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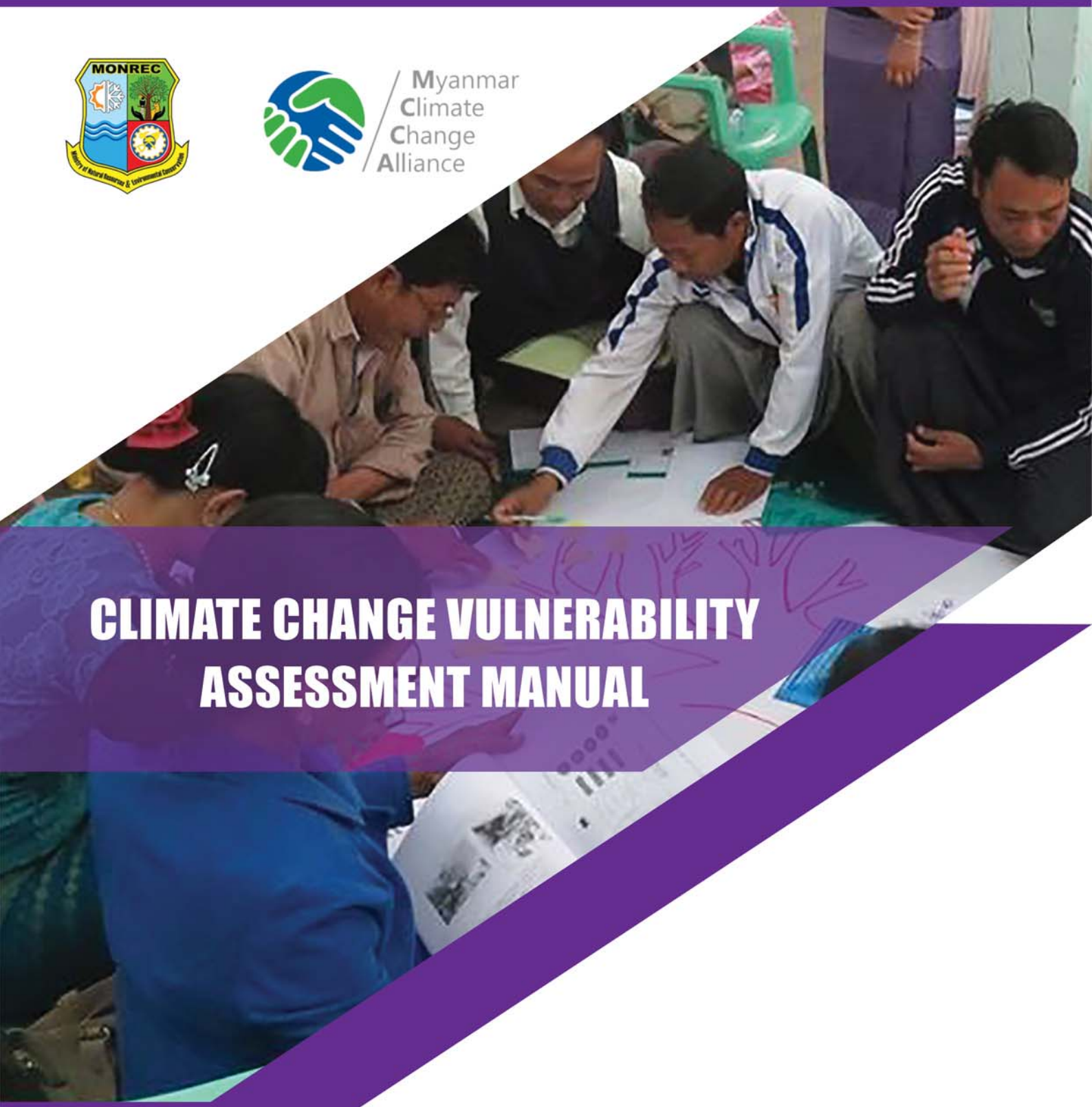

CLIMATE CHANGE VULNERABILITY ASSESSMENT MANUAL

UN HABITAT FOR A BETTER URBAN FUTURE

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List of Acronyms

CCA	climate change adaptation
GIS	geographic information system
GAD	General Administration Department
MIMU	Myanmar Information Management Unit
MoF	Matrix of Functions
RCPs	Representative Concentration Pathways

I. About this manual

What is the purpose of this manual?

This manual is intended to serve as a guide for national and local government officials on how to assess vulnerability of townships of Myanmar to climate change and hazards. The assessment framework presented herein captures a wide array of issues related to climate change and its impacts on townships and communities. Those are grouped into environmental, socio-economic and infrastructure components. Furthermore, the analytical approach allows for exploring current and future vulnerability, and carrying out a complex spatial analysis. Importantly, the proposed methodological framework is designed for the Myanmar national context since the suggested process and methods have been used in the case studies of Labutta (Delta Zone) and Pakokku (Central Dry Zone) Townships.

How was this manual developed?

This manual was developed based upon the following documents:

- Climate Change Vulnerability Assessment of Pakokku Township, the Central Dry Zone, Myanmar, 2016-2050 (Authors: Fee, L.; Gibert, M.; Bartlett R.; Capizzi, P. (forthcoming, 2017))
- Climate Change Vulnerability Assessment of Labutta Township, Ayeyawady Region, Myanmar, 2016-2050 (Authors: Fee, L.; Gibert, M.; Bartlett R.; Capizzi, P., Horton, R., Lesk, C. (forthcoming, 2017))
- Review of additional literature (see References).

How to use this book?

Section 2 of the book introduces key terms, highlights the purpose, objectives and overarching principles of the analysis, and offers recommendations for planning an assessment. Section 3 provides a step-by-step guidance on how to assess vulnerability such as guiding questions, suggested methods/tools, data sources and explanatory notes. Section 4 discusses the implications of assessment results for climate change adaptation (CCA) at a local level. A series of annexes provide additional information and technical details on the proposed methodology.

II. Framework for climate change vulnerability assessment

1. Key terms and concepts

1.1. Basic terms

Adaptation	Undertaking actions to adjust to already observed or expected climate and its effects with the objectives to: ▪ protect natural and human systems against the actual and anticipated harmful effects of climate change; ▪ exploit any opportunities they may generate; ▪ ensure the sustainability of investment and development interventions despite of current climate risks and potentially increasingly difficult climatic conditions.[1]
Climate	The average characteristics of meteorological conditions, calculated over a long period (typically 30 years or more).
Climate change	A shift in average climate parameters and/or in the magnitude of climate variability observed and persisting over long periods (typically decades or longer)[2]. To simplify, climate change suggests long-term continuous change of: (i) the average (typical) climate, e.g. average (typical) seasonal temperatures in the coastal zone of Myanmar are getting higher; (ii) variability of temperatures, precipitation, and other climate parameters, e.g. more frequent and severe rainfall and stronger winds are observed in some regions of Myanmar.
Climate change impacts	The effects of climate change (e.g. increasing temperatures and change in seasonal patterns) and extremes (e.g. heat waves, heavy rainfall, severe storms) on human systems and environment. The impacts of climate change include: ▪ Physical impacts – floods, droughts and sea level rise; ▪ Environmental – impacts on ecosystems such as loss of biodiversity, water scarcity, and land degradation; ▪ Impacts on human systems – socio-economic effects (e.g. loss of life and livelihood, food insecurity), and infrastructural consequences.

[1] MCCA Dictionary (http://myanmarccalliance.org/en/dictionary/)

[2] UN-Habitat, Standardization of DRR Terminology, 2013, Norwegian Ministry of Foreign Affairs, Department of Rural Development

Climate hazard	Any climate-related physical event (e.g. cyclone), trend (e.g. increasing temperatures in dry season) or impact (e.g. flood, sea level rise), which has the potential to cause loss of, and damage to, people, physical assets, provision of services, and ecosystems. Hazards (as well as climate change impacts) can be divided into slow onset (like drought and insect infestations), and rapid onset (like floods) events.
Climate projections	Simulations of possible future state of Earth's climate (e.g. in 2050 and 2100) using climate models. The latest global and regional climate change projections are based upon scenarios for Representative Concentration Pathways (RCPs) under assumptions concerning socio-economic and technological developments that may or may not be realised. The Intergovernmental Panel on Climate Change has defined four RCPs scenarios, which capture selected possible states of the composition of the atmosphere (i.e. concentration of greenhouse gases and aerosols) and land cover up to 2100. These four RCPs are: two in which there is little to no coordinated action on reducing global emissions (worst case – RCP8.5 and best case – RCP6), and two in which there is a serious global action on climate change (worst case – RCP4.5 and best case – RCP 2.6).
Climate variability	The variations in the mean state and other statistics (such as standard deviations, the occurrence of extremes, etc.) of the climate, attributed either to natural internal processes within the climate system, or to variations in natural or anthropogenic variables. In other words, climate variability refers to the annual fluctuation of the climate, above or below the long-term average.
Ecosystem	A system of living organisms, their environment (e.g. land, water) and the interactions within and between them.
Ecosystem services	Ecosystems provide people with numerous benefits called ecosystem services, which could be categorized as follows: ▪ Provisioning services are all products obtained from ecosystems such as food, fresh water and raw materials. For instance, people depend on lakes and rivers for water and fish, while forests are vital source of wood and food for many communities. Nature also provides people with traditional and commercial medicinal plants/raw materials (e.g. *'Thanaka'* in Myanmar). ▪ Regulating services are related to the ability of ecosystems to regulate natural processes such as water, air and soil quality control, erosion prevention and moderation of extreme events. For example, trees in urban areas provide shade in hot days and improve the air quality, while mangroves can protect communities from hazards by reducing wind speed, flooding and coastal erosion. Forests remove carbon dioxide, prevent soil erosion and landslides, and reduce the flow of water during floods. Wetlands can filter waste water (e.g. human and animal waste) and absorb floodwaters. ▪ Cultural services refer to non-material benefits such as using the nature

	for tourism, ecotourism and sports, and cultural and spiritual activities. ▪ Supporting services are those benefits related to natural processes that support and maintain all other services (e.g. soil formation, providing nutrition and habitat for species).
Gender	Socially ascribed roles, responsibilities, rights and opportunities associated with being a man or a woman, and the social relations between women and men. These are dynamic, change over time and are context-specific. Gender roles in society shape the gender division of labour, which is the allocation of the tasks and responsibilities of women and men at home, at work and in society. For example, often a division is made between: (a) productive tasks (e.g. agriculture, fisheries/aquaculture, self-employment, workers in enterprises); (b) reproductive tasks such as child care and household tasks; and (c) community tasks (UN-Women, 2014).
Weather	A condition of the atmosphere at a certain time and location described by meteorological variables such as temperature, precipitation, wind, humidity, atmospheric pressure, cloudiness.

1.2. Framing risk of, and vulnerability to, climate change and hazards

Why does the change in the climate affect Myanmar? The reason lies in the fact that the country is exposed and vulnerable to the impacts of climate change and climate-related hazards. The probability of experiencing negative impacts of climate change is called climate risk. Risk results from the interaction of climate change and hazards, exposure and vulnerability. Adaptation and mitigation actions can reduce the risk (Figure 1).

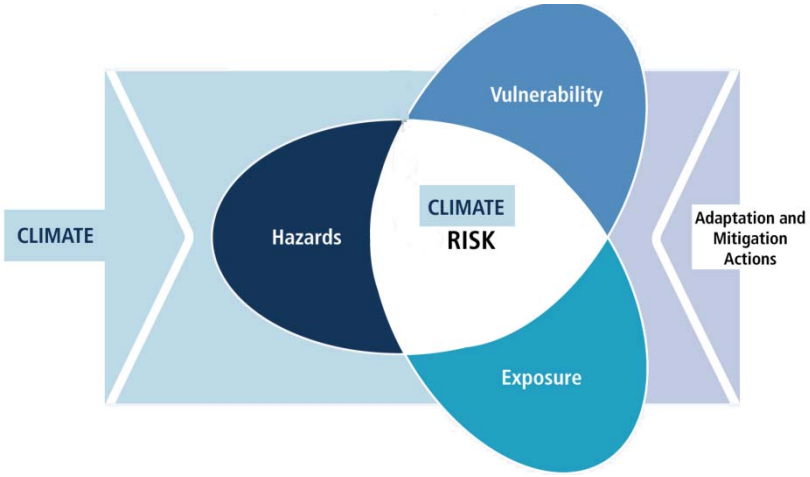


Figure 1 The concept of climate change risk (Source: adapted from IPCC, 2014)

Exposure relates to the presence of human and environmental systems (including people, livelihoods, assets and infrastructure, ecosystems, etc.) in places that could be adversely affected by climate change and hazards. For example, exposed to climate change and hazards could be: the lives and health of people; natural resources that people use such as water, land, trees; houses and

community assets; livestock and crops; public infrastructure and services such as electricity and water supply, schools and hospitals.

Vulnerability is the degree to which a system is susceptible to, or unable to cope with, the adverse effects of climate change, including climate variability and extremes. This notion is used to describe socio-economic, physical and environmental factors, which determine the sensitivity/susceptibility of a country, town, community or individual to the impact of climate change (e.g. change in seasonal patterns) and/or hazard (e.g. flood).

For example, socio-economic factors of vulnerability are poverty, low level of awareness on climate change, and dependence on climate-sensitive agricultural production. Land degradation and unsustainable natural resources management are environmental factors of vulnerability. For instance, cutting mangroves in populated coastal areas increases the vulnerability of communities because mangroves help in reducing wind speed, flooding and coastal erosion. Physical vulnerability relates to the state of infrastructure and human settlements.

Countries and communities are more vulnerable when they have low adaptive capacity. The latter specifies their ability to adjust to climate change (including to climate variability and extremes) and moderate or cope with its potential negative impacts. Adaptive capacity also relates to the ability of people to take advantage of opportunities and benefits from climate change. For example, a longer growing season due to changing climate offers opportunity to farmers to increase their income. However, their adaptive capacity is often constrained by the limited access to knowledge and technology on how to increase their production under longer growing season conditions.

Adaptation to climate change aims at reducing vulnerability and building climate resilience. Climate resilience is the ability of a system to (i) absorb stress and cope with climate change and hazards, including maintaining its basic structure, functions and adaptive capacity, and (ii) recover, adapt and transform in ways that improve its sustainability, leaving it better prepared for future climate change impacts. In this context, climate-resilient development of townships of Myanmar suggests development that ensures townships' ability to cope with current climate and its impact and to adapt to future climate change, by preserving development gains and minimising damages.

Example: Climate risk and vulnerability profile of Myanmar

Climate hazards

According to the Global Climate Risk Index ranking (Kreft S. et al., 2015), Myanmar is the second-most vulnerable country to weather-related extreme events that occurred between 1995 and 2014 worldwide. Historically, Myanmar has been affected by various climate-related disasters including cyclones and storm surges, river and flash floods, landslides, droughts, heat waves and wildfires. Future climatic change can cause: (i) increase of rapid-onset disasters such as tropical storms and cyclones, floods and storm surges; and (ii) more frequent and devastating slow-onset disasters like dry spells/droughts, diseases, loss of ecosystems, sea level rise and salinization in coastal areas, erosion.

Exposure

Large portion of the population lives in high-risk zones such as the Ayeyarwady Delta, and the Central Dry Zone. These regions have the highest exposure to hazards exacerbated by climate change. For instance, the Delta Region is exposed to strong winds and cyclones, floods and sea level rise, while the Central Dry Zone is exposed to water scarcity and frequent drought events, as well as increasing temperatures and heat extremes. Both areas have experienced changes in temperatures and erratic rainfall patterns – trends that will continue in future. The population, infrastructure, economic assets and productive activities in these regions are therefore highly exposed to recurrent severe natural hazards.

Vulnerability

Key underlying factors of vulnerability to climate change relate to:

- High socio-economic dependence (employment, income, food security) on climate-sensitive sectors like rainfed agriculture.
- Unsustainable natural resources utilization (e.g. deforestation, illegal fishing, unsustainable agricultural practices).
- High poverty, unemployment and migration rates (often conditioned by climate change and hazards).
- Human settlements/towns/cities are not prepared for the changing climate (e.g. inadequate urban planning and construction techniques, poor infrastructure). For instance, in some areas, 95 per cent of the housing is built with non-durable materials, hence not adapted to changing environmental conditions and increasing risk of hydro-meteorological hazards.
- Low adaptive capacity characterized by limited access to knowledge, technology and financing.

All these risk factors (climate hazards, exposure and vulnerability) condition the high potential impact of climate change and hazards in Myanmar, such as ecosystem degradation, rural poverty and migration. Adapting to climate change – and build resilience of townships in the process – is therefore essential not only to secure development, but also to maintain the very social, economic, and infrastructural viability of townships in the next years.

2. Aim and principles of the vulnerability assessment

2.1. Purpose and objective of the vulnerability assessment

Before identifying appropriate CCA actions, township administrators should understand the local vulnerabilities including the most vulnerable economic sectors, social groups and communities (Figure 2). This can be achieved through a vulnerability assessment, which is a process of identifying, measuring (quantifying) and analysing vulnerability to climate change and hazards.

Figure 2 Phases of local climate resilience action planning

The purpose of conducting local vulnerability assessments is to inform local, regional and national authorities (and international development organizations/donors) on:

- Underlying causes/factors of vulnerability including ecological, socio-economic and infrastructure.
- The most vulnerable locations, sectors and social groups at current time.
- Potential consequences of climate change in a short-, medium-, and long-term.
- Those sectors that require, immediate, mid-term and long-term action for building local level resilience.

The prime objective of the proposed vulnerability assessment framework is to support a long-term strategic adaptation planning including identification of objectives for a climate resilient development, and designing actions that best use the resources available to achieve them[3].

2.2. Guiding principles

Five overarching principles guide the proposed assessment methodology:

- Simplicity, to ensure ease of replication in other townships
- Measurability and availability of data, to ensure ease of update and replication
- Inclusiveness, to ensure participation of communities
- Comprehensiveness, to ensure relevance of the findings
- Spatial relevance to guide actual adaptation interventions

Guided by these principles, the proposed methodology considers the following:

- *Easy and free access to data and tools:*
  - Use of open-source or widely available software, such as QGIS[4], which reduces costs and enables national replication.
  - Use of data available at either national or local level, is easily obtained upon written request. The assessment does not use purchased high-resolution satellite imagery. Although this creates limitations in developing flood modelling, for example, it enhances the replication

[3] This is informed by the 'strategic approach' proposed in: UN-Habitat (2014) Planning for Climate Change: A Strategic, Values—based Approach for Urban Planners.

[4] QGIS is an open-source desktop geographic information system (GIS) application for creating, editing, visualising, analysing and publishing geospatial information/data, available at: http://www.qgis.org.

potential of this work. However, it is strongly advised that, whenever available, this imagery is used to the maximum possible extent.

- Use of data from the Census 2014, disaggregated at village-tract and urban ward level, as a key source of information. The national census database will be updated in future, which will allow for monitoring of changes in the structure of the townships and can also be easily accessed.

- *Inclusiveness:*
  - Adopting a participatory vulnerability assessment approach, i.e. involving communities through conducting surveys, focus group discussions, participatory mapping and other tools.
  - Equal participation of men and women and, where possible, using gender disaggregated data.
  - Engagement of the national government and the township administration throughout the process to ensure ownership of the results and replication.

- *Comprehensiveness and spatial relevance:*
  - Studying three main systems that define a township: ecological, socio-economic, and infrastructure. The assessment is designed to analyse system-wide issues and the interaction between systems. In addition, the analysis should focus on exploring local governance structures and capacities, because the institutions at township level will be ultimately responsible to adopt a plan, and ensure its implementation.
  - Identification of vulnerable groups: each group (age, capabilities, gender, economic standing) is affected in different ways by climate change, and therefore requires focused analysis. For instance, disabled people, elderly people, women and children may suffer from one and the same shock in a different manner. Therefore, the assessment teams should use differential approach to vulnerability analysis and to identification of adaptation measures.
  - Identification of the current and future spatial structure of a township, which is essential to support planning and direct interventions for adaptation, and to understand how changes in one part of a township or a region may affect others.

3. Methodological framework

The proposed vulnerability assessment process consists of identification and analysis of socio-economic, physical and environmental factors, which determine the sensitivity/susceptibility of the township to the impact of climate change (e.g. increasing temperatures, change in seasonal patterns) and/or hazard (e.g. flood, drought), using a combination of qualitative and quantitative methods. More specifically, the proposed methodology involves national and township level technical meetings; local community participatory workshops; surveys with village administrators; a desk review of literature; use of secondary socio-economic and environmental data; and creation of datasets based on available geo-referenced data.

4. Planning the vulnerability assessment

- Set clear objectives, aim, time-horizon (e.g. short-term year 2025, or long-term year 2050) and expected outcome of the vulnerability assessment.
- Define the available financial and human resources, and desired time-frame to conduct the vulnerability assessment. When resources and time are limited, township officials can choose rapid vulnerability assessment (i.e. using tools and methods which do not require significant time, resources and expertise). Advanced (detailed) assessment, which contains spatial analysis, would require personnel with relevant technical skills in geographic information system (GIS) analysis, statistics, or climate risk modelling.
- Select a multi-disciplinary team of 3-5 members, and choose a Team Leader. It is essential to have at least one environmental specialist, one socio-economic development specialist and one urban/regional planner, architect or engineer (see Table 1). For advanced (spatial) vulnerability assessment, GIS specialist should also be appointed. Supportive role could have representatives from other sectors. Overall, specialists from the following departments could be considered for the assessment team:
  - Agriculture, fisheries and livestock departments
  - Forestry, environment and tourism departments
  - Water, energy and industry departments
  - Infrastructure and transport departments
  - Township development planning department
  - Disaster risk management department
  - Education and health departments
- Using this manual, assessment teams should decide on the specific methods and tools that will be used (depending on the available resource and time). While this book provides guidance on various tools and methods for analysis, assessment teams should tailor their own approach suitable for the township of interest (e.g. develop a list of context-specific questions for community consultations and adapt the proposed survey form to the respective case study).
- Check data availability and request secondary data well in advance (e.g. Census 2014 data, or township level climate/weather data). Sample of formal letter to request Census 2014 data at the village tract/urban ward level with list of key indicators is provided in **Annex V**.
- Develop a plan for the vulnerability assessment and assign specific tasks to each group member. These should account for: a desk review of relevant documents/literature; collecting secondary and primary data (e.g. Census 2014 data; survey with village administrators); township and community level participatory workshops (see participatory tools and methods in **Section 3** and **Annex I**); data processing and analysis; and developing a final report.

Table 1 Terms of reference for selecting a vulnerability assessment team

Component	Expertise	Role	Remarks

Ecosystem	Environmental specialist	Designs the ecosystem component of the vulnerability assessment Develops land-use management analysis Provides a list of potential adaptation measures and designs adaptation scenarios for ecosystem services	The environmental specialist has an essential role in vulnerability assessment. Ideally, this role requires broad knowledge on ecosystems and biodiversity in the township of interest. However, finding an environmental specialist, with such a broad knowledge may be difficult. Yet, if possible, priority should be given to an environmental specialist able to understand the diversified effects of climate change on various ecosystem services.
Territorial system (infrastructure, planning and human settlements	Spatial development, urban, regional planner, architect and/or engineer	Writes the territorial component of the vulnerability assessment, by highlighting the linkages between ecological, socio-economic and infrastructure systems Provides a list of potential adaptive measures Designs adaptation scenarios for the territory (physical and spatial components)	This is an essential role, which ideally, should be assigned to an architect with experience in both physical planning and architecture. This role can also be divided between two specialists: one architect (or engineer) and one urban planner.
Socio-economic system	Social development specialist and economist	Writes the socio-economic component of the assessment report including Integrates gender considerations in the analysis, and identifies the needs and vulnerabilities of vulnerable groups Provides a list of potential socio-economic adaptive measures and defines socio-economic adaptation scenarios	This is an essential role, which requires a specialist with strong analytical skills and solid knowledge on development issues. For instance, the selected person should be able to understand both the economic patterns (such as level of dependency on agriculture for livelihood) and social issues (such as level of education and migration) in the context of climate change. In some cases, sectoral specialists could be included in the assessment teams, e.g. from

			agriculture, industries or social sectors.
Local climate modeling	Climate expert or partner organization	Climate modeling at regional and township levels (as relevant)	It is recommended to include this expertise only in case of large-scale assessment. In general, it is best to use regional level projections, as developed by the Department of Meteorology and Hydrology. An expert from this Department can be asked to provide support in reading the projections. In addition, projections downscaled to local level can be made in cooperation with a research/or academic organization (if enough budget).
Land-use and risk mapping	GIS specialist with environmental and infrastructure experience	Prepares basic mapping to show potential impact of climate-related hazards, e.g. sea level rise or floods, in a certain location Develops digital elevation models as needed Develops risk maps in townships and specific locations	This position has a leading role in representing key issues spatially. GIS experts can collect existing datasets from a range of sources that are essential to the assessment such as soil type and forest cover, or maps of road infrastructure.

III. Vulnerability assessment: process, methods and tools

The proposed methodology establishes a basis for analysis by describing the context and key socio-economic, ecological and infrastructure features and the spatial structure of a township[5]. This generates insights on the current situation and sources of vulnerability. As well, a vulnerability index is presented, which is a useful tool for identification of the most vulnerable locations in the township of interest. Furthermore, the proposed spatial method allows for analysis of how new climatic conditions (downscaled climate change projections) will affect people and assets. In addition, a gender-sensitive approach to vulnerability analysis is proposed. Finally, future scenarios that may materialize without adaptive action are defined and compared with potential adaptation pathways to inform local adaptation planning. The following sub-sections provide step-by-step guidance on conducting a vulnerability assessment and developing an assessment report.

Step 1: Developing a township profile

This step corresponds to developing the first section (chapter) of the vulnerability assessment report. In this chapter, assessment teams should provide the reader with a background information on key issues, which determine the vulnerability of the township of interest now and in future, including:

- ✓ Physical and environmental features (such as basic geography, local climate and exposure to climate-related hazards, natural resources)
- ✓ Demographic overview (e.g. density of the population, rural/urban ratio, migration trends)
- ✓ Administration and governance (e.g. description of the governance structure and capacities of the township, and the role of informal institutions)

What should be described in this section?

At first, township officials should develop a township profile, i.e. a basic description of physical and environmental characteristics, demographic trends, and governance structure. The following list provides guidance and recommendations on formulating a township profile.

Physical and environmental characteristics

[5] This paragraph is summarized from Fee L. et al. (2017a, forthcoming).

- Basic geography: location and physical characteristics (e.g. topography); major cities, towns and human settlements (administrative divisions)
- Local climate such as average annual/seasonal temperatures and rainfall, wind patterns
- Natural resources including their spatial distribution (location) and state (e.g. level of environmental degradation and resource depletion):
    - marine and coastal ecosystems; coastal erosion and inundation
    - water resources and hydrology; seasonal variation in water availability (e.g. rivers, groundwater); water quality
    - forests and vegetation cover, and observed changes
    - soils and soil nutrient status
    - land use and drivers of change
    - biodiversity

Demographic overview

- Basic demographics: number and density of the population, age structure, rural/urban ratio, male/female ratio
- Socio-economic demographics: household type and size, per cent of female headed households, poverty levels, migration trends, child mortality, literacy rate/level of education, economically active/inactive population (out of which women), labour-force participation. If available, use sex and age disaggregated data. Pay attention that statistical data can be biased because women's work such as post-harvest processing, net and basket making, and marketing of crops and fish, might not be considered as an 'economically active participation' in the existing statistical databases.

Administration and governance

- Key development/sectoral plans and priorities at the township level and status of integration of climate-related issues
- Description of governance structure and capacities of the township. For instance, township officials might consider including a list of state institutions, which play a role in CCA, and briefly describe their capacities (technical, financial, human). Information can be obtained through consultations with representatives from various departments.
- Village/community level informal governance structures (e.g. village leaders)

What methods and tools could be used to obtain, analyse and present information?

- **Review** of documents and published literature for the region/township.

- **Collection, analysis and graphic presentation of statistical data.** For example, Census 2014 data disaggregated at urban ward and village tract level informs all aspects of the assessment (i.e.

socio-economic and infrastructure information). In addition, a demographic chart, pie chart or column chart can be easily generated using the 2014 Census tables (Figure 3).

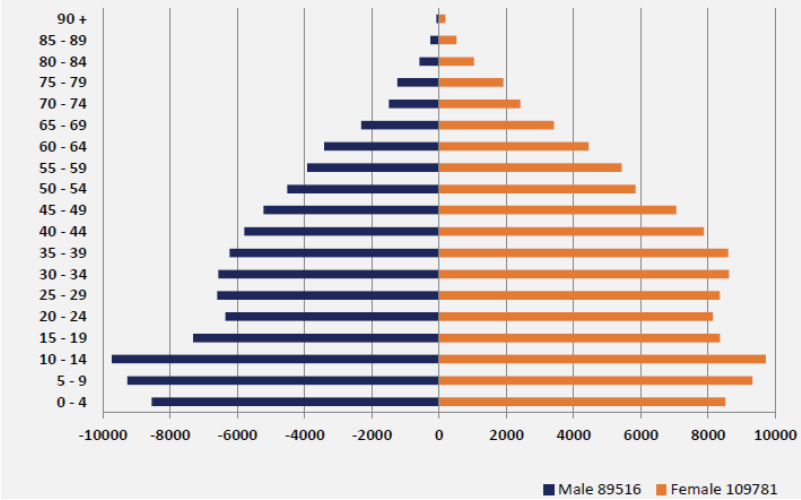


Figure 3 Example of a demographic chart: Rural population pyramid for Pakokku Township (Source: Fee, L. et al., 2017 (b))

- **Township mapping**: involves a spatial presentation of township's key features. This can be done by printing a large physical map of the township of interest. Township officials can add to the map other important information (ecosystem, infrastructure, and socio-economic features) either by drawing directly on the map or by using sticky notes. Key township features could be also mapped in a GIS environment.

To learn more, see Annex I – C: Spatial analysis tools

- **Venn diagrams** can be used as a tool for mapping key stakeholders and analysing their decision-making power with the objective to explore institutional relationships in a village. Understanding the decision-making power, relationships and processes in a community could help to identify vulnerable groups (according to age, gender, socio-economic status, skills and abilities), potential conflicts of interest and determine how local institutions can influence adaptation. The information can support the development of Administration and Governance sub-section of the township profile.

To learn more, see Annex I – A: Tool 5

Data sources

- Township maps: Myanmar Information Management Unit (MIMU) (http://www.themimu.info/gis-resources) or Google Maps.
- Information on climate and environmental features (e.g. soil type, hydrology, crops and land use): information can be requested from respective township departments.
- Census data: most of the necessary information for the development of township profile can be obtained from the 2014 Myanmar Population and Housing Census

(http://www.themimu.info/census-data). Double-check if there have been any changes in the administrative boundaries of the township of interest since 2014.

Step 2: Assessing current vulnerability to climate change and hazards

This step corresponds to developing the second section (chapter) of the vulnerability assessment report. In this chapter, assessment teams should describe the level of vulnerability of the township and corresponding underlying factors. More specifically, this chapter contains:

- ✓ Analysis of the observed climate changes including hazards
- ✓ Analysis of the factors of vulnerability to identify vulnerable sectors and groups:
  - Ecosystem conditions and impact of climate change on ecosystems
  - Socio-economic system conditions and socio-economic impacts of climate change
  - Infrastructure conditions and impact of climate change on infrastructure and human settlements
- ✓ Current disaster risk profile (risk index) to map the most vulnerable and at-risk locations

2.1. Identifying and analysing observed climate changes

What should be described in this section?

Assessment teams should obtain information on observed changes in local climate and its variability, as well as trends in frequency and magnitude of climate extremes (if possible for the last 30 years).

Key climate change indicators and observed trends across the country are:

- Increase in mean seasonal and annual temperatures
- Increase in daily maximum temperatures and number of hot days, more frequent heat waves
- Shorter monsoons
- Erratic rainfall patterns – increasing rainfall intensity (especially during the wet season) and decreasing number of rainy days
- Sea level rise
- Increase in frequency and magnitude of climate hazards:
  - increasing risk of coastal hazards (flooding, storm surges, strong winds)
  - increasing risk of forest fires
  - increasing risk of erosion and landslides
  - more frequent occurrence of drought and flood events
  - increasing intensity and frequency of cyclones

What methods and tools could be used to obtain, analyse and present information?

- **Time-series hydro-meteorological data analysis** (for observed trends at the national and sub-national levels see **Annex II**). For instance, the following variables could be analysed:
  - trends in average, minimum and maximum monthly and seasonal temperatures and precipitation
  - change in the length of monsoon period
  - change in frequency and severity of extreme events.

  Obtaining time-series data at the township level could be challenging. In such case, a mix of regional level data analysis, and bottom-up approaches such as interview or survey could be applied.

- **Participatory methods** such as group or individual interviews with community members: this approach involves facilitating a discussion on community perceptions and direct observations of changes in local climate. Older people often could provide valuable historical information. It is recommended that facilitators of this process guide the discussion through specific questions such as:
  - Do you think that temperatures are changing? Is it now cooler or warmer than before?
  - How are seasons changing?
  - Is the rainy season getting shorter or longer compared to 20-30 years ago?
  - Is it raining when it is not supposed to rain nowadays?
  - Do you think that sea level is rising? Can you recall if the coastline was wider before?
  - Can you recall some major hazards experienced in your area (e.g. floods, droughts, cyclones, heat waves)?

To learn more, see Annex I – A: Tool 1/Tool 2/Tool 3

2.2. Analysing factors of vulnerability to identify vulnerable sectors and groups

What should be described and analysed in this section?

This part of the vulnerability analysis aims to explore experienced climate change impacts and identify causes of vulnerability. The analysis should be built upon in-depth understanding on those key characteristics of the selected township, which condition its vulnerability or resilience to climate change and hazards, as described below.

Ecosystem conditions: what should be described?

- Key ecosystem services:
  - Access to ecosystem services such as access to water for drinking and irrigation, productive land, or marine resources
  - Livelihood dependency on ecosystem services (forests, agriculture and fishing, marine ecosystems)
- Environmental issues such as erosion, deforestation, pollution of water resources (e.g. from agriculture), overfishing, unsustainable land use and agricultural practices.

Socio-economic conditions: what should be described?

- Economic profile:
  - Annual output per capita and key productive sectors (e.g. agriculture, fisheries, textile industry, food processing industries, etc.) as well as their contribution to the local economy (sectoral output and employment opportunities)
  - Main agricultural output and level of economic dependency on a specific production (e.g. rice or certain type of fish); level of agricultural production diversification
  - Dominant form of farming and entrepreneurship (small, medium or large farms/businesses)
  - Access to resources such as land and financing
- Livelihood profile: main sources of livelihood and level of household income diversification; household food security; rural-urban differences
- Social issues:
  - Gender roles in community:
    - identification of the roles of men and women in family and community
    - analysis of gender equality: income generating opportunities for women/men, unpaid work women/men, daily wage women/men
    - access of women to resources (especially of women heads of households) such as land, assets (house), financing
  - Identification of socially and economically vulnerable groups such as minority groups and people with disabilities
- Health issues: overall health status and key health risks in the township related to climatic conditions and hazards

Infrastructure and connectivity conditions: what should be described?

- Description of hard infrastructure such as road network, bridges, drainage system, energy and water infrastructure and facilities, water infrastructure for irrigation and livestock use
- Description of housing conditions (construction materials and techniques used) and access to basic services including:
  - Water and sanitation – main sources of and access to drinking water, household water storage and sanitation facilities
  - Energy – access to electricity and main sources of energy (e.g. hydropower energy, wood harvesting)
  - Telecommunications – access to radio, television and the Internet

- Transportation system: land and water transport systems
- Description of location, accessibility and safety of markets and public facilities:
  - Basic health and education coverage; areas/communities with low access to markets and public facilities (hospitals, schools).
  - Cyclones/emergency centres coverage
  - Disaster resilience of public buildings
  - Connectivity challenges during seasonal floods and most affected areas in the township
  - Access to early-warning systems.

What should be analysed?

For each of the three components described above (ecosystems, socio-economic and infrastructure), the following main questions should be addressed:

- How do observed changes in climate (including climate variability and hazards) affect the selected township (considering environmental, socio-economic and infrastructure aspects)? To the extent possible, include a broad spectrum of issues such as observed impacts on:
  - crops production, fisheries and livestock
  - land productivity and water availability
  - forests and biodiversity
  - marine and coastal ecosystems
  - local economic growth, and sectoral growth rates
  - poverty levels and migration
  - access to water and energy
  - transport infrastructure and services
  - health of the population
  - access to schools, hospital and other public facilities.
- Which sectors, social groups and locations have been most impacted from recent climatic stress? Why, what makes these sectors, groups and communities vulnerable?
- What non-climatic factors have exacerbated the severity of climate change impacts? (e.g. deforestation, expansion of agricultural land)
- What coping or adapting practices/measures exist at community and township levels?

To identify gender-responsive CCA actions and tailor local climate resilience action plans that addresses the needs of both men and women, the vulnerability analysis should be *gender-sensitive*.

Gender-sensitive approach to vulnerability assessment means to *understand and give consideration* of the different rights, roles and responsibilities of women and men in the community and the relationships between them in the context of vulnerability to climate change and hazards.

Gender-sensitive vulnerability analysis implies that:

- Both qualitative and quantitative data used in vulnerability assessment has been gathered and analysed disaggregated by sex (and age).
- Both men and women have been consulted separately, for example in focus group discussions, about their perception of climate change, hazards and livelihoods.

What makes women vulnerable to the impacts of climate change?

- Limited access to resources: in some cases, women have limited access to crucial resources such as land, livestock, tools, and credit. Even in cases where women may have access to land, they have limited control over it, as they do not own it and therefore cannot make decisions regarding its use.
- Dependence on natural resources most at risk from climate change such as water and tress.
- Higher level of poverty, especially of women heads of households, because of informal employment, lower salaries and less income-generating opportunities.
- Limited access to education, skills development and information. For example, girls often receive fewer years of education than boys. Climate change would affect the income of low-income families and this could further affect the access to education. In turn, lower education level can affect girls' ability to: (i) understand and act on information concerning climate risks and adaptation measures; (ii) generate income.
- Limited participation in decision-making conditioned by traditional gender roles. As a result, women's needs and capacities are often neglected.
- Traditional women's occupations in community and family life, and responsibilities of caring for others increase the risks posed by climate change. For example, in case of a disaster women try to protect and save their relatives, which often hinder their timely escape, and access to shelter and health care. In addition, women are often socially restricted from leaving their communities (migrating) as a coping mechanism (used by men).

(UNDP, 2016; UNEP, 2016)

Example: Findings from Labutta Township

In Myanmar, the roles women in small-scale fisheries include post-harvest processing, net-building, and selling of fish. In the case study of Labutta, research findings showed that women have primary responsibilities for cleaning, smoking, salting, drying, and selling fish and seafood products at local markets. Women also pick shrimps and crabs, and dry and sell these products for extra income or to secure food for their families. However, such fishing work is often conceptualized as "not fishing", but an extension of women's traditional role of unpaid household labour. Furthermore, in the seafood industry in Labutta, men earn 5000 Kyat per day, while women only 3000 Kyat.

- Vulnerability assessment report clearly describes how observed/projected climate change affects/could potentially affect women and men differently.

What methods and tools could be used to obtain, analyse and present information?

- **Descriptive analysis** of impacts based upon national and regional level observations, and township level statistical data (if available). For instance, an analysis of historical climate data and agricultural output data can reveal the impact of climate variability and hazards on crops and livestock. Further, an analysis of climate data and output per capita can show if significant climate-related events have affected economic growth and poverty levels, and inform on the most vulnerable locations (e.g. regions of Myanmar).

- **Participatory approaches** could complement the analysis by collecting data through:

  - **Consultation with communities:** Discussions should be tailored to capture:
    - Climate change impacts on multiple sectors (e.g. ecosystems and agriculture; water and energy; transportation and industries);
    - Social aspects of vulnerability (e.g. ask community members which social groups have been most affected from experienced hazards).
    - Gender vulnerabilities (e.g. a female facilitator could conduct a separate consultation with women and girls because some women may find it easier to express their problems, needs and views in a women-only group).

  - **Participatory risk mapping** through consultation with communities: involves mapping of the most exposed locations (of people, infrastructure and assets, crops and livestock) affected by hazards.

  - Developing a **seasonal change calendar** together with communities is a useful tool to identify how recent climate changes affect community livelihood.

↳ **To learn more, see Annex I – A: Tool 1/Tool 2/Tool 3**

- **Spatial (GIS-based) analysis -** suggested methods/tools include:

- **Matrix of Functions** (MoF) is a useful method for conducting spatial and territorial analysis of current and future impacts of climate change, considering the linkages between villages and urban wards in a township.

- **Infrastructure and connectivity system analysis using GIS** can provide a spatial analysis of the sensitivity of the built environment and connectivity to natural hazards and changing climatic conditions. To conduct such spatial analysis, evaluation teams can use data obtained from local surveys, as well as census data. The analysis should provide a description of:
  - the predominant construction design, techniques and materials, with the objective to understand the vulnerability of critical assets such as housing, schools, and health facilities to climate-related hazards (e.g. droughts, cyclones, and floods);

- the availability/access to basic services (water, sanitation, electricity) that could be affected by climate change and hazards such as types of sanitation facilities and water harvesting capacities of households and communities;
- the spatial distribution of township's transport network and communities' access to services and economic activities through roads and waterways with the objective of understanding how isolation and distance contribute to vulnerability, and how climate change exacerbates this.
- the distribution of, and access to key safety infrastructure: the analysis should highlight issues such as cyclone shelter availability and whether shelters are strategically located.

To learn more, see Annex I – C: Spatial analysis tools

2.3. Developing current disaster risk profile (risk index) to map the most vulnerable and at-risk locations

Developing indicators and computing a **vulnerability and risk index** could support the analysis by providing an overview of the most vulnerable locations to current climate hazards.

What is a vulnerability indicator?

Indicator is an observed value of a variable, which could be measured in qualitative and quantitative scales.

Vulnerability index is a composite indicator, i.e. function of observable variables (indicators). Vulnerability indices are widely used in climate change science and policy analysis. Main advantages of the use composite indicators in policy-making relate to:

- Allow for summarising complex information with a view to supporting decision makers.
- It is easier to communicate and interpret one composite indicator than many separate indicators
- Easy to measure progress over time and identify issues (OECD, 2008).

However, vulnerability indicators reduce complexity, which could lead to misinterpretation of information (Hinkel, 2011), and therefore it is recommended that assessment teams use this method in a combination with other approaches proposed in this book.

Various methods and approaches to indicator-based vulnerability assessment are proposed by researchers and practitioners. In this book, a simplified method based upon the use of categorical variables as proxies for measuring factors of exposure and vulnerability is suggested.

What is a categorical variable?

Categorical variable is a variable with limited (usually small) number of possible values such as 1,2 and 3. In the proposed methodology, vulnerability indicators datasets are converted to categorical data by dividing indicator values into groups on basis of a qualitative property (in this case 'level of vulnerability').

To learn more, see Annex I – B

Data sources

- Township maps: MIMU (http://www.themimu.info/gis-resources) or Google Maps.
- Information on climate and environmental features (e.g. soil type, hydrology, crops and land use): information can be requested from respective township departments.
- Ecosystems and services: MIMU map, community consultations and participatory mapping.
- Census data: most of the necessary information for the development of township profile can be obtained from the 2014 Myanmar Population and Housing Census (http://www.themimu.info/census-data). Double-check if there have been any changes in the administrative boundaries of the township of interest since 2014.
- Census data at the village tract/urban ward level can also be requested from the Department of Population of the Ministry of Labour, Immigration and Population.
- Data on hard infrastructure, and productive and livelihood sectors: Township General Administration Department (GAD).

Step 3: Assessing future climate change risk

This step corresponds to developing the third section (chapter) of the vulnerability assessment report. In this chapter, assessment teams should explain how projected changes in climate can affect the township in future under business-as-usual scenario.

- ✓ Summary of climate change projections
- ✓ Potential impacts and future climate change risk

3.1. Climate change projections

What should be described in this section?

This sub-section should examine the future projections of temperatures, precipitation patterns, sea level rise, seasonal changes/shifts, and climate extremes (e.g. droughts, floods, cyclones).

What methods and tools could be used to obtain, analyse and present information?

Identifying future climate in the selected township of interest could be informed by available national and sub-national (regional) level projections. To date, secondary sources are:

- The climate risk information for Myanmar report "Assessing Climate Risk in Myanmar: Summary for Policymakers and Planners" (Horton R. et al., 2016)
- Myanmar National Adaptation Programme of Action to Climate Change (2012)

- Myanmar Initial National Communication under the United Nations Framework Convention on Climate Change (2012)
- Myanmar Climate Change Strategy and Action Plan 2016-2030.

Annex II contains summary of:

- the latest climate change projections at the national and regional levels;
- list of potential climate hazards and vulnerable regions.

This section of the assessment report should contain tables and figures of projected changes for key climate indicators such as temperatures, precipitations, seasonal patterns, sea level rise.

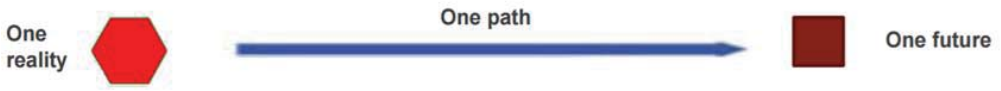
3.2. Identifying potential impacts of climate change and assessing future risk

What should be described in this section?

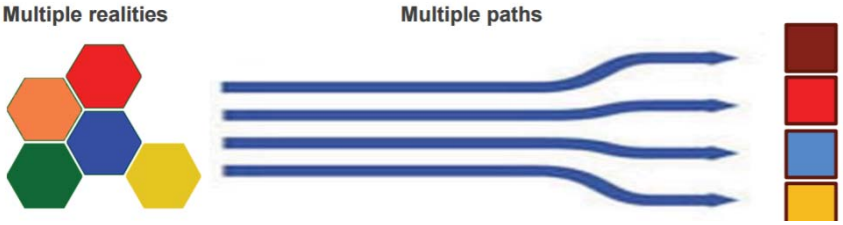
This step of the vulnerability analysis aims to explore potential climate change impacts and develop future risk profile of the township of interest. The analysis builds upon the findings of the previous steps of the assessment, and possible future scenarios for socio-economic, environmental and infrastructure developments. The findings will show the future climate risk profile of township under business-as-usual scenario (i.e. no adaptation action) (see **Chapter 4**).

Difference between a scenario and forecast:

- A forecast suggests one pathway to the future (Figure 4 (a)). For example, using technology we can forecast when a storm or cyclone will reach Myanmar.
- Scenario is a possible future state of climate, environment and socio-economic characteristics of township. Therefore, scenario planning involves considering how multiple variables (e.g. climate, ecosystems, infrastructure, and socio-economic variables) could change and lead to multiple futures (e.g. high climate change impacts, or medium climate change impacts) (Figure 4 (b)). Scenario planning is considered a more effective way for governments to plan so-called 'no-regret' actions.



(a)



(b)

Figure 4 Graphic representation of forecast (a) and scenario (b)[6]

[6] Graphi nt presenta

Main issues to be addressed in this sub-section:

- How would expected (projected) changes in climate (including climate variability and hazards) likely affect the selected township considering environmental, socio-economic and infrastructure aspects? To the extent possible, include a broad spectrum of issues such as potential impacts on:
  - Agriculture, natural resources and ecosystem services
  - Human settlements, industry and infrastructure
  - Human health, well-being and security

  Summary table of potential impacts of climate change and hazards on townships of Myanmar is attached as **Annex III** and could be used to guide the analysis.

- Which sectors, social groups and locations could potentially be most impacted from expected climatic stress? Why, what makes these sectors, groups and communities vulnerable?
- What non-climatic factors could exacerbate the severity of the identified potential climate change impacts? (e.g. rapid urbanization, deforestation, expansion of agricultural land)

What methods and tools could be used to obtain, analyse and present information?

☐ **Literature review** on potential impacts or **working with experts to develop sectoral impact assessment studies** for the selected township. The second option involves the use of simulation models (most often sector-specific), which requires significant data input and technical expertise.

☐ **Potential impact pathways graph** is a visual presentation of the complex relationship between projected climate changes, potential hazards and multiple primary and secondary impacts. The graph could be developed through a review of national and sub-national level studies on potential impacts, analysis of secondary data at the township level, and consultation with communities. The latter, which is a participatory method, allows for reflecting local (e.g. community level) vulnerabilities.

↳ **To learn more, see Annex I – A: Tool 4**

☐ **Spatial (GIS-based) analysis:**

- **Assessing potential impacts of rapid and slow onset climate hazards:** key features of the ecological, socio-economic and infrastructure systems are linked with the projected climatic changes for the township, and illustrated in a GIS environment. For instance, a coefficient for climate change for each projected change is assigned and multiplied against a given feature, such as crops.

Example from Labutta

Spatial analysis reveals that the capacity of the population to benefit from agriculture will decline sharply by 2050 due to climate stress and decline in ecosystem services including freshwater, soil and crops (Figure 5).

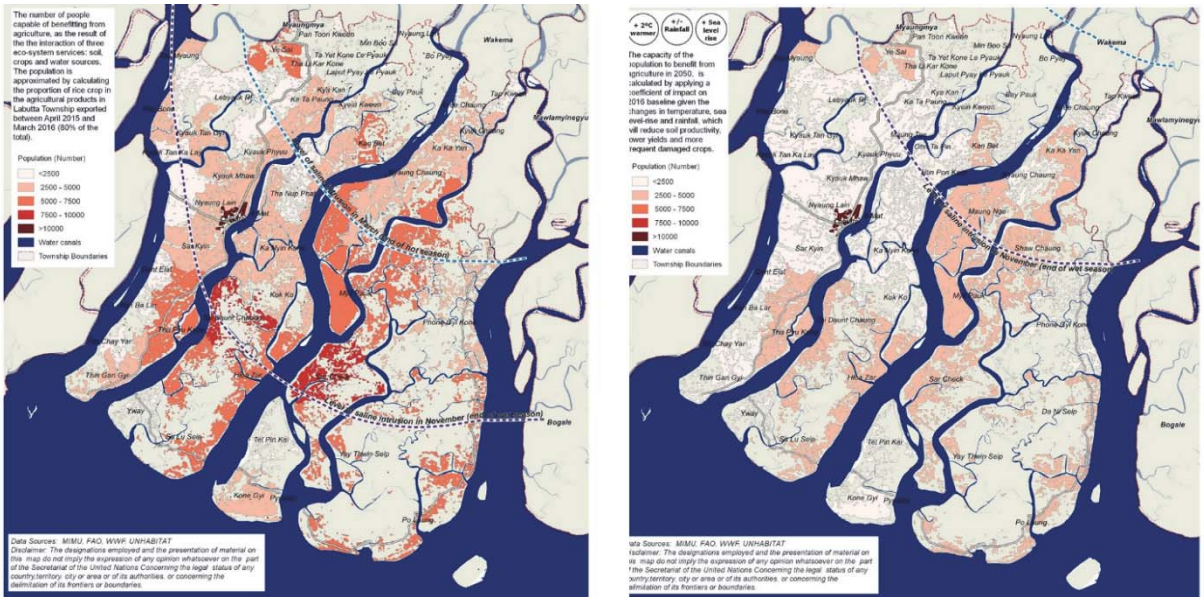


Figure 5 Capacity of the population to benefit from agriculture in 2016 (left) and 2050 (right)

- **Analysis of MoF for 2050** could be used to explore the impact of climate change on the socio-economic and infrastructure development across the township (if MoF is used as a tool for current vulnerability analysis).

To learn more, see Annex I – C: Spatial analysis tools, and Annex I – D: Determination of coefficients of change under 'business-as-usual' scenario

Step 4: Summarizing findings

This step corresponds to developing the forth section (chapter) of the vulnerability assessment report. In this chapter, assessment teams summarize the overall findings of the assessment, and propose a long list of potential adaptation options.

What should be described in this section?

The vulnerability assessment findings could be summarized in a table and key messages highlighted. Emphasis should be on current vulnerabilities and potential future impacts on ecosystems, socio-economic systems and the built environment. Results should show the most vulnerable sectors, social groups and locations in the selected township to current and future climate pressures.

In addition, at the last stage of the vulnerability assessment process, township officials could develop a long list of adaptation options through consultations with communities and relevant stakeholders. The findings could serve as a starting point for identification of adaptation priorities and specific actions.

IV. Policy implications of vulnerability assessment results

Policy-makers can identify scenarios and develop a vision of the future based upon the vulnerability assessment results. To achieve this, assessment teams should present their findings to a wide range of stakeholders. The best way is to organize a consultative meeting where policy-makers can discuss future scenarios and agree on a long-term CCA pathway.

The objective of using scenarios to develop policies is to ensure that a broader range of possible options is considered. Three broad scenarios of the future, which can help local and national governments to plan for local CCA actions are proposed below (Table 2).

Table 2 Suggested scenarios for 2050[7]

Scenario	Required response and impact
A: Business as Usual	**Response:** authorities and communities do not recognize the urgent need to address current and future climate change impacts and vulnerabilities, and no action is taken. **Impact:** climate change will increasingly affect people's life, livelihoods, health and safety until 2050 and beyond; current socio-economic and environmental vulnerabilities will aggravate; development will be impeded.
B: Resilience is built to maintain current living standards by 2050	**Response:** authorities and communities recognize the urgent need to address current and future climate change impacts and vulnerabilities. However, there are limited capacities for large-scale investments and CCA responses (financial, technical and human constraints). Under this scenario, local adaptation plans can focus on: ▪ Improved environmental management, sustainable natural resources utilization and land-use planning, ecosystems restoration and conservation, introduction of climate-smart agricultural practices ▪ Limited investment in infrastructure but sufficient to ensure that functionality is maintained to present levels, e.g. improving transport infrastructure and networks, and access to public services; and diversification of water and energy sources at a community or household level.

[7] This table is developed based upon vulnerability assessment studies conducted in Labutta and Pakokku (Fee, L. et al., 2017(a) and (b)).

	▪ Small-scale socio-economic measures such as agricultural production diversification, and improved access to microfinance/loans. **Impact:** while climate change will affect people's life, livelihoods, health and safety until 2050, townships can maintain current living standards; however, social development and economic growth would be challenged by climate change.
C: Resilience is built that enables economic and social development, despite changes in climate by 2050	**Response:** authorities and communities recognize the urgent need to address current and future climate change impacts and vulnerabilities, and are committed to implement a wide range of low- and high-cost CCA measures. Townships have the support of national authorities and international partners to achieve environmental, infrastructural and socio-economic objectives. These could be: 1) Healthy ecosystem that sustains life; 2) Resilient infrastructure that protects people and promotes development; 3) Diversified economy that supports sustainable and resilient economic and social development. **Impact:** climate change will affect people's life, livelihoods, health and safety until 2050, and beyond; however, townships will be able to maintain current living standards and to achieve development goals.

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Annexes

Annex I. Tools for vulnerability assessment

A. Participatory tools

Tool 1: Semi-structured interview with community members

What is a semi-structured interview?

Semi-structured interview is a discussion in an informal way using open questions. Group interviews and focus group discussions are types of semi-structured interviews.

- **Group interview** is a type of semi-structured interview, which aims at obtaining community level information.
- **Focus group discussion** is a type of semi-structured interview, which aims at discussing a specific topic in detail with a small group of persons who are well familiar with the topic of interest.

How to facilitate a group interview and focus group discussion?

- Prepare a list of key issues in advance and select one person from your group to lead the interview (nevertheless, the other group members can also ask questions)
- Use open-ended questions such as 'what', 'why', 'who', 'when' and ask for concrete examples; if you have questions arising from the given answers, ask new questions
- Try to involve everyone from the focus group to express opinion and share information
- Thoroughly record the answers
- Present results to community and facilitate discussion on the findings.

(MNRE Lao PDR, 2016)

Tool 1 (a): Group interview with community members with focus on ecosystems profile, observed climate changes and impacts on ecosystems and agriculture

What issues should be explored during the group interview?

The objective of the interview is to obtain information for developing the ecosystems component of the vulnerability analysis including ecosystems profile and impact of observed climate changes on ecosystems. Specific questions are suggested in the table below.

Ecosystems profile	What are the main natural assets available in your community? What is the state of these natural assets (level of environmental degradation and resource depletion)? Depending on the case study, the following natural resources should be explored: ▪ marine and coastal ecosystems; coastal erosion and inundation ▪ water resources and hydrology; seasonal variation in water availability (e.g. rivers, groundwater); water quality ▪ forests and vegetation cover, and observed changes ▪ soils and soil nutrient status ▪ land use and drivers of change ▪ biodiversity Additional questions could be: What is the access of the community to water for drinking and irrigation, productive land (e.g. for agriculture and livestock), or marine resources? To what extent the community depends on natural resources for livelihood? Are there any environmental issues in this community such as erosion, deforestation, pollution of water resources (e.g. from agriculture), illegal fishing, expansion of agricultural land, 'slash-and-burn' practices?
Impact of observed climate change on ecosystems	Explore people's perception for changes in local climate. Some examples: ▪ Do you think that temperatures are changing? Is it now cooler or warmer than before? ▪ How are seasons changing? Is the rainy season getting shorter or longer compared to 20-30 years ago? Is it raining when it is not supposed to rain nowadays? ▪ Do you think that sea level is rising? Can you recall if the coastline was wider before? How does this affect your livelihood? ▪ Can you recall some major hazards experienced in your area (e.g. floods, droughts, cyclones, heat waves)? For each of the observed changes/hazards, ask how this has affected the environment and ecosystems including: ▪ crops production, fisheries and livestock ▪ soil and land productivity (short- and long-term effects) ▪ water quality and availability, overall access to water for drinking and irrigation ▪ forests and biodiversity

	• marine and coastal ecosystems Afterwards, try to find out what does the community do in response to the observed changes and hazards.

How to present the key findings to the community?
Draw a simple table on a large paper/on a flip chart and summarize the obtained information into main points using the above suggested outline.

Tool 1 (b): Group interview with community members with focus on socio-economic profile, observed climate changes and impacts on livelihood

What issues should be explored during the group interview?
The objective of the interview is to obtain information for developing the socio-economic component of the vulnerability analysis including socio-economic profile and impact of observed climate changes on community livelihood. Specific questions are suggested in the table below.

Socio-economic profile	Main productive sectors (agriculture, fisheries, business/industries) Level of household income diversification and overall food security of the community Agriculture sector profile information such as: • dominant form of farming (small, medium or large farms) • main agricultural production and level of crops diversification • economic dependency on specific production (e.g. rice or certain type of fish) Financial capacity such as access to credit, loans and insurance. Social issues such as access to education and health care, migration.
Impact of observed climate change on livelihood and productive sectors	Explore people's perception for changes in local climate. Some examples: • Do you think that temperatures are changing? Is it now cooler or warmer than before? • How are seasons changing? Is the rainy season getting shorter or longer compared to 20-30 years ago? Is it raining when it is not supposed to rain nowadays? • Do you think that sea level is rising? Can you recall if the coastline was wider before? How does this affect your livelihood? • Can you recall some major hazards experienced in your area (e.g. floods, droughts, cyclones, heat waves)? For each of the observed changes/hazards, ask how this has affected the social and economic life of the community including: • income generation and food security, poverty levels and

	migration ▪ the productive sectors (e.g. agricultural production loss in a short- and long-term) ▪ the health of the population ▪ the access to education Afterwards, try to find out what does the community do in response to the observed changes and hazards. Finally, ask respondents who are the most vulnerable people in the community such as minority groups and people with disabilities, or those living in a flood-prone area.

How to present the key findings to the community?
Draw a simple table on a large paper/on a flip chart and summarize the obtained information into main points using the above suggested outline.

Tool 1 (c): Group interview with community members with focus on infrastructure profile, observed climate changes and impacts on infrastructure

What issues should be explored during the group interview?
The objective of the interview is to obtain information for developing the infrastructure component of the vulnerability analysis including infrastructure profile and impact of observed climate changes on community infrastructure and connectivity. Specific questions are suggested in the table below.

Infrastructure profile	Explore the community infrastructure, including what infrastructure, housing and public facilities are available, how are they maintained and are they resilient to climate hazards such as floods and droughts. Consider the following categories: ▪ Housing including building materials, design and retrofitting status ▪ Households access to water, sanitation and electricity, e.g. availability of drinking water infiltration wells, hand/motor pumps, tap water, roof-top harvesting systems, sanitation facilities ▪ Main sources of energy and electrification status ▪ Water infrastructure and facilities such as dams, canals, farm ponds, irrigation and drainage systems of agricultural fields ▪ Road infrastructure and accessibility ▪ Flood control/protection infrastructure such as drainage systems, dykes, elevated evacuation routes ▪ Disaster-resilient infrastructure for storage of food and seeds/grains, and shelters for livestock

	▪ Access to, and availability and condition of hospitals and public health centres ▪ Monasteries, Pagoda, schools and other community buildings and multipurpose shelters (e.g. cyclone shelters). Explore whether these facilities are available particularly for vulnerable group like children, women, disabled and elderly persons.
Impact of observed climate change on infrastructure	Explore people's perception for changes in local climate. Some examples: ▪ Do you think that temperatures are changing? Is it now cooler or warmer than before? ▪ How are seasons changing? Is the rainy season getting shorter or longer compared to 20-30 years ago? Is it raining when it is not supposed to rain nowadays? ▪ Do you think that sea level is rising? Can you recall if the coastline was wider before? How does this affect your livelihood? ▪ Can you recall some major hazards experienced in your area (e.g. floods, droughts, cyclones, heat waves)? For each of the observed changes/hazards, ask how this has affected the housing, infrastructure, public facilities and connectivity of the community. For example: were there many destroyed houses and roads? was the access to hospitals and schools affected? did you have access to water and electricity? Afterwards, try to find out what does the community do in response to the observed changes and hazards. Finally, ask respondents who are the most vulnerable people in the community such as minority groups and people with disabilities, or those living in a flood-prone area.

How to present the key findings?

Draw a simple table on a large paper/on a flip chart and summarize the obtained information into main points using the above suggested outline.

Tool 1 (d): Focus group discussion with community members (women and girls) to explore gender roles and vulnerabilities

What issues should be explored during the focus group discussion?

The objective of the discussion is to understand gender roles in the community and identify vulnerabilities and needs of both men and women. Guiding questions are outlined below.

Understanding livelihood to create community profile	What are the main labour-related activities in your community? What kind of work men do? Is it paid? How much? What do women do, and are they paid? How much? The following aspects could be considered: ▪ Productive roles: paid work (e.g. agriculture, employment and other income-generating activities), subsistence production ▪ Reproductive roles: domestic work (water, fuel, cooking, market), childcare and care of the sick and elderly ▪ Community-related activities/duties
	What are the main livelihood assets available in your community? Who has access to these resources – both men and women? How and why? The following aspects could be considered: ▪ Human assets: such as health services, education, skills/training ▪ Natural assets: land, water, forest, fish, ecosystem service ▪ Social assets: e.g. social networks, voluntary groups ▪ Physical assets: housing and basic infrastructure (e.g. water, energy), transportation, communications ▪ Financial assets: e.g. credit, loans, insurance
	Who takes important decisions in your community? Are women involved in community decision-making? If 'no', why? If 'yes' in what way? (e.g. decision on the management of resources and community planning process)
Assessing current vulnerability	What happens when there is flood/drought? How is the community affected? How are men affected? How are women, elderly and children affected? What men usually do in such case? What about women? What are their roles?
Assessing future vulnerability	What would happen in future when the local climate is getting warmer, and rainfall is changing (and sea level is rising)? How would this affect men? What about women? Why?
Identifying needs	Given the expected climate change, what are the needs of your community? What would help you to reduce the impact of climate change? What do women need? What do men need? The following aspects could be considered: ▪ Women's and men's needs to perform their productive (labour and income-related) and reproductive (family care) roles under the challenges of climate change ▪ Long-term strategic perspective related to transformation of

	gender roles in family and community such as increased access to decision-making and resources

How to present the key findings to community?

Draw a simple table on a large paper/on a flip chart and summarize the obtained information into main points using the above table.

Tool 2: Participatory community and risk mapping

What is participatory mapping?

Participatory mapping is a process of drawing a village/community map based upon information and knowledge shared by local people. It is recommended that women, men, and children from different social groups participate in this process.

Participatory mapping could be used to develop community and hazard/risk maps:

- Community mapping is used to indicate the spatial location of natural resources (main ecosystem services), land-use types (e.g. forest area, agricultural fields and residential areas), important community assets and infrastructure (e.g. roads, bridges, energy grid, water infrastructure and utilities), and other features.
- Hazard/risk mapping could be viewed as an extension of community mapping. It illustrates the hazard-prone locations, as well as people, ecosystems and assets most at risk of hazards such as floods. Other information that could be mapped include: safe areas/route to safe areas, and local capacities such as rescue posts.

Steps in participatory mapping:

- Decide what kind of information is needed and prepare a list of questions. Bring necessary materials for the mapping (e.g. printed map of the area, flip chart, markers and pencils, paper/transparent paper, colour paper/sticky notes, etc.).
- Find and gather community members who know the area and are willing to share their knowledge.

How to facilitate a participatory mapping?

- Using the printed map and transparent paper, ask people to draw the map on their own. However, provide guidance with your questions and stimulate discussions on important issues.
- Ask people to provide examples as much as possible
- While community is drawing the map, write down in detail what people say because this information will be used in the vulnerability assessment.
- Present results to community and facilitate discussion on the findings.

What issues should be explored through the mapping exercise?

The objective of this exercise is to create a spatial profile of the community, including to illustrate the exposure of people, ecosystems, assets, and infrastructure to hazards and climate change

impacts (e.g. sea level rise)

The following specific issues could be drawn on the map:

- spatial location of natural resources and main ecosystem services
- land-use types (e.g. forest area, agricultural fields and residential areas)
- important community assets and infrastructure (e.g. roads, bridges, energy grid, water infrastructure and utilities)
- location of/access to cyclones/emergency centres
- other features: location of/access to markets, schools, health facilities
- most at risk locations, assets and people, based upon community's experience from past disasters.

In addition, you can collect other information relevant to support the development of infrastructure and connectivity profile of the community. More specifically, community members could be asked to share their knowledge and experience about:

- Connectivity challenges during seasonal floods (if relevant to the case study)
- Access to early-warning systems.
- Access to telecommunications (radio, television and the Internet)
- Access to electricity and main sources of energy (e.g. hydropower energy, wood harvesting)
- Main sources of and access to drinking water, household water storage and sanitation facilities

How to present the key findings to community?

Together with the produced map, prepare a summary of the obtained information in the form of bullet points (e.g. on a flip chart).

Tool 3: Developing community seasonal change calendar to identify observed climate changes and impacts on livelihood

What is a community seasonal change calendar?

Developing a seasonal calendar together with communities is a useful tool to identify how recent climate changes affect community livelihood. The calendar could be developed by drawing a simple table on a large piece of paper/flip chart as shown below.

Season (length)	Key events (annual cycle)	Typical climate	Observed changes	Observed impacts
Hot season (March-May)				
Wet season (June-October)				
Cool season (November-February)				

How to facilitate the process of developing community seasonal calendar and what issues should be explored?

Draw the above table and ask people to list:

- Key events (column two), which relate to any significant for the life of a community event during a year such as planting and harvesting, start of school year or seasonal income generating opportunities. Ask what do men and women do, as well as children and elderly, throughout community's annual cycle.

- Climate indicators (columns three and four) could be temperatures, timing and intensity of rainfall, wind patterns, and types and occurrence of hazards. For example, to explore this you can ask the following questions:
  - Do you think that temperatures are changing? Is it now cooler or warmer than before?
  - How are seasons changing? Is the rainy season getting shorter or longer compared to 20-30 years ago? Is it raining when it is not supposed to rain nowadays?
  - Do you think that sea level is rising? Can you recall if the coastline was wider before? How does this affect your livelihood?
  - Can you recall some major hazards experienced in your area (e.g. floods, droughts, cyclones, heat waves)?

- Observed impacts relate to any hardship or loss experienced by community due to observed changes such as disruption of the annual events cycle. For example, a shift/change in seasonal patterns could affect the growing period, while annual floods may disrupt access to school and affect small-scale producers. Ask about impacts on:
  - Impact on ecosystems (e.g. forest, soil, water resources)
  - Productive sectors (e.g. agriculture, fisheries, livestock, local production)
  - Transportation and connectivity (e.g. access to markets, schools, health services)
  - Access to water and energy
  - Health and social impacts (e.g. impacts on the poorest households, on women and children)

Remember:

- The objective is to identify how recent climate changes affect community livelihood
- Ask guiding questions but leave community members to fill the table on their own
- Ask people to provide examples as much as possible
- While community is filling the calendar, write down in detail what people say because this information will be used in the vulnerability assessment.

How to present the key findings to community?

Together with the produced calendar, prepare a summary of the obtained information in the form of bullet points (e.g. on a flip chart).

Tool 4: Developing a Potential Impact Pathways graph

What is a Potential Impact Pathways graph?

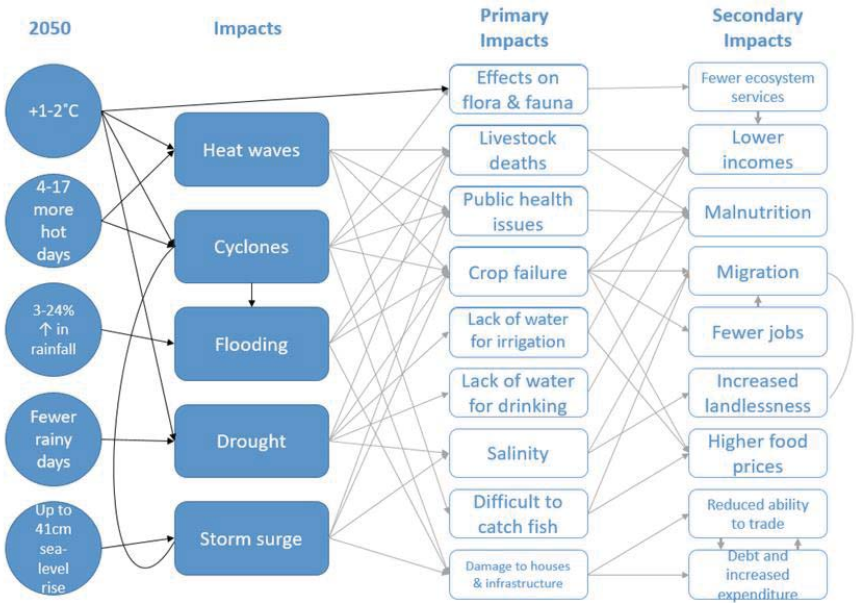
Potential Impact Pathways graph is a visual presentation of the complex relationship between projected climate changes, potential hazards and multiple primary and secondary impacts (see the example provided below).

How to facilitate the process?

Working in small groups, stimulate discussion using open-ended questions such as these suggested below.

- What would happen in future when the local climate is getting warmer, and rainfall is changing (and sea level is rising)?
- How would this affect:
  - environment and natural resources such as land/soil, water, forests, fish, etc.
  - agriculture and food security
  - local production, income and migration
  - access to water and energy, and other services such as transportation and education
  - health of people
- How would this affect men? How would this affect women? How would this affect elderly and children?

Note: **Annex III** of this manual could be used as a reference on potential impacts, categorized as primary impacts (i.e. those that are directly caused by climate change and/or climate hazard) and secondary impacts (i.e. those that have slow onset or occur due to primary impacts). It should be noted that some impacts could be a result of the combined effects of climate change and multiple hazards.



Example: Pathways to potential climate change impact in Labutta Township (2050)

Tool 5: Developing a Venn Diagram

What is a Venn diagram?

Venn diagrams are used as a tool for mapping key stakeholders and analysing their decision-making power with the objective to explore institutional relationships in a village. Understanding the decision-making power, relationships and processes in a community could help to identify vulnerable groups (according to age, gender, socio-economic status, skills and abilities), potential conflict of interest in the context of climate change, and determine how local institutions can influence adaptation.

Developing a Venn diagram involves drawing circles on a paper, whereas each circle represents a stakeholder. Bigger circles are drawn to present institution/stakeholder with more power in the village. The distance between circles represents the degree of influence or contact between institutions (the bigger the distance is, the lower influence or contact between stakeholders is). Stakeholders to be considered in the analysis include: individuals, governance structures (including government and governmental departments, committees and community groups), and service providers within the community (e.g. local businesses).

Example of stakeholder mapping using Venn diagram (Source: BRACED Myanmar Alliance, 2015)

How to facilitate the process?

The following questions could guide the exercise:

- Who are the decision makers/leaders? How many of them are women?
- Who are the most vulnerable/marginalised people in the community? Why?
- Are there community-based organizations? What roles do they play and are they supported by the community?
- What are the relationships between different actors in the community (what is dividing and connecting different actors)? What are the gender roles/norms?
- What factors influence the change in decision-making power?
- What actors are relevant to any identified tensions in the community?
- Are there any plans that identify vulnerable groups and have specific plans or activities to address them?
- Are any organisations or institutions working in the community to address the needs or requirements of vulnerable people? What are they doing/what services do they provide?
- Are there any self-help groups in the community?

(BRACED Myanmar Alliance, 2015)

References:

BRACED Myanmar Alliance (2015). BRACED Community Resilience Assessment & Action Handbook. Available at: http://www.braced.org/contentAsset/raw-data/127f0e24-a44a-4468-abca-96db853f6558/attachmentFile.

Ministry of Natural Resources and Environment of Lao PDR (2016). Community-Based Disaster Risk Reduction Manual in Lao PDR. Available at: http://www.adpc.net/igo/category/ID1020/doc/2016-mQHt38-ADPC-CBDRR_Manual_Lao_PDR_.pdf.

B. Developing current vulnerability index

Proposed methodology for computing current vulnerability index:

- List measurable indicators that correspond to key factors of risk and vulnerability to climate change and hazards (see Table A1)

Table A1 Sample list of indicators for measuring vulnerability

Component	Sample list of indicators
Exposure to hazards	Exposure to floods Exposure to drought Exposure to strong winds Exposure to storm surge and salinization due to sea level rise Exposure to cyclone
Ecosystem	Access to drinking water Access to irrigation water Quality of forest Share of rain-fed agricultural production in the total agricultural output Crops production diversification Land productivity/soil quality
Socio-economic	Level of education completed Income per capita Labour-force participation rate Income dependency on agriculture or fisheries Population density
Infrastructure	Type of household units Access to basic services Access to transportation Access to cyclone shelters Access to protection shelters Water infrastructure and level of diversification of sources of drinking water Energy infrastructure and level of diversification of sources of energy

- Choose two to four variables to measure exposure to hazards and each component of vulnerability (ecosystem, socio-economic and infrastructure). Select the most relevant indicators and ensure that data is available and accessible.
- Collect data and develop spreadsheet table using available computer software (e.g. Microsoft Excel). The first column should contain list of towns/villages/human settlements in the selected township. The rows should contain data on the selected indicators.

- Group the data values of each variable into four categories: 1 to measure the lowest and 4 the highest level of vulnerability conditioned by the respective variable (see Table A2).

Table A2 Example: Categorizing variables [8]

(i) Ecosystems indicators

	I1. Access to drinking water	*I2. Quality of the forest*	*I3. Access to irrigation water*
1	*50% HHs having access to surface water and 50% having access to groundwater*		*50% HHs having access to surface water and 50% having access to groundwater.*
2	*0-25% HHs having access to surface water*		*0-25% HHs having access to surface water*
3	*50-75% HHs having access to surface water*		*50-75% HHs having access to surface water*
4	*75-100% HHs having access to surface water*		*75-100% HHs having access to surface water*

(ii) Socio-economic indicators

	I1. Level of education completed	*I2. Income per capita*	*I3. Labour force participation rate*
1	*75-100% population 25 years and over with high school, diploma or vocational training completed*	*Labutta town is the main trade centre*	*75-100% labour force participation rate population 10 years and over*
2	*50-75% population 25 years and over with high school, diploma or vocational training completed*	*Northern area is a mix of agri and industry*	*50-75% labour force participation rate population 10 years and over*
3	*25-50% population 25 years and over with high school, diploma or vocational training completed*	*Next lowest incomes are in fisheries, which we assume dominates in the coast*	*25-50% labour force participation rate population 10 years and over*
4	*0-25% population 25 years and over with high school, diploma or vocational training completed*	*Lowest incomes in agriculture, which is the dominant livelihood in the central area*	*0-25% labour force participation rate population 10 years and over*

(iii) Infrastructure indicators

	I1. Type of housing units	*I2. Access to transport services*	*I3. Access to cyclone shelters*
1	*0-25% houses built with local materials*	*75-100% households having transport items*	*0-25% population uncovered*
2	*25-50% houses built with local materials*	*50-75% household having transport items*	*25-50% population uncovered*
3	*50-75% houses built with local materials*	*25-50% household having transport items*	*50-75% population uncovered*
4	*75-100% houses built with local materials*	*0-25% household having transport items*	*75-100% population uncovered*

(iv) Exposure indicators

Sea level rise

[8] Extracted from: Fee, L. et al., 2017(a) (forthcoming)

Annex I – B: Vulnerability index

	Storm surge	Salinization
0	Northern and central areas	
1	Coastal Areas	Northern areas
2		Central areas
3		Coastal areas
4		

Intense rainfall

	Flooding
0	
1	Northern areas
2	Central and coastal areas
3	
4	

Increase in temperature

	Cyclone	Drought/ Heat Waves
0		
1		All areas
2		
3		
4	All areas	

- The information can then be analysed using various software tools. Current vulnerability index for each town/village could be generated using the following formula:

Vulnerability Index = ∑ (ecosystem, socio-economic, infrastructure values) x ∑ (exposure values)

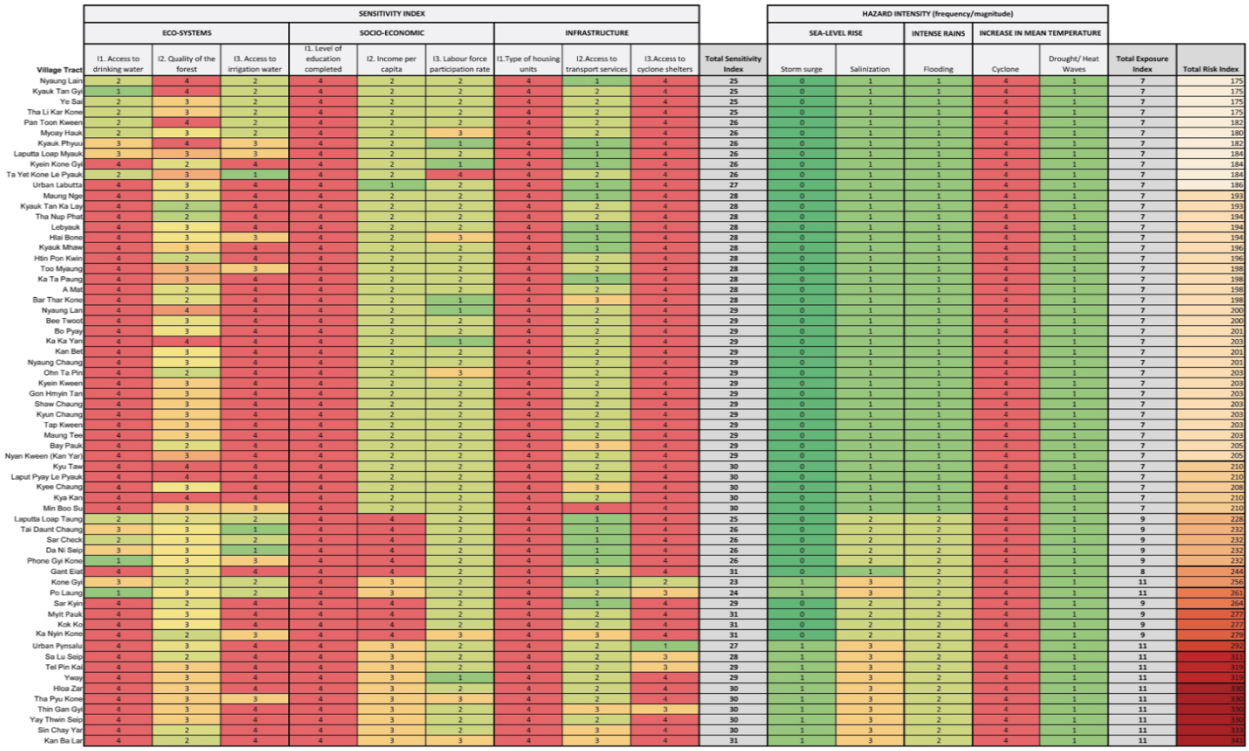
Note: 'Value' refers to number of category (1,2,3 and 4 as shown in Table A2).

Example:

Refer to Table A2. Assume that: (i) village A is located in the coastal area (i.e. vulnerability to flooding category 2); (ii) 50-75% of the households have access to surface water (vulnerability category 3); (iii) only 0-25% of the population have completed education (vulnerability category 4); and (iv) 50-75% of the houses are built with local materials and hence are not climate resilient (vulnerability category 3).

Vulnerability Index for village A = (3+4+3) x 2=20

- After calculating vulnerability index for each town/village, ranking of the most vulnerable locations could be easily performed (Figure A1)



	SENSITIVITY INDEX										HAZARD INTENSITY (frequency/magnitude)						
	ECO-SYSTEMS			SOCIO-ECONOMIC			INFRASTRUCTURE				SEA-LEVEL RISE		INTENSE RAINS	INCREASE IN MEAN TEMPERATURE			
Village Tract	I1. Access to drinking water	I2. Quality of the forest	I3. Access to irrigation water	I1. Level of education completed	I2. Income per capita	I3. Labour force participation rate	I1.Type of housing units	I2.Access to transport services	I3.Access to cyclone shelters	Total Sensitivity Index	Storm surge	Salinization	Flooding	Cyclone	Drought/ Heat Waves	Total Exposure Index	Total Risk Index
Nyaung Lain	2	4	2	4	2	2	4	1	4	25	0	1	1	4	1	7	175
Kyauk Tan Gyi	1	4	2	4	2	2	4	2	4	25	0	1	1	4	1	7	175
Ye Sai	2	3	2	4	2	2	4	2	4	25	0	1	1	4	1	7	175
Tha Li Kar Kone	2	3	2	4	2	2	4	2	4	25	0	1	1	4	1	7	175
Pan Toon Kween	2	4	2	4	2	2	4	2	4	26	0	1	1	4	1	7	182
Myoay Hauk	2	3	2	4	2	3	4	2	4	26	0	1	1	4	1	7	180
Kyauk Phyau	3	4	3	4	2	1	4	1	4	26	0	1	1	4	1	7	182
Laputta Loap Myauk	3	3	3	4	2	2	4	1	4	26	0	1	1	4	1	7	184
Kyein Kone Gyi	4	2	4	4	2	1	4	1	4	26	0	1	1	4	1	7	184
Ta Yet Kone Le Pyauk	2	3	1	4	2	4	4	2	4	26	0	1	1	4	1	7	184
Urban Labutta	4	3	4	4	1	2	4	1	4	27	0	1	1	4	1	7	186
Maung Nge	4	3	4	4	2	2	4	1	4	28	0	1	1	4	1	7	193
Kyauk Tan Ka Lay	4	2	4	4	2	2	4	2	4	28	0	1	1	4	1	7	193
Tha Nup Phat	4	2	4	4	2	2	4	2	4	28	0	1	1	4	1	7	194
Lobyauk	4	3	4	4	2	2	4	1	4	28	0	1	1	4	1	7	194
Hlai Bone	4	3	3	4	2	3	4	1	4	28	0	1	1	4	1	7	194
Kyauk Mhaw	4	3	4	4	2	2	4	1	4	28	0	1	1	4	1	7	196
Htin Pon Kwin	4	2	4	4	2	2	4	2	4	28	0	1	1	4	1	7	196
Too Myaung	4	3	3	4	2	2	4	2	4	28	0	1	1	4	1	7	198
Ka Ta Paung	4	3	4	4	2	2	4	1	4	28	0	1	1	4	1	7	198
A Mat	4	2	4	4	2	2	4	2	4	28	0	1	1	4	1	7	198
Bar Thar Kone	4	2	4	4	2	1	4	3	4	28	0	1	1	4	1	7	198
Nyaung Lan	4	4	4	4	2	1	4	2	4	29	0	1	1	4	1	7	200
Bee Twoot	4	3	4	4	2	2	4	2	4	29	0	1	1	4	1	7	200
Bo Pyay	4	3	4	4	2	2	4	2	4	29	0	1	1	4	1	7	201
Ka Ka Yan	4	4	4	4	2	1	4	2	4	29	0	1	1	4	1	7	203
Kan Bet	4	3	4	4	2	2	4	2	4	29	0	1	1	4	1	7	201
Nyaung Chaung	4	3	4	4	2	2	4	2	4	29	0	1	1	4	1	7	201
Ohn Ta Pin	4	2	4	4	2	3	4	2	4	29	0	1	1	4	1	7	203
Kyein Kween	4	3	4	4	2	2	4	2	4	29	0	1	1	4	1	7	203
Gon Hmyin Tan	4	3	4	4	2	2	4	2	4	29	0	1	1	4	1	7	203
Shaw Chaung	4	3	4	4	2	2	4	2	4	29	0	1	1	4	1	7	203
Kyun Chaung	4	3	4	4	2	2	4	2	4	29	0	1	1	4	1	7	203
Tap Kween	4	3	4	4	2	2	4	2	4	29	0	1	1	4	1	7	203
Maung Tee	4	3	4	4	2	2	4	2	4	29	0	1	1	4	1	7	203
Bay Pauk	4	2	4	4	2	2	4	3	4	29	0	1	1	4	1	7	205
Nyan Kween (Kan Yar)	4	3	4	4	2	2	4	2	4	29	0	1	1	4	1	7	205
Kyu Taw	4	4	4	4	2	2	4	2	4	30	0	1	1	4	1	7	210
Laput Pyay Le Pyauk	4	4	4	4	2	2	4	2	4	30	0	1	1	4	1	7	210
Kyee Chaung	4	3	4	4	2	2	4	3	4	30	0	1	1	4	1	7	208
Kya Kan	4	4	4	4	2	2	4	2	4	30	0	1	1	4	1	7	210
Min Boo Su	4	3	3	4	2	2	4	4	4	30	0	1	1	4	1	7	210
Laputta Loap Taung	2	2	2	4	4	2	4	1	4	25	0	2	2	4	1	9	228
Tai Daunt Chaung	3	3	1	4	4	2	4	1	4	26	0	2	2	4	1	9	232
Sar Check	2	3	2	4	4	2	4	1	4	26	0	2	2	4	1	9	232
Da Ni Seip	3	3	1	4	4	2	4	1	4	26	0	2	2	4	1	9	232
Phone Gyi Kone	1	3	3	4	4	2	4	1	4	26	0	2	2	4	1	9	232
Gant Eiat	4	3	4	4	4	2	4	2	4	31	0	1	2	4	1	8	244
Kone Gyi	3	2	2	4	3	2	4	1	2	23	1	3	2	4	1	11	256
Po Laung	1	3	2	4	3	2	4	2	3	24	1	3	2	4	1	11	263
Sar Kyin	4	2	4	4	4	2	4	1	4	29	0	2	2	4	1	9	264
Myit Pauk	4	3	4	4	4	2	4	2	4	31	0	2	2	4	1	9	277
Kok Ko	4	3	4	4	4	2	4	2	4	31	0	2	2	4	1	9	277
Ka Nyin Kone	4	2	3	4	4	3	4	3	4	31	0	2	2	4	1	9	279
Urban Pynsalu	4	3	4	4	3	2	4	2	1	27	1	3	2	4	1	11	292
Sa Lu Seip	4	2	4	4	3	2	4	2	3	28	1	3	2	4	1	11	312
Tel Pin Kai	4	3	4	4	3	2	4	2	3	29	1	3	2	4	1	11	315
Yway	4	3	4	4	3	1	4	2	4	29	1	3	2	4	1	11	319
Hloa Zar	4	3	4	4	3	2	4	2	4	30	1	3	2	4	1	11	330
Tha Pyu Kone	4	3	3	4	3	3	4	2	4	30	1	3	2	4	1	11	330
Thin Gan Gyi	4	3	4	4	3	2	4	3	3	30	1	3	2	4	1	11	330
Yay Thein Seip	4	3	4	4	3	2	4	2	4	30	1	3	2	4	1	11	330
Sin Chay Yar	4	2	4	4	3	2	4	3	4	30	1	3	2	4	1	11	330
Kan Ba Lar	4	2	4	4	3	3	4	3	4	31	1	3	2	4	1	11	341

Figure A1 Computation of current vulnerability index for Labutta Township[9]

[9] Extracted from: Fee, L. et al., 2017(a) (forthcoming)

C. Spatial analysis tools

C.1. Suggested list of maps and open sources of GIS data

ADMINISTRATIVE BOUNDARIES

Shapefiles	Source
Township boundaries	MIMU
Village tract boundaries with names	MIMU
Main settlements: towns, sub-villages	MIMU
Main roads/railway	MIMU
Hydrography (e.g. rivers, streams, canals, ocean)	MIMU

DEMOGRAPHY

Shapefiles	Source
Population/density	Census
Township boundaries	MIMU
Village tract boundaries with names	MIMU
Main settlements: towns, sub-villages	MIMU
Main roads/railway	MIMU
Hydrography (e.g. rivers, streams, canals, ocean)	MIMU

PHYSICAL CHARACTERISTICS

Topography

Shapefiles	Source
Digital elevation model	Landsat
Hydrography (e.g. rivers, streams, canals, ocean)	MIMU
Township boundaries	MIMU

Soil types

Shapefiles	Source
Soil Types	FAO
Township boundaries	MIMU

Forest

Shapefiles	Source
Type of forest (e.g. mangrove, scrubland, open forest)	Landsat
Change in forest 2002-2014	WWF
Hydrography (e.g. rivers, streams, canals, ocean)	MIMU
Main roads/railroad	MIMU
Main settlements: towns, sub-villages	MIMU
Village tract boundaries with names	MIMU
Township boundaries	MIMU

Normalized difference vegetation index (NDVI)

Shapefiles	Source
NDVI	Landsat
Main roads/railroad	MIMU
Main settlements: towns, sub-villages	MIMU
Village tract boundaries with names	MIMU
Township boundaries	MIMU

WATER

Superficial water

Shapefiles	Source
Watersheds	to be requested from the Ministry of Irrigation
Hydrography (e.g. rivers, streams, canals, ocean)	MIMU
Dams	WWF/township PDF map
Topography	Processed from digital elevated model
Main settlements: towns, sub-villages	MIMU
Township boundaries	MIMU

Groundwater

Shapefiles	Source
Aquifers	to be requested from the Ministry of Irrigation
Township boundaries	MIMU

Sources of water

Shapefiles	Source
Drinking water at HHS	Census
Non-drinking water	Census
Main settlements: towns, sub-villages	MIMU
Village tract boundaries with names	MIMU
Township boundaries	MIMU

ECONOMIC ACTIVITIES

Agriculture and livestock

Shapefiles	Source
Type of agriculture: rain fed /irrigated	Landsat
Livestock	Matrix of Functions
Type of Crops	Matrix of Functions
Hydrography (e.g. rivers, streams, canals, ocean)	MIMU
Main roads/railroad	MIMU
Main settlements: towns, sub-villages	MIMU
Village tract boundaries with names	MIMU
Township boundaries	MIMU

Fisheries and Aquaculture

Shapefiles	Source
Fisheries	to requested from township administration

Aquaculture	to requested from township administration
Hydrography (e.g. rivers, streams, canals, ocean)	MIMU
Main roads/railroad	MIMU
Main settlements: towns, sub-villages	MIMU
Village tract boundaries with names	MIMU
Township boundaries	MIMU

INFRASTRUCTURE

Public infrastructure and Basic Services

Shapefiles	Source
Township boundaries	MIMU
Village tract boundaries with names	MIMU
Main settlements: towns, sub-villages	MIMU
Roads by type /railway	MIMU
Hydrography (e.g. rivers, streams, canals, ocean)	MIMU
Telecommunication towers /Electricity lines and towers	Township PDF maps to requested from township administration
Health centres	Township PDF maps to requested from township administration
Schools	Township PDF maps to requested from township administration
Cyclone shelters	Township PDF maps to requested from township administration

Housing

Shapefiles	Source
Township boundaries	MIMU
Village tract boundaries with names	MIMU
Main settlements: towns, sub-villages	MIMU
Roads by type /railway	MIMU
Hydrography (e.g. rivers, streams, canals, ocean)	MIMU
Type of housing	Census

C.2. Matrix of Functions[10]

What is a Matrix of Functions?

MoF is used to identify and assess the relations amongst villages and urban wards in township. Furthermore, MoF describes: (i) which services and functions are available in each ward and the village tract of the township; (ii) what is the hierarchy and importance of these settlements one to another; (iii) where functions are missing; and (iv) how balanced the spatial development of the township is. Applied to climate change, it increases the understanding of how the current spatial structure of the township enables or inhibits the resilience of the area to the changes in climate. The

[10] Extracted from Annex A3 of Fee, L. et al., 2017(a) (forthcoming)

MoF is developed by collecting data with a simple questionnaire to determine where services are available. Key functions are listed, processed and mapped through GIS.

The assumption in this proposed assessment method, is that those human settlements where fewer functions are present are more vulnerable, and their vulnerability would be reduced by providing the services that are largely missing. At the township level, the method allows for visualising the linkages between villages such as the degree of dependency in terms of health or education services.

An analysis using the MoF produces a set of hypotheses and assumptions about the existing network of human settlements and its organisation by:

- Determining a preliminary functional hierarchy of human settlements, which provides a baseline of conditions within the region and establishes a hierarchy of settlements_(functional classification) based on its combination and diversity of physical infrastructure, social and economic activities located in them.
- Defining the current spatial structure of the township based on the "territorial influence" and socio- economic linkages between settlements.

How to develop MoF?

Step1: Filling the questionnaire

The analysis is based on the data collected at Village Tract (VT) level (basic administrative unit of reference that identify a human settlement) through the distribution of a questionnaire filled by village representatives for inventorying the presence or absence of 82 functions– as exhaustively as possible - existing services, activities, equipment and infrastructure - with an economic, administrative, social or cultural function - for each Village Tract and Ward (see the sample below).

Sample: Questionnaire for inventorying the functions in each Village Tract

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	1.6. Public Water Network on Grid (piped water) □.□ □□□□□□□□□□□□□□	
	1.7. Irrigation system □.□ □□□□□□□□□□ □□□□	
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□	4.7. Motor Vehicle Repair garage (motorbike /car) □.□ □□□□□□□□□/□□□□ □□□□□□□□□□□□□	
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[11] http://www.moh.gov.mm/file/HEALTH%20SERVICES%20IN%20MYANMAR.pdf

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Step 2: Matrix of functions production

The information collected through the survey enables planners and policy-makers to analyse the township's level of physical and socio-economic development.

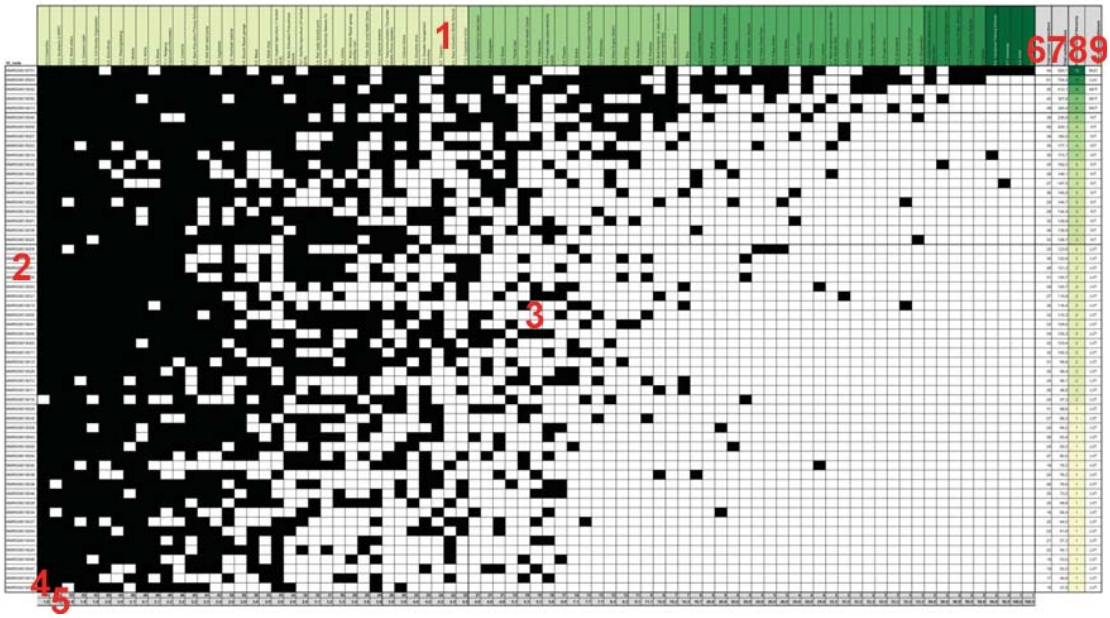

Figure C1 Organization of the Matrix of Functions

The data collected should be fed into an ordered matrix (e.g. Excel table) (Figure C1), where:

- The first column shows the "functions", ordered from left to right according to its frequency of presence;
- The first row shows the name of VT (Human Settlements), ordered from top to bottom as per the highest presence of functions in it;
- In the table (or matrix) itself, a black cell indicates the presence of the function (NB: not how many times the function is present, just if it is present or not – this is a normalised method), while a white cell indicates its absence in the VT concerned;
- The second-to-last row shows the "functions' frequency", i.e. the number of times that a given function is present in all the VT;
- The last row shows the "functions' weighted value", calculated by dividing 100 (the conventional total value of each function) with the frequency: thus, functions are assigned a weight in inverse proportion to the frequency with which they occur.
- The first column following the matrix itself (i.e. the black and white cells) shows the total number of existing functions for each VT;
- The third-to-last column shows the "total centrality score" calculated by adding the "weighted values" of the functions in as far as present in the row of the given VT;

- The second-to-last column shows the "condensed level of hierarchy" obtained by fixing a level whenever a big gap appears between one value of the centrality score and the next value;
- The last column shows the grouping and classification of the Village Tracts according to the following 6 typologies: Main Village Tracts (MVT), Intermediate Village Tracts (IVT), Local Village Tracts (LVT); Main Urban Centres (MUC). Intermediate Urban Centre (IUC) and Local Urban Centre (LUC)

How to develop an ordered matrix?

Sum the number of times a function occurs, which is the **function frequency**, and by convention divides by 100 to obtain the **function weight**. Hence, basic functions which occur often, obtain a low weight and rare central functions obtain a high weight. Therefore, each black square in the matrix (Figure C1 and Figure C2) represents a present function and has an associated weight. When the weights of all functions present in each administrative unit are summed, the **"centrality score"** emerges for each settlement. Then, after sorting by function weight and centrality score the **"ordered matrix"** is established. This ordered matrix is then interpreted to group basic, intermediate, and central settlements and determine a "set of functions" that should be covered considering the highest presence of a function for each category in the context of the region.

Considering *basic settlements* as the lowest level, an implicit assumption is that in a "*regular/standard distribution*" any higher hierarchical level should contain the number of functions of the precedent level(s) plus their own specific functions, hence the matrix allows to identifying settlements where functions are "missing" and whether functions of higher levels are present.

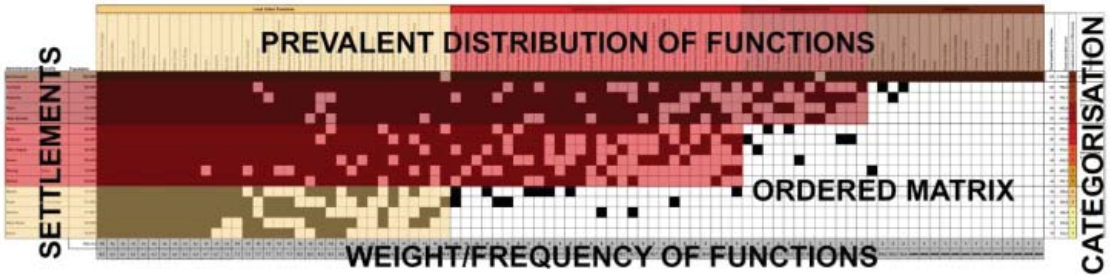

Figure C2 Example of a fictional ordered Matrix of Functions with four levels (colors) of centrality

In addition, a GIS mapping of the different typologies of settlements helps visualizing how balanced the spatial development of the region is, which, from the perspective of improving the urban settlements gives already some clear indications in terms of prioritization for preliminary needed investments in each settlement.

Step 3: Spatial analysis of the MoF

(i) Determining the preliminary functional hierarchy of human settlements

The analysis of the MoF allows to establish a functional hierarchy of settlements based on their "Total Centrality Score". Three types of Rural Village Tracts (local village tracts, intermediate village tracts and main village tracts) and two types of Urban Wards (local urban centre and main urban centre) are identified. Furthermore, a "set of functions" that should be covered is derived considering the highest presence of a function for each typology. Considering the Local Village Tract (LVT) as the basic level, an implicit assumption is that in a "regular/standard distribution" any higher hierarchical level contains the number of functions of the precedent level(s) plus their own specific functions.

Example: Typologies of Rural Village Tracts in Labutta Township

Type	Local village tract (LVT)
Centrality Score	38.97 – 118.73 Level of hierarchy 1 2
Level of development	Is considered the lowest level of infrastructure and socio-economic development, rain fed water and solar panels is the main energy source, while boats are the main mean of transportation. Only basic health and education coverage is provided, and the basic needs are provided through small groceries and street sellers. Agriculture is the main economic activity (mainly rice and vegetables) together with fishermen
Number and type of functions that should be covered	23 functions Eco-system services: Mangrove, Rice, Small streams, Roof/wall material (leaves), Vegetables, Livestock Infrastructure: Rain water harvest pond, Boat transport on daily basis (two ways same day), Private solar panel electricity supply, Unpaved roads Socio-economic services: Basic Education Primary Schools, Basic Education Post-Primary Schools, Midwife, Public Sub Rural Health Centre, Religious Organization/Monastery, Civil Society Organisation, Disaster management committee, NGOs, Carpenters, Fishermen, Street sellers, Weaving/sewing, Groceries shop
Type	Intermediate village tracts (IVT)
Centrality Score	131.39- 187.66 Level of hierarchy 3 4 5
Level of development	Is considered the second to the lowest level of infrastructure and socio-economic development. More transportation facilities, security services and industries (mainly aquaculture) are provided.
Number and type of functions that should be covered	33 functions (23 from previous category +10) Infrastructure: Port/Harbour, Cyclone Shelter, Boat transport every two days (one way per day) Socio-economic services: Kindergarten, Basic Education Middle Schools, Cultural Centre, Cooperative Union, Bicycle Repair garage, Plumbers, Aquaculture (Crabs / Shrimps)
Type	Main village tracts (MVT)
Centrality Score	219.01- 308.05 Level of hierarchy 6 7 8

Level of development	Is considered the highest level of rural settlements. Access to more public utilities and transportation infrastructure allows the presence of more types of economic activities
Number and type of functions that should be covered	50 functions (33 from previous category +17) Eco-system services: Rivers, Beans Infrastructure: Telecommunication Transmitter (Mobile Phone repeater), Paved road, Well with hand pump, Irrigation system, Petrol Supply Station, Bus transport on daily basis Socio-economic services: Basic Education High Schools, Public Rural Health Centre, Motor Vehicle Repair garage (motorbike /car), Salt production, Pharmacy, General Market, Fire Station, Police Check Point

Example: Typologies of Urban Wards in Labutta Township

Type	Local urban centres (LUC)			
Centrality Score	523.62	Level of	9 10	11
Level of development	Lowest level of urban settlement. Presence of more types of markets and specialised own account workers.			
Number and type of functions that should be covered	61 functions (50 from previous category +11) Eco-system services: Flowers, Wood for charcoal Infrastructure: Storm water drainage system Socio-economic services: Private Clinic, Public Station Hospital, Fish market, Post office, Police Station, Electricians, Livestock Market, Lawyers			
Type	Main urban centres (MUC)			
Centrality Score	835.17	Level of hierarchy	15	
Level of development	Highest level of physical and socio-economic development, covering the highest number of functions and the most unique ones across the Township.			
Functional complexity	72 functions (61 from previous category +11) Eco-system services: Maize, Groundnuts Infrastructure: Bus Station, Public Electricity Network On Grid, Radio station Socio-economic services: Public Township Hospital, Dentist, Accountants, Banks/ western union, Hotel, Eye specialist			

(ii) Mapping the typologies of village tracts

This could help visualising the spatial distribution of the levels of infrastructure and socio-economic development of the township.

Example from Labutta Township (see Figure C3)

Mapping of the type of settlements in Labutta Township revealed that:

- More than 70 per cent of the village tracts are classified as local village tracts (LVT), providing only basic health and education services and some basic needs;

- Intermediate village tracts (IVT) are mainly located along the water canals and the main road linking Labutta to Myaugnmya which allows the presence of higher range of cultural and security services and some industries (mainly aquaculture);
- Main village tracts (MVT), located surrounding Labutta town and Pyinsalu town and in the central area, have access to more public utilities and transportation infrastructure which allows the presence of more types of economic activities;
- Pyinsalu Town has the highest level of physical and socio-economic development in the southern area, with more types of markets and specialised own account workers;
- Labutta Town is the main urban centre, covering the highest number of functions and the most unique ones across the Township.
- The assumption, in this assessment, is that human settlements that have fewer functions available are more vulnerable, and their vulnerability would be reduced by providing the services that are largely missing. Eastern areas of the township are the most vulnerable to climate change and hazards.

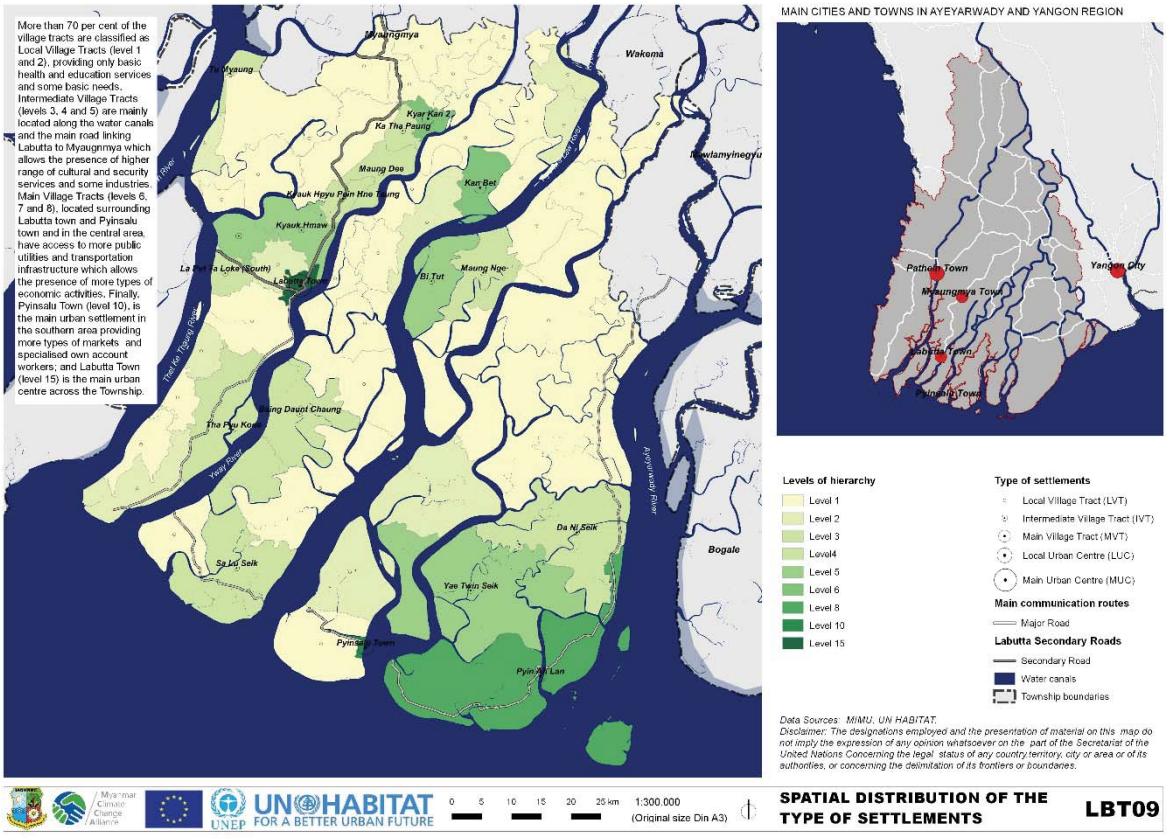

Figure C3 Spatial distribution of the type of settlements in Labutta Township

(iii) Defining the current spatial structure of the township

Under a regional planning perspective, where a region is not only a system of functionally diversified settlements but also a network of social, economic, and physical interactions, the analysis of the spatial linkages among the Village Tracts and Wards helps to, for example, determine the degree of dependency in terms of health or education services.

A cartographic representation of the "condensed levels of hierarchy" (levels of centrality of each settlement) by using isopleths[12] allows for: (i) visualising the level of "territorial influence" (or not) of each Village Tract over its neighbouring Village Tracts at Township and Regional level; and, (ii) identifying "clusters" of settlements (or areas of concentration of settlements), which are strongly interconnected and work cooperatively in terms of socio-economic activities.

The map can be drawn by hand or mapped in GIS (Figure C4). From the isopleth map the spatial structure emerges. It visualizes the "territorial linkages" of each settlement and identifies "clusters" of settlements (or areas of concentration of urban settlements) which are strongly interconnected and work cooperatively in terms of socio-economic activities. Under the strategy of socio-economic complementarity, the analysis of the existing and missing functions in the settlements within these "clusters", helps to define priority investments for clustering services and facilities, considering the proposed regional settlement system, the distribution of functions among settlements and the settlement hierarchy.

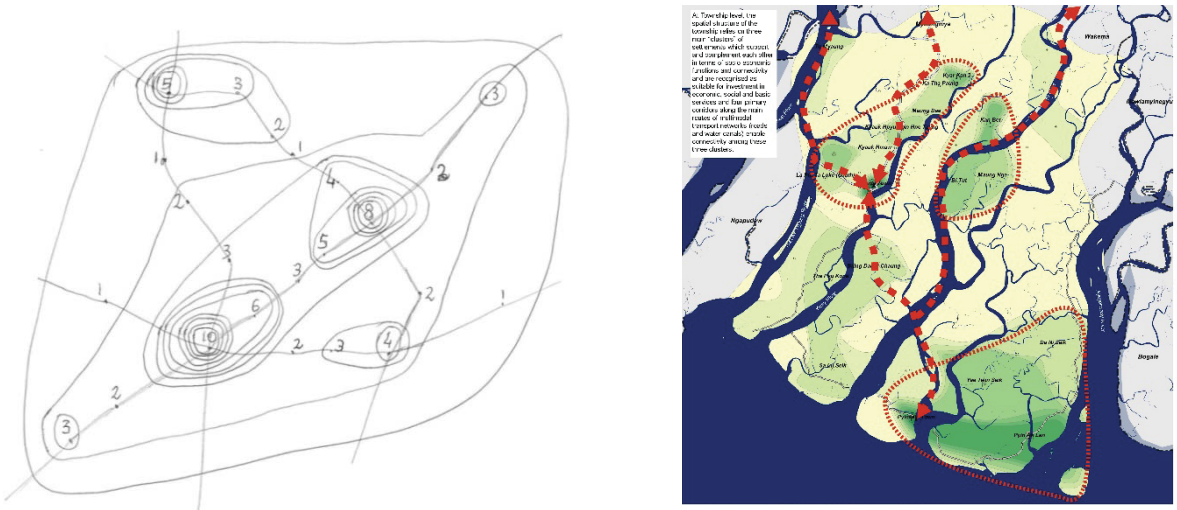

Figure C4. Examples of isopleth map (left is fictional and right from Myanmar). Each isopleth represents a level in the centrality index. The higher the number isopleths around a settlement, the more central it is. The axes represent the road network.

Example from Labutta Township (see Figure C5)

According to vulnerability assessment results, the current spatial structure of Labutta township relies on:

- At regional level, Myaungmya provides main socio-economic functions to the northern area of the township, while Pathein provides the highest level of education and health facilities and represents the main market for the agricultural products and provisioning needs of the township
- At township, three main "Clusters" of settlements or priority areas of economic, social and basic services development, composed of a network of human settlements which support and

[12] NB: In meteorology, an isopleth indicates a geographical line connecting points showing an equal level of incidence of a specific meteorological feature. In the case of the MoF, the term is used to indicate a geographical line representing a specific condensed level of hierarchy.

complement each other in terms of socio-economic functions and road connectivity and are recognised as suitable for investment in economic, social and basic services.

- Four Primary Corridors along main (existing and proposed) routes of multimodal transport networks which enable connectivity among the "Clusters" of settlements and/or human settlements adjoining townships and regions. Labutta Town is well connected with Pathein through the main paved road and the Thet Ke Thaung river, while Pyinsalu's main transportation route to Labutta is through the Pya Ma Law and Yway rivers and to Kan Bet and further Wakema Township and Yangon through Pya Ma Law river. These corridors remain crucial to support the economy of the southern areas of the township.

Location	North western area		
Territorial Influence	The "territorial influence" of Labutta Town, considered the main urban and trade centre of the township, is observed along the main road to Myangmya and along the secondary road to Laputta Loke (Thet Ke Thaung River).		
Village Tracts	Name	Level of hierarchy	Typology
	Labutta Town	15	MUC
	Kyar Kan	6	MVT
	Kyauk Hmaw	5	IVT
	La Put Ta Loke (North)	5	IVT
	Kyauk Hpyu Pein Hne Taung	4	IVT
	La Put Ta Loke (South)	3	IVT
	Ka Tha Paung	3	IVT
	Maung Dee	3	IVT
	Nyaung Lein	2	LVT
Total Population	62,327 inhabitants (20% of the total population of the		
Functional complexity	This "cluster" has the highest levels of physical development which allows the presence of more types of economic activities.		

Location	Southern area		
Territorial Influence	The "territorial influence" of Pynsalu Town, considered the main urban and trade centre of the southernmost part of the township, is observed toeards the west, along the secondary road to Pyn An Lah.		
Village Tracts	Name	Level of hierarchy	Typology
	Pyinsalu Town	10	LUC
	Pyin Ah Lan	8	MVT
	Yae Twin Seik	5	IVT
	Da Ni Seik	3	IVT
Total Population	24,907 inhabitants (8% of the total population of the township)		

Functional complexity	Despite Pyinsalu Town being the economic centre of this cluster, it only provides local markets (fish and livestock) and some specialised own account workers (lawyers and electricians), which, at township level, shows the economic dependency with Labutta Town. Pyin Ah Lan is the most important village tract in terms of health services (Station

Location	North-Central area		
Territorial Influence	Centred in Kan Bet includes the surrounding village tracts located at the centre of the township along the Pya Ma Law		
Village Tracts	Name	Level of	Typology
	Kan Bet	6	MVT
	Bi Tut	5	IVT
	Maung Nge	4	IVT
	Htin Pon Kwin	2	LVT
Total Population	26,409 inhabitants (9% of the total population of the township)		
Functional complexity	These four village tracts configure a cluster strategically located at the centre of the township, their access to more public utilities (wells and irrigation channels) and transportation infrastructure (paved road, harbour) allows higher yields and		

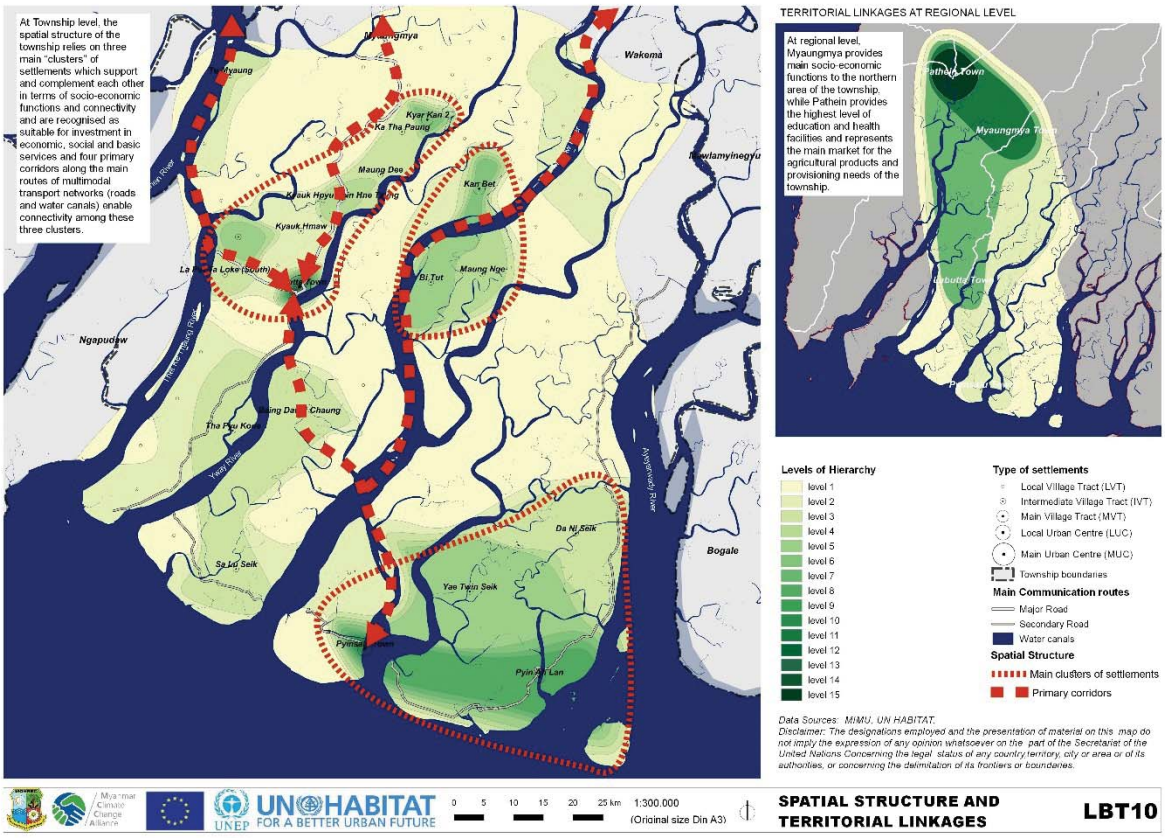

Figure C5 Spatial structure and territorial linkages of Labutta Township

D. Determination of coefficients of change under 'business-as-usual' scenario

This tool can be used to develop future vulnerability scenarios in GIS environment. The purpose of this method is to build scenarios *(not forecasts)* that show how given new climatic features will affect infrastructure, agriculture, and the economy.

The suggested method builds upon three key assumptions:

- ✓ First, that **no adaptive measures** will be taken (business-as-usual);
- ✓ Second, that **literature and experience used to develop assumptions for potential impacts of climate change in future on specific sectors are accurate**.
- ✓ Finally, all **projections are themselves built on future emission scenarios** such as the RCP 4.5 and 8.5. **Extreme scenarios should also be included in the analysis**, to ensure that planning considers the worst-case scenarios.

The methodology for determining coefficients of change under business-as-usual scenario is presented thought the case study of Labutta.

Example from Labutta (coastal area case study)[13]

The coefficients of change are based on the current trends and have been defined to show the worst future scenario in 2050, 'business-as-usual', that assumes no adaptation actions are taken. As such, they should be considered as the "estimated reduction" to 2016 baseline given the projected climate changes in temperature, rainfall and sea level rise.

The future vulnerabilities are determined by applying coefficients of change to the current capacities of the people of Labutta to benefit from:

- Agriculture
- Freshwater resources
- Forestry resources
- Transport services
- Livelihoods

Capacity of the population to benefit from agriculture

The capacity of the population to benefit from agriculture relies mainly on three eco-systems services: freshwater, soil and crops. The future scenario in 2050, is estimated by applying a coefficient of reduction on 2016's baseline, which will result in lower soil productivity, lower yields and more frequent damaged crops.

▪ Assumptions

[13] Extracted from Annex A4 of Fee, L. et al., 2017(a) (forthcoming)

- *The percentage of employed people working in agriculture in 20162 is proportional to the number of people who depend on rice production*
- *The observed impacts and trends will continue and no adaptive measure has been considered*

▪ *Coefficient of Climate Change (based on current trends)*

CC Rice production= 30% decline in rain-fed areas and 15% in irrigated areas

SE ASIA CROP MODELLING (2016): includes rainfall and temperature

CC Salinization= 8% decline in rain fed areas

CC Hazard recurrence= 10%

DELTA STRESS: Since 1970, nine cyclonic storms have impacted Myanmar; about one every three years on average.

▪ Calculations

(i) Population depending on agriculture in 2016 = 80% of the total population in each VT (Census 2014)

*(ii) Population depending on agriculture in 2050 = (i) – [(i)*0.30 (CC rice production) + (i)*0.08 (CC salinization)+ (i)*0,1 (CC hazard recurrence)*

	AREA AND TYPE OF AGRICULTURE		POPULATION DEPENDING ON AGRICULTURE	COEFFICIENTS OF CLIMATE CHANGE			POPULATION DEPENDING ON AGRICULTURE
Village Tract Code	Area	Type of irrigation	2016	Rice production	Salinization	Hazard recurrence	2050
MMR017016001	Northern area	Rainfed Agriculture	4704	0,3	0,08	0,1	2446
MMR017016002	Northern area	Rainfed Agriculture	3041	0,3	0,08	0,1	1581
MMR017016003	Northern area	Irrigated Agriculture	2170	0,3		0,1	1302
MMR017016004	Central area	Rainfed Agriculture	2412	0,3	0,08	0,1	1254
MMR017016005	Central area	Rainfed Agriculture	4432	0,3	0,08	0,1	2305
MMR017016006	Central area	Rainfed Agriculture	2683	0,3	0,08	0,1	1395
MMR017016007	Northern area	Rainfed Agriculture	2765	0,3	0,08	0,1	1438
MMR017016008	Northern area	Rainfed Agriculture	1884	0,3	0,08	0,1	980
MMR017016009	Northern area	Rainfed Agriculture	2358	0,3	0,08	0,1	1226
MMR017016010	Northern area	Irrigated Agriculture	3947	0,3		0,1	2368
MMR017016011	Northern area	Irrigated Agriculture	6439	0,3		0,1	3864
MMR017016012	Northern area	Rainfed Agriculture	3547	0,3	0,08	0,1	1845
MMR017016014	Northern area	Rainfed Agriculture	3130	0,3	0,08	0,1	1627

Capacity of the population to have access to freshwater sources for drinking use

The capacity of the population to access surface freshwater sources for drinking in 2050, if no adaptive measure is considered, is calculated by applying a coefficient of impact on 2016's baseline given the changes in temperature, sea level-rise and rainfall, which will result in salinization of freshwater sources in coastal areas and central areas, more evaporation of water from uncovered sources across the township and damaged water facilities for longer periods across the township.

▪ Assumptions

- *The percentage of people having access to drinking water from census 2014 remains the same in 2016*
- *The observed impacts and trends will continue and no adaptive measure has been considered*

▪ Coefficient of Climate Change (based on current trends)

The following coefficients are spatially based considering the observed impacts and trends to estimate the worst future scenario to identify the most vulnerable areas of the township to maintain and support current living standards assessed in 2016.

CC Salinization= 90% decline in coastal and 50% central areas

Strong tidal and storm surges create large-scale intrusion events, salinizing drinking water supplies, inundating fields, rivers and streams with saline water. Sea-level rise coupled with increased upstream water use could increase the geographic extent of saltwater intrusion (DELTA STRESS)

CC Evaporation= 25% decline in all areas

Regardless of the quantity of water available increased temperatures will increase evaporation rates, raising the concentration of dissolved salts in the water often deeming it unsuitable for drinking purposes (Ministry of Agriculture and Irrigation, 2012, DELTA ALLIANCE)

CC Floods= 20% decline in coastal areas and 10% decline in central and northern areas

The late onset and early withdrawal of the monsoon period will result in large quantities of rain falling over short periods. This will result in flooding, contamination of water resources, erosion and limited replenishment of waterways (DELTA ALLIANCE)

▪ Calculations

(i) Households having access to drinking water in 2016 from surface freshwater sources = total number of HHs having access to "ponds, river, streams and waterfalls" per census 2014 in VT

*(ii) Households having access to drinking water in 2050 from surface freshwater sources in coastal areas= (i) –[(i)*0.90 (CC Salinization)+(i)*0.25 (CC evaporation) + (i)*0.20 (CC floods)]*

*(iii) Households having access to drinking water in 2050 from surface freshwater sources in central areas= (i) –[(i)*0.50 (CC Salinization)+(i)*0.25 (CC evaporation) + (i)*0.10 (CC floods)]*

*(iv) Households having access to drinking water in 2050 from surface freshwater sources in northern areas= (i) –[(i)*0.25 (CC evaporation) + (i)*0.10 (CC floods)]*

(v) Households having access to drinking water in 2050 from surface freshwater sources= (ii)+(iii)+(iv)

Village Tract Code	LOCATION	NUMBER OF HHs HAVING ACCESS TO DRINKING WATER	COEFFICIENTS OF CLIMATE CHANGE			NUMBER OF HHs HAVING ACCESS TO DRINKING WATER
	Area	2016	Salinization	Evaporation	Floods	2050
MMR017016001	Northern area	1303		0,25	0,1	847
MMR017016002	Northern area	326		0,25	0,1	212
MMR017016003	Northern area	491		0,25	0,1	319
MMR017016004	Central area	322	0,5	0,25	0,1	48
MMR017016005	Central area	1274	0,5	0,25	0,1	191
MMR017016006	Central area	891	0,5	0,25	0,1	134
MMR017016007	Northern area	902		0,25	0,1	586
MMR017016008	Northern area	622		0,25	0,1	404
MMR017016009	Northern area	715		0,25	0,1	465

Mangrove coverage

The quality of mangrove forest in 2050, if no adaptive measure is considered, is calculated by considering the quality of forest in 2016 will worsen, given the deforestation trends, due to human activities such as wood harvesting and coastal development (paddy fields and shrimp/fish ponds); the changes in temperature, sea level-rise and rainfall, which result loss of land destroying the mangrove cover and the coastal protection provided. In addition, stronger storms and large quantities of rain falling over short periods will result in flooding and erosion of soils.

▪ Assumptions

- *Intact forest areas in 2016 become degraded forest areas in 2050*
- *Degraded forest areas in 2016 become deforested areas in 2050*

▪ Coefficient of Climate Change (based on current trends)

The following coefficients are spatially based considering the observed impacts and trends to estimate the worst future scenario to identify the most vulnerable areas of the township to maintain and support current living standards assessed in 2016.

CC Deforestation

Mangrove forests have been cleared and substantially degraded since the late 1970s, losing 64% of their total area between 1978 and 2011 as agriculture—and specifically paddy rice—has expanded to be the dominant land use. This corresponds to an average deforestation rate of 51km2 (3%) per year, which would lead to total mangrove loss by as early as 2019 in a worst scenario.

▪ Calculations

(i) Area of Intact forest in 2016 = total hectares of intact mangrove in each village tract in 2016

(ii) Area of Degraded mangrove in 2016 = total hectares of degraded mangrove in each village tract in 2016

(iii) Area of Deforested mangrove in 2016 = total hectares of intact mangrove in each village tract in 2016

(iv) Area of Degraded mangrove in 2050= (i)

(v) Area of Deforested mangrove in 2016 = (ii)+(iii)

Village Tract code	LOCATION	MANGROVES			
	Area	2016		2050	
		Quality of forest	Area (ha)	Quality of forest	Area (ha)
MMR017016000	Northern area	Intact forest	23,43	Degraded forest	23,43
		Degraded forest	1987,54	Deforested forest	2144,51
		Deforested forest	156,97		
MMR017016001	Northern area	Intact forest	4,85	Degraded forest	4,85
		Degraded forest	56,69	Deforested forest	79,08
		Deforested forest	22,39		
MMR017016002	Northern area	Degraded forest	41,84	Deforested forest	41,84

Capacity of the population to have access to transportation services

Population's mobility in 2050 is estimated to be reduced specially in coastal and central areas, where the projected sea-level rise will result in loss of land destroying the vegetation cover, especially mangroves, and the coastal protection provided. In addition, stronger storms and large quantities of rain falling over short periods will result in flooding and erosion of soils. This will damage the already underdeveloped transport infrastructure for longer period of time reducing the percentage of households possessing transportation assets (vehicles, canoes,..) being able to use them.

▪ Assumptions

- *The number of people having access to transportation services in 2016, is calculated by assuming that the percentage of households possessing transportation assets (vehicles, canoes...) is able to use the current system of transportation (roads and water facilities) as a result of the protection provided by the vegetation cover and type of soils.*
- *The observed impacts and trends will continue and no adaptive measure has been considered*

▪ Coefficient of Climate Change (based on current trends)

The following coefficients are spatially based considering the observed impacts and trends to estimate the worst future scenario to identify the most vulnerable areas of the township to maintain and support current living standards assessed in 2016.

CCC inundation: *90% decline in coastal areas*

Sea-level rise of 40cm in 2050 results in loss of some secondary and tertiary roads in coastal areas reducing 90 per cent (0.90) the use of land transport items (cars, motorbikes...).

CCC cyclone and strong winds: 50% decline in coastal areas and 25% in central areas

More frequent cyclones and stronger winds during the period from 2014 to 2050 results in destruction of bridges and jetties reducing by half (0.50) the use of all transport items in coastal areas and by a quarter (0.25) in central areas.

CCC floods: 10% decline in all areas

More intense rains result in roads and bridges reducing by 10 per cent (0,10) the use of transport items across the township in 2050

▪ Calculations

(i) Households having land transportation items in 2016 (Number)= total number of HHs having "car, motorcycle, bicycle and cart" per census 2014 in each VT

(ii) Households having water transportation items in 2016 (Number)= total number of HHs having access to "canoe/boat and motor boat" per census 2014 in each VT

(iii) Total number of households having transportation items in 2016= (i) +(ii)

*(iv) Households using transportation items in 2050 in coastal areas (Number) = (iii) – [(i)*0.50 (CCC inundation) +(iii)*0.50 (CCC cyclone and strong winds) + (iii)*0.10 (CCC floods)4*

*(v) Households using transportation in 2050 in central areas (Number) = (iii)*0.25 (CCC cyclone and strong winds) + (iii)*0.10 (CCC floods)5*

*(vi) Households using transportation in 2050 in northern areas (Number) = (iii)*0.10 (CCC floods)6*

(vii) Total number of households using transportation in 2050 = (iv)+(v)+(vi)

	LOCATION	NUMBER OF HHs USING TRANSPORT ITEMS	COEFFICIENTS OF CLIMATE CHANGE			NUMBER OF HHs USING TRANSPORT ITEMS
Village Tract Code	Area	2016	Inundation	Cyclone and strong winds	Floods	2050
MMR017016001	Northern area	1173			0,1	1086
MMR017016002	Northern area	785			0,1	713
MMR017016003	Northern area	693			0,1	637
MMR017016004	Central area	814		0,25	0,1	544
MMR017016005	Central area	1173		0,25	0,1	795
MMR017016006	Central area	374		0,25	0,1	272
MMR017016007	Northern area	475			0,1	465

Annex II. Climate change in Myanmar: key indicators, observed trends and future projections

Note: the information in this section is summarized from: Horton R. et al., 2016; MNREC, 2017; MNREC, 2012(b). For full references, go to Reference section above.

II.1 Climate change indicators: observed and projected trends, and vulnerable regions

Climate change and hazard	Vulnerable regions
Climate change indicators: · Increasing mean seasonal and annual temperatures · Increase in daily maximum temperatures and number of hot days, more frequent heat waves · Shorter monsoons · Erratic rainfall patterns – increasing rainfall intensity (especially during the wet season) and decreasing number of rainy days	· All regions
Drought, extreme high temperature/heat waves	· Arid and semi-arid central belt of the country · The Central Dry Zone
Intense rains, river and flash floods	· The Northern Hilly Region, mountainous and hilly areas in Kayin, Kachin, Shan, Mon and Chin states · The Central Dry Zone · The Ayeyarwady Delta and low-lying coastal areas · Upper reaches of river systems and low-lying areas along major river systems
Sea level rise and increasing risk of coastal hazards (flooding, storm surges, strong winds, cyclones)	· Coastal areas mainly Rakhine State, the Ayeyarwady Delta, and Mon State

II.2 Observed increase per decade in daily average temperatures, daily maximum temperatures, and precipitation over the period 1981 to 2010

	Temperatures	Maximum temperatures	Precipitation
Myanmar (average)	**0.25°C**	**0.40°C**	-
Inland areas	0.35°C	0.57°C	2.5%
Coastal areas	0.14°C	0.23°C	4.5%

II.3 Projected increase in mean annual temperature in 2011-2040 and 2041-2070 compared to the 1980-2005 average

Region	2011-2040		2041-2070	
Myanmar (All Regions)	**0.7°C**	**to 1.1°C**	**1.3°C**	**to 2.7°C**
Ayeyarwady Delta	0.5°C	to 0.9°C	1.1°C	to 2.1°C
Central Dry Zone	0.7°C	to 1.1°C	1.2°C	to 2.7°C
Northern Hilly	0.7°C	to 1.2°C	1.4°C	to 2.8°C
Rakhine Coastal	0.7°C	to 0.9°C	1.2°C	to 2.4°C
Eastern Hilly	0.7°C	to 1.2°C	1.4°C	to 2.8°C
Southern Coastal	0.6°C	to 1.0°C	1.1°C	to 2.4°C
Yangon Deltaic	0.6°C	to 1.0°C	1.2°C	to 2.4°C
Southern Interior	0.7°C	to 1.1°C	1.3°C	to 2.6°C

II.4 Projected change in mean annual precipitation in the 2011-2040 and 2041-2070 compared to the 1980-2005 average

Region	2011-2040		2041-2070	
Myanmar (All Regions)	**+1%**	**to +11%**	**+6%**	**to +23%**
Ayeyarwady Delta	-1%	to +11%	+3%	to +23%
Central Dry Zone	+2%	to +11%	+8%	to +22%
Northern Hilly	+2%	to +13%	+7%	to +27%
Rakhine Coastal	0%	to +9%	+5%	to +20%
Eastern Hilly	0%	to +10%	+7%	to +24%
Southern Coastal	-1%	to +8%	+3%	to +16%
Yangon Deltaic	0%	to +12%	+5%	to +24%
Southern Interior	+1%	to +11%	+7%	to +25%

II.5 Projections of sea level rise above 2000-2004 base period levels in Myanmar

Timeline	Sea level rise
2020s	5 cm to 13 cm
2050s	20 cm to 41 cm
2080s	37 cm to 83 cm

Annex III. Potential impacts of climate change

Projected climatic changes and potential hazards	Potential impacts		
	Agriculture, natural resources and ecosystem services	**Human settlements, industry and infrastructure**	**Human health, well-being and security**
Increase in average temperatures, extreme heat events and droughts, changing/ shifting rainfall patterns	Direct impacts on crop productivity, especially in rain-fed areas Direct impacts to rain-fed rice production Increased incidences of plant pests and diseases Livestock health deterioration or death due to feed and water shortages, heat stress, and animal diseases Increased aridity and soil moisture loss due to evaporation, resulting in reduced productivity and erosion Increase in demand for irrigation (resulting in increasing pressure on water and land resources) Reduced water for irrigation due to decrease in water flows and increased evaporation Reduced ground- and surface water availability Increased risk of forest fires Increased concentration of dissolved salts in the water due to evaporation	Heat waves and urban heat island effect Disruptions to hydropower supply (consequent increase in wood harvesting) Increase in energy demand for cooling Increased water shortages in urban areas Higher air pollution levels in urban areas Reduced water availability for drinking and sanitation Impacts on local industries such as higher input prices (e.g. water, energy) and health decline of workers	Health risks as result of heat stress and dehydration, especially to elderly and pregnant women Cardiovascular system illness Emerging health risks due to reduced water availability for drinking and sanitation Disruption of school process due to heat waves or severe droughts

	Increased salinity concentrations in some aquifers, further limiting water availability Increased soil alkalinity primarily caused by using saline groundwater for irrigation, in turn reducing productivity Alteration of river flow, and consequent impacts to freshwater biodiversity Reduced nutrient and sediment deposition, which maintains healthy soils and provides nutrients to aquatic ecosystems and mangrove systems Reduced flood water retention, resulting from reduced soil moisture Ecosystem productivity declines as water availability for vegetation growth decreases Decline in marine biodiversity, caused by oceanic warming and acidification		
Intense rainfall and floods	Damage to crops due to severe inundation of land Flash floods, intense surface run-off and soil erosion, resulting in damage of crops Waterlogging and washing away of top soil and nutrients, resulting in decline of crop productivity Increased risk of	River floods, flash floods, and urban flooding, with direct loss of assets, houses and urban infrastructure Disturbance to river systems, making them more frequently impassable Destruction of roads and harbours/port facilities due to landslides in	Still water after flooding events conditions rise in vector-borne diseases such as malaria, filarial, dengue and other pathogens Rise in water-borne diseases such as diarrhoea, cholera and poisoning caused by biological and chemical contaminants in water Lack of clean water for

	landslides, resulting in destruction of agricultural lands Direct loss of seeds and grain stocks Direct loss of livestock Loss of vegetation as result of floods and landslides Contamination of water resources caused by river and flash floods Decreased groundwater flow and recharge, as most flows run-off downstream rather than recharging local aquifers	riverbank areas Siltation and sedimentation of waterways and dams, due to large-scale erosion processes Reduced water storage capacity of dams, as well as structural damages Damage to water storage and distribution facilities and infrastructure Damage to water infrastructure such as pumps, shallow dug wells and tube wells, irrigation systems, and storage ponds	drinking and sanitation and health consequences Affected/destroyed school buildings Decreased access to schools (e.g. blocked or destroyed roads)
Cyclones, strong winds	Direct loss of crops Direct loss of seed and grain stocks Soil erosion due to removal of surface layer of soils, resulting in decline of agricultural productivity Loss of coastal ecosystems due to strong cyclones, and consequent decline of fish and shrimp stocks Direct loss of livestock Direct loss of trees and plants	Damage to energy infrastructure (e.g. dams, electricity grid, gas pipelines, solar panels of households, etc.) Damage to water storage and distribution facilities and infrastructure Damage to water infrastructure such as pumps, shallow dug wells and tube wells, irrigation systems, and storage ponds Damages to road infrastructure, including bridges Loss/damage of assets, houses and urban infrastructure Damaged schools and public health infrastructure due to cyclones	Injuries and illness, loss of lives Social and mental stress from disaster and displacement Heightened risks to health and life for pregnant women, children, elderly and sick people, who have limited mobility Lack of clean water for drinking and sanitation and health consequences Displacement of people and communities

		Impacts on small-scale household production Damage to manufacturing and industrial facilities Direct loss of fishing boats Toxic spillage of hazardous materials, such as oil or gas	
Sea level rise, coastal erosion and storm surge	Permanent inundation of coastal areas, consequent loss of agricultural land Constraints to rice production due to saltwater intrusion Soil salinization resulting in reduced crop productivity Intrusion of salt water into groundwater systems, impacting irrigated agriculture Large-scale saline intrusion from strong tidal and storm surges, leading to salinization of land and water resources Destruction of coastal ecosystems and riverbanks Coastal ecosystems degradation, resulting in a decline of fish and shrimp stocks Deterioration of marine and coastal ecosystems and ecosystem services	Loss of assets, and impacts on infrastructure because of coastal erosion and storm surges Loss of assets, houses, and urban infrastructure due to permanent coastal inundation Impacts on local industries	Lack of clean water for consumption Displacement, increasing number of landless people, migration Conflicts over land and use of natural resources Decline in connectivity in coastal areas and the delta due to permanent coastal inundation and hence: · reduced access of small producers to markets and consequent loss of income · reduced access to work place, resulting in less job opportunities · reduced access to basic services such as hospitals, schools and shelters

Climate change – secondary and long-term consequences	Reduced agricultural productivity in a long-term Increasing human pressure on water, land and forest resources Lower productivity of ecosystems, resulting in decline of yield in agriculture and fisheries Desertification (resulting e.g. from intense rains following lengthier dry periods, which increases run-off rate and soil erosion; deforestation and heat stress) Loss of tree and plant species, and in turn reducing carbon storage and sequestration capacity	Higher prices of manufactured goods Disruption of trade and consequent loss of income Impacts on small-scale household production, such as textiles Increased maintenance and operational costs of dams Reduced access to water and hydropower energy especially in urban areas	Decreased household incomes and consequent food and income insecurity, and limited ability of families to cover school costs (leading to a decline in literacy rates) Low or negative economic growth, unemployment and migration Conflicts over land and use of natural resources Higher food, water and energy prices and consequent rise in the number of food, water and energy insecure households Loss of food and income security assets for rural households Health decline as result of high air and water pollution (e.g. respiratory ailments), reduced access to drinking water and food (malnutrition)

Annex IV. Proposed organisation of the vulnerability assessment report

Section	Content
Executive summary	Brief overview of purpose, objectives and methods of the assessment, and summary of main findings.
1. Introduction	The introductory chapter could set the background and clarify the objectives of the assessment. Brief description of the methodology and limitations of the analysis could also be highlighted.
2. Township profile	Overview of physical and environmental characteristics, socio-economic characteristics, infrastructure and connectivity profile, administration and governance
3. Current vulnerability to climate change and hazards	Overview of observed climate changes and analysis of factors of vulnerability Current vulnerability index Summary of current vulnerabilities: vulnerable sectors, social groups and locations
4. Future climate change risk	Overview of future climate change projections, potential impacts and future risk profile
5. Overall findings and outlook	Summary of findings and scenarios for 2050 Summary of potential adaptation options as identified through consultations (long list of adaptation options)
Annexes	Any relevant information such as list of communities included in consultations, survey questionnaires used to collect data, summary of statistical data used, etc.

Annex V. Sample of a formal letter for requesting Census 2014 data

Director General
Department of Population
Ministry of Immigration and Population

Subject: Request of disaggregated Census 2014 data for assessing vulnerability to climate change and disasters

Dear Director General,

As indicated in the Myanmar Climate Change Strategy and Aciton Plan 2016-2030, we are proceeding to develop local level plans on adaptation to climate change, and disaster risks mitigation. The methodology for these assessments includes studying basic socio-economic and infrastructure conditions, which are gathered in the Myanmar Census 2014. In this respect, we would like to request your support to access local Census data as follows:

- Information at the *village-tract/ward level* (as specified in the list attached) for the following townships: Pakokku and Laputta.
- At the *township level* for townships surrounding Pakokku in the Magway and Mandalay regions, (as specified in the list attached) and surrounding Laputta in the Ayeyarwaddy division.

This Census 2014 data (as specified in the annex to this letter) is to be obtained from the Department of Population under the Ministry of Immigration and Population

Hoping that you will be able to obtain this important information for the activity, please find attached a list of the data required. Please don't hesitate to contact me, should you need any further clarification.

Once again, I would like to thank you for your support.

Yours Sincerely,
(signature)

Annex. Data Requested at the Village Tract Level

Table number (as published in the census)	Description
	Series A – Demographic Characteristics
A-1	Population by household type, sex and sex ratio by urban and rural
A-2	Conventional households by sex of the head, per cent of female headed households, population by type of household and mean household size
A-3	Population by urban/rural and sex; sex ratio and per cent of population urban
A-4	Population by urban/rural, sex and single years of age
A-5	Population by urban/rural, sex and 5-year age groups
A-6	Population by selected age-groups and dependency ratios by urban and rural
A-7	Conventional households by size of the household
	Series B – Social Characteristics
B-1	Population in conventional households by relationship to the head of household and sex
B-2	Population in conventional households and institutions aged 10 years and over by marital status, 5-year age group and sex
B-3	Population aged 15 years and over by marital status, district, township and sex
	Series C – Migration
C-1	Former conventional household members living abroad by country of residence, district of reporting household and sex
C-2	Former conventional household members living abroad by country of residence, sex and duration of residence abroad
	Series D – Education
D-1	Population in conventional households 5 years and over, by sex, literacy and age group
D-2	Population in conventional households 15 years and over, by sex, literacy and urban/rural
D-4	Population in conventional households 5 - 29 years, by sex, school/college attendance
D-6a	Population 25 years and over by highest level of education completed and sex (both households and institutions)
	Series E: Economic Activity
E-1a	Population 10 years and over by usual activity status, labour-force participation rate, unemployment rate and employment to population ratio by sex and age group
E-1b	Population 10 years and over by usual activity status, labour-force participation rate, unemployment rate and employment to population ratio by sex and age group - urban
E-1c	Population 10 years and over by usual activity status, labour-force participation rate, unemployment rate and employment to population ratio by sex and age group – rural

E-2	Population 10 years and over by usual activity status and sex
	Series F – Births
F-1	Women in conventional households aged 15 - 54 by children ever born to ever-married women and children dead, by age of mother
F-2	Women in conventional households aged 15 - 49 by number of live births in the last 12 months for ever-married women and number of those newly-born who have died, by age of mother
	Series G – Identity Cards
G-1	Population 10 years and over by type of identity card and age group
G-2	Population 10 years and over by type of identity card and Urban/Rural
	Series H – Disability
H-1	Population in conventional households and institutions by disability prevalence rate, type of disability, sex and age group
H-2	Population (conventional households and institutions) by disability prevalence rate, type of disability and sex
	Series I – Housing Conditions
I-1	Conventional households by type of housing unit
I-2	Conventional households by type of ownership of housing unit
I-3	Conventional households by type of toilet
I-4a	Conventional households by main construction material for the roof
I-4b	Conventional households by main construction material for the external walls
I-4c	Conventional households by main construction material for the floors
	Series J – Household Amenities
J-1	Conventional households by main source of lighting
J-2	Conventional households by source of water for drinking
J-3	Conventional households by source of water for non-drinking use
J-4	Conventional households by main type of cooking fuel
J-5	Conventional households by availability of communication and related amenities
J-6	Conventional households by availability of transportation items

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