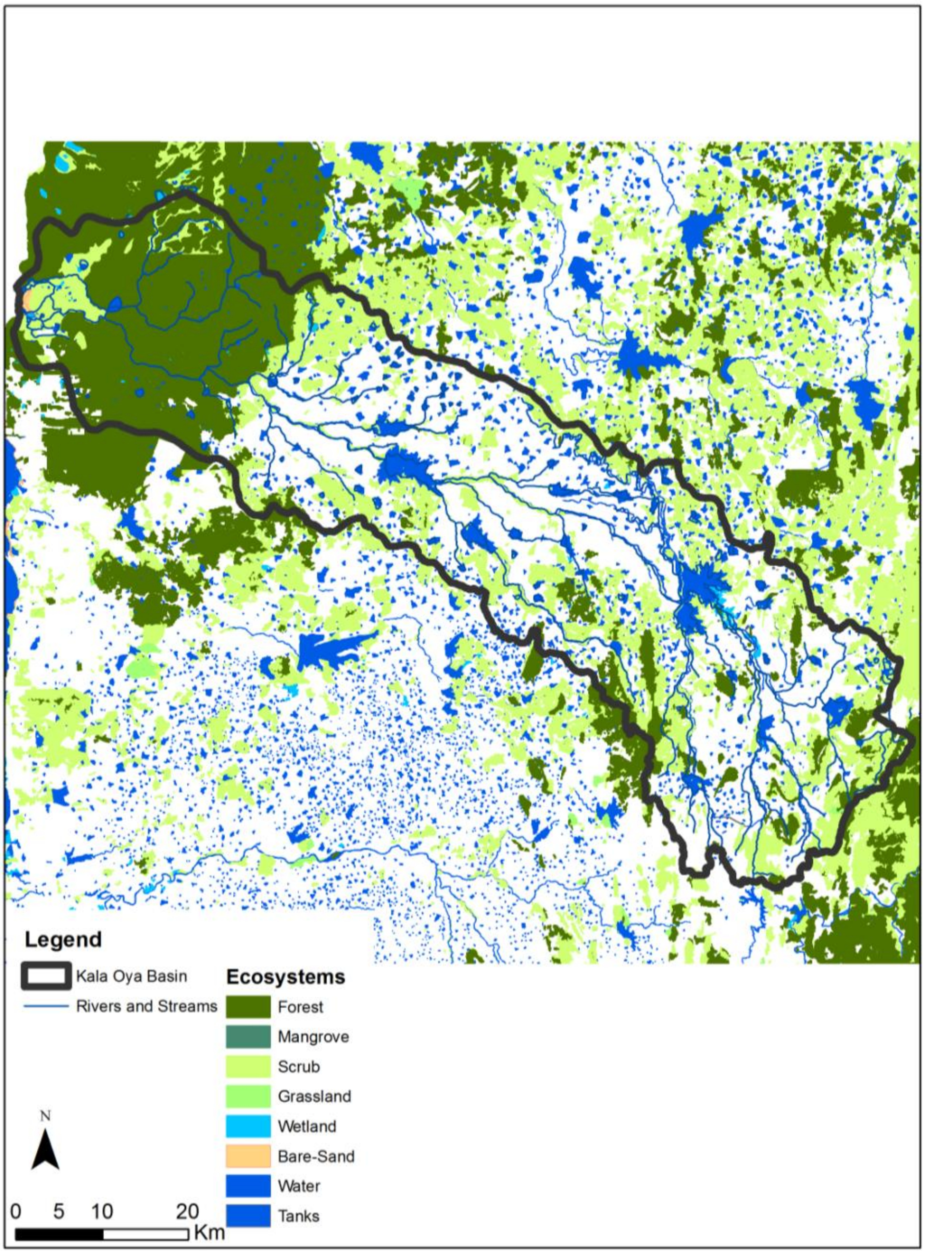


Figure 9. Natural ecosystems in the Kala Oya basin. Note that this classification, from a Land use – Land cover map of Sri Lanka is broad, and does not include the extent of ecosystems provided in the NBSAP. Therefore, expert knowledge may be necessary to develop a suitable map of all representative ecosystems.

Ecosystem Process Priorities. Identify the important ecological processes (and services) that have to be conserved.

Mapping ecosystem services can be a difficult task. But where possible the sources of any ecosystem services, such as water sources, forest patches that support pollinators, fruit dispersal pathways (e.g. fruit bat flight paths), etc. can be identified and mapped.

Examples that should be considered are as follows:

- Forested watersheds of the headwaters of streams and rivers that protect the water sources. The forests create a sponge effect where water percolates into the ground and is then released gradually in a regulated and sustainable way. If the forests are removed, the water sources will dry out, and the impacts of the loss of water sources will be felt for many kilometres down river. Rainfall will runoff rapidly, instead of being absorbed into the ground, causing floods and erosion.

- Forests support many insects, birds, and mammals that are also crop pollinators. Studies have shown that even the loss of a single pollinator that is essential to pollinate a crop can result in a significant decline in productivity and yield. Therefore, it is important to maintain the sources of these pollinators.
- Fruit bats roost on trees in a particular area, but travel long distances to find food. During these feeding migrations, the bats play an important role in seed dispersal. If the roosting trees are removed the bat colonies will disappear, and the forests that depend on them for regeneration will be affected.

This exercise will require field surveys and expert consultation. Some information will also be available from the NBSAP. The process that can be followed consists of the following steps:

i. List the ecosystem processes and services in the landscape.

ii. Identify which of these processes are also important ecosystem services that benefit people (e.g., hydrological flows, disaster risk reduction at large scales, water availability for downstream communities, carbon sequestration contributions to national and sub-national goals, etc.)

iii. Identify the source locations of these processes and where they will impact or support ecosystem functions. Map the spatial linkages in a GIS.

iv. Identify and map the natural areas or sites that play an ecological infrastructure role by generating or delivering valuable services to people; e.g., forest patches that support pollinators, headwaters of streams and spring sources etc.

Step 2. Set targets for conservation.

After the representative biodiversity for conservation have been identified, the planners must set ‘targets’ for conservation. These targets will indicate how much and where the biodiversity can be conserved. For example, it will show how much area of an ecosystem can be—or should be—conserved in the landscape, or how large a population of a particular species (e.g., elephants) can be supported in the landscape. A spatial mapping analysis can then also show where these can be conserved to achieve the desired targets. The spatial mapping should not be satisfied with only focussing on available habitats or intact ecosystems, but should also try to identify areas that can be restored to accommodate more ambitious targets by creating additional habitats or enhancing ecological connectivity by restoring and managing corridors. This is important because in many fragmented landscapes, the existing habitat is inadequate to ensure long term persistence and survival of species or sustainability of an ecosystem.

There are no universal parametres that can be applied to set conservation targets. Different species will require different habitat areas, and in different configurations. For instance, an endemic species with a highly restricted range distribution may require a small area, but that area will have to be of a very specific set of environmental conditions. Large, generalist species (e.g., elephant) can live in a wide range of habitat types, ranging from highly intact to relatively degraded, but also requires large spatial areas with enough food and water. The size and configuration will also depend on the degree of connectivity, food and water availability, and level of disturbance and conflict with people. Some of these parametres can also change seasonally. Therefore, in-depth ecological knowledge is required to set targets, and planners would not be expected have too this knowledge within themselves. Thus, this exercise will require expert consultation. Some information will also be available from the NBSAP.

The process that can be followed consists of the following steps:

i. Take decisions on how much spatial areas of ecosystems, habitats, and species population sizes can and should be conserved in the landscape. Quantitative targets may not be possible for all biodiversity components (i.e., for all species or ecosystems etc.). The targets will have to be in relation to, and consider national targets.

ii. Conduct a spatial analysis in GIS to identify where the key biodiversity targets can be conserved in the landscape based on available ecosystems and habitats. (Note that in many cases the habitats for several species will overlap).

iii. Decide how much habitat will have to be restored, based on species conservation targets. For example, if a target is to conserve a population of 'X' number of elephants, identify how much habitat will be necessary. This target should also consider the national conservation targets, if any have been set.

iv. Identify where these habitats can be restored based on the decisions above. This will also be dependent on potential for restoration.

This process will require a GIS exercise. Several GIS models that can be applied in this analysis are presented in Chapter 4. The spatial analysis expertize within the planning teams will have to be developed to use and apply these models. However, the parameters that have to be applied to run the models will require input from biodiversity experts.

Some points and principles of conservation planning to consider (also see Chapter 3, Table 2) in the process are:

- Identify the extents of the different ecosystems that have to be–or can be– represented in the landscape, based on the targets that are set.
- Identify and prioritize the larger patches over smaller fragments; the former are more resilient to threats and external impacts.
- Identify and prioritize patches that are closer together over patches that are further apart. The former have better ecological connectivity that can promote species exchanges, environmental flows, etc.
- Ask if more ambitious targets can be set and achieved by restoring important areas that have been degraded to provide more habitat. The restoration areas can also be selected through GIS analysis that looks at habitat connectivity to create corridors for some of the 'landscape species' (see Chapter 4) or connecting ecosystem flows such as riparian corridors or headwater forests to restore stream flows.

Step 3. Prioritizing Conservation Units

In this step, the biodiversity targets that have been identified will be prioritized for conservation. In most cases, lack of resources, time, funds, and even land-use conflicts may require that some biodiversity targets require more attention, and sooner. Therefore, planners will have to take decisions and perform triage to identify what the most important biodiversity targets are for that landscape. However, it is important to note that every effort should be made to conserve all biodiversity represented in the landscape; prioritization does not imply that some species or ecosystem processes should be allowed to disappear or degrade, or become completely converted throughout the landscape.

The prioritization can be guided by several principles and criteria that are widely used in conservation planning. Detailed descriptions are also provided in Chapter 3.

I. Prioritize species conservation targets.

   Identify and prioritize:

   a. Endemic species. These are irreplaceable species that are also of national and global importance. Loss of these species from the country or from the landscape will mean that they are lost from the entire global repository of biodiversity. Overall, most endemism in Sri Lanka is concentrated in the central mountain ranges but the isolated rock outcrops (Inselbergs) in the dry zone are also centres of endemism (see Chapter 3). Ritigala, for instance, has a high level of endemic plants, and these would become a high conservation priority.

   b. Keystone species. These are species that play a very important role in sustaining ecosystem processes and functions. For example, bats play an important role in dispersing seeds across the landscape. If the bats are removed, the ecosystem structure and composition can change. Not all Keystone species are large, charismatic species; therefore, selection of these species should be done carefully and with expert input.

   c. Apex predators. These are usually the large carnivores that control ecosystem processes from the top of the food web. Loss of these species can result in cascading changes and shifts in ecosystem structure, function, and composition.

   d. 'Ecosystem engineers'. These are species that can create, significantly modify, maintain, or even destroy a habitat if they exceed the 'carrying capacity' of a habitat. These species can have severe impacts on the ecosystem composition, including at landscape scales.

   e. 'Umbrella species'. These are the large, space-requiring species. Usually, the ecological requirements of these species can also provide a conservation 'umbrella' for several other species in the landscape. Therefore, these species can be used as 'proxy' species for overall biodiversity in conservation planning.

   f. 'Flagship species'. These are usually charismatic species with high profiles that also have cultural or social values; e.g., elephant.

   Note that some species may be classified under several of these categories.

II. Prioritize ecosystems and habitats for conservation.

   Some general principles and guidelines for identifying and prioritizing ecosystems and habitats are provided in Chapter 3. These include the following:

   g. Ensure representation of all ecosystems, habitats, and ecological communities.

   h. Prioritize habitats and ecosystems with endemic species.

   i. Prioritize larger areas or habitat patches over smaller patches because the former are more resilient to threats and will support more biodiversity.

   j. Prioritize patches that are closer and less isolated because they have greater potential for connectivity, including through restoration where possible and necessary.

   k. Prioritize ecosystems that provide habitats for most or more species/biodiversity. But there should be representation of all ecosystems.

I. Prioritize habitats with the opportunity to conserve best examples (populations, habitat etc.) of target species, processes, and ecosystems.

III. Identify the key pressures and threats to biodiversity in the landscape to prioritize interventions to mitigate the threats.

This exercise will also require consultation with key biodiversity experts who can identify the threats to priority targets. The threats can be from sources such as land cover change, habitat loss and fragmentation, over extraction of water, riparian destruction, overharvesting natural resources that lead to ecosystem degradation, water abstraction, invasive alien species, etc.

Software such as Miradi (https://www.miradi.org/) (Chapter 4) can be used to conduct threat analyses.

Step 4. Assessment of Protection and Gaps

Protected areas are the cornerstones of a conservation strategy. In a landscape context, protected areas harbour core species populations and well-protected representative and sensitive ecosystems. Therefore, an analysis to determine how much of the conservation targets are within these core areas are necessary. Gaps in protection should be filled through additional protected areas, shifts in existing protected areas boundaries, or stricter protective measures outside of the protected areas network.

The following steps provide guidance on how to conduct such a gap analysis.

i. Identify how much of each ecosystem type and species habitat requirements are protected at the national level, and assess any recommendations for additional protection.

This information is available from the protected areas databases maintained by the Department of Wildlife Conservation and Forest Department. These can be used as the base layer for the protected areas. The NBSAP and the National Biodiversity Secretariat can be consulted for information on conservation gaps at the national level.

ii. Identify and map the extent of habitats and ecosystems that the landscape contributes to the national targets.

iii. Identify protection gaps of representative ecosystems and habitats in the landscape. Take decisions if: a) all representative biodiversity in the landscape is included within conservation areas; and b) if the landscape can contribute to filling in national protection gaps. Note that some protection gaps need not be gazetted as PAs under the FFPO or the Forest Ordinance, but can be declared as Environmental Protection Areas under the NEA as well, or can be conserved as community forests or home gardens, depending on the species and field situation. These are decisions that planners have to make, in consultation with biologists.

Use spatial analyses to identify these areas using a simple overlay of the national protected areas database with the conservation priorities identified in the section before (steps 1-3 above).

Photo credits: Sampath de Alwis Goonatilake @ IUCN

Step 5. Integrating and Mainstreaming Biodiversity Conservation Areas into Land-Use Plans

This is a critical step in landscape planning, since it is essential that the conservation areas that have been identified and prioritized are integrated into national and district-level land-use planning processes and plans. Conservation areas are frequently viewed as 'undeveloped' land, whereas in reality they are areas with high biodiversity values that also support and sustain human livelihoods and economic development by providing important ecosystem goods and services. These ecosystem services and the intact ecosystem that support them are also essential to sustain and support economic development, including infrastructure built at great economic cost; e.g., a highway along a cleared hill slope will be vulnerable to landslides and erosion.

By integrating these biodiversity conservation areas into landscape-scale land-use plans, the conservation areas are assigned a land-use function. These lands will then not be seen as undeveloped areas that can be allocated for other uses.

Integrating the conservation areas into land-use plans in an explicit way can also reduce conflicts between environmentalists and developers, facilitating faster economic development. However, because development invariably has larger impact footprints that go beyond the immediate development area, proper IEEs and EIAs are necessary.

During this process the conservation priorities that have been identified are based on biodiversity criteria alone, whereas other on-going planning processes would have also been identified in some lands for different purposes creating land-use conflicts. Therefore, the conservation areas identified in Steps 3 and 4 must be overlaid with on-going development plans in a GIS to reconcile land-use and land allocation conflicts.

i. Overlay existing and planned land use spatial data on the biodiversity conservation priorities identified in Steps 3 and 4.

ii. Identify the areas of conflict (i.e., areas that have emerged as biodiversity conservation priorities that have also been identified for other development or human use areas).

iii. Reconcile development priorities with biodiversity conservation priorities. The priorities identified in Step 4 should take precedence, whereas some of the areas identified in Step 3 can be negotiated. Where development takes precedence, engineering designs and realignments to infrastructure can help to minimize environmental impacts. For example, wildlife corridors can be integrated with highways through overpasses and underpasses to maintain 'connectivity' for both people and wildlife (Figure 10).

iv. The final land use map, representing the integration of Green and Grey Infrastructure should be the basis for future development and conservation.

Photo credits: Sampath de Alwis Goonatilake @ IUCN

Figure 10. Overpasses and underpasses that allow integration of roads with wildlife crossings. These kinds of infrastructure can be used in planning for Grey and Green infrastructure. Photocredits: top: Ecoduct – Wildlife Bridge – the Netherlands alizul2 blog. Bottom: http://io9.gizmodo.com/5989331/how-well-live-in-a-future-where-cities-have-become-forests

CHAPTER 3 – SRI LANKA'S BIODIVERSITY DISTRIBUTION AND CONSERVATION PRIORITIES

What is Biodiversity?

Biodiversity is the variety of life on Earth. It includes diversity within a given species (genetic diversity), the diversity between species (species diversity), and the diverse ecosystems resulting due to complex interactions among living and the non-living components of a given environment (ecosystem diversity). It also includes the ecological processes that sustain and maintain ecosystems.

The Importance of Biodiversity

Biodiversity provides goods and services, commonly referred to as Biodiversity and Ecosystem Services (BES), upon which all people depend in their day to day lives, but also sustain economic development. The Biodiversity and Ecosystem Services range from tangible (food, medicine, fibre, wood) to intangible (pollination, seed dispersal, nutrient recycling, climate regulation, flood regulation, pest and disease control, water purification, clean air, recreation, spiritual inspiration) benefits. Loss or degradation of ecosystems that provide these benefits can result in conflict and disasters. Thus, conservation of biodiversity is critically important to sustain livelihoods and wellbeing of people, and to ensure political and governance stability.

Sri Lanka's Biodiversity

Sri Lanka is a moderate-sized continental island listed as the 25^{th} largest in the world. Despite the relatively small size, the island has a wide variety of climatic, topographic and soil conditions that has resulted in a diverse array of aquatic and terrestrial habitats and a biodiversity rich in endemism. Being a continental island, Sri Lanka is endowed with a long and convoluted coastline of ~1680 km. Therefore, nearly 24% of the land area of Sri Lanka comes under the coastal zone. The shelf around the northern and north-western part of the island is broad, whereas the shelf ends more abruptly in the south and east of the island.

For a moderate sized island, Sri Lanka supports an unusually high biodiversity, including large populations of several species of mega fauna (Asian elephant, leopard, sloth bear, sambur, etc.) that do not occur in other similar-sized islands, and the presence of a large proportion of endemic species; i.e., species that are naturally found only in Sri Lanka. Therefore, Sri Lanka, along with the Western Ghats mountain range of India, is listed as one of the 35 biodiversity hotspots of the world (Myers et al. 2000) and have ecoregions that are global priorities for biodiversity conservation (Olson et al. 2001, Wikramanayake et al 2002).

Historically, Sri Lanka was part of the ancient Gondwanaland, located adjacent to the present-day African continent (Deraniyagala 1992). Around 160 million years ago, the Deccan plate, which comprised India and Sri Lanka, broke away from the Gondwanaland and drifted northwards to collide with the Asian plate, around 40-50 million years ago. Thereafter, Sri Lanka became separated and reattached to the mainland several times during alternating periods of global warming and ice ages, when the land bridge became submerged. The first separation occurred about 20 million years ago and the last about 2.5 million years ago (Deraniyagala 1958).

When the land bridge—known as Adam's bridge—became exposed during the ice ages, species could move from the mainland and colonize the island. But during the long interglacial periods, when the sea levels rose, this migratory path was cut off. The species on the island then evolved in isolation into new species, increasing the levels of endemism.

But while these zoogeographic, climatic, topographic and edaphic factors have shaped the richness and distribution of biodiversity in Sri Lanka, during the last two to three thousand years land use changes brought about by humans have been instrumental in large-scale habitat changes that have had both positive and negative influences on Sri Lanka's biodiversity. According to the available historical records and fossil evidence, much of the island was covered with forests in the past. However, the forests in Sri Lanka have been subjected to major remodelling by natural forces such as climate change in the geologic past and in more recent times by human activities. At present, more than two thirds of the forest habitats in Sri Lanka are found in the dry zone. However, the tree density, diversity and endemism in the dry zone forests are comparatively lower than the wet zone forests, which makes the dry zone forests much more open, with denser undergrowth that can support higher densities of grazing and browsing ungulates. These include large populations of charismatic species such as Asian elephant (*Elephas maximus*), leopard (*Panthera pardus*), sloth bear (*Melursus ursinus*), sambur (*Rusa unicolor*), and spotted deer (*Axis axis*).

The low endemism in the dry forests could be attributed to anthropogenic clearing during the last several thousand years to make way for agriculture during the height of the hydraulic civilization that existed in the dry zone of Sri Lanka. After the decline of the hydraulic civilization, these forests have re-grown to their present status, but the localized and environmentally sensitive endemic species would have been extirpated. Therefore, only a few endemic species are seen in these forest habitats. Furthermore, the more frequent connectivity with the continent that resulted in species exchanges and colonizations would have caused endemic species to be ecologically outcompeted. The long time periods required for evolution in isolation that gives rise to new, endemic species would also have been interrupted in the dry zone because of the relatively more frequent species exchanges with the mainland as land bridge connections were made and broken.

However, there are two very unique forest habitats within the dry zone that support relatively high levels of endemism. These are the riverine forests and forests associated with rock outcrops (Inselbergs) scattered throughout the dry zone. These forests have different climatic conditions compared to the dry forest matrices in the rest of the dry zone, that have allowed local speciation and thus presence of endemic species.

The rainforests in the wetter southwestern quarter of the island are believed to have remained isolated from the nearest rainforests in the Western Ghats of India even during the glacial periods, thus isolating the species adapted to wet conditions for longer periods of time, allowing evolution of higher levels of endemism. Rainforests are also more structured and complex than dry forests, creating a higher degree of microhabitat complexity and more 'niches' that support higher species richness. Within the wet zone there are marked altitudinal variations, with the lowland, submontane and montane rain forests exhibiting different species communities and levels of richness and endemism. Thus, more than 75% of the endemic species in Sri Lanka are now restricted to the wet zone, making these forests a conservation priority.

Unfortunately, over the past couple of centuries most of the wet zone forests have been converted and fragmented, and only a fraction of the original forest cover now remains. There are reasons to believe that this forest conversion has displaced and extirpated many species, including the extinction of large numbers of endemic species. For instance 18 species of frogs have become extinct from Sri Lanka during the last century, which is the highest number of amphibian extinctions recorded for any country. Species such as the Asian elephant have been extirpated from the wet zone, and are now restricted to the dry zone of Sri Lanka. Deforestation and forest fragmentation for crops and human settlements have restricted species to small habitat patches, and has intensified human-wildlife conflicts. Thus, a planned conservation strategy is now urgently needed to prevent further loss and erosion of Sri Lanka's biodiversity.

What are Ecosystems?

An ecosystem is a dynamic association of plant, animal and micro-organism communities and their non-living environment interacting as a functional unit. Ecosystems can be classified based on physical attributes (e.g., aquatic or terrestrial), origin (e.g., natural or manmade), vegetation type (e.g., forest or grasslands), and climatic variants (e.g., wet zone or dry zone). Table 1 provides a list of the different types of ecosystems that are found in Sri Lanka (from NBSAP 2016).

Table 1. Major ecosystems of Sri Lanka (Source: National Biodiversity Strategy and Action Plan)

Major Ecosystem Types	Variants of Major Ecosystems	
	Natural	**Anthropogenic**
Forests (Tree dominated)		
Lowland wet evergreen forest Mid-elevation evergreen forest Montane evergreen forest Moist-mixed evergreen forest Dry-mixed evergreen forest Arid-mixed evergreen forest	Rock out crop forests Swamp forests Isolated hill forests Riverine evergreen forest Sea shore scrublands Sand dune scrublands Sand dune forests Palmyra woodland	Secondary forest Sparse open forest Dry deciduous thorn scrublands Forest plantations —Monoculture Forest plantations — Mixed culture
Grasslands (Herb dominated)		
Montane upper wet *patana* Montane lower wet *patana* Humid zone dry *patana* Summer zone dry *patana* Upland savannas Lowland savannas Dry (*damana*) grasslands Flood plain grasslands	Montane Peat bog Intermediate upper *patana* Intermediate lower *patana* Dry zone grasslands Drawdown areas of large tanks	Pasturelands *Kekilla* fernlands Wet (*talava*) grasslands
Caves		
Above-ground caves Below-ground caves		Abandoned mines Railway tunnels
Other Man-made ecosystems		
		Public parks and gardens Home gardens Abandoned lands and road side Agro plantations —Mixed culture Agro plantations —Monoculture
Lentic (standing) Water Bodies		
	Natural	**Anthropogenic**
Fresh and Brackish water Villus	River expansion lakes Mangroves Lagoons Flood plains (*Villu*) Salt marsh Tidal flats	Reservoirs Tanks Ponds Aquaculture bodies Salterns
Lotic (running) Water Bodies		

Major Ecosystem Types	Variants of Major Ecosystems	
	Natural	Anthropogenic
	Natural	Anthropogenic
Rivers and streams	Estuaries Waterfalls and their spray zone	Canals
	Marshlands	
	Natural	Anthropogenic
Marshes	Thermal marshes	Paddy fields
	Beach	
	Natural	Anthropogenic
Sandy shores Rocky shores Gravelly shores Dead coral beaches	Sand Dune	Riprap structures Breakwaters and groynes
	Shallow Water (Less than 200m)	
Seagrass meadows Seaweeds Mud bottoms Sand bottoms		Ports

Linkages between ecological processes, livelihoods and human wellbeing

The complex interactions among species and their environment are ecological processes that in turn provide humans with goods and services that are collectively called biodiversity and ecosystem services (BES). These services support human livelihoods and wellbeing and sustain economic development (Millennium Ecosystem Assessment 2003). The following set of examples demonstrates the links between ecosystem processes and human livelihoods and wellbeing.

1. Some species such as bees, bats and sunbirds feed on nectar produced by plants. In the process pollen present in the flowers gets attached to their bodies, and are carried from flower to flower to pollinate the flowers. Pollination is an essential step for fruit and seed production in plants. Destruction of forests will result in reduction of source habitat for pollinators, and therefore reduction in fruit production and seed set, thus reducing crop yields which will lead to loss of income for farmers.

2. Populations of different organisms inhabiting an ecosystem are regulated by their natural enemies (predators, parasites and pathogens) or competitors. A varied range of animals, including spiders, wasps, dragonflies, lizards, frogs, birds and insectivorous bats that feed or parasitize on pest species regulate these pests and disease vectors. Destruction of natural habitats will result in loss of such natural enemies and therefore increased crop losses or increased incidences of vector borne diseases.

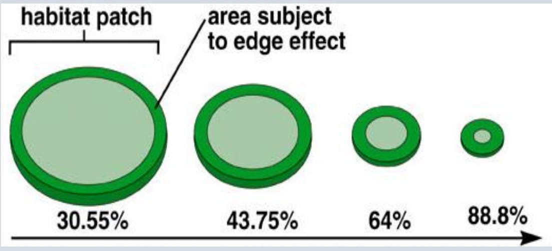
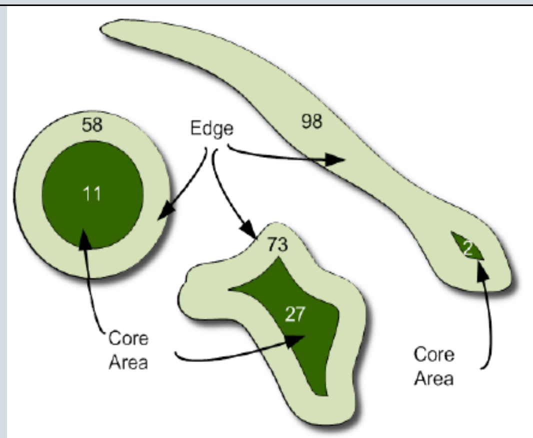
3. Trees in the forest help to intercept the fog/rain and retard the velocity of rain drops reaching the ground. Leaf litter accumulating in the forest floor acts like a giant sponge to absorb the rainwater that reaches the ground and releases it slowly into streams. This will ensure a continuous supply of water in the streams. The roots of the trees hold the soil together preventing it from getting washed away. This is an ecological process known as 'regulation of hydrological flows'. When the forest in the stream catchments are destroyed the rain water reaches the ground at a higher velocity dislodging the soil particles and washing them away with surface flow increasing the sediment load in the streams and rivers. The water also flows rapidly into the stream resulting in high flows during rain and drying up of streams soon after the rains stop, resulting in high fluctuations in stream flows. The sediment carried in

the stream will be deposited in river beds and reservoirs built across the river resulting in siltation. Rivers that become blocked by silt and other debris can result in flash floods. The remaining sediments will be carried by the river to the ocean depositing them on offshore habitats such as coral reefs and seagrass beds smothering these ecosystems.

Guidelines for prioritizing ecosystems for conservation

All ecosystems are not the same and cannot be treated equally due to variation in their extent, spatial distribution, species diversity, ability to support critical species, and significance of ecological/ evolutionary process that they support. Therefore, when selecting ecosystems for conservation, different ecosystems should be assigned different priority levels based on an objective a set of criteria. Some of the criteria that can be used for prioritization and the reason for selecting these criteria are given in Table 2.

Table 2. Criteria that can be used for prioritization of ecosystems for conservation

<table>
<tr><th>Criterion</th><th colspan="2">Reason for selection</th></tr>
<tr><td>Extent</td><td colspan="2">Some ecosystems have a very small extent in Sri Lanka (e.g. the extent of mangrove forests is less than 1%, while dry mixed evergreen forests cover more than 20% of Sri Lanka). The rarer ecosystem types, if represented in the landscape, should be given a high priority, especially if most of the rare ecosystems are converted and the remaining areas are threatened.</td></tr>
<tr><td>Distribution</td><td colspan="2">Some ecosystems show a highly restricted distribution in Sri Lanka (e.g., Savanna ecosystems are restricted to mid-low elevations of the south-eastern part of Sri Lanka while dry mixed evergreen forest are distributed throughout the dry zone). Ecosystem that show a restricted distribution should be given a high priority over a widely distributed ecosystem when represented in the landscape.</td></tr>
<tr><td rowspan="2">Patch size</td><td colspan="2">Some ecosystems exist as several patches or fragments of different sizes (e.g. Mangrove forests, Savannah forests, lowland wet evergreen forests). Species diversity and core area (area that is undisturbed by human activity) are directly proportional to patch size. Therefore forest fragments that have a large patch size should receive a high priority.</td></tr>
<tr><td colspan="2">
</td></tr>
<tr><td>Patch shape</td><td>Shape of the ecosystem patch/ fragment can have an impact on disturbance to the core area. A linear patch is more vulnerable to impacts extending into the core than a rounder patch. Therefore, round-shaped patches/ fragments should be given a high priority.</td><td>
</td></tr>
<tr><td>Contiguity and connectivity</td><td colspan="2">Patches that are located closer together have more potential for ecological connectivity that patches that are further apart. This connectivity is important to support species movements, gene flow, environmental flows and other ecological interactions across the landscape and between core areas. Therefore, patches that are located closer and are less isolated with better</td></tr>
</table>

Criterion	Reason for selection
	potential for connectivity through restoration or establishment of corridors should be given a high priority.
Species diversity	Species richness (number of species per unit area) of different ecosystems varies (e.g. wet zone forests support high species diversity and endemism compared to dry zone forests). Ecosystems that can support high species richness, endemism and threatened species should be given a high priority. But all representative habitats should be included.
Support critical species	Some ecosystems or habitats are essential for the survival of an endemic, critically endangered, migratory or restricted range species (critical species). Such ecosystems should be given a high priority.
Ecological/ evolutionary process supported	Some ecosystems support unique assemblages of species or associated with key evolutionary processes (e.g. Adam's bridge is a critical land bridge that has facilitated exchange of species between Sri Lanka and Indian mainland) or provide key ecosystem services. Such ecosystems should be given a high priority.
Ecosystems that support congregatory species	Some ecosystems support significant concentrations or numbers of individuals of congregatory species (e.g. Vankalai Sanctuary support a significant proportion of migratory bird species to Sri Lanka). Such ecosystems should be given high priority.
Ecosystems that are socially important	Some ecosystems support biodiversity of significant social, economic, or cultural importance to local communities. Such ecosystems should be given high priority.

Guidelines to prioritize species for conservation

Like the ecosystems, all species cannot be treated equally due to their variation in population size, distribution, habitat specialization and sensitivity, value assigned by people, ability to promote economic enterprise such as tourism, social and cultural significance, etc. Therefore, when selecting species for conservation, different species should be assigned different priority levels based on a set of objective criteria. Some of the criteria that can be used for prioritization and the reason for selecting these criteria are given in Table 3. Note that some species can fit under more than one category.

Table 3. Criteria that can be used for prioritization of species for conservation

Criterion	Reason for selection
Threatened species	Conservation status defines the probability of long term survival of a given species. It can be assessed on a global scale or national scale. These assessments are done periodically and the outcome is published in the form of global or national Red List. Species that are listed as Critically Endangered, Endangered or Vulnerable in these lists are commonly referred to as threatened species. Such species should be assigned a high priority.
Endemic species	These are species that are completely restricted to Sri Lanka. Some endemic species have a wide distribution within Sri Lanka (e.g. Jungle fowl), while others have highly restricted distributions even within Sri Lanka with a range distribution of a single location (e.g., several of the rainforest frogs and fishes). The latter are referred to as 'point endemics'. Endemic species should be given high priority. Within this group, point endemics should be given higher priority.
Habitat specialists	These are the species with a very narrow ecological niche. Usually these species are adapted to a certain habitat type, and cannot survive in elsewhere. The specialization can be based on host plants or other interspecific dependencies, environmental conditions (temperature, moisture, dissolved oxygen in aquatic species, etc.), elevation range etc.
Restricted range species	Some native species show a wide distribution (e.g. House crow) while others are restricted to a certain region of the country, (e.g., There are many bird and butterfly species that are restricted to northern region or Savanna ecosystems in Uva region). Such native species with restricted range should be given a high priority over a moderate/ wide spread native species.

Criterion	Reason for selection
Landscape species	These are species that require large areas of habitat (e.g. Asian elephants) and therefore are likely to become threatened easily due to loss or fragmentation of habitat. Such species should be given a high priority.
Umbrella Species	These species that have large ranges and therefore, conservation plans for such species also protect habitats for many other species and ecosystem processes. Mammalian carnivores or large vertebrates usually make good umbrella species for landscape or regional scale conservation planning, since their ecological spatial requirements extend to landscape scales. Such species should be given a high priority.
Keystone species	These are species that are essential to maintain ecosystem structure, composition, function or processes. Loss of such species will result in significant changes in ecosystem and therefore they should be given high priority.
Flagship species	These are culturally and socially important species (e.g., Asian elephants) that can be used to motivate or promote conservation action. Such species should be given high priority.
Introduced species	Some species are introduced to a country intentionally (e.g. Tilapia was introduced as a food fish) or unintentionally (Tank cleaner has been introduced accidentally). Some of these introduced species spread rapidly threatening native species or causing economic damage. These are referred to as Alien Invasive Species. Such species should not be taken into consideration during conservation prioritization.

Guidelines for identifying pressures on biodiversity

Even though biodiversity is an important resource providing many goods and services that are essential for human livelihoods and wellbeing, biodiversity continues to decline at global, national, and local scales. Loss of biodiversity leads to loss of ecosystem services which prompts human responses and actions that lead to further loss of biodiversity services; e.g., loss of pollinators because of forest loss leads to reduction in crop yields which prompt further expansion of area under cultivation into intact natural ecosystems that leads to further loss of forests and pollinators, creating a vicious spiral that pushes the world more and more towards a crisis situation. Loss, degradation and fragmentation of habitat, introduction of alien invasive species, increasing the interface of human-wildlife conflict, over exploitation of natural resources (both legal and illegal), and encroachment into natural areas are some of the key drivers contributing to loss of biodiversity at present. However, the emerging threats from climate change can also act in synergy with current proximate and local threats to increase the severity of impacts on natural ecosystems and biodiversity, in turn feeding back on the wellbeing of human communities and economic development goals. Therefore, careful land-use planning that takes into consideration landscape-level linkages and incorporating key biodiversity components and conservation principles to avoid or minimize the drivers mentioned above is a critical step towards addressing the current biodiversity crisis. Thus, even the existing land-use plans should be closely scrutinized to determine whether they include appropriate conservation plans.

If not, conservation targets identified through a systematic planning process should be integrated into the land-use plans to prevent: loss, degradation and fragmentation of critical habitat; disruption of migration or local movements of animals; further encroachment into natural areas; escalation of human-wildlife conflict; and degradation and loss of ecosystem processes and services. The plans should also strive to set aside areas for restoration of key biodiversity and ecosystem services in a given landscape to meet ambitious and necessary conservation targets.

Guidelines for identifying conservation gaps

The National Biodiversity Strategy and Action Plan (NBSAP) for the period 2016-2022 has identified 12 national targets and 88 actions which should serve as the road map to ensure conservation, sustainable use and equitable sharing of biodiversity in Sri Lanka. This plan should be used as a guiding document to identify sub-national targets for a given landscape to ensure achievement of these national targets. Once the sub-national targets are set, an analysis can be done to identify the gaps between the current situation and the expected targets to modify the land-use maps.

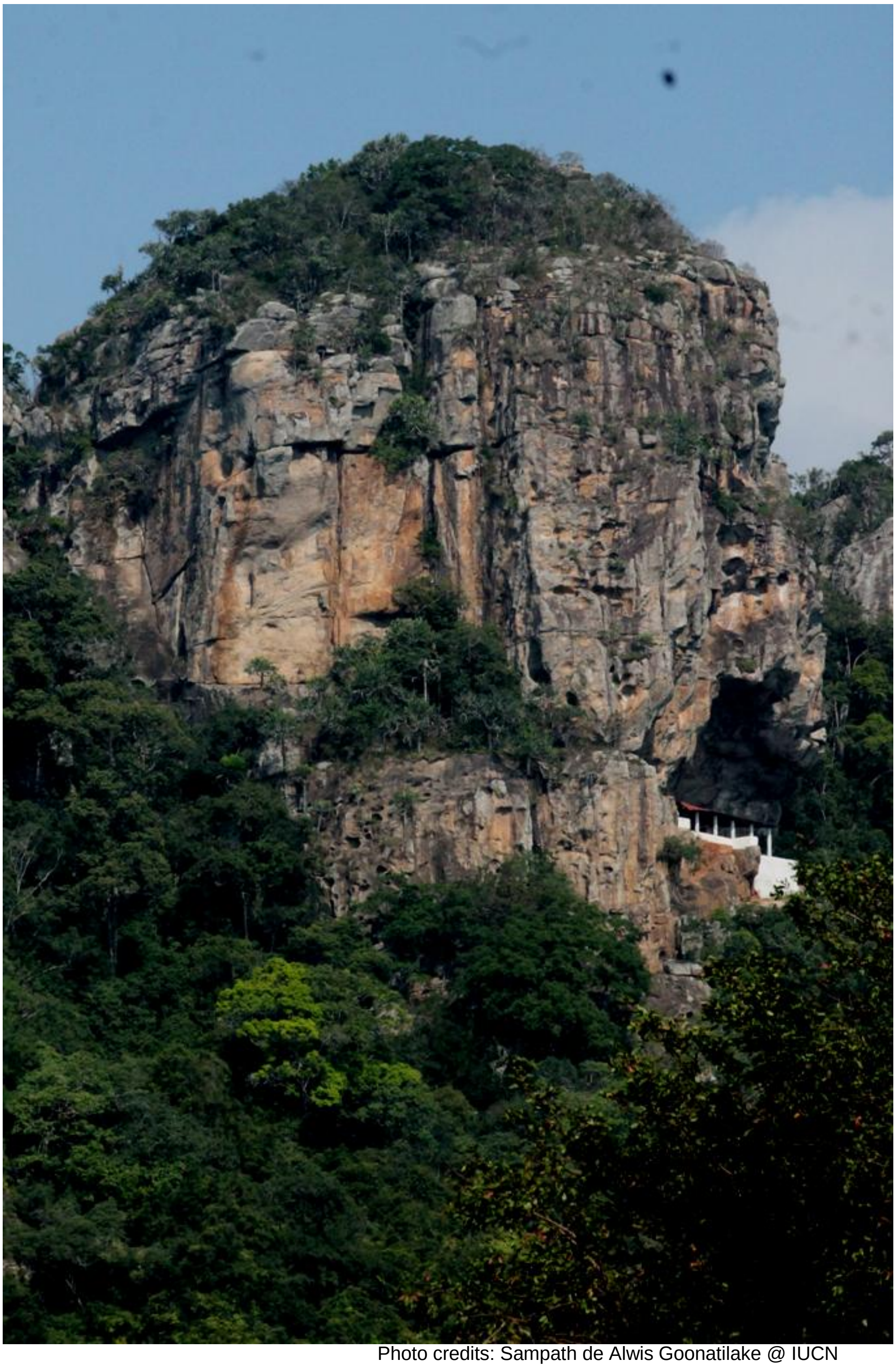


Photo credits: Sampath de Alwis Goonatilake @ IUCN

CHAPTER 4. DATA AND TOOLS FOR BIODIVERSITY INTEGRATED SPATIAL PLANNING

Spatial data requirements, scale, and availability

The spatial data layers needed for conservation planning at landscape scales range from the ideal data needed to the more realistic situation of the data that is available. In most instances, the ideal data layers are unavailable and planners will have to settle for, and use proxy data sets. Some of the human-use and development-related spatial data will already be in use by the planning teams and could be available, but may also need updating.

Landscape-scale conservation planning does not require fine-scale data. Vector data at moderate scales (Figure 11) ranging from 1:20,000 to even 1:50,000 will work well. Striking the correct balance in selecting scales will also depend, to some extent on the conservation targets. A landscape with high levels of endemism will require land cover data favouring the higher resolution scale in order to identify and classify the habitats of these highly localized species. However, very fine scale data that identifies in individual houses or trees is not necessary.

The land use and land cover (LULC) data layer will be the base map for the analysis, along with the topography data. A Digital Elevation Model (DEM) can be used to represent the topography. The LULC map should ideally have all (or as many as possible) the major ecosystems indicated in Table 1 classified in the attribute. The LULC data layer will also provide information on human-use areas, from agriculture to settlement patterns.

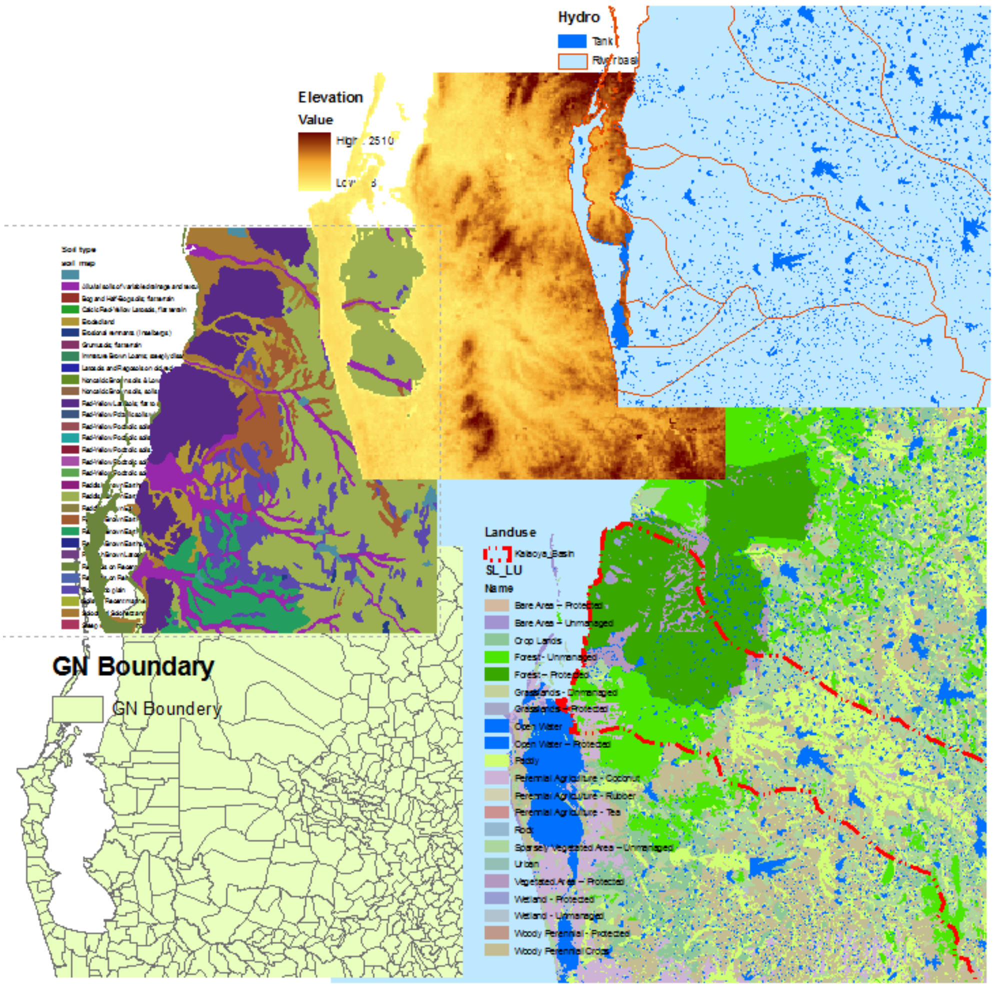


Figure 11. Moderate resolution geo-spatial data layers for study area

Other required data layers are:

1. The protected areas database. This should include all protected areas, especially those under the management of the Department of Wildlife Conservation and Forest Department. The protected areas database can also be downloaded from http://www.protectedplanet.net/
2. Other natural and semi-natural ecosystems and habitats that can contribute to biodiversity (e.g., temple lands, clusters of home gardens, etc.)
3. Species distribution maps
4. Climatic Zones
5. Rivers, streams, and other water bodies.
6. Watersheds
7. Soil map
8. Locations of historical and archaeological sites and culturally important sites
9. Administrative units (district, DS divisions)
10. Major infrastructure (roads, rail roads, irrigation schemes, major cities, towns, villages etc.)
11. Socio-economic data (spatial)
12. Drought, flood, and other disaster-prone areas
13. Land ownership (private, government, etc.)

Data layers 1-9 will be used to identify conservation areas based on conservation targets within the landscape

Data layers 10-13 will be used to assess threats to conservation areas and conservation targets, to reconcile conservation priorities with development priorities, and develop mitigations to reduce impacts from inevitable development priorities.

Several websites have some of the national and regional data layers for free download (e.g., http://www.diva-gis.org/Data , http://libguides.nus.edu.sg/gis). But most of the national datasets are available with many government line agencies. Some of these spatial data and agencies managing the data are provided in Table 4.

Table 4. National spatial databases useful and relevant for landscape-scale conservation planning that are available within government institutions.

Type of spatial data	Source Line Agency
Distribution of species	Biodiversity secretariat, Ministry of Mahaweli Development and Environment (MMDE)
Distribution of forest cover	Forest Department
Protected area boundaries	Forest Department, Department of Wildlife Conservation, Central Environment Authority, Coast Conservation and Coastal resource Management Department, North Western Provincial Environmental Statute
Threatened and endemic species distribution in	Red List data base of Biodiversity Secretariat, MMDE

Type of spatial data	Source Line Agency
Kala Oya basin	
Provincial distribution of IAS	On-going studies by Biodiversity Secretariat, MMDE
Wetlands of International Importance	Department of Wildlife Conservation
Human-wildlife conflict	Department of Wildlife Conservation
Critical Wildlife Corridors	Department of Wildlife Conservation and Report on Protected Area Gap analysis
Species inventories of forests	Forest Department, Department of Wildlife Conservation, Biodiversity Secretariat
Biodiversity assessment and water quality of Kala Oya river Basin	Mahaweli Authority of Sri Lanka
Distribution of large tanks and reservoirs	Irrigation Department and Mahaweli Authority of Sri Lanka, International Water Management Institute
Distribution of small tanks	Department of Agrarian Development
Land use	Land use Policy and Planning Department and Survey Department, Urban development Authority
Area under cultivation and cropping patterns	Department of Agriculture, Research Institutes (Coconut, Tea, Rubber, Rice, minor crops)

Remote sensing data and resource access:

- Satellite imagery is now widely available, including free imagery in the public domain. Moderate resolution (30-250m) multispectral satellite data and 30m digital elevation data are available through free web sources such as USGS website (http://earthexplorer.usgs.gov/). Availability of past satellite data is an advantage for time-series analyses to identify and evaluate trends in land cover change and spatial spread of several types of processes; e.g., expansion of urban areas, and impacts of disasters such as floods, drought and earth slips, and the post-disaster recovery. However, all these imageries will have to be classified before use. Unless the planning team has remote sensing capacity and capability, this step will have to be outsourced.
- Modis data can be used to assess the extent of forest cover that has been lost. Terra MODIS and Aqua MODIS view the entire Earth's surface every 1 to 2 days, and acquire data in 36 spectral bands, or groups of wavelengths. The data, at 250 m resolution can be downloaded from http://modis.gsfc.nasa.gov/
- Global Forest Watch (GFW) is another free web-based resource that allows users to create custom maps, analyze forest trends, subscribe to alerts of forest loss, and to download forest data for their area of interest. Users can also contribute to GFW by sharing data via GFW's crowdsourcing tools, blogs, and discussion groups. The forest cover is based on Landsat imagery and is downloadable. http://www.wri.org/our-work/project/global-forest-watch and http://www.globalforestwatch.org/map
- Remote sensing elevation data can be used to delineate catchments at different scales, even up to micro-catchment level for management planning at sub-landscape levels.

- Free global viewers such as Google Earth (https://www.google.com/earth/) and ESRI Earth (http://www.esri.com/software/arcgis-earth) can be used to generate and view spatial data.

Tools, extensions, and models for conservation spatial planning

There are several tools and extensions developed for landscape-scale conservation planning. Most are freely available for download. The available extensions include software such as Maxent that is now widely used to model and map species habitats at landscape scales to the Linkage Mapper package to model and map ecological connectivity by identifying corridors and bottlenecks, and Marxan that can design an optimized network of representative protected areas within the landscape based on assigned conservation targets. Miradi can be used for threat analysis to conservation targets.

The following section presents some key spatial analysis tools for biodiversity conservation planning. Training on how to use these tools will be provided to land-use planners already proficient with GIS Software (ArcGIS), but the help files and introductory material available in the respective websites will help GIS analysts to learn through application.

Maxent

Maxent—or the Maximum Entropy approach to modelling species distributions—is designed to predict and create a map of the potential distribution of a species based on habitat parametres of its known locations (Figures 1-3). In most instances, the distribution data that is collected for a species consists of some number of sighting (direct or indirect) or historic collection records (from herbarium or museums). For some species, these known locations can be few and widespread. Although such data can provide a range distribution, it does not provide an accurate spatial description of the habitat available for occupancy at a landscape-scale. Maxent can be used to model such a habitat map, and also provide information on the relative contributions of various habitat parametres to the probability of the occurrence or occupancy of the species in a habitat or area.

Maxent is widely used to map species' habitats at landscape scales, but can also be used to predict and map the distributions of ecosystems. It is also scalable, from landscapes to national and regional scales.

The software can be downloaded from https://www.cs.princeton.edu/~schapire/maxent/ or http://www.gbif.org/resource/81279

Maxent is a stand-alone program, and the outputs can be used in ArcGIS or other spatial software to map the potential habitat of a species or distribution of an ecosystem. Multiple habitat distribution layers generated for several target species can be overlayed or compared in GIS to identify and prioritize conservation areas (Figure 12).

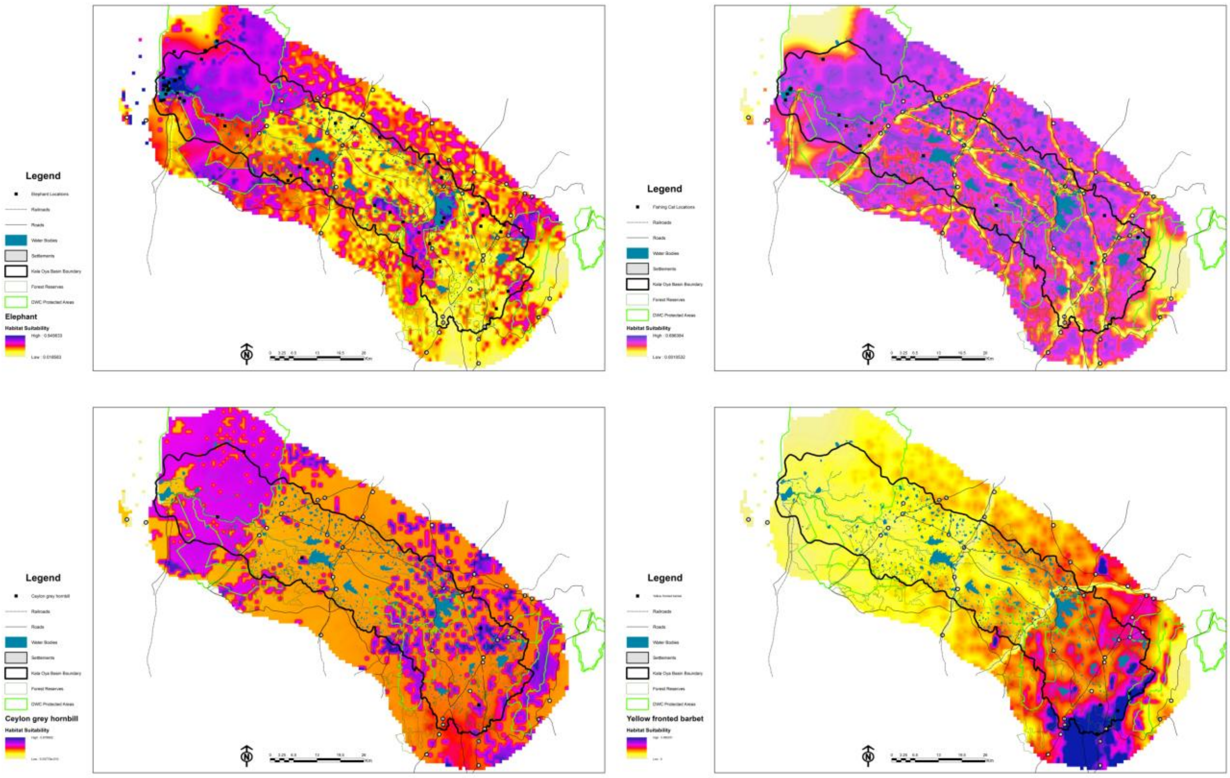


Figure 12. Maxent outputs generated several focal species in the Kala Oya basin, based on biodiversity surveys. The maps show the projected habitat suitability for elephant (landscape species), fishing cat (habitat specialist), Ceylon Grey hornbill (endemic forest-dwelling bird), and the Yellow-fronted barbet (an endemic bird species that is usually found in the wet zone forests). The map suggests that the best unfragmented forests for elephants are in the western part of the landscape, which has a protected area complex of national parks, sanctuaries, and forest reserves. Habitat in the rest of the basin is highly fragmented, which can create high human elephant conflict. Fishing cat habitat, however, is quite widespread across the landscape, but the best habitat is close to water sources. Roads fragment fishing cat habitat. The best habitat for hornbills is also in the forested areas in the western parts of the basin, but the habitat across the basin is relatively suitable. The best habitat for the Yellow fronted barbet is in the southeastern corner of the basin. This is primarily a wet zone forest and forest garden bird, and its range does not extend into the drier areas of the Kala Oya basin. Thus, the best opportunities to conserve this species would be in other regions of Sri Lanka.

Cost-Distance Analysis

Cost-distance analysis is an extension in ArcGIS that can be used to determine the ecological cost to a dispersing or migrating species as it leaves a core area (usually a protected area) and moves through the landscape matrix. The landscape matrix usually consists of inhospitable terrain or less suitable habitat, reducing the probability of survival. The further an animal has to travel to reach another core area, the less the probability of survival. The survival probability is the 'ecological cost' to the animal; thus the name cost-distance model. The model calculates the ecological cost based on habitat suitability scores assigned to the different habitats and other land-use categories in the landscape. Thus, planners will assign relatively higher costs to unsuitable land uses, and lower cost scores to better habitat for that species. The model algorithm will calculate the cost of moving through the landscape based on the relative costs of the raster grid scores around the grid occupied by the animal as it moves through the landscape cost surface. The cost surface can be built using multiple data parameters that define the habitat (e.g., terrain, vegetation, elevation, soil, etc.). The output will be a cost surface that spatially depicts potential corridors or habitat linkages for species or even ecosystem processes and environmental flows (Figure 13).

Cost-distance analyses are used to identify movement corridors for large species that require large, connected spatial areas, dispersal or migratory corridors, or even environmental flows.

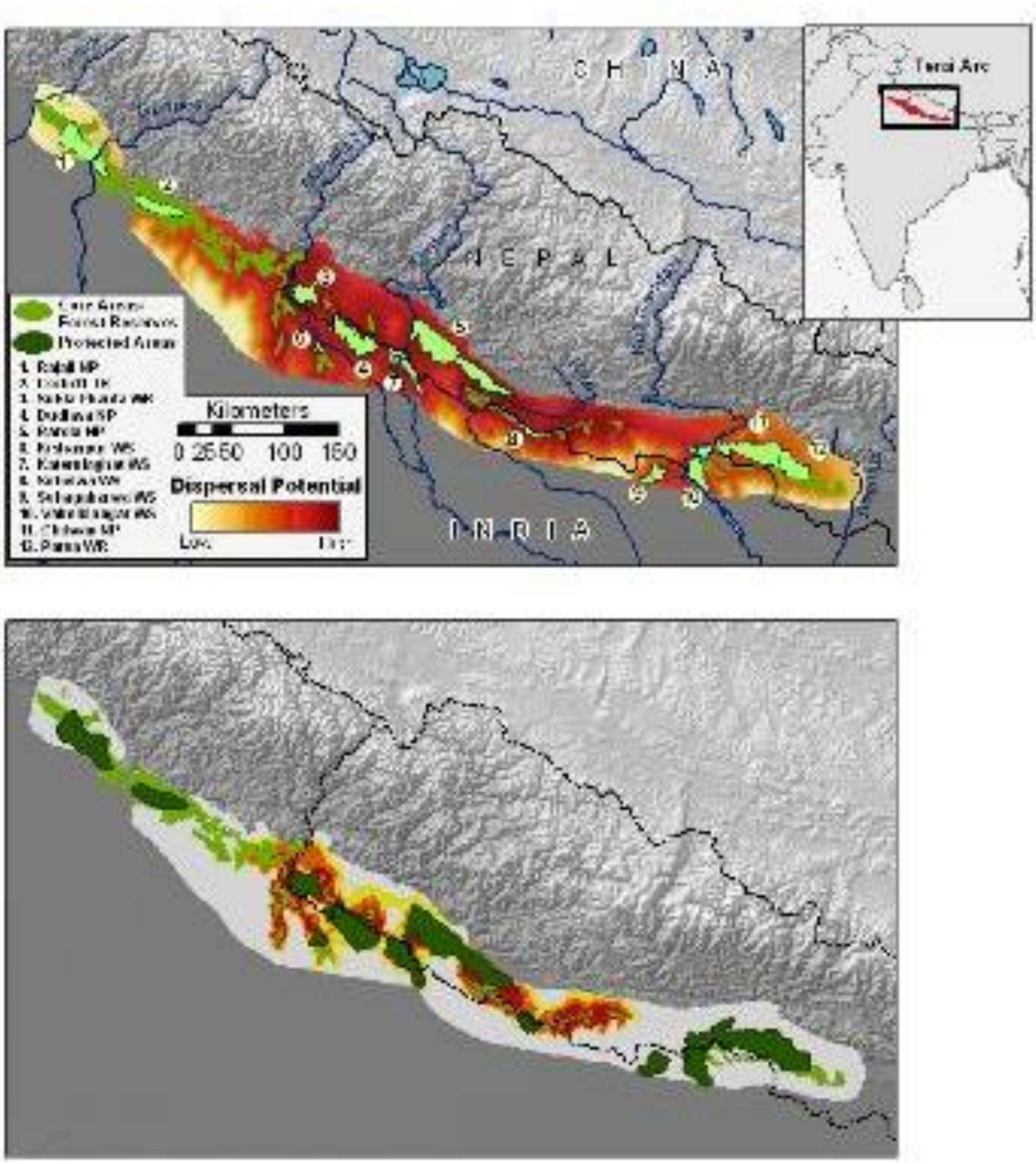


Figure 13. Cost distance analyses used to identify corridors for tigers in the Himalaya (Nepal and northern India). The darker red areas represent better connectivity and corridors for tigers to move between protected areas (in green). From Wikramanayake et al 2004.

Circuitscape

Circuitscape is an open-source program developed to identify habitat corridors. But it is best used to identify ‘pinch points’ or corridor bottlenecks, which are areas where the corridors are very narrow and can be easily broken. These bottlenecks represent areas that have to be urgently restored or secured from further degradation to maintain corridor functionality.

Circuitscape is based on the theory of electrical current flow through a circuit of conductors and resistors. The algorithm treats the landscape as a conductive surface, with low resistances assigned to good habitats that are most permeable to movement and/or allow gene flow, and high resistances assigned to poor dispersal habitat or to movement barriers (Figure 14). The algorithm then calculates relative ‘resistances’, ‘currents’, and ‘voltages’ that represents ecological processes and barriers across the landscapes.

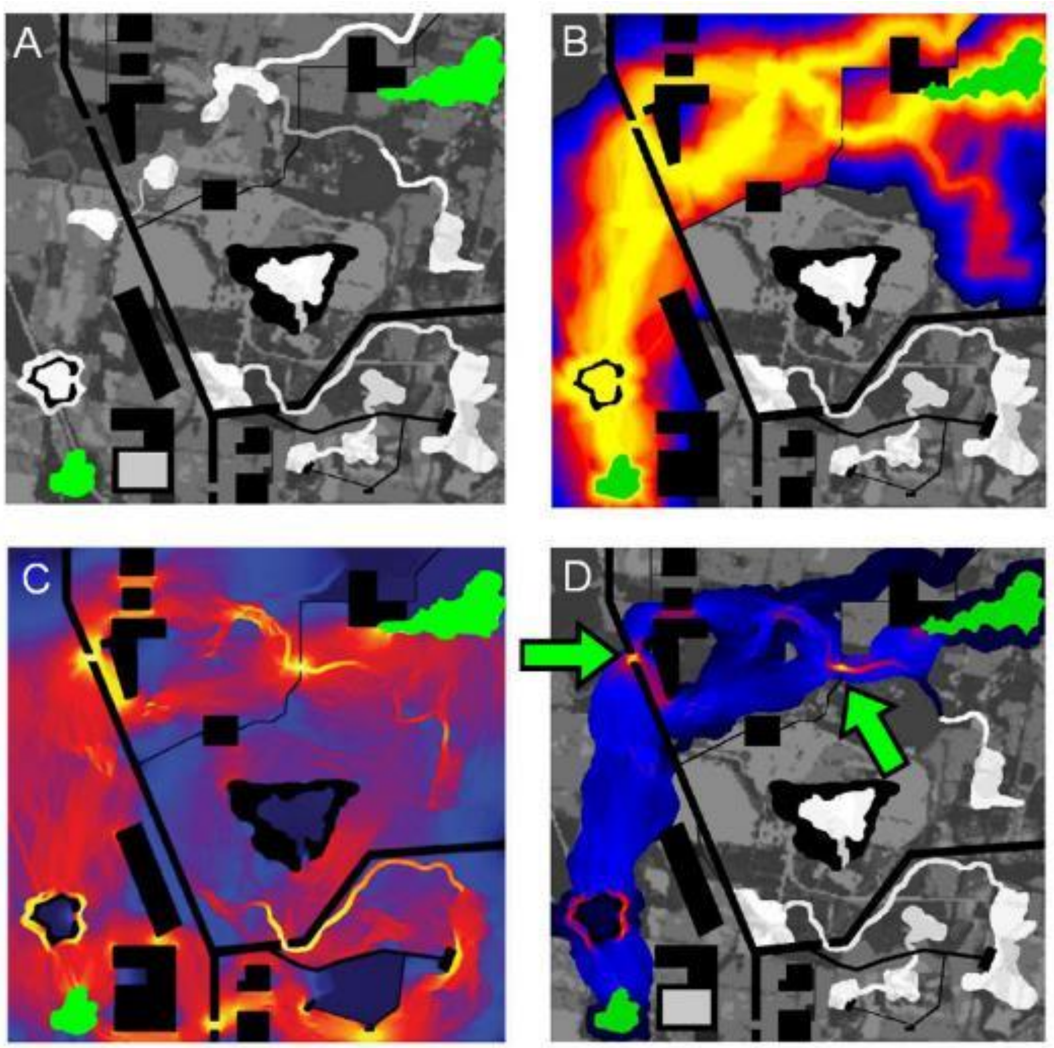


Figure 14. Figure showing Circuitscape application to a landscape. (A) is an example map of the landscape, with assigned landscape resistances ranging from 1 (white) to infinity (black). (B) Results from the least-cost model between habitat patches in lower-left and upper-right corners of the map shown in green. (C) Circuitscape output for the same two habitat patches. Circuitscape complements least-cost path results by identifying “pinch points,” or corridor bottlenecks in bright yellow. (D) hybridized least-cost corridor and circuit theory model in Linkage Mapper that shows the most efficient corridor pathways (in blue) and the corridor bottlenecks (in red and yellow) approaches, showing the most efficient movement pathways and critical pinch points within them. From McRae et al. (2008).

Ideally, Circuitscape should be combined with least-cost pathways analysis (available in ArcGIS toolbox as an extension), where the latter will identify the corridors with the least ecological cost to a dispersing animal and the former will identify corridor bottlenecks. Circuitscape is available from http://www.circuitscape.org/

Linkage Mapper

Linkage Mapper is an ArcGIS tool that combines Circuitscape and Least Cost pathways extension into a single package. It also includes other functions, such as mapping corridor barriers and clusters of protected areas that can be most efficiently connected. Linkage Mapper is available as an ArcGIS tool downloadable from http://www.circuitscape.org/linkagemapper

Marxan

Marxan is a program designed to aid in systematic planning of an optimized network of protected areas that represents all conservation targets. The decision support algorithm optimizes selection of reserves to achieve efficient allocation of resources across the different range of natural resource and land use types, from strict protected areas to sustainable use areas (Figure 15).

The software allows planners to identify new protected areas to fill in gaps in conservation, report on the performance of the protected areas, and to develop multiple-use zoning plans for natural resource management within the landscape. It can be applied to terrestrial, freshwater, and marine systems.

Marxan can be downloaded freely from http://www.uq.edu.au/marxan/

Photo credits: Sampath de Alwis Goonatilake @ IUCN

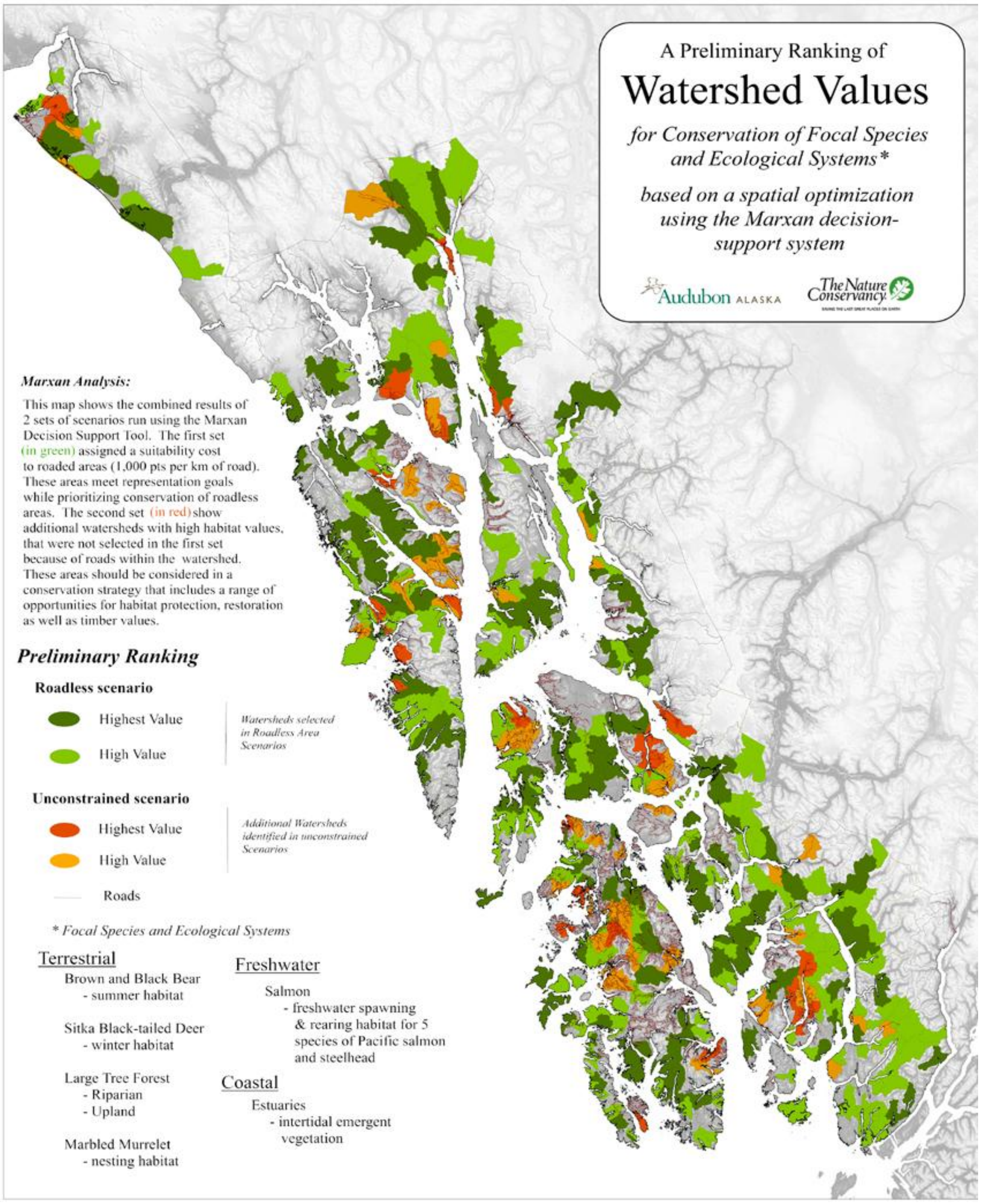


Figure 15. Conservation priorities in Alaska identified for protection using Marxan. Priorities were identified based on watershed values. Image from http://www.oceanecology.ca/conservation.htm

Zonation

Zonation is another program that uses a hierarchical prioritization process to identify a system of protected areas. The algorithm iteratively removes the raster grids with the least conservation values across the landscape. The program allows the landscape to be zoned according to conservation values (Figure 16).

Zonation can be downloaded from http://cbig.it.helsinki.fi/software/zonation/

The user manual is available at
http://cbig.it.helsinki.fi/files/zonation/ZONATION_v3.1_Manual_120416.pdf

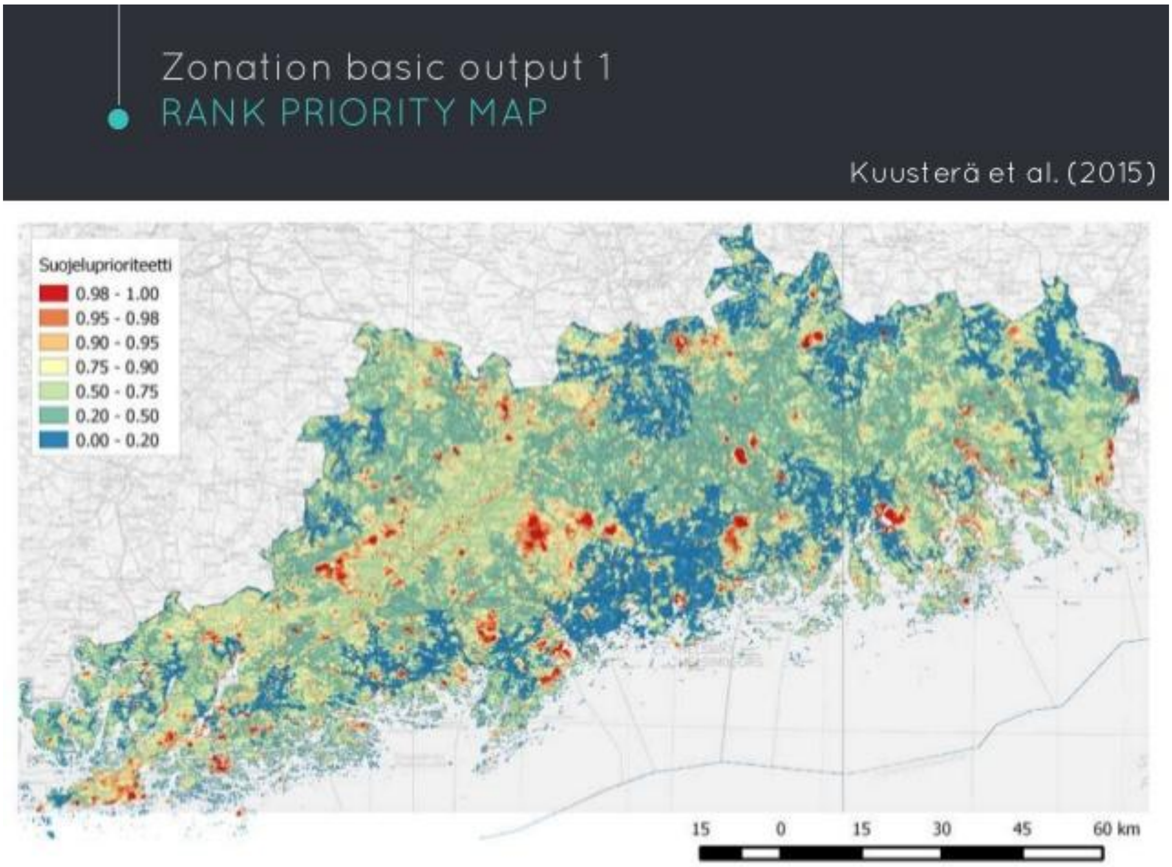


Figure 16. Output from Zonation that show priority conservation areas (in red). Image from http://www.slideshare.net/jlehtoma/tools-for-spatial-conservation-prioritization

PANDA

PANDA (Protected Areas Network Design Application) is a stand-alone application that provides a user-friendly framework for systematic protected areas network design. The program allows planners to explore different configurations of the protected areas system within the area of interest, including at landscape scales. The planners can interactively configure the protected areas system by adjusting or modifying the status of four managed planning units; i.e., Included, Protected, Available, and Excluded. The planner can then explore the attribute table to assess and analyze the resulting changes to achieve the desired conservation targets and assess the associated costs. PANDA interacts with Marxan to display the results in ArcGIS format. The planner can use the PANDA main interface to refine Marxan solutions.

PANDA can be downloaded here. http://www.mappamondogis.it/panda.htm

But note that PANDA is designed for ArcGIS 9.x and may not be compatible with ArcGIS 10.x

Protected Area Tools (PAT)

PAT was designed as a user-friendly tool to evaluate and fill protected area gaps. It is a systematic, logical tool that helps planners to: evaluate threats to ecosystems and habitats; identify a comprehensive, representative suite of conservation areas; and create an optimal solution to meet habitat conservation goals and targets. PAT consists of three conservation modules which operate within ArcGIS; namely, the Environmental Risk Surface (ERS), Relative Biodiversity Index (RBI), and Marxan Tools

PAT can be downloaded herehttp://maps.usm.edu/pat/ and the tutorial can be downloaded from here http://maps.usm.edu/pat/tutorial.html

Miradi

Miradi is a tool that allows project teams to design, manage, monitor, and learn for adaptive project management. But it can also be used to identify and prioritize threats to conservation targets. The outputs include a conceptual model of threats to conservation targets (Figure 17) and a visual interpretation of threat rankings (Figure 18).

The threats are identified and ranked in a stakeholder or expert workshop setting.

The application is downloadable from https://www.miradi.org/download/ and the tutorial from here www.conservationgateway.org/Documents/Miradi-Self-guided-Tutorial_2012-10-22.pptx

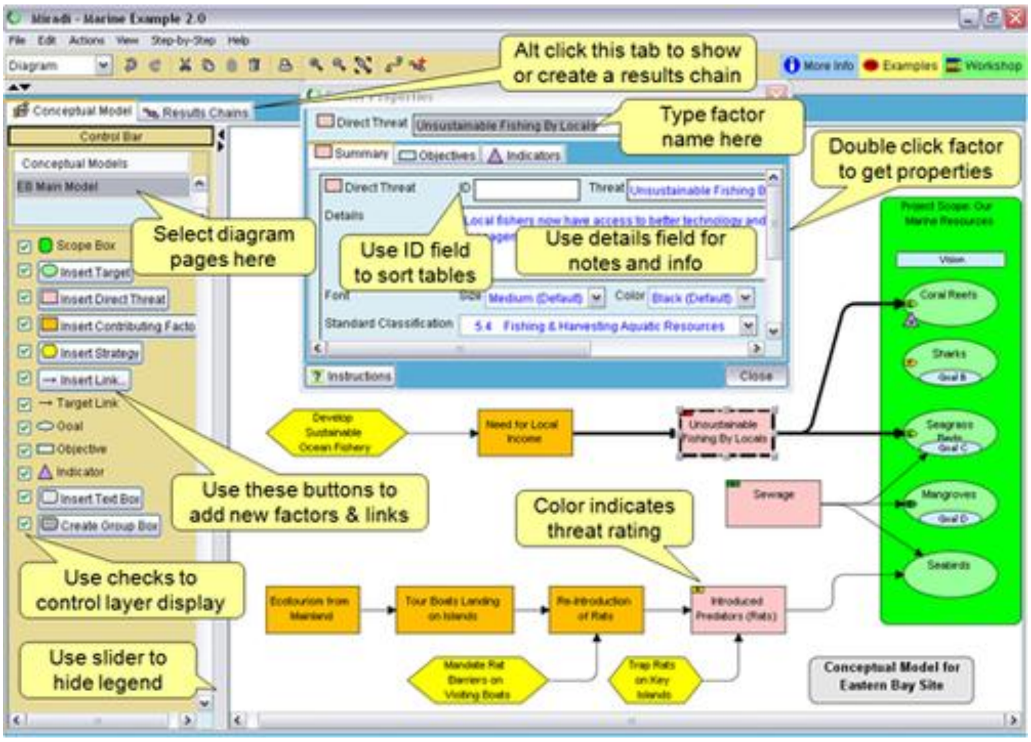


Figure 17. Conceptual model from Miradi to show how threats are linked to conservation targets. Image from https://www.miradi.org/software-features/

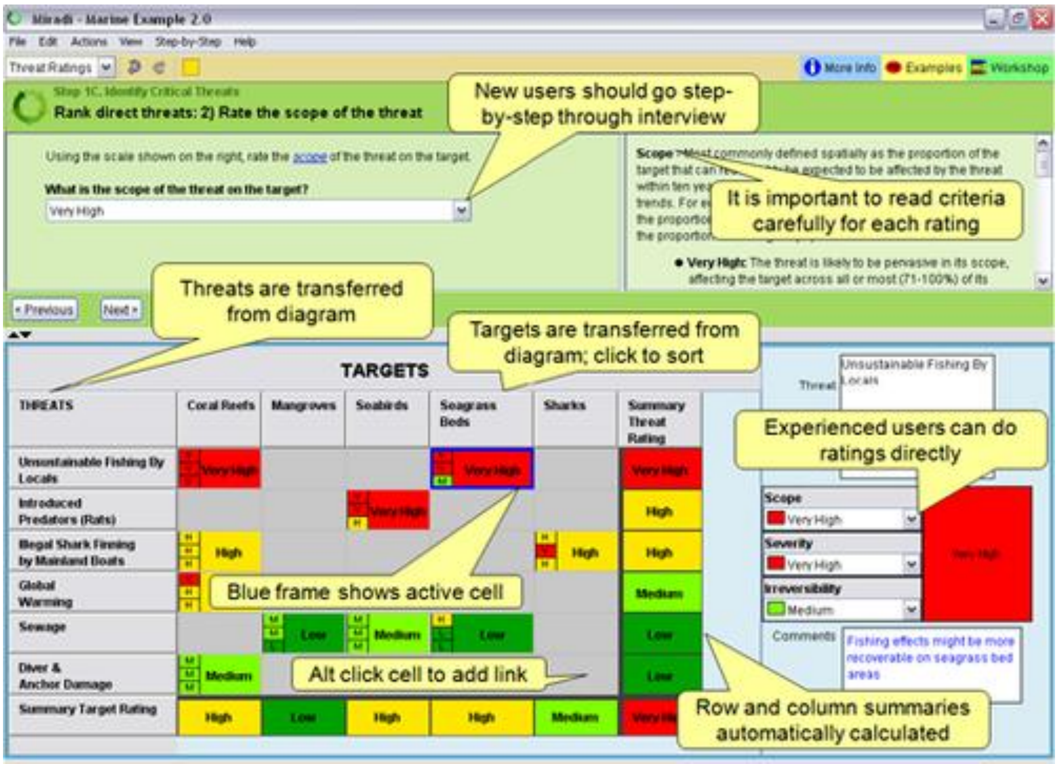


Figure 18. Miradi output of threat rankings for conservation targets. Image from https://www.miradi.org/software-features/

Photo credits: Sampath de Alwis Goonatilake @ IUCN

CHAPTER 5 – ENABLING LAWS, POLICIES AND REGULATIONS FOR INTEGRATING BIODIVERSITY CONSERVATION AND SUSTAINING ECOSYSTEM SERVICES IN ENVIRONMENTALLY SENSITIVE AREAS IN LANDSCAPE PLANNING

Sri Lanka's ecosystems and biological diversity provide a range of critical environmental services that provides protection from natural disasters, sustains livelihoods, and plays vital roles in economic development. In order to protect the ecosystems and their constituent biodiversity the government has promulgated several laws, policies, and regulations.

The Constitution of the Republic of Sri Lanka

The 1978 Constitution of Sri Lanka provides that "the State shall protect, preserve and improve the environment for the benefit of the community", enshrined under Article 27 (14) – Directive Principles of State Policy while the Article 28 (f) imposes a fundamental duty on every person in Sri Lanka, stating that "The exercise and engagement of rights and freedom is inseparable from the performance of duties and obligations, and accordingly, it is the duty of every person in Sri Lanka to protect nature and conserve its riches".

Blue Green Strategy

The Government of Sri Lanka, in line with this provision in the Constitution, announced an era of 'blue-green development' to "employ appropriate measures to utilize limited resources of the world for a sustainable production process and consumption for the benefit of future generations"[2]. Under this blue-green strategy the Blue Economy/Blue Development refer to the oceanic economy and marine resources. Accordingly Sri Lanka will adopt policies to ensure, *inter alia*, sustainability of marine wealth by preserving marine biological resources such as Ocean Fish Resources, Other Marine Biological Resources, etc. The Green economy/Green Development refers to ensuring that the industry and production sectors become eco-friendly, developing Green Agriculture and Green Energy, while bringing in the green element to sectors such as construction, transport and urban and rural development.

National Biodiversity Strategy and Action Plan & Biodiversity Conservation Action Plan (BCAP)

The overall national goal of biodiversity conservation, as stated in the Biodiversity Conservation Action Plan (BCAP) which was undertaken in response to Article 6 of the Convention of Biological Diversity (CBD) in early 1996, is to 'conserve the biological diversity of Sri Lanka, while fostering its sustainable use for the benefit of the present and future generations'. It was followed by the preparation of an 'Addendum' to the BCAP in 2003. The two documents, BCAP and Addendum to the BCAP serve as the key strategic action plans as of 2014, showing the pathways to achieve the key objectives governing biodiversity conservation in Sri Lanka. In the BCAP, the ecosystem diversity of Sri Lanka was categorized into four broad thematic areas: (1) Forests; (2) Wetlands; (3) Coastal and Marine systems, and (4) Agricultural systems. The strategy has been updated in 2016.

National Environment Policy - 2003

The policy aims to promote the sound management of Sri Lanka's environment balancing the needs for social and economic development and environment integrity. It also aims to manage the environment by linking together the activities, interests, and perspectives of stakeholders, and to assure environmental accountability.

[2] http://www.srilankanext.lk/pdf/a-blue-green-era_english.pdf

National Forestry Policy – 1995

The policy was drawn up to provide clear directions for safeguarding the remaining natural forests of the country in order to conserve biodiversity, soil and water resources. In accordance with the policy, the forests under the jurisdiction of the Forest Department are being reclassified and placed under four management systems ranging from strict conservation, non-extractive use, management of multiple use forests for sustainable production of wood, and management of forests with community participation.

The National Policy on Wild Life Conservation - 2000

The policy renews the commitment of the government to conserve wildlife resources by promoting conservation, maintaining ecological processes and life sustaining systems, managing genetic diversity and ensuring sustainable utilization and sharing of equitable benefits arising from biodiversity. It emphasizes the need for effective protected area management with the participation of local communities.

National Biosafety Policy – 2005

The policy on biosafety set the overall framework in which adequate safety measures will be developed and put into force to minimize possible risks to human health and the environment while extracting maximum benefits from any potential that modern bio technology may offer.

National Policy on Wetlands – 2005

All wetlands comprise of a combination of soils, water, plants and animals. The interplay between these elements allow wetlands to perform several functions that are beneficial to humankind, while generating healthy wildlife, fisheries, and forest resources. This policy seeks to give effect to National Environment Policy and other relevant national policies in the conservation of these vital habitats, while respecting national commitments towards relevant international conventions, protocols, treaties and agreements to which Sri Lanka is a party.

National Policy on Elephant Conservation – 2006

The elephant has been so closely associated with Sri Lanka's history, culture, religions, mythology and even politics that it would be difficult to imagine the island without it. Therefore, the present policy was developed to ensure the long-term survival of the elephant in the wild in Sri Lanka through the mitigation of the human-elephant conflict.

National Policy on Sand as a Resource for the Construction Industry – 2006

This policy statement reflects Sri Lanka's constitutional, international and national obligations, including the Mines and Minerals Act No. 33 of 1992, the National Environmental Act of 1980, the Coast Conservation Act of 1981 and other relevant legislation, regulations and policy statements. It defines the commitment of the Government, in partnership with the people, to effectively manage the construction-sand resource for the benefit of present and future generations.

The National Physical Planning Policy

National Physical Planning Department is authorized to formulate and implement the national physical planning policy; the making and implementation of a national physical plan with the object of promoting and regulating integrated planning of economic, social, physical and environmental aspects of land in Sri Lanka; to provide for the protection of natural amenities, the conservation of natural environment, buildings of architectural and historic interest and places of natural beauty.

SIGNIFICANT LEGISLATION FOR THE PROTECTION, CONSERVATION & MANAGEMENT OF THE ENVIRONMENT

The National Environmental Act (NEA) No. 47 of 1980 as amended

The NEA was created as an umbrella law to address environmental issues and to establish the Central Environmental Authority (CEA). The NEA provides three primary approaches to conservation and sustainability. They are environmental protection, environmental quality and environmental impact assessments and approval of projects (EIAs).

The Forest Ordinance No. 16 of 1907, and its subsequent amendments

The Forest Ordinance was enacted for the conservation, protection and sustainable management of the forest resources and utilization of forest products as well as for the regulation of the transport of timber and forest produce and other activities related to such transport. Under this Ordinance there are 3 categories of forests protected under the Forest Ordinance. They are Conservation Forest, Reserved Forest and Village Forest. The forest ordinance also has provision on the use of land adjoining the forest land.

The Fauna and Flora Protection Ordinance No. 2 of 1937, and subsequent amendments

The FFPO was enacted to provide for the protection and conservation of the fauna and flora of Sri Lanka and their habitats, for the prevention of commercial and other misuse of such fauna and flora and their habitats and for the conservation of the biodiversity of Sri Lanka.

The National Heritage Wilderness Area Act No. 3 of 1988

This act was formulated to overcome some inherent weaknesses of the Forest Ordinance and to provide for the preservation of unique ecosystems and genetic resources, physical land, biological formations and precisely delineated areas constituting the habitats of threatened plant and animal species of universal scientific or conservation value. This law provides legal provisions for the management of very special protected areas.

Coast Conservation Act No. 57 of 1981, and the amendment No.64 of 1988

This Act was enacted to make provision for a survey of the Coastal Zone and the preparation of a Coastal Zone Management Plan, to regulate and control development activities within the Coastal Zone, to make provision for the formulation and execution of schemes of work for coast conservation within the coastal zone.

The State Lands Ordinance No. 8 of 1947 and its two amendments

This ordinance deals with the power of the state to sell, lease, grant or otherwise dispose of state lands for management and control. This ordinance provides for the grant and disposition of state lands in Sri Lanka, for the management and control of such lands and the foreshore and for the regulation of the use of the water of lakes and public streams.

OTHER RELEVANT LEGISLATION

- Felling of Trees Control Act No. 9 of 1951
- The Fisheries and Aquatic Resources Act No. 2 of 1996
- Marine Pollution Prevention Act No. 59 of 1981
- National Aquatic Resources and Development Agency Act No. 54 of 1981
- Plant Protection Act No. 35 of 1999
- Water Hyacinth Ordinance No 09 of 1909
- Botanic Gardens Ordinance No. 31 of 1928.
- Soil Conservation Act, No. 25 of 1951; amended in 1996.
- Agrarian Research and Training Institute Act No 5 of 1972
- Agrarian Services Act No. 58 of 1979, and its subsequent amendments
- Control of Pesticides Act, No. 33 of 1980, as amended by No. 6 of 1994
- Land Development Ordinance No.19 of 1935; and its subsequent amendments.
- Colombo District (Low Lying Areas) Reclamation and Development Board Act of 1968, and the
- Sri Lanka Land Reclamation and Development Corporation Act No. 52 of 1982.
- Town and Country Planning Ordinance No.13 of 1946.
- Housing and Town Improvement Ordinance, No.19 of 1950.
- Urban Development Authority Law of 1978, and subsequent amendments
- Mahaweli Authority of Sri Lanka Act No. 23 of 1979; subsequent amendments
- Mines and Minerals Act No. 33 of 1992.
- Water Resources Board Act No.29 of 1964.
- Science and Technology Development Act No. 11 of 1994.

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ANNEX 1 – DETAILED INSTRUCTIONS FOR USING MAXENT, INCLUDING DATA PREPARATION AND ANALYSIS.

Maxent—or Maximum Entropy Model—is widely used to model the distribution of suitable habitat for species at landscape scales, using point observation data. It is a Java-based, stand-along program. The species input files are comma delineated .csv files, while the environmental variables should be in asci format.

Tutorials for Maxent can be downloaded from various websites, including these: https://www.cs.princeton.edu/~schapire/**maxent**/**tutorial**/**tutorial**.doc

www.amnh.org/content/download/141371/.../LinC3_SpeciesDistModeling_Ex.pdf

web2.uconn.edu/cyberinfra/module3/Downloads/Day%204%20-%20**Maxent**.pdf

The program can also be freely downloaded from several sites.

This annex provides a step-by-step guide to prepare data layers for species habitat mapping, using an example from Sri Lanka; the Kala Oya basin. But users are also encouraged to read the other tutorials to get a better understanding of the process.

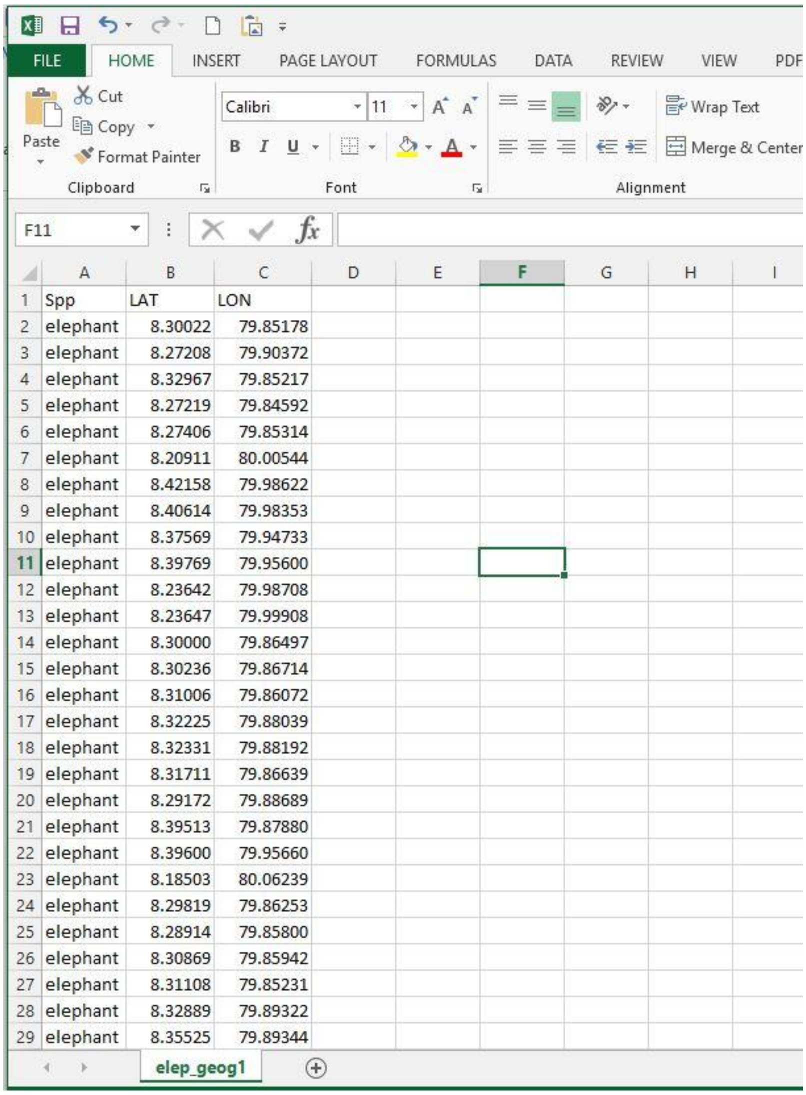
The annex is meant for planners with GIS experience and knowledge. The steps described in this annex are based on the commands and functions in ArcGIS 10.3.1 (ESRI). The specific commands and command windows may be slightly different in previous or newer versions of ArcGIS, but the process and steps will be the same.

There are several basic steps to the process. The first part of the process is to prepare the data layers in ArcGIS (or Q-GIS). The Maxent analysis is done outside of ArcGIS, and the output is then imported back into ArcGIS to create the final overlays.

The steps are as follows:

1. Bring all data layers into a GIS project. These include the species distribution point data and the environmental or habitat layers.
    a. All these layers **must** be in the same projection. But note that the type of projection itself does not matter. In the example described below, we use a Geographic projection.
2. Convert all the environmental data layers to raster format.
    a. When doing so, choose one layer as a base layer that can be referenced to select the grid cell size for all other layers. In this example we have used the DEM.
    b. After the data layers are converted to raster format, they have to be clipped with a layer that is considered to be the Area of Interest layer (AoI). This is because all the environmental layers **must** have the same extent. If a layer has even a small difference to others, Maxent will not run. Clipping all the layers with the AoI layer will make sure all layers have exactly the same spatial extent.
    c. Spatial layers such as roads, and protected areas must be reclassified to assign a value to the grid cells that are outside the road or protected area, etc. Animals or plants will occupy areas outside of these features. If the areas outside the features do not have a value, they will not be included in the Maxent analysis.

3. The species data layers have to be converted to comma delineated csv files. To do this, open the dbf files (from the ArcGIS layer) from the species spatial data layers in Excel. The format for these files should be only three columns: species, latitude, and longitude (Figure 1). All other columns should be deleted. Save the file as a comma delineated file, which will have the following name format: speciesname.csv. Note that the 'speciesname' should be the name of the species.
4. After the raster layers are prepared for the environmental data layers they have to be converted to ASCII format using the data management functions in Arc toolbox. These ASCII files will then be used in Maxent outside of the ArcGIS program.
5. After running Maxent, go back to ArcGIS and convert the output, which will be in ASCII format, back into raster.



	A	B	C
1	Spp	LAT	LON
2	elephant	8.30022	79.85178
3	elephant	8.27208	79.90372
4	elephant	8.32967	79.85217
5	elephant	8.27219	79.84592
6	elephant	8.27406	79.85314
7	elephant	8.20911	80.00544
8	elephant	8.42158	79.98622
9	elephant	8.40614	79.98353
10	elephant	8.37569	79.94733
11	elephant	8.39769	79.95600
12	elephant	8.23642	79.98708
13	elephant	8.23647	79.99908
14	elephant	8.30000	79.86497
15	elephant	8.30236	79.86714
16	elephant	8.31006	79.86072
17	elephant	8.32225	79.88039
18	elephant	8.32331	79.88192
19	elephant	8.31711	79.86639
20	elephant	8.29172	79.88689
21	elephant	8.39513	79.87880
22	elephant	8.39600	79.95660
23	elephant	8.18503	80.06239
24	elephant	8.29819	79.86253
25	elephant	8.28914	79.85800
26	elephant	8.30869	79.85942
27	elephant	8.31108	79.85231
28	elephant	8.32889	79.89322
29	elephant	8.35525	79.89344

Figure 1. Format for preparing the species location data. The data should consist of only three columns, the species name, latitude (LAT), and longitude (LON). This file presents the elephant location data from the Kala Oya basin.

In the following section, we provide a step-by-step outline of the data preparation and analytical processes using several data layers from the Kala Oya Basin.

Take the time to do this process carefully because all layers must be completed the same way, and the extents of the output layers have to match exactly.

First, create a workspace (pathway and folder) in your computer for the output files. Choose a pathway where you can find and retrieve the files easily.

The species data used are observation points for:

1. Elephant (a wide ranging mega vertebrate)
2. Fishing cat (a habitat specialist)
3. Brown capped babbler (an endemic species)
4. Ceylon grey hornbill (an endemic forest-dwelling bird that is found in the dry zone)
5. Yellow fronted barbet (an endemic forest bird that is usually found in wet zone forests)

The environmental layers used are:

1. Land use-land cover (including water bodies) from a 2010 database. This layer represents the different habitats that a species would use or avoid, based on the land use and land cover type. The layer includes all land uses by people (e.g., agriculture, etc.) and the natural habitats categorized as forests, scrub, grasslands, water bodies, etc.
2. Major roads. Roads fragment habitats and disrupt ecological connectivity and block animal movements. The disturbance along roads can also encourage the growth of invasive plant species that can displace other, more important indigenous plant species, including habitat sensitive, endangered, or endemic species. Vehicle traffic can also kill animals that attempt to cross roads (e.g., fishing cats are often killed by cars). The narrow, unpaved roads and jeep tracks, etc. have been removed from the analysis because disturbance levels are lower along these roads and most animals can cross these roads easily. But planners should consult with biologists and ecologists to decide what roads to keep, and what can be removed from the analysis.
3. Railway lines. This is another type of linear infrastructure that can disrupt ecological connectivity and cause animals deaths. For example, elephants are often killed or badly injured by collisions with trains.
4. Major settlements. Major settlements have been included in the analysis because many species of wildlife will avoid these areas. However, some species do use urban habitats, and if any observation data of species in urban habitats are included in the observation database, Maxent will consider these areas as habitat.
5. DWC protected areas.
6. Forest reserves.
7. Distance to water layer. This layer was derived using the method described in Annex 2. Water is a defining variable for species distributions. Therefore, a layer that assigns values to grid cells based on the nearest distance to a water body was created using the model builder shown in Annex 2.
8. Digital elevation model (90 metre; DEM). The DEM provides topographical information: elevation, slope, and aspect that can influence species distributions.

We also created an Area of Interest (AoI) layer to place a boundary around the spatial area that we are interested in. This area includes habitat outside the Kala Oya basin because animals can use habitats outside the basin boundary, and plants can be found in areas outside the basin boundary. This continuity and ecological connectivity around the Area of Interest (in this instance the Kala Oya basin) must also be considered in landscape spatial planning. Therefore, the AoI layer was created by buffering 10 km outside the Kala Oya basin boundary using the buffer function in ArcGIS.

Data Processing

Step 1. The first step is to project all layers to a single projection. It doesn't matter what the projection is; just that they have to be the same for all layers. In this example, we used a Geographic projection (GCS_WGS_1984). This was done using the projection function in the ArcGIS toolbox (Figure 2).

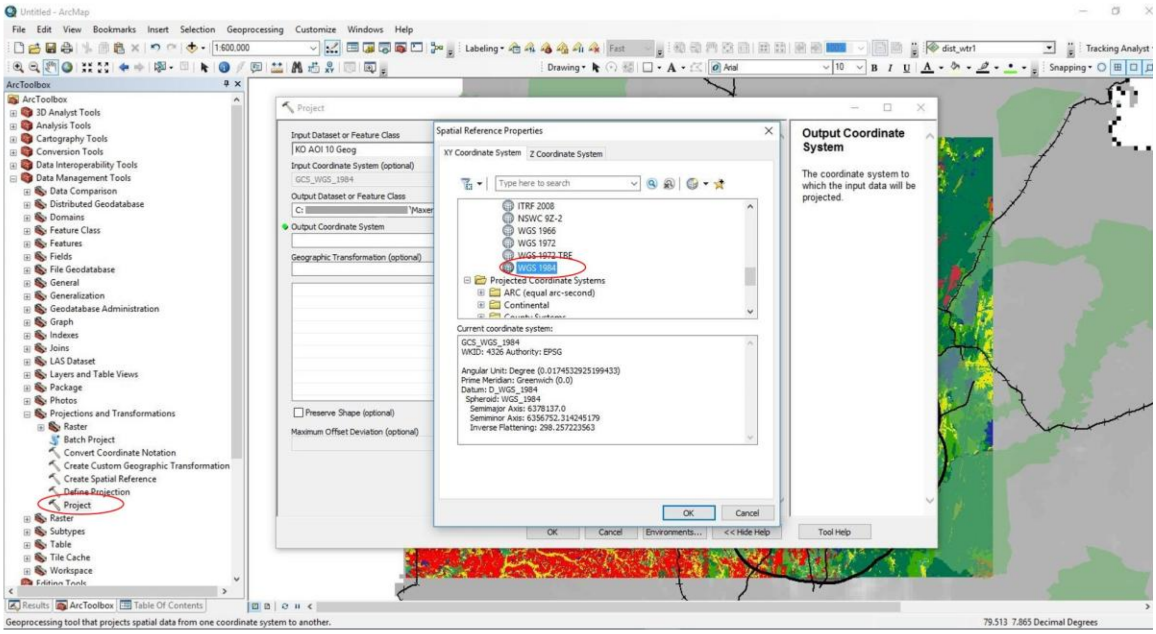


Figure 2.

Step 2. Convert all layers to raster format. In this example, the data layers 1-6 that we used were feature layers (vector), and these were converted to raster format in ArcGIS. Note that when these data are converted the grid cell size was referenced to the DEM grid cell size. This is necessary to make sure that all the raster layers match.

To do this, go to the 'Output cell size' box in the window and select the DEM from the folder where you have saved it (Figure 3).[3]

[3] *Note that the folder and file pathways to these files will depend on where different planners will save their files. The specific pathways in the figures have been erased in these examples to prevent confusion. But these pathways will be where different planners save their own files.*

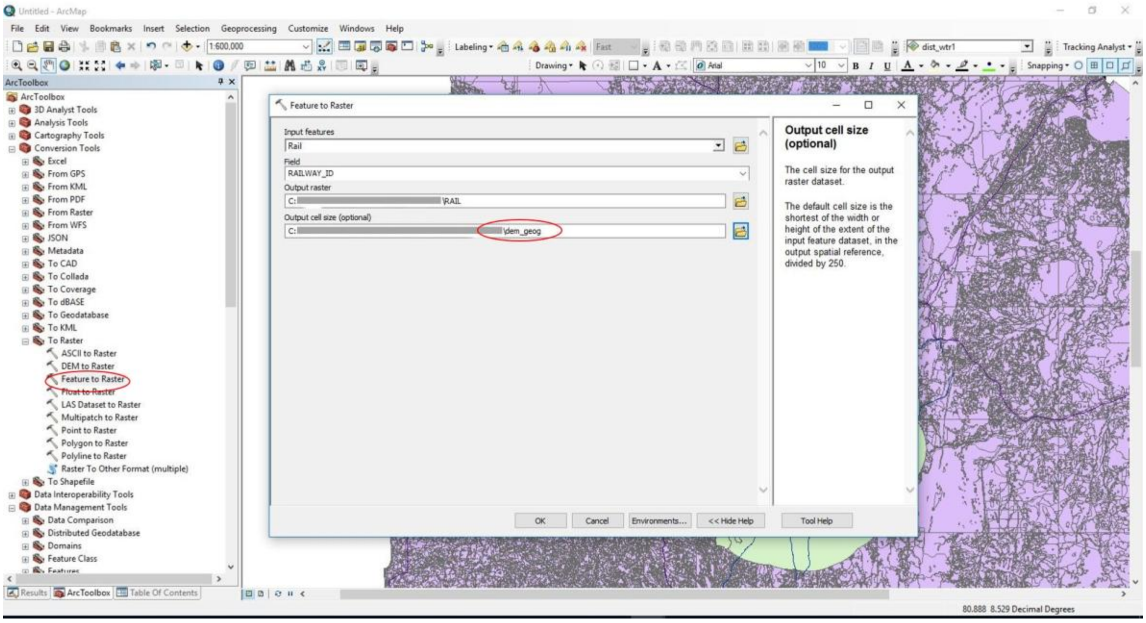


Figure 3.

Step 3. Reclassify all linear data (e.g., roads, railways, etc.) and isolated polygon data (e.g. protected areas) where the matrix will be represented as 'no data'. To do this:

1. Select the 'Reclassify' function in 'Spatial Analyst Tools' -> 'Raster' in the Arc Toolbox
2. Replace the 'Nodata' with a number value in the 'New Data' column (Figure 4). In this example, for the road layer, we have entered 1 as the new data value for 'NoData' grids.
3. In order to ensure that the required extent is processed, go to 'Environment Settings' -> 'Processing Extent' and select the AoI file from the folder where you have stored it (in this example, its KO_AOI.shp). Note that the AoI file can be a vector file.
4. In the Snap Raster window, select the DEM (Figure 4).

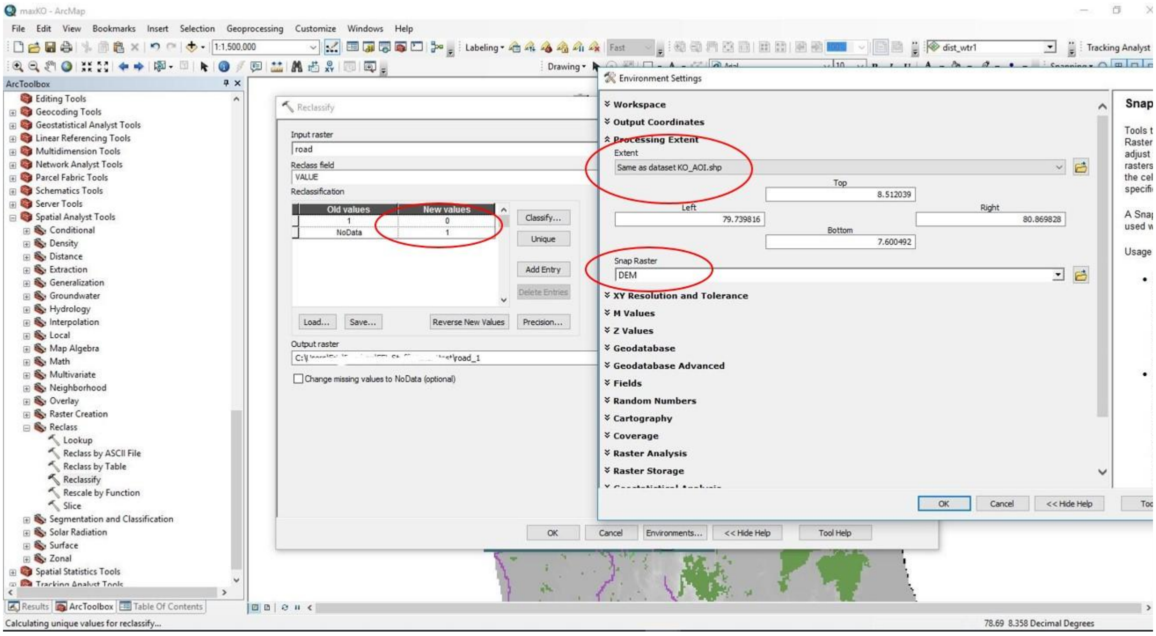


Figure 4.

Selecting the AoI file and snapping the raster to the grid will make sure that the entire extent of the Area of Interest will be selected in the layer. Figure 5 shows the AOI selected for the FR layer using this process. Note that the rectangular area selected includes the entire Area of Interest.

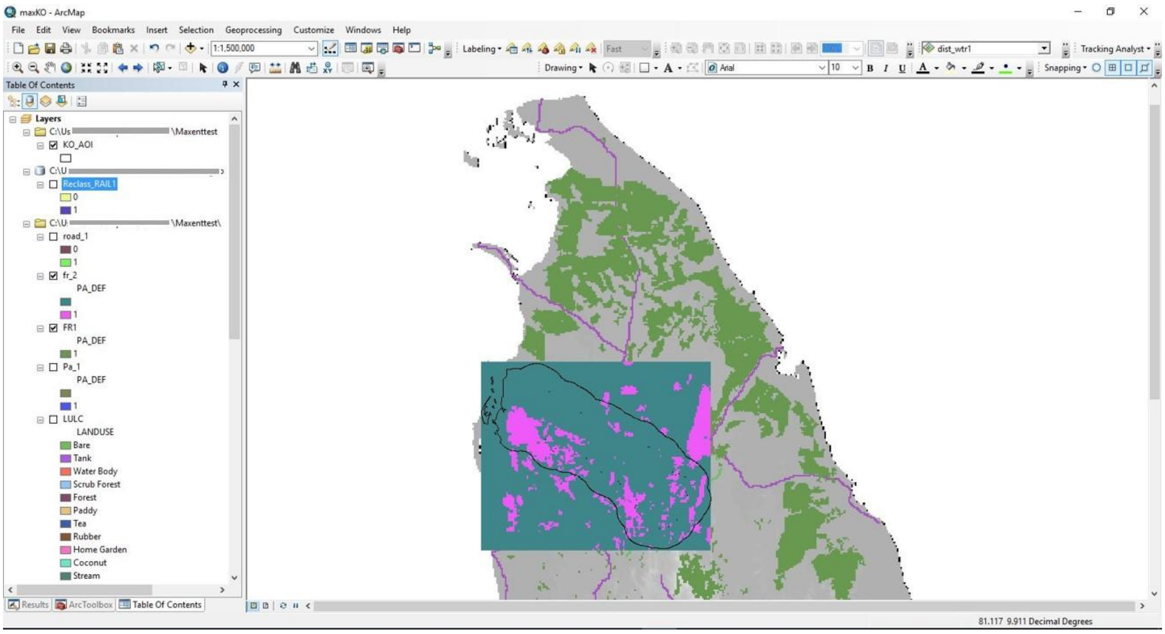


Figure 5

Step 4. After all the files have been converted to raster files, they have to be clipped with the AOI file to make the extents of all layers exactly the same.

There are two ways to do this. In one method, you can use the raster calculator to multiply a column in the raster layer with the AOI layer (this has to be a raster file as well). This has to be done with each data layer.

In the second method, you can overlay the AOI layer on each data layer. This method is described below for the railroad layer. To do this:

1. Go to 'Data Management' -> 'Raster' -> Raster Processing' and select 'Clip' (see Figure 6).
2. Select the reclassified railroad layer as the Input Raster.
3. Select the AOI layer (KO_AOI file. Note that this can be a vector file)
4. Check the 'Use Input Features for Clipping' box to make sure that the AOI layer is used to clip the data layer.
5. Provide a pathway and a file name for the clipped output file
6. Check the 'Maintain Clipping Extent' box. (This will clip the data layer exactly to the AOI).
7. Select OK.
8. Complete this process for all data layers that you will use in Maxent.

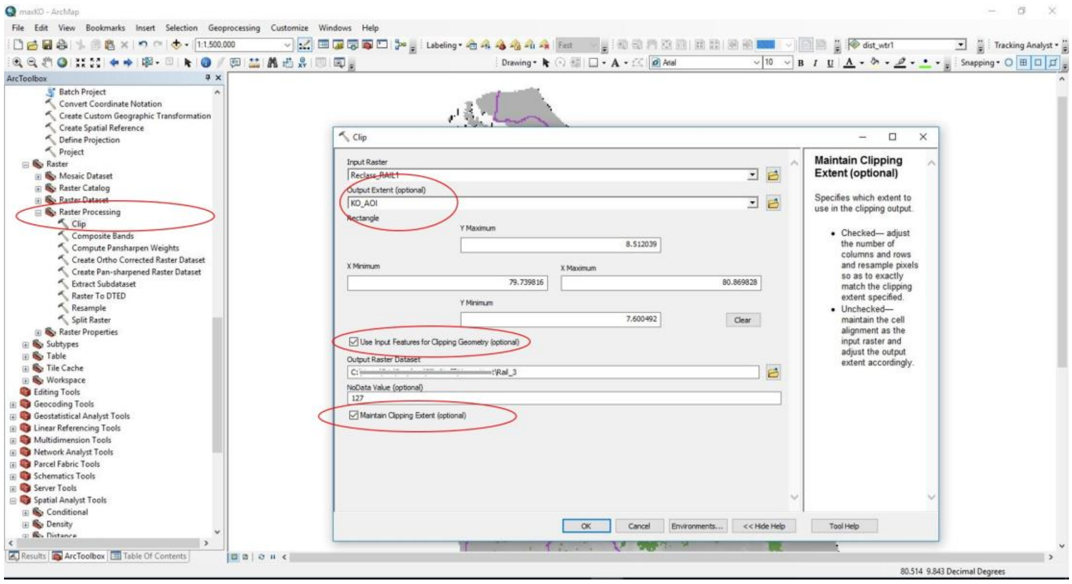


Figure 6

Figure 7 shows the same process for the Protected Areas layer (Pa_1). Note that in both cases, the maximum and minimum values for X and Y are identical. This is important to ensure that that are extent of the clipped areas are identical.

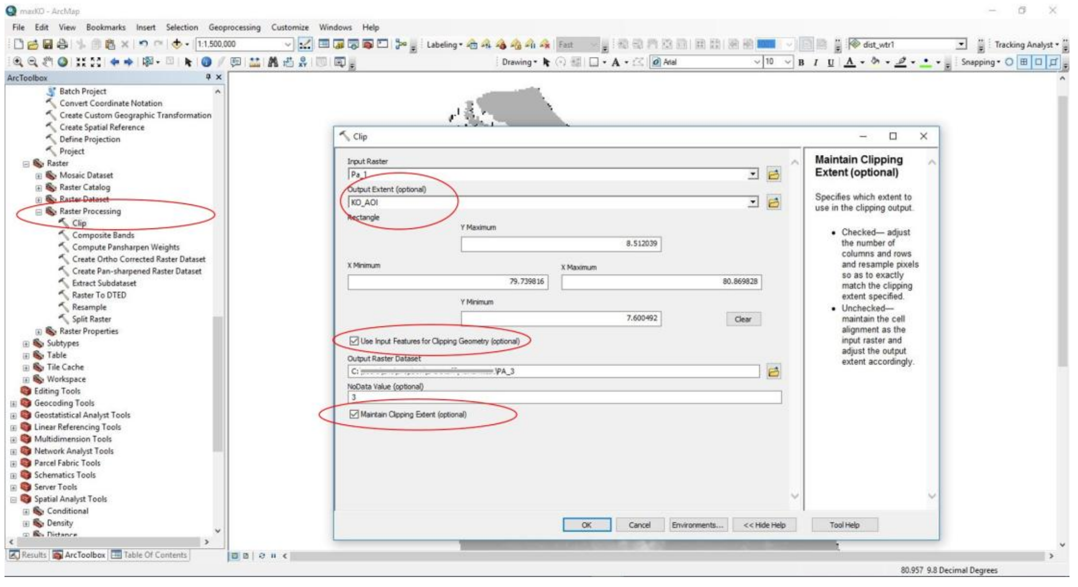


Figure 7

Step 5. Project all the raster files again. They can be re-projected to the same projection. In the example below, we use the Forest Reserve layer (FR_3).[4]

1. Select ‘Projections and Transformations’ -> ‘Raster’ -> ‘Project’ from Arc Toolbox (Figure 8).
2. Name the output file in the appropriate workspace (folder).
3. Use the same projection, or select a different projection. If a different projection is selected, all other layers must be projected to this same projection.
4. Use the reference file (in this case the DEM with the same projection) to select the Output Cell Size. The output cell size must be the same for all environmental data layers that will be used in Maxent.
5. Select OK and run the projection.

[4] Note: the original forest reserve layer was named FR-1. When it was reclassified, it was renamed FR-2. When it was clipped to the AOI it was again renamed FR_3. The output from the raster re-projection was named FR_4. Naming the files in sequence helps to keep track of the latest files in the process.

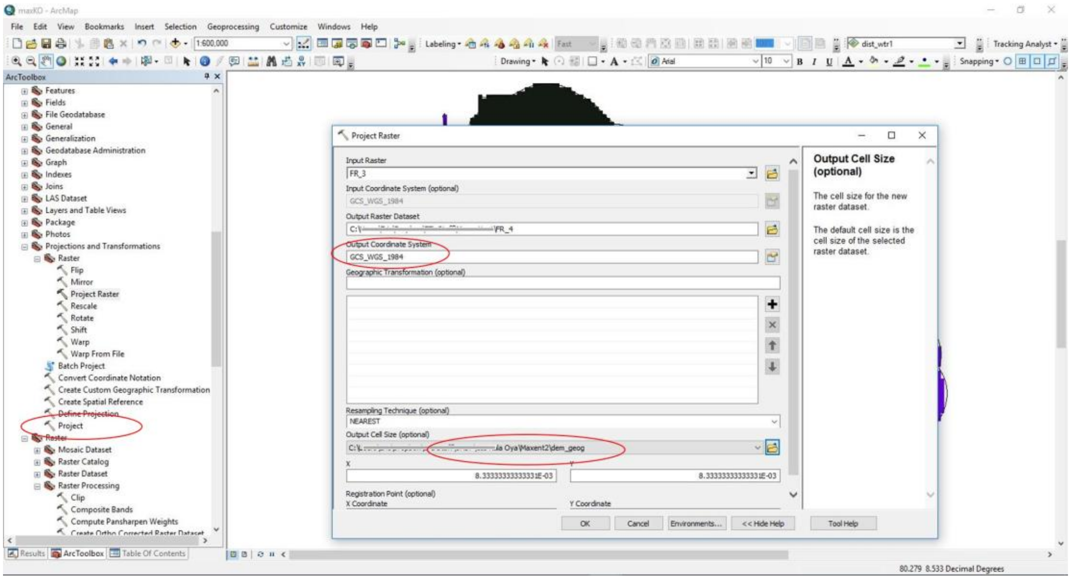


Figure 8

Step 6. Convert the raster files to ASCII format. Maxent will read the environmental data layers in ASCII format (Figure 9).

1. Go to ‘Conversion Tools’ in Arc toolbox -> ‘From Raster’ -> ‘Raster to ASCII.
2. Select the environmental data raster files as the Input raster
3. Select the file folder/workspace where you want to save it, and give the output file a name
4. Select OK to save the file.
5. Repeat the process for every environmental layer file derived from Step 5.

Note: make sure that the output file has an ‘asc’ at the end, indicating it’s in ASCII format. Some versions of ArcGIS will try to save it as a ‘txt’ file. If this happens, double click on the output file name in the window (shown below) and manually change the ‘txt’ to ‘asc’.

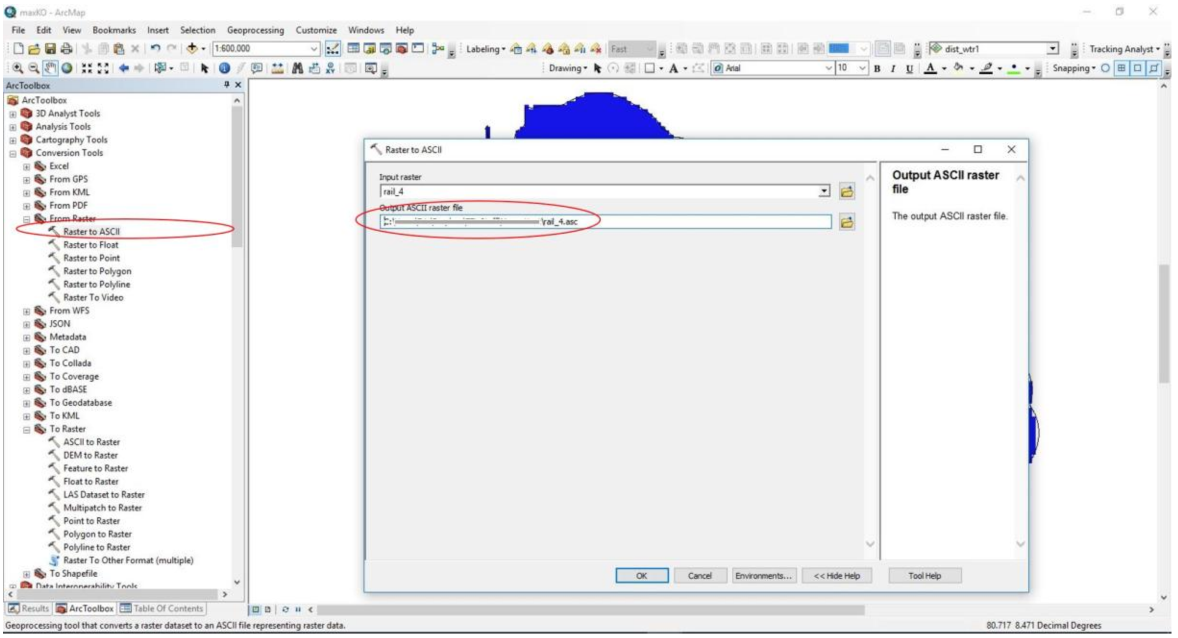


Figure 9.

The ASCII files are now ready to run in Maxent. If the process was done correctly all the environmental layers that have been prepared will have the same extent.

Check the ASCII files by opening them in Notepad, and check the first six rows (Figure 10). Make sure that the ‘xllcorner’, ‘yllcorner’, and the ‘cellsize’ are identical in all the ASCII files.

If they are not, the layers will not be accepted by Maxent, and it will mean that something was not right in the data processing steps.

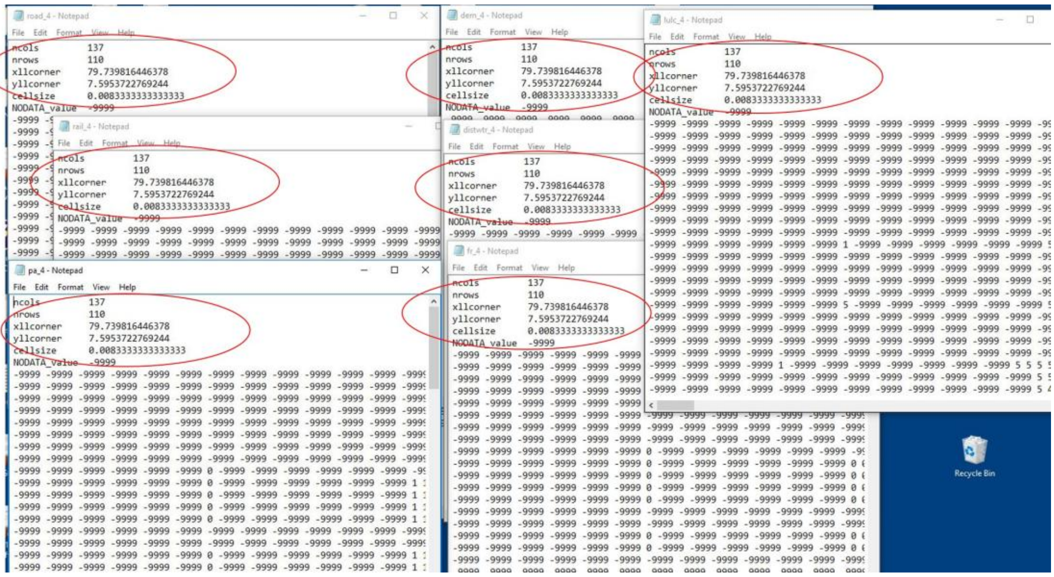


Figure 10

Running Maxent

Step 7. This is the step where you run Maxent.

1. Open Maxent by double clicking on the exe file (or shortcut).
2. Enter the species file on the left side of the screen. Do this by navigating to the folder where you saved the species file, which should be in ‘csv’ format (as described earlier). When the file is selected it should appear as indicated in Figure 11, with a check mark against the species file name. In the example in Figure 11, we are using observation data points for elephants.
3. Select the environmental layers on the right side of the screen. Browse to the folder where you saved the ASCII files (you may have to click on ‘All files’ in the “Files of Type’ command line for the ‘asc’ files to show.
4. When you select on ‘asc’ file, the other files should also be loaded and will be shown in the window. If not, select all the files you want to use. If there are other ‘asc’ files that you don’t want to use also in the folder they should be de-selected.
5. In the dropdown menu choose categorical or continuous, depending on the data type. In this example below, the DEM and Distance to Water layers are continuous data, but all other layers are categorical.

6. Check the boxes to 'Create response curves', Make pictures of predictions', and 'Do jackknife to measure variable importance'. These outputs will help you to analyze your results.
7. Create a folder in the 'Output directory' where the outputs will be saved.
8. Create a folder in the 'Projection layers directory/file' where the temp files will be saved.
9. Run Maxent

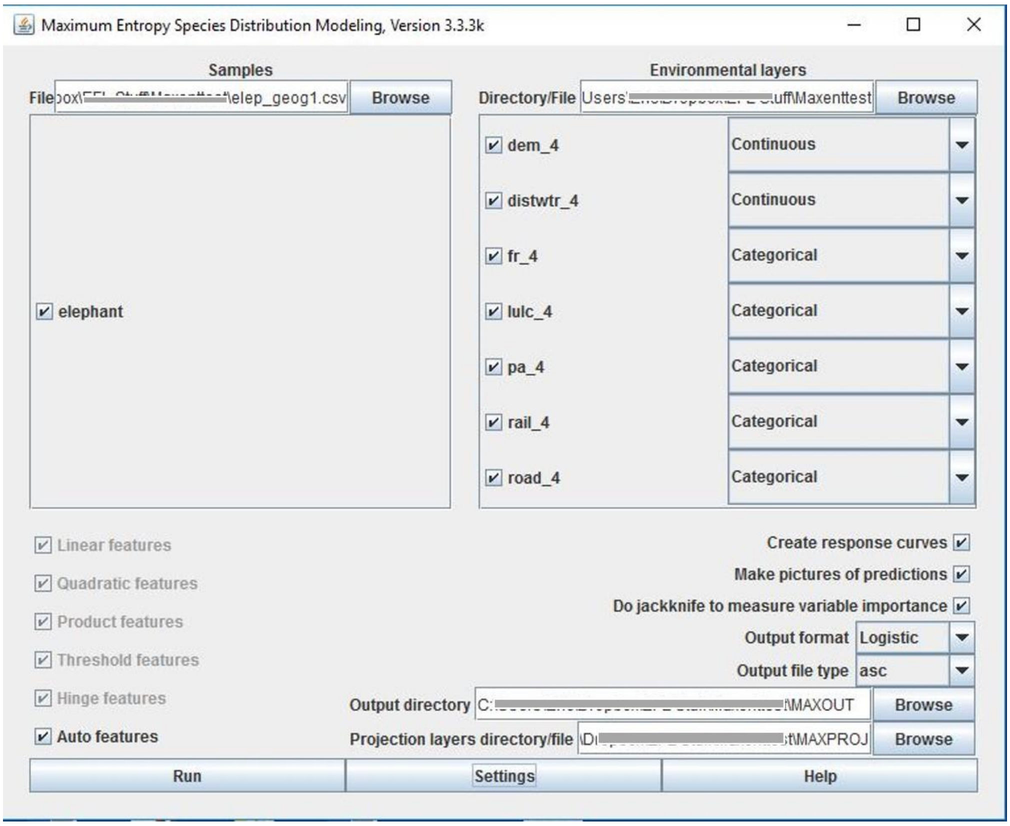


Figure 11

Display Results

Step 8. Import the Maxent output into ArcGIS. The output will include an ASCII file of the habitat suitability for the species. This file has to be converted to a raster file that can be imported and displayed in ArcGIS as follows:

1. Open the 'Conversion Tools' -> 'To Raster' from the Arc Toolbox
2. Select the ASCII file from the Maxent output folder that was specified when running Maxent by browsing for it in the 'Input ASCII raster file' window. In the example below, it is the 'elephant.asc' file (Figure 12).
3. Name an output raster file (Figure 13).
4. Select 'FLOAT' in the Output data option (Figure 13).
5. Click 'OK'

The result will be a raster output like in Figure 14 that shows the suitability of the landscape as elephant habitat. The high suitability is indicated by the whiter and light gray colours and the low suitable habitats by the black and darker colours in the white to black colour ramp.

Improve the map:

1. Select Layer Properties (right click on the layer name), and the 'Display' tab
2. Choose 'Bilinear Interpolation (for continuous data)' in the 'Resample during display' using the drop down menu (Figure 15).
3. Go to the 'Symbology' tab and select a different colour ramp (Figure 16), for a better representation of the suitable habitat as indicated in Figure 17, where the most suitable habitats for elephants are shown as the bright pink, purple and blue colours, and the non-suitable colours in yellows.
4. Overlay features such as water bodies, roads, settlements etc. on the map to show the context of why the habitat is suitable or not suitable.

To generate a raster attribute table for the habitat layer, follow these steps:

1. In ArcToolbox, Select Data Management Tools -> Raster -> Raster Dataset -> Copy Raster
2. In the Pixel Type drop down, select the 32_Bit_Signed_Integer. This converts the 32 Bit floating point raster to a 32 Bit signed integer raster
3. In ArcToolBox, Data Management Tools -> Raster -> Raster Properties -> Build Raster Attribute Table
4. Input the 32 Bit signed integer output raster from Step 1. This output will now have a raster attribute table.

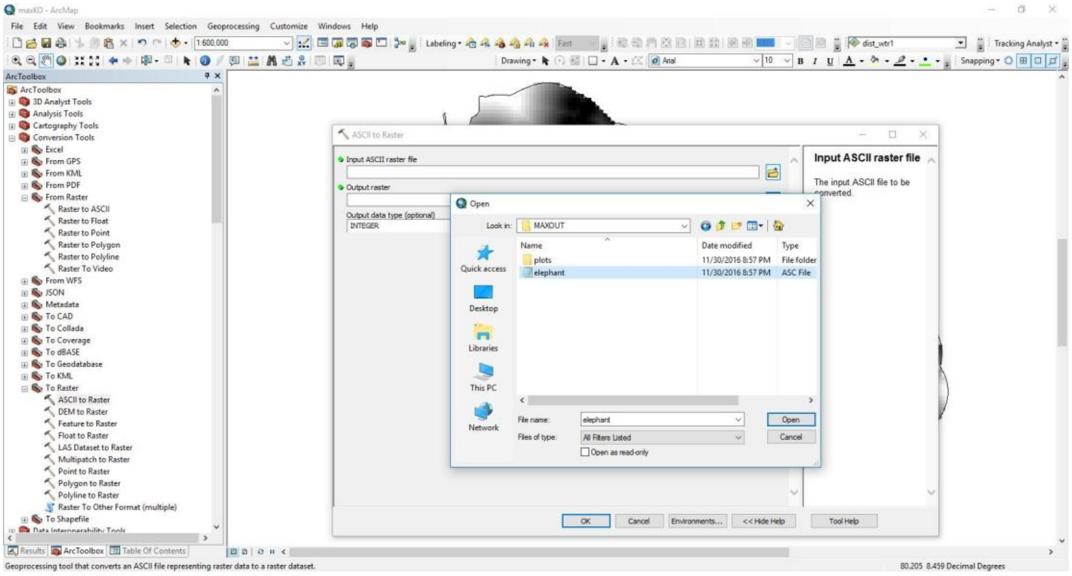


Figure 12

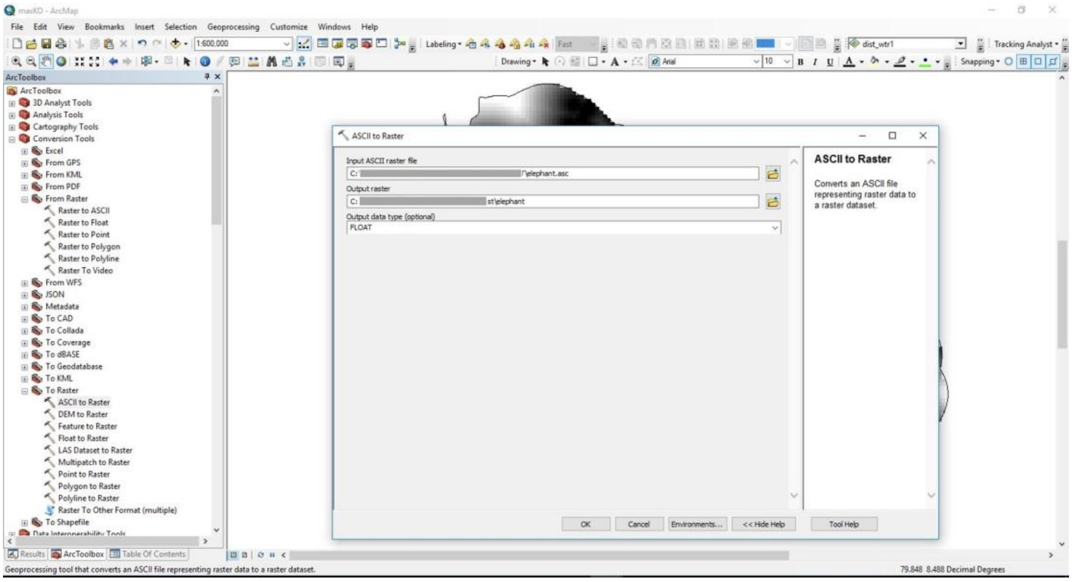


Figure 13

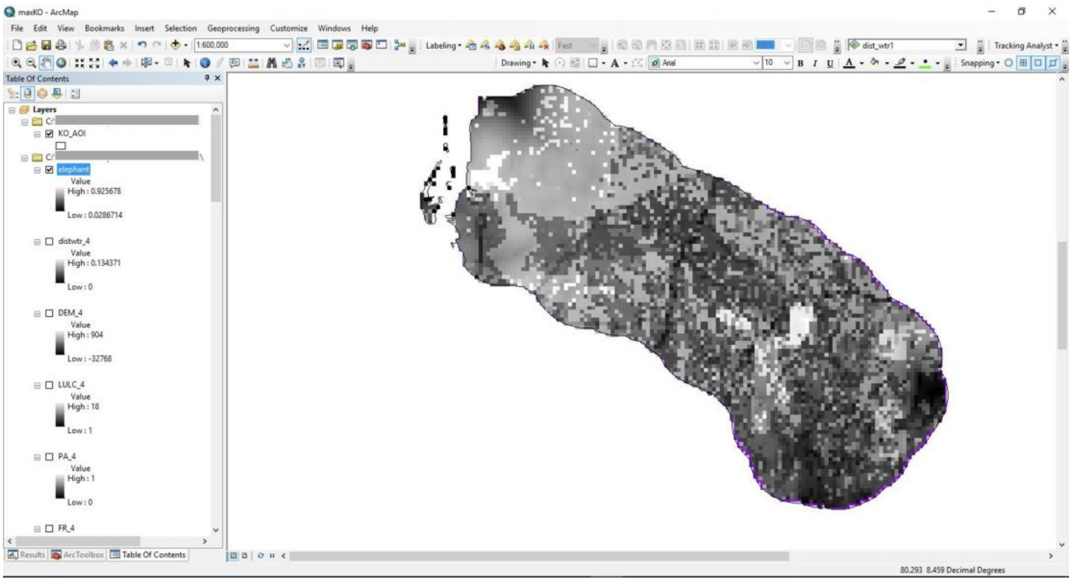


Figure 14

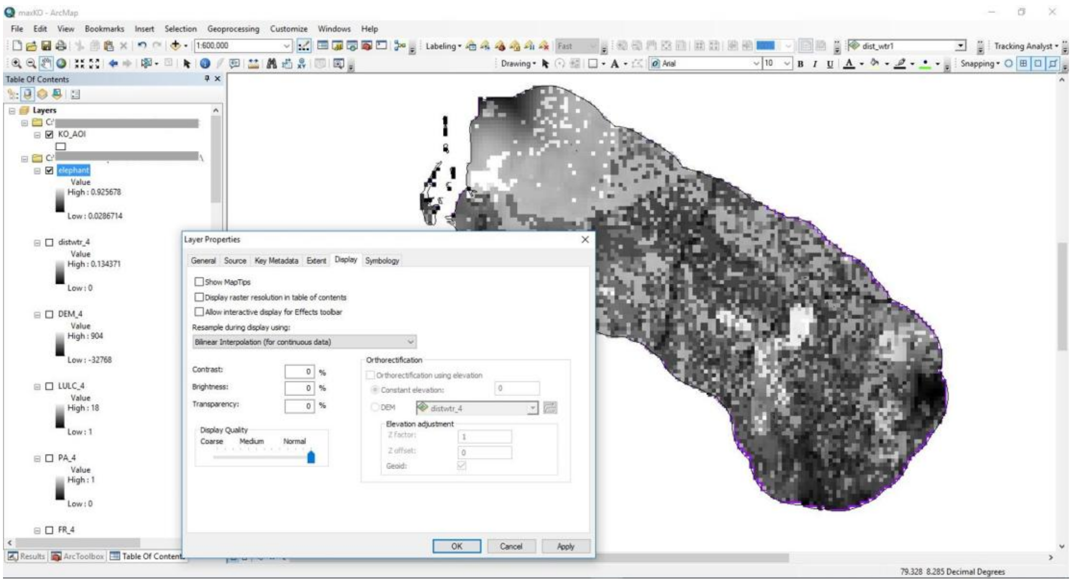


Figure 15

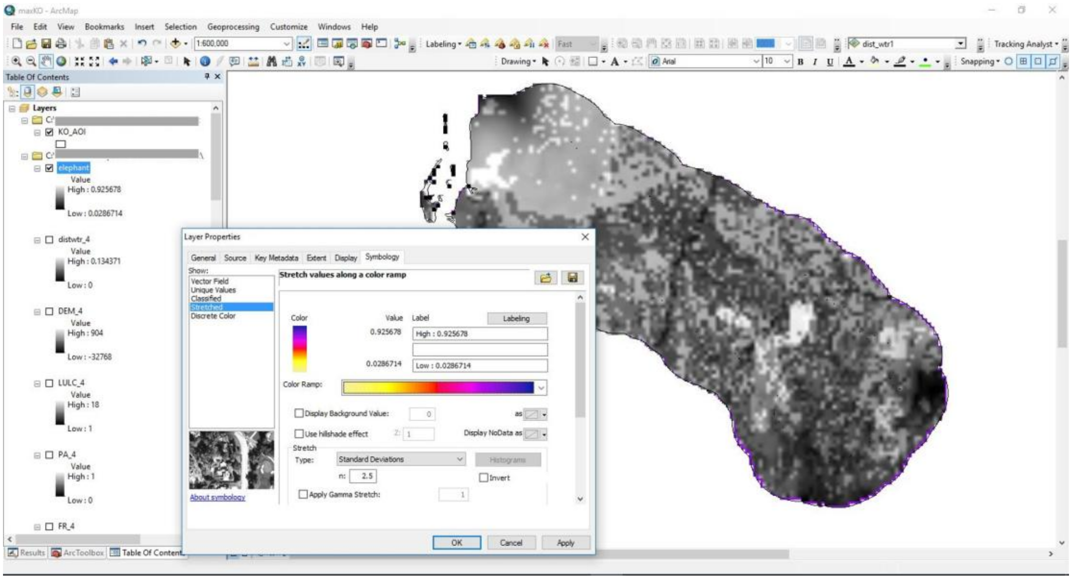


Figure 16

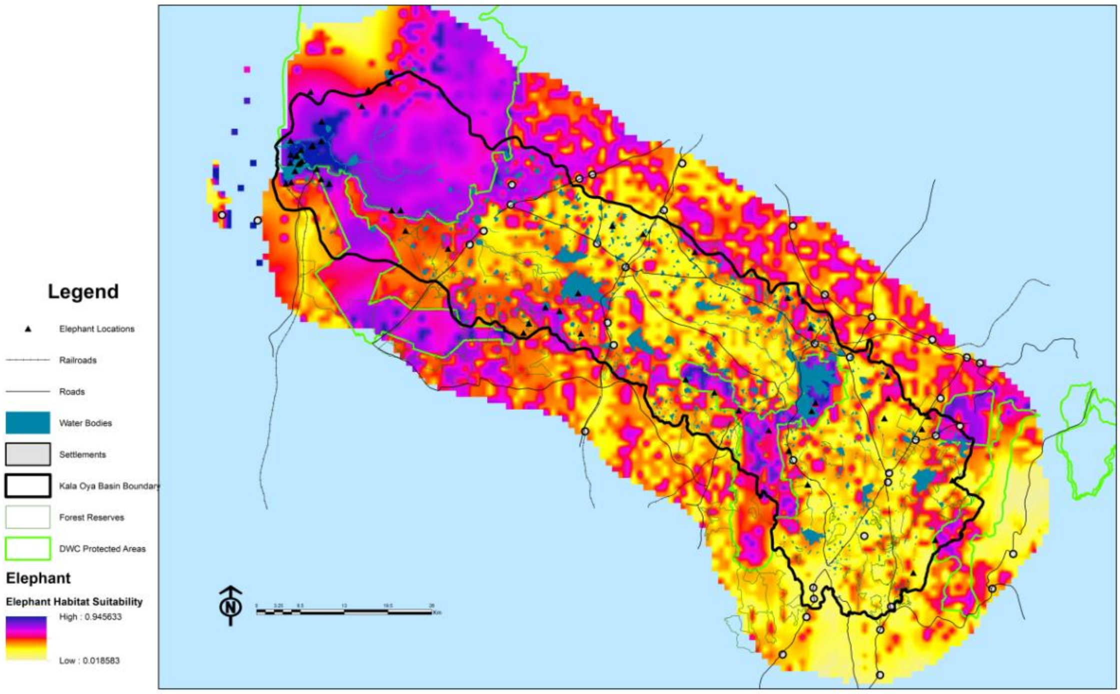


Figure 17

Analysis of Maxent Outputs

Interpretation of the Maxent outputs can help to understand the relative contributions and importance of the environmental variables in predicting the suitability of habitat for a species. The outputs will be saved in the Maxent output folder as several files, including a html file that will open in a web browser (Explorer, Firefox, Chrome, etc.).

The output includes a table with three columns (Table 1). This table provides estimates of relative contributions of the different environmental variables that were used in the Maxent model. Table 1 provides the outputs for elephants, and indicates that land use-land cover, protected areas, DEM, and distance to water contributed the most towards predicting elephant habitat suitability.

Table 1. Relative contributions of the environmental variables to predicting the distribution of elephant suitability.

Variable	Percent contribution	Permutation importance
lulc_4	40.9	26.6
pa_4	33.6	35
dem_4	13.8	30.9
distwtr_4	11	3.8
rail_4	0.7	3.7
road_4	0	0
fr_4	0	0

The graph (Figure 18) shows the results of the Jackknife test of variable importance to predict elephant habitat suitability. Here, land use –land cover (lulc_4) was the environmental variable with the highest gain when used in isolation, and seems to provide the most useful information by itself. The environmental variable that decreases the gain the most when it is omitted from the set of variables is also lulc_4, indicating that it has the most information that isn't present in the other variables.

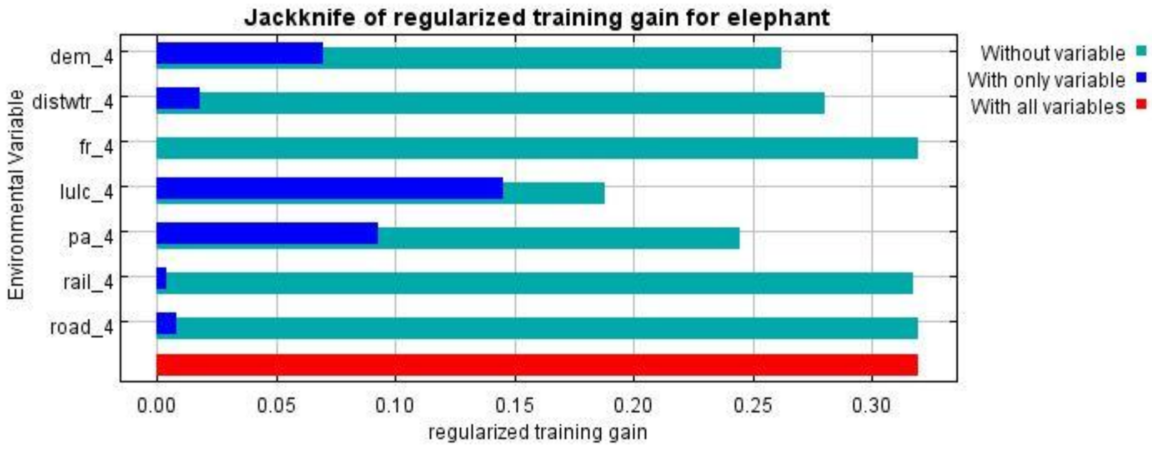


Figure 18. Results of Jackknife test of variable importance for elephants. The graph indicates that the environmental variable with highest gain when used in isolation is lulc_4, which indicates that it has the most useful information by itself (dark blue bar). The environmental variable that decreases the gain the most when it is omitted is also lulc_4, which indicates that it also has the most information that isn't present in the other variables (light blue bar).

A comparison of the results for elephants with the results for fishing cats (Table 2) shows that for fishing cats, distance to water was the most important variable, followed by land use-land cover, and roads. This makes ecological sense, because fishing cats are usually found close to water sources, and may be avoiding roads.

Table 2. Relative contributions of the environmental variables to predicting the distribution of fishing cat suitability.

Variable	Percent contribution	Permutation importance
distwtr_4	43	57.1
lulc_4	32.9	40
road_4	23.9	0
fr_4	0.1	0
dem_4	0	3
pa_4	0	0
rail_4	0	0

More information about the outputs are available from Maxent tutorials that can be downloaded from the internet, or by clicking on the links that are generated at the end of the html output file.

ANNEX 2 – THIS ANNEX DESCRIBES HOW TO CREATE A DISTANCE TO WATER RASTER LAYER.

This layer is a useful habitat layer to use in Maxent. The methodology is based on a paper by L. Carter (2011), which has also attached at the end of this Annex for further details. The descriptions in this Annex are based on a layer prepared for the Kala Oya Basin.

Step 1. (Figure 1)

- Open an ArcGIS project window.
- Load your water feature layer. This is a vector (shp) file.
- Load the Area of Interest file (AoI). This is a raster file.
- Make sure that both files are in the same projection.

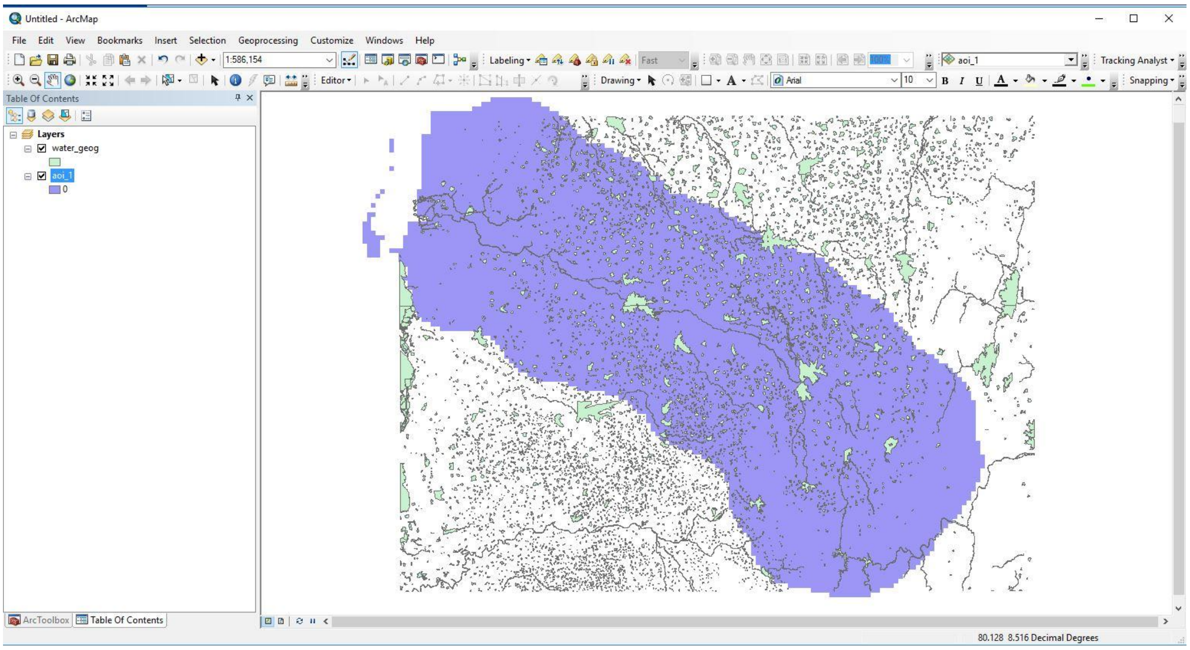


Figure 1

Step 2. (Figure 2)

- Click the model builder button, and open a model builder window
- Click ‘Model’ and select ‘Model Properties’
- Select the ‘Environments’ tab
- Check the ‘Output Coordinates’ and ‘Processing Extent’ boxes
- Click the ‘Values’ button

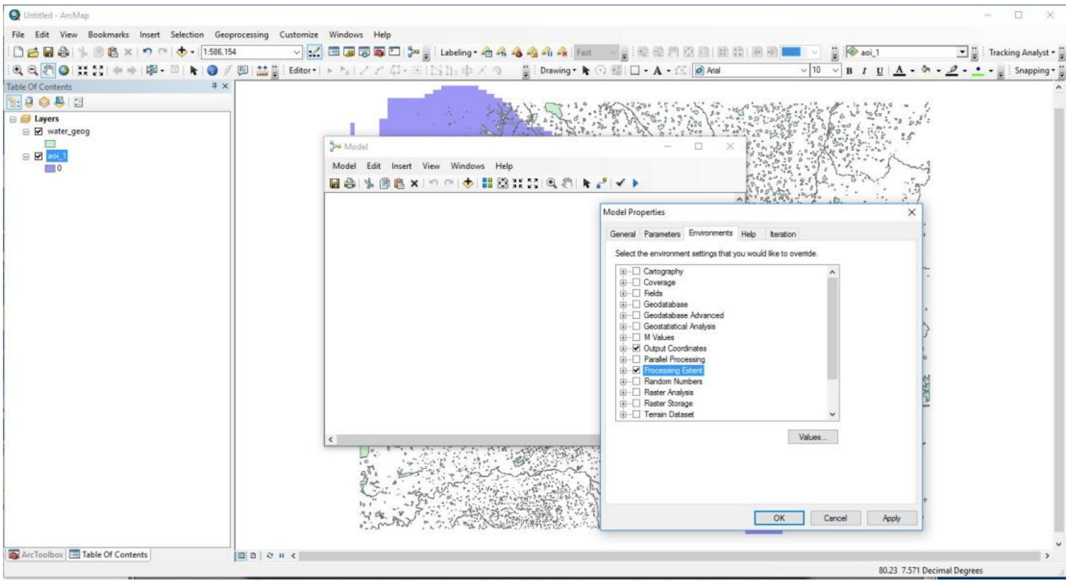


Figure 2

Step 3. (Figure 3)

- Select your 'Output Coordinate System'. This can be the same as one of your layers that's already loaded. In this case, it is the water layer, which is in geographic projection; i.e., water-geog.
- Select your extent. In this case it is the aoi_1 layer, which is the area of interest file. This is a raster file.
- Select the same file in the 'Snap Raster' window.
- Click 'OK'

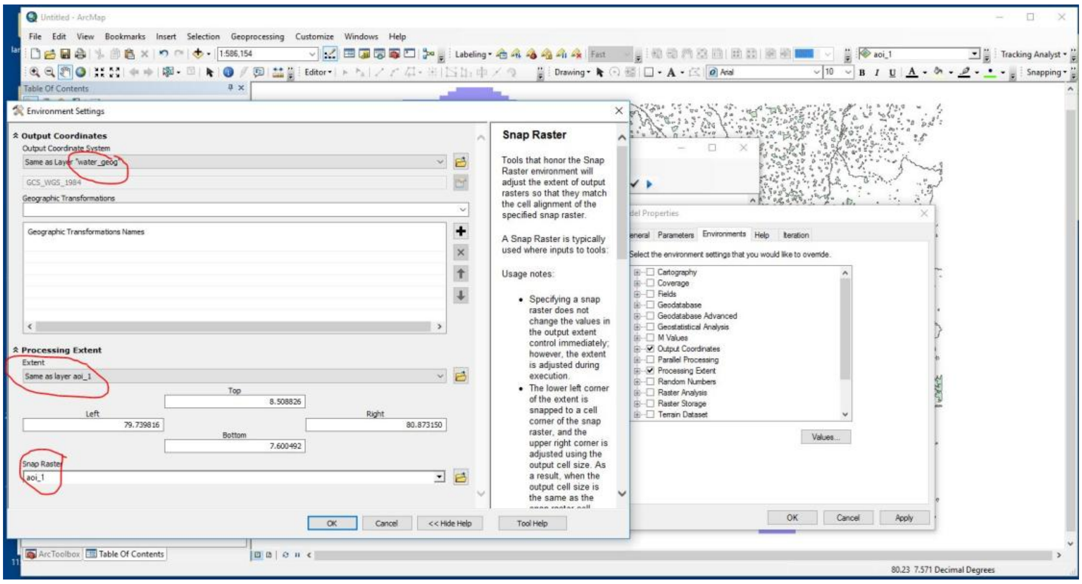


Figure 3

Step 4.

- Drag the water layer into the Model Builder window.

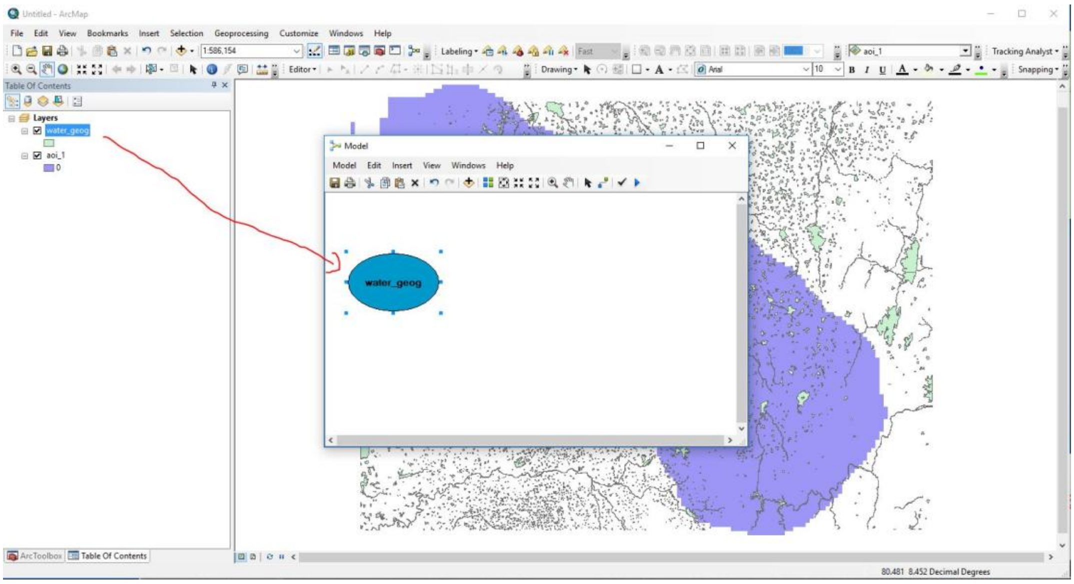


Figure 4

Step 5. (Figure 5a,b)

- In the search window, search for 'distance'
- Select 'Euclidean Distance' (highlighted here), and drag it into the Model Builder Window (Figure 5a).
- It will create three linked boxes like in Figure 5b.
- Double click the box 'Euclidean Distance'

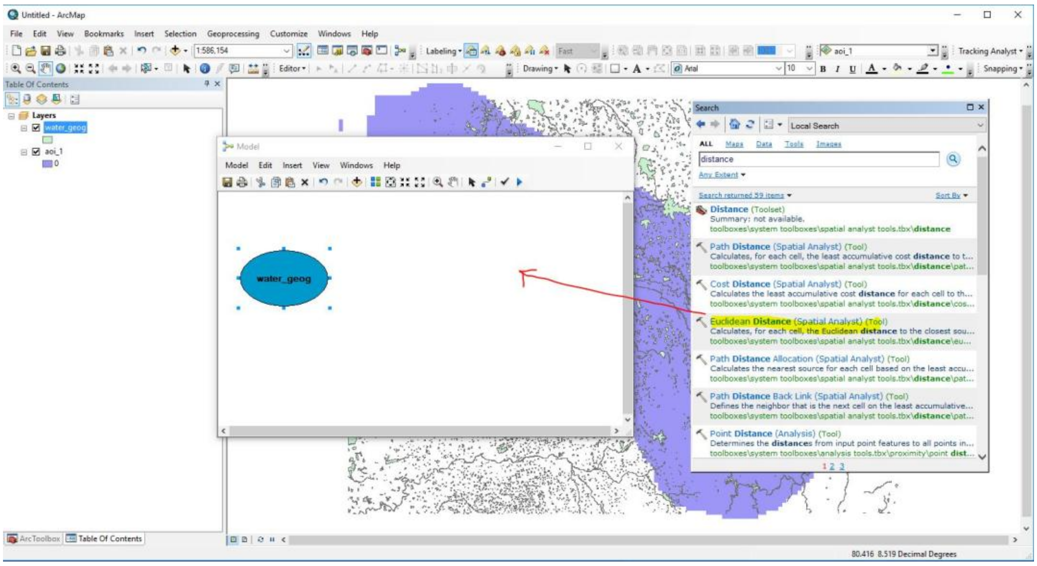


Figure 5a

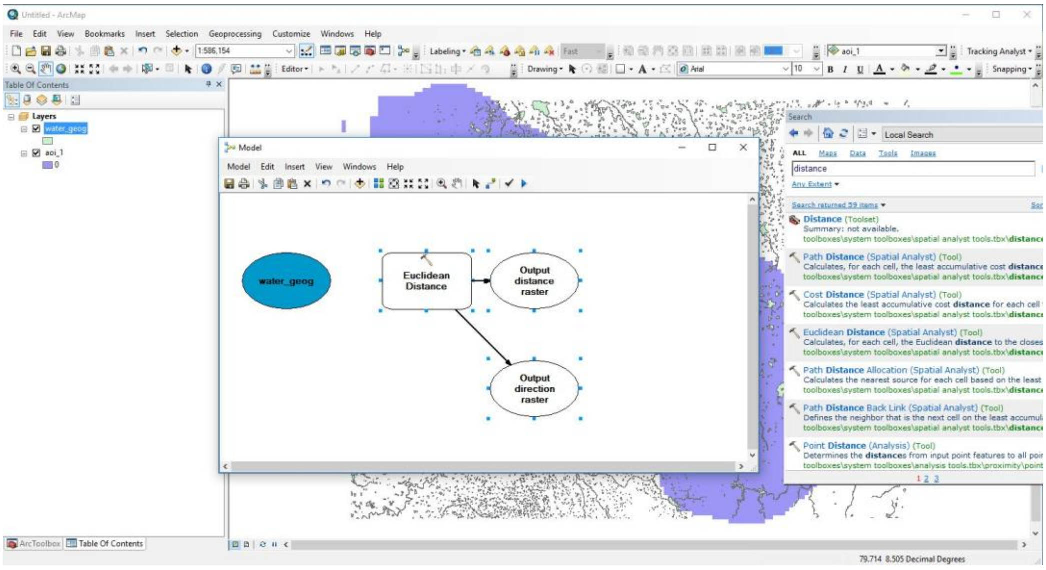


Figure 5b

Step 6 (Figure 6)

- Select the 'Input raster or feature source data' file. This will be the water layer
- Select the output file pathway/folder, and name the output file in the 'Output distance raster' window.
- Select a reference file to select your raster grid size in the 'Output cell size' window. It is advisable to use the DEM for this. Make sure the DEM is in the same projection as the other layers.
- Click 'OK'

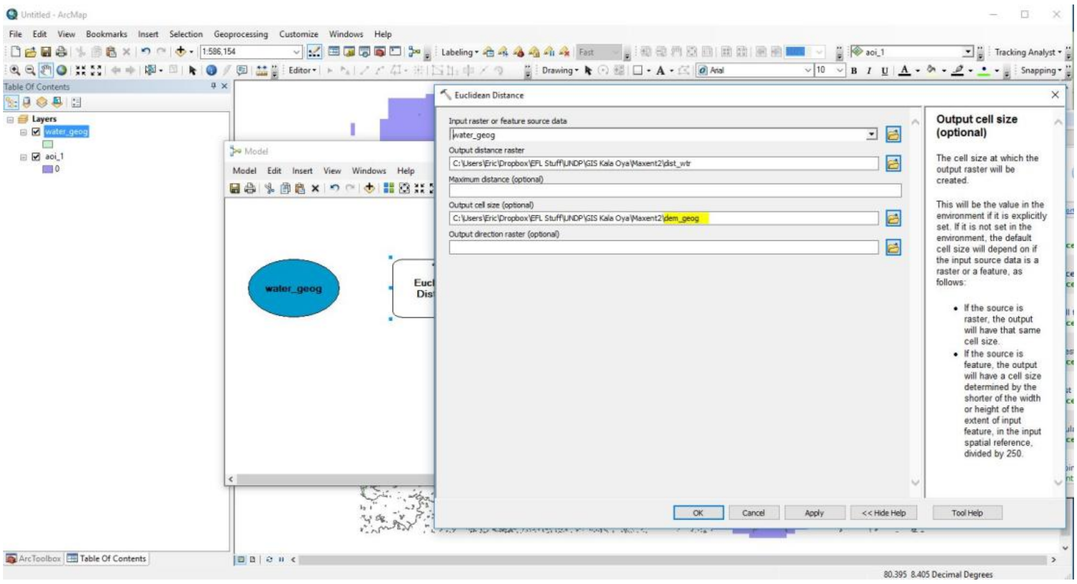


Figure 6

Step 7. (Figure 7).

- Click ‘Model’
- Choose ‘Run Entire Model’
- Open the output raster, which is your distance to water layer

Note that this same process can be used to create layers that show distance to Protected Areas, or distance to roads, settlements etc.

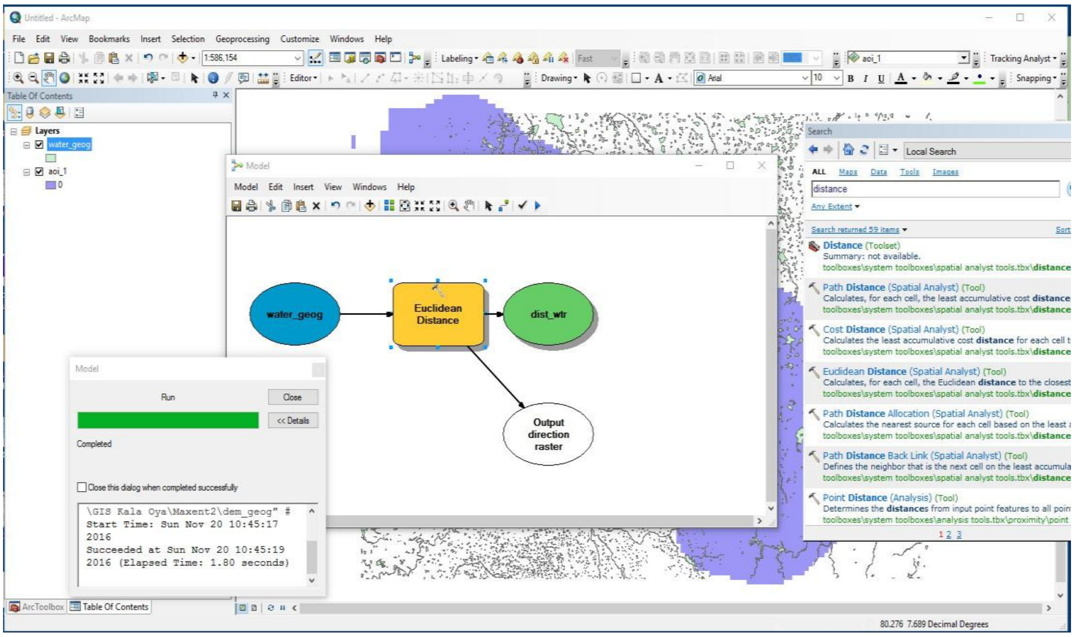


Figure 7

ANNEX 3 – INCORPORATE GPS DATA INTO GIS AND EXTRACTION SPATIAL INFORMATION ON BIODIVERSITY FOR LANDUSE PLANNING.

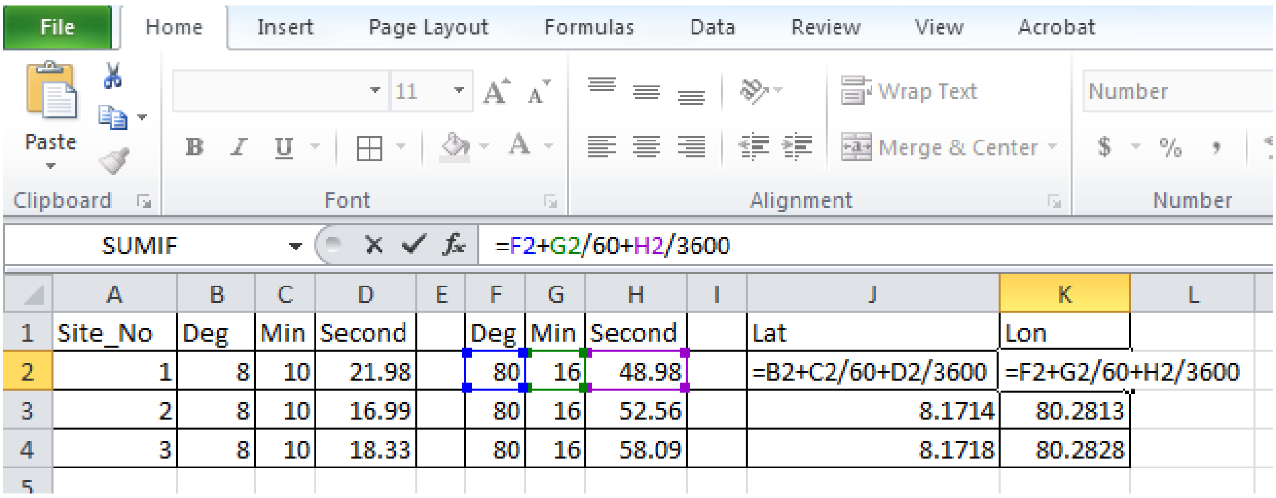
Descriptions on ecosystem and biodiversity related data collected during field surveys need to be incorporated in to GIS prior to perform geo-spatial analysis for biodiversity analysis.

1. Processing location coordinate data

Location coordinates may be recorded using Global Positioning System (GPS) or browsing web-based Global Viewer (such as google earth or yahoo map) for recording location coordinates. Recording of coordinates is preferred in the format of degree decimal (eg: 80.2845; 7.3756^{o}) using geographic coordinate system (WGS84) for easy import into ARCGIS. If location coordinates have already been collected using Degree Minute Second (80^{o} 14' 45"; 7^{o} 22' 35") format, convert them into degree decimal format using a simple calculation as illustrated in following excel spread sheet.

Figure 1: Converting "Degree Minute Second" format into "Degree Decimal" format coordinates

DD = Deg + Min/60 + Sec/3600



	A	B	C	D	E	F	G	H	I	J	K	L
1	Site_No	Deg	Min	Second		Deg	Min	Second		Lat	Lon	
2	1	8	10	21.98		80	16	48.98		=B2+C2/60+D2/3600	=F2+G2/60+H2/3600	
3	2	8	10	16.99		80	16	52.56		8.1714	80.2813	
4	3	8	10	18.33		80	16	58.09		8.1718	80.2828	
5												

Location coordinates of each investigated ecosystems need to be arrange in a table as illustrated bellow

Figure 2: Location coordinates and location name.

	A	B	C	D	E
7					
8	**ID**	**NAME**	**LAT**	**LON**	**BASIN**
9	1	Kala Oya river mouth at Gange Wadiya (LB)	8.29933	79.84233	Lower
10	2	Kala Oya Riverine Forest	8.30506	79.85767	Lower
11	3	Monaravillu Tank	8.29758	79.86458	Lower
12	4	Kala Oya Riverine Forest near Monaravillu	8.30506	79.85775	Lower
13	5	Mangrove Forest - Kala Oya (RB)	8.30022	79.85178	Lower
14	6	Ralmaduwa	8.27208	79.90372	Lower
15	7	Along the Pomparippu ara	8.32967	79.85217	Lower
16	8	Kumburawa Tank (Sinna Kulam in map)	8.32544	79.86992	Lower
17	9	Mangrove Forest near Pomparippu area - Kala Oya (LB)	8.33125	79.85503	Lower
18	10	Lunu Oya	8.28361	79.85506	Lower
19	11	Hena-gahachchi Ela -RB of Lunu Oya	8.29272	79.85422	Lower
20	12	Transect near Puttalam cement quarry	8.27219	79.84592	Lower
21	13	Transect in the old quarry near Gange Wadiya	8.28800	79.84936	Lower
22	14	Ailiya Salt Marsh - LB of Lunu Oya	8.27406	79.85314	Lower
23	15	Causeway in the Lunu Oya	8.27394	79.87447	Lower
24	16	Mangrove Forest near the Puttalam railway gate	8.25169	79.86808	Lower
25	17	Tabbowa Sanctuary (near road to Ralmadhu)	8.28139	80.09972	Lower

2. Processing of species record data

Following table contains species status, conservation status and occurrence in each location. Only the location ID or Number can be seen and marked as "1", if relevant species was found at each location.

Figure 3: Species occurrence at each location.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z
8		Location Descriptors	M Amarasinghe, S Goonatilleke, S Jayamanne, N Peiris, D Weerakoon																							
9		Abbreviations Used	EN: Endemic, EX: Exotic, MI: Migrant, VG: Vagrant, TR: Threatened					Location ID / Number																		
10	ID	Classification	Sciencetific Name	Common Name	Species Status	Conservation Status	Priority	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
338																										
339		Class: Mammalia		Mammals																						
340	309	Family: Bovidae	Bos indicus	Domestic cow	EX			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
341	310		Bubalus bubalis	Domestic water buffalo	EX			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
342	311		Capra hircus	Domestic goat	EX			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
343	312	Family: Canidae	Canis aureus	Jackal				0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
344	313	Family: Cercopithecidae	Macaca sinica	Toque monkey	EN		x	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
345	314		Semnopithecus priam	Grey Langur				1	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0
346	315		Semnopithecus vetulus	Purple faced leaf monkey	EN	EN	x	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
347	316	Family: Cervidae	Axis axis	Spotted deer				0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0
348	317		Rusa unicolor	Sambur		NT	x	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0
349	318		Muntiacus muntjak	Barking dear		NT	x	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
350	319	Family: Elephantidae	Elephas maximus	Elephant		EN	x	0	0	0	0	1	1	1	0	0	0	0	1	0	1	0	0	0	0	0
351	320	Family: Felidae	Felis chaus	Jungle cat		TR	x	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
352	321		Panthera pardus	Leopard		NT	x	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
353	322		Prionailurus rubiginosus	Rusty spotted cat		EN	x	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
354	323		Prionailurus viverrinus	Fishing cat		EN	x	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0

The above table (containing species information) need to be re-arranged in order to get recorded species against each location.

Figure 4: Transpose data (exchange column and rows)

Steps: Select data range→ copy → paste in new worksheet using paste special→ select transpose check box → Click OK button.

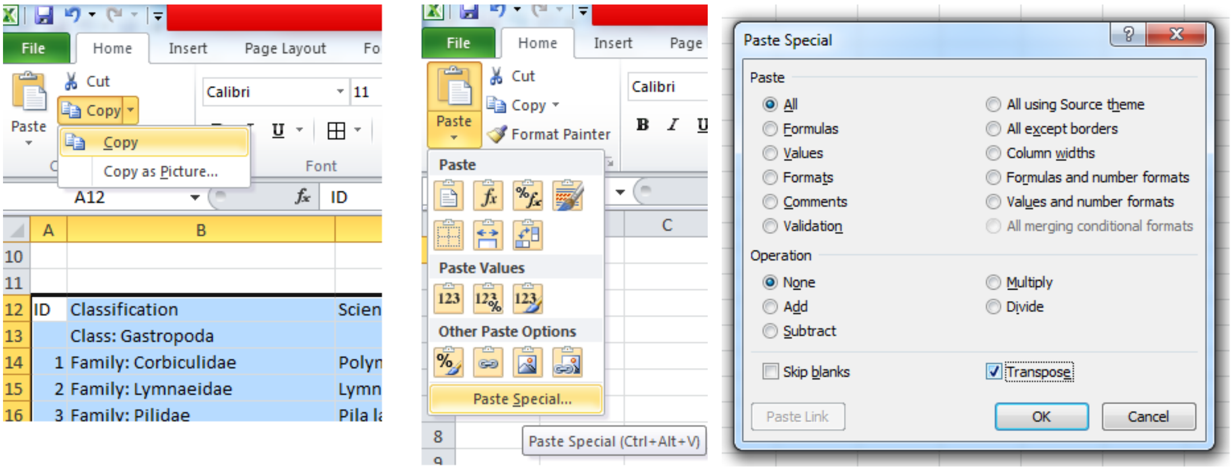


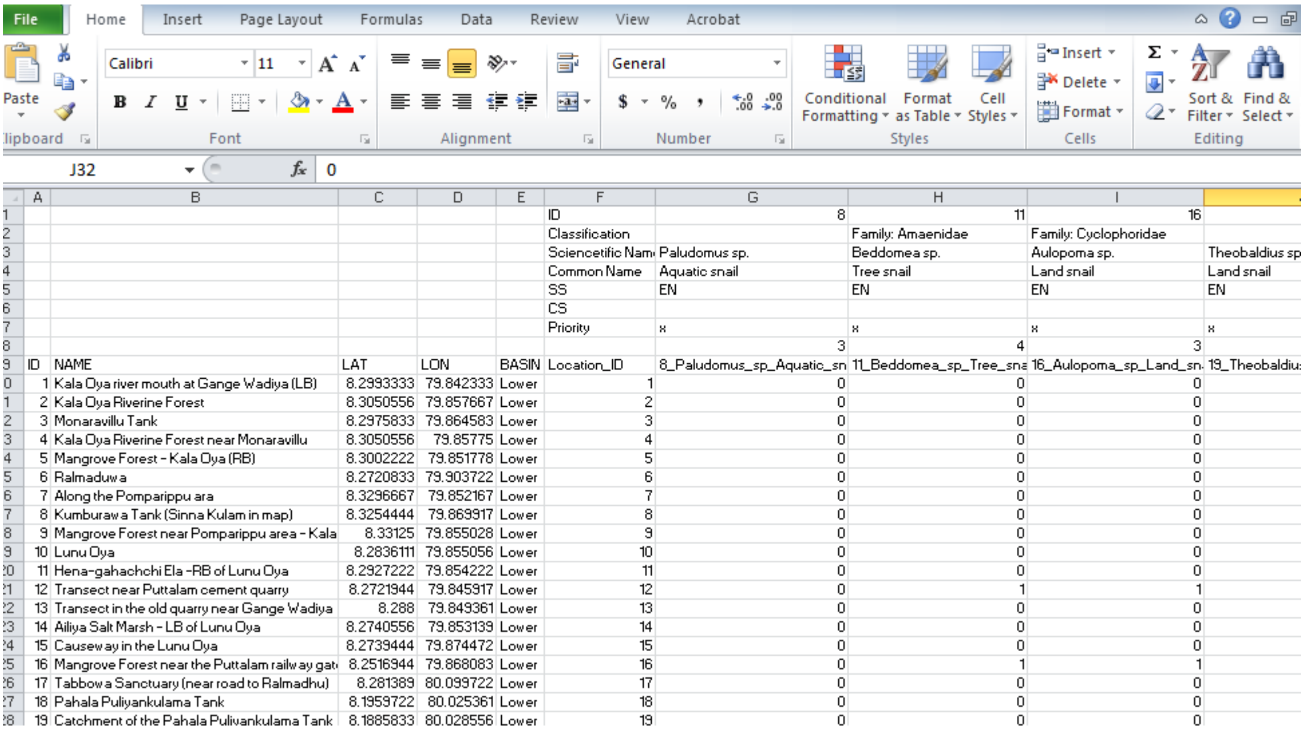
Figure 5: Resultant table after data transpose

	A	B	C	D	E	F	G	
1	ID	8	11	16	19	22	46	
2	Classification		Family: Amaenidae	Family: Cyclophoridae		Family: Gecarcinucidae		Fa
3	Sciencetific Name	Paludomus sp.	Beddomea sp.	Aulopoma sp.	Theobaldius sp.	Oziothelphusa mineriyaensis	Papilio crino	A
4	Common Name	Aquatic snail	Tree snail	Land snail	Land snail	Fresh water crab	Banded peacock	Le
5	SS	EN	EN	EN	EN	EN		EN
6	CS					LC	VU	LC
7	Priority	x	x	x	x	x	x	x
8	Location ID							
9	1	0	0	0	0	0	0	
10	2	0	0	0	0	0	0	
11	3	0	0	0	0	0	0	
12	4	0	0	0	0	0	0	
13	5	0	0	0	0	0	0	
14	6	0	0	0	0	0	0	

3. Merge species file and location coordinate file

Copy and insert location coordinate details into the file containing species detail following normal procedures to get file illustrated in following figure.

Figure 6: spread sheet containing location, its coordinates and recorded species in each location

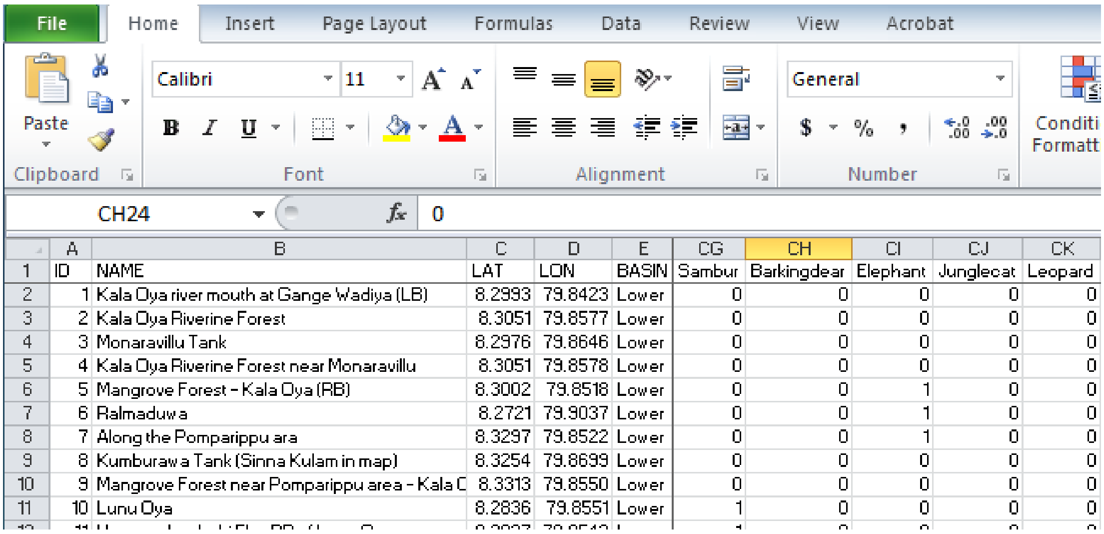


ID	NAME	LAT	LON	BASIN					
					ID	8	11	16	
					Classification		Family: Amaenidae	Family: Cyclophoridae	
					Sciencetific Nam	Paludomus sp.	Beddomea sp.	Aulopoma sp.	Theobaldius sp
					Common Name	Aquatic snail	Tree snail	Land snail	Land snail
					SS	EN	EN	EN	EN
					CS				
					Priority	x	x	x	x
						3	4	3	
ID	NAME	LAT	LON	BASIN	Location_ID	8_Paludomus_sp_Aquatic_sn	11_Beddomea_sp_Tree_sna	16_Aulopoma_sp_Land_sn	19_Theobaldius
1	Kala Oya river mouth at Gange Wadiya (LB)	8.2993333	79.842333	Lower	1	0	0	0	
2	Kala Oya Riverine Forest	8.3050556	79.857667	Lower	2	0	0	0	
3	Monaravillu Tank	8.2975833	79.864583	Lower	3	0	0	0	
4	Kala Oya Riverine Forest near Monaravillu	8.3050556	79.85775	Lower	4	0	0	0	
5	Mangrove Forest - Kala Oya (RB)	8.3002222	79.851778	Lower	5	0	0	0	
6	Ralmaduwa	8.2720833	79.903722	Lower	6	0	0	0	
7	Along the Pomparippu ara	8.3296667	79.852167	Lower	7	0	0	0	
8	Kumburawa Tank (Sinna Kulam in map)	8.3254444	79.869917	Lower	8	0	0	0	
9	Mangrove Forest near Pomparippu area - Kala	8.33125	79.855028	Lower	9	0	0	0	
10	Lunu Oya	8.2836111	79.855056	Lower	10	0	0	0	
11	Hena-gahachchi Ela -RB of Lunu Oya	8.2927222	79.854222	Lower	11	0	0	0	
12	Transect near Puttalam cement quarry	8.2721944	79.845917	Lower	12	0	1	1	
13	Transect in the old quarry near Gange Wadiya	8.288	79.849361	Lower	13	0	0	0	
14	Ailiya Salt Marsh - LB of Lunu Oya	8.2740556	79.853139	Lower	14	0	0	0	
15	Causeway in the Lunu Oya	8.2739444	79.874472	Lower	15	0	0	0	
16	Mangrove Forest near the Puttalam railway gat	8.2516944	79.868083	Lower	16	0	1	1	
17	Tabbowa Sanctuary (near road to Ralmadhu)	8.281389	80.099722	Lower	17	0	0	0	
18	Pahala Puliyankulama Tank	8.1959722	80.025361	Lower	18	0	0	0	
19	Catchment of the Pahala Puliyankulama Tank	8.1885833	80.028556	Lower	19	0	0	0	

4. Preparing excel worksheet for ARCGIS import compatible format by re-arranging column headings (header raw)

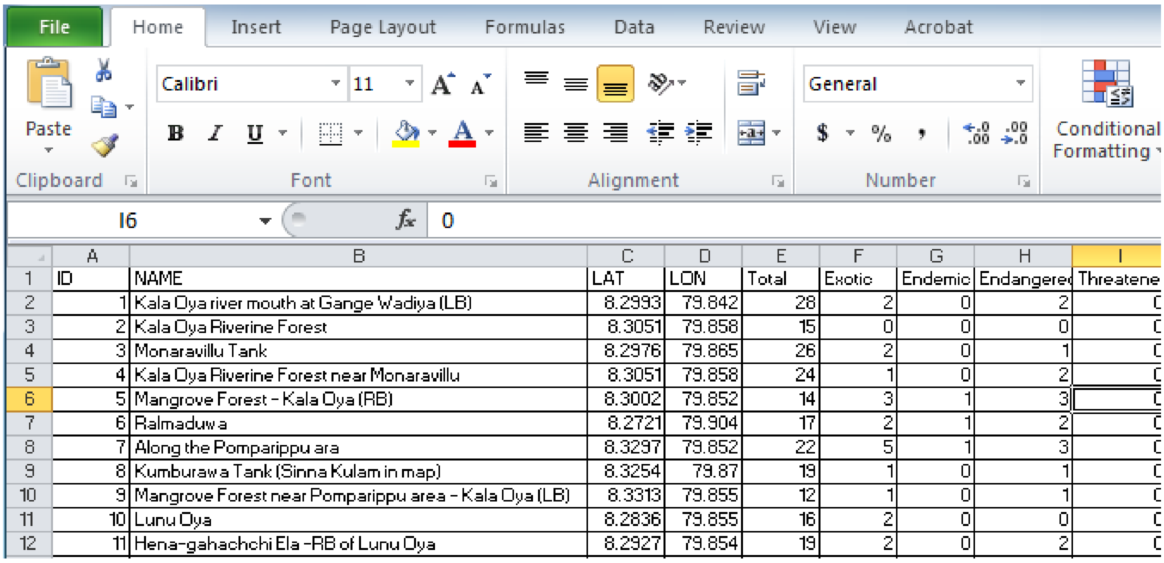
For ARCGIS import, each record should have latitude & longitude; data file should contain only one header raw; column heading should be less than 8 characters. Fig 7 & 8 illustrate excel sheets suitable for importing into ARCGIS.

Figure 7: Excel worksheet compatible for import into ARCGIS for species occurrence in each location



ID	NAME	LAT	LON	BASIN	Sambur	Barkingdear	Elephant	Junglecat	Leopard
1	Kala Oya river mouth at Gange Wadiya (LB)	8.2993	79.8423	Lower	0	0	0	0	0
2	Kala Oya Riverine Forest	8.3051	79.8577	Lower	0	0	0	0	0
3	Monaravillu Tank	8.2976	79.8646	Lower	0	0	0	0	0
4	Kala Oya Riverine Forest near Monaravillu	8.3051	79.8578	Lower	0	0	0	0	0
5	Mangrove Forest - Kala Oya (RB)	8.3002	79.8518	Lower	0	0	1	0	0
6	Ralmaduwa	8.2721	79.9037	Lower	0	0	1	0	0
7	Along the Pomparippu ara	8.3297	79.8522	Lower	0	0	1	0	0
8	Kumburawa Tank (Sinna Kulam in map)	8.3254	79.8699	Lower	0	0	0	0	0
9	Mangrove Forest near Pomparippu area - Kala C	8.3313	79.8550	Lower	0	0	0	0	0
10	Lunu Oya	8.2836	79.8551	Lower	1	0	0	0	0

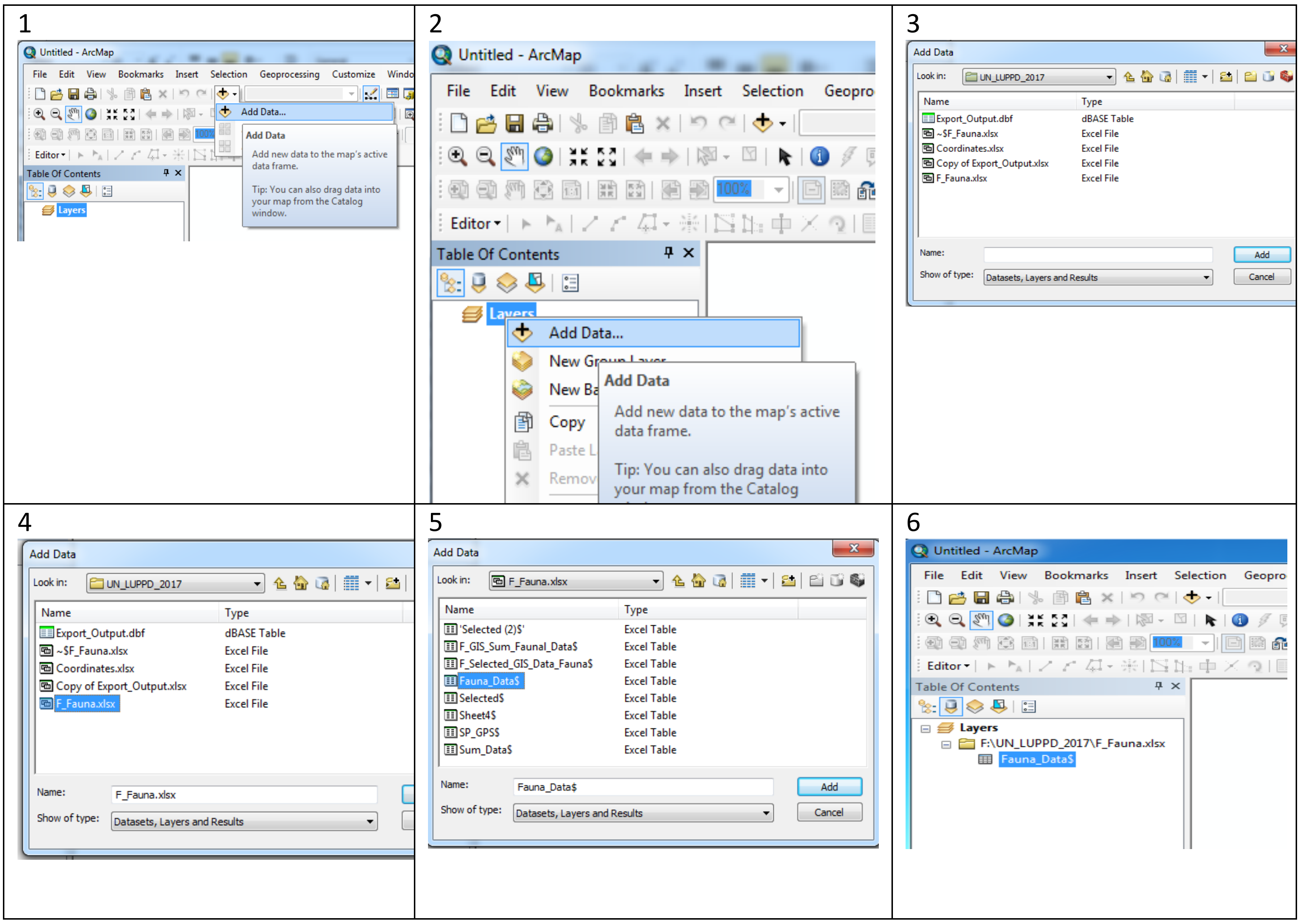
Figure 8: Excel worksheet compatible for import into ARCGIS for species occurrence in each location



ID	NAME	LAT	LON	Total	Exotic	Endemic	Endangered	Threatene
1	Kala Oya river mouth at Gange Wadiya (LB)	8.2993	79.842	28	2	0	2	0
2	Kala Oya Riverine Forest	8.3051	79.858	15	0	0	0	0
3	Monaravillu Tank	8.2976	79.865	26	2	0	1	0
4	Kala Oya Riverine Forest near Monaravillu	8.3051	79.858	24	1	0	2	0
5	Mangrove Forest - Kala Oya (RB)	8.3002	79.852	14	3	1	3	0
6	Ralmaduwa	8.2721	79.904	17	2	1	2	0
7	Along the Pomparippu ara	8.3297	79.852	22	5	1	3	0
8	Kumburawa Tank (Sinna Kulam in map)	8.3254	79.87	19	1	0	1	0
9	Mangrove Forest near Pomparippu area - Kala Oya (LB)	8.3313	79.855	12	1	0	1	0
10	Lunu Oya	8.2836	79.855	16	2	0	0	0
11	Hena-gahachchi Ela -RB of Lunu Oya	8.2927	79.854	19	2	0	2	0

5. Add excel worksheet to ARCGIS

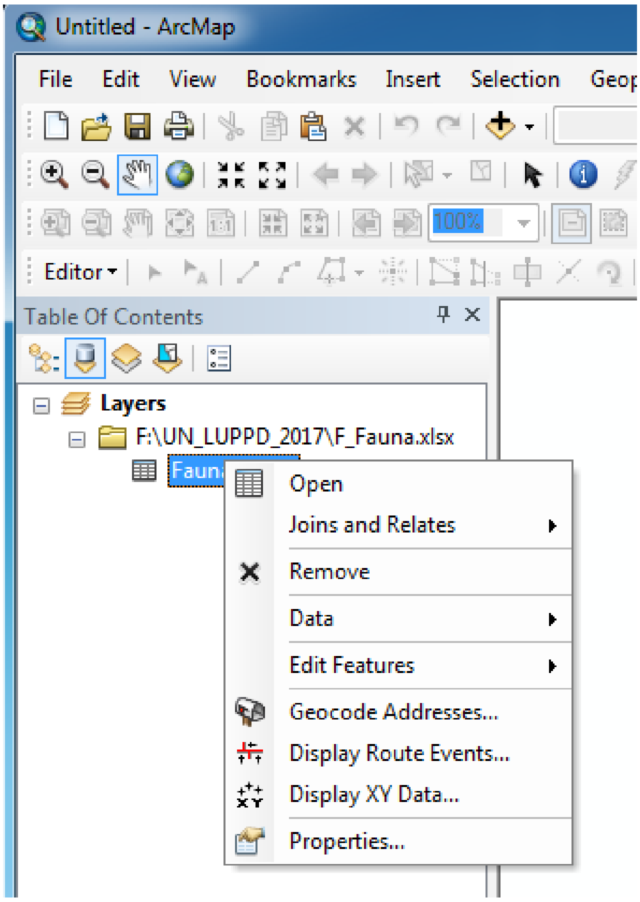
Open ARCGIS→ click on add data icon in standard toolbar (1)or right mouse click on layers in table of content or left mouse and select add data menu (2) →browse/open folder containing prepared excel file (3) → click add button or double click on excel file(4)→ then the worksheets of excel file will appears(5) →select relevant worksheet & click add button→The worksheet will open in ARCGIS as a table(6).



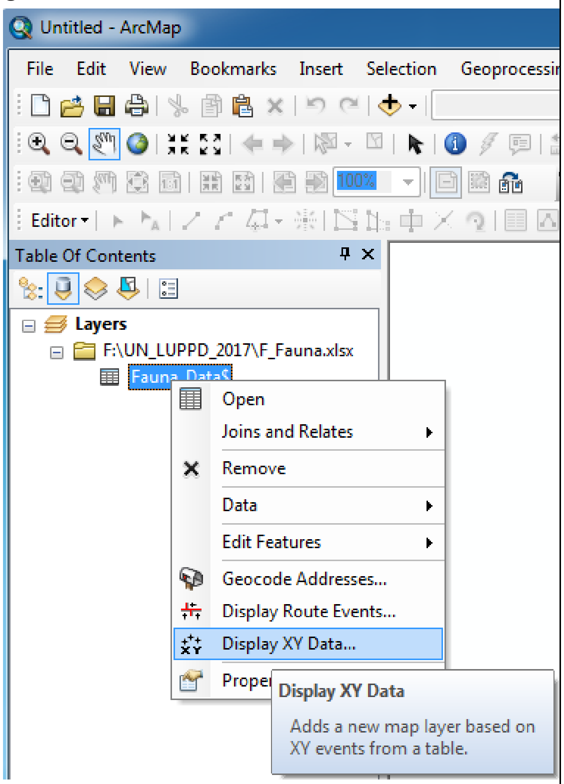
6. Convert and open tabular location data is point map

Right mouse click on the table in ARCGUS (7)→Select Display XY data (8)→Select X field as LON & Y Field as LAT (9)→on 'show detail' check box (10)→Click edit for assigning coordinate system→Then 'spatial Reference Properties' window will appear(11)→Select 'Geographic Coordinate Systems'→Select 'World'(12) →Select 'WGS 1984'(13)→ click 'OK' button in 'spatial Reference Properties ' window (13)→Click 'OK' button in 'Display XY data' window(14)→ignore 'object ID' error by clicking 'OK' button (15)→Temporary point map will open in ARCGIS (16)→right click on temporary even file(17)Select 'Data' menu & 'Export Data' submenu (18)→'Export Data' window will open(19)→provide suitable file name in 'output feature class' and click 'OK' button(20)→ then file will be saved & can be used for display with any other map layers (21) or further analysis.

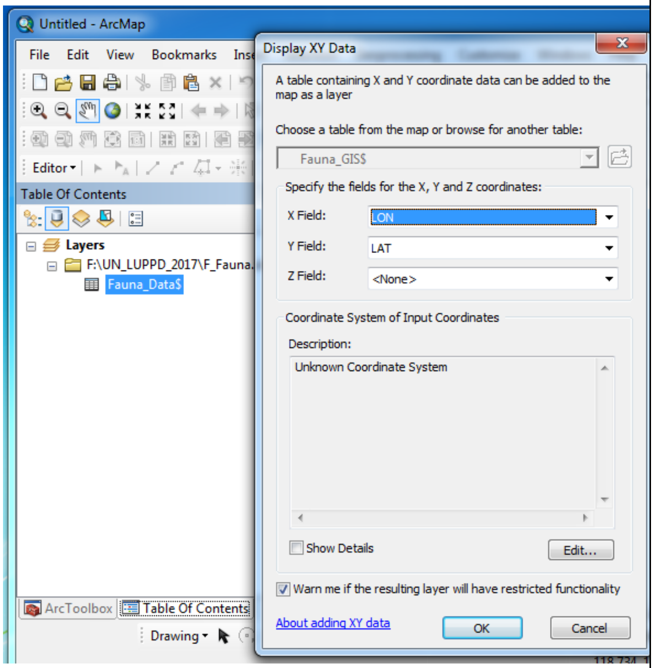
7



8



9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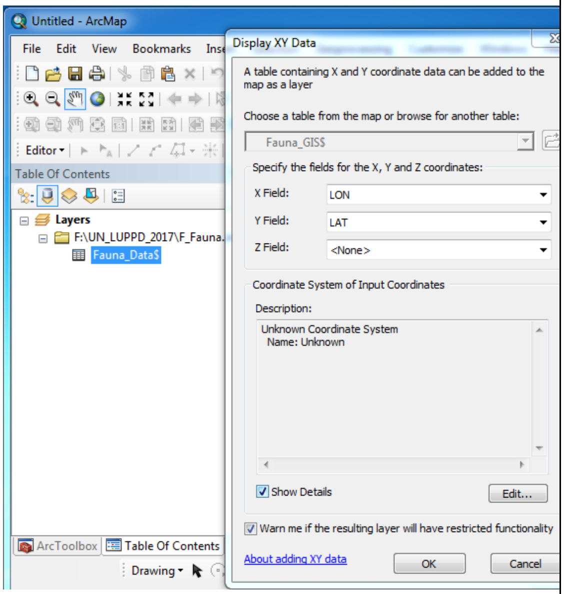
File Edit View Bookmarks Ins
Editor
Table Of Contents
Layers
F:\UN_LUPPD_2017\F_Fauna
Fauna_Data$
ArcToolbox
Table Of Contents
Drawing
Display XY Data
A table containing X and Y coordinate data can be added to the map as a layer
Choose a table from the map or browse for another table:
Fauna_GIS$
Specify the fields for the X, Y and Z coordinates:
X Field: LON
Y Field: LAT
Z Field: <None>
Coordinate System of Input Coordinates
Description:
Unknown Coordinate System
Show Details
Edit...
Warn me if the resulting layer will have restricted functionality
About adding XY data
OK
Cancel

10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Editor
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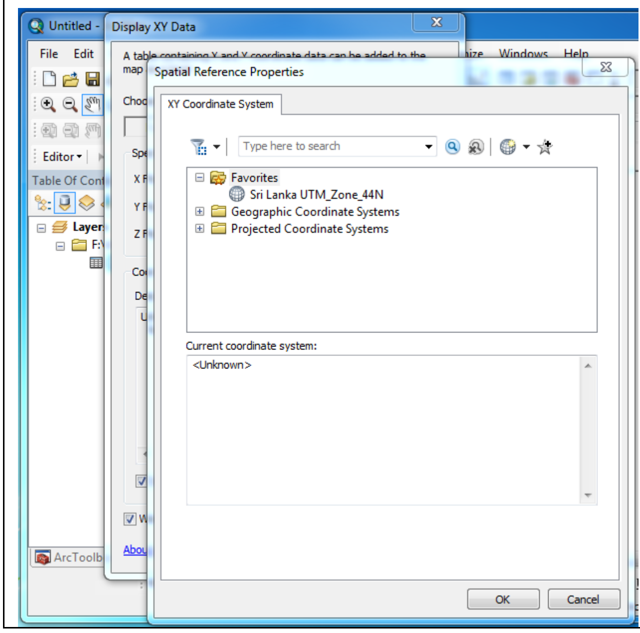
Layers
F:\UN_LUPPD_2017\F_Fauna
Fauna_Data$
ArcToolbox
Table Of Contents
Drawing
Display XY Data
A table containing X and Y coordinate data can be added to the map as a layer
Choose a table from the map or browse for another table:
Fauna_GIS$
Specify the fields for the X, Y and Z coordinates:
X Field: LON
Y Field: LAT
Z Field: <None>
Coordinate System of Input Coordinates
Description:
Unknown Coordinate System
Name: Unknown
Show Details
Edit...
Warn me if the resulting layer will have restricted functionality
About adding XY data
OK
Cancel

11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File Edit
Editor
Layers
ArcToolb
Spatial Reference Properties
XY Coordinate System
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Favorites
Sri Lanka UTM_Zone_44N
Geographic Coordinate Systems
Projected Coordinate Systems
Current coordinate system:
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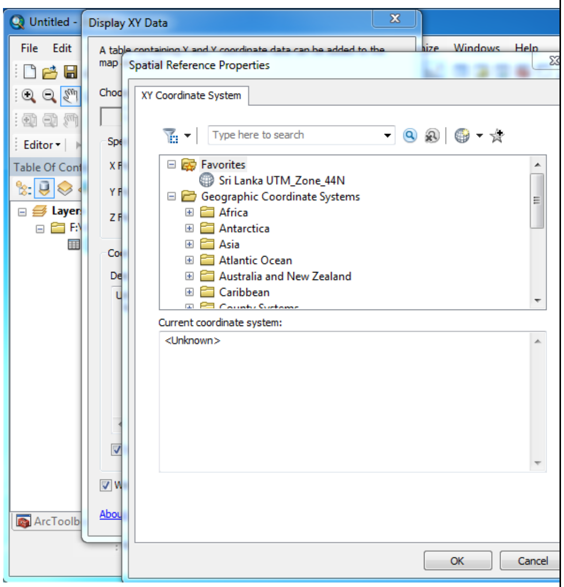
OK
Cancel

12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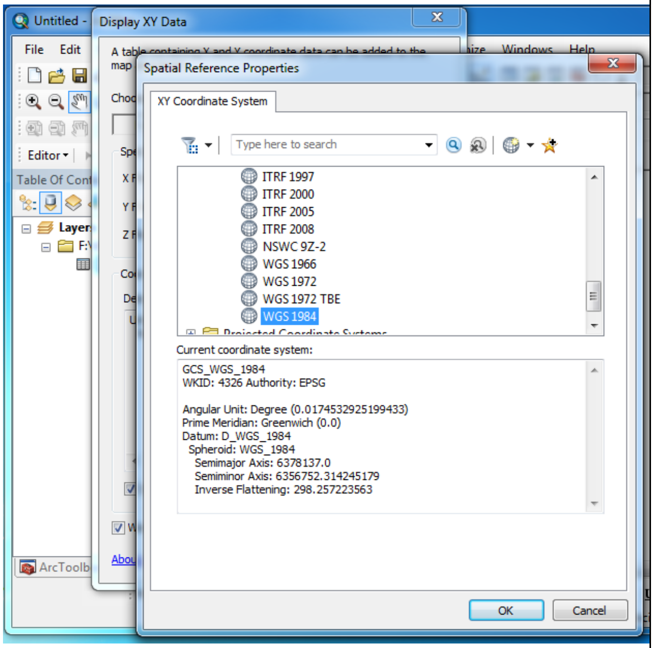
Display XY Data
File Edit
Editor
Table Of Cont
ArcToolb
Spatial Reference Properties
XY Coordinate System
Type here to search
Favorites
Sri Lanka UTM_Zone_44N
Geographic Coordinate Systems
Africa
Antarctica
Asia
Atlantic Ocean
Australia and New Zealand
Caribbean
Current coordinate system:
<Unknown>
OK
Cancel

13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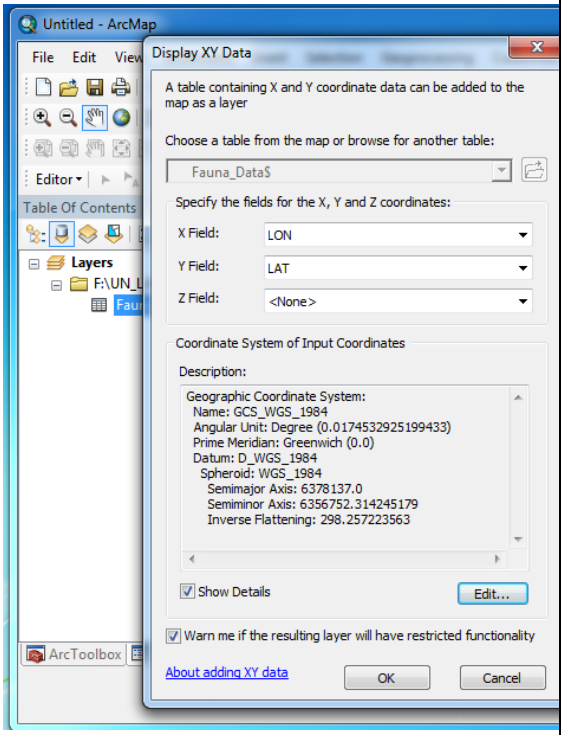
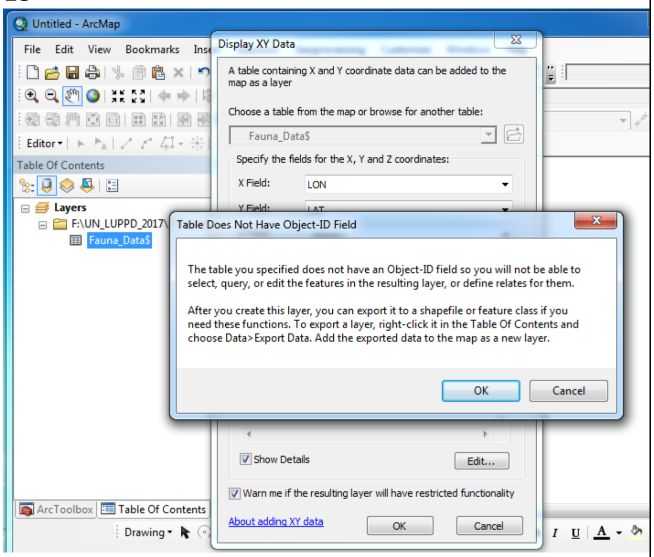
Spatial Reference Properties
XY Coordinate System
Type here to search
ITRF 1997
ITRF 2000
ITRF 2005
ITRF 2008
NSWC 9Z-2
WGS 1966
WGS 1972
WGS 1972 TBE
WGS 1984
Current coordinate system:
GCS_WGS_1984
WKID: 4326 Authority: EPSG
Angular Unit: Degree (0.0174532925199433)
Prime Meridian: Greenwich (0.0)
Datum: D_WGS_1984
Spheroid: WGS_1984
Semimajor Axis: 6378137.0
Semiminor Axis: 6356752.314245179
Inverse Flattening: 298.257223563
OK
Cancel

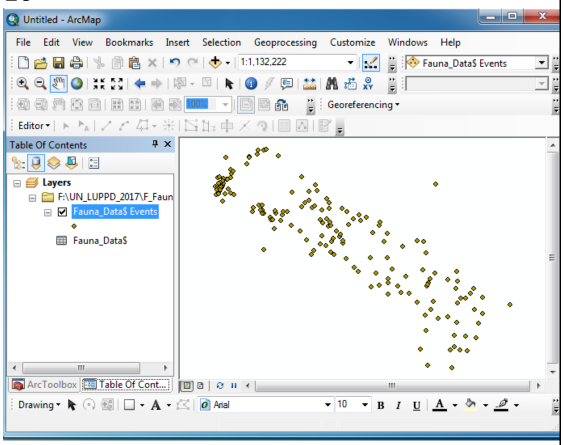
14


Untitled - ArcMap
Display XY Data
A table containing X and Y coordinate data can be added to the map as a layer
Choose a table from the map or browse for another table:
Fauna_Data$
Specify the fields for the X, Y and Z coordinates:
X Field: LON
Y Field: LAT
Z Field: <None>
Coordinate System of Input Coordinates
Description:
Geographic Coordinate System:
Name: GCS_WGS_1984
Angular Unit: Degree (0.0174532925199433)
Prime Meridian: Greenwich (0.0)
Datum: D_WGS_1984
Spheroid: WGS_1984
Semimajor Axis: 6378137.0
Semiminor Axis: 6356752.314245179
Inverse Flattening: 298.257223563
Show Details
Edit...
Warn me if the resulting layer will have restricted functionality
About adding XY data
OK
Cancel

15


Untitled - ArcMap
Display XY Data
Table Does Not Have Object-ID Field
The table you specified does not have an Object-ID field so you will not be able to select, query, or edit the features in the resulting layer, or define relates for them.
After you create this layer, you can export it to a shapefile or feature class if you need these functions. To export a layer, right-click it in the Table Of Contents and choose Data>Export Data. Add the exported data to the map as a new layer.
OK
Cancel

16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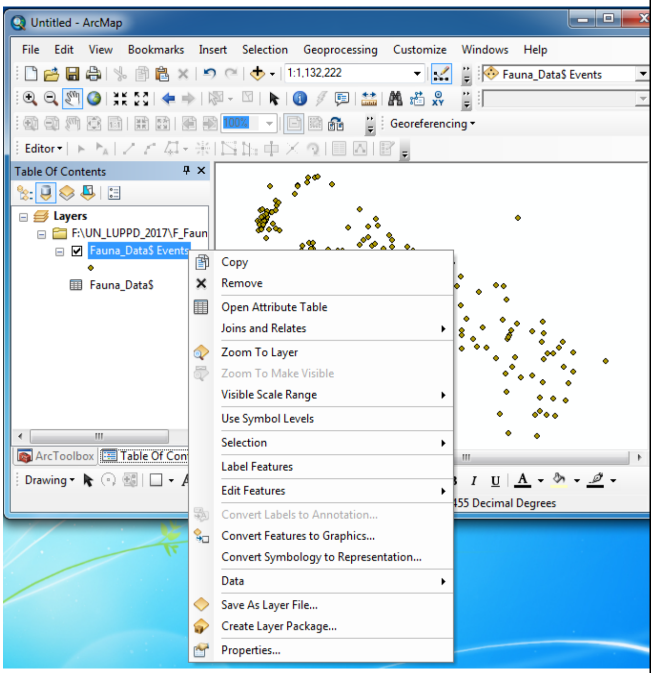
Layers
Fauna_Data$ Events
Fauna_Data$

17



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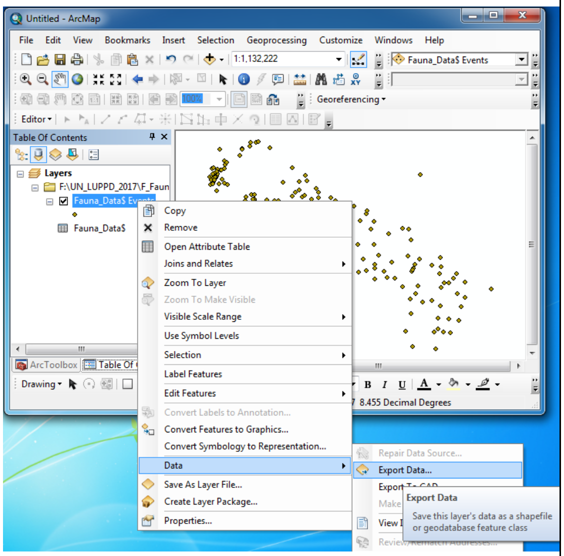
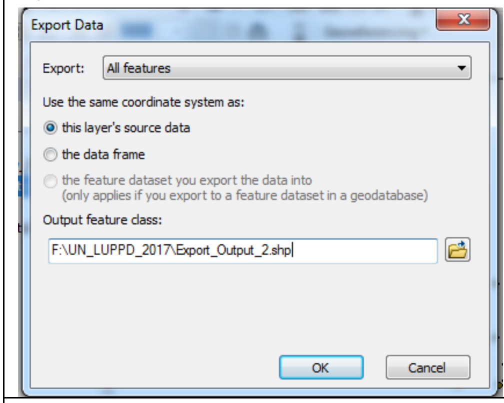
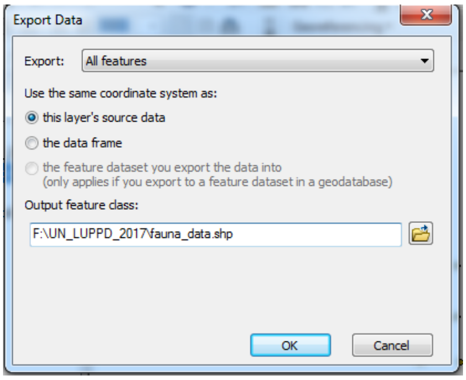


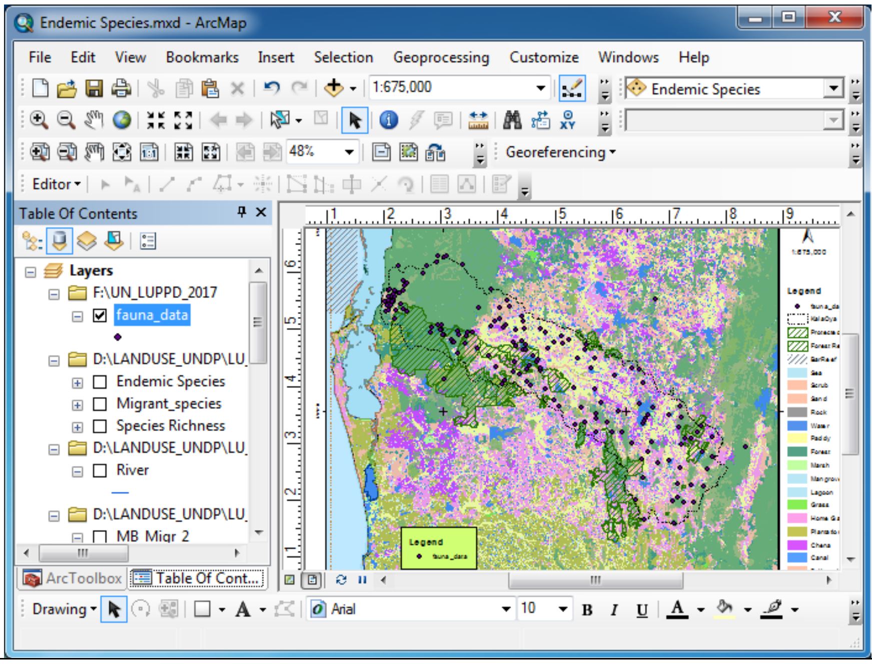
19


Export Data
Export: All features
Use the same coordinate system as:
this layer's source data
the data frame
the feature dataset you export the data into
(only applies if you export to a feature dataset in a geodatabase)
Output feature class:
F:\UN_LUPPD_2017\Export_Output_2.shp
OK
Cancel

20


Export Data
Export: All features
Use the same coordinate system as:
this layer's source data
the data frame
the feature dataset you export the data into
(only applies if you export to a feature dataset in a geodatabase)
Output feature class:
F:\UN_LUPPD_2017\fauna_data.shp
OK
Cancel

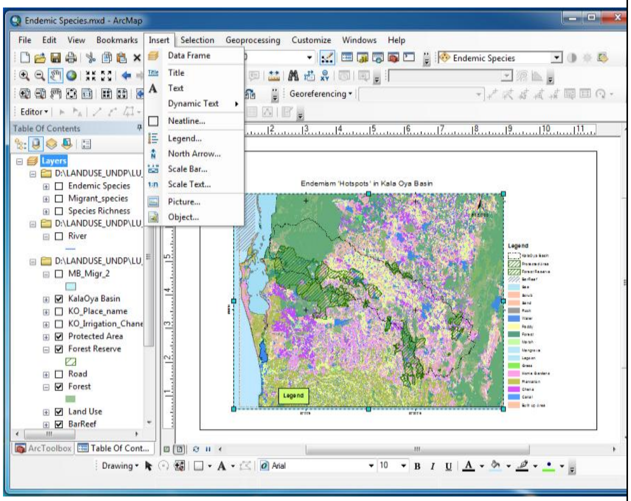
21



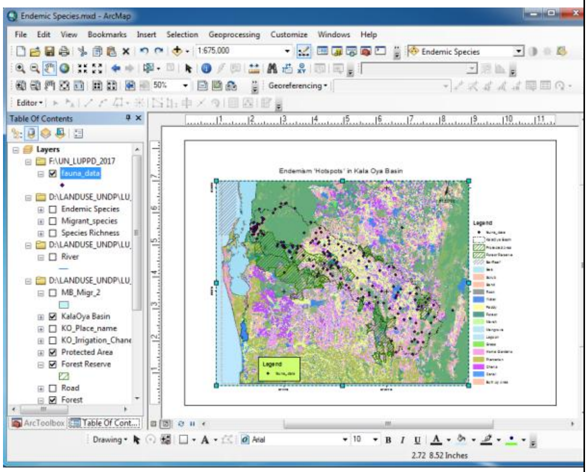
7. Prepare map layouts to illustrate biodiversity related spatial information using point layer

Pre-requirement: prepare map layout using available map layers such as landuse, conservation area, basin boundary, etc and add required annotations using 'insert' menu of ARCGIS (1) → add point map created above as a layer (2)→ right mouse click on point map and select properties (3)→then 'layer Properties' window will appear (4)→select 'Quantities' menu (5)→Select required column as 'Field- Value' (6)→Click 'OK' button after adjusting required features ((7).

1



2



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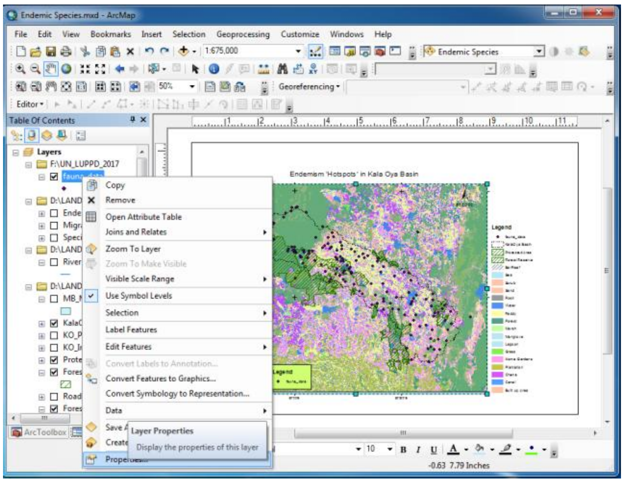

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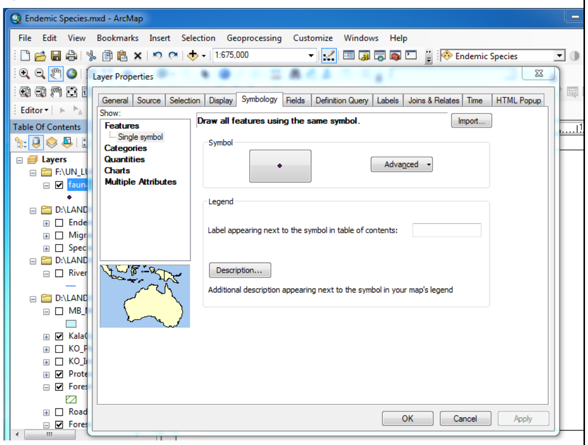

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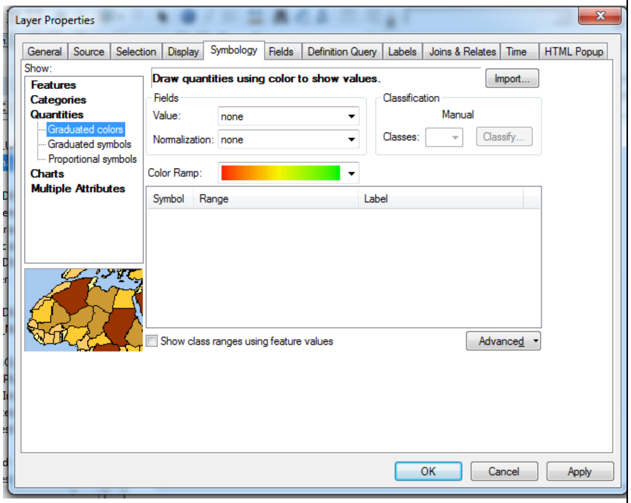
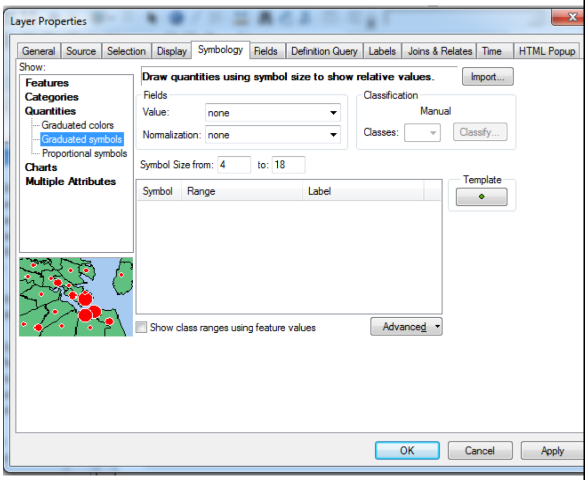

Layer Properties
General
Source
Selection
Display
Symbology
Fields
Definition Query
Labels
Joins & Relates
Time
HTML Popup
Show:
Features
Categories
Quantities
Graduated colors
Graduated symbols
Proportional symbols
Charts
Multiple Attributes
Draw quantities using color to show values.
Import...
Fields
Value:
none
Normalization:
none
Classification
Manual
Classes:
Classify...
Color Ramp:
Symbol
Range
Label
Show class ranges using feature values
Advanced
OK
Cancel
Apply

6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General
Source
Selection
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Symbology
Fields
Definition Query
Labels
Joins & Relates
Time
HTML Popup
Show:
Features
Categories
Quantities
Graduated colors
Graduated symbols
Proportional symbols
Charts
Multiple Attributes
Draw quantities using symbol size to show relative values.
Import...
Fields
Value:
none
Normalization:
none
Classification
Manual
Classes:
Classify...
Symbol Size from: 4 to: 18
Template
Symbol
Range
Label
Show class ranges using feature values
Advanced
OK
Cancel
Apply

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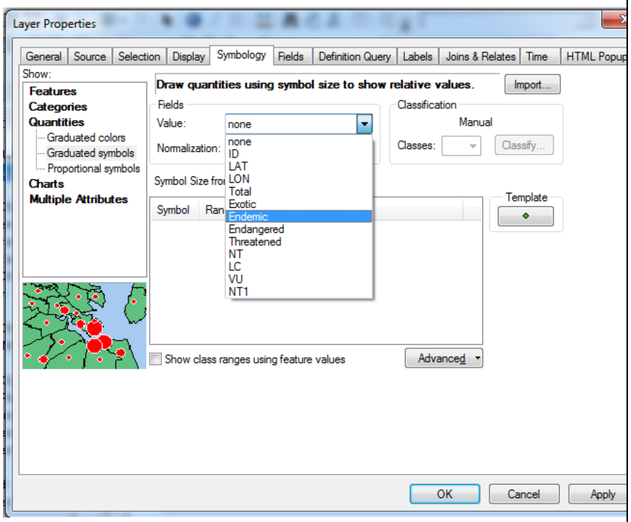
Layer Properties
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LAT
LON
Total
Exotic
Endemic
Endangered
Threatened
NT
LC
VU
NT1
Template
Symbol
Show class ranges using feature values
Advanced
OK
Cancel
Apply

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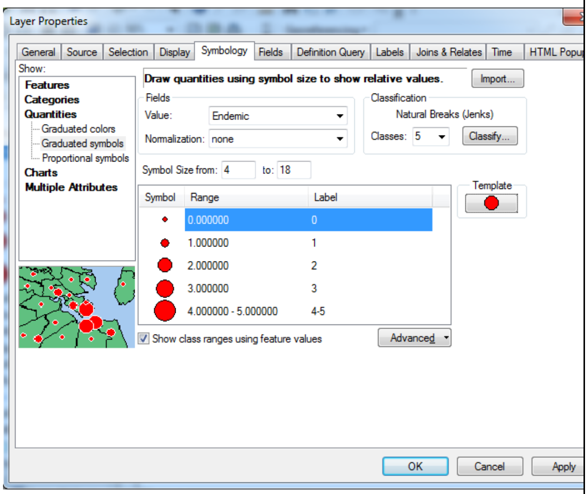
Layer Properties
General
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Show:
Features
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Quantities
Graduated colors
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Draw quantities using symbol size to show relative values.
Import...
Fields
Value:
Endemic
Normalization:
none
Classification
Natural Breaks (Jenks)
Classes: 5
Classify...
Symbol Size from: 4 to: 18
Template
Symbol
Range
Label
0.000000
0
1.000000
1
2.000000
2
3.000000
3
4.000000 - 5.000000
4-5
Show class ranges using feature values
Advanced
OK
Cancel
Apply

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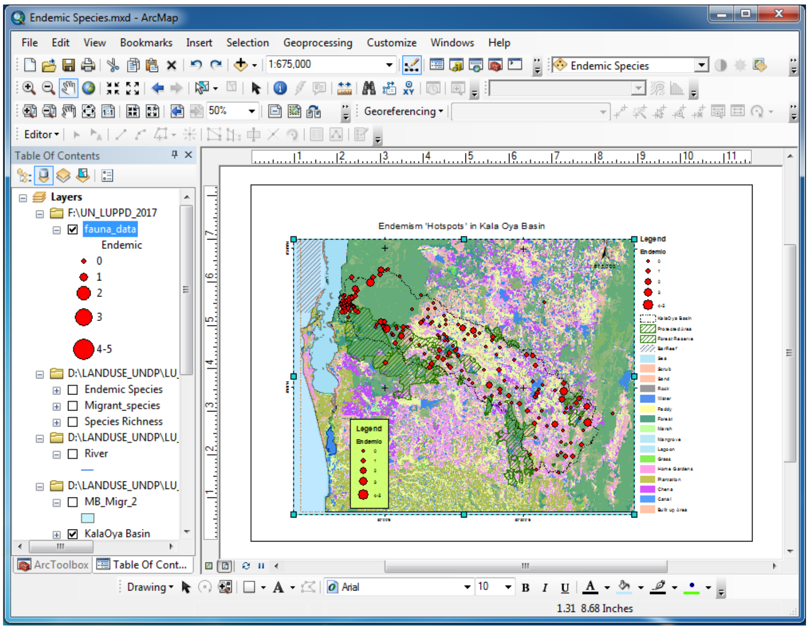
Endemic Species.mxd - ArcMap
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Endemic Species
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Editor
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River
MB_Migr_2
KalaOya Basin
ArcToolbox
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Drawing
Arial
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1.31 8.68 Inches