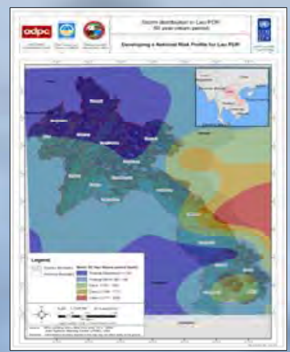
Lao People's Democratic Republic

Peace Independence Democracy Unity Prosperity

Lao PDR

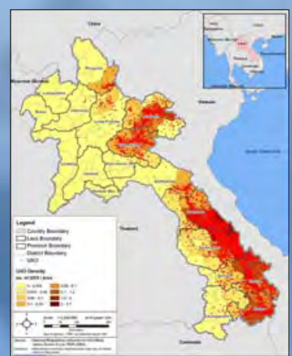
Drought

Storm



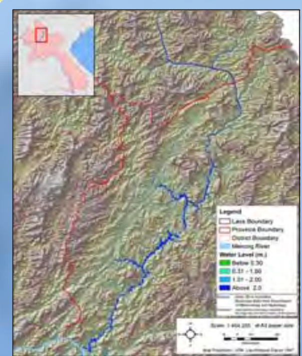
Landslide

UXO

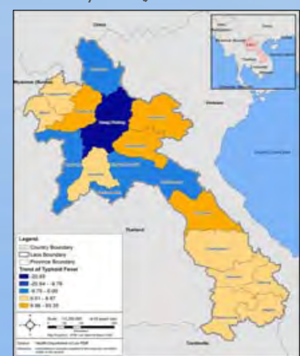


Earthquake

Flood



Epidemics



Developing a National Risk Profile of Lao PDR

Part 1: Hazard Assessment

2010

Lao People's Democratic Republic

Peace Independence Democracy Unity Prosperity

National Risk Profile of Lao PDR

November 2010

National Disaster Management Committee

Government of Lao PDR

United Nationals Development Programme (UNDP) Lao PDR

Technical support of ADPC and the Public Work and Transport Institute (PTI), Ministry of Public Works and Transport.

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The project team owes its deepest gratitude to the National Disaster Management Office (NDMO), Government of Lao PDR for its immense support during the implementation of this project. NDMO helped make this project possible by organizing several consultation workshops with national technical and development departments and agencies. The leading national technical departments and agencies provided full support throughout the development of the methodology for this project and throughout the project implementation in terms of data provision. The project team extends warm gratitude to the UNDP Lao PDR for providing the necessary financial support to implement this project and develop the national risk profile of Lao PDR. The project team is grateful to the Global Risk Identification Programme unit (GRIP) of BCPR, UNDP regional office Bangkok and Geneva for their technical support. This report will be one of the essential guiding tools for the implementation of disaster risk reduction measures in Lao PDR.

The project team extends their greatest thanks to its project partner, the Public Works and Transport Institute (PTI), Lao PDR, for providing all the technical and administrative support needed to complete the project. This mutual technical cooperation and collaboration has rendered immense benefit to the project outcomes, as well as furthering institutions in building their professional capacity.

The team would like to thank all stakeholders with whom the project team consulted with during the course of the implementation of this project. These interactions have greatly enriched the quality of the project outcomes. We would like to thank all technical consultants and advisors, particularly Dr. KWD Nandalal for the flood hazard and risk assessment, Mr. Kamal Budhathoki for the drought hazard assessment and Dr. Potty Jayraman for the storm hazard modeling.

The project team would also like to thank all ADPC colleagues and staff who have provided the necessary support for the development of the GIS based database, data analysis, report preparation and financial-administrative support. The team extends gratitude to Ms. Joy Waddell for all her editorial support in bringing this report to its current format.

PREFACE

It is my great honor to present this report on “Developing the National Risk Profile of Lao PDR”. This report received overwhelming support from the Government of Lao PDR and was produced in close collaboration with a number of national focal, technical and scientific agencies related to disaster risk reduction. The methodology used for this report was developed following rigorous discussion and consultation with all leading national government and non-governmental agencies. This report was financially supported by the United Nations Development Programme (UNDP) based in Lao PDR; technical advice and support was provided by the GRIP unit of BCPR of UNDP, Geneva.

This report highlights the regional experiences intrinsic to the work of the Asian Disaster Preparedness Center (ADPC) and the Public Works and Transport Institute (PTI) in disaster risk assessment and mapping in the region. The project objectives include mapping out all hazard prone areas (based on historic disaster events), identifying and assessing the exposure, vulnerability and risk of people, property, critical facilities, infrastructure and economic activities in those hazards prone areas; and creating preliminary national multi-hazard profiles, in terms of the type of hazard and affected sectors, so as to identify the risk priorities for the national disaster risk reduction strategies.

Upon fulfilling the objectives of this report, the project team produced a two-part report. Part one covers an overview of the project, a description of the baseline data, and hazard assessment and mapping for earthquakes, floods, drought, landslides, epidemics and diseases, UXO and storms hazards at the national level. Thus, part one results in the development of a multi-hazard risk map for Lao PDR. Part two of this report discusses the methodology for exposure, vulnerability and risk assessment for various hazards. In addition, part two recommends necessary intervention strategies for disaster risk reduction. The recommendations are segmented into eight sections: policy; institutional mandates and institutional development; hazard, vulnerability and risk assessment; multi-hazard early warning systems; preparedness and response plans; the integration of disaster risk reduction into development planning; community-based disaster risk management; and public awareness, education and training.

I hope that this report will prove to be useful to the National Disaster Management Office (NDMO), the Government of Lao PDR, the Water Resources and Environment Institute (WERI), the Department of Meteorology and Hydrology, the Lao National Mekong Committee (LNMC), the National Geographic Department, Department of Planning (DoP), the Ministry of Agriculture and Forestry (MAF), the Department of Planning, the Ministry of Health and others through its provision of sectorally-based disaster management planning. This report is formatted in a user-friendly manner such that all disciplines are able to apply the information and recommendations provided in this report for the safe and sustainable development of each respective sector. The ultimate goal is for the two volumes within this report to serve as a practical guide for disaster managers, as well as to enable them to use the information provided effectively for the benefit of the millions of people living in disaster prone areas of Lao PDR.

I would like to extend my sincere gratitude to the Government of Lao PDR, UNDP Lao PDR, the national stakeholders involved and the project partners for their partnership, consultation, support and advice.

Bangkok, November 2010

Dr. Bhichit Rattakul

Executive Director, ADPC

ABBREVIATION

ABD	Acute Bloody Diarrhea
ACD	Asian Cooperation Dialogue
ADB	Asian Development Bank
ADPC	Asian Disaster Preparedness Center
ARTI	Acute Respiratory Tract Infection
AWD	Acute Watery Diarrhea
CAgM	Commission for Agriculture Meteorology
CRED	Centre for Research on the Epidemiology of Disasters
CTG	Consultation Technical Group
DEM	Digital Elevation Model
DHF	Dengue Hemorrhagic Fever
DMG	Department of Mines and Geology
DMH	Department of Meteorology and Hydrology
DOA	Department Of Agriculture
DoG	Department of Geology
DoP	Department of Planning
DRR	Disaster Risk Reduction
FAO	Food and Agriculture Organization
GDP	Gross Domestic Product
GIS	Geographic Information System
GRID	Global Resource Information Database
JTWC	Joint Typhoon Warning Center
Lao PDR	Lao People's Democratic Republic
LDS	Lao Department of Statistics
LNMC	Lao National Mekong Committee
MAF	Ministry of Agriculture and Forestry
MEM	Ministry of Energy and Mines
MIH	Ministry of Industry and Handicraft
MMI	Modified Mercalli Intensity
MPI	Ministry of Planning and Investment
NAFRI	National Agricultural and Forestry Research Institute
NCDC	National Climatic Data Center
NDMC	National Drought Mitigation Centre
NDMO	National Disaster Management Office
NGD	National Geography Department
NGO	Non Governmental Organization
NOAA	National Oceanic Atmospheric Administration
NRA	National Regulation Authority
NSC	National Statistic Center
NTA	National Tourism Authority
OCHA	Office for the Coordination of Humanitarian Affairs
PTI	Public Work and Transport Institute
SPI	Standard Precipitation Index
TMD	Thai Meteorological Department
TWG	Technical Working Group
UNDP	United Nations Development Programme
UNOCHA	United Nations Office for the Coordination of Humanitarian Affairs
USACE	United States Army Corps Engineering
USGS	United States Geological Survey
UXOs	Unexploded Ordnances
WMO	World Meteorological Organization
WREA	Administration
WREI	Water Resources and Environment Institute

EXECUTIVE SUMMARY

The Hazard Assessment report will serve as a basis for making appropriate Disaster Risk Reduction (DRR) strategies and prioritizing them for Lao PDR's short and long term development planning. This report provides analyses and assessments of seven potential hazards in Lao PDR. The seven hazards include earthquakes, floods, landslides, epidemics, unexploded ordnances (UXOs), drought and storms. The methodology used in this hazard assessment study is primarily divided into two main phases: baseline data collection and hazard scenario development/mapping.

The report is organized as follows: Chapter One presents the overview of the project, the project partners, key stakeholders and sources of data. The chapter further explains the constraints and challenges in implementation. Chapter Two presents the demographics, physical infrastructure profile, socio-economic information and the disaster profile of Lao PDR at the provincial level. Chapter Three presents the details of the hazard assessment and mapping for floods, earthquakes, landslides, epidemics, UXOs, drought and storms. All the findings are presented in maps and tables which can be referred to under each hazard assessment section. The hazard assessment chapter presents the overview, past work in respective hazard assessments, brief methodology, how to refer to the hazard maps and analysis of those hazard maps, along with recommendations.

The study reveals that Lao PDR is prone to various geological, hydro-meteorological and human-induced hazards with specific degrees of severity. A brief note on each hazard is provided below:

(i) ***Earthquake:*** The earthquake hazard maps were developed using MMI scale. The hazard assessment was based on earthquake intensity maps developed by UNOCHA. The results show that one fourth of the area of Lao PDR is located in a high earthquake hazard zone. These areas include Xayabury, Bokeo, Oudomxay, Luangnamtha and Phongsaly provinces. More than 30% of the country is located in a moderate earthquake hazard zone, while 43.62% falls in a low earthquake risk zone.

(ii) ***Flood:*** Flood hazard maps were developed for the most flood-prone river basins. Eight rivers were identified and determined for flood hazard and risk assessments in accordance with the past history of flooding as well as in consultation with various flood-related agencies. The rivers identified in the assessment include Nan Ou, Nam Ngum, Nam Ngiap, Nam Xan, Se Bangfai, Xe Banghiang, Xe Don and Xe Kong. Results show that several districts located within these eight river basins are prone to flooding; with different water levels and areas of inundation.

(iii) ***Landslide:*** A large part of the country is located in low to medium landslide susceptibility zones. Only 5.24 % of the country is prone to very high landslide susceptibility. These high susceptibility zones are localized in the southeast and central part of Lao PDR.

(iv) ***Epidemic:*** Among the ten diseases highlighted in Lao PDR, the trend shows that Acute Bloody Diarrhea, Acute Respiratory Tract Infection, and Acute Watery Diarrhea cases are increasing, whilst Malaria is decreasing.

(v) ***Unexploded Ordnances (UXOs):*** Several districts of Khamuane and Savannaket province have a very high density of UXOs ranging from 2 – 4 UXOs per square kilometer. Several other districts in Huaphanh, Xienghuang, Saravane, Sekong and Attapeu were also identified as areas with a high density of UXOs.

(vi) ***Drought:*** Due to the limited availability of data, only climatological data from 1993 to 2008 was considered for the drought assessment. SPI was used for drought analysis at different time scales. It was found that droughts of all categories occur in Lao PDR in all four durations. Moderate drought frequently occurs in all the durations but severe and extreme droughts are less common; except for severe drought in the dry season which has occurred many times. Drought was relatively more frequent in the first and third 5-year periods of analysis, with a lull in between.

Probability of occurrence of drought of any category is found to be highest (27%) in Phalan in the dry season. It is also found to be high (25-27%) in Phiengluang in the other three durations. It should be noted that both the stations contain only about one decade of data and as a result of this lack of data availability amongst stations, it was difficult to make conclusive statements on drought-prone areas. In Lao PDR, southern parts of the central region, northern parts of the central region and southern parts of the northern region appear as drought susceptible areas in both dry and wet seasons.

(vii) ***Storm:*** Storm hazard assessments were carried out for four storm return periods (10, 20, 30 and 50 years). The assessment analyzed areas covered in various provinces with regards to storms. Findings show that the Khammouane province is the most vulnerable province in the country. For 50 years return period, a class 3 (178 – 209 km/hr) storm is expected to hit parts of Khammouane province. The hazard assessment was based on the collection of relevant authentic data from various focal departments and agencies. For assessment purposes, well-established technical methodologies were used and further validated by the focal departments.

During the implementation phase, the following constraints were observed:

(i) For the hazard assessment, several data and information on geological, hydro-meteorological, geo-morphological, epidemiology, and UXOs were available as separate datasets which needed to be merged. This restricted the robustness of the hazard modeling. Additional attempts were made to generate and modify the data and information based on available data suited to the modeling requirements. Development of the hazard assessment methodology was largely dependent upon availability of data and resources.

(ii) The data available from various departments and agencies was usually not relevant to the study requirements. The data was not consistent in nature and required rigorous processing. The analyses and assessments were carried out with limited resources. The assess,emts were largely dependent on secondary-source data/information and existing validated data. Very limited country-specific data was available for certain hazards and therefore the accuracy of the results might be affected.

The report further recommends the following:

- The report has identified districts and provinces in Lao PDR that are prone to multi-hazards. It is recommended that focal departments conduct detailed studies, at provincial level, for those provinces impacted by multiple hazards.
- The hazard-prone provinces should be given first priority for disaster mitigation interventions. It is recommended that the focal departments, agencies and ministries give special emphasis for disaster mitigation in multiple hazard provinces and districts. It is necessary, however, to also consider the exposure of lives and necessary infrastructure in these identified provinces and districts.
- The multi-hazard map should be the base map for all necessary DRR interventions.
- In order to get a clear and more detailed picture of the potential hazards in Lao PDR, it is recommended that networking systems of hazard monitoring and observation from Lao PDR's neighboring countries such as Thailand, Cambodia, Vietnam and China, are integrated and utilized along with the results from these multi-hazard assessments.

1 PROJECT BACKGROUND

1.1 BACKGROUND

The Asian Disaster Preparedness Centre (ADPC), in association with the Public Works and Transport Institute(PTI), was awarded the task of providing consultancy services to develop a preliminary National Disaster Risk Profile of Lao PDR. The ADPC team worked in close association with the National Disaster Management Office (NDMO) and other national agencies in all aspects of project implementation. Close linkages, partnership arrangement and previous experience in working with NDMO, Water Resource and Environment Agency, MAF, MEM, MOH, and so on, facilitated secondary data collection, hazard-specific information exchange and sharing of any other data relevant to the study. In addition, assistance was sought from other initiatives such as the ADPC implemented LANGOCA project (funded by Save the Children Australia. The outputs of these projects provided useful inputs to the Project on National Disaster Risk Profile of Lao PDR.

The project covered various technical and management activities including the review of ongoing studies and activities related to various hydro-meteorological, geological and biological hazards. The project established assessments for hazards, vulnerability and exposure of physical infrastructure and various production, as well as in the human, social and environmental sectors. Economic projections of losses caused by existing major hazards were carried out. The major outcome was to provide a way for identifying institutional gaps, prioritizing DRR and providing options for institutional measures.

The study provided an opportunity to share existing information, data and resources to develop comprehensive hazard assessments. Several recent studies have been carried out by various technical and scientific research organizations in hazard assessments at micro-level for pilot areas. The preliminary assessment on data availability, however, has indicated that hazard maps for most types of hazards are not available at national or regional level in Lao PDR. The present study collated all existing information and studies; developing a robust methodology at national level which was supported by proven technical tools.

1.2 PROJECT OBJECTIVES AND STATEMENT OF WORK

1.2.1 PROJECT OBJECTIVE

The findings of the National Risk Profile of Lao PDR, including the national risk profiling for the country, will create the basis for incorporating appropriate risk reduction strategies and prioritizing them into the country's development planning by the Government of Lao PDR. It is expected that the findings of the proposed study will allow decision makers to prioritize risk mitigation investments and measures to strengthen the emergency preparedness and response mechanisms for reducing future losses and damages due to natural disasters. It would further assist donor agencies, development partners and so on, in adopting a risk reduction strategy for Lao PDR through appropriate financing mechanisms.

The main objectives of the proposed study was to:

- map out all hazard prone areas and respective hazard zones based on historic disaster events;
- identify and assess the exposure of people, property, critical facilities, infrastructure and economic activities to those hazards;
- carry out preliminary assessments of the potential damage state of the identified elements at risk with reference to expected hazard intensities;
- and create preliminary national multi-hazard profiles in terms of hazards and sectors to identify priorities for National Disaster Risk Reduction Strategies.

1.2.2 SCOPE OF ASSIGNMENT

The scope of the project is as follows:

- Development of multi-hazard profiles;
  - o Systematic description of the physical characteristics of hazards such as sources of threats, magnitude, duration, extent and intensity (spatial distribution).
  - o Collection of hazard zoning maps and plausible hazard event scenarios for the major hazards prevailing in Lao PDR (for example wind storms, floods, droughts, earthquakes and UXOs).
- Inventory of multi-sectoral exposures for the following elements at risks;
  - o Population in terms of poverty and vulnerability.
  - o Buildings in terms of their structure type and functionality.
  - o Livelihoods.
  - o Critical facilities.
  - o Infrastructure.
- Development of a comprehensive national risk profile which reflects multi-hazard and multi-sectoral principals;
  - o The analysis unit for risk aggregation is proposed to be at least at the provincial level under the jurisdiction of the Central Government.
- Identification of national high-risk areas in terms of different hazard types and sectors and relevant DRR and response options.

1.2.3 PROJECT CONSTRAINTS

(i) ***Resource Constraints*:** The project was allocated with limited funding to cover project studies and scope. Not all the data that was available from various departments and agencies was relevant to the study requirements. The data was not consistent in nature and required rigorous processing. It would have been better if the highest priority disasters were studied in a more detailed manner. With limited resources the Project Team depended largely on secondary sources of data and information. The Project Team collected data from various authentic sources which ranged from government ministries, departments, agencies, research and technical organizations. The information generated in this project relied on this secondary, existing validated data and not on field-based data collection.

(ii) ***Time Limitation*:** The time allocated for the project was limited to six months. In the stated time frame, extensive hazard, vulnerability and risk assessments along with risk analysis was carried out. The project outputs largely depended on the availability of data from the national agencies. These agencies usually had their own rules and regulations in data sharing and the Project Team ensured that all agencies extended cooperation in releasing data. Since the time frame for the project was limited, the Project Team was under pressure to collect data in time and process it to a desired level in order to ensure high quality results.

(iii) ***Precision Standards*:** In general the hazard assessments were carried out using scientific tools and were validated with field checks. Since the time and resources were limited, the Project Team validated the outcomes of the hazard maps with well-established data and information that was available. The outcomes were validated using statistical tools and other relevant methods and the products were developed on a suitable scale.

(iv) ***Availability of Data*:** For the assessment of hazards, vulnerability and associated risks, several datasets were required: geological, hydro-meteorological, geo-morphological, socio-economic, census and infrastructure data. Some information was available, however, a large quantity of data was missing. This restricted the robustness of the hazard modeling. The Project Team attempted to generate and modify the data and information based on available data suited to the modeling requirements.

(v) ***Technical Methodology*:** Development of methodology for the hazard, vulnerability and risk assessments was largely dependent on availability of data and resources.

(vi) ***Classification of Hazard for Modeling*:** Based on available data it was found that earthquakes, floods, drought, landslides, epidemics and UXOs are major problems in Lao PDR. The Project Team developed hazard, vulnerability and risk mapping for the above-mentioned hazards.

(vii) ***Loss Estimation Data*:** The data compiled by various departments for economic losses were based on rough estimates. As a result this may not provide a fair projection of economic losses. Efforts were made to develop economic loss projections based on scientific models.

1.2.4 CHALLENGES IN EXECUTING THE PROJECT

(i) ***Availability of Data***: The availability of data was the greatest challenge. Lao PDR has carried out remarkable data-genrating activities and this data is available in fragments from various departments. Collecting the data from the various agencies within the limited time frame was one of the key challenges since all source agencies had their own regulations with regards to data sharing.

(ii) ***Meeting with Stakeholders***: NDMO had formed a Technical Working Group (TWG) comprising of various relevant technical agencies, departments and ministries to provide necessary technical support. They reviewed and evaluated the approach adopted by the Project Team to meet the objectives. These TWG meetings were organized at the end of important milestones of the project and success of such meetings was due to the commitment of the members.

(iii) ***Cooperation with Various Stakeholders***: The project collected data from various important stakeholders. Cooperation between the various stakeholders was difficult to achieve because of differing individual and administrative policies.

1.2.5 EXPECTED BENEFITS TO THE NATION

(i) At present several agencies have carried out risk assessments for different parts of the country, at different scales. The current study outcomes will enhance the qualitative and quantitative aspects of different agencies' work. The study developed comprehensive risk assessment profiles for the whole country at the provincial level.

(ii) The project attempted to develop tools for physical vulnerability assessments of various assets at national level. This will further help in identifying the most vulnerable sectors and necessary measures to reduce the impacts.

(iii) The national sector-specific risk projections will assist concerned stakeholders to prioritize DRR strategies.

(iv) The study will bring out existing gaps in DRR strategies. The study has also recommended measures to improve decision making capacity.

(v) The outcome will be useful for mainstreaming DRR in various sectors at different levels.

(vi) The assessment will help district and regional decision makers, policy makers and development agencies to prepare DRR planning.

(vii) Based on the outcome of this project, the government may take necessary actions for capacity building for DRR.

(viii) The project proposed robust methodology for hazard, vulnerability and risk assessments in close collaboration with national technical departments and agencies. The level of assessment is from national to provincial level and these models can be replicated in other regions and countries.

(ix) One of the project outcomes was to develop economic loss profiles of defined physical and social assets, caused by various major hazards. This will help in budget allocation for various vital infrastructure and assets in terms of DRR strategies.

(x) The study will hopefully facilitate financial support from international organizations for measures and actions that reduce the risk associated with natural hazards in Lao PDR.

1.3 PROJECT STAKEHOLDERS

The project involved three types of stakeholders: the Project Team, focal institutions and project beneficiaries such as other associated agencies, the World Bank, UNDP and so on.

The Project Team included technical staff from ADPC and PTI. Apart from these agencies, there was a team of national and international experts in economic modeling, seismic analysis, statistics and flood modeling.

The National Disaster Management Office (NDMO) was the focal point for advice, direction and evaluation as per the defined terms and references. The Consultation Technical Group (CTG) was formed which included senior representation of various focal departments. UNDP was the observer during the study period whilst ADPC convened and facilitated the logistics as per the requirements.

The Project Team identified several beneficiaries. The role of beneficiary stakeholders was to provide necessary data and information for assessments of economic impacts in the respective sectors. The large group of beneficiary stakeholders included the Water Resources and Environment Institute (WERI), Department of Labour and Social Welfare, Remote Sensing Center, Water Resources and Environment Authority (WREA), Department of Meteorology and Hydrology, Lao National Mekong Committee (LNMC), Technical Support Division, Mekong River Commission Secretariat, National Geographic Department, Department of Planning (DoP), Ministry of Agriculture and Forestry (MAF), Statistical Division, National Agricultural and Forestry Research Institute (NAFRI), National Educational Research Institute, Ministry of Education, National Statistics Department, Ministry of Planning and Investment (MPI), Department of Planning, Department of Energy, Ministry of Energy and Mines (MEM), GIS Division, Department of Geography, National University of Lao PDR, Center for Laboratory and Epidemiology, Department of Hygiene and Prevention, Ministry of Health, and the National Agricultural and Forestry Research Institute (NAFRI).

1.4 METHODOLOGY

The methodology used in this study is primarily divided into three main phases:

- Baseline data collection and hazard scenario development;
- Vulnerability and susceptibility assessment and mapping; and
- Exposure and risk analysis.

The final result of the hazard and risk assessments formed the genesis for national level disaster risk mitigation strategies. The methodology has been represented as a flow chart in Figure 1.1. Figure 1.2 shows the subcomponents of the main activities. Further detailed methodology of each hazard is presented in Chapter 3.

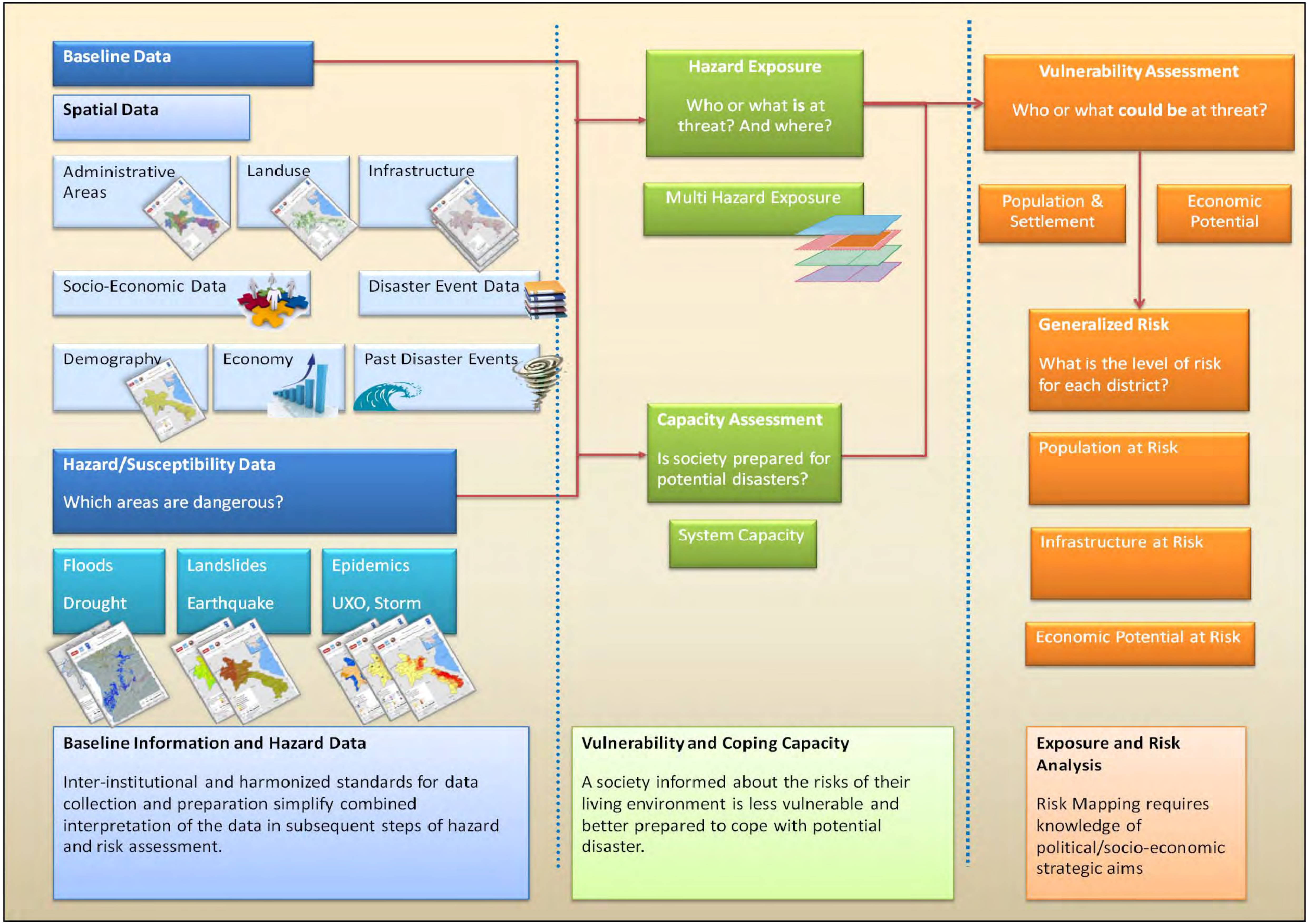


Figure 1.1 Flowchart showing process of hazard-vulnerability and risk assessment for Lao PDR

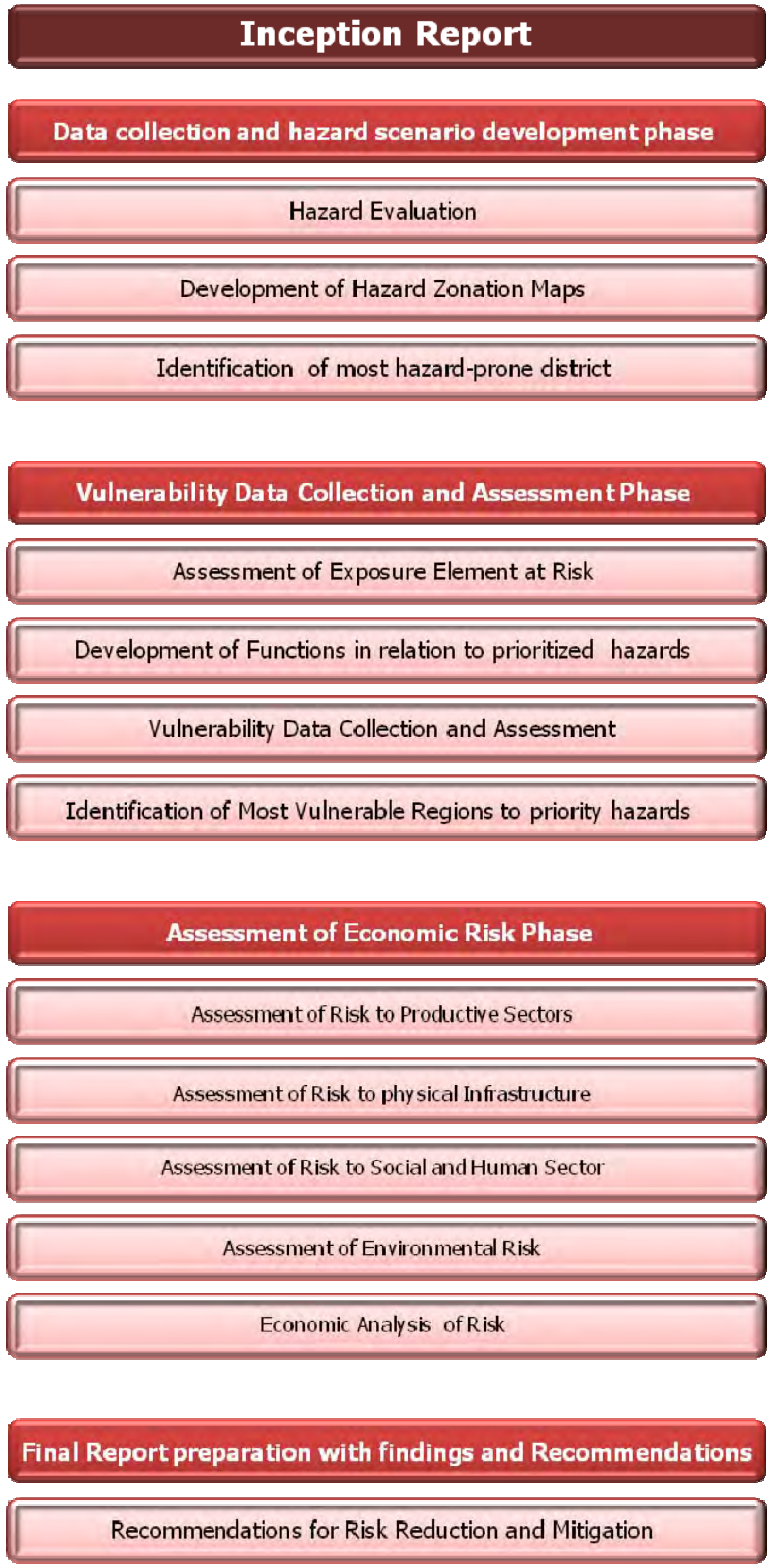


Figure 1.2 Process for Hazards Risk Assessment

Definition of key terms

Key terms used in the context of the proposed **"Develop a National Risk Profile of Lao PDR"** are given below. The terminology used is generally consistent with the recommendations of ISSMGE Glossary of Risk Assessment terms.

- ***Danger (Threat)***: Natural phenomenon that could lead to damage: described by geometry, mechanical and other characteristics. Description of a threat involves no forecasting.
- ***Hazard***: Probability that a particular danger (threat) will occur within a given period of time.
- ***Exposure***: The assessment of exposure of people, assets and the environment to a certain hazard involves assessing current and future socio-economic, land use and other trends. Accounting for changes in exposure is important as reductions in future damages and losses often may be compensated by the sheer increase in people and assets in harm's way.
- ***Vulnerability***: The degree of loss to a given element or set of elements within the area affected by a hazard.
- ***Risk***: Measure of probability and severity of an adverse effect to life, health, property, or the environment. Mathematically, risk is defined as Risk = Hazard x Potential worth of loss, also often written as Risk = Hazard x Elements at risk x Vulnerability.
- ***Damages***: Damage represents the total or partial destruction of physical assets such as infrastructure, buildings, furniture and equipment. Damage occurs at the time of the disaster and is measured at replacement value.
- ***Losses***: Losses are changes in economic flows that arise as a result of damage. They include declines in production and sales or increased production costs; lower revenues and higher production costs in the provision of services; and increased expenditures arising from the disaster. They occur after the disaster and over a relatively long period of time until full reconstruction and recovery have been attained.

1.5 PROJECT OUTCOMES

Several project outcomes resulted from this study, including:

- Hazards Scenario Development:
  - Hazard Zonation maps for floods, landslides, earthquakes, drought, epidemics, storms and UXOs;
  - Identification of the most hazard-prone areas; and
  - Analysis and interpretation of hazard assessment for various disasters .
- Vulnerability and Exposure Assessment:
  - GIS maps showing elements at risk for various identified sectors;
  - Disaster damage matrix for related sectors;
  - Preliminary estimated direct and indirect losses with regard to forecasted scenarios on sectors.
- Final Report which included the following:
  - Synthesis report of hazards, vulnerability and exposure assessment of Lao PDR at national level; and
  - Recommendations for prioritizing risk mitigation investments. Measures to strengthen the emergency preparedness and response mechanisms to floods, landslides, earthquakes, drought, epidemics, storms and UXOs. These measures included optimization of financial instruments and improvement of institutional measures such as policy, legal and institutional development measures.

2 BASELINE DATA AND INFORMATION

2.1 ADMINISTRATIVE DIVISON AND GEOGRAPHY OF LAO PDR

Lao PDR is a landlocked country located in Southeast Asia, surrounded by Myanmar, Cambodia, China, Thailand and Vietnam. The Mekong River serves as a border between Lao PDR and neighboring Myanmar and Thailand, as well as an important transport route in the region. Table 2.1 shows the Lao PDR country border and its length (ACD, 2010).

Table 2.1 Borders of Lao PDR

Region	Borders with	Length of borders(km)
North	China	505
South	Cambodia	435
East	Vietnam	2,069
North-West	Myanmar	236
West	Thailand	1,835

Geographically, Lao PDR is divided into three regions: namely the northern, central and southern regions. Administratively, however, the country is divided into 18 political provinces (shown in Table 2.2). Names of the districts in each province are presented in the annexes.

Table 2.2 Administrative province of Lao PDR (Source: (NSC, 2005))

Province (18)	Number of Districts (139)	Number of Villages (10,552)
Vientiane Mun	9	499
Phongsaly	9	607
Louang Namtha	5	380
Oudamxai	7	587
Bokeo	5	354
Louangprabhang	11	855
Houphan	8	784
Xayabury	10	487
Xiang khuang	8	541
Vientiane	12	593
Borikhamxay	6	327
Khammouane	9	803
Savannakhet	15	1,543
Saravane	8	724
Xekong	4	253
Champassack	10	924
Attapeu	5	207
Xaisomboun SR	5	84

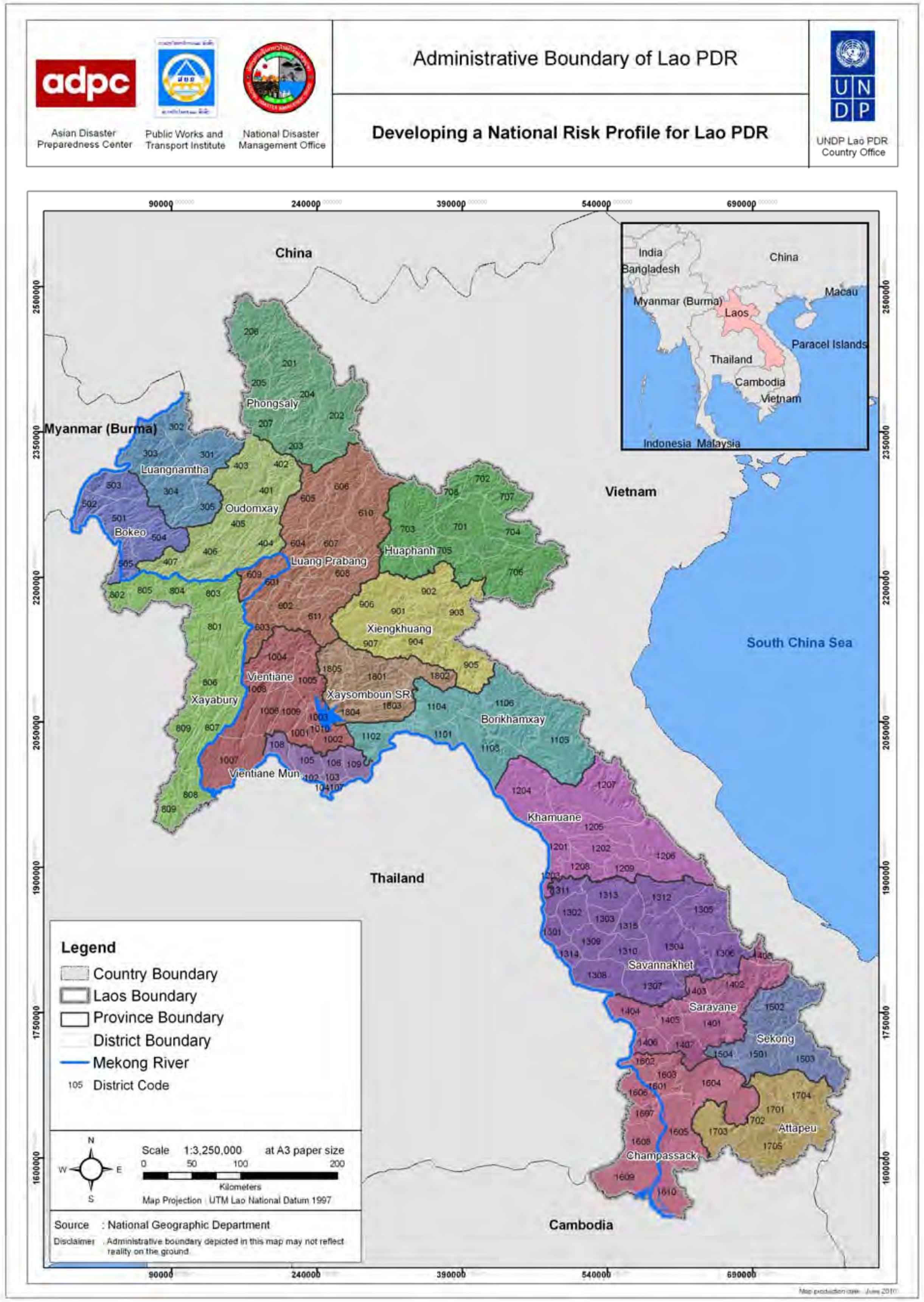


Figure 2.1 Administrative map of Lao PDR (Source: (NSC, 2005))

2.2 POPULATION OF LAO PDR

Population Characteristics

Lao PDR is characterized by a large number of young people. This condition is treated as a positive aspect with regards to the mobilization of predominantly young communities to protect their settlements against disaster risk. Studies of disaster causalities have indicated that the young and the old are often most at risk (World Disaster Report 2002). They are, for example, less mobile (capable of evacuation), more dependent, have less resistance to disease and often command fewer resources. Increasing casualties in disasters can therefore be anticipated in this age group.

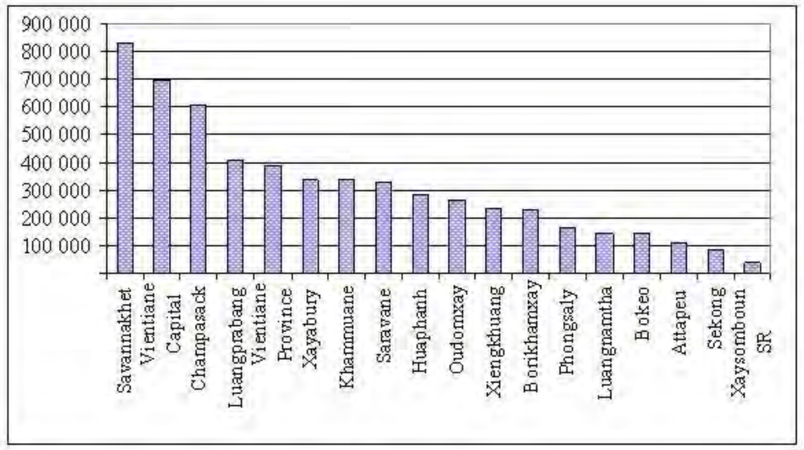


Figure 2.2 Distribution of Population of Lao PDR by province (Source : (NSC, 2005))

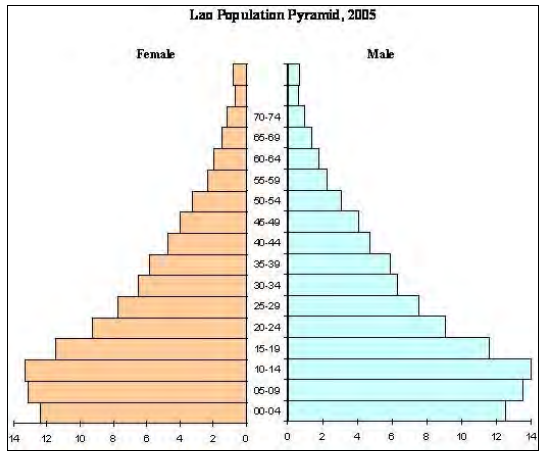


Figure 2.3 Population Pyramid of Lao PDR, 2005 (Source : (NSC, 2005))

Population Density

Figure 2.4 and Figure 2.5 show the population density in Lao PDR at district level. The population density is divided into five classes ranging from 0 – 25 persons per sq km to more than 300 persons per sq km. The map shows that only a few districts in Lao PDR have a population density of more than 300 persons per sq km: Sisattanak, Chantihabouri, Sikhottabong and Xaisettha. These districts are located in the Vientiane province which is the capital of Lao PDR. The Sisattanak District has the highest population in the capital (about 1417 persons per sq km). Pakxe District, located in Champassak province, also has a high population density of about 387 persons per sq km. More than 70% of districts in the country have population densities of less than or equal to 25 persons per sq km (NSC, 2005).

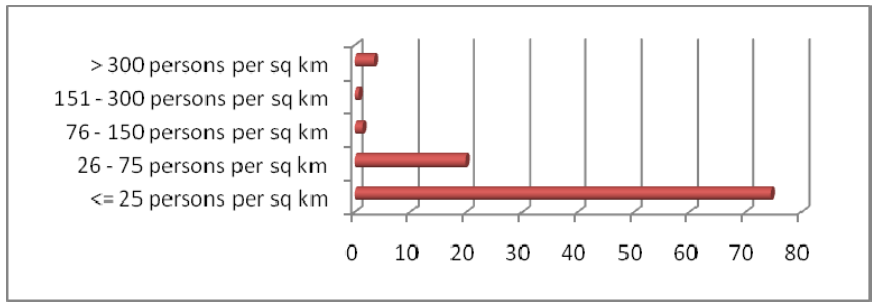


Figure 2.4 Population Density at district level in Lao PDR (Source : (NSC, 2005))

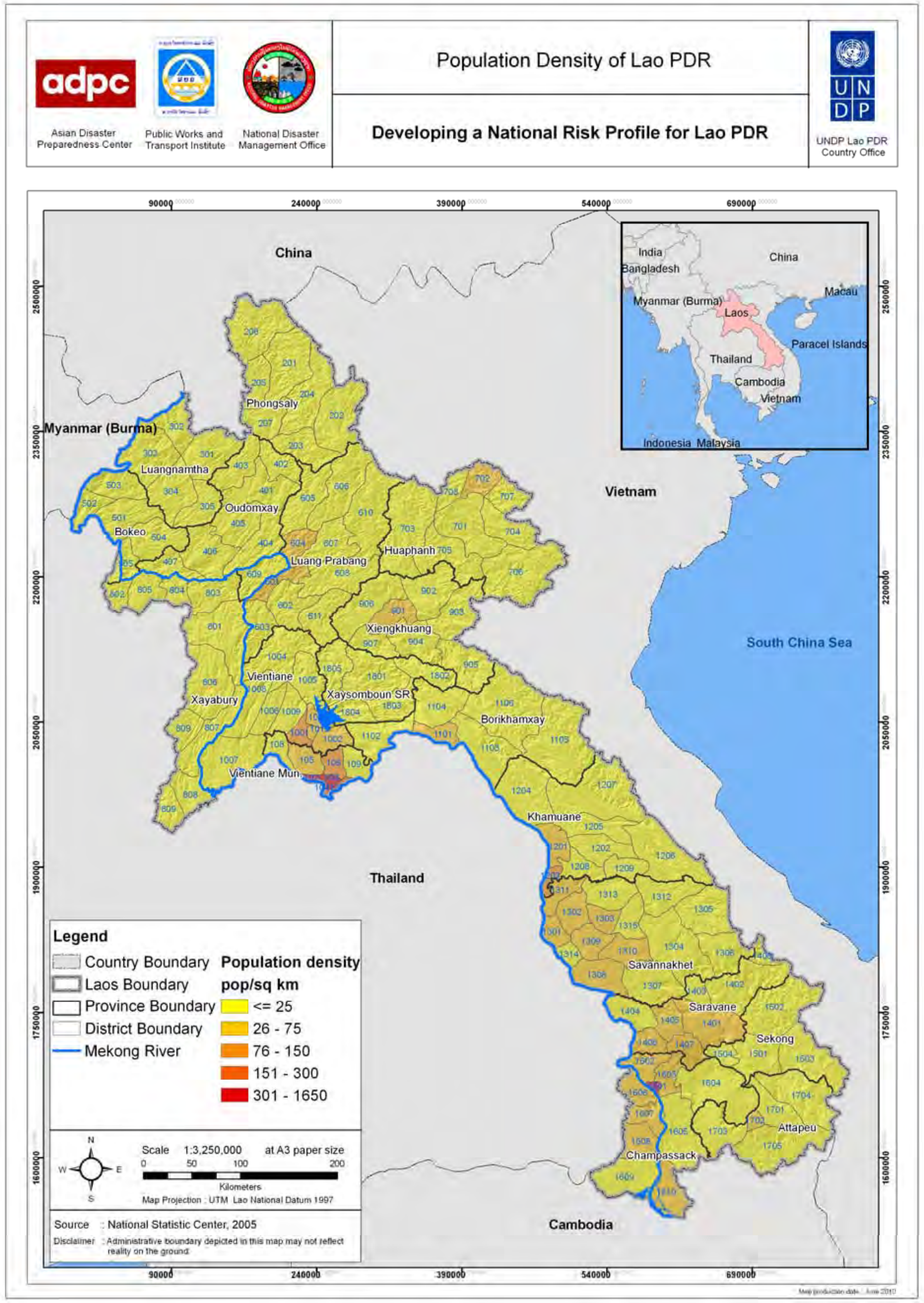


Figure 2.5 Population Density of Lao PDR at District level (Source: (NSC, 2005))

2.3 CLIMATE AND TOPOGRAPHY OF LAO PDR

The topography of Lao PDR is dominated by mountainous areas and alluvial plains. About two thirds of the country is mountainous and thickly forested, with elevations above 500 meters, typically characterized by steep terrain, narrow river valleys and low agricultural potential. This mountainous landscape extends across most of the north of the country, especially in the Annam Range, along with the border of Vietnam. The mountains reach heights of more than 2,700 m (8,860 ft), with Pou Bia, the highest point in Lao PDR, rising to 2,817 m (9,242 ft) in the north-central part of the country. Only three passes cross the mountains to link Lao PDR with Vietnam. The Tran Ninh Plateau, in the northeast, rises to between 1,020 m and 1,370 m (3,350– 4,500 ft), and the fertile Bolovens Plateau, in the south, reaches a height of about 1,070 m (3,500 ft). The alluvial plains and terraces of the Mekong and its tributaries cover only about 20% of the land area. Broad alluvial plains, where much of the rice crop is grown, are found only in the south and west along the Mekong River and its tributaries. The Vientiane plain is the most extensive of these alluvial plains.

Lao PDR has a tropical monsoon climate. The climate is hot and tropical, with the rainy season between May and October, when temperatures are at their highest. The cool dry season runs from November through February, with a hot dry season in March and April. Monsoons generally occur at the same time across the country, although that time may vary significantly from one year to the next. Rainfall is not always adequate for rice cultivation, however, and the relatively high average precipitation conceals years when rainfall may be only half or less than the norm; causing significant declines in rice yields. Such droughts are often regional, leaving production in other parts of the country unaffected. Temperatures range from highs of around 40°C along the Mekong in March and April, to lows of 5°C or less in the uplands of Xiangkhoang and Phôngsali in January.

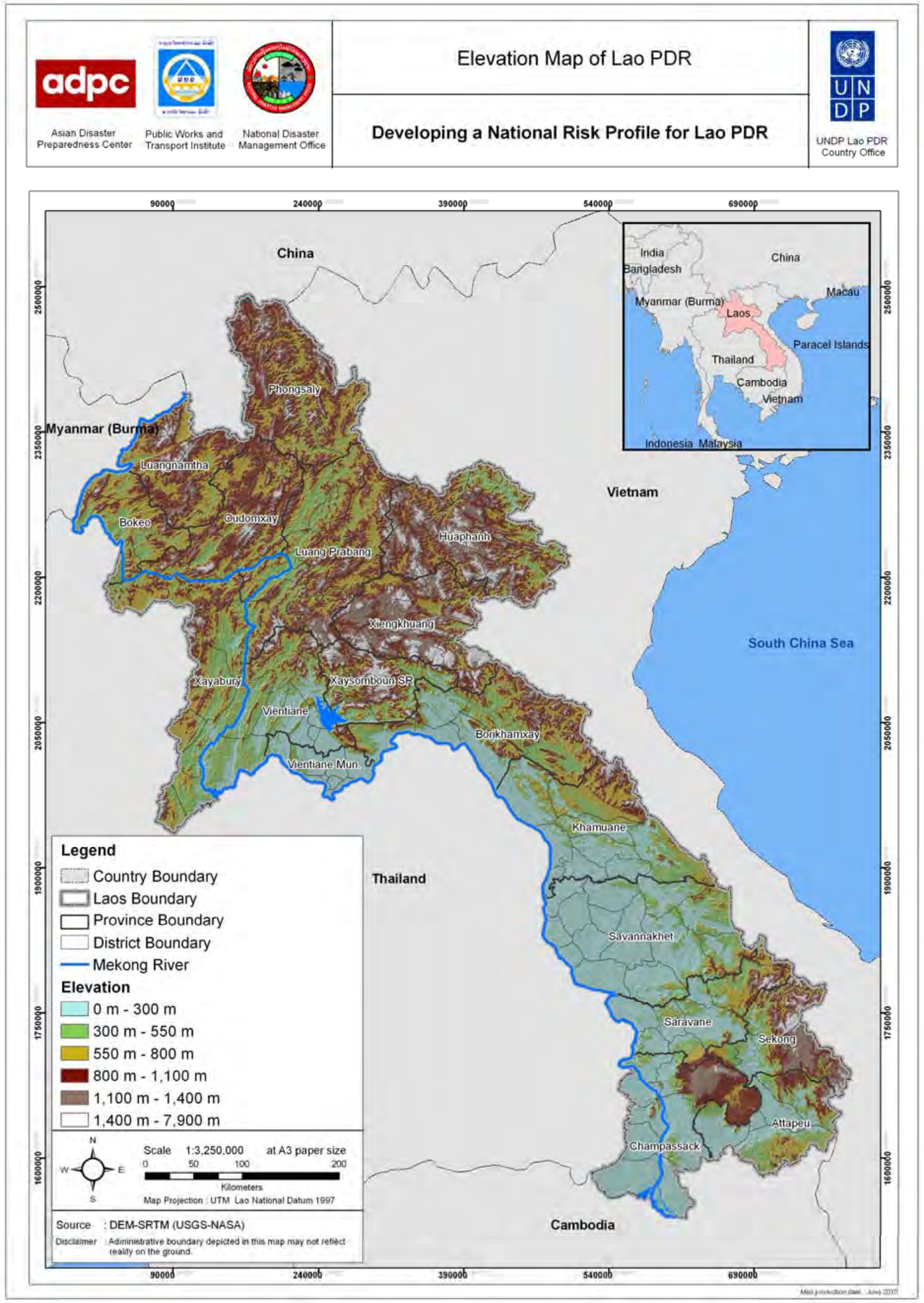


Figure 2.6 Topography and elevation map of Lao PDR

2.4 LAND USE / LAND COVER

The Government of Lao PDR's Department of Geography (DoG, 2009) has classified land use and cover into 19 categories (see Table 2.3). Land use is dominated by "mixed deciduous" which covers 37.37% of total land use area, followed by "un-stocked forest" which covers 31.73 % of the area. This type of mixed deciduous land use is equally distributed across the country with a higher portion in the northern and southern parts of the country. Spatial distribution of land use in Lao PDR is presented in Figure 2.7. Figure 2.8 shows that the north of Lao PDR is dominated by steep mountain ranges that are mostly covered by forests. The central region is known for its extensive caves and impressive limestone landscapes. The southern part of Lao PDR is dominated by the Mekong delta. It largely accommodates the country's population and agriculture.

Table 2.3 Distribution of land use types in Lao PDR (Area) (Source : Digital Land Use Map, (DoG, 2009))

Type of land use	Area (sq km)	Type of land use	Area (sq km)
Dry evergreen	12,362.61	Savannah	1,385.39
Mixed deciduous	85,692.54	Scrub	2,088.16
Other land	10.63	Rice paddy	10,783.25
Dry dipterocarp	14,082.71	Agricultural plantation	842.76
Other land	75.79	Other agricultural land	317.01
Coniferous forest	1,266.89	Barren land and rock	2,164.93
Mixed broad-leafed coniferous	1,106.05	Grass land	6,810.43
Forest plantation	22.73	Swamp	574.76
Bamboo	8,750.21	Urban and built-up area	128.6
Unstock forest	72,758.53	Other land	17.24
Other land	7.51	Water bodies	2,401.89
Ray	5,643.61		

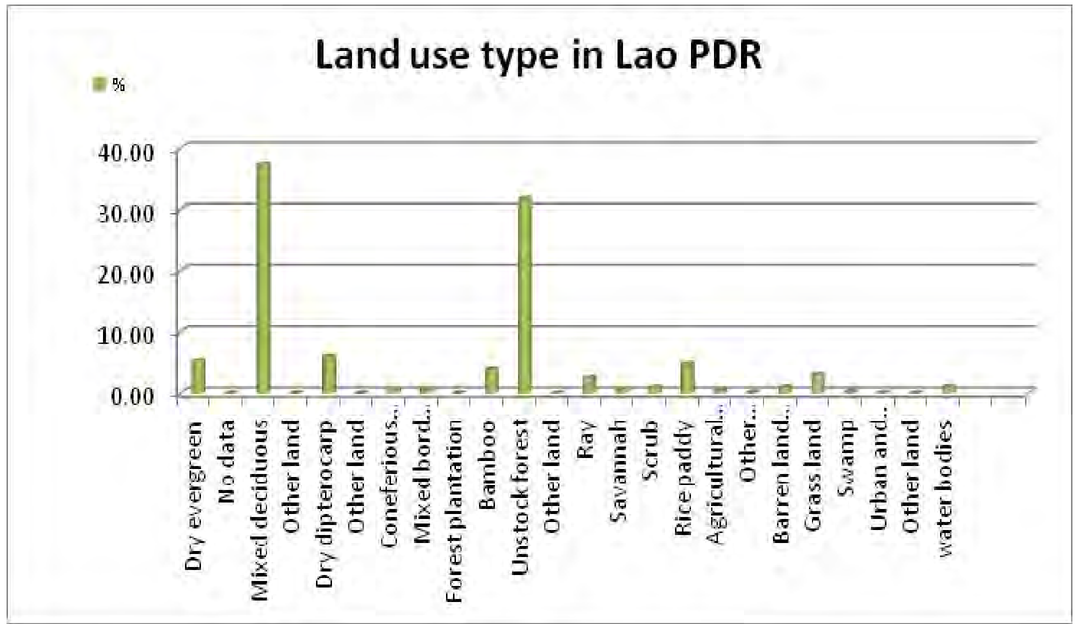


Figure 2.7 Land use type in Lao PDR (Source : Digital Land Use Map, (DoG, 2009))

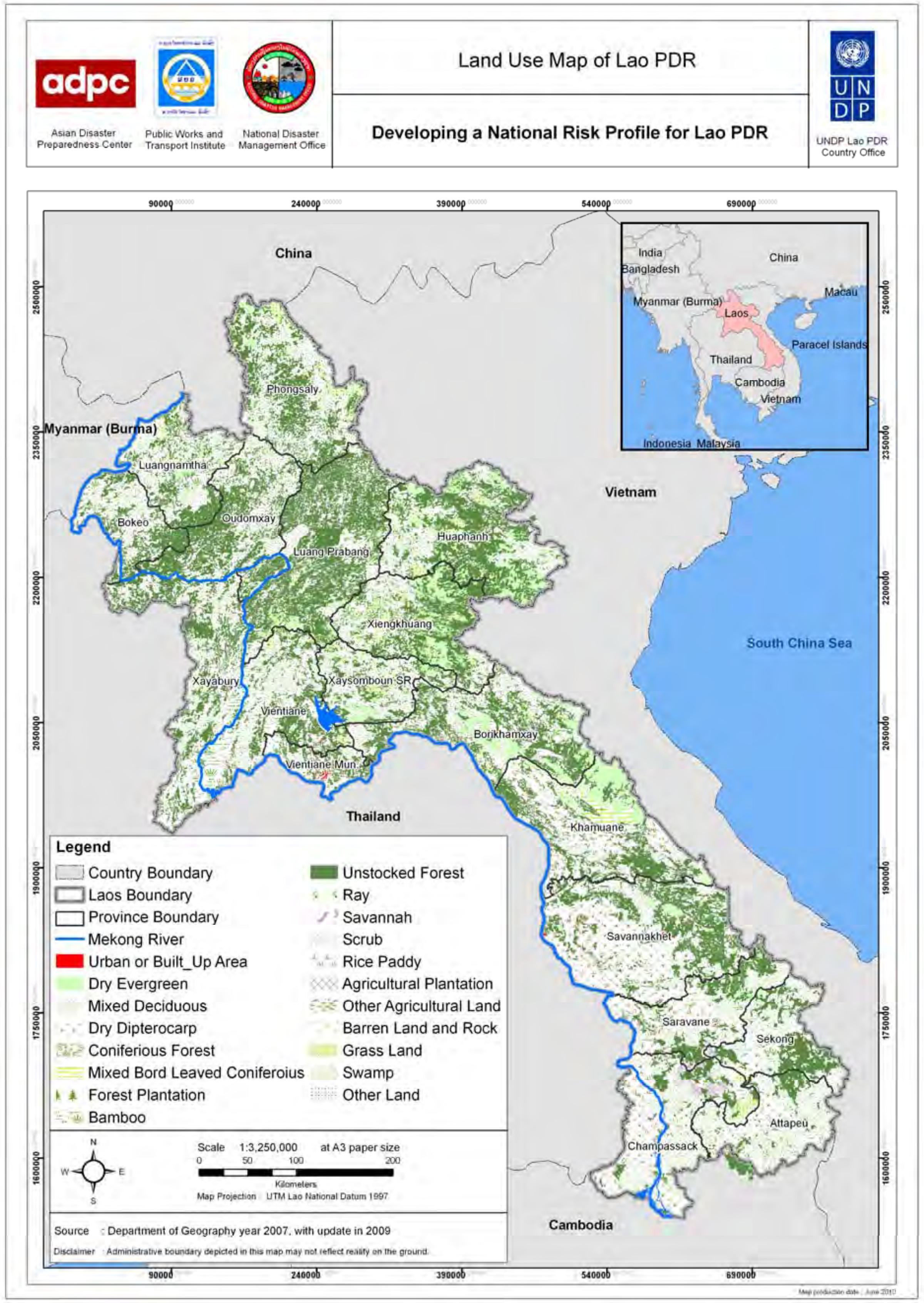


Figure 2.8 Land use map of Lao PDR (Source: (DoG, 2009))

2.5 NATURAL DISASTER PROFILE OF LAO PDR

Lao PDR has a rugged mountainous terrain in its northern parts, as well as valleys and floodplains within the remaining areas. Lao PDR has a comparatively low natural disaster profile compared to the rest of the South East Asian (SEA) region. The main hazards in Lao PDR are annual river- and flash-floods, landslides, forest- and community-fires, acute water shortages during specific months of the year, occasional wind storms and typhoons, agricultural pests, rodent infestations and animal- and human-epidemics. Human-induced hazards such as fire, traffic accidents and UXOs also exist in Lao PDR.

EM-DAT (EM-DAT, 2010) has published a broader profile of disasters in Lao PDR. The profile shows that drought has affected a large population: in five drought events more than 4.25 million were affected. Epidemics have proven to be the biggest killer with about 578 people killed in five events. More frequent events are floods in the Mekong River which have affected more than 3.45 million people.

Table 2.4 Natural disaster profile of Lao PDR (Source: (EM-DAT, 2010))

<table>
<tr><th>Disaster</th><th></th><th>Number of Events</th><th>Killed</th><th>Total Affected</th><th>Damage (000 US$)</th></tr>
<tr><td>Drought</td><td>Drought</td><td>5</td><td>-</td><td>4250000</td><td>1000</td></tr>
<tr><td rowspan="3">Epidemic</td><td>Unspecified</td><td>3</td><td>44</td><td>9685</td><td>-</td></tr>
<tr><td>Bacterial Infectious Diseases</td><td>2</td><td>534</td><td>8244</td><td>-</td></tr>
<tr><td>Viral Infectious Diseases</td><td>3</td><td>208</td><td>2000</td><td>-</td></tr>
<tr><td rowspan="2">Flood</td><td>Unspecified</td><td>10</td><td>76</td><td>1878600</td><td>2480</td></tr>
<tr><td>General flood</td><td>8</td><td>358</td><td>1569740</td><td>37128</td></tr>
<tr><td rowspan="2">Storm</td><td>Unspecified</td><td>2</td><td>8</td><td>38435</td><td>302301</td></tr>
<tr><td>Tropical cyclone</td><td>3</td><td>64</td><td>1397764</td><td>103650</td></tr>
</table>

Floods in Lao PDR

The country is prone to regular flooding due to the location of major rivers such as the Mekong and Sekong. Apart from the Mekong, there are several minor rivers such as Nam Ou, Se Bang Fai, Se Bang Heng, Se Kong, Nam Jha, and Nam Beng, Nam San, Nam Ngiep, Nam Ngum, Nam Lik and Sedone, which are responsible for floods in the country. The Asian Development Bank (ADB) supported project, implemented by Vision RI Connexion Services Private Limited, has published a document on the status of floods and drought[1] risk management and mitigation in 2009. The report explains the profile of floods in Lao PDR. Since 1966 the country has experienced 25 floods of various magnitude and duration. There are six important flood prone areas. Among them five areas are under the influence of the Mekong River and one area is covered under the Se Kong River.

The causative factors for floods in the country include insufficient and inadequate protective dykes along the critical points, poor functioning of water control gates, lack of pumping stations or mobile pumps when inundation occurs, small and shallow natural channels to drain flood water, deforestation, land degradation, river straightening works and 'hardened' catchments which result in increasing and rapid concentration of runoff, reclamation of wetlands, low lying areas and poor land use planning.

Climate change and rapid deforestation in the country has led to frequent and severe floods. Table 2.4 shows the occurrence of floods in the country. Flooding will occur along the Mekong plain, for example, if there is more than 200mm of rain in two days.

Some of the reported flooding is triggered by storms. Severe tropical storm 'Xangsane' in 2006 caused severe floods in the central and southern part of the country. In 2007 tropical storm 'Lekima' resulted in huge damage and loss exceeding 2006 records; with large damage reported to paddy cropping. More flood-related damage and losses were reported in Luangnamtha province and Vientiane in 2007. Two people were killed and over 600 villages were affected by the floodwater. Almost 160,000ha of rice crops were damaged due to prolonged submergence as well as 30% of planted vegetable crops. Similarly, in August 2008, areas of Luang Prabang and Vientiane were flooded. Tropical storm 'Ketsana' in September 2009 has also led to severe flooding along the storm path. Table 2.5 shows the year of floods, damaging factors, monetary damage (USD) and the regions that were flooded. Out of 33 events, the central region of the country was most affected by the floods.

[1] TA 6456-REG, preparing the greater Mekong sub-region flood and drought risk management and mitigation project, Lao PDR Inception report, Vision RI connexion services private limited, July 2009

Table 2.5 Damage caused by floods in Lao PDR from 1966-2008 (Source: (Vision-RI, 2009))

S. No	Year	Type of Damage	Damage cost (USD ,000)	Place of Damage
1	1966	Large Flood	13,800	Central
2	1968	Flood	2,830	Central and Southern
3	1969	Flood	1,020	Southern
4	1970	Flood	30	Central
5	1971	Large Flood	3,573	Central
6	1972	Flood and Drought	40	Central
7	1973	Flood	3.7	Central
8	1974	Flood	180	
9	1976	Flash Flood	9,000	Central
10	1978	Large Flood	5,700	Central and Southern
11	1979	Flood and Drought	3,600	Northern and Southern
12	1980	Flood	3,000	Central
13	1981	Flood	682	Central
14	1984	Flood	3,430	Central and Southern
15	1985	Large Flood	1,000	Northern
16	1986	Flood and Drought	2,000	Central and Southern
17	1990	Flood	100	Central
18	1991	Flood and Drought	3,650	Central
19	1992	Flood, Drought and Forest Fire	302,151.20	Central (F) and Northern (D)
20	1993	Flood and Drought	21,827.93	Central and Southern
21	1994	Flood	21,150	Central and Southern
22	1995	Flood	15,000	Central
23	1996	Large Flood and Drought	10,500	Central
24	1997	Flood and Drought	1,860.30	Southern
25	1999	Flood	7,450	Central
26	2000	Flood	6,684.23	Central and Southern
27	2001	Flash Flood	808.5	Central and Southern
28	2002	Large Flood, Flash Flood and Landslide	14,170	Northern, Central and Southern
29	2004	Flood	750.399	Southern
30	2005	Flash Flood and Landslide	1,316.58	Central and Southern
31	2006	Flood	3,636	Central and Southern
32	2007	Flash Flood	8,056	Northern, Central and Southern
33	2008	Large flood and Flash Flood	4,384.40	Northern and Central

Drought

In Lao PDR, drought has resulted in damages of up to 40 Million US$ in 1988 and 20 Million US$ in 1989. Since the largest portion of the Lao population lives in rural areas and depends largely on agriculture, they are most vulnerable to periodic droughts. In recent years, natural disasters resulting from climate abnormalities have resulted in frequent droughts and floods. Table 2.6 shows the historical account of damages caused by drought.

Table 2.6 Drought events and damage in Lao PDR (Source: (Vision-RI, 2009))

S. No	Year	Type of Damage	Damage cost (USD ,000)	Place of Damage
1	1967	Drought	5,120	Central and Southern
2	1975	Drought	N/A	Central
3	1982	Drought	N/A	N/A
4	1983	Drought	N/A	N/A
5	1987	Drought	5,000	Central and Southern
6	1988	Drought	40,000	Southern
7	1989	Drought	20,000	Southern
8	1998	Drought	5,763	Northern and Southern
9	2003	Drought	16,500	Central And Southern

Earthquake Risk

Although the Department of Meteorology and Hydrology (DMH) monitor seismic activity in Lao PDR, limited literature and information is available about seismic activity. Some seismic activity has been reported in the northeastern part of the country. The Office for the Coordination of Humanitarian Affairs (OCHA) has carried out regional level multi-hazard mapping of the country. Their map shows three major disasters including earthquakes, volcanoes and tropical storm risks. As per the report, Phongsaly, Namtha, Bokeo and Oudomxay fall in moderate to high seismic risk areas with earthquake intensity VII or less expected. Larger parts of Sayabouri and Luang Prabang, and a smaller portion of Vientiane are exposed to earthquake intensity VI and less. Larger parts of Luang Prabang, Houaphanh, Xiang Khohang, Sayabouri, Vientiane 1 & 2 and the northwest of Vientiane falls under moderate-low seismic risk zone, which may expect Intensity V and less. Remaining regions fall under low seismic risk. Some of the work related to active fault assessment has been done by the Department of Mineral Resources (DMR) and the Government of Thailand. The current status of research and development reveals more intense work should be carried out in the country for seismic hazard assessment. The Report on Power System Planning Study in the MIH, Lao PDR (ADB, 1998), presents a distribution plot of seismic events for Lao PDR. This gives the evidence of more seismic events in the northwest part of Lao PDR. Some 6.0+ earthquake magnitudes have been reported in the northwest provinces.

Storms

Several typhoons have been reported with the most significant, recent typhoons being Xangsane (2006), Lekima (2007) and Ketsana (2009). These typhoons have rendered colossal losses of human lives, property and agriculture. Compared to floods, storms are more damaging to the economy. The Centre for Research on the Epidemiology of Disasters (CRED)'s data shows that economic losses due to storms are around 305.9 Million USD whilst for floods they come to 22.828 Million USD. Not many reports or data are available for storm events in Lao PDR.

Epidemics

CRED has compiled a very extensive disaster database for Lao PDR. Of all the disasters in Lao PDR, epidemics are the most frequent (EM-DAT, 2010). As stated in the report, most of the human losses in Lao PDR are due to epidemics, storms and floods. From 1981-2008, 891 deaths were reported due to epidemics, storms and floods; whilst 784 of these deaths were due to epidemics. Dengue, Acute Water And Bloody Diarrhea, Typhoid and Acute Respiratory Tract Infections are common diseases reported in the country.

UXOs

The National Regulatory Authority for UXO/Mine Action Sector in Lao PDR (NRA, 2008) is mandated to manage UXO mitigation in the country. UXOs have a lethal history in Lao PDR as they continue to kill large numbers of people and livestock, impede infrastructure development and deny access to agricultural and pastoral lands. Living with the constant fear of UXOs has reduced productivity even in low risk areas where the population lack alternative livelihoods. Villagers in these poor areas are forced to undertake high risk activities such as farming contaminated land. The victims continue to live in acute poverty and chronic malnutrition; risking injury and death by working on UXO-contaminated land.

In 1997, a survey conducted by Handicap International Belgium identified 11,000 people throughout Lao PDR who were injured or killed by UXOs between 1973 and 1996. Following this survey, UXO Lao and other organizations working in the UXO Sector have collected data of subsequent UXO accidents. Despite this, under-reporting of incidents is certain; with data reported from limited parts of the nine affected provinces. Figure 2.9 shows the impact trend of UXOs in Lao PDR. The impacts are classified into four types: accidents, casualties, deaths and injury. The classification has been extended, based on gender and age factors. The graph shows the decline in casualties and impacts but there is still an urgent need for mitigation intervention.

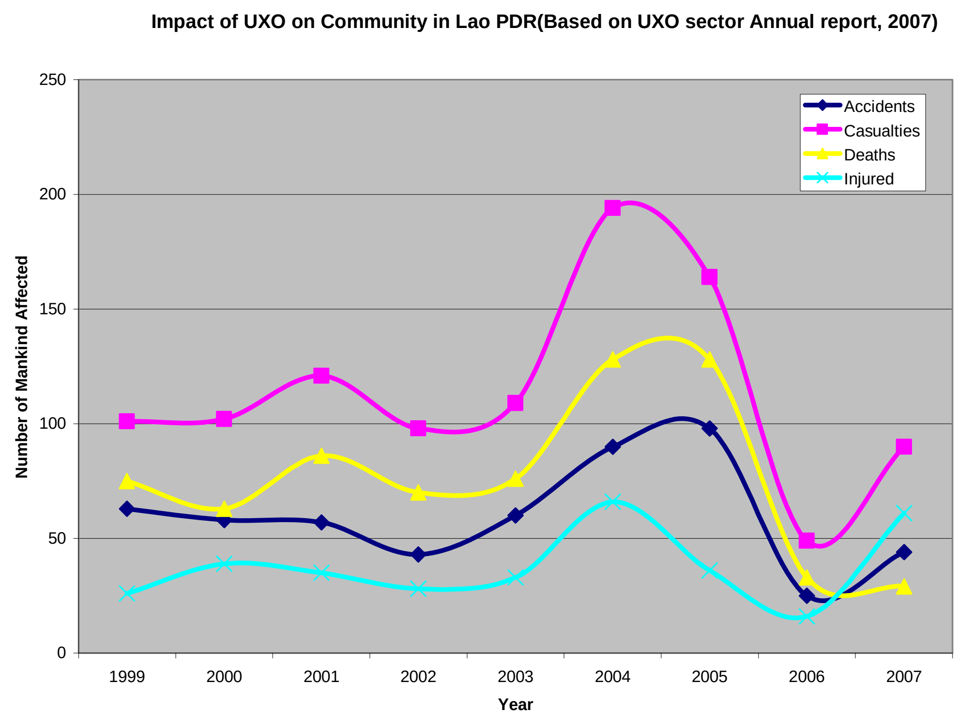


Figure 2.9 Impact of UXOs in Lao PDR

Landslides

The country is prone to landslides which are mostly triggered by heavy precipitation in the northern provinces. There is, however, no detailed database available at any of the focal agencies.

2.6 DISASTER DATABASE AT PROVINCIAL LEVEL

The Project Team collected disaster-related data from various focal agencies identified for the hazard assessment. Observations reveal that still there is paucity of detailed disaster data in the country. Several initiatives have, however, been undertaken by leading International NGOs along with NDMO to create a disaster catalog. One of the recent initiatives is LANGOCA project implemented jointly by ADPC and Save the Children, Australia. ADPC has already carried out a pilot study for collecting and compiling past disaster data for Sayaburi province and shown great success in developing a comprehensive historical disaster events database. The database has been prepared based on the DesInventar[2] (Disaster Inventory System) database (DesInventar, 2009). The report further analyzes the Sayaburi disaster database. There are six types of disasters reported in Sayaburi: house fires, wind storms, flooding, drought and disease outbreaks.

Fires are the most frequent event in Sayaburi. Figure 2.10 shows the profile of losses caused by fire in Sayaburi. Figure 2.11 shows the loss profile due to storms and

Table 2.7 and Table 2.8 show the loss profile due to drought and diseases in Sayaburi.

Under the LANGOCA project, disaster event databases will be up-scaled to produce similar data from the whole country, under the project "Establishing Disaster Risk Management Information System"**.** The data is compiled using the updated version of DesInventar software developed by UNDP. The National Risk Profile Project Team will support the activities of provincial level data collection by providing resource inputs and technical manpower to the LANGOCA project. The collected data will be used for various components of hazard and vulnerability assessments under the National Risk Profile Project.

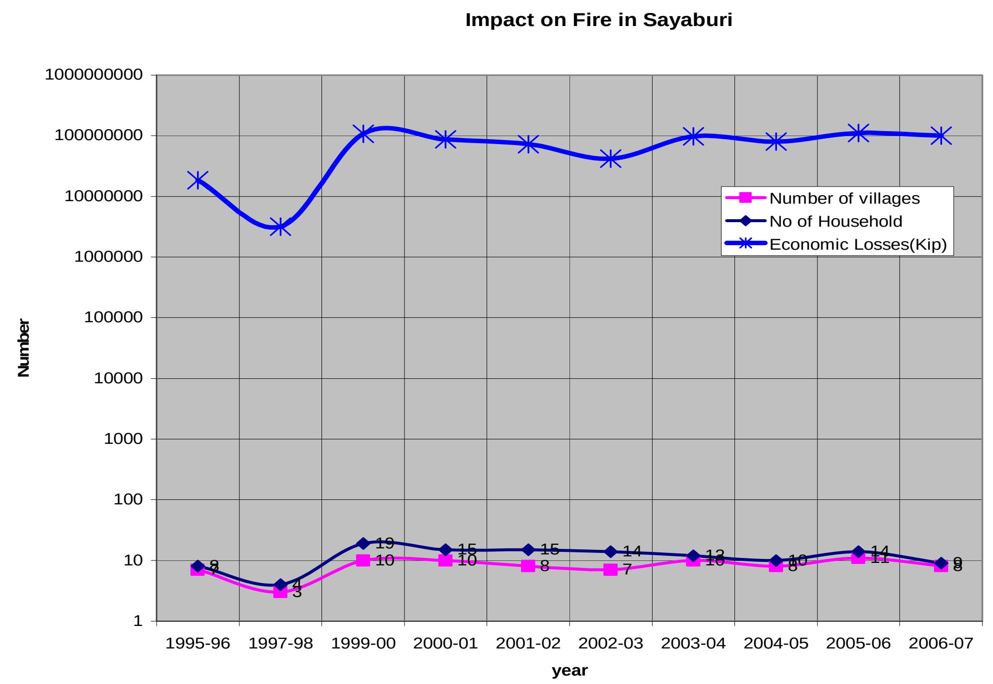
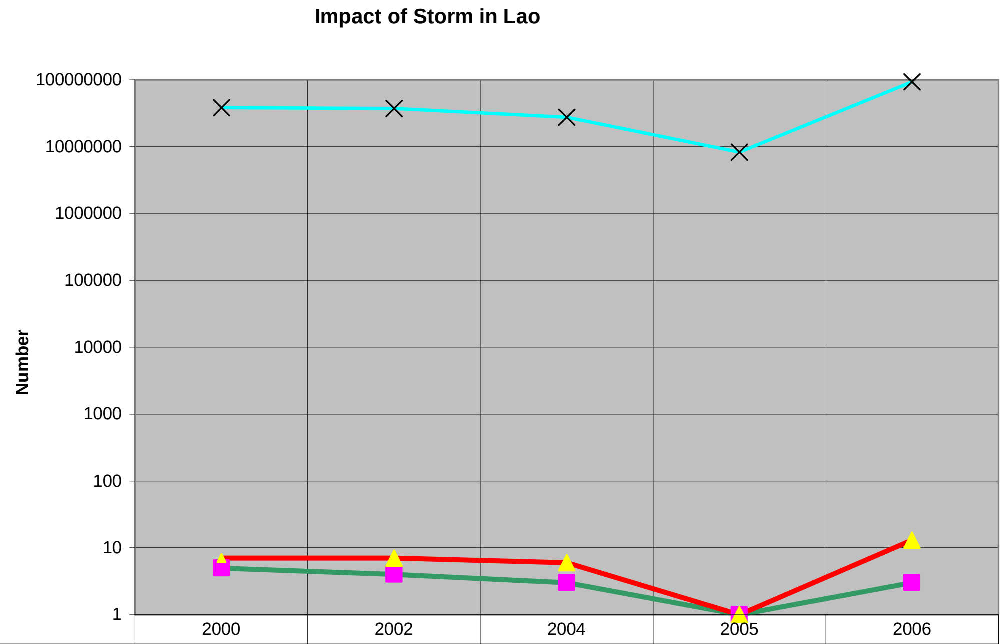


Figure 2.10 Impact of Fire in Sayaburi



	2000	2002	2004	2005	2006
Number of Villages	5	4	3	1	3
Number of Family	7	7	6	1	13
Economic Losses(in Kip)	38,340,000	37,420,000	27,512,000	8,251,000	92,560,000

Year

Figure 2.11 Impact of Storms in Lao PDR

2 (http://www.desinventar.org/)

Table 2.7 Drought profile of Sayaburi (Source: (DesInventar, 2009))

Year	No of Villages	Number of families	Economic Losses (Kip)
2007	10	279	429,240,000
	16	757	174,400,000
	7	33	29,000,000

Table 2.8 Animal Diseases in Sayaburi (Source: (DesInventar, 2009))

Year	Number of Animal / Livestock	Economic Losses(Kip)
2005	167	145,900,000
2006	152	119,000,000
2007	152	95,200,000

2.7 DISASTER TREND IN LAO PDR

For the purposes of this study, seven of the most frequent disasters were considered: earthquakes, landslides, floods, drought, storms, epidemics and UXOs. In the absence of sufficient data, producing trend lines for disaster events was not possible. A crude trend was established, however, based on CRED, GRID, and the national database. The CRED report presents a graph showing disaster-induced deaths. 86% of deaths have been reported due to epidemics, followed by floods (8%) and storms (6%). Floods have the highest impacts, affecting 58% of the population whist storms and droughts only affect 27% and 15% of the population respectively. Economic losses are mostly caused by storms (305.95 Million USD) followed by floods (22.828 Million USD).

Prevention web identifies the status of human and economic exposure for Lao PDR. These details are presented in Table 2.9 and Table 2.10.

Table 2.9 Human exposure profile of Lao PDR [3]

Hazard type	Population exposed	Percentage of population (%)	Country ranking
Cyclone	1,430	0.02	70th out of 89
Drought	313,984	5.34	86th out of 184
Flood	63,545	1.08	37th out of 162
Landslide	1,848	0.03	46th out of 162
Earthquake	29,892	0.51	85th out of 153
Tsunami	0		0th out of 265

[3] (Source:http://www.preventionweb.net/english/countries/statistics/risk.php?cid=94)

Table 2.10 Economic exposure profile of Lao PDR [4]

Hazard type	GDP exposed (billions-US$)	Percentage of GDP (%)	Country ranking
Cyclone	0		77th out of 89
Flood	0.03	1.10	83rd out of 162
Landslide	0.01	0.37	77th out of 162
Earthquake	0.11	4.03	113th out of 153
Tsunami	0		0th out of 265

2.8 SOURCE OF DATA AND INFORMATION

Several focal government departments and institutions were involved in providing the various types of data relevant to this project. The Project Team initiated the consultative process with these key stakeholders and collected the various data from the various stakeholders throughout this process. The agencies identified for such consultations and specific data they provided are shown in Table 2.11, shown below:

Table 2.11 Source of data and information

No.	Name of Organization	Type of Data
1	National Disaster Management Office	Disaster profile – hazard types, occurrence, extent, economic losses, etc.
2	Lao Department of Statistics	Census 2005 dataset, Statistical Yearbook, information about geographical overview, general demographic characteristics, migration, literacy and education, health & disabilities, ethnicity and religion, economic activities, housing and living conditions and poverty and inequality
3	Department of Meteorology & Hydrology	Climate and meteorological data, rainfall information, spatial temperature distribution, early warning communication systems, daily wind speed, seismic recording, flood discharge at various basins
4	Soil Survey and Land Classification Center National Agriculture and Forestry Institute (NAFRI)	Forest cover, Soil maps
5	Ministry of Agriculture and Forestry	Crop pattern, production yield, crop typology, drought events, crops affected by floods and droughts
6	Department of Irrigation	Irrigation infrastructure database and production
7	Ministry of Health	Epidemic data , health infrastructure
8	Malaria Department	Case of malaria
9	Ministry of Education	Education units and associated database

[4] (Source:http://www.preventionweb.net/english/countries/statistics/risk.php?cid=94)

No.	Name of Organization	Type of Data
10	National Geographic Department	Ground survey, aerial photography, photogrammetry, geo-information and cadastral map Topographic database at scale 1:25,000 and 1:50,000 Topographic database at scales 1:100,000 Topographic database at scale 1:500,000& 1:1000,000 At 1:100,000 Scale, the attributes and features are as below: Details of Layers: · Admin Boundary /Transport /Building /Hydrography /Contour /Designated area /Utility lines Attributes details: · Functional use: terminal/ commercial/ customs/ factory / fire stations/ health posts/ hospitals/ industrial/ petrol pumps/ post office/ power stations/ railway station/ residence/ ropeways/ schools/ telephone office/ transformer station/ monuments/ chimney/ mining · Religious building: Temple/ stupa/ mane/ church/ mosque/ cemetery/ crematorium ·Structure type: Cave/ chimney/ gate/ mining site/ open shed/ revetment/ ruins/ view towers/ wall · Contour: contour value, spot elevation · Administrative area: country/ province/ district / village · Designated area: national parks/ wild life reserve/ sanctuary / conservation area/ reserved forest Feature Class: · Transportation: Roads: Highway/ regional road/ provincial road/ district road/ other roads Trails and tracks: Cart track / Railways /Ropeways/ Bridge/ other crossings/ Tunnel/ Airport / Buildings · Built up area: Buildings/ Religious/ Other structures · Land cover: Cultivation / Vegetation/ Forest/ Others · Hydrography: River/ Streams/ Glaciers/ Canals/ Ponds/ lakes · Utility: Electricity/ Telephone/ Telegraph/ Transmission/ Tower/ Pipe Line/ Water Line/ Sewerage Line
11	Department of Geology and Mines	Tectonic map with legend 1:500,000 scale • Geo-morphological maps 1:200,000 scale • Geological maps 1:200,000 scale.
12	Ministry of Communication, Transport, Post and Construction	Community , government built infrastructure , roads database
13	National Regulatory Authority	UXO data

2.9 INFRASTRUCTURE

2.9.1 EDUCATION

The educational institutes of Lao PDR were classified into three main categories: kindergarten and crèches, general education and vocational education. The general education category includes primary, secondary and upper secondary schools, whilst the vocational education category includes universities, institutes, technical secondary schools and technical first schools. In 2005 the total number of education institutes was 10716; comprising of 1170 kindergarten and crèches, 9422 general education institutes and 124 vocational education institutes (LDS, 2007). Figure 2.12 shows the numbers of educational institutes for every 1000 students in 2007.

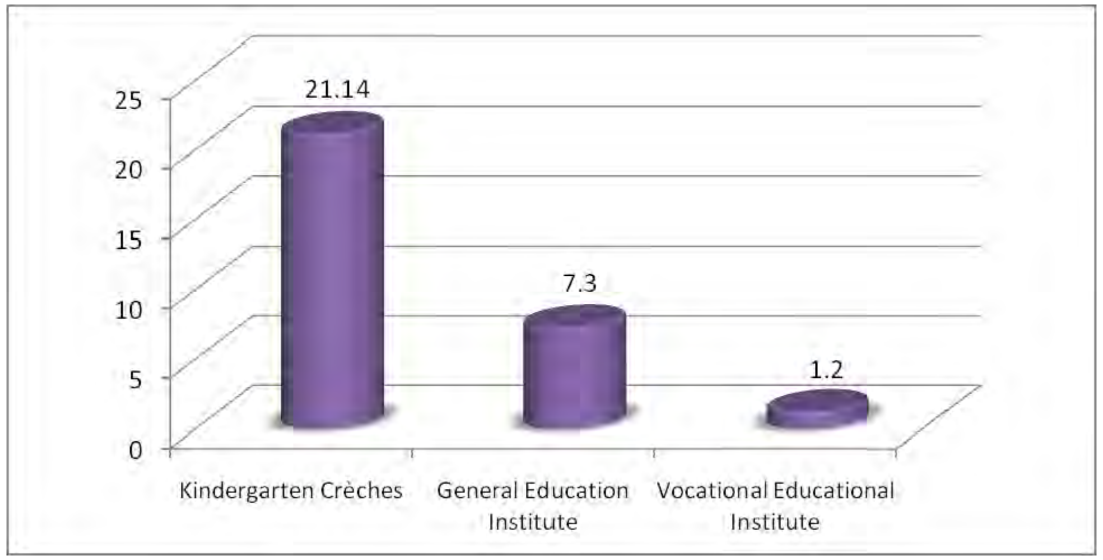


Figure 2.12 Numbers of educational institutes per thousand students (Source: (LDS, 2007))

According to the GIS-based data from NGD (NGD, 2010) the total number of schools in Lao PDR is 10093. School density per capita is highest in Savannakhet province (22.95%) and lowest in Xaysomboun SR province (1.35%). The province-wide ratio of school per thousand people ranges from 3.49 (Xiengkhuang province) to 0.62 (Vientiane province). Figure 2.13 shows the province-wide distribution of numbers of schools in Lao PDR. On average, 21.14, 7.3 and 1.2 educational institutes were available for every 1000 students for kindergarten, general education and vocational education respectively.

According to the 2005 census, literacy rates in Lao PDR have increased from 60% in 1995 to 73% in 2005. The literacy rate has increased nationwide and priority provinces have shown improvement that is higher than the national average. Net enrollment in primary schools also rose from 58% in 1991 to 84% in 2005. The literacy rate is highest in Vientiane Capital (92%) and lowest in the Phongsaly province (43%). The rate is also higher in urban areas (89%) and lowest in rural areas (54%). This difference between urban and rural areas is because of the lower number of schools per capital in rural areas as well as the lack of road infrastructure. Men are generally more literate (83%) than women (60%) in Lao PDR.

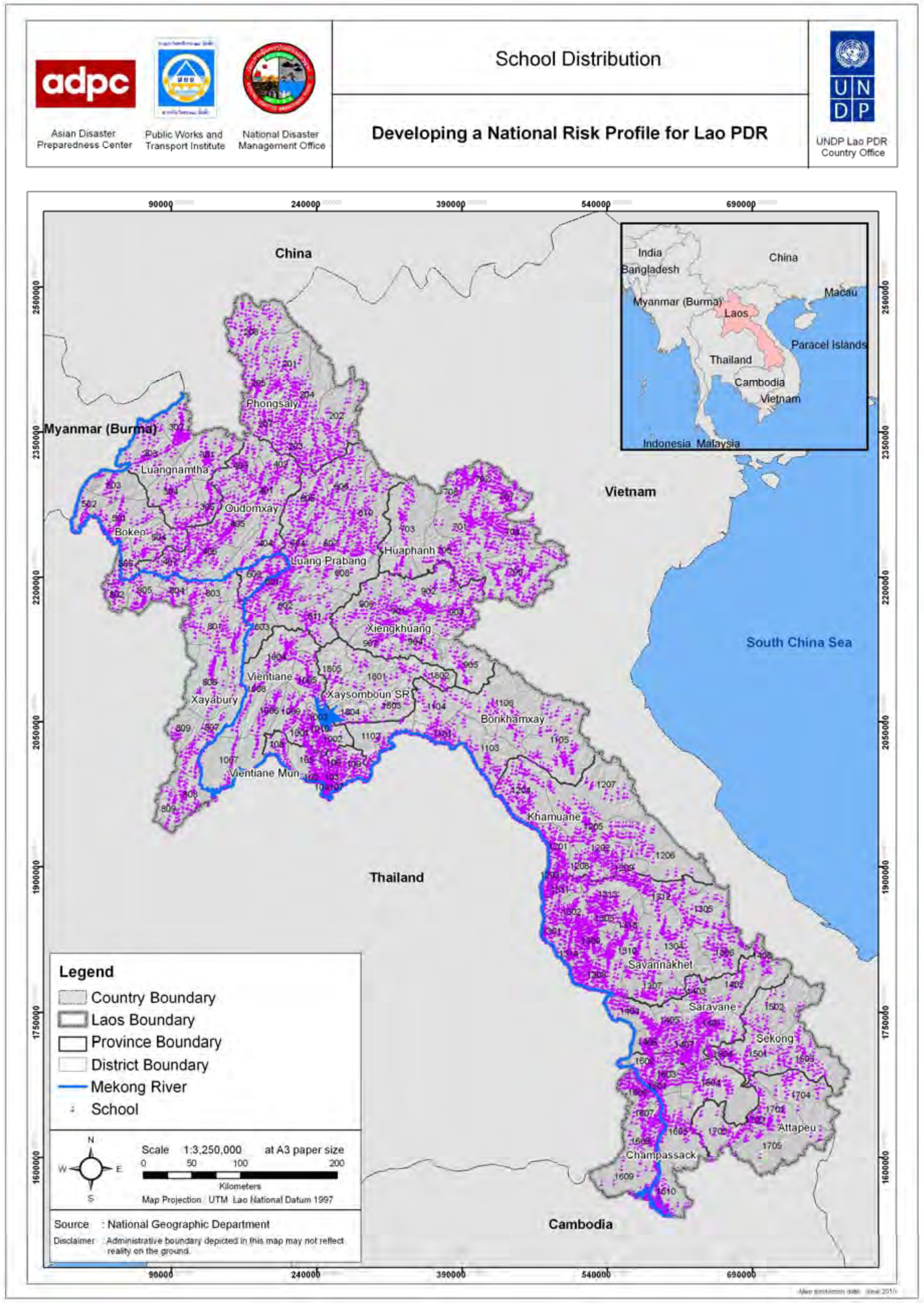


Figure 2.13 Map showing province-wide distribution of schools in Lao PDR (Source: (NGD, 2010))

2.9.2 HEALTH

According to the GIS-based information from NGD (NGD, 2010), the estimated total number of health institutes in Lao PDR is 991. These include the central hospitals, curative centers, regional hospitals, provincial hospitals, district hospitals, private clinics and dispensaries. The highest numbers of health institutes are located in Vientiane Capital (13.72%) and Saravane (13.02%) province. On the other hand, there is no health institute in Bokeo province.

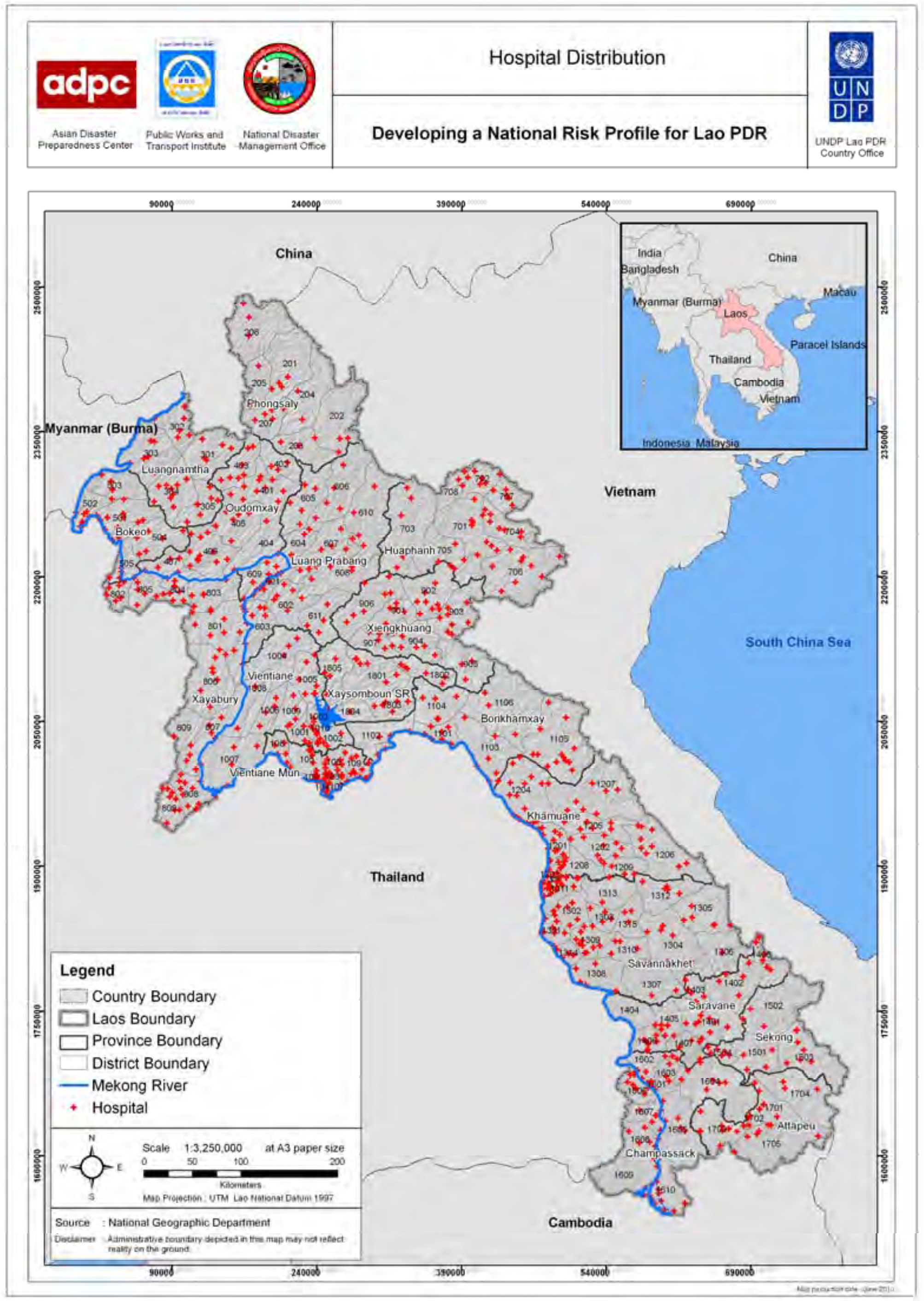


Figure 2.14 Map showing the province-wide distribution of health institutes in Lao PDR (Source: (NGD, 2010))

Figure 2.14 shows province-wide distribution of health institutes in Lao PDR (NGD, 2010). The number of health institutes versus population ratio shows that on average there are 0.18 health institutes available for every 1000 people.

In 2007, the total number of beds was 6995 in these health institutes and the bed versus population ratio was 1.23 beds for every 1000 people (LDS, 2007). Figure 2.15 shows the number of beds for every 1000 people in 2007.

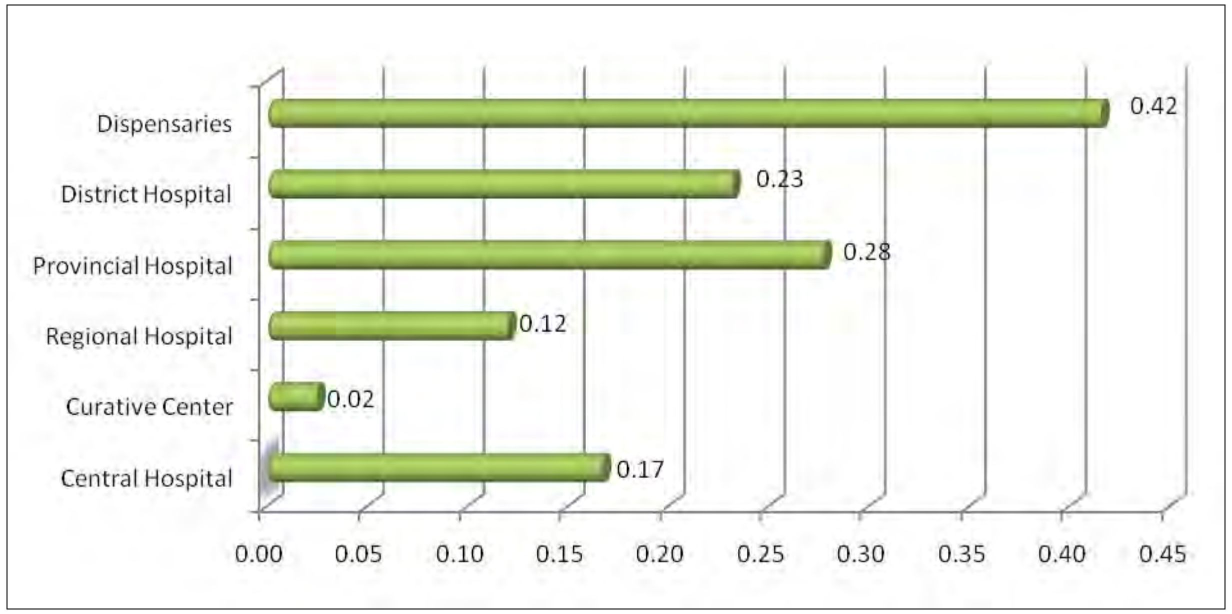


Figure 2.15 Number of beds for every thousand people (Source: (LDS, 2007))

2.9.3 TRANSPORTATION

There is no railway system and access to the sea in Lao PDR. The country depends primarily on road transport and, to a lesser extent, on river and air transport. Statistics show that in 2007, road transport carried about 88% of passenger traffic (passenger/km) and about 81% of freight traffic (ton/km) (LDS, 2007). Figure 2.16 and Figure 2.17 show the distribution of freight traffic and passenger traffic respectively, that was carried by different transport systems in 2007.

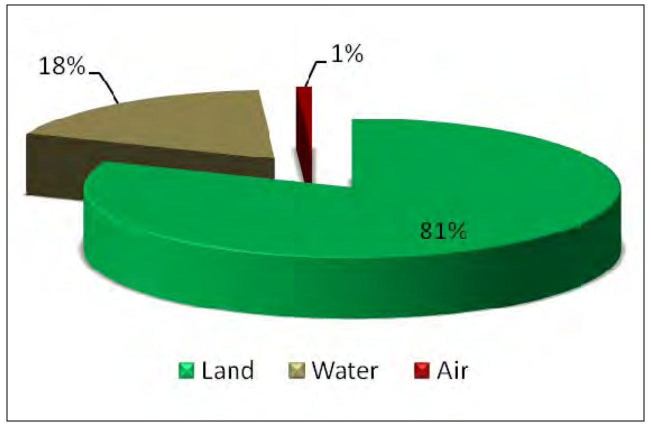


Figure 2.16 Freight traffic (passenger/km) in Lao PDR(Source: (LDS, 2007))

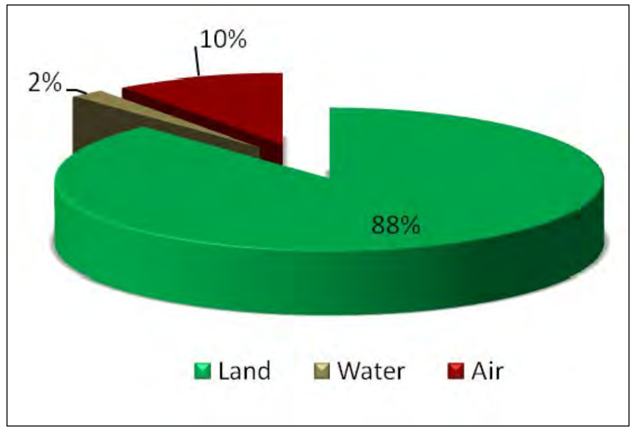


Figure 2.17 Passenger traffic (passenger/km) in Lao PDR(Source: (LDS, 2007))

The entire Lao road network is estimated to be 58,800km (NGD, 2010). It comprises of 4,610km of main (national and provincial) roads (7.85%), and 54,190km of district and local roads (92.15%). A high density of main roads is found in Borikhamxay province (511 km) in the central region, and Luang Prabang (437 km) and Xaignabouri (417 km) provinces in the northern region. Figure 2.18 shows the province-wide density of roads in Lao PDR. About 40% of the main road network is paved and the rest has gravel or earth surfaces. The public road network system of Lao PDR is mostly in a deteriorated condition. About 69% of the total main roads are classified as in poor or bad condition.

The Mekong River and its tributaries, the Nam Ou and Se Kong rivers, flow through Lao PDR for over 2,000km; providing a natural means of transportation. Rapids, falls, and low water levels during the dry season, however, reduce its navigability to only 1,300km (Nogales, 2004).

There are three international airports, nine domestic airports and 54 airfields in the country. Domestic air transport, though small in volume, plays a significant role by providing passenger services between important urban areas and to areas otherwise inaccessible.

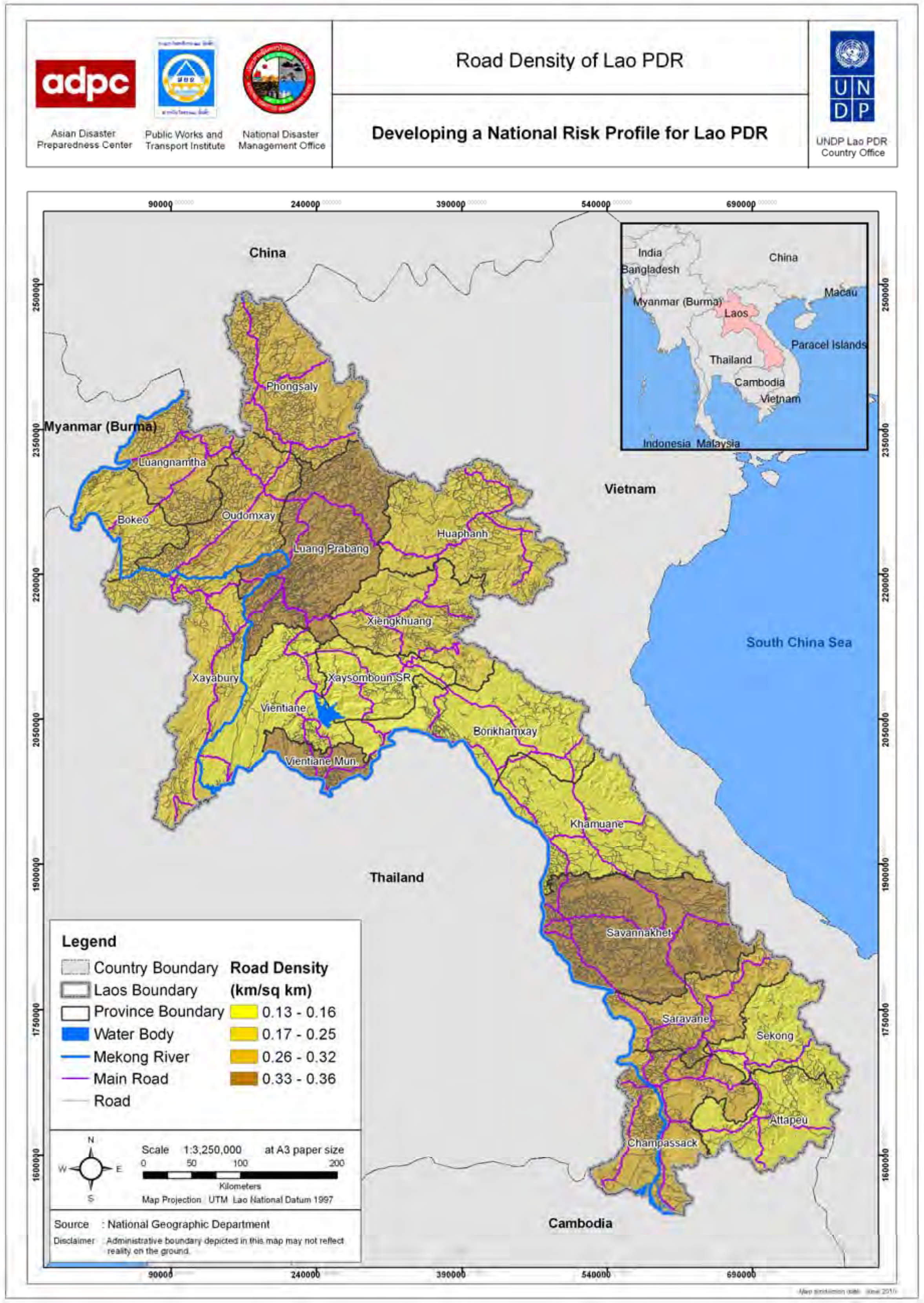


Figure 2.18 Map showing the province-wide density of roads in Lao PDR (Source: (NGD, 2010))

2.9.4 HOUSING

Private housing in Lao PDR has been classified into two basic categories: permanent and temporary houses (Census, 2005). The main basis of this classification is the type of building materials used for the roof, walls and floor. Permanent houses include concrete/brick houses, wooden houses and concrete/wooden houses. Temporary houses include semi-permanent houses with structures made from bamboo, plywood and grass. According to the Population and Housing Census (2005) about 90% of households live in permanent houses and about 10% are in temporary houses. Based on the accessibility to roads, private housing has again been classified into three categories: urban, rural with road access and rural without road access. The statistics show that there are 72.1% of households living in rural houses (51.56% rural with road access and 20.54% rural without road access) and 27.9% households living in urban houses (Figure 2.19).

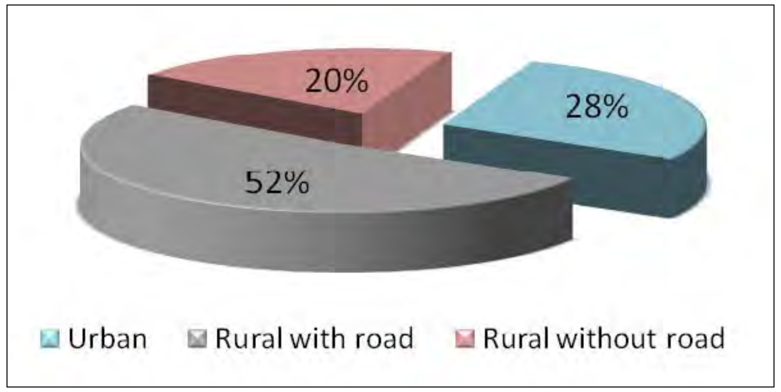


Figure 2.19 Households living in houses in terms of access to road (Source: (LDS, 2007))

There are five types of private housing occupancy that exist in Lao PDR. These are owners, tenants, lodgers, tied accommodation and other. The other category includes those who stay free in dwellings but constitute a separate household. About 90% of households live in their own houses and only 0.1% of households live there for free. The other type of living arrangement, such as tenant, lodger and tied accommodation, are found in urban areas (6%). In rural areas almost 100% of households live in their own houses.

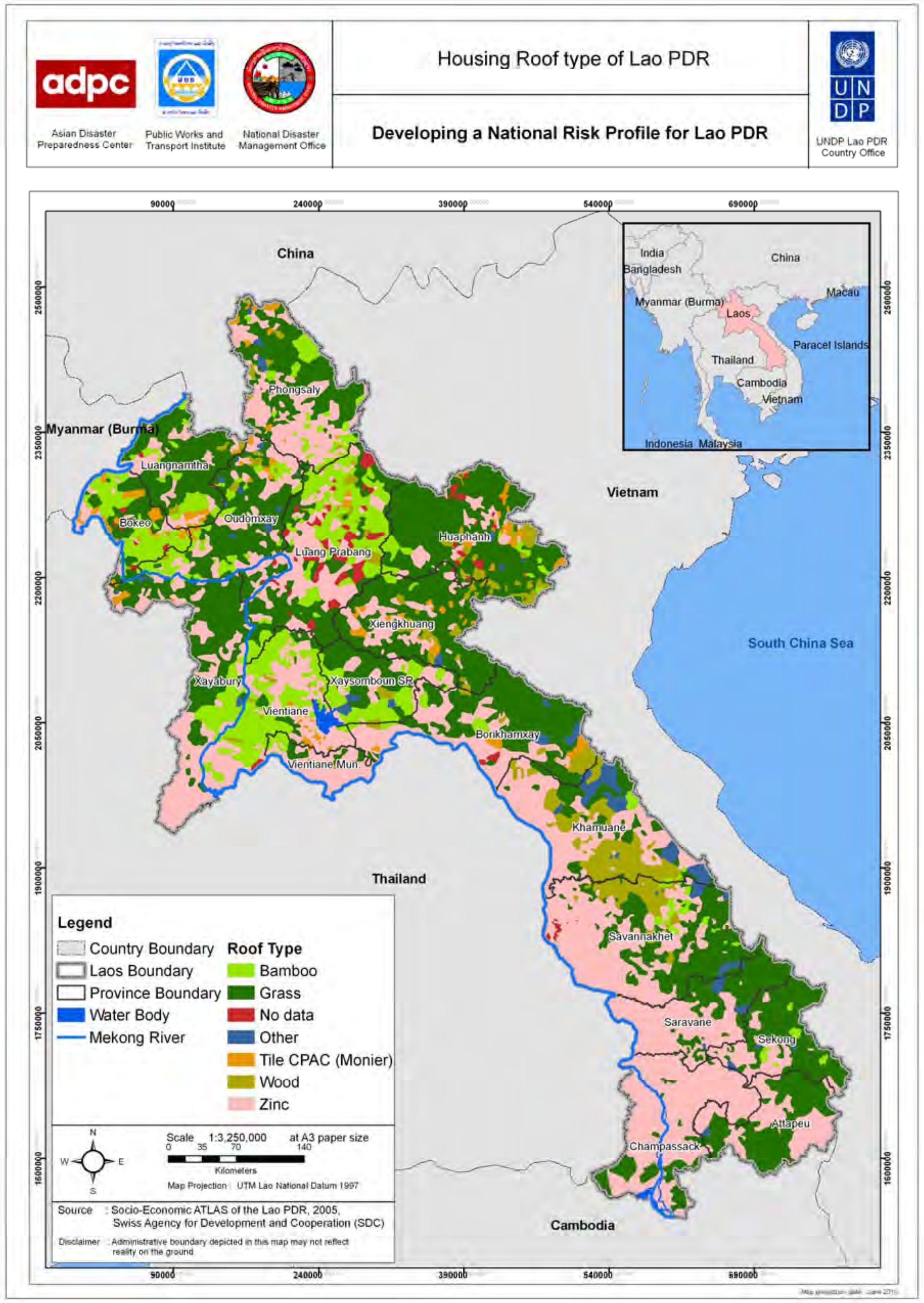


Figure 2.20 Map showing the distribution of housing roof type (Source: (Census, 2005))

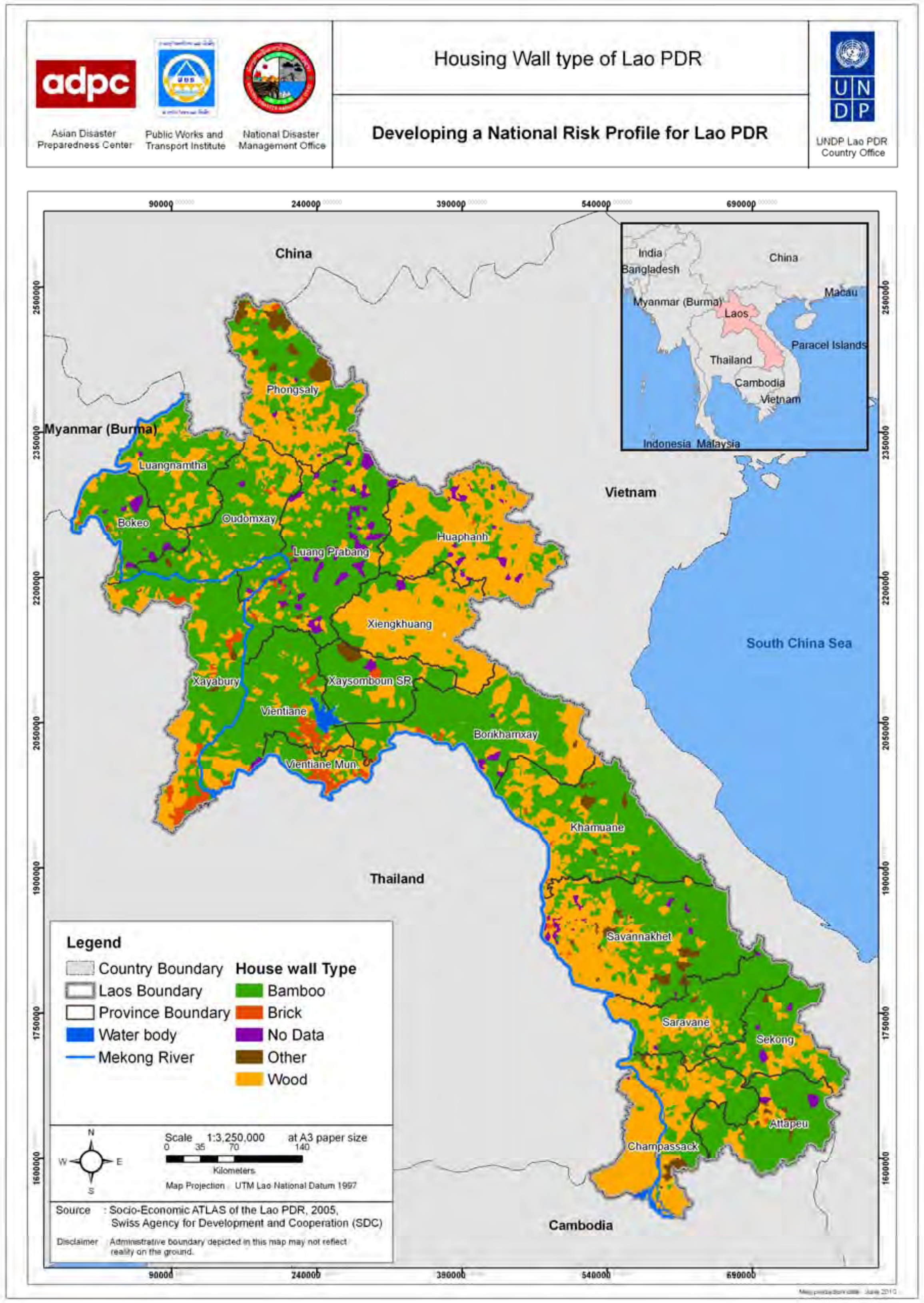


Figure 2.21 Map showing the distribution of housing wall type (Source: (Census, 2005))

2.9.5 IRRIGATION AND WATER RESOURCES

In Lao PDR all areas are irrigated by surface irrigation; sprinkler and micro-irrigation are not used (FAO, 2007). Irrigation is classified into two categories: rain-fed lowland and dry season irrigation. In 2008 the total area equipped for irrigation was estimated at 755,858ha (DOA, 2008). 661,328ha of this area receive rain-fed lowland irrigation during the wet season whilst 94,530ha receives dry season irrigation. The rain-fed lowland irrigation is common throughout the country but the dry season irrigation is mainly concentrated in the central region (70.55% of total dry season irrigated areas), especially near the major cities like Savannakhet (27.65%) and Vientiane Capital (22.3%). Dry season irrigated areas in the southern and northern regions are 18.8% and 10.55% respectively. Figure 2.22 shows the distribution of dry season irrigated areas by region. River diversion is the main source of water for irrigation schemes.

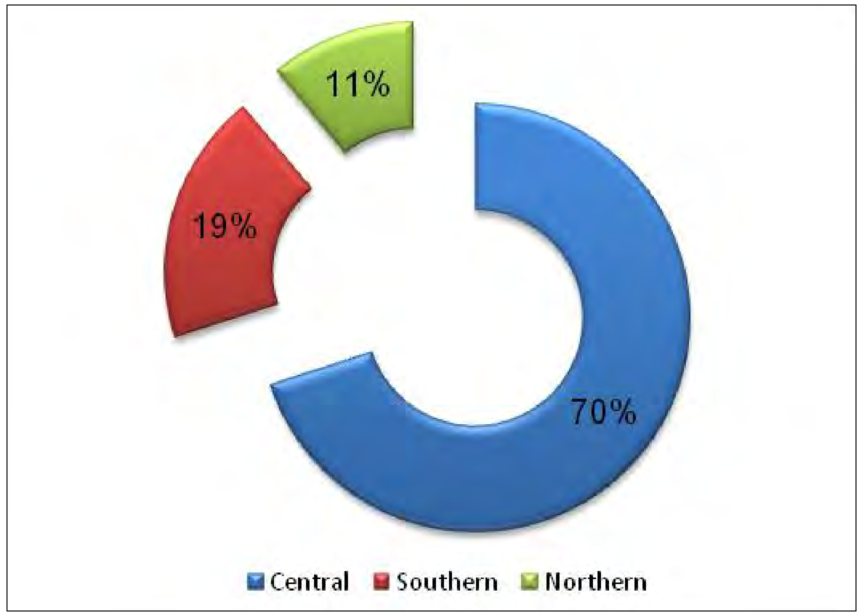


Figure 2.22 Dry season irrigated area by region in Lao PDR (Source: (DOA, 2008)).

2.9.6 FISHERIES

The fisheries sector of Lao PDR includes both captured fisheries and aquaculture. Lao PDR is located in the Mekong River Basin and the Mekong catchment comprises about 97% of the total area of the country (FAO, 2002). Freshwater resources are dominated by rivers and the country includes some of the most pristine of all the Mekong tributaries. River fisheries dominate the sector. Floodplain and swamp fisheries occur in localized areas and are generally more common in the south of the country. The country has one large reservoir, Nam Ngum, with a modest production and a number of smaller reservoirs used for hydropower and mainly irrigation. Aquaculture is poorly developed, compared to SEA standards.

According to the Fisheries Division, the production figure of inland captured fisheries was about 30,000 metric tones (MT) nationally in 1999. The figure was estimated based on the household survey in 1997/98 related to expenditure and consumption of fish. The official figures for total production (1990-1999) from inland captured fisheries are shown in Figure 2.23. Lao PDR is not a net exporter of fish. Considerable quantities of fish pass informally between Lao PDR and Thailand, especially in the south and along the Mekong River, which forms much of the 1800 km international border between the two countries (FAO, 2002).

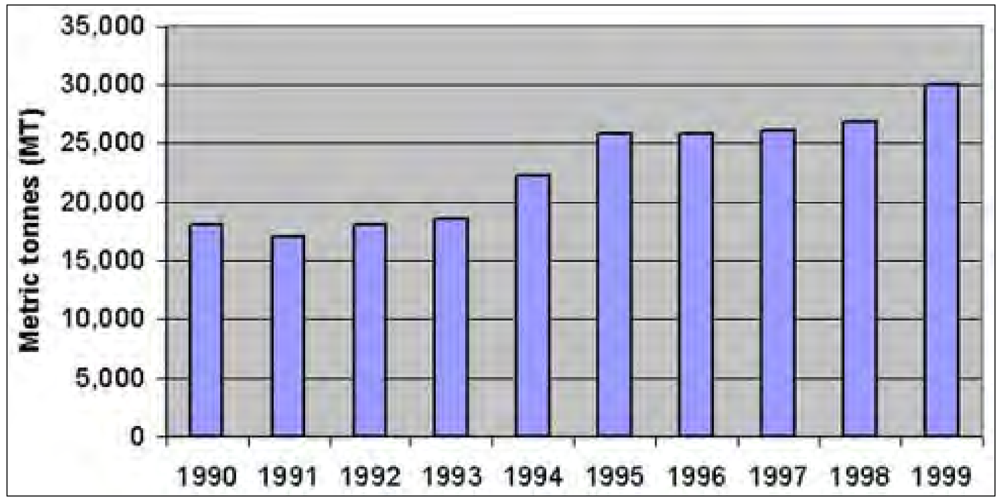


Figure 2.23 Production of inland captured fish in Lao PDR (Source: (FAO, 2002))

2.9.7 AGRICULTURE

Lao PDR is primarily an agricultural economy and this sector contributes about 37% (estimated in 2009) of the GDP (U.S. Department of State, 2010). About 80% of the total population is involved in agricultural activities (Thibaut, 2010). Agricultural land is 11,943 sq km, which is about 5% of total land area of the country (NGD, 2010). It covers both swidden (slash-and-burn) agricultural field or "hai" and permanent agriculture. In 2008 the total agriculture planted was 1,398,752ha and crop production was 6,207,470 MT (DOA, 2008). The major crops in terms of agricultural production are rice (47.16%), maize (15.25%), vegetables (13.07%), starchy roots (6.9%) and fruits (6.36%). Figure 2.24 shows distribution of crop production by type in 2008. Most of the rice is produced in the central region of the country (54.8%) because this region is comparatively low in nature.

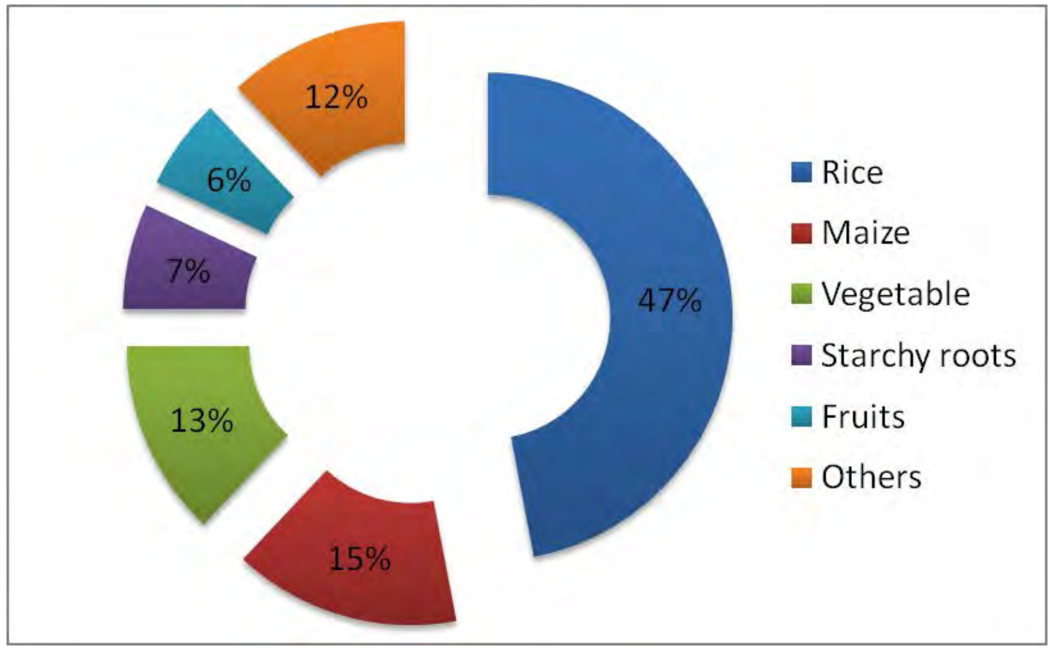


Figure 2.24 Crop production by type in Lao PDR (Source: (DOA, 2008)).

The agricultural sector of Lao PDR has not played a major role in the country's foreign trade. The major export products from this sector are timber, lumber, plywood and coffee.

2.9.8 ECONOMY AND EMPLOYMENT

Lao PDR is a landlocked, least developed country (LDC) surrounded by prosperous neighboring countries with strong economic growth. In 2009 Lao PDR's GDP growth rate was 6.5%, which is below the average growth (7.5%) of the previous 5 years (ADB, 2010). The main contributors of Lao PDR's GDP growth are industrial (3.8%), agricultural (0.7%) and from the service sector (1.7%). Figure 2.25 shows the contribution of the major three sectors to GDP growth.

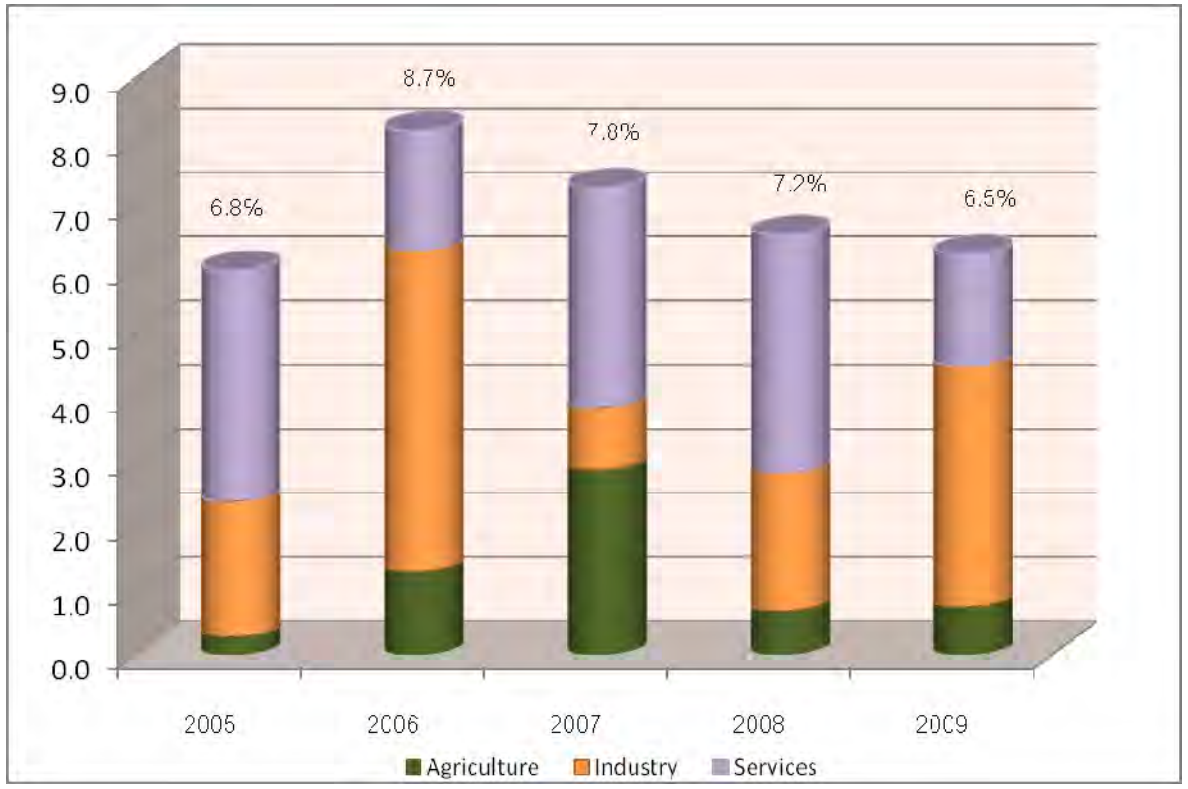


Figure 2.25 Contribution of the major three sectors to GDP growth (Source: (ADB, 2010)).

The principal exported goods of Lao PDR are electric power, plywood and coffee. Lao PDR's principal imported goods are motorized vehicles, paper, sugar, medicine and rice.

About 98.6% of the economically active populations of Lao PDR are employed (Census, 2005). The economically active population has been defined as the population of 10 years and above. Students, household workers, retired, sick and the elderly have not been considered in this category. Figure 2.26 shows the percentage of employed and unemployed economically active population in Lao PDR. These employed populations are engaged in seven broad employment sectors: government, parastatal, private, state enterprise, employer, own-account worker and unpaid family worker. Figure 2.27 shows how the economically active population is engaged in different employment sectors. The statistics show that the majority among these employments are unpaid family workers (46%) and own account workers mainly in agriculture (42%). The Vientiane Capital, Savannakhet and Saravane province have a higher proportion of economically active employment.

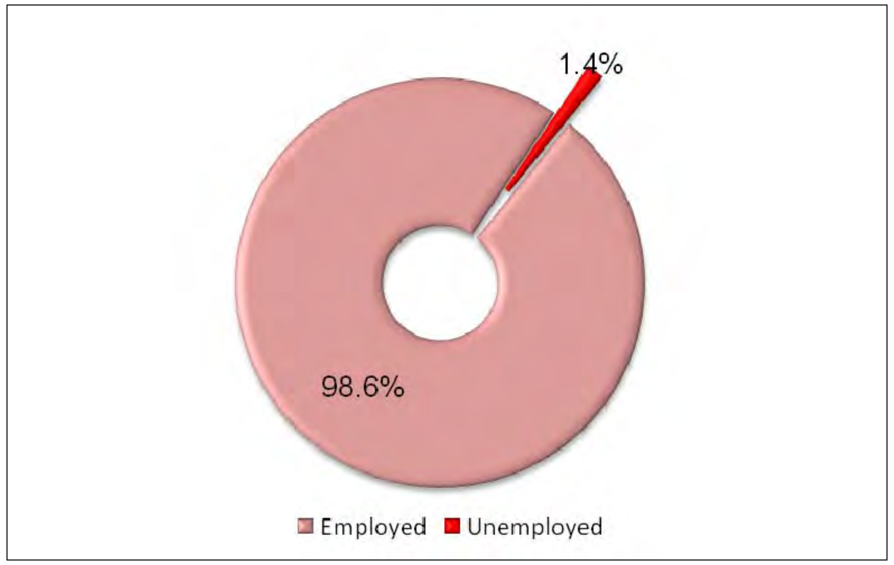


Figure 2.26 Employed and unemployed economically active population (Source: (Census, 2005))

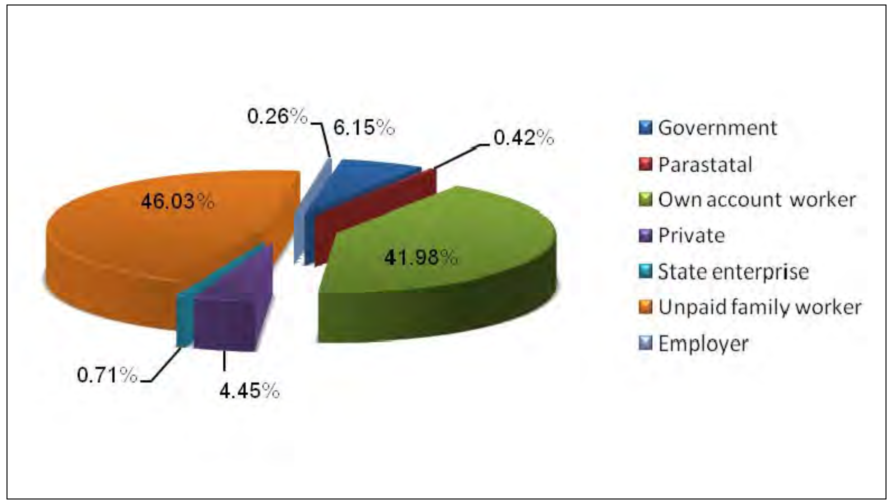


Figure 2.27 Population engaged in different employment sectors (Source: (Census, 2005))

2.9.9 TOURISM

The tourism industry in Lao PDR has grown impressively since 1990; becoming a major contributor to national income and employment. The great potential for expanding the tourism sector lies in the country's stunning natural environment, rich culture and heritage, and its location surrounded by such popular tourist destinations as Thailand, China, Vietnam, and Cambodia. Lao PDR also has a great quantity of natural resources such as rivers, mountains, and vast numbers of wild bird and animal species. The total protected forest covers about 36.54 sq. km all over the country (NTA, 2006). It comprises of 15.8 sq. km in the central region, 11.47 sq. km in the northern region and 9.27 sq. km in the southern region of Lao PDR. Given these advantages, tourism is now the major earner of foreign exchange for the country.

At present there is a total of 15 international checkpoints in Lao PDR and tourists are able to get visas on arrival at 13 of these checkpoints. There are now three international airports in the country. From 1995 to 2007 the number of tourists entering the country increased at the average rate of 18.67% per annum (LDS, 2007); earning the country huge revenue. In 2004, for instance, the tourism sector earned revenue of 118,947,707 US$. Figure 2.28 shows the number of tourists that entered Lao PDR from 1995-2007. Based on the recent growing number of tourists and regular flow rate, the National Tourism Authority of Lao PDR estimated that there will be three million tourists in 2020 with an expected revenue of 250-350 million US Dollars per year (NTA, 2006). Tourists in Lao PDR come from almost all over the world. Figure 2.29 shows the distribution of tourists, by region of origin, that visited Lao PDR in 2007.

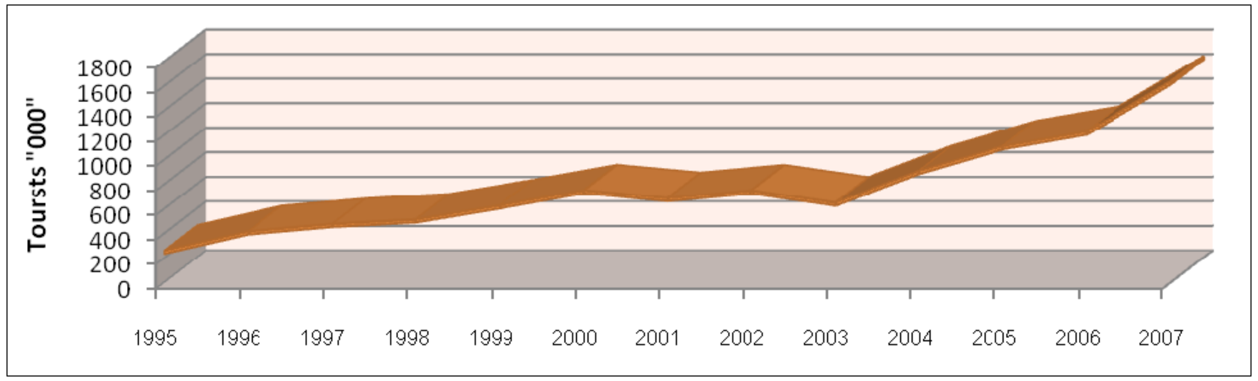


Figure 2.28 Number of tourists that entered Lao PDR from 1995-2007 (Source: (LDS, 2007))

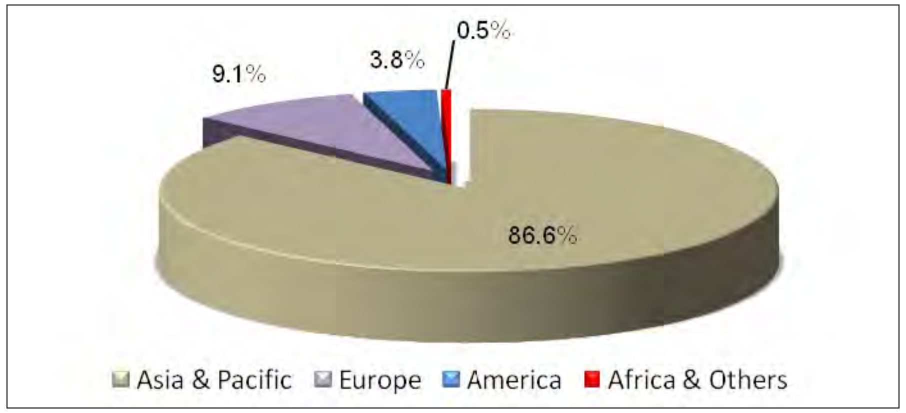


Figure 2.29 Distribution of tourists, by region of origin, that visited in 2007 (Source: (LDS, 2007))

2.10 TELECOMMUNICATION

At least 15 provinces of Lao PDR are already connected with optical fiber. So far, the passive fiber optic connection has been installed, connecting all 18 provinces. The national fiber network is already being used for domestic telecommunication, both fixed and mobile, as well as for international internet access. In 2007 there were 88 automatic, 1 magnetic and 5 mobile telephone centers (LDS, 2007). Like any other country, mobile phones are increasingly popular in Lao PDR. In 2007, the number of telephone booths established and in operation was 1,185,982 and 1,075,012 mobile phones were used. Mobile phones were distributed throughout the country but fixed telephones were mostly concentrated in cities; especially in Vientiane Capital. The number of telephones by sector in 2007 is shown in Figure 2.30.

Figure 2.30 Number of telephones by sector in 2007 (Source: (LDS, 2007))

2.11 POWER

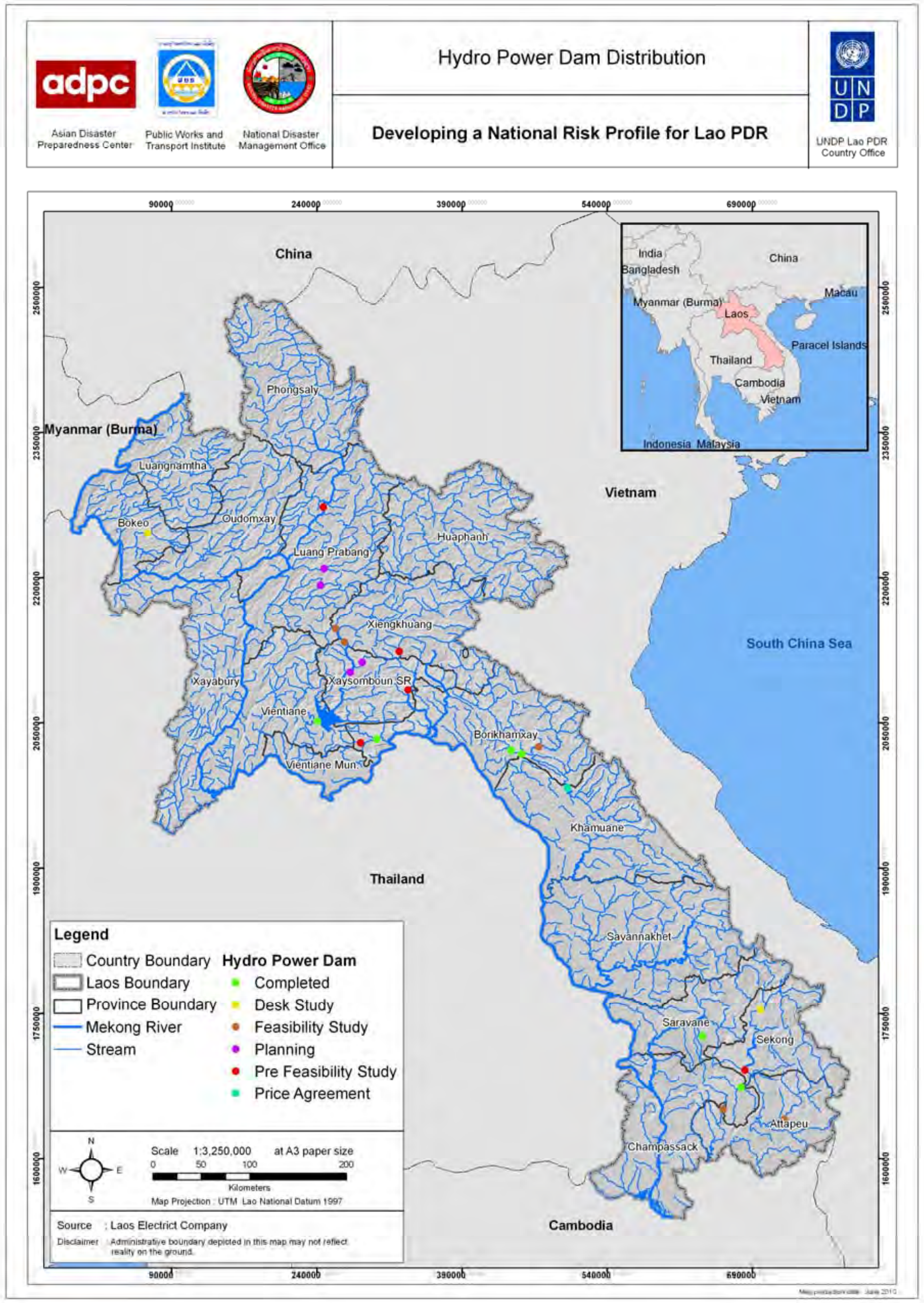


Figure 2.31 Map showing the distribution of hydropower dams in different provinces (Source: (NGD, 2010))

The power sector in Lao PDR serves two vital national priorities: (1) it promotes economic and social advancement by providing a reliable and affordable domestic power supply; and (2) it earns foreign exchange from electricity exports. The 18 tributaries of the Mekong River serve as potential for the generation of hydropower for export and development projects. At present there are 112 dams in Lao PDR (NGD, 2010) and most of these dams (50) are located in Savannakhet province. Figure 2.31 shows the distribution of hydropower dams in the different provinces.

The power sector, especially hydropower, has already become an important contributor to Lao PDR's economic growth. The total hydropower generation capacity accounts for 87 dams or about 25,000 MW and thermo-electrical power of more than 3,000 MW for export to neighboring countries as well as for domestic industries (NGD, 2010). In 2008 the export of electricity amounted to approximately 30% of all Lao PDR's export levels. Figure 2.32 shows power generation and export of electricity between 2001 and 2008.

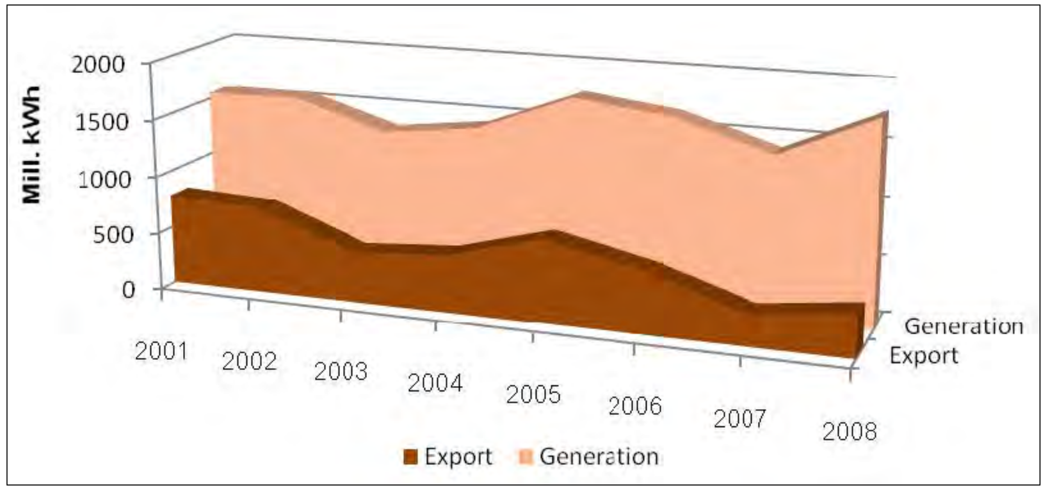


Figure 2.32 Power generation and export between 2001 and 2008 [5]

2.12 MINERAL AND QUARRY

Lao PDR has an abundance of metallic and bulk minerals. There is a wide variety of metals such as gold, silver, platinum, copper, lead, zinc, tin, antimony and iron. Non-metals available in Lao PDR include amber, amethyst, quartz, beryl, sapphires, kaolin, limestone, gypsum, potash, salt, sand and gravel. According to the Department of Geology (DoG, 2009) Lao PDR has a total of 572 mining deposits and prospects and 47% of these deposits and prospects were found to contain gold, copper, lead and/or zinc. Mining is one of the most important factors influencing the current high economic growth in Lao PDR. Figure 2.33 shows the export value of minerals from 2000 to 2004 (UNDP, 2006).

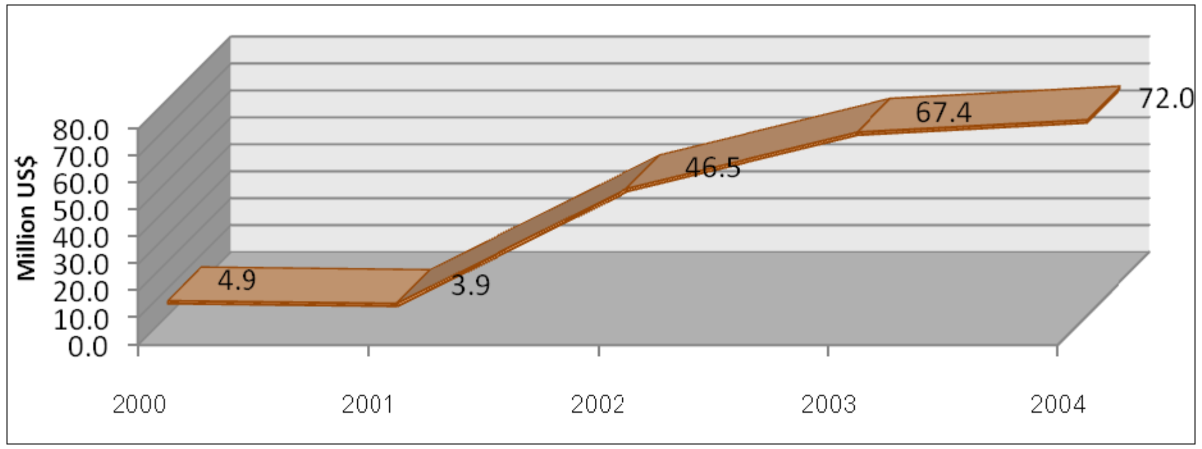


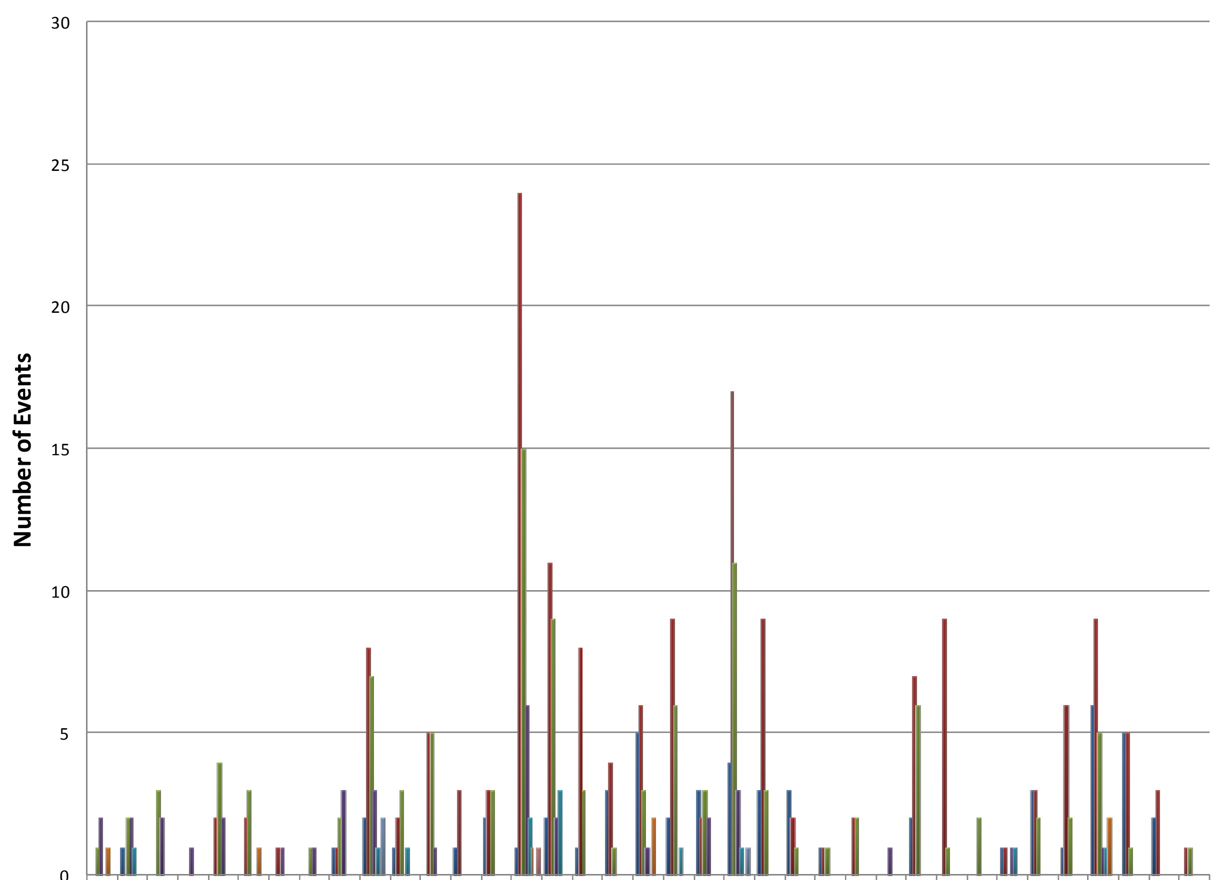
Figure 2.33 Export value of minerals from 2000-2004 in Lao PDR (Source: (UNDP, 2006))

[5] http://www.poweringprogress.org/index.php?option=com_content&view=article&id=90&Itemid=125

3 HAZARD ASSESSMENT

3.1 EARTHQUAKE HAZARD ASSESSMENT

Lao PDR is prone to moderate to negligible earthquake risk. The country has witnessed several small and moderate scale earthquakes in the past in northern and western parts of the country. Only one event of more than a seven magnitude was reported in the past. The details of earthquake events for the last 38 years are plotted in Figure 3.1. The Department of Mines and Geology is responsible for monitoring seismic activity in the country. The earthquake hazard map was developed by UNOCHA in Modified Mercalli Intensity (MMI) scale. The MMI scale is a simple indicator for understanding the severity of earthquake hazards.



	1973	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
3.6 - 4.0		1							1	2	1		1	2	1	2	1	3	5	2
4.1 - 4.5					2	2	1		1	8	2	5	3	3	2	1	8	4	6	9
4.6 - 5.0	1	2	3		4	3		1	2	7	3	5		3	1	9	3	1	3	6
5.1 - 5.5	2	2	2	1	2		1	1	3	3		1			6	2			1	
5.6 - 6.0		1								1	1				2	3				1
6.1 - 6.5	1					1									1				2	
6.6 - 7.0										2										
7.1 - 7.5															1					

	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
3.6 - 4.0	3	4	3	3	1			2			1	3	1	6	5	2	
4.1 - 4.5	2	1	9	2	1	2		7	9		1	3	6	9	5	3	1
4.6 - 5.0	3	1	3	1	1	2		6	1	2		2	2	5	1		1
5.1 - 5.5	2	3					1				1			1			
5.6 - 6.0		1									1			1			
6.1 - 6.5														2			
6.6 - 7.0		1															
7.1 - 7.5																	

Figure 3.1 Earthquake events in Lao PDR (based on USGS catalogue)

3.1.1 MAP CONTENT

Earthquake hazard maps were developed in MMI scale, which shows distribution of intensity throughout the country. The earthquake hazard map, in Figure 3.2 was prepared for 250 year return period.

3.1.2 APPLICATION OF MAPS IN DISASTER RISK MANAGEMENT

Earthquake hazard maps have been developed at the national scale for Lao PDR. Earthquake-prone areas have been delineated at the province level. Theses hazard maps were developed for several purposes, including:

- Earthquake hazard maps will be helpful for physical and infrastructural development in the country. The maps will help policy makers and decision-makers to understand the severity of earthquake hazard and take necessary action to sustain the development through the introduction of necessary programs and measures.
- Important sectors like education, health, housing, lifelines and transportation need special attention for earthquake safety. The earthquake zones will provide understanding about expected performance of structures during earthquakes and necessary measures to protect the structures.
- The zones will further help the local urban government to introduce and enforce building bylaws and codes to protect urban infrastructure.
- The maps will help national and international NGOs to prioritize their DRR strategies.

3.1.3 DATA SOURCES

Data used for producing maps was sourced from the following:

- Earthquake catalog for Lao PDR area. This can be downloaded from the USGS (USGS) website: http://earthquake.usgs.gov/earthquakes/eqarchives/epic/
- Earthquake hazard maps of the country are available online.

3.1.4 METHODOLOGY

The present earthquake hazard maps for Lao PDR were developed by the United Nations Office for Coordination of Humanitarian Affairs, OCHA Regional office for Asia and the Pacific, Bangkok. The map can be found on OCHA's website (http://ochaonline.un.org).

The UNOCHA earthquake hazard map was developed using map data from Global Discovery, FAO, Smithsonian Institute, Pacific Disaster Center, UNISYS and Munich Reinsurance Group. The earthquake map is presented in Modified Mercalli Scale (MMI). The MMI scale classifies the severity of earthquake shaking on a scale of I to XII. The lowest intensities are not felt by people, while the highest intensities correspond to nearly total destruction of all constructed facilities. The MMI maps derived from UNOCHA were in turn classified into four earthquake hazard categories for this study: negligible, low, moderate and high. The severity of earthquake hazard is illustrated in Figure 3.2.

3.1.5 HOW TO READ THE MAP

The hazard zones were calibrated, based on MMI distribution. Table 3.1 shows the relationship between intensity and severity zones. High seismic risk has been demarcated by red, followed by orange and yellow representing moderate and low seismic zones respectively. The map illustrates the geographical coverage of low, moderate and high seismic zones.

Table 3.1 Earthquake hazard zone scale

Zone	MMI Range	Color	Description
Low	I-V	yellow	Felt by nearly everyone. People awakened. Cracked walls, trees disturbed.
Moderate	VI	Orange	Felt by all. Many run outdoors. Furniture moves. Slight damage occurs.
High	VII	Red	Everyone runs outdoors. Poorly built buildings suffer severe damage. Slight damage everywhere else. Roofs and upper parts of building constructions damaged

The map is accompanied with Table 3.2 which shows seismic hazard zoning maps for return periods of 250 years within each province as per the format given in Figure 3.2.

3.1.6 ANALYSIS OF HAZARD ASSESSMENT

Table 3.2 shows province -wide coverage of various zones for stated return periods.

Table 3.2 Distribution of Seismic Hazard Zone in Lao PDR

	SN	Area in each Province		Total Area (sq km)	Number of districts	% Area Covered by Earthquake Hazard
		Name of Province	Area (sq km)			
VII MMI	1	Xayabury	15,541.07		5	56.7
	2	Bokeo	6,989.57		5	94.47
	3	Oudomxay	11,794.83		7	100
	4	Luangnamtha	9,605.49		5	100
	5	Phongsaly	15,470.98		7	97.6
				59,401.94		**25.78**
VI MMI	1	Xaysomboun SR	7,709.64		5	97.98
	2	Vientiane	12,591.74		10	90.28
	3	Xiengkhuang	12,715.39		7	95.87
	4	Huaphanh	17,522.78		8	99.96
	5	Luang Prabang	19,971.56		11	56.89
				70,511.11		**30.6**
I-V MMI	1	Attapeu	9,551.72		5	100
	2	Champassack	14,982.04		10	100
	3	Sekong	8,396.82		4	100
	4	Saravane	10,163.70		8	100
	5	Savannakhet	21,400.51		15	100
	6	Khamuane	16,724.40		9	100
	7	Borikhamxay	15,711.30		6	94.71
	8	Vientiane Mun.	3,586.91		9	67.97
				100,517.40		**43.62**
				230,430.44		

Xayabury, Bokeo, Oudomxay, Luangnamtha and Phongsaly provinces fall in a high earthquake hazard zone. Besides Xayaburi, more than 94% areas of other four provinces fall in a high earthquake hazard zone. The map shows that a quarter of the area of Lao PDR falls in a high earthquake hazard zone.

Xaysomboun SR, Vientiane, Xiengkhuang, Huaphanh and Luang Prabang provinces fall in a moderate earthquake hazard zone. The expected earthquake intensity in these provinces is VI or less. More than 30% of the country lies in a moderate earthquake hazard zone. Besides Luang Prabang, more than 90 % of the geographical area of these four provinces falls in a moderate earthquake hazard zone.

Similarly, the remaining eight provinces fall in a low earthquake hazard zone. 43.62 % of the country's area falls in a low earthquake risk zone.

3.1.7 SPECIAL REMARKS

- The earthquake hazard maps have been developed using MMI scale. The hazard assessment is based on earthquake intensity maps developed by UNOCHA. The objective of developing MMI scale map is to help policy makers and decision makers understand the distribution and severity of earthquake risk in the country. Though PGA maps are more precise and could be understood and used by seismologists, geologists and civil engineers, it is not used by other sectoral development and planning professionals. The maps developed for this report should therefore be more easily referred to and understood by a larger section of society.

3.1.8 RECOMMENDATIONS

- The Government of Lao PDR has set up a Meteorological Network, earthquake monitoring and Telecommunication National Seismological Center under the Department of Meteorology and Hydrology. The purpose of the center is to compile and monitor seismic activity in the country. There is a network of seismic stations in the country that monitor ongoing seismic activities. There is still a need to enhance this monitoring system.
- More earthquake events have been reported in the northwest of the country. There is a need for more intensive study in earthquake active areas.
- At present, past earthquake isoseismal maps are not available. It is necessary to develop this system, so that earthquake isoseismal maps could be plotted in detail after the earthquakes.
- Further study on active faults within Lao PDR should be carried out for refined prediction of its tectonic behavior.

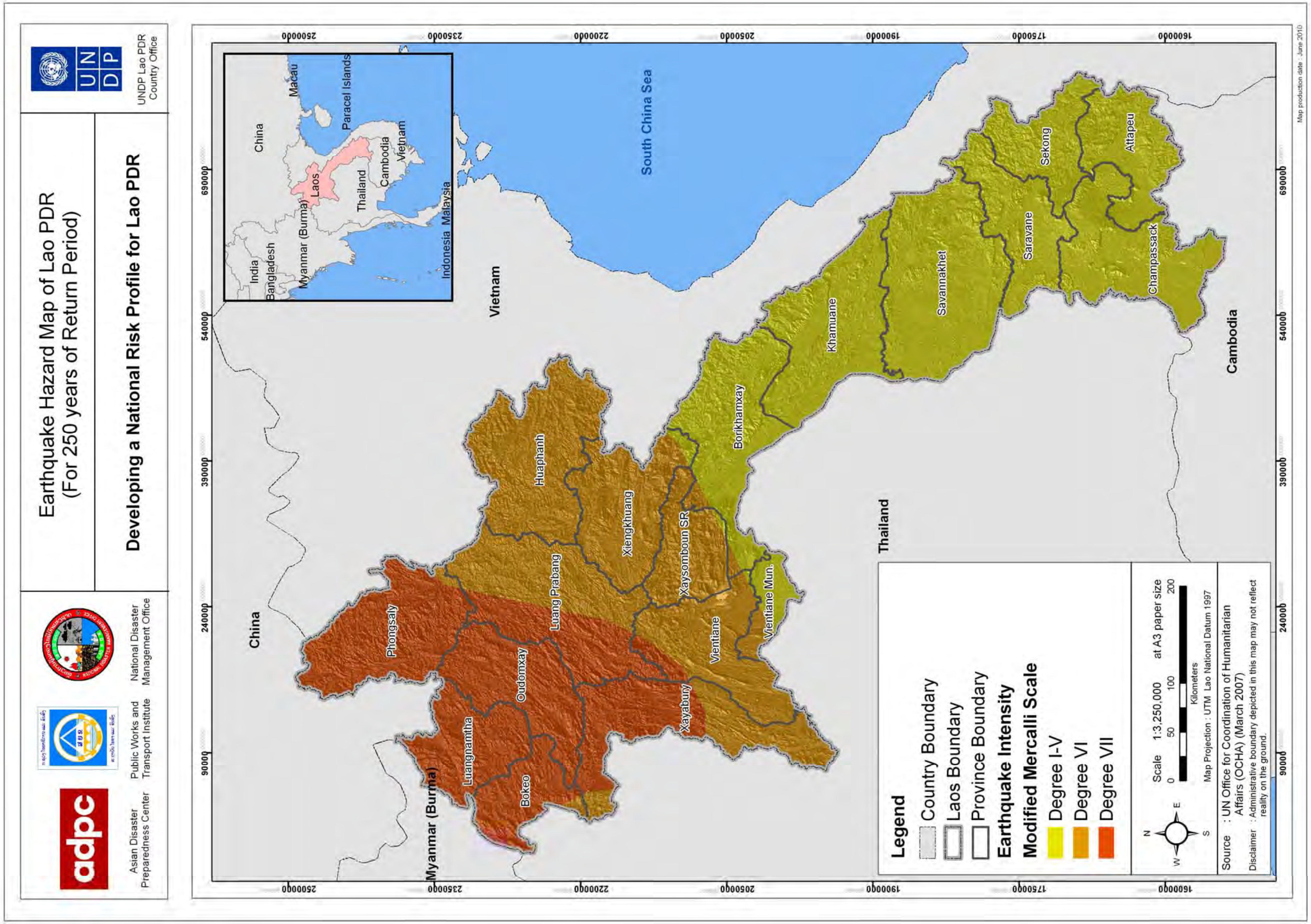


Figure 3.2 Earthquake hazard map of Lao PDR

3.2 FLOOD HAZARD ASSESSMENT

3.2.1 BACKGROUND

Flood hazard has been regularly reported and become a major concern in Lao PDR due to the country's vicinity to major rivers such as the Mekong and Xekong. Figure 3.3 shows the historical account of damage caused by floods in Lao PDR.

In this study, flood hazard mapping for Lao PDR were carried out national level. As a result, the flood hazard maps are not expected to depict any finer detail. A total of 8 river basins have been analyzed across the country of Lao PDR and will be discussed further in this chapter.

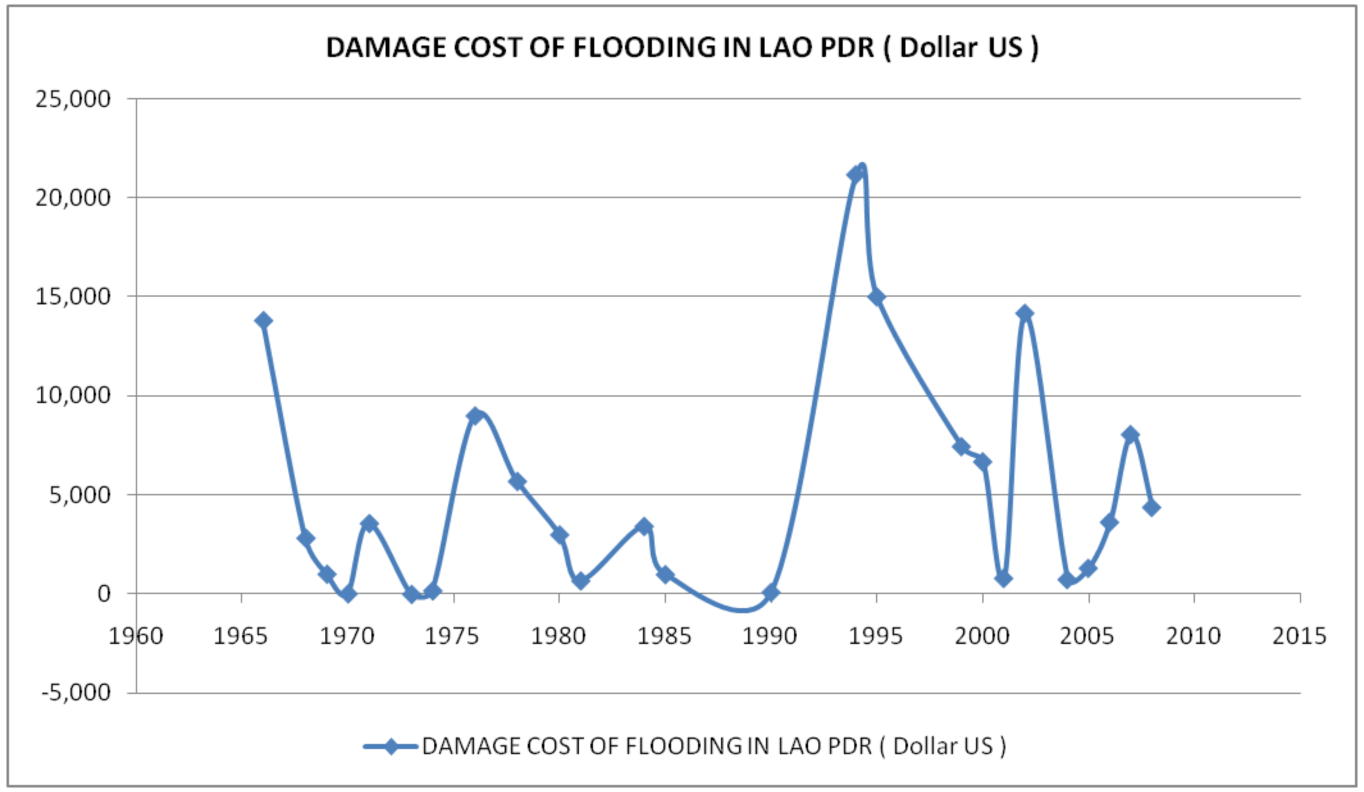


Figure 3.3 Damage Cost of Flooding in Lao PDR from 1966 to 2008 (Source: (Vision-RI, 2009))

3.2.2 MAP CONTENT

Flood hazard maps were developed for the most flood prone river basins. Eight rivers have been identified and determined for flood hazard and risk assessments in accordance with the past history of flooding as well as in consultation with flood-related agencies. These rivers are Nan Ou, Nam Ngum, Nam Ngiap, Nam Xan, Se Bangfai, Xe Banghiang, Xe Don and Xe Kong. The flood hazard maps show the flood inundation and flood water depth with various return period scenarios. These return periods are 10 years, 50 years and 100 years. It is noted that the bigger the return period, the worst the flood scenario. The flood inundation area for a particular scenario has been indicated in square kilometers. The results of the flood hazard maps are shown in Figure 3.13 to Figure 3.20

3.2.3 APPLICATION OF MAPS IN DISASTER RISK MANAGEMENT

The purposes of developing these hazard maps include:

- The flood hazard maps can be used by policy makers, decision makers and planners as a basis for future master plans and safe development. The authority can take necessary actions to reduce the impacts on various economic sectors such as agriculture, housing, tourism, industry and production.
- The flood hazard maps will help the government of Lao PDR and local authorities to understand the severity of flood hazards in the depicted areas and develop necessary mitigation and preparedness plans.
- The flood hazard maps can help policy makers, decision makers, planner and other related actors to plan and implement an effective system of the flood management in Lao PDR.
- The flood hazard maps will help international and national relief agencies and humanitarian organizations to prioritize hazard disaster preparedness and mitigation interventions.
- The Department of Agriculture may use these maps to change crop patterns and develop other non structural measures for reducing the negative impacts flooding has on agriculture.

3.2.4 DATA SOURCES

For extensive flood hazard mapping, detailed hydrological, meteorological, demographic and geomorphologic data are required. It is also important to understand the scale of the flood hazard assessment. More precise and detailed data is required for site-specific flood studies. The objective of the current project is to develop flood hazard maps at the national scale. The current hazard maps have been developed based on data available from focal departments, as well as established authentic sources. The parameters are classified into the following categories, along with their sources:

a. **Hydrological Data** (Department of Meteorology and Hydrology, Lao PDR);
- Extreme discharge data.
- Daily rainfall data.
- Rainfall station and discharge station.

b. **Land Use/ Land Cover)** (Source : National Geographic Department, NGD, Lao PDR);
c. **Elevation** (Source : Aster resolution 30 Meters, http://asterweb.jpl.nasa.gov/gdem.asp); and
d. **River Network and Catchments** (Google Earth and National Geographic Department, Lao PDR)

Software required for Flood Hazard Assessment

The flood hazard assessment has been developed using ArcGIS 9.3 software (ESRI, 2010), with HEC-GeoHMS (USACE, 2009a), HEC-GeoRAS (USACE, 2009b) and HEC-RAS (USACE, 2009c) extensions.

The Geospatial Hydrologic Modeling Extension (HEC-GeoHMS)[6] was developed as a geospatial hydrology toolkit which uses ArcGIS to develop a number of hydrologic modeling inputs for the Hydrologic Engineering Center's Hydrologic Modeling System, HEC-HMS. ArcGIS software is available from the Environmental Systems Research Institute, Inc. (ESRI). Analyzing digital terrain data, HEC-GeoHMS transforms the drainage paths and watershed boundaries into a hydrologic data structure that represents the drainage network. The program allows users to visualize spatial information, document watershed characteristics, perform spatial analysis and delineate sub basins and streams.

HEC-GeoRAS[7] is a set of procedures, tools, and utilities for processing geospatial data in ArcGIS using a graphical user interface (GUI). The interface allows the preparation of geometric data for import into HEC-RAS and processes simulation results exported from HEC-RAS. To create the import file, the user must have an existing digital terrain model (DTM) of the river system in the ArcInfo TIN format, or Digital Elevation Model (DEM). The user creates a series of line themes pertinent to developing geometric data for HEC-RAS. The themes created are the Stream Centerline, Flow Path Centerlines (*optional*), Main Channel Banks (*optional*), and Cross Section Cut Lines referred to as the *RAS Themes*.

HEC-RAS[8] is designed to perform one-dimensional hydraulic calculations for a full network of natural and constructed channels. The HEC-RAS system contains four one-dimensional river analysis components for: (1) steady flow water surface profile computations; (2) unsteady flow simulation; (3) movable boundary sediment transport computations; and (4) water quality analysis. A key element is that all four components use a common geometric data representation and common geometric and hydraulic computation routines.

3.2.5 METHODOLOGY FOR FLOOD HAZARD MAPPING

Figure 3.4 shows the methodology for mapping the flood inundation area and depth for various return periods. The methodology for flood hazard mapping was developed based on available secondary data from various authentic sources such as DMH and NGD. The methodology largely used software such as Hec-GeoRAS, Hec-GoHMS, Hec-RAS and ArcGIS 9.3 as stated above. The creation of the river basin and river profile was validated using Google-Earth/map images of the river basin. The following are the steps used in the development of flood inundation maps:

- Extraction and profiling of river and basin from Aster data using HEC-GeoHMS.
- Creation of river center line, bank line, cross section in GIS platform by using HEC-GeoRAS.
- Estimation of floods at different return periods (this analysis uses three different return periods; 10, 50 and 100 years) for each river using Extreme Type I distribution (Gamble distribution). Rainfall data have been used to calculate return period in case of no discharge data.
- Computation of flood levels using HEC-RAS.
- Export of the result from HEC-RAS into GIS platform for mapping of flood inundation areas.
- Development of flood inundation maps (area and depth).

Based on the proposed methodology, the flood hazard maps for specified rivers were developed and are presented in Figure 3.13 to Figure 3.20.

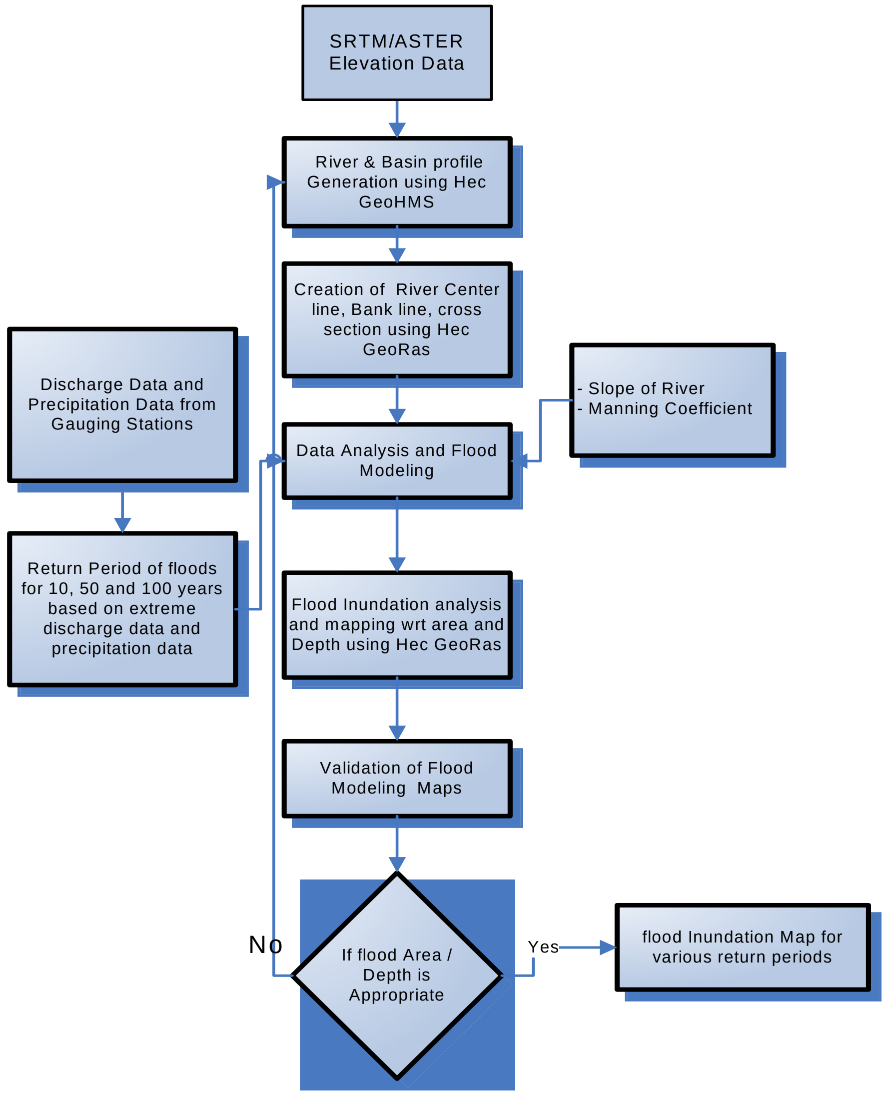


Figure 3.4 Flowchart showing the methodology for flood hazard assessments

3.2.6 HOW TO READ THE MAP

Each river flood hazard map shows the following:

- National, provincial and district boundaries
- River network
- Area and depth of inundation for particular return period. Each color of flood inundation area represents different levels of flood depth
  - Dark Green : Depth below 0.3 meter
  - Light Green : Depth between 0.3 to 1 meter
  - Light Blue: Depth between 1 to 2 meter
  - Dark Blue: Depth above 2 meter

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[6] HEC-GEoHMS software website reference http://www.hec.usace.army.mil/software/hec-geohms/index.html referred on 5th May 2010.
[7] HEC-GEORAS software website reference http://www.hec.usace.army.mil/software/hec-ras/hec-georas.html referred on 5th May 2010
[8] HEC-RAS software website reference http://www.hec.usace.army.mil/software/hec-ras/hecras-features.html referred on 6th May 2010.

3.2.7 ANALYSIS OF HAZARD ASSESSMENT

The flood hazard maps show areas of inundation and flood depths in their river basins. These maps, showing the different return periods, were overlaid on provincial and district maps. Results provided area and depth of flood water covered in respective provinces and districts. For analysis purposes, the flood water depth and area covered in various districts were worked out for all the identified eight river basins.

For Nam Ngiap River, there are three districts within two provinces (Borikhan and Pakxan district in Borikhamxay province and Hom district in Xaysomboun SR province) which could be flooded. Most of the flood depth measured is more than two meters. The largest flood inundation is in Borikan district which is about 13 sq km approximately. The graph in Figure 3.5 shows the inundation area for different depths of the Nam Ngiap River.

There are two districts (Borikhan and Pakxan district) which could be affected by flooding from Nam Xan River in Borikhamxay province. The largest inundation area is in Borikhan district which is more than 20 sq km approximately. The graph in Figure 3.6 shows the inundation area for different depths of the Nam Xan River.

Nam Ou River, Phongsaly and Luang Prabang province are prone to flooding. There are two districts (Mai and Khoa district) flooded in the Phongsaly province. Most of the flooding is in the Luang Prabang province (in Ngoy, Nambak, Pakxeng and Pak Ou district) and the inundation is greater than flood inundation in Phongsaly. The graph in Figure 3.7 shows the inundation area for different depths of the Nam Ou River.

Flood inundation of Se Bangfai is located in two provinces: Khamunae (in Mahaxai, Xebangfai and Nongbok district) and Savannakhet (Xaibouri and Atsaphon district). The largest inundation area is in Xebangfai district which is more than 160 sq km approximately. The graph in Figure 3.8 shows the inundation area for different depths of the Se Bangfai River.

For the Xe Banghiang River, only the Savannakhet province will be flooded. Seven districts are prone to flooding: Xephon, Phin, Champon, Nong, Xonbouri, Songkhon, and Thapangtho. The largest inundation is in Sangkhon district which covers 250 sq km approximately. The graph in Figure 3.9 shows the inundation area for different depths of the Xe Banghiang River.

For Xe Kong River, the flood inundation area covers nine districts within two provinces: Karum and Lamam district in Sekong province and Thateng, Pakxong, Sanxai, Sanamxai, Samakkhixa, Phouvong and Xaisettha district in Attapeu province. The largest inundation area is in the Samakkhixa district which covers more than 100 sq km approximately. The graph in Figure 3.10 shows the inundation area for different depths of the Xe Kong River.

For the Nam Ngum River, there are three provinces prone to flooding: Borikhumxay, Vientiane and Vientiane municipality. The largest inundation area is the Pak Ngum district in the Vientiane province which covers more than 100 sq km. The graph in Figure 3.11 shows the inundation area for different depths of Nam Ngum River.

Flood inundation of Xe Don River is located in two provinces: five districts affected by flooding in Saravane and and three districts in Champassack. The most affected area is in theKhongxedon district (Saravane province) where the flood inundation is more than 26 sq km. The graph in Figure 3.12 shows the inundation area for different depths of the Xe Don River.

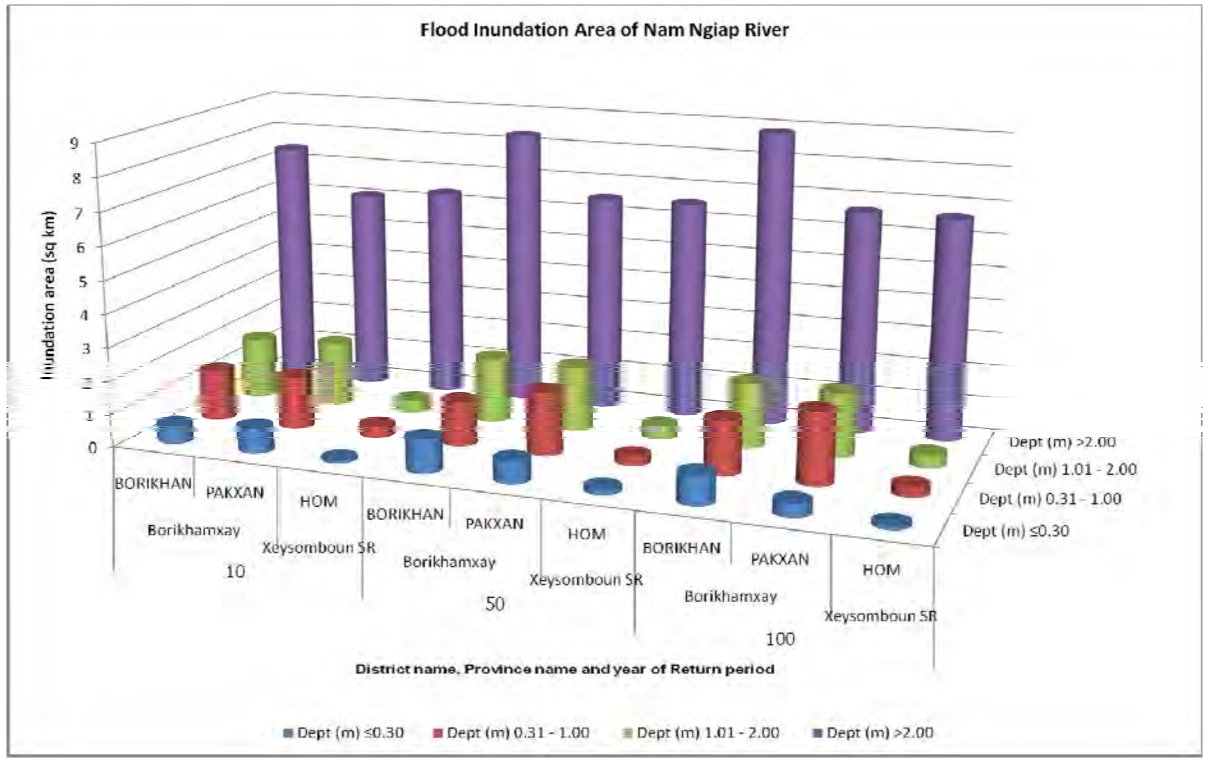


Figure 3.5 Flood inundation area in different depths of Nam Ngiap River

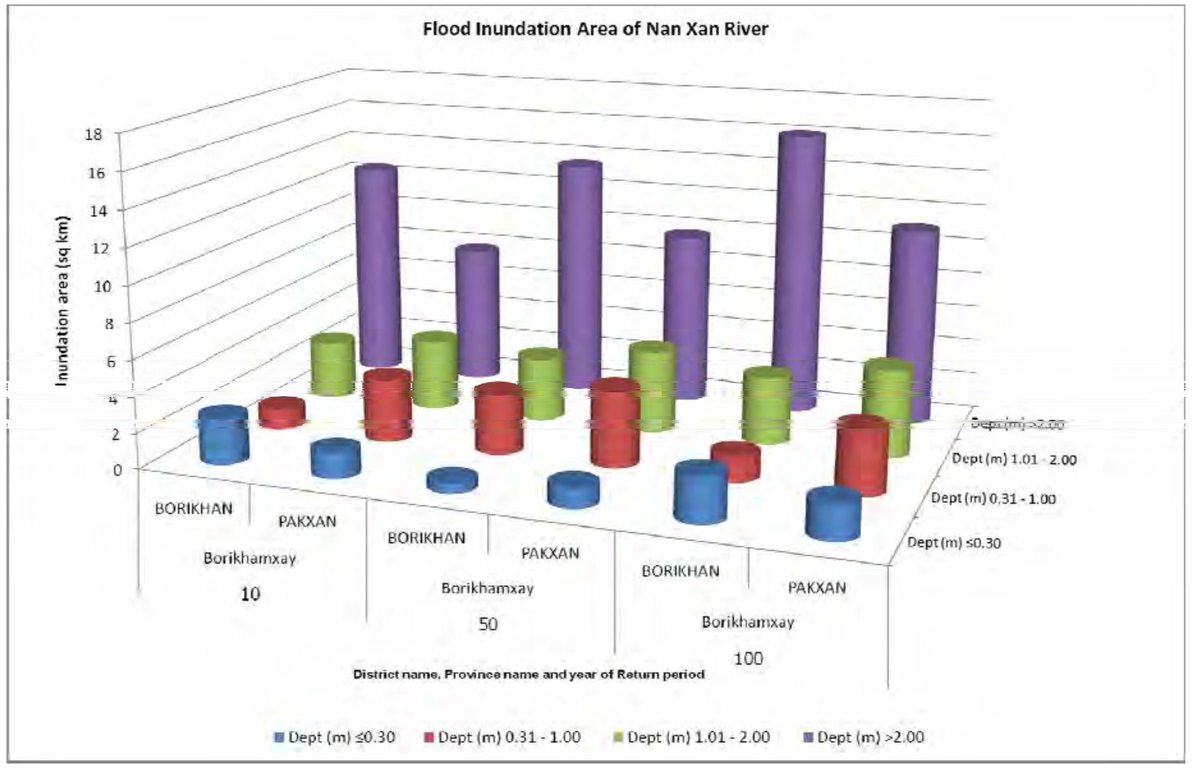


Figure 3.6 Flood inundation area in different depths of Nam Xan River

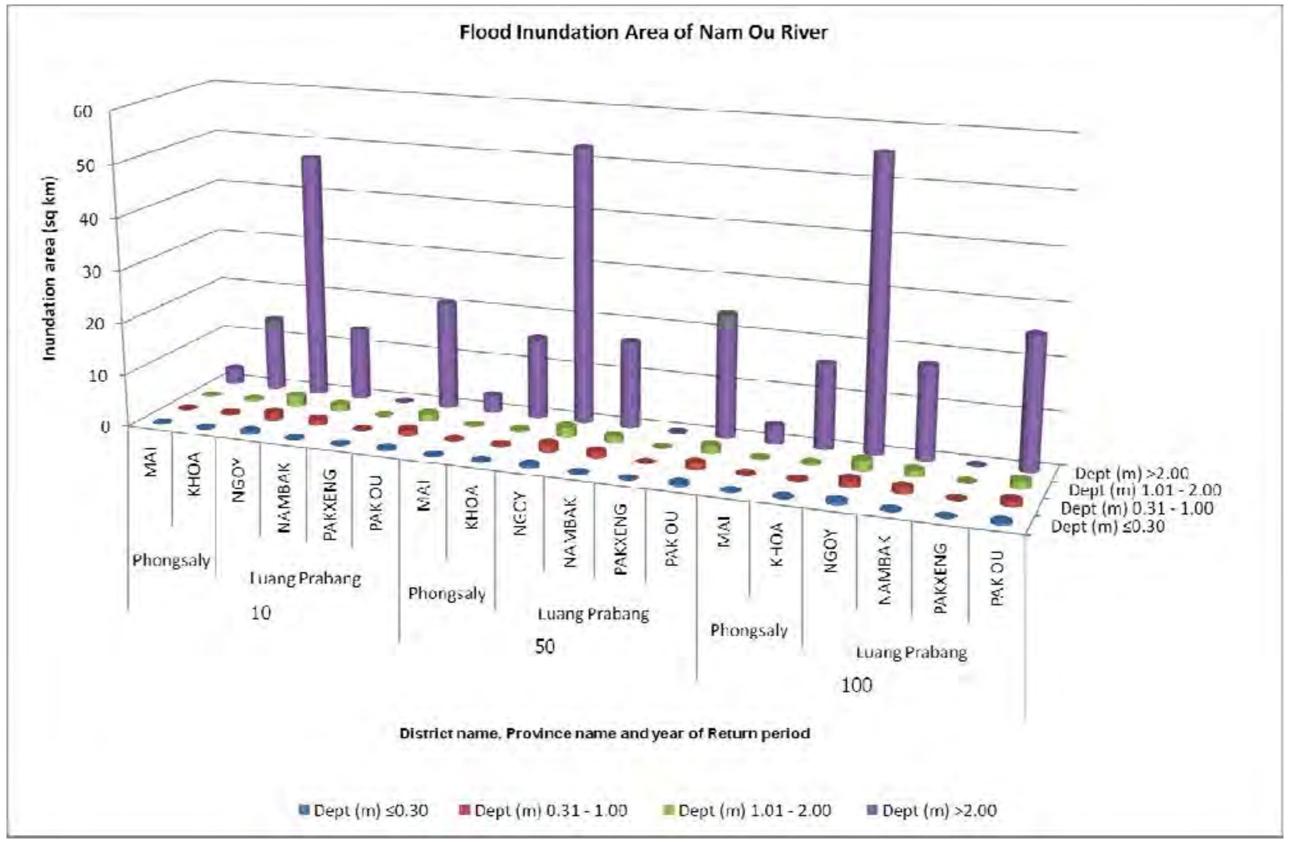


Figure 3.7 Flood inundation area in different depths of Nam Ou River

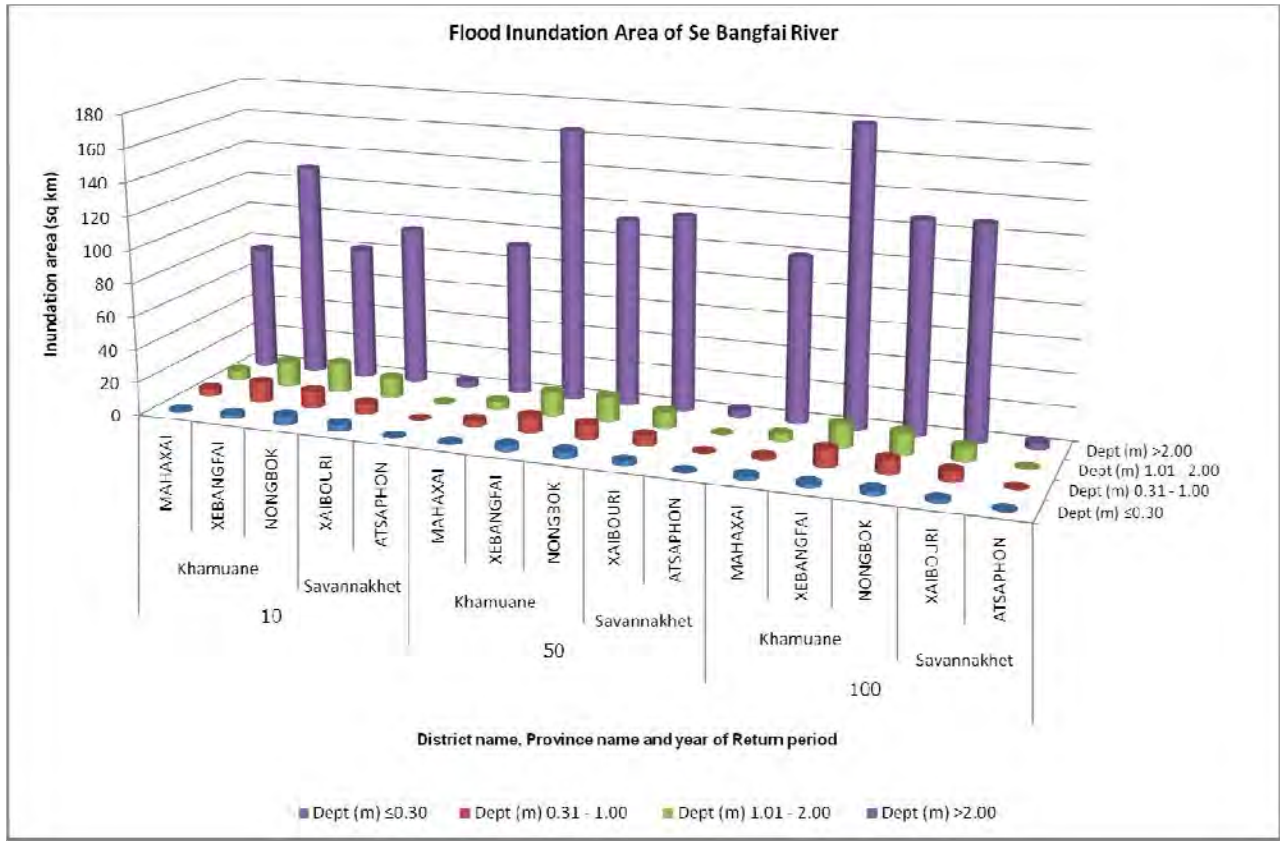


Figure 3.8 Flood inundation area in different depths of Se Bangfai River

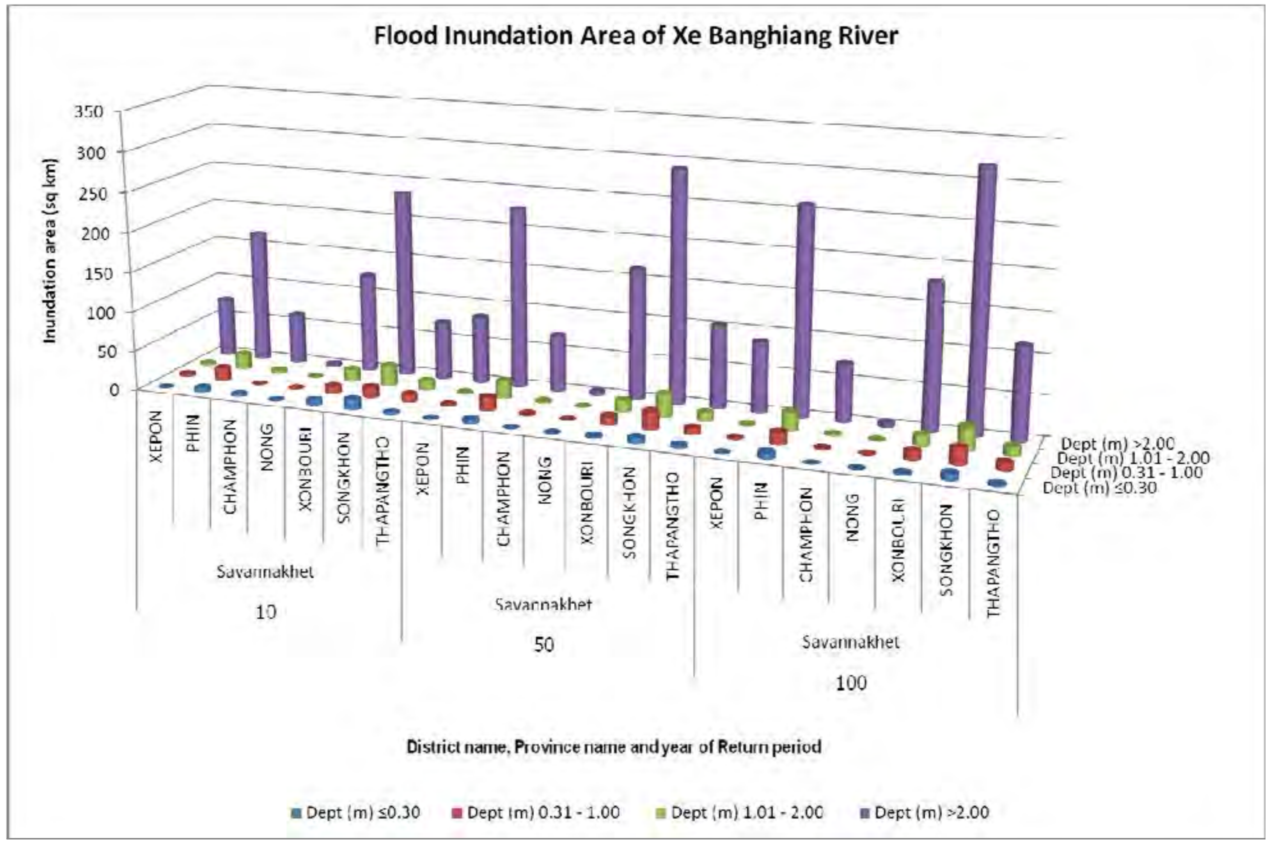


Figure 3.9 Flood inundation area in different depths of Xe Banghiang River

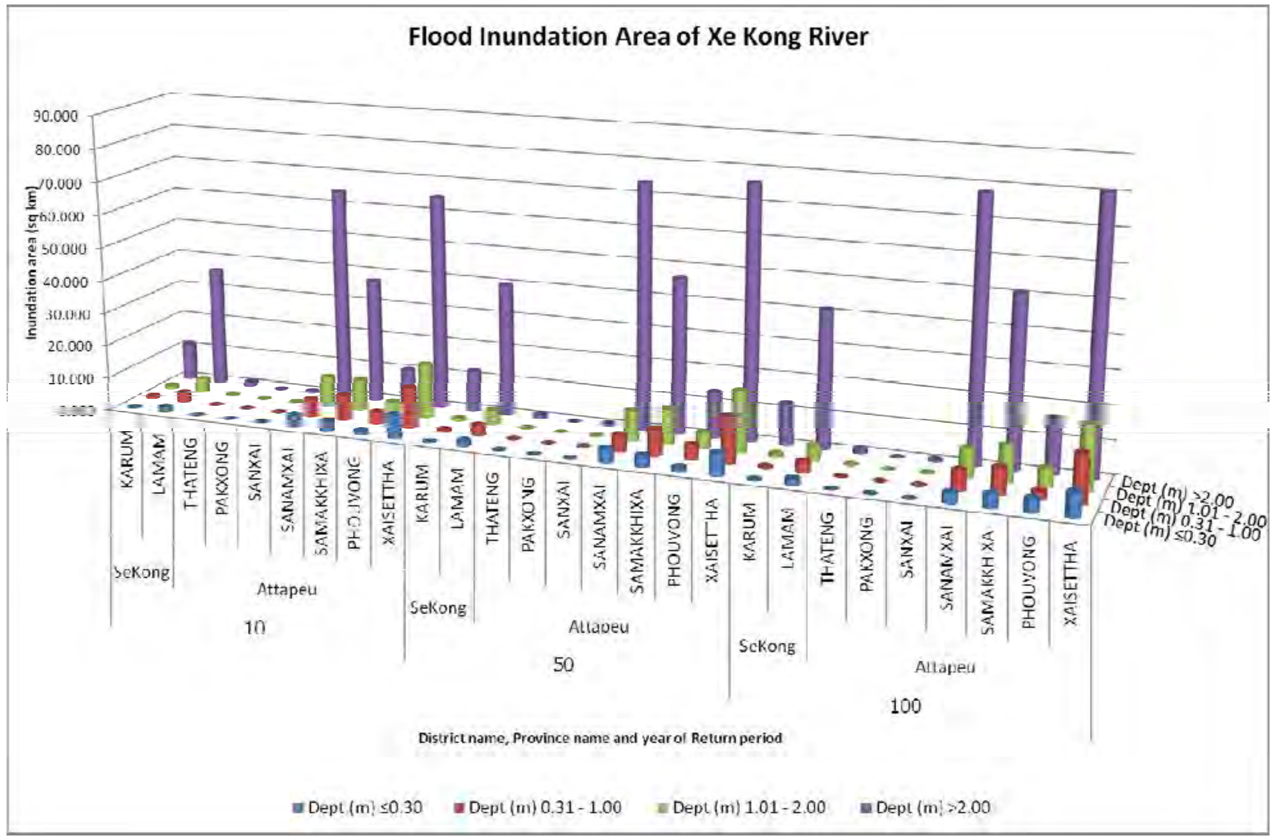


Figure 3.10 Flood inundation area in different depths of Xe Kong River

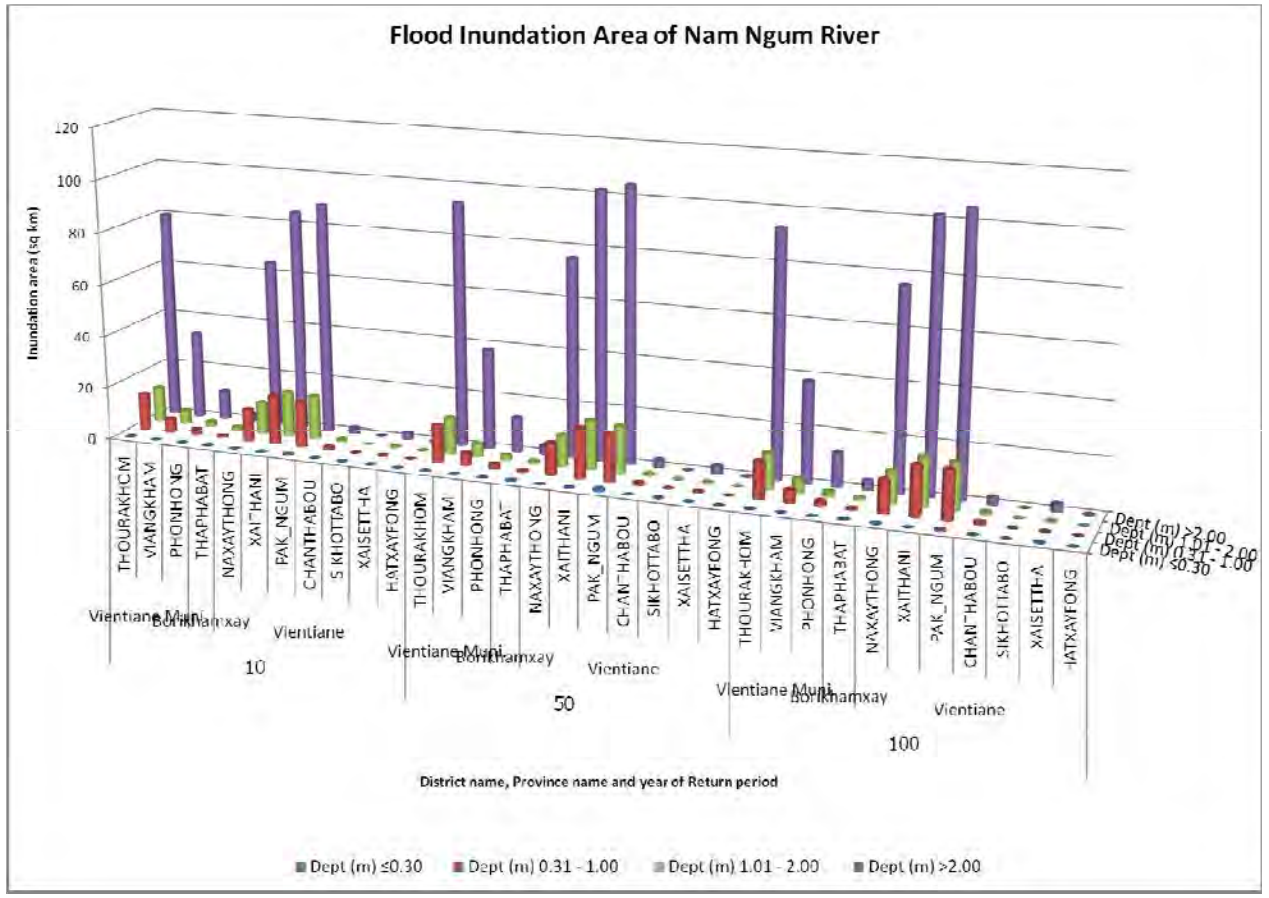


Figure 3.11 Flood inundation area in different depths of Nam Ngum River

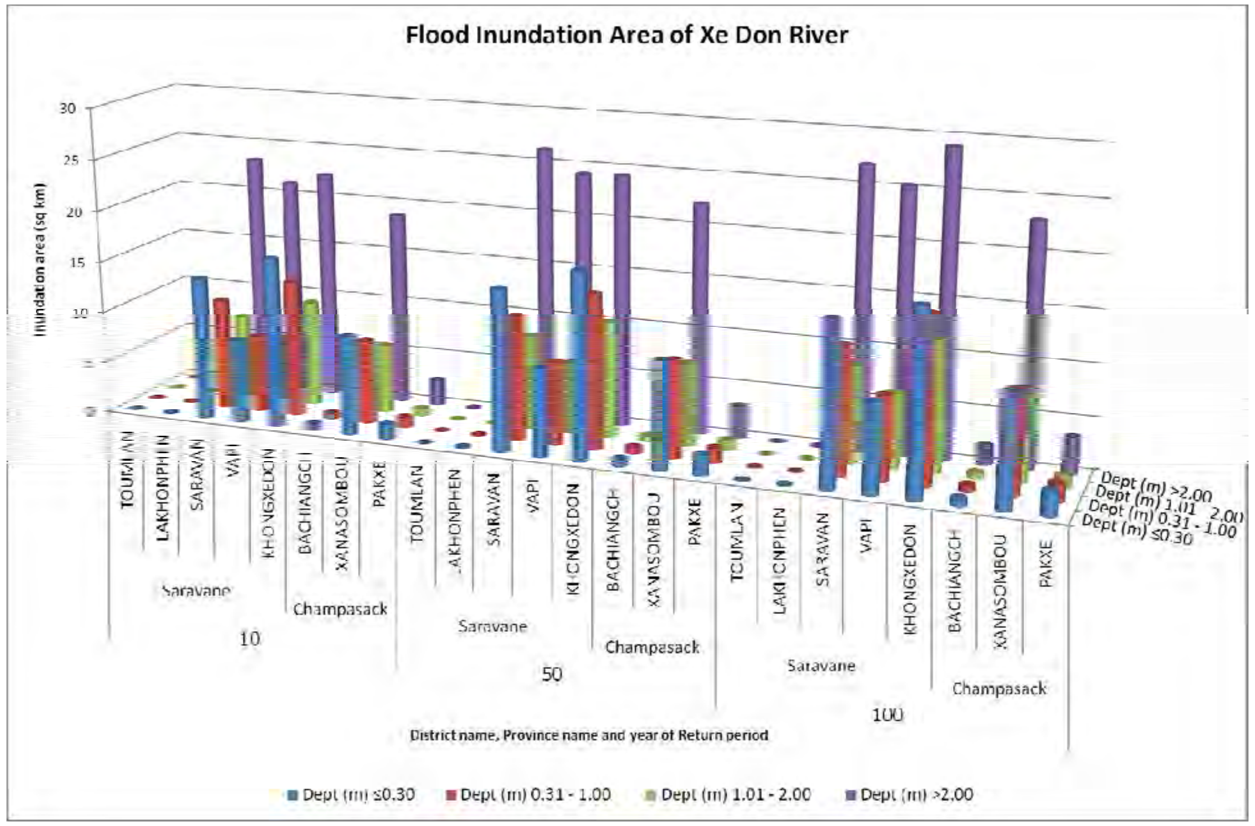


Figure 3.12. Flood inundation area in different depths of Xe Don River

3.2.8 RECOMMENDATIONS

- Flood hazard assessments for Lao PDR have been done at the national level for eirght priority river basins. The study has used secondary data primarily from the Department of Meteorology and Hydrology, the Irrigation Department, and Department of Mining and Power. Due to the limited access to detailed data and field visits, the results of the flood hazard assessment are limited to the national level. It is recommended that site-specific flood hazard mapping is carried out for local-level analysis and more detailed planning.
- Since Lao PDR is frequently affected by flooding, the national-level inundation maps of Lao PDR should be used for developing more detailed flood inundation maps for the country. The detailed inundation maps will help policy makers, planners, decision makers and related actors to better plan and implement an effective flood management system.
- The current flood hazard maps have been developed for eight of the most important river basins in Lao PDR. These river basins are frequently reported to have flooding that affects lives and properties. In order to have a clearer and more complete picture of flood hazards in Lao PDR, it is recommended that the inundation maps of Mekong River developed by other agencies, such as Mekong River Commission (MRC), are incorporated into future assessments and planning.

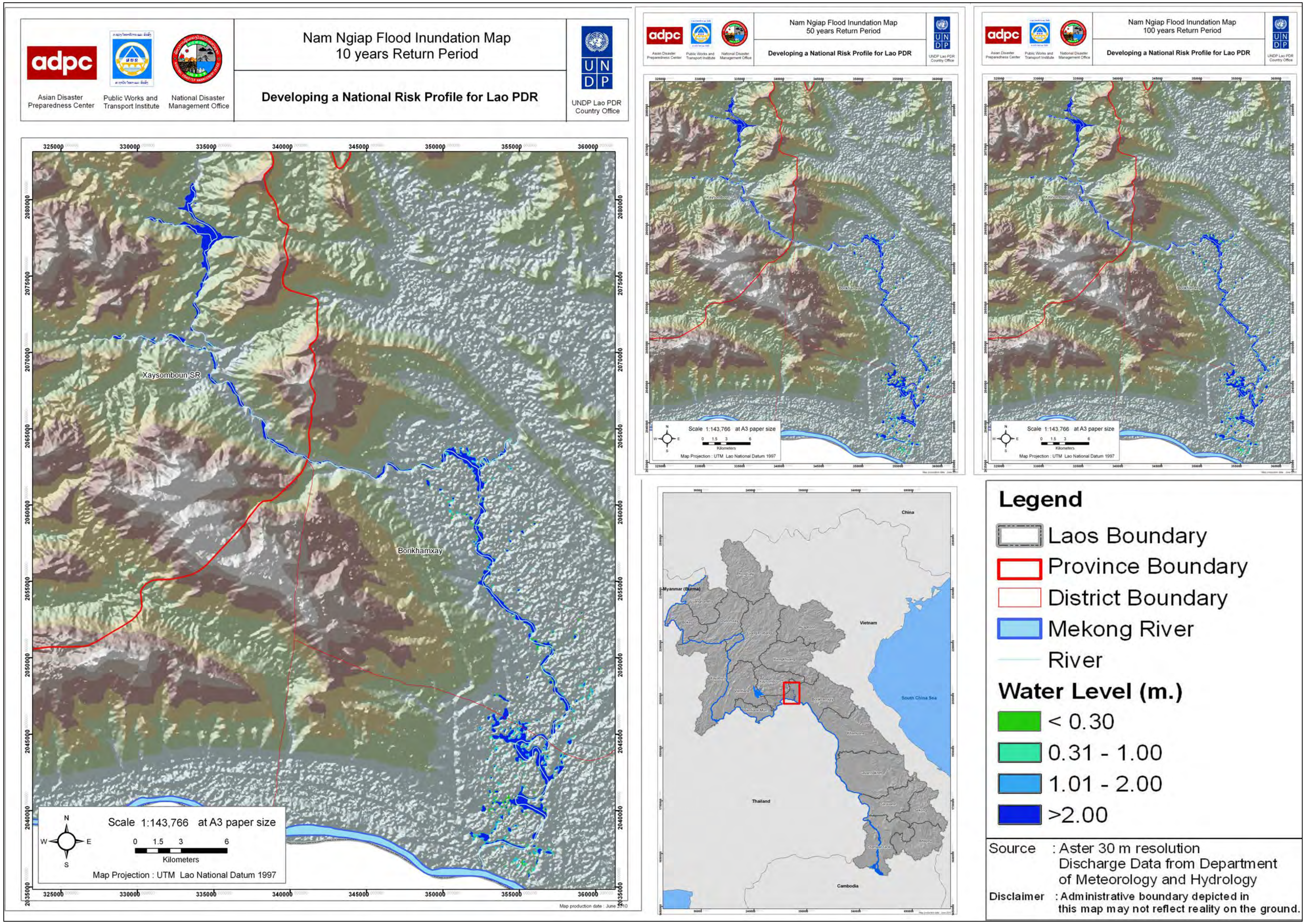


Figure 3.13 Nam Ngiap flood inundation for 10, 50 and 100 years return period

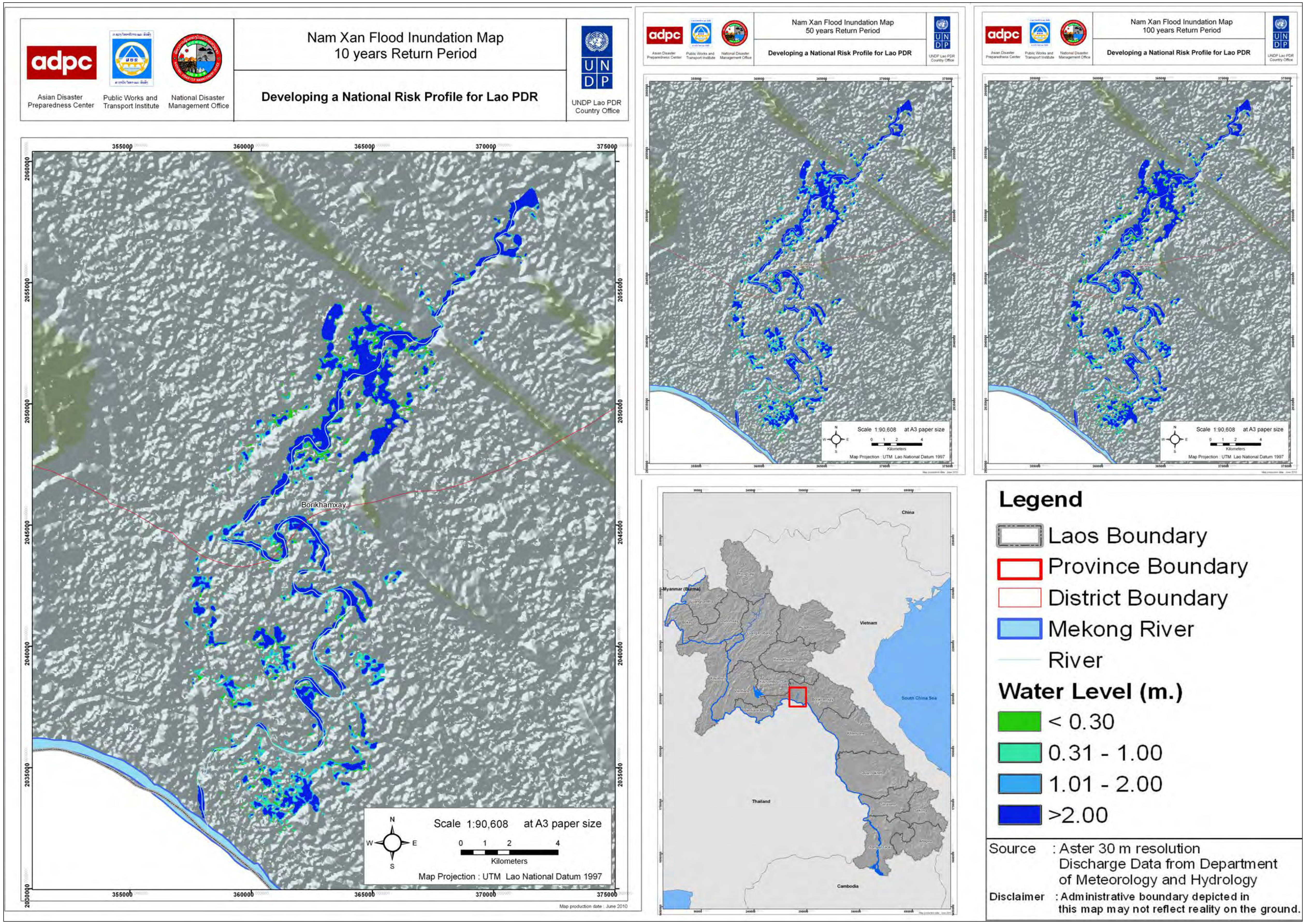


Figure 3.14 Nam Xan flood inundation for 10, 50 and 100 years return period

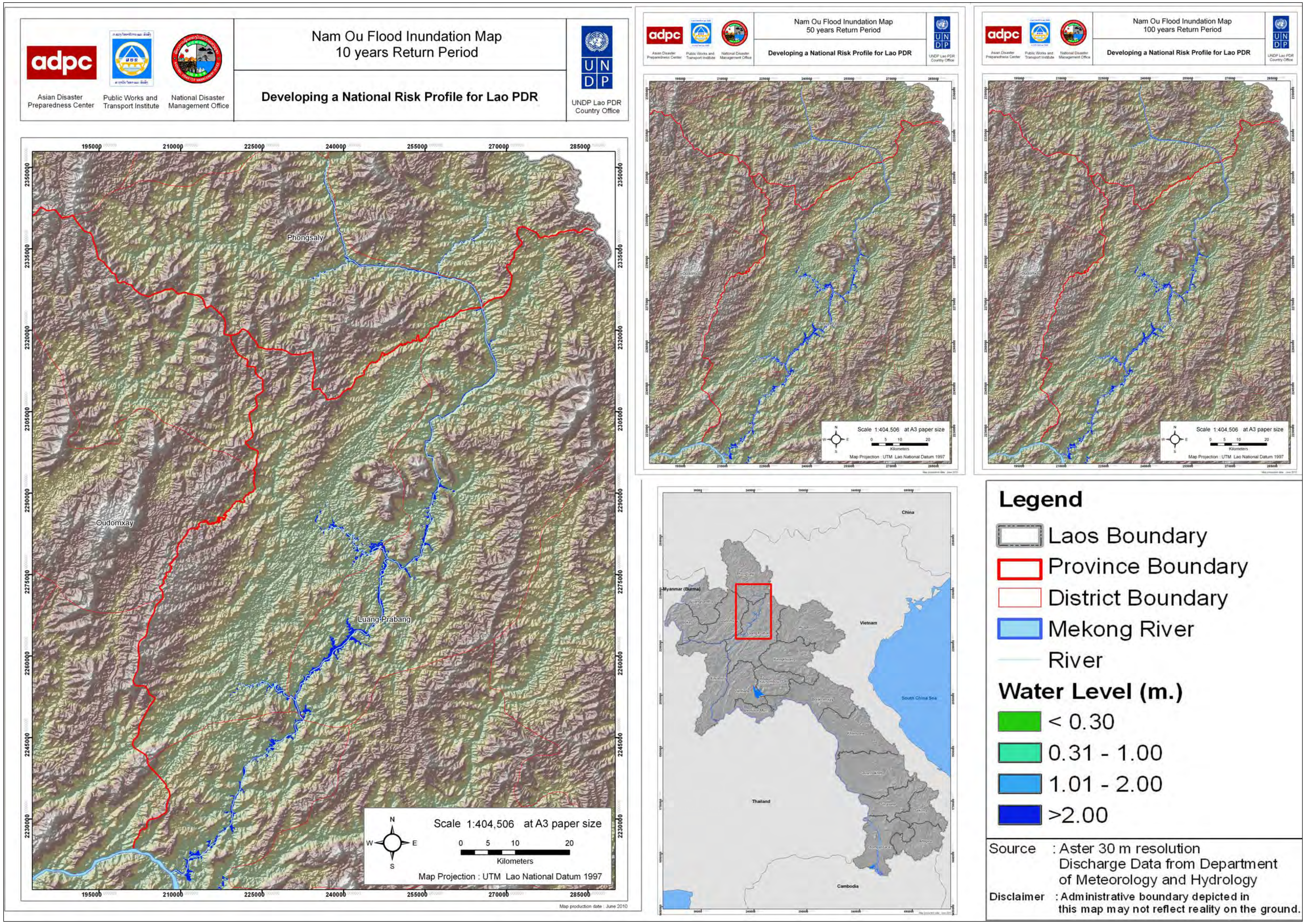


Figure 3.15 Nam Ou flood inundation for 10, 50 and 100 years return period

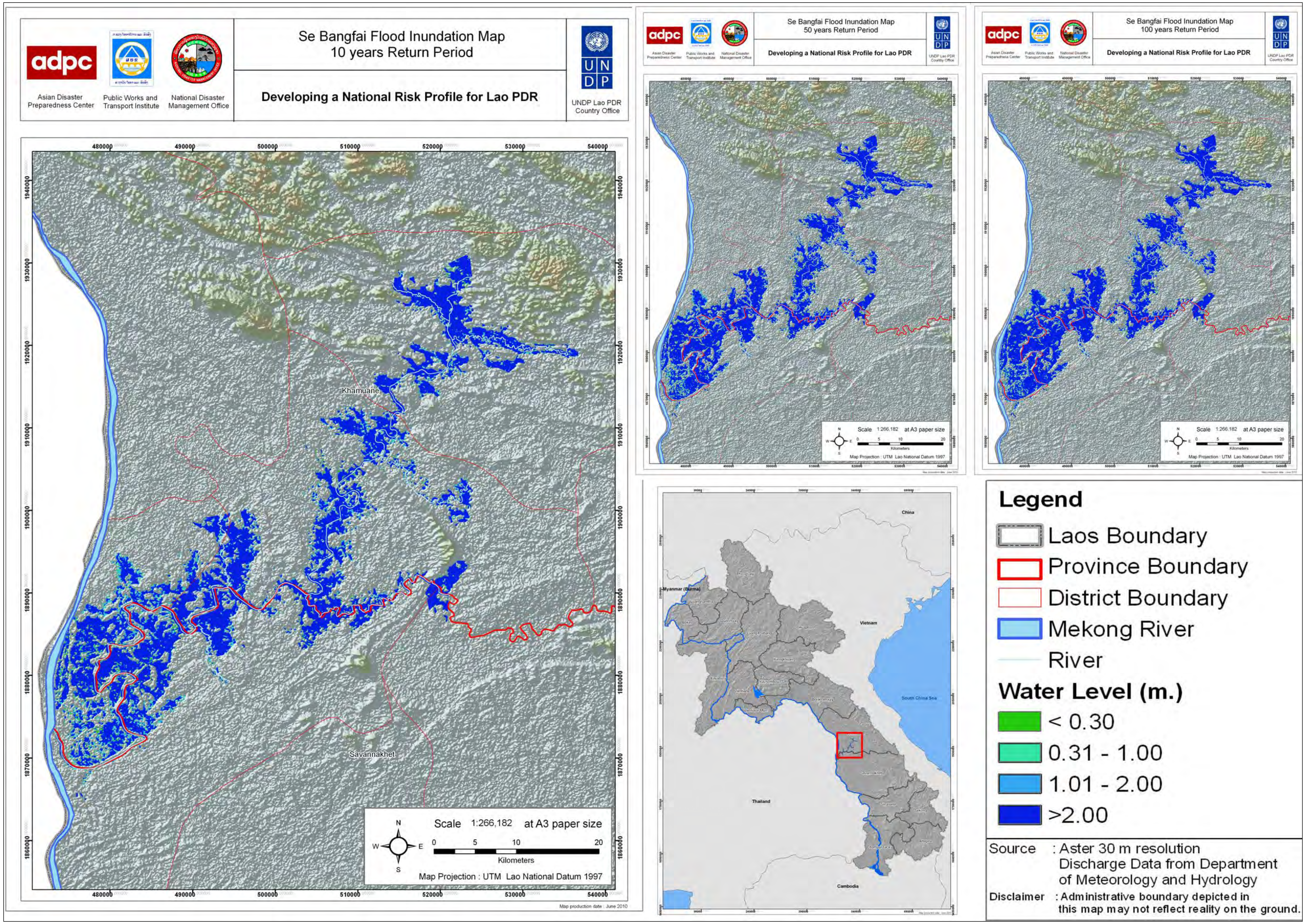


Figure 3.16 Se Bangfai flood inundation for 10, 50 and 100 years return period

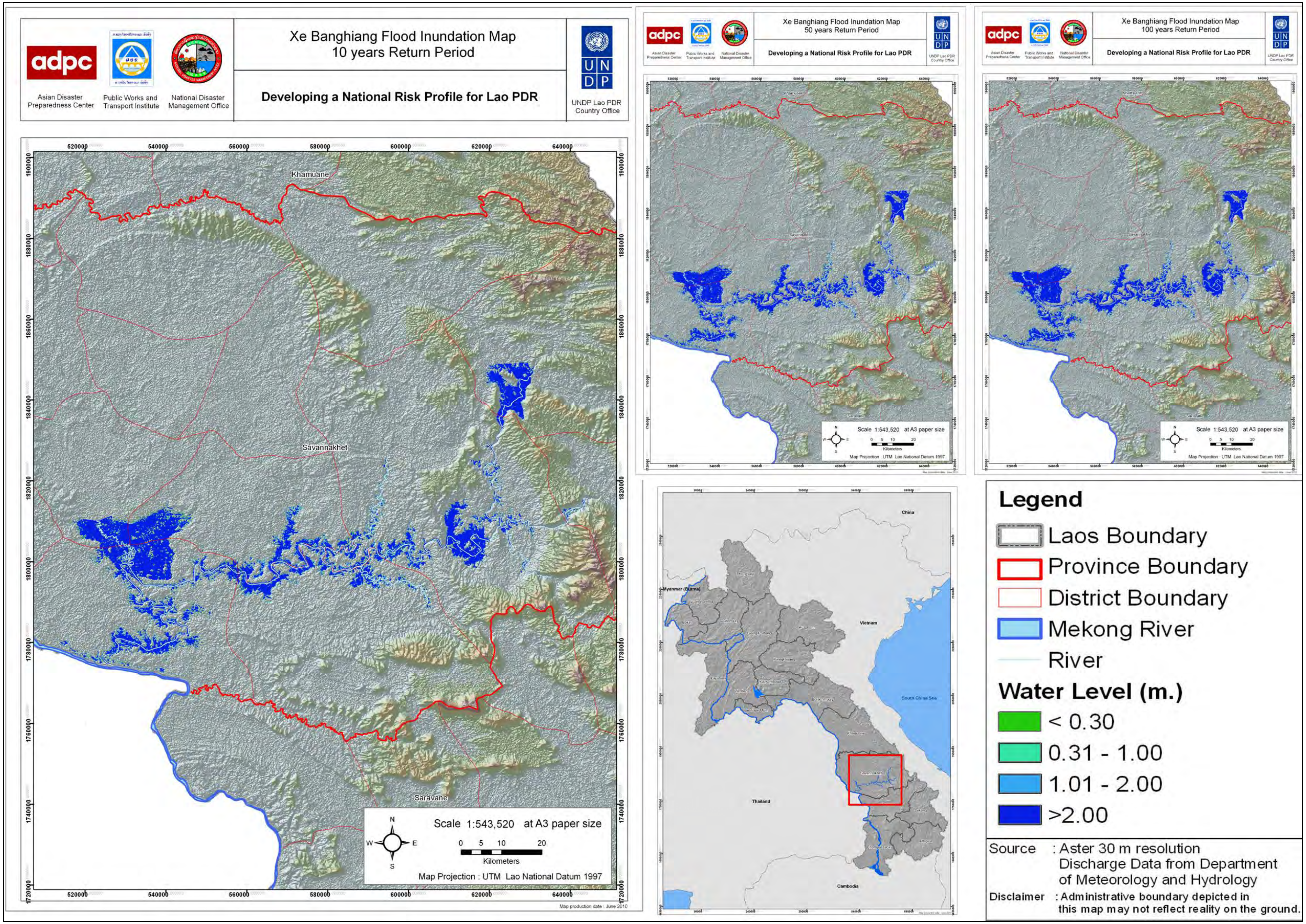


Figure 3.17 Xe Banghiang flood inundation for 10, 50 and 100 years return period

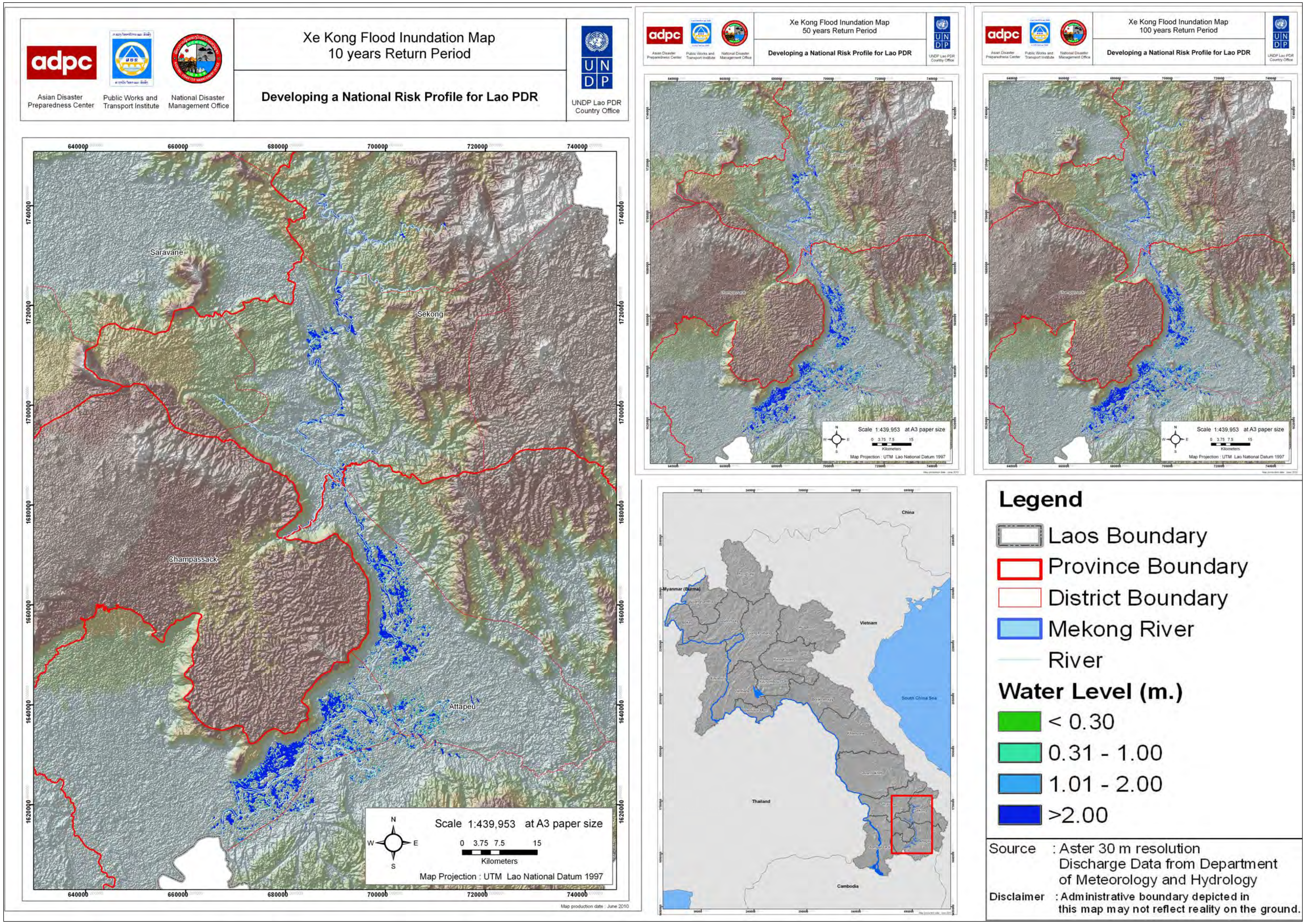


Figure 3.18 Xe Kong flood inundation for 10, 50 and 100 years return period

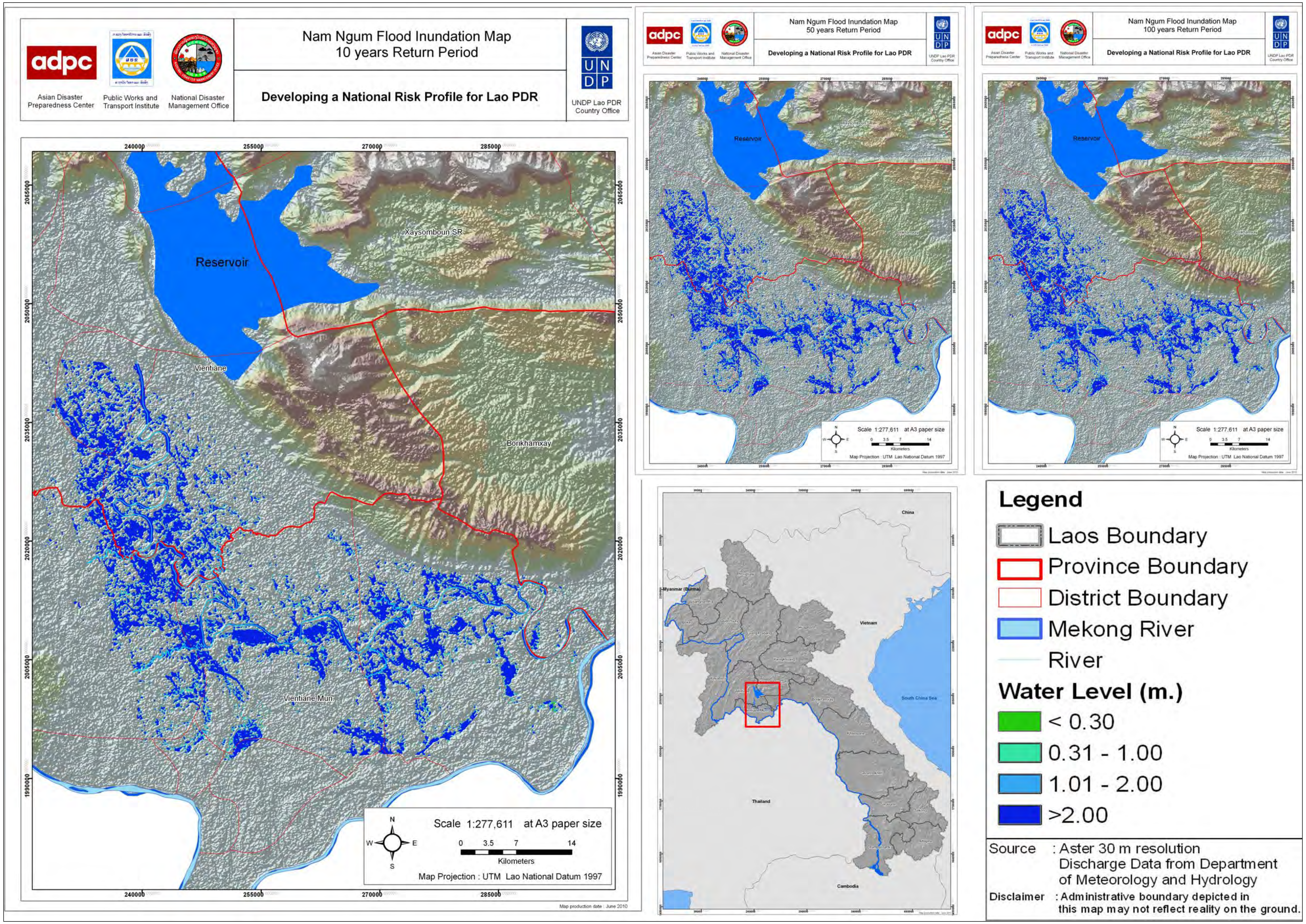


Figure 3.19 Nam Ngum flood inundation for 10, 50 and 100 years return period

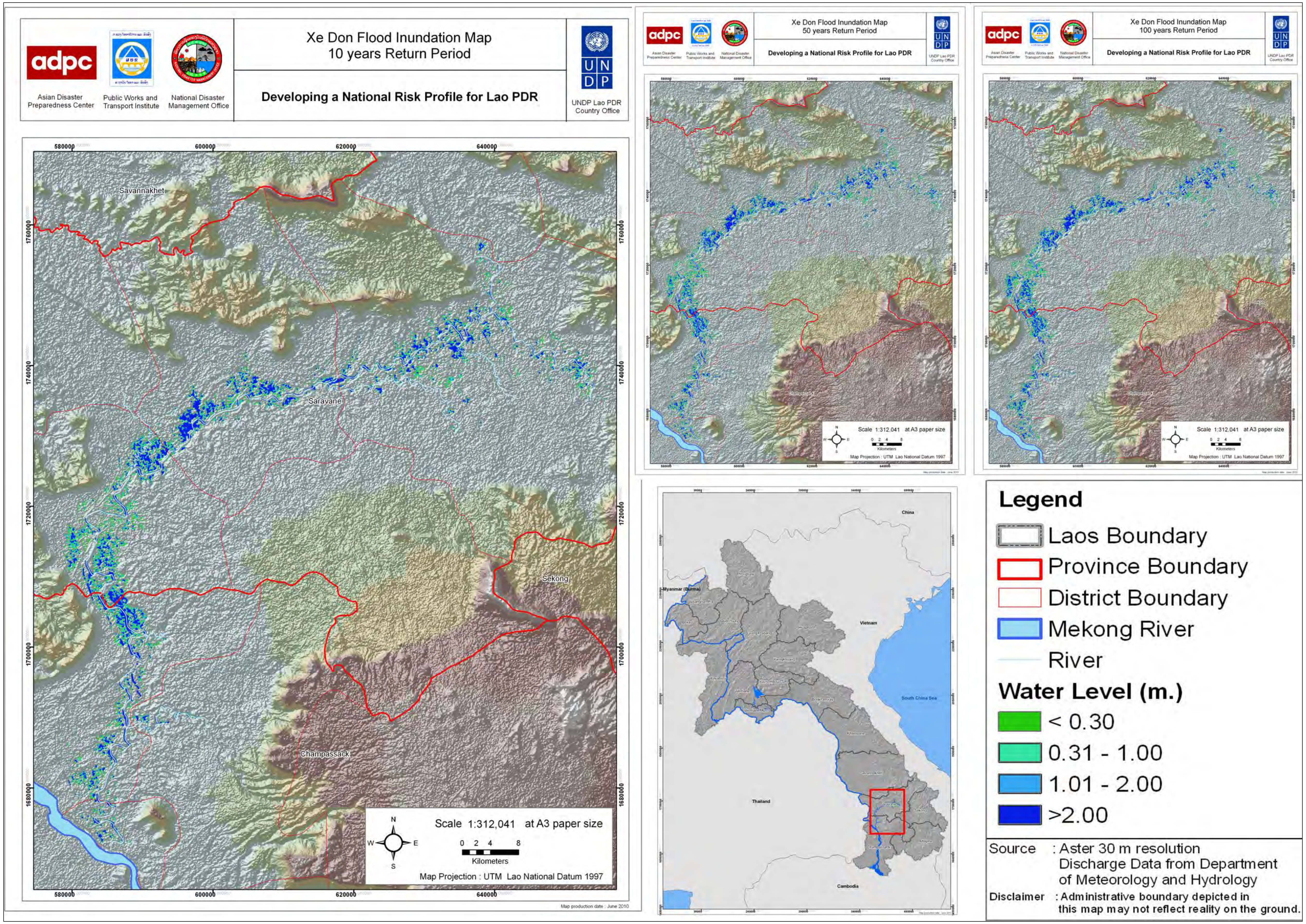


Figure 3.20 Xe Don flood inundation for 10, 50 and 100 years return period

3.3 LANDSLIDE HAZARD ASSESSMENT

Slope stability in Lao PDR is related to weather conditions. Landslides usually affect transport infrastructure during the moonson season in Lao PDR. Rainfall is the main triggering factor for landslide occurrences. Other principal factors influencing landslides include slope gradient, rock condition (lithology) and land use.

3.3.1 MAP CONTENT

The landslide hazard map (Figure 3.23) shows spatial distribution of susceptibility zones. The range of zones are negligible, low, medium, high, and very high. Provincial and district boundaries are marked as overlay layers for more detailed spatial distribution.

3.3.2 APPLICATION OF MAPS IN DISASTER RISK MANAGEMENT

- The maps will help planning and development agencies when carrying out physical and social development in hazard prone areas.
- The maps will be especially helpful to the Ministry of Public Works and Transport (PTI), Ministry of Labor and Social Welfare, Department of Planning, Department of Irrigation, Water Resources and Environment Administration, and the Department of Electricity Development.
- The study reveals that the road sector is most prone to landslides during the monsoon season. The Department of Roads has initiated several structural mitigation projects at the local level. The maps will help to identify the sites for structural and non structural mitigation projects. The maps will help in prioritizing site-specific studies and mitigation interventions.
- The maps will help the department to focus on landslide disaster-prone areas and seek cooperation with various other response agencies and departments for better disaster preparedness. The map will help Lao PDR's NDMO to arrange more appropriate evacuation routes and zones when landslide hazards occur.

3.3.3 DATA SOURCES

- Elevation data for producing slope gradients from ASTER DEM (METI, 2006) which can be downloaded from http://asterweb.jpl.nasa.gov/
- Landuse data from the National Geographic Department (NGD), Lao PDR.
- Geological map of Lao from the Department of Mines and Geology (DMG), Lao PDR.
- Precipitation data from the Department of Meteorology and Hydrology (DMH), Lao PDR.

3.3.4 METHODOLOGY

The landslide hazard assessment methodology uses a semi-quantitative approach which considers explicitly a number of factors influencing ground stability. A range of scores and settings for each factor may be used to assess the extent to which that factor is favourable or unfavourable to the occurrence of instability (hazard). A good example of such a semi-quantitative approach was the ranking method used in Cuba (Abella, 2007). Overall the method can be found in Annexure 1(Trifunac, 1975; Junrong, 1992; Zhang, 1999).

Four thematic layers were created: slope gradient, land use, rock condition (lithology) and rainfall. Each of the thematic layers was ranked into five classes each, from safe condition to the most prone condition for landslide hazard (see Annexure 1). Those layers are then combined with different values of weighting. Slope influences 40% of landslide occurrence, land use contributes to 20%, lithology to 20%, and rainfall to 20%. The approach results are illustrated in a susceptibility map with ranks of 1 to 5 which define the landslide susceptibility from safe (negligible) to very susceptible (very high).

Complete and detailed methodology can be found in Annexure 1.

3.3.5 HOW TO READ THE MAP

The map shows the spatial distibution of several landslide susceptibility classes in Lao PDR. Provincial boundaries are demarcated for detailed susceptibility in specific regions. Description of colors can be seen in Table 3.3.

Table 3.3 Color table of Landslide susceptibility

Landslide Susceptibility
Negligible
Low
Medium
High
Very High

3.3.6 ANALYSIS OF HAZARD ASSESSMENT

Landslide hazard susceptibility in Lao PDR is classified into five zones as stated above. Larger parts of the country fall in low to medium landslide susceptibility zones (Figure 3.21). Only 5.24% of the country is prone to very high and high landslide susceptibility. Identification of very high and high susceptibility zones are priority areas for landslide hazard risk assessments. These high susceptible zones are localized in the southeast and central part of Lao PDR.

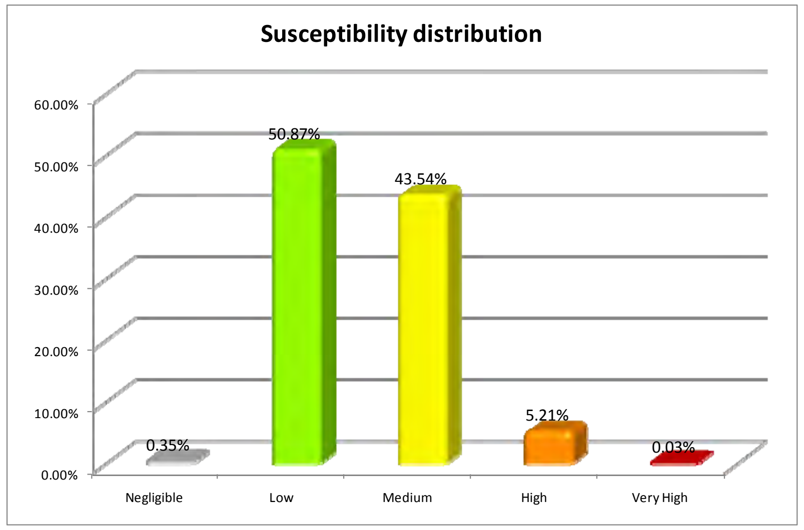


Figure 3.21 Distribution of landslide susceptibility in Lao PDR.

Negligible zones have distinguished slope gradients that are considerably flat or nearly flat. Low susceptibility zones are governed by low slope gradients and marine rock-types. Medium and high susceptibility zones are governed by medium slope gradients and terrestrial rock-types which are also characterized by thick soil deposits.

Four provinces including Xekong, Attapeu, Xaisomboun SR, and Borikhamxai have more than 10% of land coverage in high susceptibility zones, which are shown in Figure 3.22. High landslide susceptibility zones in Xekong and Attapeu are located in the southeast part of Lao, especially in conservation areas (Xe Xap and Dong Amphan). The high landslide susceptible areas in Xaisomboun Sr and Borikhamxai (and Khammouane) are also located in conservation areas (Nam Kading and Phou Khao Khouay).

Three provinces, namely Saravane, Phongsaly and Khmmouane, are in high landslide susceptibility zones between 5 to 10 %. The distribution of landslide susceptibility zones in the country is presented in

Table 3.4.

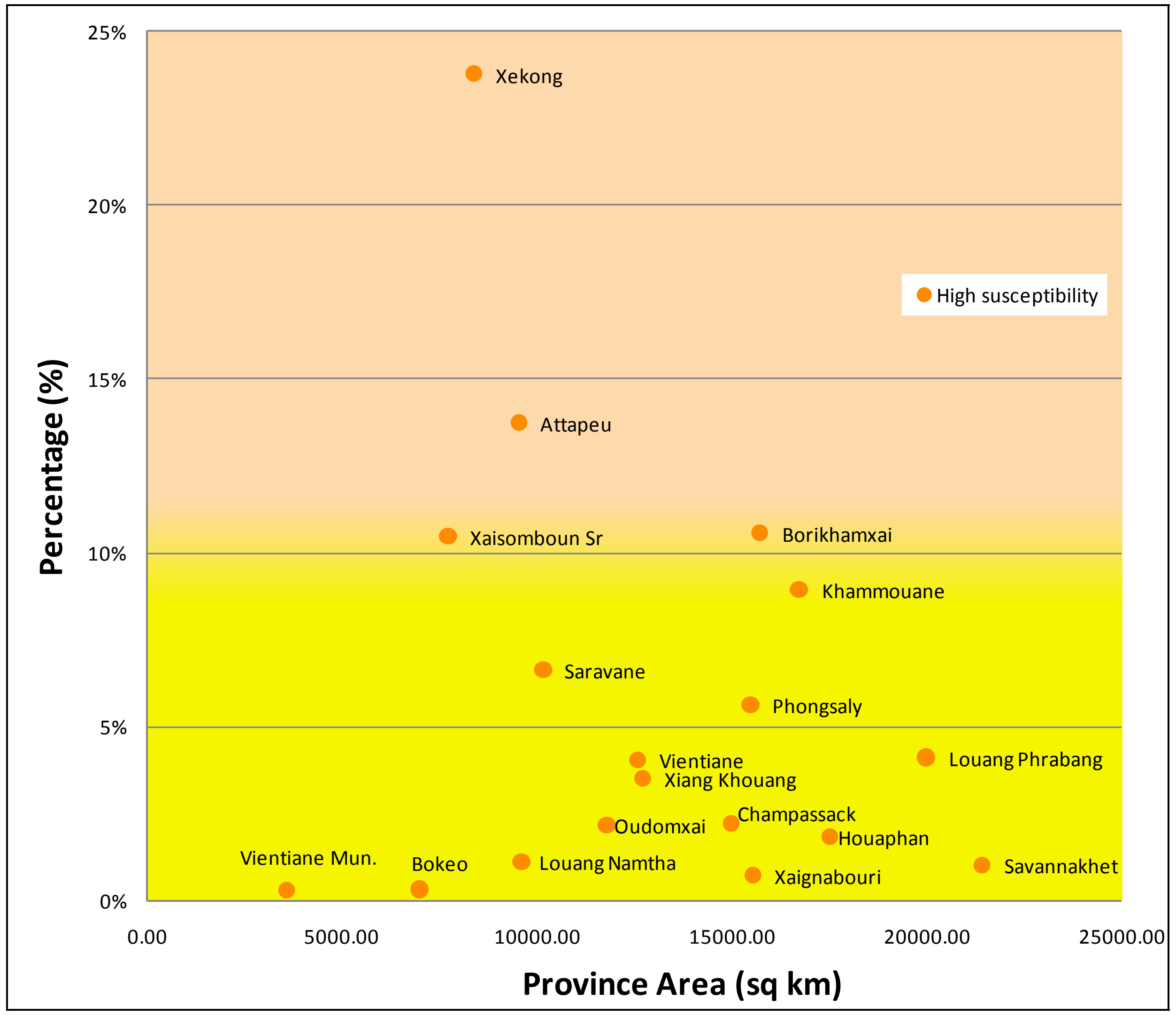


Figure 3.22 High susceptibility percentage vs provincial area crossplot

Attapeu, Phongsaly, Xekong, Xaisomboun Sr, and Houaphan are four provinces with larger medium susceptibility zones as shown in

Table 3.4. Medium susceptibility zones in Attapeu province have major roads connecting Lao with Vietnam that go through hilly and mountainous areas with a high susceptibility of landslides. Phongsaly has dense road networks within medium and high susceptibility zones in the northern part of Lao PDR. Landslide hazards have been closely related with transportation infrastructure throughout Lao PDR. There are some major roads that cross country borders and traverse through high susceptible landslide zones have high maintenance problems.

Table 3.4 Landslide hazard susceptibility percentage per province

Province	Negligible	Low	Medium	High	Very High
Xaisomboun Sr	0.72%	32.17%	56.63%	10.48%	
Attapeu		19.38%	66.82%	13.75%	0.06%
Champassack		64.57%	33.20%	2.22%	0.01%
Xekong		18.26%	57.96%	23.77%	0.00%
Saravane		51.41%	41.94%	6.64%	0.00%
Savannakhet	0.10%	78.35%	20.52%	1.04%	
Khammouane	0.00%	53.56%	37.10%	8.95%	0.39%
Borikhamxai	0.06%	39.87%	49.48%	10.58%	0.00%
Vientiane	0.30%	58.60%	37.03%	4.07%	
Xiang Khouang	1.27%	48.37%	46.84%	3.52%	
Xaignabouri	0.44%	61.40%	37.43%	0.73%	
Houaphan	0.69%	45.99%	51.47%	1.85%	
Louang Phrabang	0.22%	45.84%	49.81%	4.12%	
Bokeo	3.42%	72.57%	23.66%	0.34%	
Oudomxai	0.01%	48.46%	49.33%	2.20%	
Louang Namtha	0.42%	54.77%	43.68%	1.13%	
Phongsaly	0.01%	34.83%	59.51%	5.65%	
Vientiane Mun.	0.02%	76.34%	23.31%	0.32%	

3.3.7 SPECIAL REMARKS

A landslide inventory database for Lao PDR does not exist for the whole country. A specific rating system for landslide susceptibility in Lao also has not been developed. Therefore this assessment used a rating system (semi-quantitative approach) for landslide susceptibility assessment.

3.3.8 RECOMMENDATIONS

- Analysis of parameters related to landslide susceptibility is necessary to create a rating system by Lao PDR landslide experts, either qualitative or quantitative. This rating system can be used for analyzing susceptibility for the whole of Lao PDR.
- More detailed analysis on high and very high susceptibility zones are recommended in the context of transportation infrastructure.
- In relation to precipitation and flood, a dynamic model for landslides should be developed for Lao PDR. Due to landslide occurrence that is closely related with specific rainfall periods, the threshold of a precipitation-triggered landslide can be a vital help in disaster risk management.

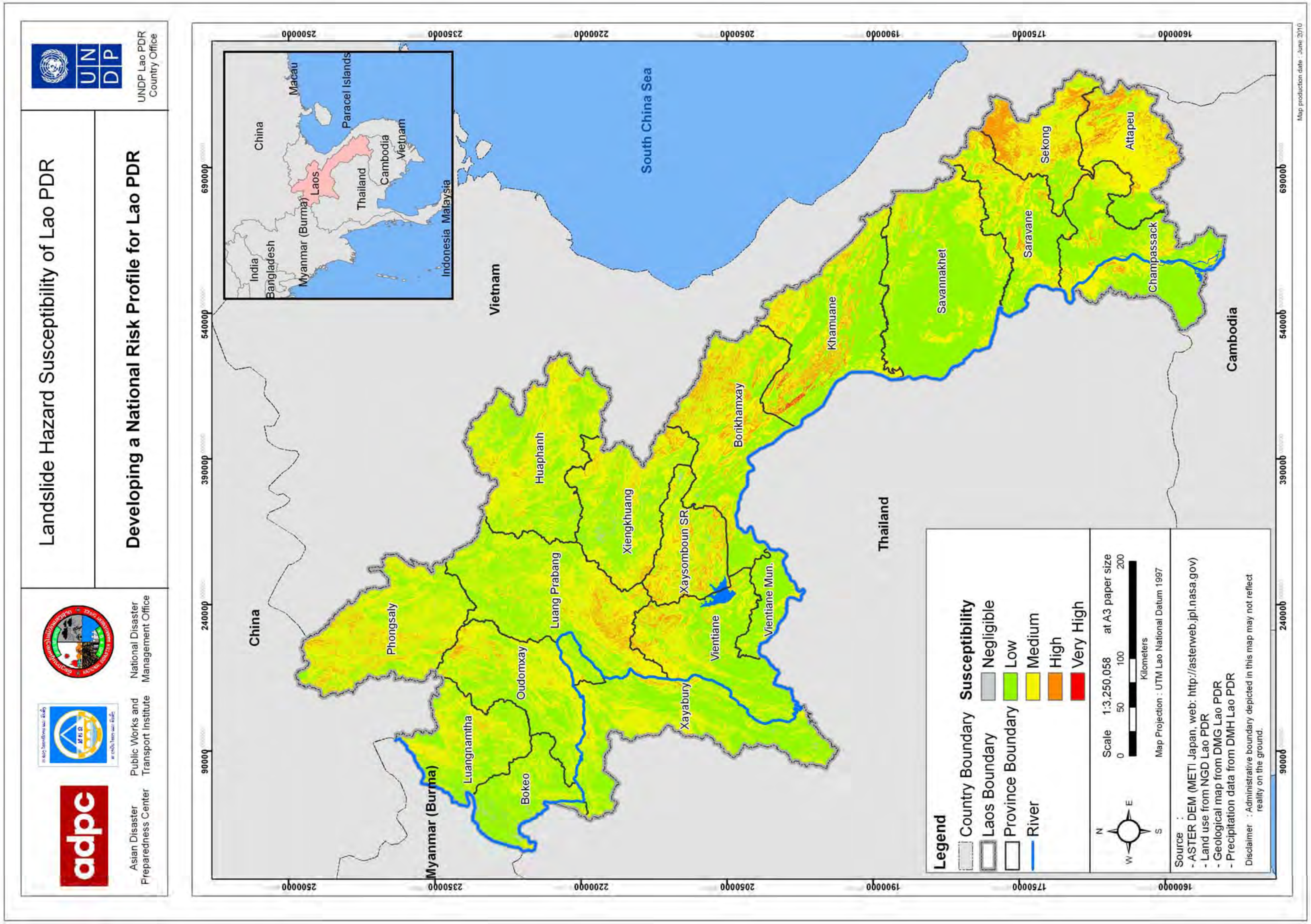


Figure 3.23 Landslide hazard susceptibility map of Lao PDR

3.4 EPIDEMIC HAZARD ASSESSMENT

3.4.1 BACKGROUND

An epidemic refers to the occurrence of more cases of a disease than would normally be expected in a community or region during a given time period. Epidemics are commonly thought to involve outbreaks of acute infectious disease[9].

Disease and epidemics occur as a result of the interaction of three factors: agents, hosts and environment. Agents cause the disease, hosts are susceptible to it and environmental conditions permit host exposure to the agent. An understanding of the interaction between agent, host and environment is crucial for the selection of the best approach to prevent or control the continuing spread of an epidemic.

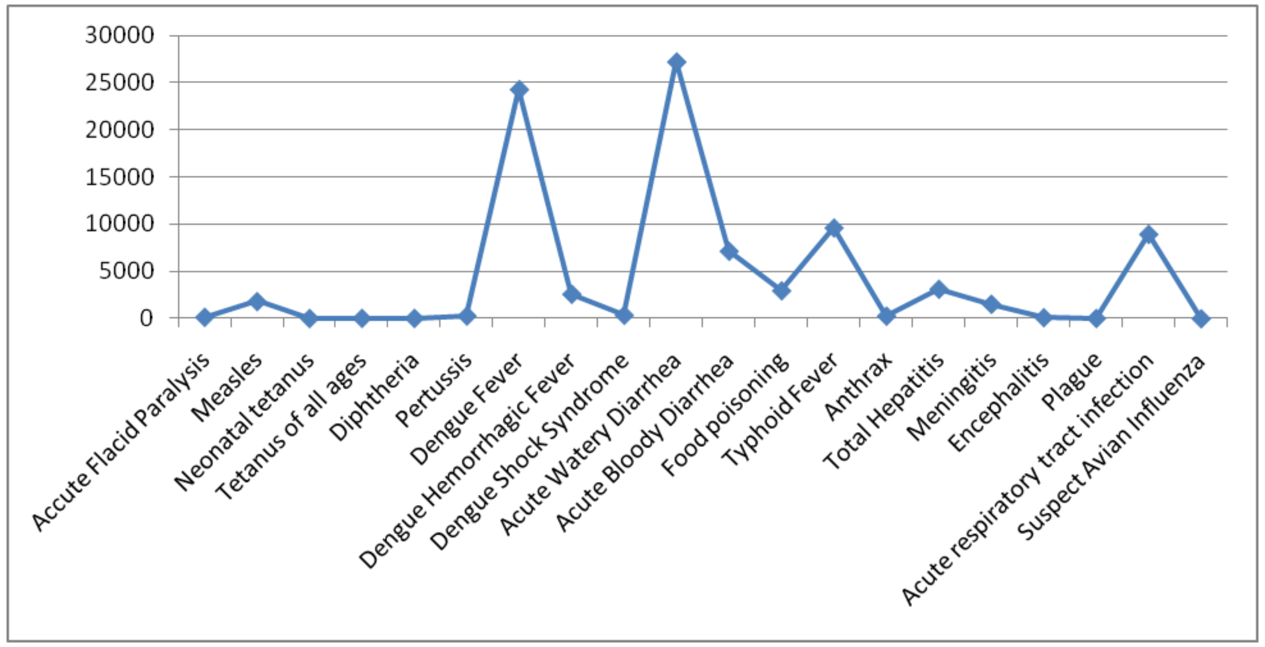


Figure 3.24 Accumulative number of cases from 2004 to 2008 in Lao PDR

Lao PDR experienced outbreaks of a large range of major diseases such as Typhoid, Malaria and Cholera. The Health Department of Lao PDR have been regularly monitoring and reporting on 22 diseases, including Malaria. Among the 22, the ten highest diseases, in term of number of cases reported, have been identified and will be discussed further in this chapter. Figure 3.24 shows the accumulative number of cases of each disease reported in Lao PDR.

3.4.2 MAP CONTENT

For the disease hazard assessment ten diseases were analyzed: Acute Bloody Diarrhea, Acute Respiratory Tract Infection, Acute Watery Diarrhea, Dengue Fever, Dengue Hemorrhagic Fever, Food Poisoning, Hepatitis, Malaria, Measles and Typhoid Fever. Limited data on diseases was available for all the provinces. The chronology of events was restricted to about five years except for Malaria which has data available for 10 years. The disease susceptibility map shows specific disease-prone provinces with certain severity and trends of disease. The maps are indicators of up/down trends of specified diseases.

3.4.3 APPLICATION OF DISEASE HAZARD MAPS

- The susceptibility maps will provide necessary guidance to the Department of Health and National Planning agencies for allocating necessary budget for eradication or reduction of diseases and outbreaks.
- Based on these maps, the national and provincial agencies can give special attention to health, hygiene, vector control, poverty and health infrastructure in high disease-susceptible provinces.
- The maps will be helpful for national and international health service agencies and NGOs to provide necessary support to susceptible provinces.
- The susceptibility map renders additional dimensions to identify causative factors of diseases. Frequent flooding in some low lying areas, for example, may lead to water- and vector-borne diseases.

3.4.4 DATA SOURCES

- Malaria Department: Ten years of data for Malaria.
- National Health Department of Lao PDR: Five years of data for Acute Bloody Diarrhea, Acute Respiratory Tract Infection, Acute Watery Diarrhea, Dengue Fever, Dengue Hemorrhagic Fever, Food Poisoning, Hepatitis, Measles and Typhoid Fever.

3.4.5 SPECIAL REMARKS

- Disease data is available from 2005 to 2009 (five years) and from 1998 to 2008 (10 years) for Malaria.
- The methodology for disease mapping is based on the exposure of communities to specific diseases.

[9] (http://www.answers.com/topic/epidemic)

3.4.6 METHODOLOGY

The methodology for disease susceptibility maps were prepared using the methodology shown in Figure 3.25. The steps were as follows:

a. Collection of Data: The data related to number of cases, population and mortality was collected from authentic sources and then validated. The database is generated for susceptibility mapping due to various diseases.

b. Development of disease susceptibility maps:

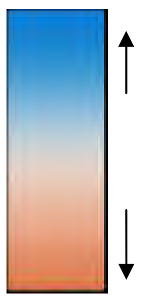
- The disease data for each province was collected for each year since 2005 and since 1998 for malaria. Population growth was further calculated through statistical projection methods on an annual basis based on population data from the National Statistic Center of Lao PDR (NSC, 2005). The Incidence Index (II) was developed, which is the simple ratio of diseases cases reported in a particular year and the population for a specific province. This index is dimensionless.

$$\text{Incidence Index (II)} = \frac{\text{Number of cases reported for each class of Disease in specific province in specific year}}{\text{Total population in specific province for specfic year}}$$

- The II has been calculated for each class of disease for each year. The regression analysis is carried out to get the generalized II for a particular district for the span of the study period. The analysis has been further carried out for overall II for all provinces. The details of the susceptibility maps can be found in Figure 3.26 to Figure 3.35.

3.4.7 HOW TO READ THE MAP

- The susceptibility map shows the trend of each disease. Background colors of the map represent trends of five years of disease outbreaks since 2005 to 2009 (10 years for Malaria since 1998 to 2008). There are two tones of color which represent different trends of disease:
  - Trend of decreasing disease is represented by a blue tone: the higher the decrease the darker the blue, vice versa the lower the decrease the lighter the blue tone.
  - Trend of increasing disease is represented by an orange tone: the higher the increase the darker the orange, vice versa the lower the increase the lighter the orange tone.
  - For multi disease maps, the trend of increasing is represented by a pie chart



Decreasing Trend

Increasing Trend

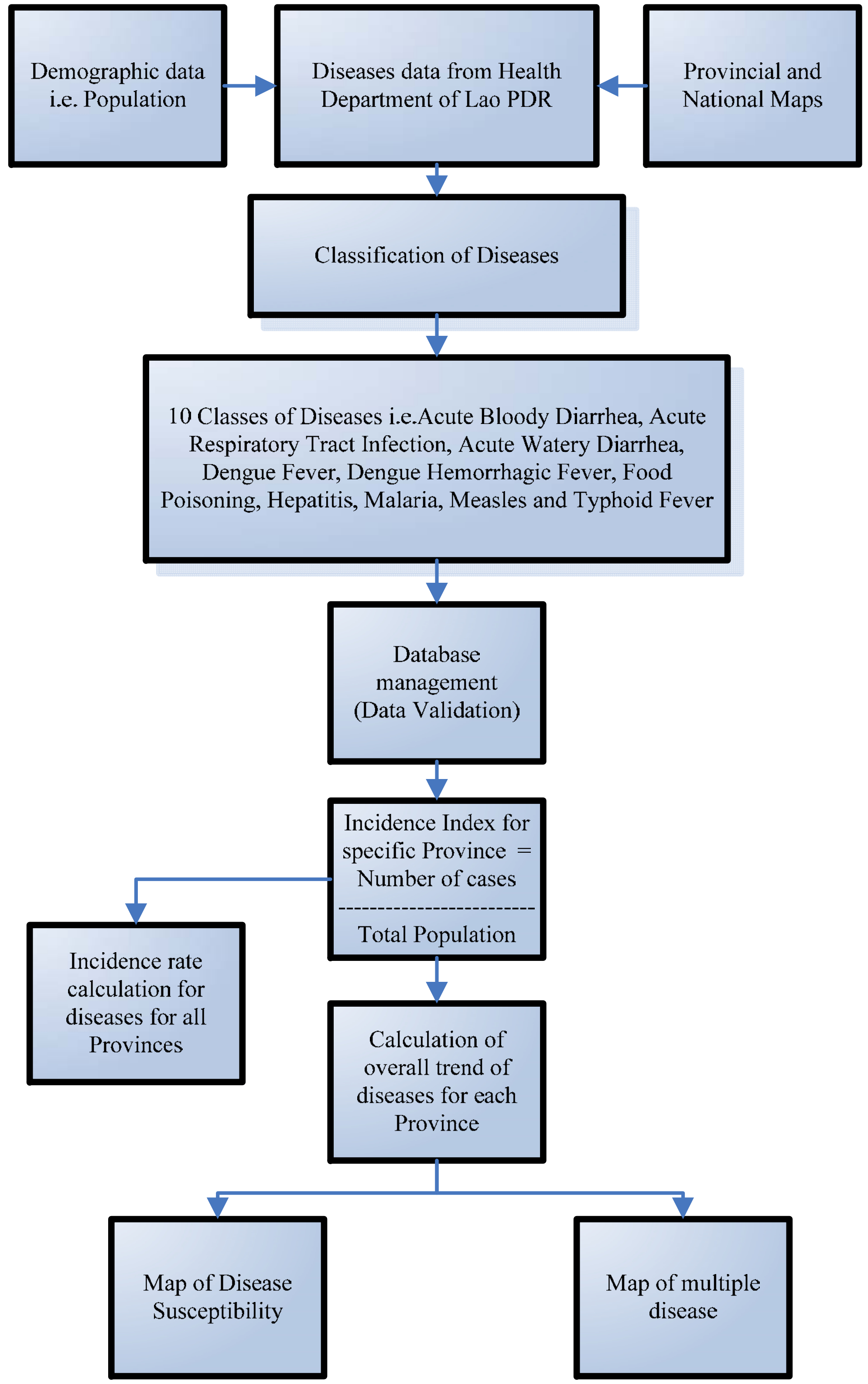


Figure 3.25 Methodology chart for Epidemic Assessments

3.4.8 ANALYSIS OF DISEASE HAZARDS

Figure 3.26 to Figure 3.35 show the trend analysis of ten diseases. The trend shows that Acute Bloody Diarrhea, Acute Respiratory Tract Infection, and Acute Watery Diarrhea cases are increasing. The trend of Malaria, on the other hand, is decreasing. The analysis and observation of hazard assessment is as follows:

- In the ase of Acute Boody Diarrhea (ABD), Sekong is the most susceptible. Bokeo, Vientian, Xiengkhaung, Borikhamxay, Saravane and Attapeu are also highly susceptible. The trend of ABD in Lungnamtha, Phongsaly, Xayabury, Xaysomboun SR and Vientiane Municipality are decreasing.
- The trend of Acute Respiratory Tract Infection (ARTI) in Bokeo, Borikhamxay and Sekong is highest. The analysis further shows that Savannakhet and Saravane also have increasing trends. The trend of ARTI in Phongsaly, Luang Prabang, Huaphanh and Xaysomboun SR is decreasing.
- The analysis reveals that Borikhamxay and Sekong have the highest increasing trend of Acute Watery Diarrhae (AWD). Vientiane Municipality, Xayabury, Luang Prabang, Huaphanh, Champassack and Attapeu show gradual increasing trends. Phongsaly and Xaysomboun SR have a decreasing trend of AWD.
- The trend of Dengue Fever is increasing in Bokeo, Saravane and Attapeu. Borikhamxay has a highly decreasing trend whilst Phongsaly, Xayabury, Xiengkhuang, Xaysomboun SR, Savannakhet and Champassack are slightly decreasing.
- Attapeu has the highest increasing trend of Dengue Hemorrhagic Fever (DHF). For Phongsaly, Luangnamtha, Oudomxay, Huaphanh, Xaysomboun SR, Borikhamxay and Sekong the trend is decreasing. The most decreased trend is in Savannakhet and Champassack.
- More cases of Food Poising has been reported in Borikhamxay and Savannakhet. The trend is decreasing in Huaphanh, Luang Phabang, Vientiane, Vientiane municipality and Champassack.
- The trend of Hepatitis is very much increased in Oudomxay, Vientiane and Khamuane. Meanwhile, Borikhamxay and Savannakhet have highly decreasing trends.
- Most of the provinces, except Sekong and Attapeu, have decreasing trends of Malaria. Khamuane, Savannakhet and Saravane have the highest decreasing trend.
- Luang Phabang and Champassack have the highest increasing trend of Measles. Phonsaly, Xayabury and Savannakhet have the highest decreasing trend.
- Oudomxay, Huaphanh, Xiengkhuang and Khamuane have a highly increasing trend of Typhoid Fever. A decreasing trend is found in Luang Phabang, Phongsaly, Xayabury, Xaysonboun SR, Vientiane municipality and Borikhamxay province.
- For multiple diseases, seven provinces, namely, Xekong, Khammouane, Bokeo, Oudomxai, Attapeu, Vientiane and Houaphan have the highest increasing trend while three other provinces including Xaignabouri, Xaisomboun SR and Phongsaly have a decreasing trend. Xaisomboun SR is the only province which has only a decreasing trend and no increasing trend for the all 10 diseases.

3.4.9 RECOMMENDATIONS

- Susceptibility maps pinpoint the exact areas affected, the trend and the severity of diseases. This provides ample information for further health investigation by the health department and other health-related agencies regarding the disease’s causative factors and appropriate actions.
- This map implies that health departments and other related agencies take necessary interventions to manage the risks:
    - Interventions geared towards the agents and environment causing the disease. Hazard Reduction Program is necessary which includes strategies, activities or interventions to reduce the occurrence of health hazards or the exposure of the communities to the hazard. For example the Dengue Prevention Program which employs Source Reduction Strategy in the context of eliminating mosquito breeding places in the community.
    - Consider interventions that can strengthen identified health vulnerabilities or weaknesses of the community. For example, the province that has the highest incidence of Acute Watery Diarrhea and a vulnerability assessment that shows lack of sources of safe water can develop a health program that provides safe drinking water.
    - The identified diseases on the map indicate the need for Health Emergency Preparedness Programs to develop the capacity of the health department, related agencies and even the affected communities to manage the health risks such as outbreaks or epidemics. Areas that can be considered include policy, guidelines, plan development, capability building of health workers, health facility upgrading, health education and advocacy and provision of logistical resources.
    - This susceptibility map indicates a need to develop systems such as information management systems, a good disease monitoring and surveillance system, as well as early warning and alert system.
    - This susceptibility map signals the need for community risk reduction initiatives as a basis for the establishment of public health programs that can prepare the communities to manage the risks of health emergencies or disasters.

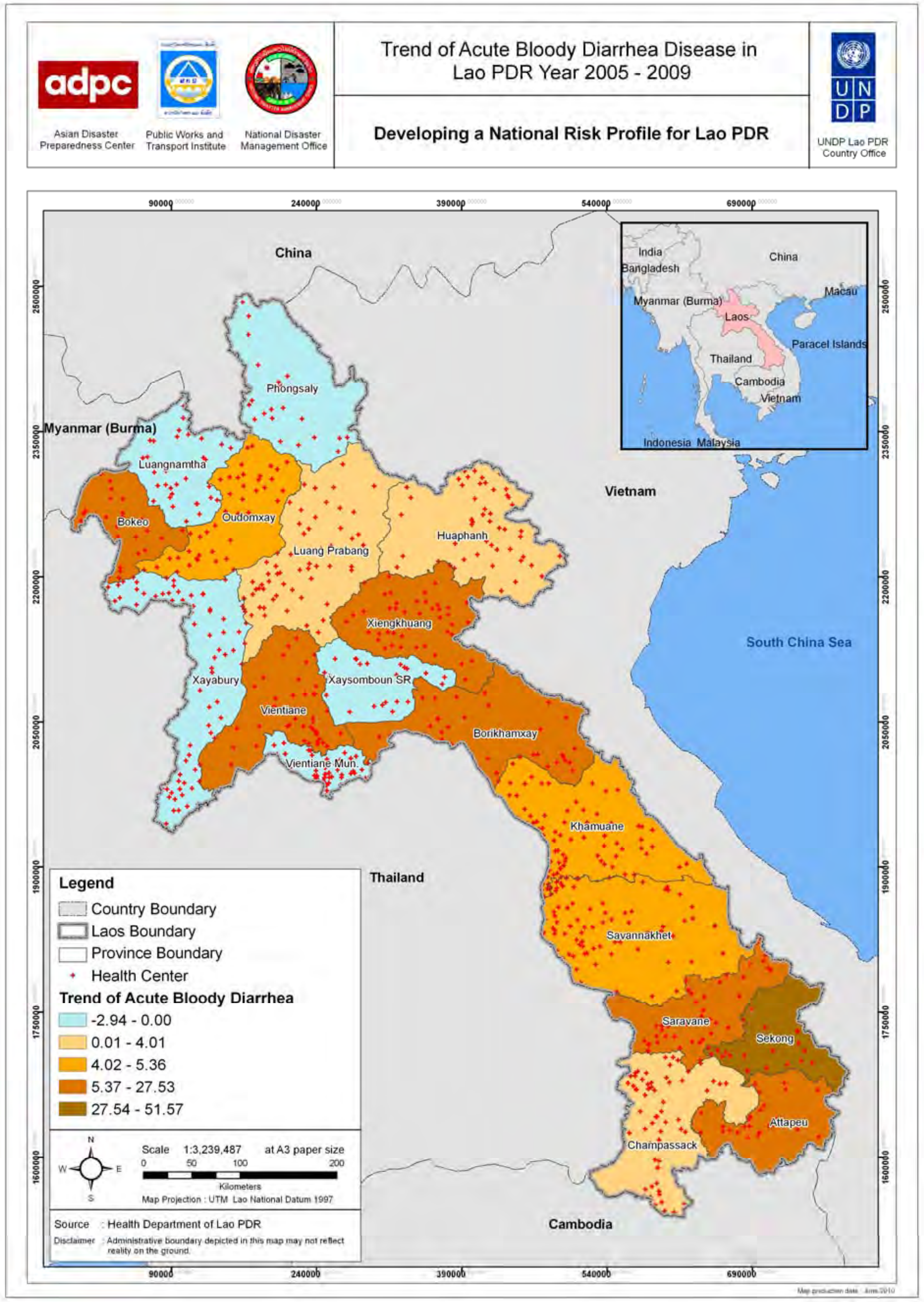


Figure 3.26 Map showing disease susceptibility for Acute Bloody Diarrhea

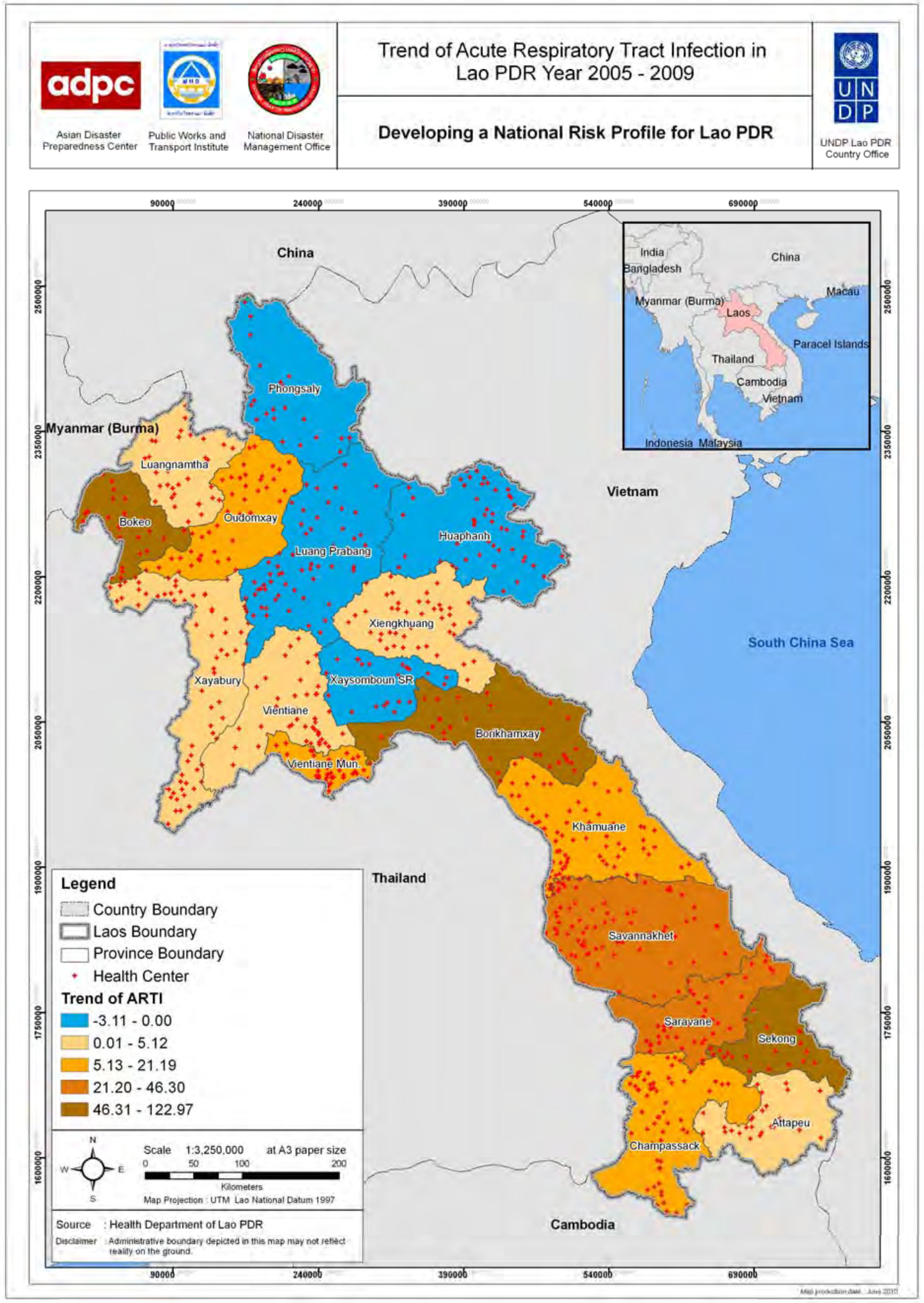


Figure 3.27 Map showing disease susceptibility for Acute Respiratory Tract Infection

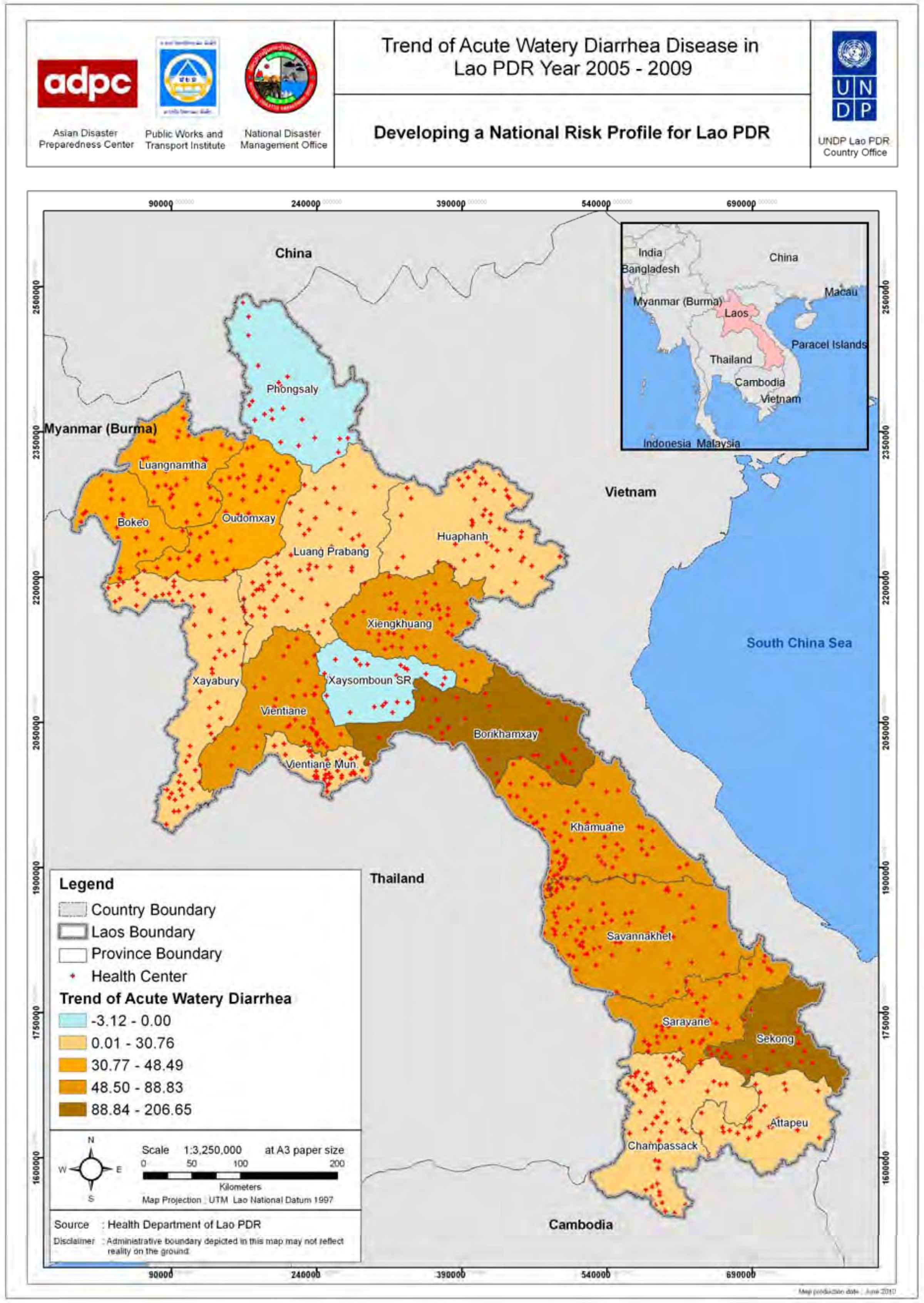


Figure 3.28 Map showing disease susceptibility for Acute Watery Diarrhea

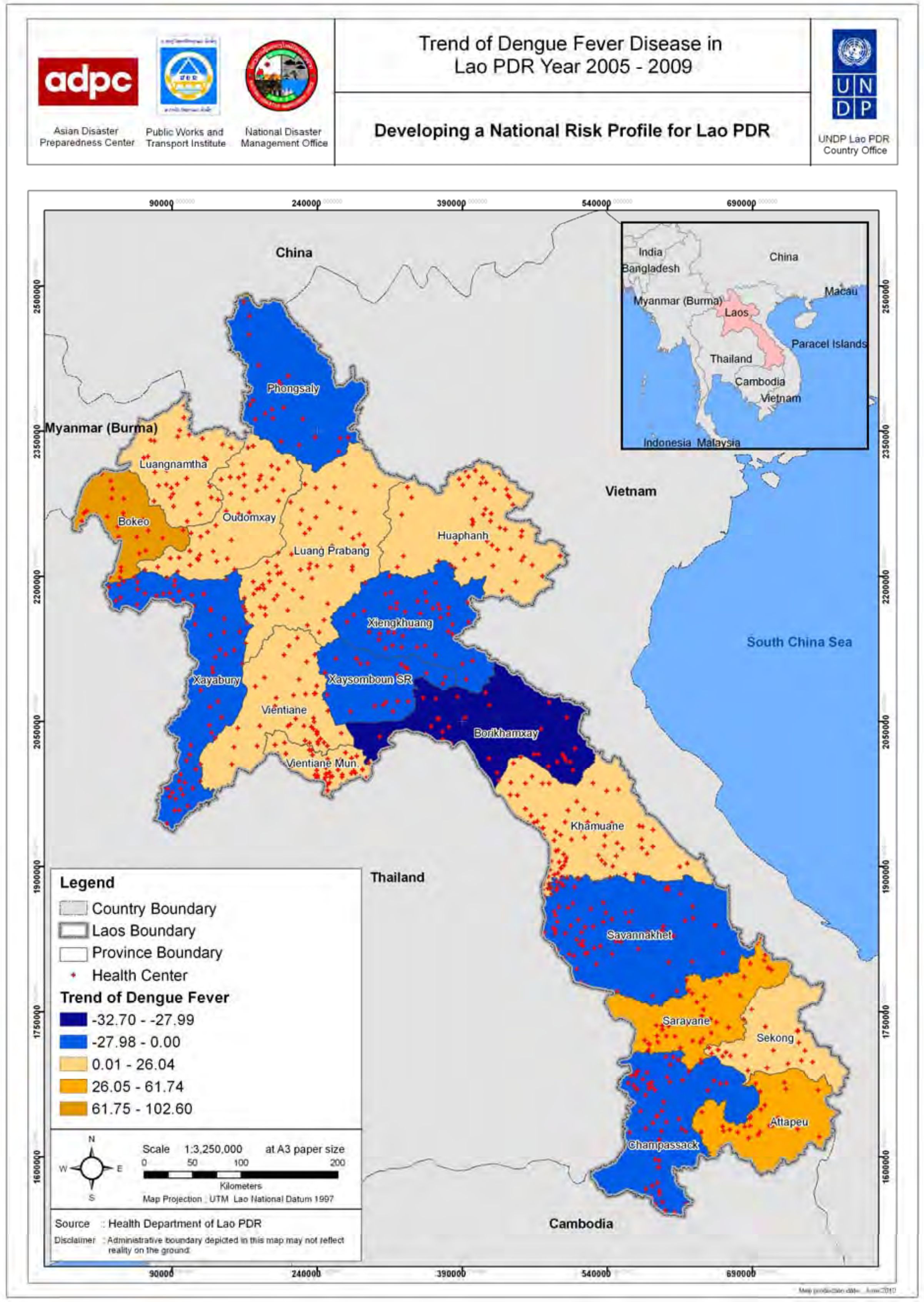


Figure 3.29 Map showing disease susceptibility for Dengue Fever

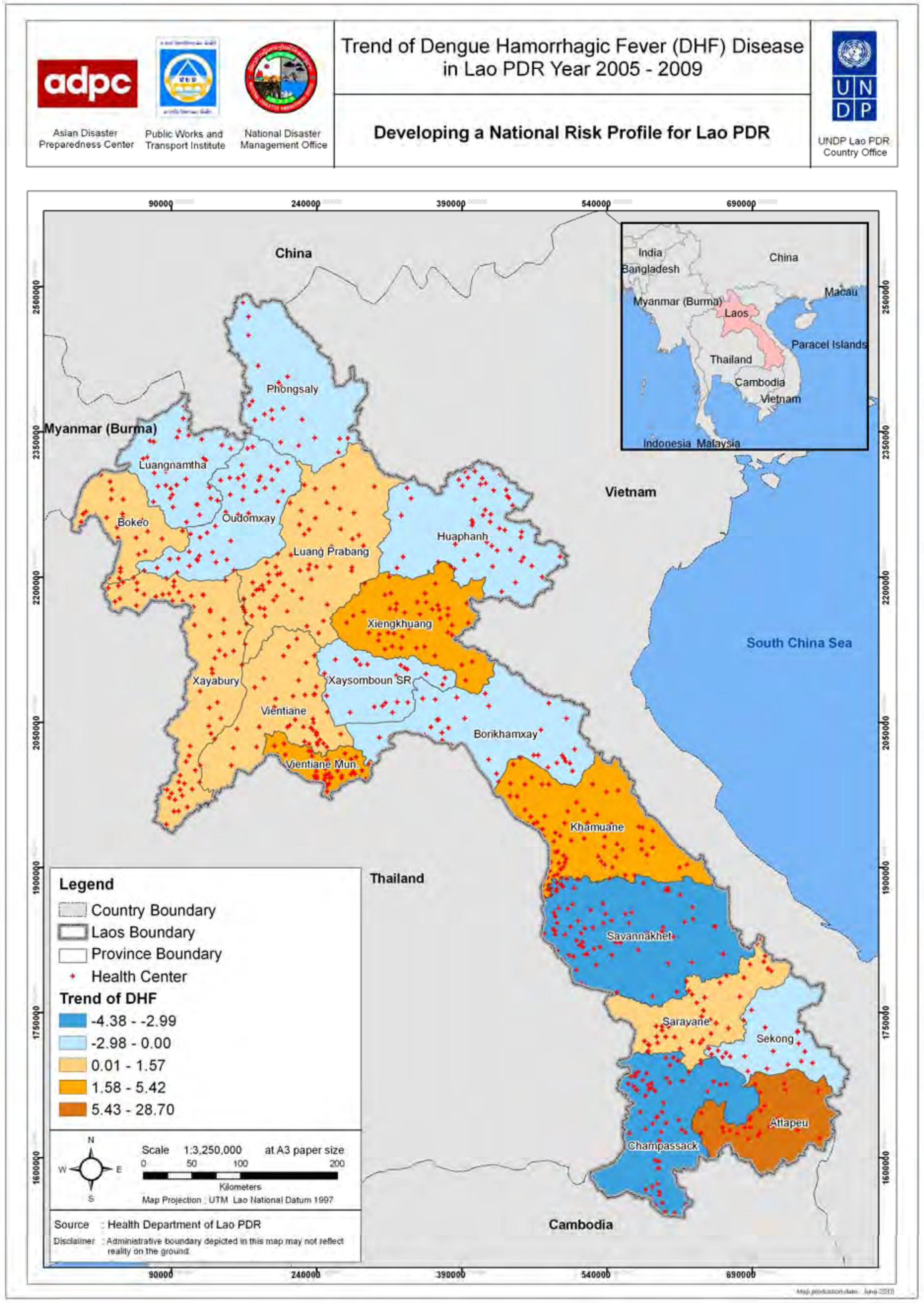


Figure 3.30 Map showing disease susceptibility for Dengue Hemorrhagic Fever

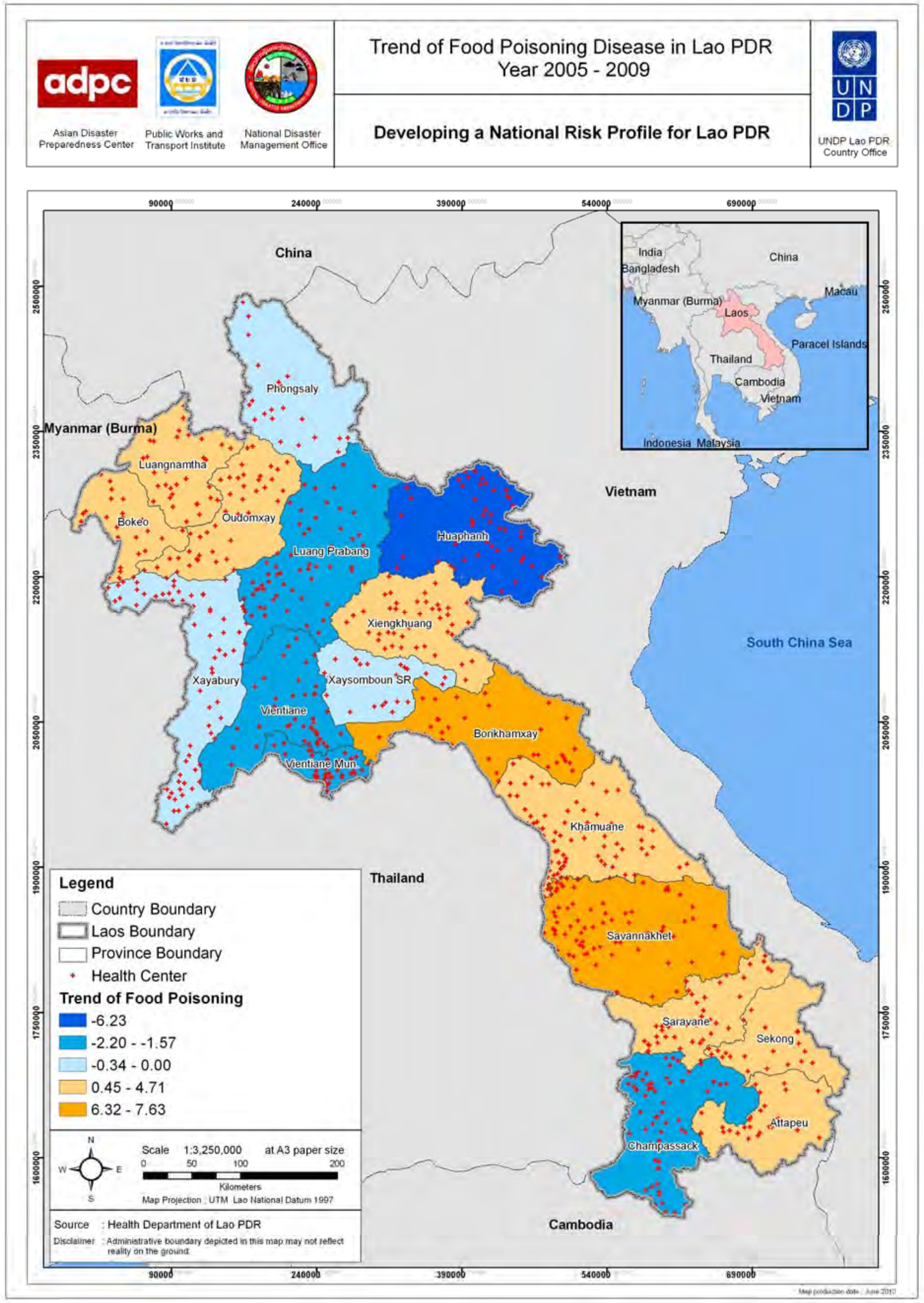


Figure 3.31 Map showing disease susceptibility for Food Poisoning

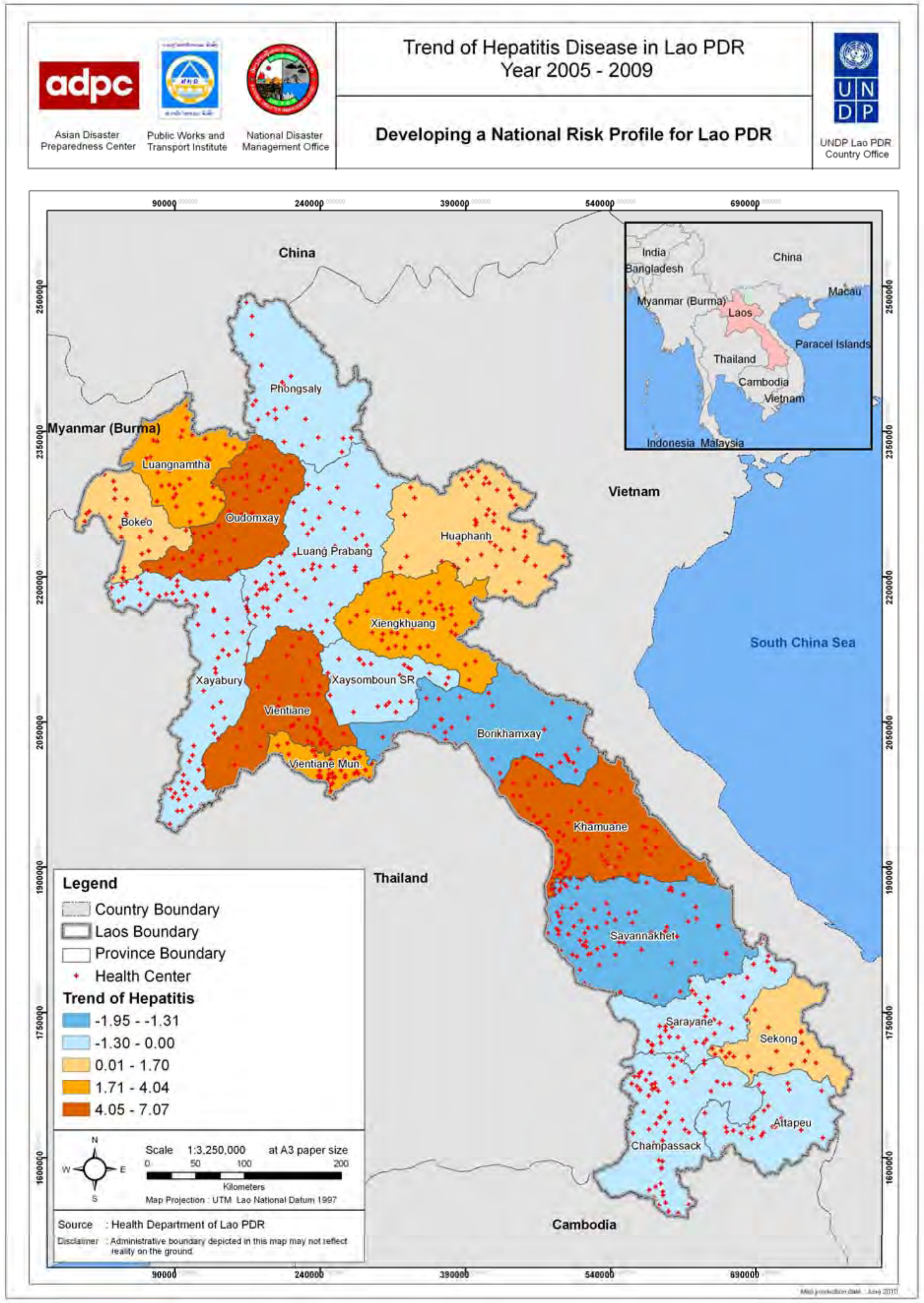


Figure 3.32 Map showing disease susceptibility for Hepatitis

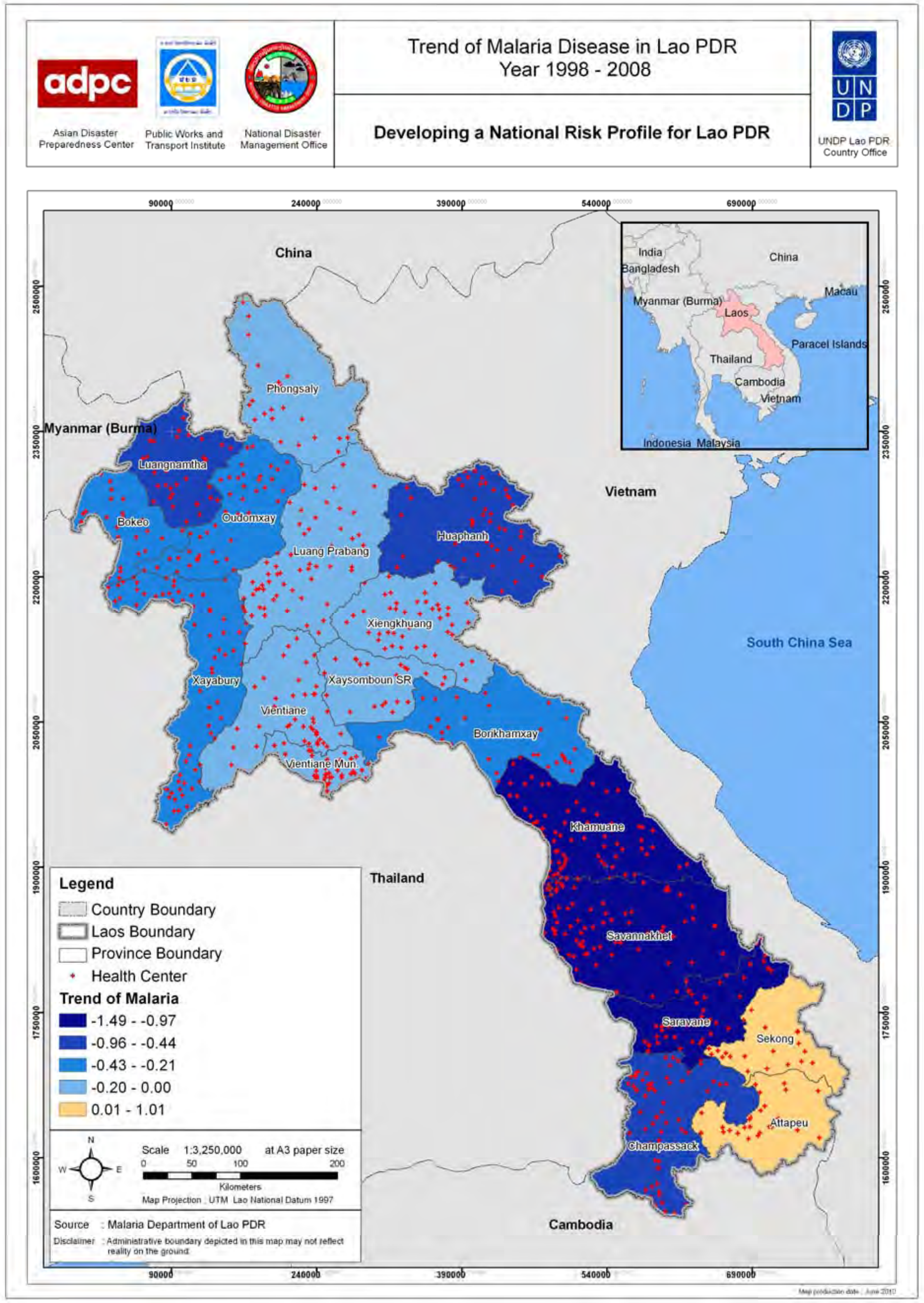


Figure 3.33 Map showing disease susceptibility for Malaria

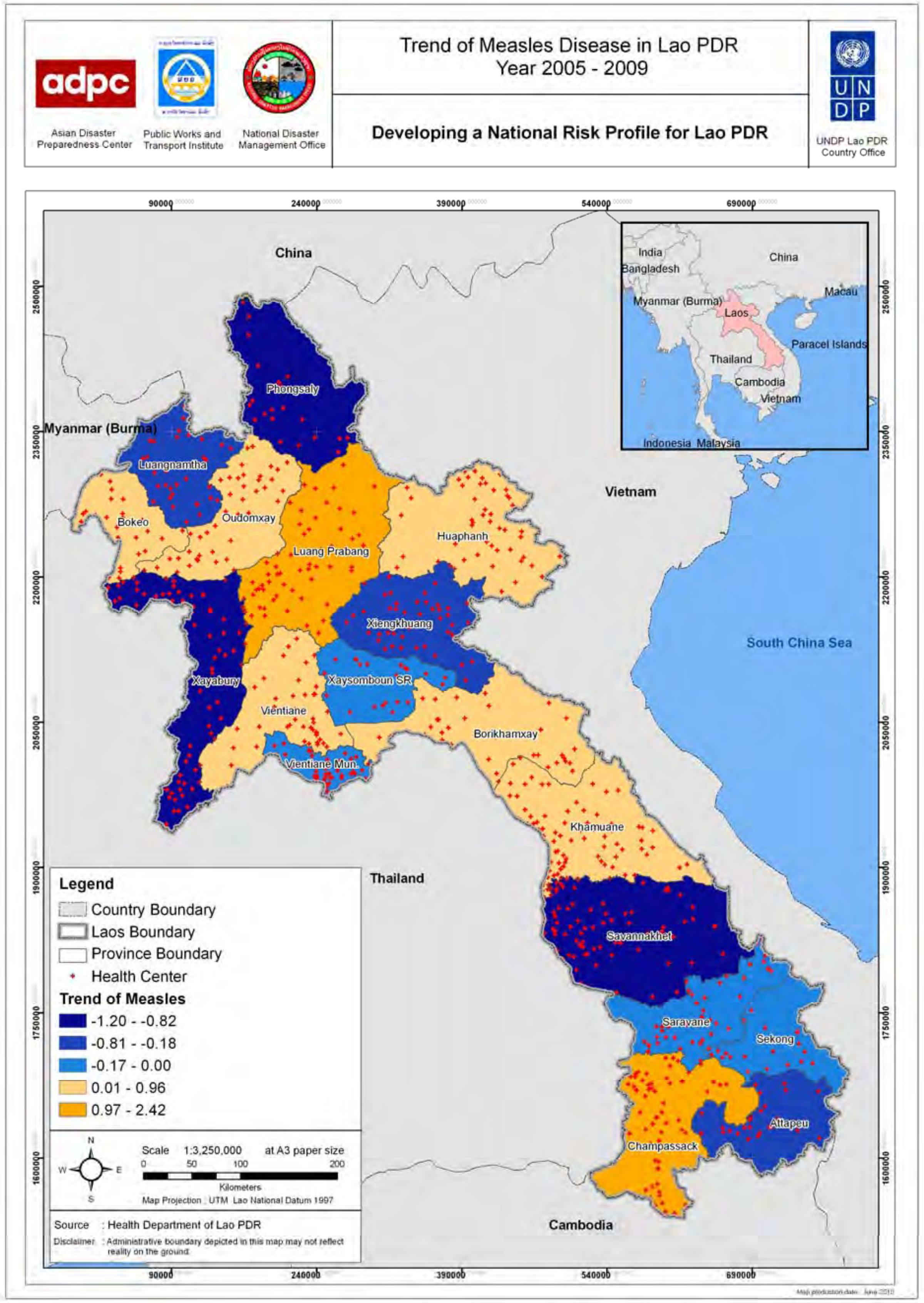


Figure 3.34 Map showing disease susceptibility for Measles

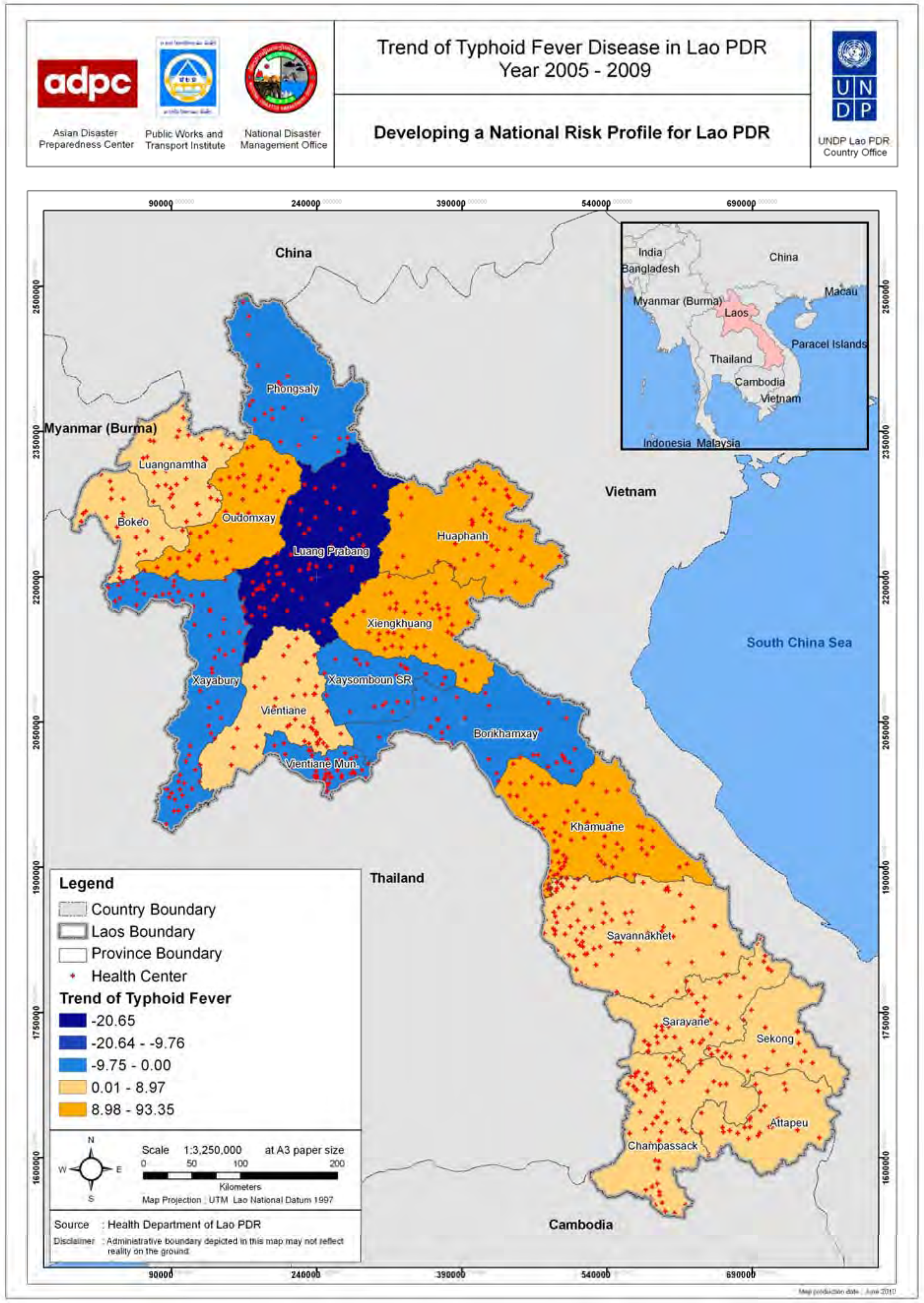


Figure 3.35 Map showing disease susceptibility for Typhoid Fever

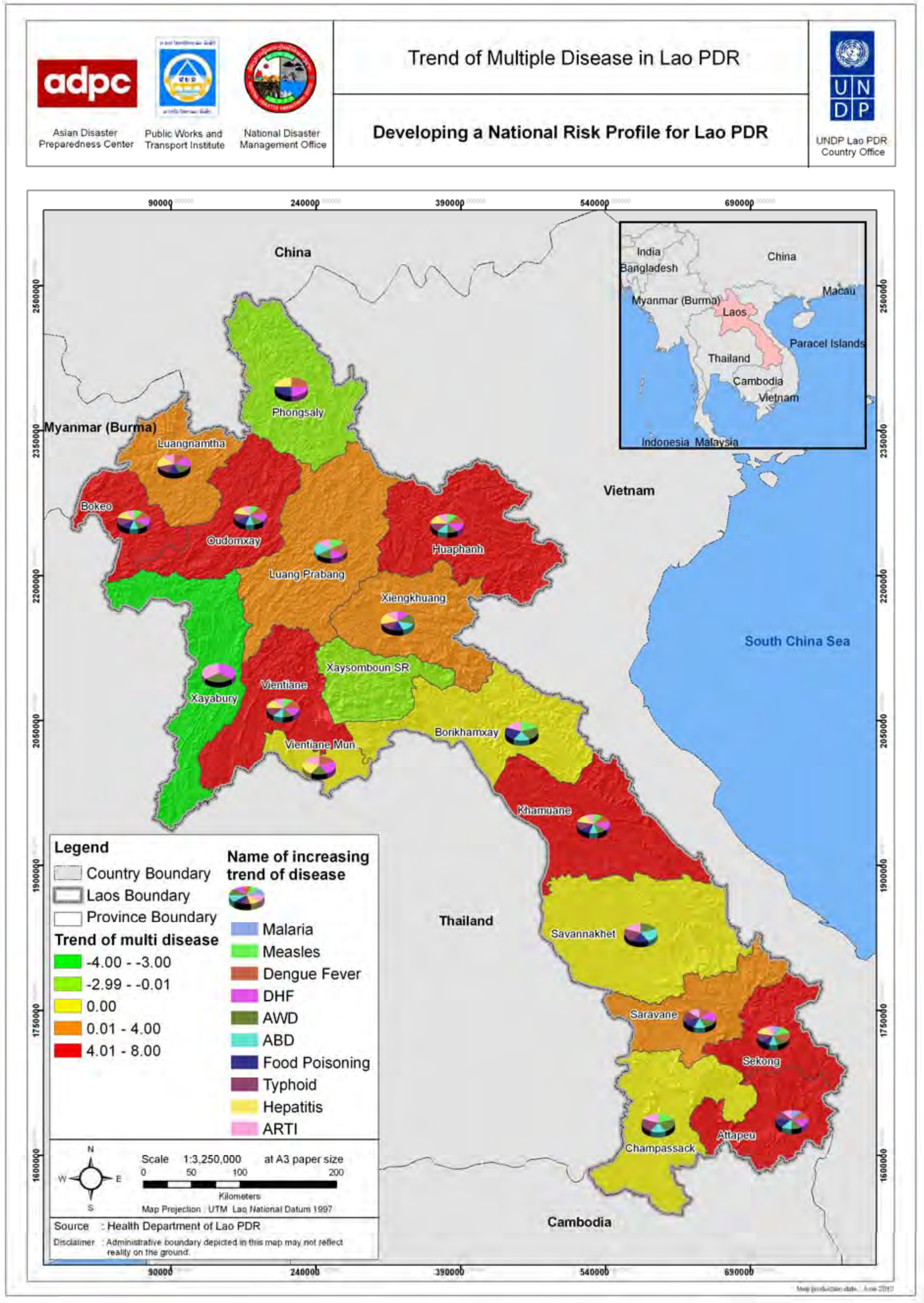


Figure 3.36 Map showing multiple diseases in Lao PDR

3.5 UXO HAZARD ASSESSMENT

3.5.1 BACKGROUND

UXOs or unexploded ordnances are explosive weapons that failed to detonate when they were fired, dropped, launched or projected. These UXOs still pose the risk of exploding. Throughout the second Indochina War (1964 – 1973), more than 580,000 bombing missions dropped over two million tons of explosive ordnances on the territory of Lao PDR, making it, per capita, the most heavily-bomb nation in the world (NRA, 2008).The UXOs were mostly cluster munitions that Lao PDR people call 'bombies". An estimated 270 million tons of various types of bombs were dropped and around 30% failed to explode; remaining alive. The NRA Annual Report shows that around 80 million bombies are scattered and buried in the land of Lao PDR. It is reported that big bombs weighing between 100 to 30,000 pounds, rockets, heavy artillery shell, hand grenades and large quantities of other types of shells were used and remain dangerous in Lao PDR.

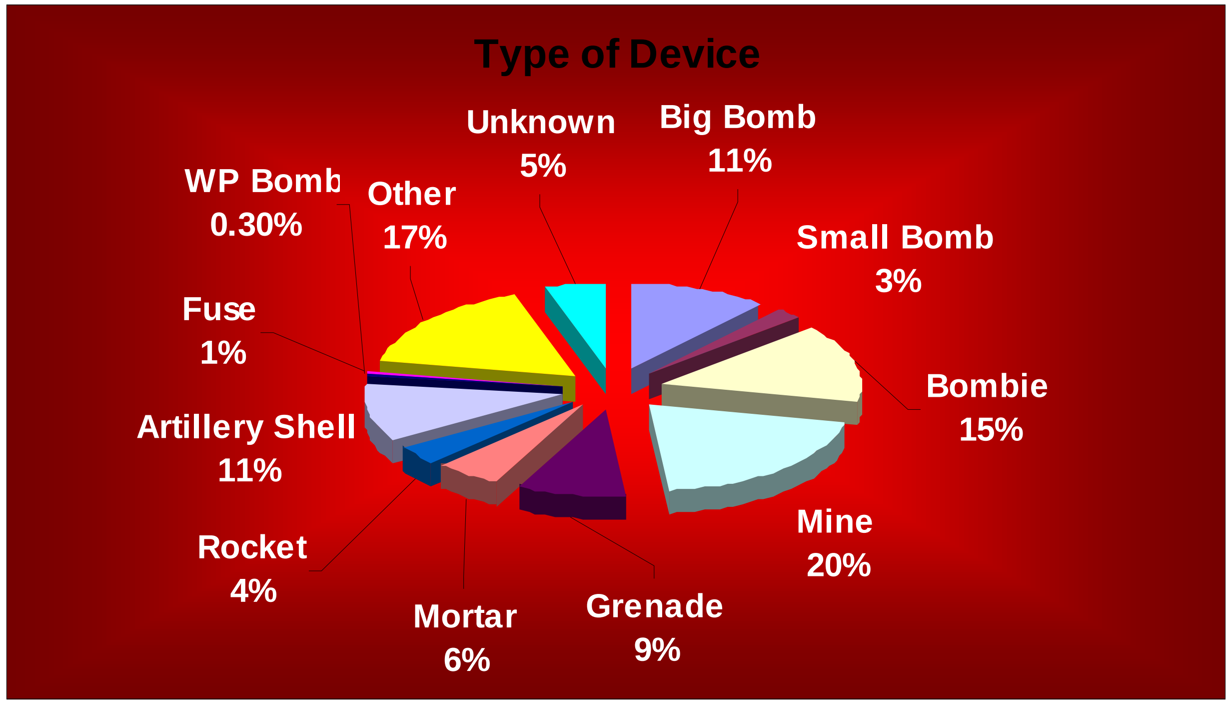


Figure 3.37 Survey of Victims and Accidents based on UXO type (Source: (NRA, 2008))

The National Regulatory Authority (NRA) conducted surveys on victims and accidents induced by UXOs. The report reveals that at national level, bombies have accounted for some 15% of accidents where the type of device has been identified, whereas mines come in at 20%. Big bombs accounted for 11% of accidents. The other percentage consists of small bomb, grenades, mortars, rockets, artillery shells, other and unknown. Figure 3.37 shows the results of the survey, by NRA-UXO, on victims and accidents based on the type of device.

3.5.2 MAP CONTENT

UXO hazard maps were prepared based on UXO distribution and density. UXO distribution maps show the spatial distribution of UXOs across the country of Lao PDR, while the UXO density map depicts the density of UXOs. UXO density is defined as the number of UXOs per square kilometer.

3.5.3 APPLICATION OF UXO HAZARD MAP

The UXO hazard map was developed based on the type of UXOs and spatial distribution data collected from NRA. The map of UXO categories and density was used to assess the risk at district level across the country of Lao PDR. Therefore, the UXO hazard map should be read as a combination of the distribution and density of UXOs. These maps were developed for several reasons:

- The map will help stakeholders, decision makers and policy makers to better understand the severity of UXO hazards and take the necessary decisions, actions and mitigation measures; especially for the development of affected communities and for infrastructure expansion.
- The map will help UXO-related actors, local, national and international NGOs, as well as donors. to prioritize DRR strategies.
- The map will help set priorities in mitigation interventions in UXO hazard areas, based on the potential impact of remaining UXOs.

3.5.4 DATA SOURCES

The main source of data on UXO spatial distribution and types of UXOs was the NRA for UXO/Mine Action Sector of Lao PDR (UXO-NRA). The NRA is the leading institution in the UXO/Mine Action Sector which is responsible for coordinating all UXO/Mine Action activities in Lao PDR (http://www.nra.gov.la/).

3.5.5 METHODOLOGY

The methodology for UXO hazard map development was mainly adapted from the NRA-UXO. The UXO hazard risk analysis uses site-specific data on the distribution and density of UXOs to estimate the threat to human health and environment. UXO distribution is spatially mapped and categorized based on its type. The spatial distribution of UXOs was used to classify the density of UXOs, which is defined as the number of UXOs per square kilometer; helping to estimate the risk of UXO hazard. The schematic diagram in Figure 3.38 shows the methodology used for UXO hazard assessment and mapping. The numerical and tabular data of UXO distribution was obtained from NRA-UXO. The data includes the coordinate locations of each UXO, the type and categories, targets as well as aircrafts. The following steps were used in the development of UXO hazard maps.

- Extraction and plotting of the coordinate location of UXOs. The plotted coordinates of UXOs resulted in a spatial distribution map of UXOs across the country of Lao PDR.
- Preparation of the administrative map of Lao PDR.
- Overlay the spatial distribution map of UXOs and administrative map at district level.
- The density map of UXOs at district level was obtained by calculating the number of UXOs in each district divided by the area of each district (km^2).
- UXO density was then classified into eight classes.

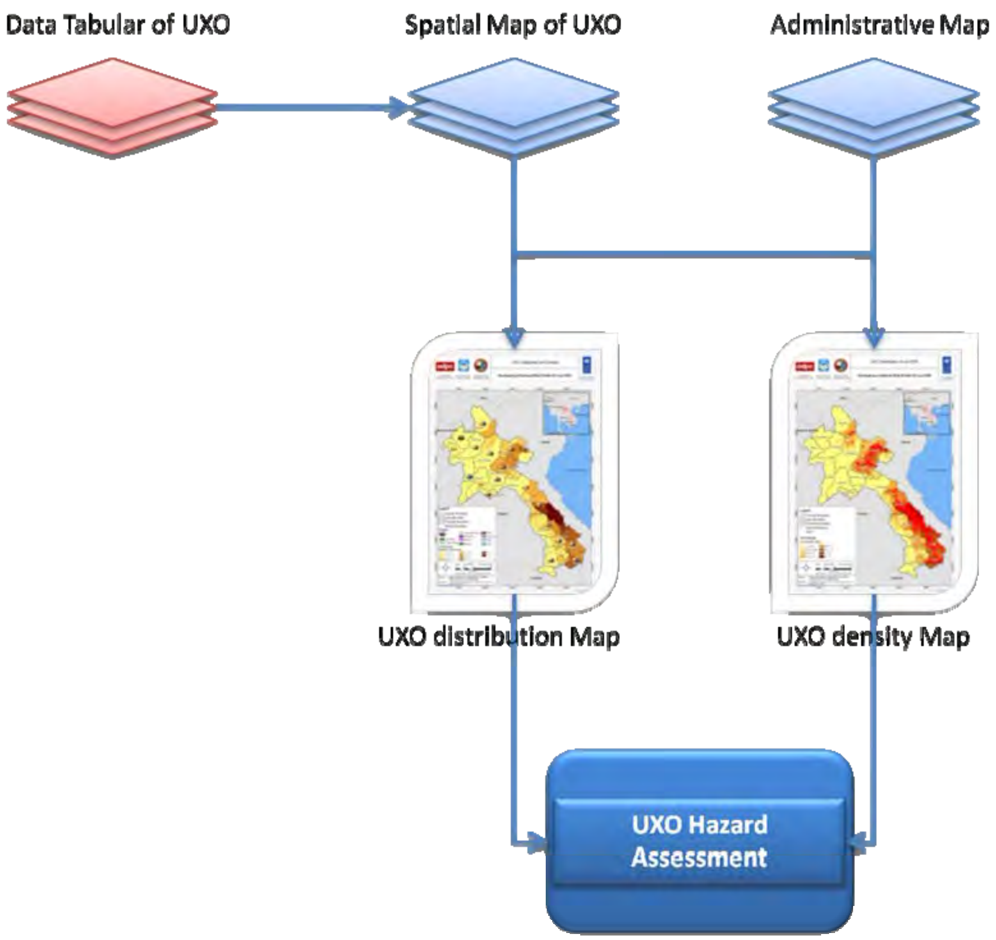
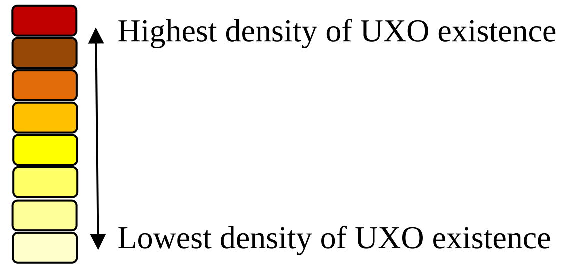


Figure 3.38 Flowchart showing the methodology for UXO hazard assessment

3.5.6 HOW TO READ THE MAP

The density of UXOs was created based on the total number of UXOs per square kilometers. The class or category of this density is represented by color gradation color from yellow to red. Red represents a higher density of UXOs and white represents a lower density of UXOs.



3.5.7 ANALYSIS OF UXO HAZARD ASSESSMENT & MAPPING

With respect to its threat to human health and the environment, UXOs differ from other hazards in several ways. UXOs present an immediate risk of acute physical injury from fire or explosion resulting from accidental or unintentional detonation (BRAC, 1999). Figure 3.39 and Figure 3.40 show the spatial distribution and density of UXOs which represent the level of UXO hazard. It can be concluded from the maps that the UXOs exist across Lao PDR. Different types of UXOs, such as incendiary, ammunition, cluster bombs, rockets and other type of general purpose UXOs can be found across the country. In terms of the type of UXOs, the most common type found in Lao PDR is UXOs for general purposes. The other most common types of UXOs are ammunition and incendiary. The existence of cluster bombs is also something that cannot be ignored. The density map of UXOs shows a number of UXOs per square kilometer. It can be concluded from the hazard assessment that several districts of Khamuane and Savannaket province have a very high density of UXOs ranging 2 – 4 UXOs per square kilometer. Several other districts in Huaphanh, Xienghuang, Saravane, Sekong and Attapeu have also been identified as areas with a high density of UXOs.

3.5.8 SPACIAL REMARKS

Due to limited access to the latest data related to UXOs in Lao PDR, UXO distribution density might have changed as a result of clearance activities that have been carried out recently in Lao PDR. Related to it, there are some remarks that need special attention from UXO-related actors, as follow:

- The latest data on current UXO existence and related casualty distributions need to be collected and surveyed.
- Several districts and provinces need more attention and immediate action: Boualapha, Xaibouathong and Mahaxai Districts in Khamuane province; Vilabouri, Xepon, and Nong Districts in Savannakhet province.

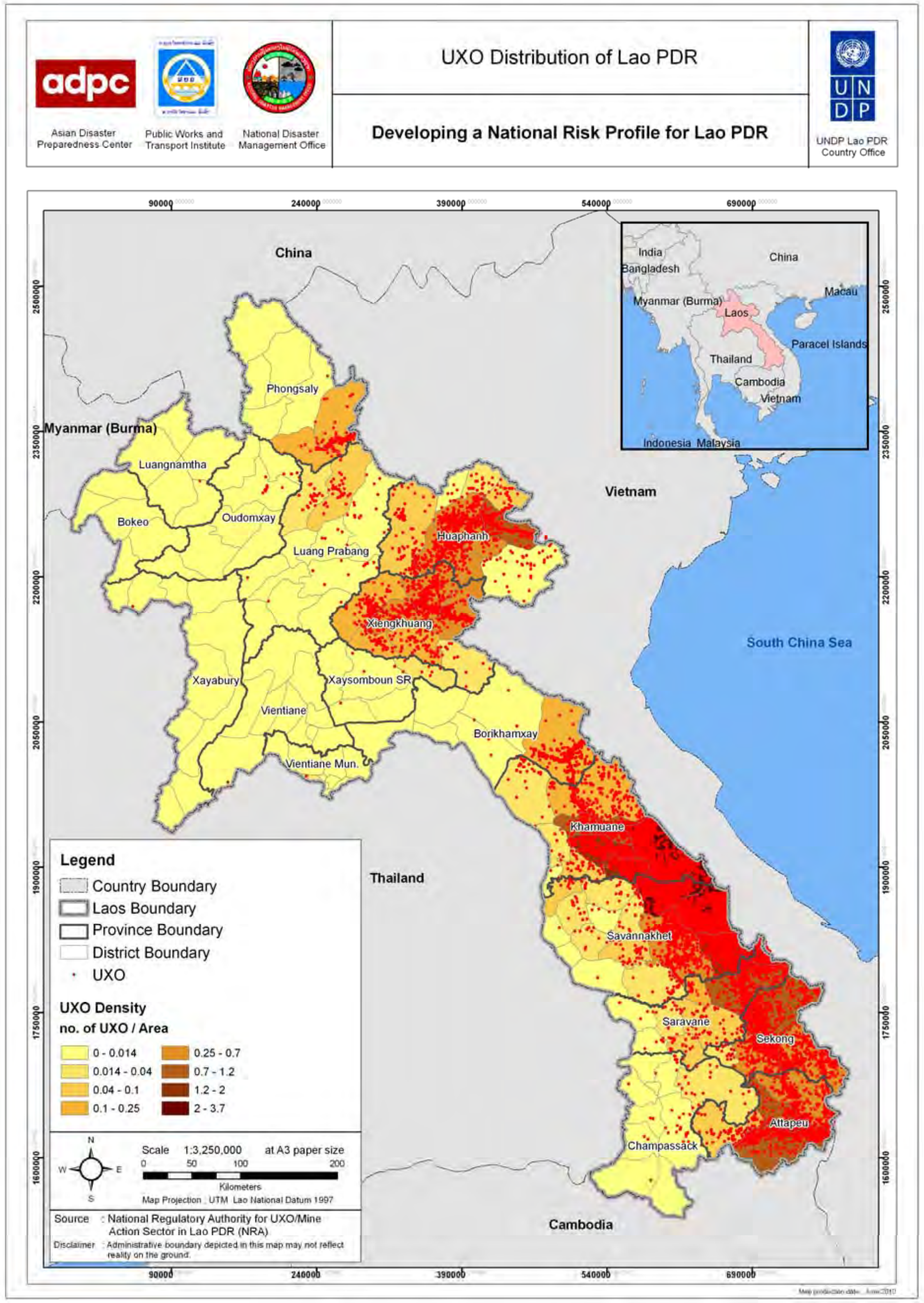


Figure 3.39 Map showing the distribution of UXOs in Lao PDR (Source: (NRA, 2008))

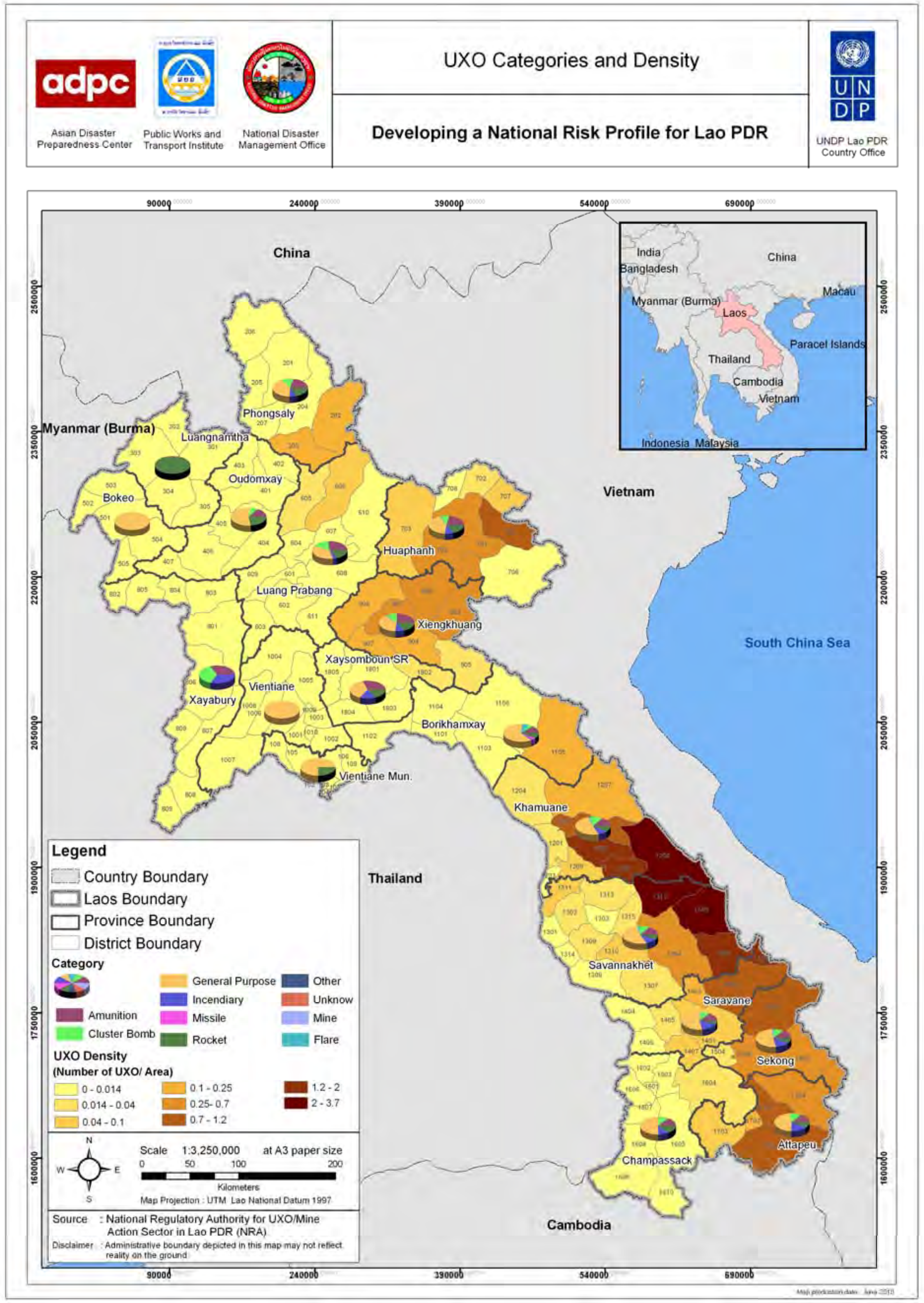


Figure 3.40 Map showing the density of UXOs in Lao PDR (Source: (NRA, 2008))

3.6 DROUGHT HAZARD ASSESSMENT

3.6.1 BACKGROUND

Drought management in Lao PDR is now a priority area of cooperation for countries in the region. To support drought preparedness and mitigation efforts the establishment of a real-time early warning and drought assessment and monitoring system is necessary. Drought is closely related to disaster management and food security, hence, its analysis and monitoring is indispensable to ensure the safety of people in this region. Throughout the last century, scientists created drought indices to identify drought impacts. In this regard, emphasis was given to analyze drought in Lao PDR through the calculation of Standardized Precipitation Index (SPI). The findings of this activity will create the basis for incorporating appropriate risk reduction strategies and prioritizing them into the country's development planning. Concerned government authorities can use drought indices to assess and respond to drought.

There is large spatial and temporal variability in rainfall pattern in Lao PDR resulting in severe flooding in some parts of the country and drought in other parts, at the same time. Every year the country experiences either a short or long dry period even within the wet season. As a result, study on drought in time and space is essential. It is also important to know the probability of having a consecutive dry period during the different seasons. Advances in climate knowledge and prediction capacity on the seasonal time-scale can contribute to adaptive management and resilience within the hydro-climatic system for livelihood security (WMO, 2005). Therefore, study on drought hazards, especially drought monitoring and assessment, are essential for implementing mitigation and adaptive measures to reduce drought impact in Lao PDR.

3.6.2 MAP CONTENT

The map shows the set of susceptibility maps developed based on SPI. SPI is based on the collected data from 16 stations of rainfall and precipitation across the country of Lao PDR. The 16 stations are well-distributed with coverage from the southern tip (Muong Mahaxai) to northern end (Phongsaly). The study therefore began with the analysis of monthly rainfall data of those stations available from the Department of Meteorology and Hydrology (DMH), Lao PDR. The period of available data from different stations varies from 9 to 30 years.

3.6.3 APPLICATION OF DROUGHT HAZARD MAP IN DISASTER RISK MANAGEMENT

The output products of this study provide an essential step towards addressing the issue of drought vulnerability in the country and can be used as a guide for drought management strategies and mitigation purposes. Identifying regional vulnerabilities can lead to an adjustment in practices in water resource sectors and can help decision makers to take drought into account from a hazard perspective and include the concept of drought vulnerability into natural resource planning. This can further help decision makers to select suitable strategies for food security, cropping patterns and resource mobilization.

3.6.4 DATA SOURCES

Reliable supporting documents, maps, appropriate models and methods for developing SPI were collected from various sources. To cover the entire country, an attempt was made to collect data from at least one representative station in all the provinces. Unfortunately, data is available from only 16 stations which do not cover all the provinces of the country. The study therefore began with the analysis of monthly rainfall data from those available stations. The necessary climatic data required for computing the indices, for example monthly total rainfall and monthly mean temperature, was collected from the Department of Meteorology and Hydrology. Some of the sources of data are as follow:

- Fengthong, T. 2007: Climate Change and Human Health in Lao PDR, Regional Workshop on Climate Change and Human Health in Asia. From Evidence to Action, Bali Indonesia.
- Gibbs, W. J. and Maher, J. V., 1967. Rainfall deciles as drought indicators. Bureau of Meteorology Bulletin, No. 48, Commonwealth of Australia, Melbourne.
- http://www.internationalfloodnetwork.org/AR2006/AR13Oudmicht.pdf, 2006. Flood Forecasting system and flood management in Lao PDR.
- http://www.faorap-apcas.org/lao/Lao%20Background.pdf: Profile of the Lao People's Democratic Republic (Lao PDR): I Background
- National Climatic Data Center (NCDC), 2006. Climate of 2006, U.S. Standardized Precipitation Index.
- NDMC, 2009. Monitoring Drought. National Drought Mitigation Centre, University of Nebraska–Lincoln
- Warning of Drought/Food Shortages in South and Southeast Asia: Final Report. National Oceanic Atmospheric Administration (NOAA), Environmental Data and Information Service (EDIS), Centre for Environmental Assessment Service (CEAS), Model Branch, University of Missouri Atmospheric Science Department in Columbia, Missouri, USA.
- World Meteorological Organization (WMO), Commission for Agriculture Meteorology (CAgM), 1986. Drought Probability Maps prepared by Rao, G. Appa, Agricultural Meteorology, CAgM Report No. 24; CAgM-VIII Rapporteur on Drought Probability maps, WMO/TD – No. 207
- World Meteorological Organization, 1992. International Meteorological Vocabulary, WMO Report NO. 182, 2nd edn. WMO: Geneva; 784.
- World Meteorological Organization, 2005. Meteoworld (weather. Climate. Water), WMO, August 2005.

3.6.5 SPACIAL REMARKS

Besides its advantages, practical applications of SPI have the following limitations (Guttman, 1999):

- Long term data is needed to compute SPI. It is recommended to have at least 30 consecutive years of data but most stations, especially in developing countries, lack such long time series of data.
- SPI analysis has its strength in identifying temporal variation in precipitation at different locations with respect to available climatological values. There is, however, not much data available in Lao PDR for a robust spatial comparison, using SPI analysis, to identify drought prone areas.

- SPI does not take into account the surplus or deficit in precipitation in preceding seasons into its computation. In reality, precipitation in preceding seasons also has a large influence on current soil moisture content.
- Another limitation of SPI emerges from the standardization process of the index itself. Drought measured by SPI can occur with the same frequency at all locations when considered over a long time period.
- Misleadingly large positive or negative SPI values may result when the index is applied at short time steps to regions of low seasonal precipitation (Sonmez, 2005).

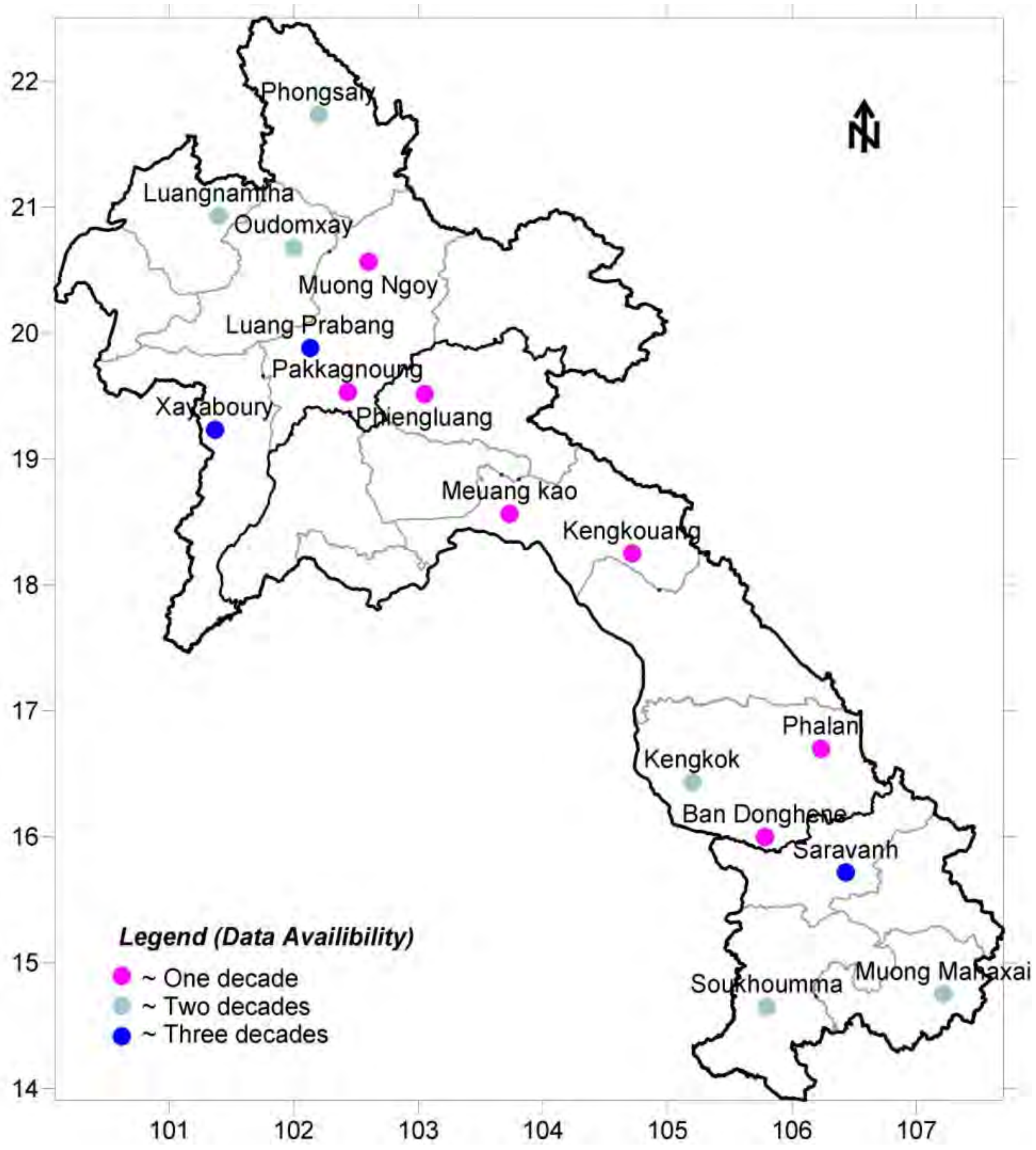


Figure 3.41 Geographical distributions and data availability of the stations used in the analysis

3.6.6 METHODOLOGY

SPI was chosen for this study because of its simplicity and because it is based only on precipitation data. SPI has many advantages over other drought indices, such as the Palmer approach, which requires more variables. The SPI was calculated from monthly precipitation records by first fitting in the gamma probability distribution function and then transforming the results into a normal distribution in such a way that the mean SPI is set to zero (McKee, 1993; Edwards, 1997). Figure 3.41 and Table 3.5 show the geographical distributions and data availability of the stations used in the analysis. The program used for the computation of SPI is **SPI_SL_6.exe** was developed by the National Drought Mitigation Center, USA. The program computed the SPI for up to six intervals of time (i.e. 1-, 2-, 3-, 4-, 6-, 12 month SPI). This temporal flexibility allowed the SPI to be useful in both long-term hydrological applications and short-term agriculture (Sirda, 2003). The negative and positive values of SPI stand for drought and wet conditions. The input file used was an ASCII text file containing 3 columns: Year, Month and Monthly Precipitation Value, in that order. The precipitation total which could not include decimals was shown in either inches or mm. The missing data was reported as -9900 and the output file had a .dat (or .txt or .spi etc.) extension.

Table 3.5 List of meteorological stations used for analysis

No	Site No	Region	Province	Station Name	Lat	Long	Alt.	Year Available
1	140506	Southern	Champassack	Soukhoumma	14.65	105.80	95	1993 – 2008
2	150602	Southern	Saravane	Saravanh	15.72	106.43	170	1981 - 2009
3	160504	Central	Savannakhet	Donghene	16.00	105.78	188	1999 - 2009
4	160505	Central	Savannakhet	Kengkok	16.43	105.20	126	1990 - 2008
5	160506	Central	Savannakhet	Phalan	16.70	106.23	197	1993 - 2008
6	170502	Southern	Attapeu	Muong Mahaxai	14.75	107.22	399	1991 - 2008
7	180307	Central	Borikhamxay	Meuang Kao	18.57	103.73	166	1999 - 2008
8	180405	Central	Borikhamxay	Kengkouang	18.25	104.72	430	1991 - 2009
9	190103	Northern	Xayaboury	Xayaboury	19.23	101.37	323	1980 - 2009
10	190202	Northern	Luang Prabang	Luang Prabang	19.88	102.13	293	1980 - 2009
11	190203	Northern	Luang Prabang	Pakkagnoung	19.53	102.43	190	1994 - 2008
12	190303	Central	Xiengkhuang	Phiengluang	19.52	103.05	1056	1996 - 2008
13	200101	Northern	Luangnamtha	Luangnamtha	20.93	101.40	600	1993 - 2009
14	200201	Northern	Luang Prabang	Muong Ngoy	20.57	102.60	386	1995 - 2008
15	200204	Northern	Oudomxay	Oudomxay	20.68	102.00	550	1991 - 2009
16	210201	Northern	Phongsaly	Phongsaly	21.73	102.20	637	1988 - 2009

The purpose of this analysis was to assign a single numeric value to precipitation which can then be compared across regions with different climates. Here, three categories of drought, (Table 3.5) based on McKee et al. (1993, 1995), were considered in the study for computation of the indices and used for analysis of drought hazard in Lao PDR (Table 3.6). The computation took into account the two main seasons, as well as the mainly rainy months of June to September and the annual season from April to March (Table 3.6.). April to March as the annual basis was chosen by taking into consideration the beginning of the wet season and end of the dry season. SPI values from -0.99 to 0.99 was considered as normal. The methodology for drought computation and its impact is presented as a flow chart in Figure 3.42.

Drought frequency was computed for climatological periods and drought variations were compared at different locations. Spatial and temporal variations of drought were investigated for different durations as shown in Table 3.6. The probability of drought occurrence was computed based on frequency distribution; expressed as a percentage with a value not exceeding 100%. The occurrences in varying drought categories were analyzed in different time steps of 1, 4, 6 and 12 months so as to compute the indices. The occurrence of moderate, severe, extreme and moderate to extreme droughts in different durations for each year were analyzed at each station. Drought occurrences were investigated based on the frequency of events for each drought category; based on duration and the total period of the study.

Table 3.6 Duration used for drought indices analysis

No	Duration	Corresponding months
1	Dry Season	October to March
2	Wet Season	April to September
3	Main Rainy Months	June, July, August and September
4	Annual	April to March

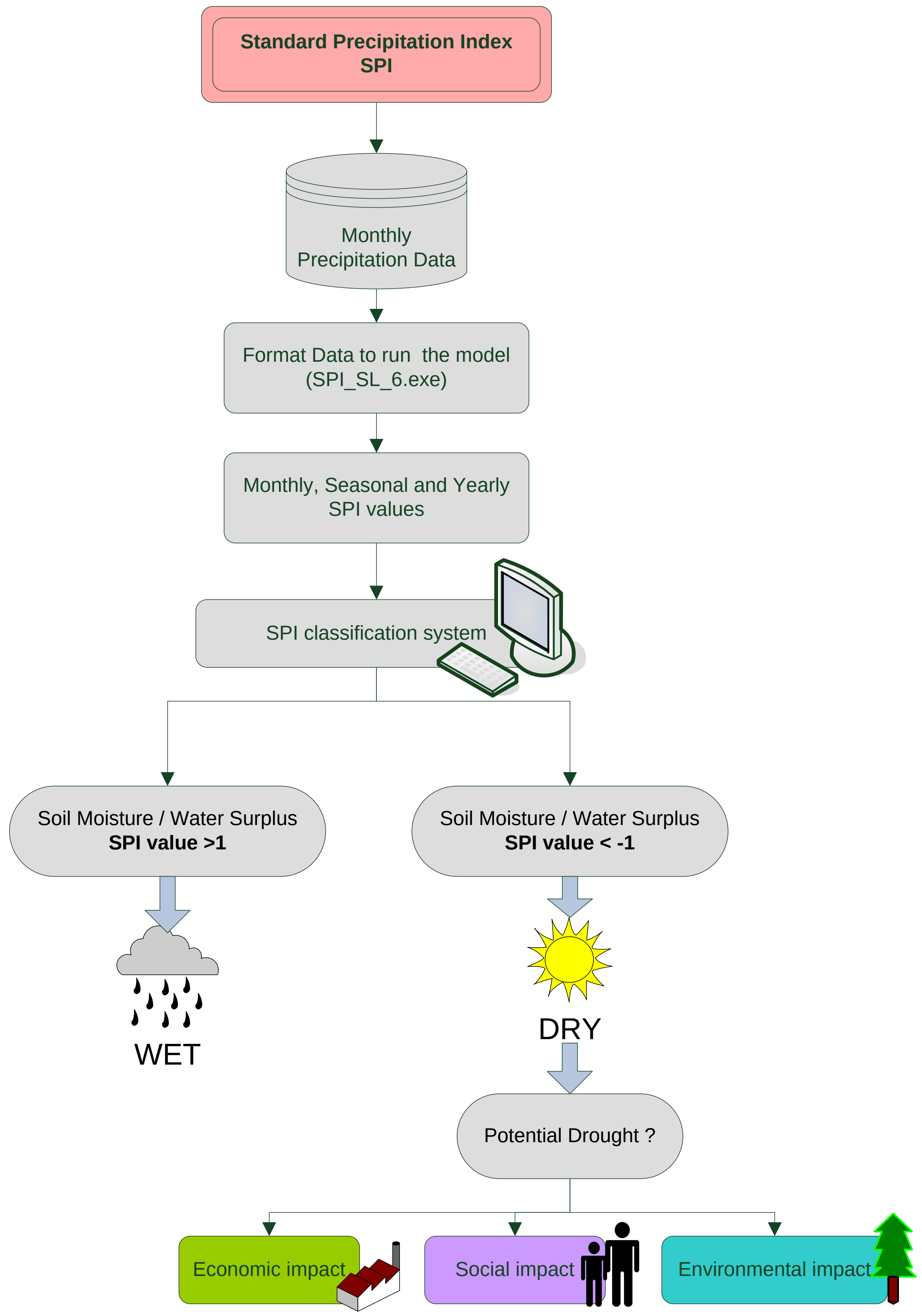
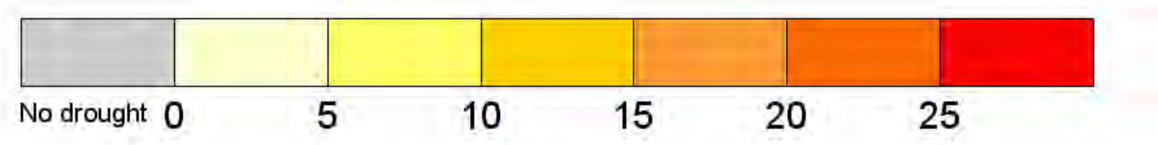


Figure 3.42 Methodology of drought index computation using SPI

3.6.7 HOW TO READ THE MAP

Drought susceptibility maps were prepared based on the probability of drought occurrence (moderate, severe, extreme, and moderate to extreme) in identified stations. The climatological drought susceptibility maps in different seasons are shown in terms of classification from low to high drought susceptible areas in four seasons. The maps in Figure 3.43 to Figure 3.46 show spatial distibution of several drought susceptibility classes in Lao PDR. Provincial boundaries are demarcated for detailed susceptibility in specific regions. The description of colors can be seen below. From the figure given, one can easily locate low to high susceptibility areas in the different seasons.



3.6.8 ANALYSIS OF DROUGHT HAZARD ASSESSMENT

Annual time series of drought occurrences of different categories and its aggregate for different durations is depicted in Figure 3.48 to Figure 3.51. Summary of drought years and the percentage of stations affected by droughts of different durations is presented in Table 3.7. It should be noted that the period is limited from 1993 (or 1994) to 2008; when data is available from most (at least 11 stations out of 16) of the stations. This is done to avoid disproportionate weighting of individual stations in the analysis when data is available from only a few stations.

Drought is observed in more than half (50%) of the stations for the 2005 dry season and in 1998 from the June to September period. Drought spread is always less than 50% in the wet season and the April to March period. Similarly, it is observed in many (25-50%) stations in 3-4 years for different durations, while it is observed in some (10-25%) stations in 1-4 years for different durations. The spread of drought is limited to only a few (<10%) stations in 3-5 years in different seasons.

Drought was not observed in any station in about one third of the year during the wet season and April to March. Drought was also not observed in any station in about one quarter and one fifth of the year from June to September and in the dry season. The likelihood of drought occurrence in one or more stations is highest in the dry season and least in the wet season.

Table 3.7 Summary of drought occurrence and its coverage

% of Stations	Dry Season	Wet Season	June- September	April–March (Annual)
None	2000, 2001, 2003	1996, 1999, 2000, 2002, 2004, 2005	1996, 2002, 2004, 2005	1997, 2000, 2001, 2003, 2005, 2006
< 10	1996, 1997, 2002, 2006, 2008	1994, 1997, 2001	1994, 1995, 1997, 1999, 2000, 2001	1995, 1996, 1998, 2002
10-25	1998, 2007	1995, 2003, 2007, 2008	2003, 2008	2008
25-50	1994, 1995, 1999, 2004	1993, 1998, 2006	1993, 2006, 2007	1994, 1999, 2004, 2007
>50	2005	Nil	1998	Nil

Table 3.8 Probability of drought occurrence (%) at different stations

Station	Dry Season			Wet Season			June-Sept.			April-March		
	MOD	SED	EXD	MOD	SED	EXD	MOD	SED	EXD	MOD	SED	EXD
Soukhoumma	7	13	0	0	13	0	6	13	0	0	13	0
Saravanh	4	4	4	7	11	0	15	0	4	12	8	0
Donghene	0	0	14	11	11	0	22	0	0	14	0	0
Kengkok	6	0	6	5	0	5	5	0	5	6	6	6
Phalan	9	18	0	7	7	0	21	0	0	18	0	0
Muong Mahaxai	12	0	0	6	0	6	11	0	6	0	0	6
Meuang kao	11	0	0	10	10	0	10	0	10	11	11	0
Kengkouang	17	8	0	0	7	7	7	0	7	0	9	9
Xayaboury	7	10	0	13	3	0	17	3	0	3	10	0
Luang Prabang	10	3	3	13	7	0	7	10	0	7	7	0
Pakkagnoung	14	0	7	13	0	0	13	0	0	14	0	0
Phiengluang	0	0	11	27	0	0	27	0	0	13	13	0
Luangnamtha	0	13	0	0	6	6	6	0	6	0	6	6
Muong Ngoy	8	0	0	7	0	0	14	0	0	8	0	0
Oudomxay	11	11	0	5	5	5	5	5	5	11	0	6
Phongsaly	10	5	0	9	5	5	14	0	5	10	10	0

Threshold rainfall for drought occurrence (corresponding to SPI equal to **minus one**) is also computed for all durations at each station (Table 3.9). In line with seasonal and regional distribution of rainfall, these thresholds are higher in regions/seasons of high rainfall and vice versa.

Table 3.9 Threshold rainfall values (mm) at different stations

No	Site No	Region	Province	Station Name	Dry Season	Wet Season	June-Sept.	April-March
1	140506	Southern	Champassack	Soukhoumma	95	1450	1195	1595
2	150602	Southern	Saravane	Saravanh	92	1490	1230	1635
3	160504 √	Central	Savannakhet	Donghene √	50	1275	855	1425
4	160505	Central	Savannakhet	Kengkok	70	1055	810	1245
5	160506	Central	Savannakhet	Phalan	39	996	740	1130
6	170502	Southern	Attapeu	Muong Mahaxai	86	2035	1710	2160
7	180307	Central	Borikhamxay	Meuang Kao	105	2535	2045	2660
8	180405	Central	Borikhamxay	Kengkouang	53	1535	1295	1580
9	190103	Northern	Xayaboury	Xayaboury	103	945	660	1115
10	190202	Northern	Luang Prabang	Luang Prabang	138	965	730	1153
11	190203	Northern	Luang Prabang	Pakkagnoung	50	1541	1225	1660
12	190303	Central	Xiengkhuang	Phiengluang	72	1665	904	1255
13	200101	Northern	Luangnamtha	Luangnamtha	160	947	710	1140
14	200201	Northern	Luang Prabang	Muong Ngoy	62	835	610	902
15	200204	Northern	Oudomxay	Oudomxay	132	1040	777	1220
16	210201	Northern	Phongsaly	Phongsaly	176	1090	830	1292

Note: √ Low confidence in the tabulated values as data is available only for a few years.

Empirically, low drought susceptible and high drought susceptible areas have been categorized as areas having 15% to 20 %, and more than 20% probabilities respectively, based on the analysis of probability of drought occurrence at various station. These areas are listed in Table 3.10.

Table 3.10 Moderate drought susceptible areas

Severity of Drought	Duration	Low Susceptibility	High Susceptibility
Moderate drought	Dry Season	Kengkouang and its surrounding	None
	Wet Season	Some parts of Luang Prabang, Huaphanh, Vientiane; Most parts of Xiengkhuang, Xaysomboun SR	Northwest parts of Xiengkhuang
	June-Sept	Most parts of Huaphanh, Xaysomboun SR; Few parts of Xiengkhuang, Luang Prabang, Eastern parts of Vientiane and central parts of Xayaboury; Most parts of Saravanh, Eastern tip of Khanuane and Sekong; Some parts of Savannakhet	Northeast parts of Xiengkhuang; A few parts of neighboring provinces; Southeast parts of Saravanh
	April-March	None	None
Severe drought	Dry Season	Phalan and its surrounding area; South East tip of Khamuane	None
	Wet Season	None	None
	June-Sept	None	None
	April-March	None	None
Extreme drought	Dry Season	None	None
	Wet Season	None	None
	June-Sept	None	None
	April-March	None	None
Moderate to Extreme Drought	Dry Season	All parts of Xayaboury, Oudomxay except surroundings of Oudomxay station; Most parts of Vientiane, Western half of Veintiane mun.; Western parts of Luang Prabang and Xaysomboun SR; Southern parts of Luangnamtha and Bokeo; South East parts of Huaphanh, Central portion of Borikhamxay,Southwest tip of Khamuane; Some parts of Savannakhet, Saravanh, Northern tip of Sekong; Most part of Champassack and Western corner of Attapeu	Surroundings of Oudomxay and Pakkagnoung; Most parts of Khamuane; Few parts of Borikhamxay and Savannakhet
	Wet Season	All parts of Xayaboury, Vientiane, Vientiane mun. and Huaphanh; Most parts of the Phongsaly, Oudomxay, Luang Prabang, Borikhamxay; Western parts of Xaysomboun SR; Northern portion of Southern region and southern portion of central region	All parts of Xiengkhuang; Most parts of Xaysomboun SR and neighboring parts of Borikhamxay; Surrounding area of Donghene station
	June-Sept	Most parts of Northern region except Luangnamtha and its surroundings, and Huaphanh; All parts of Vientiane, Vientiane mun.; Most parts of Borikhamxay, Eastern Half of Khamuane and central part of Savannakhet; Almost all parts of Southern region	All parts of Xiengkhuang; Most parts of Huaphanh and Xaysomboun SR and northern parts of Borikhamxay; Eastern parts of Savannakhet; Northern parts of Saravane
	April-March	Most parts of Huaphanh, Phongsaly; Few parts of Oudomxay; Most parts of central region except Xiengkhuang and its surrounding; Most of parts of Saravane; Few parts of Sekong and Champassack	Xiengkhuang and its surrounding

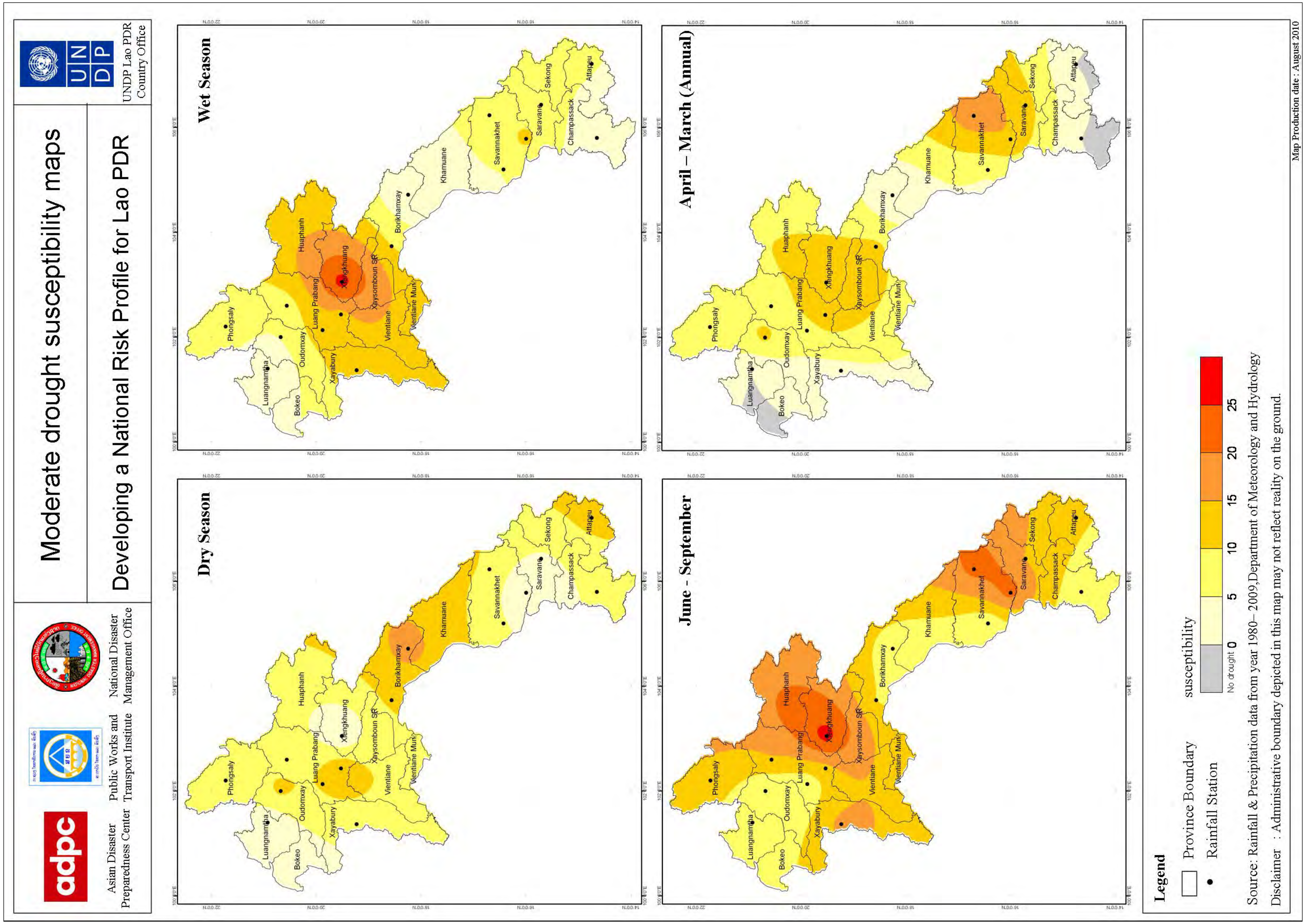


Figure 3.43 Moderate drought susceptibility maps for (a) Dry Season (b) Wet Season (c) June-Sept. and (d) April-March (Annual).

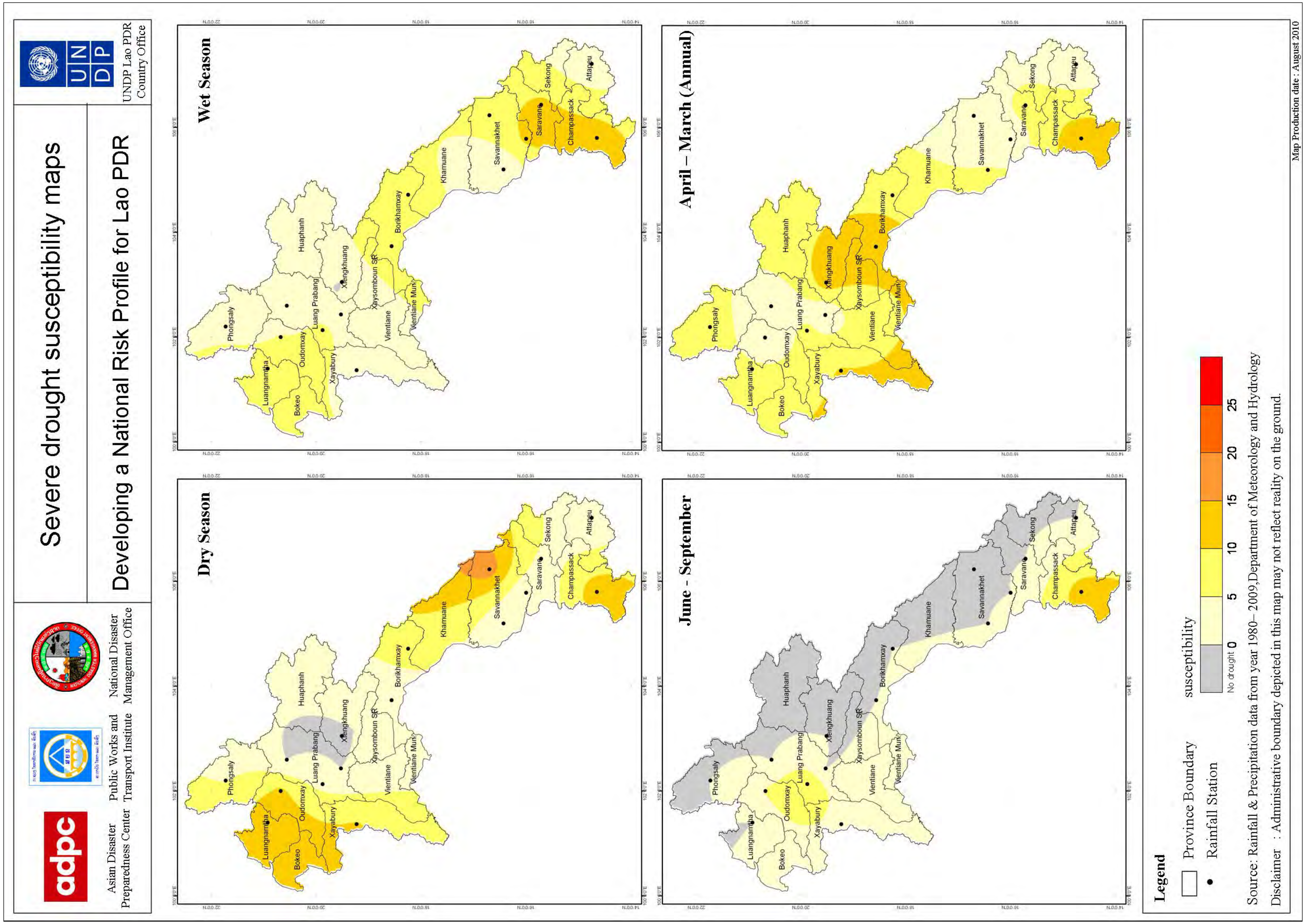


Figure 3.44 Severe drought susceptibility maps for (a) Dry Season (b) Wet Season (c) June-Sept. and (d) April-March (Annual).

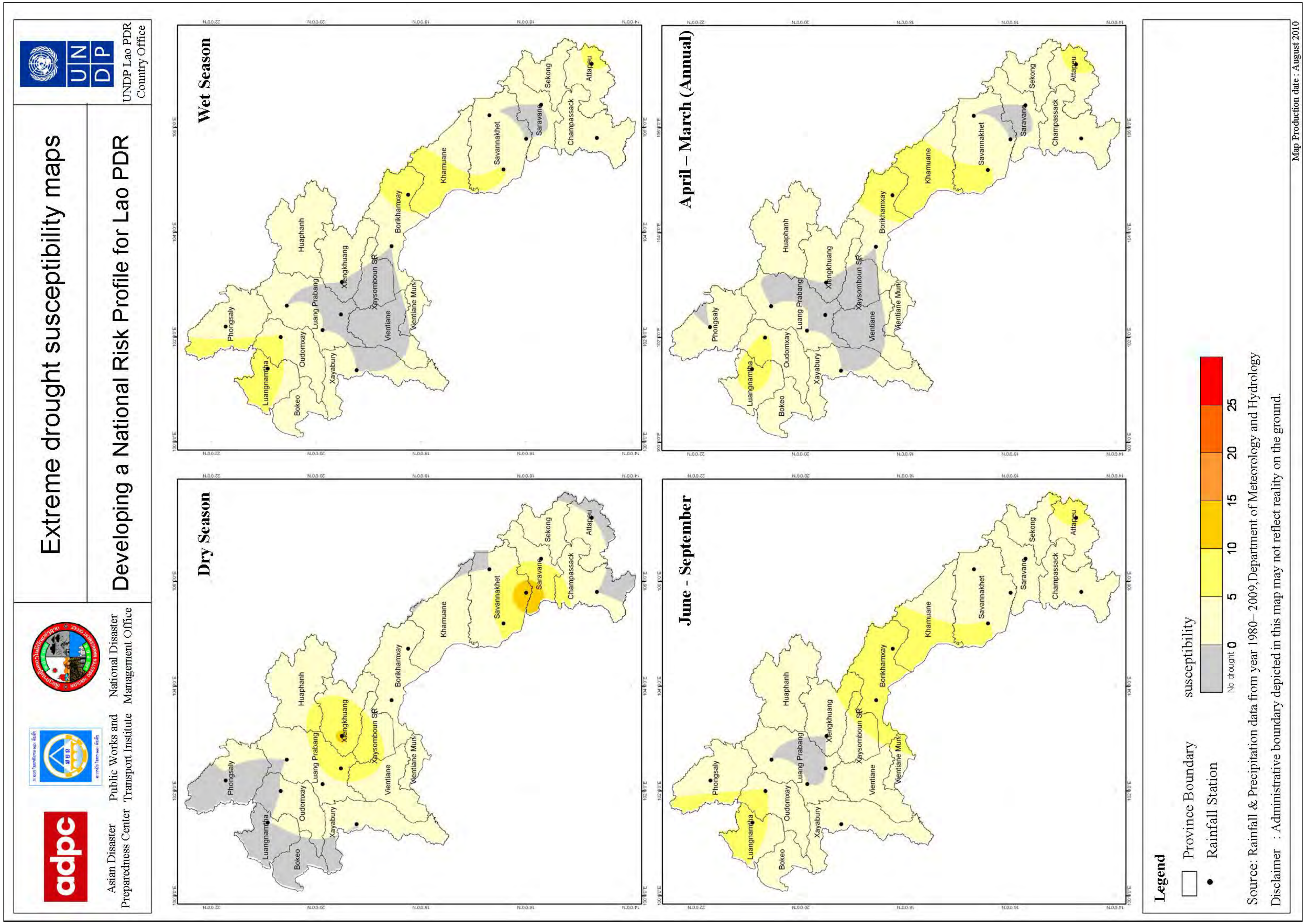


Figure 3.45 Extreme drought susceptibility maps for (a) Dry Season (b) Wet Season (c) June-Sept and (d) April-March (Annual).

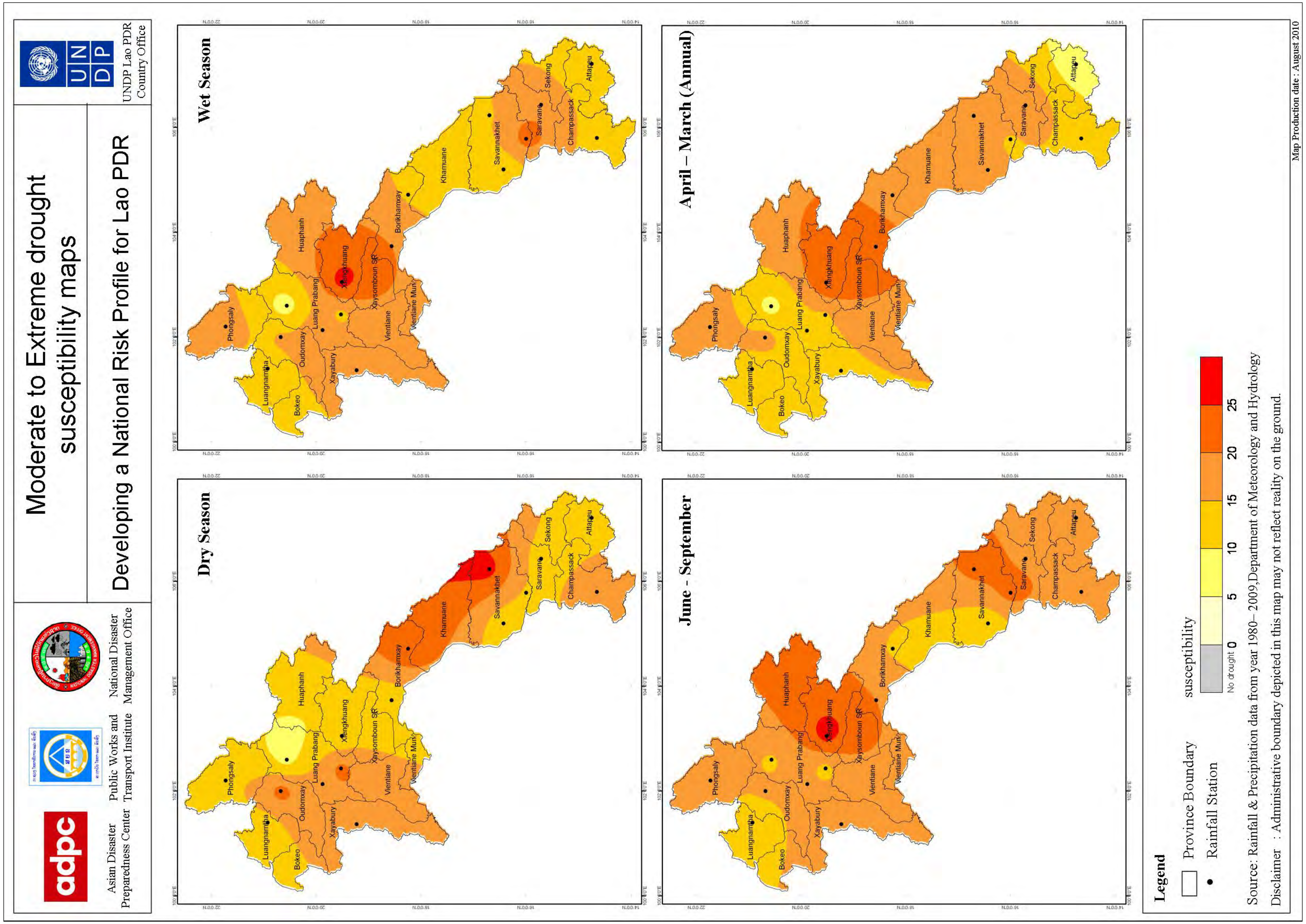


Figure 3.46 Moderate to extreme drought susceptibility maps for (a) Dry Season (b) Wet Season (c) June-Sept. and (d) April-March (Annual).

Three stations (Saravanh, Xayaboury and Luang Prabang) contain nearly three decades of precipitation data. Moderate to extreme decadal drought susceptibility maps for these three stations were prepared based on the probability of occurrence of droughts (Figure 3.47(a) and (b)). Decadal variation of probability of occurrence of droughts in different decades in each station and amongst the stations can be compared from these figures. As per the empirical definition of low and high drought susceptibility (defined above) each station has suffered one high susceptible drought in the wet season either in the first or second decade. A high susceptible drought has occurred only once at Xaboury in the first decade in the dry season.

In Saravanh, drought susceptibility has changed from below low susceptible class in last the two decades to high susceptible class in the first decade during the dry wet season. Similarly in Luang Prabrang, drought susceptibility has gradually decreased from high susceptibility to below low susceptibility during the wet season. On the contrary, drought susceptibility in the dry season in Luang Prabrang has increased to low the susceptible category. In Xayaboury, drought susceptibility was observed to vary randomly over the decades during the two seasons, lacking a clear signal.

(a) (b)

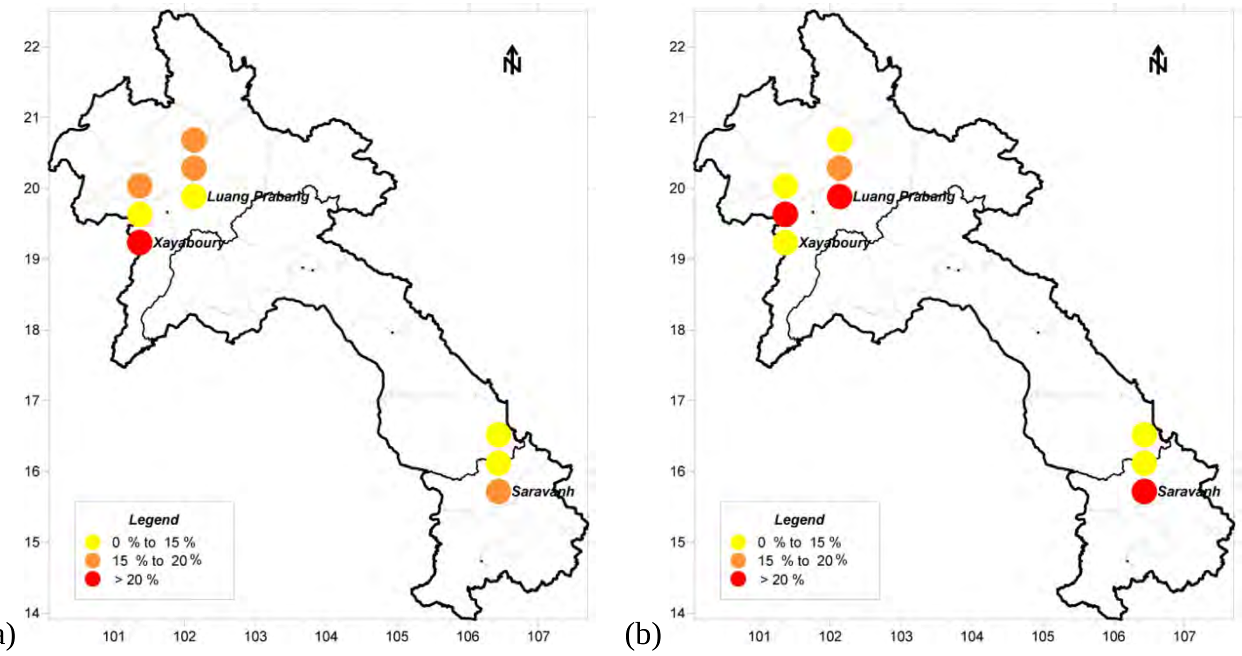


Figure 3.47 Decadal variation of moderate to extreme (decadal) drought susceptibility maps for three stations in (a) Dry Season and (b) Wet Season
(The lower, middle and upper circles in each station corresponds to the 1st (1980-1989), 2nd (1990-1999) and last (2000-2009) decades respectively)

Table 3.11 Summary of drought occurrence and its coverage

% of Stations	Dry Season	Wet Season	June- September	April – March (Annual)
None	2000, 2001, 2003	1996, 1999, 2000, 2002, 2004, 2005	1996, 2002, 2004, 2005	1997, 2000, 2001, 2003, 2005, 2006
< 10	1996, 1997, 2002, 2006, 2008	1994, 1997, 2001	1994, 1995, 1997, 1999, 2000, 2001	1995, 1996, 1998, 2002
10-25	1998, 2007	1995, 2003, 2007, 2008	2003, 2008	2008
25-50	1994, 1995, 1999, 2004	1993, 1998, 2006	1993, 2006, 2007	1994, 1999, 2004, 2007
>50	2005	Nil	1998	Nil

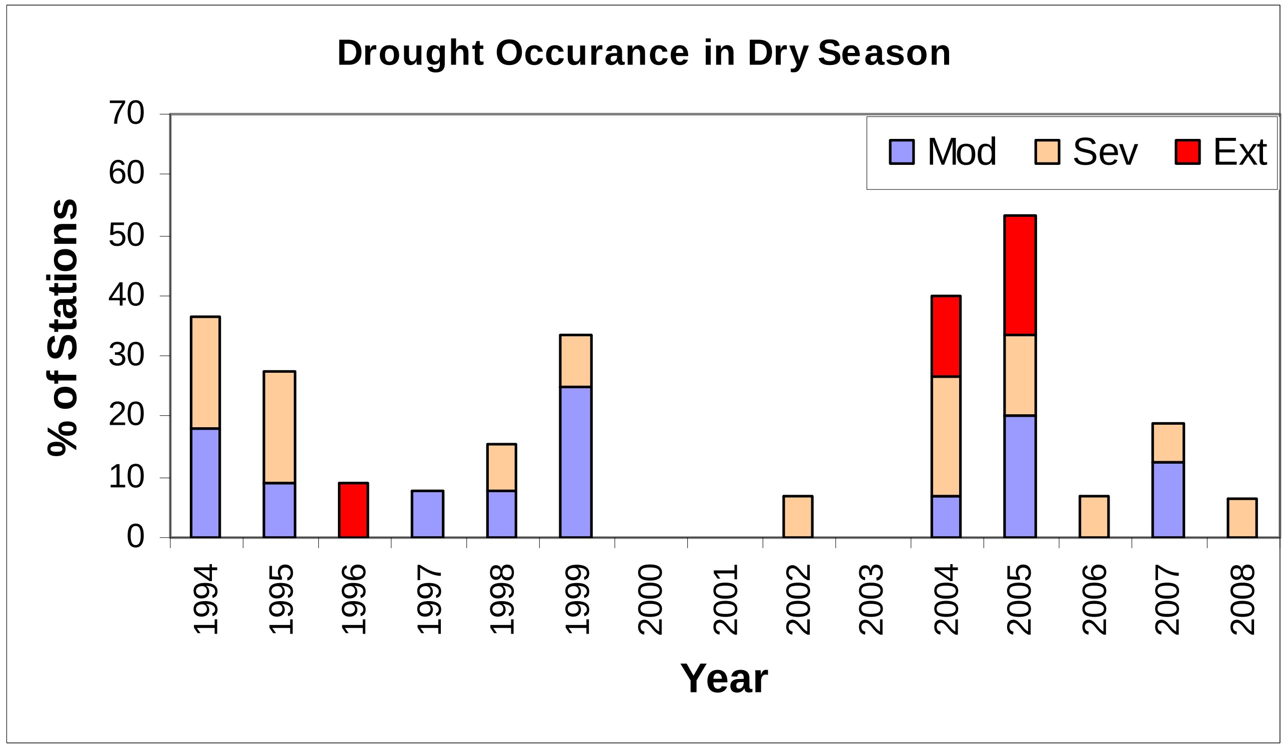


Figure 3.48 Drought occurrence in the dry season

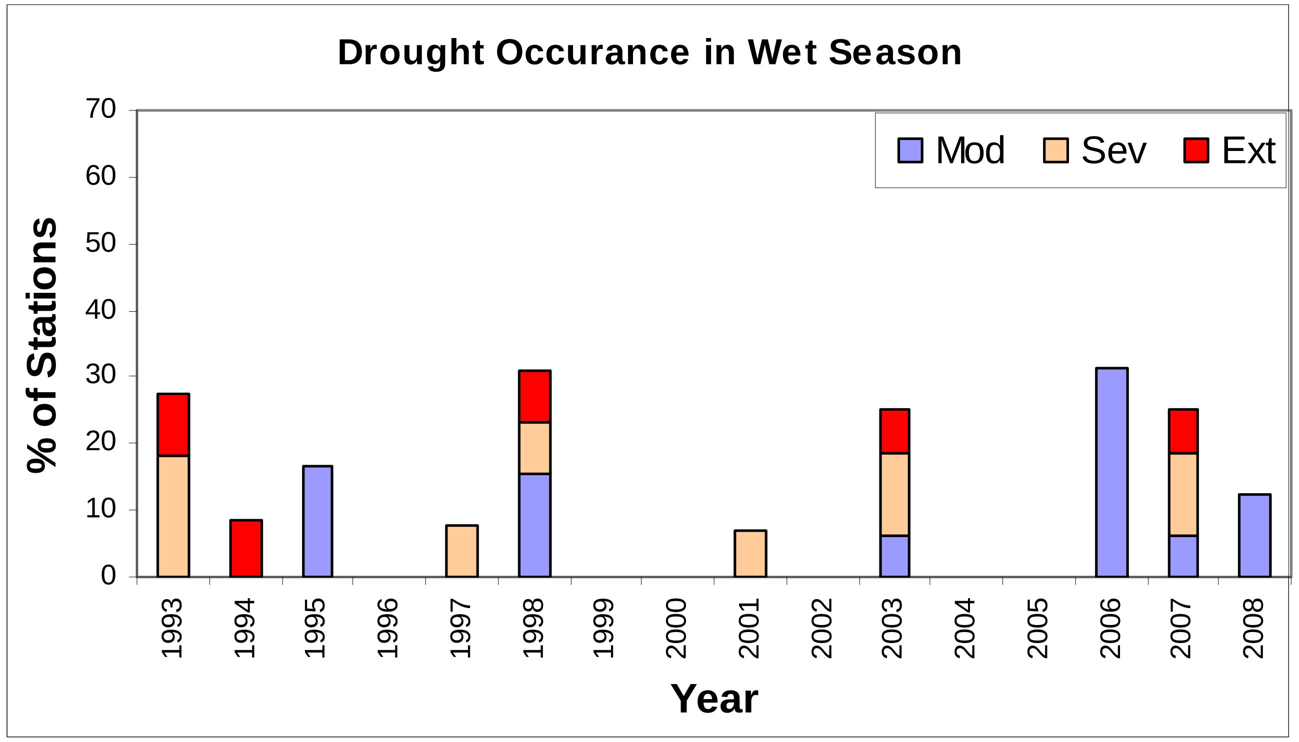


Figure 3.49 Drought occurrence in the wet season

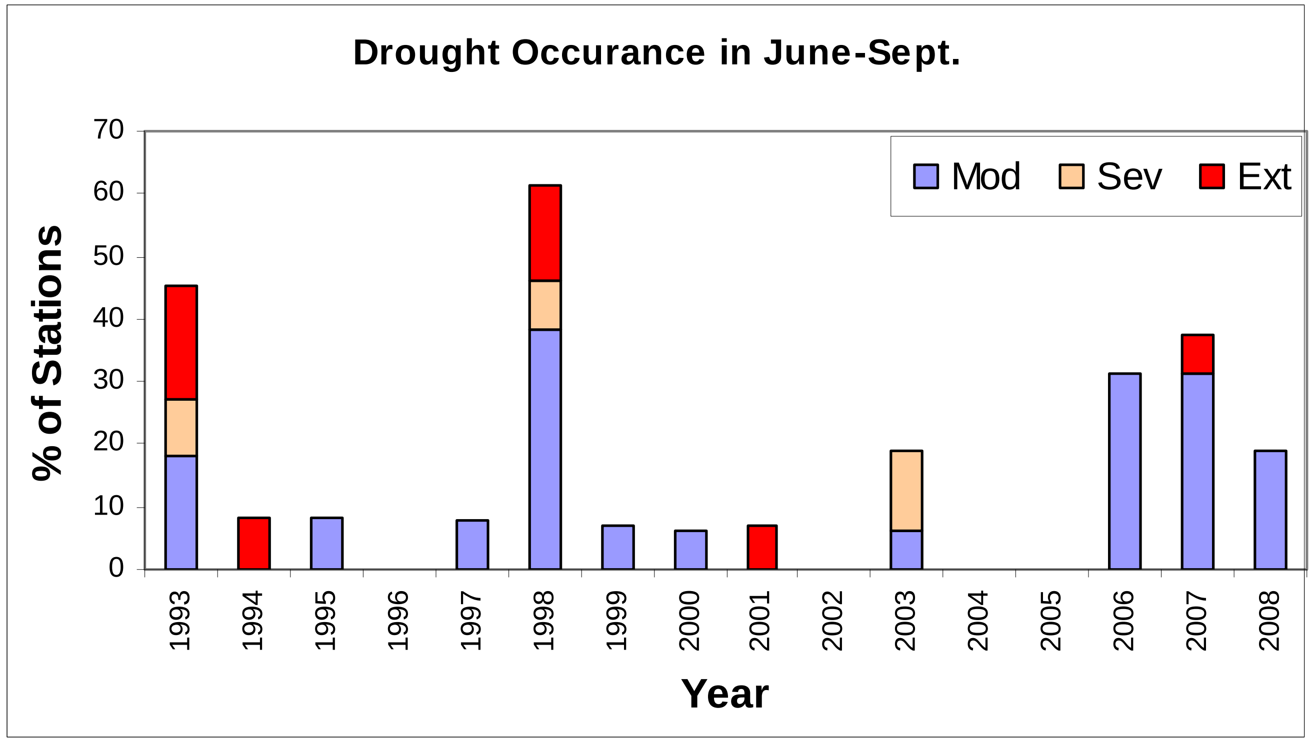


Figure 3.50 Drought occurrence in June to September

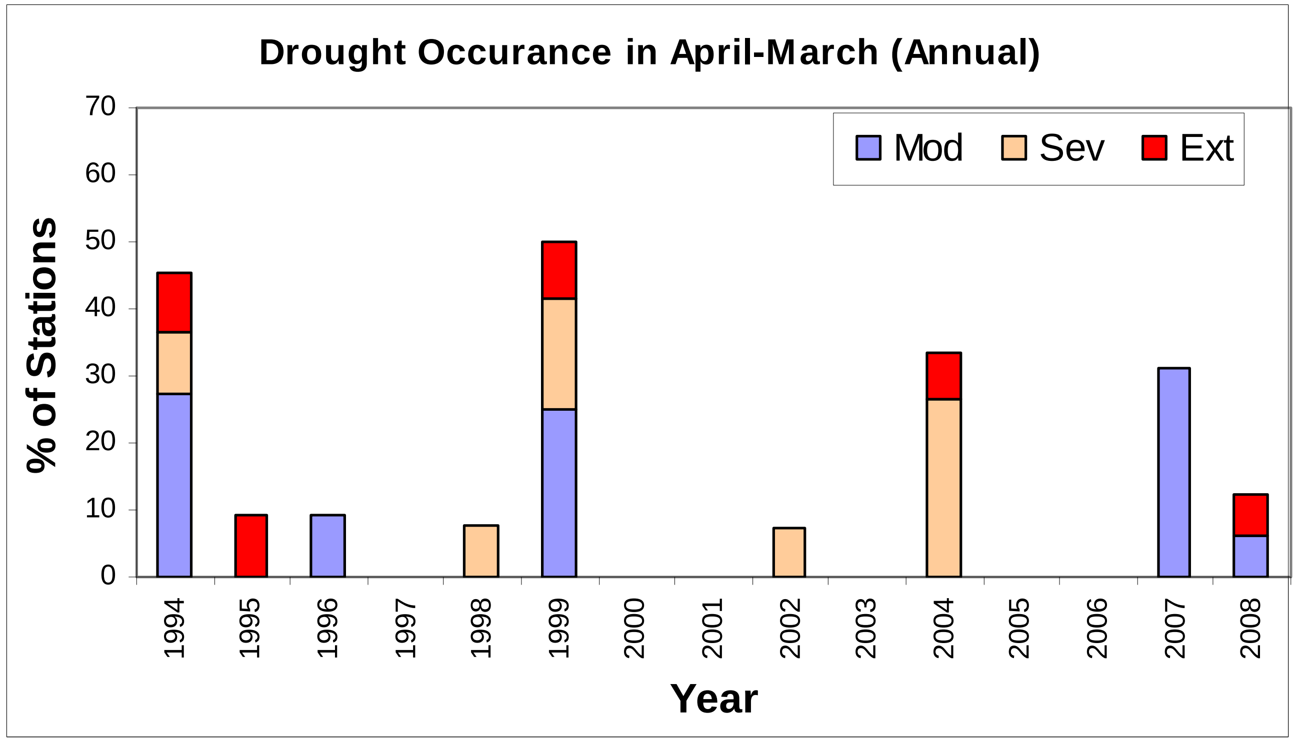


Figure 3.51 Drought occurrence in April to March (Annual)

3.6.9 CONCLUSION AND RECOMMENDATIONS

SPI was used for drought analysis at different time scales. It is found that drought of all categories occur in Lao PDR in all four durations. Moderate drought frequently occurs in all the durations but severe and extreme droughts are less common except for severe droughts in the dry season where it has occurred many times. Drought was relatively more frequent in first and third 5-year periods of analysis, with a lull in between.

Probability of occurrence of drought of any category is found to be highest (27%) at Phalan in the dry season. Probability of drought occurrences is also highest (25-27%) at Phiengluang for the other three durations. It should be noted that both Phalan and Phiengluang stations contain only about one decade of data. Because of data paucity in coverage and the large variability in data availability amongst stations, it was difficult to make conclusive statements on drought-prone area..

Rainfall thresholds of different locations and in different seasons/duration provide quantitative benchmarks to evaluate temporal and regional variations of precipitation in near real time basis. Appropriate adaptive/mitigation measures could be taken, based on this information. This might also provide valuable insight to planners and decision makers in prioritizing the areas for development of irrigation projects, managing water resources and designing appropriate crop diversification schemes for different regions/seasons.

Finally, the output products of this study provide an essential step towards addressing the issue of drought vulnerability in the country and can be used as a guide for drought management strategies for mitigation purposes. Identifying regional vulnerabilities can lead to adjustment in practices in water-dependent sectors and can help decision makers to take drought into account from a hazard perspective and include the concept of drought vulnerability into natural resource planning.

Following recommendations are prescribed based on the present study:

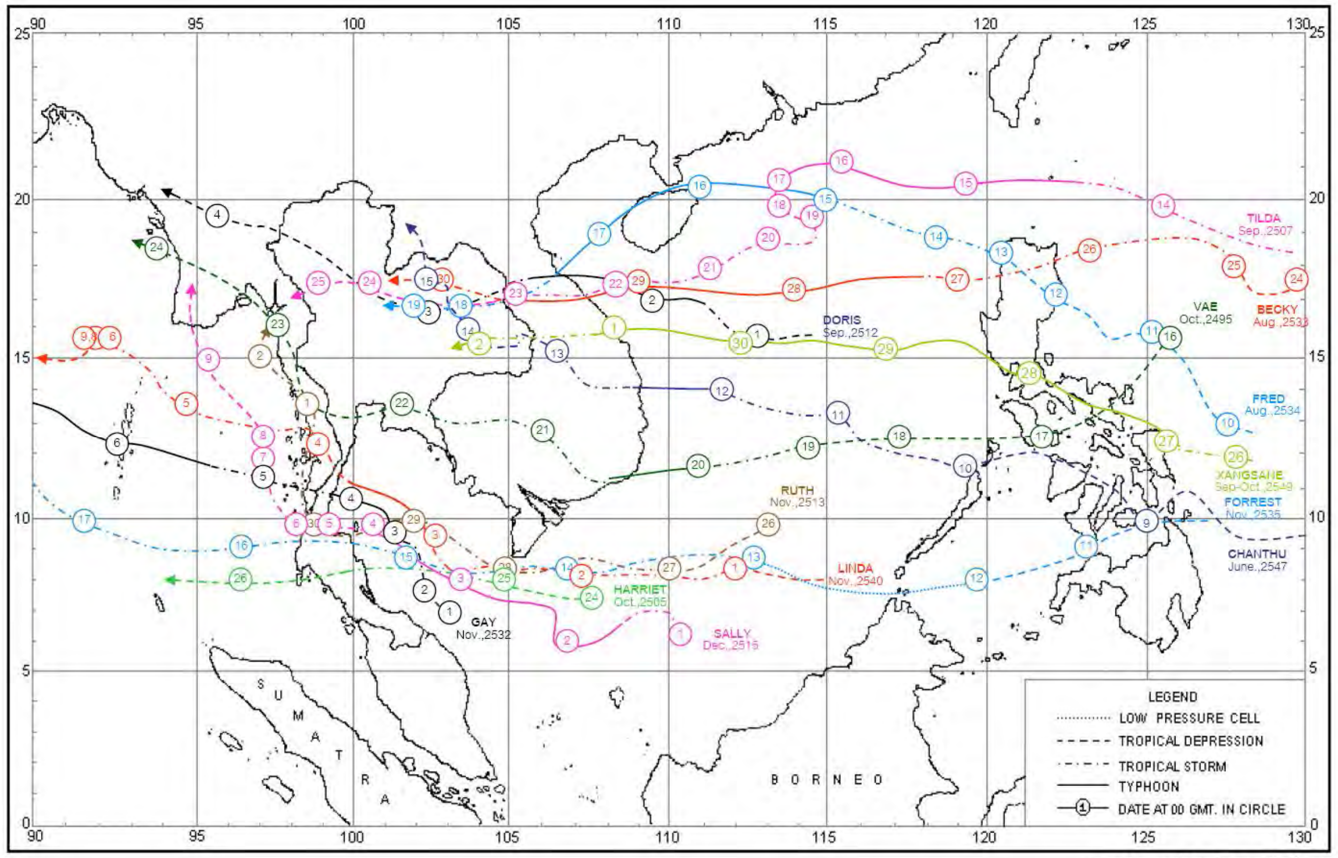
- Importance should be given to improve the quantity and quality of climatic data so as to enhance the quality of drought hazard assessments of Lao PDR.
- Priority should be given to establish stations in data sparse regions.. Special, attention should be given to northern Lao PDR.
- Emphasis should be placed on installing equipment that measures water holding capacity and wilting point (soil properties) of different types of soils in Lao PDR. This can then calculate SMI (Soil Moisture Index) simultaneously with SPI.
- Study on wet and dry spells of one week, two weeks or three weeks and so on should be carried out to monitor agricultural drought.
- There is a need to develop Meteorological, Agricultural and Hydrological drought declaration criteria for Lao PDR.
- The study of drought in Lao PDR with remote sensing data should be promoted.
- As more data becomes available, drought susceptibility maps and threshold rainfall for drought should be upgraded. Ideally, at least 30 years of continuous, reliable and common datasets for each province is needed to have better analysis and assessment of drought hazard from which drought susceptible areas of Lao PDR could be identified more accurately.

3.7 STORM HAZARD ASSESSMENT

3.7.1 BACKGROUND

A storm is any disturbed state of an astronomical body's atmosphere, especially affecting its surface, and strongly implying severe weather (en.wikipedia.org/wiki/Storm). Based on past history, the country of Lao PDR has witnessed several storms from tropical depressions (0 – 62 km/hr) to very strong storm s(category 3 which has its velocity of 178 – 209 km/hr). The storm tracks of past events from 1951 to 2006 are shown in Figure 3.52.

The most recent storm which hit the country was Tropical Storm Ketsana which hit southern Lao PDR on 29 September 2009. The storm brought heavy rains and strong winds, causing heavy flooding in the provinces of Xekong, Attepeu, Savannakhet, Champassak and Saravan. Houses, crops, roads and other infrastructure were severely damaged by the rains.



กลุ่มภูมิอากาศ สำนักพัฒนาอุตุนิยมวิทยา

Figure 3.52 Storm tracks of past events from 1951 – 2006 (Source: (TMD, 2006))

3.7.2 MAP CONTENT

The current storm track and expected return period maps were developed based on data available from a storm/typhoon- related international agency called the Joint Typhoon Warning Center (JTWC), USA. The data were converted and classified into World Meteorological Organization (WMO) scale. The map shows the distribution of intensity throughout the country. The maps were prepared for 10, 20, 30 and 50 years return period. The storm track map from year 1979 - 2009 is shown in Figure 3.53.

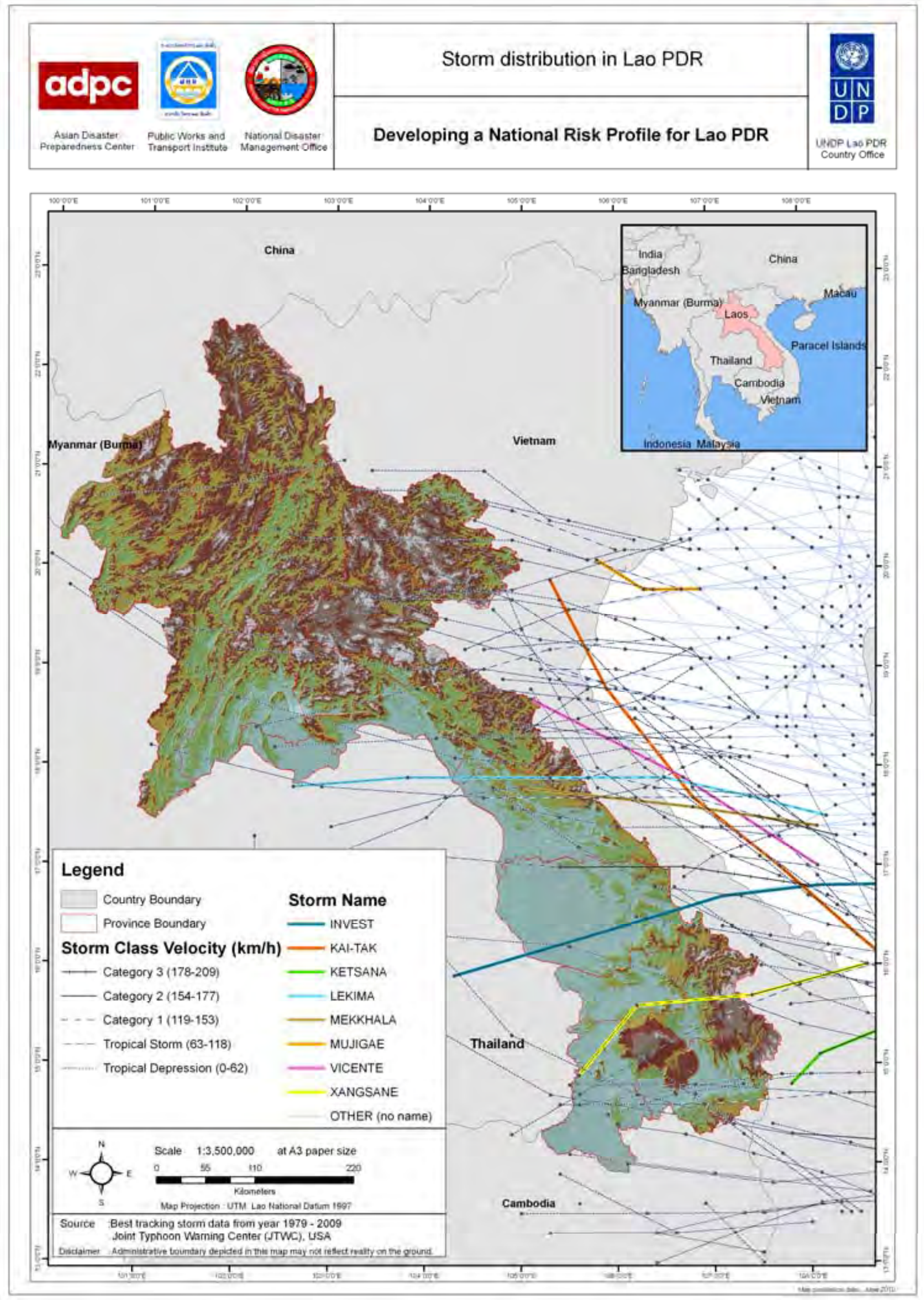


Figure 3.53 Storm tracks of past events in Lo PDR from 1979 – 2009

3.7.3 APPLICATION OF STORM MAP IN DISASTER RISK MANAGEMENT

Storm maps were developed on a national scale for Lao PDR. Storm-prone areas were delineated at provincial level based on the return period of past events. The storm maps were developed for several purposes:

- Storm maps will be helpful for physical and infrastructural development in the country. The map will help policy makers and decision makers to understand the severity of potential storms and take necessary action to sustain the development through the introduction of necessary programs and measures.
- All the map results will be useful for the planning and design department to make decisions. These maps could provide a basis for the government to predict storms and estimate storm-related disaster damage.
- Education, health, housing, lifelines and transportation sectors need special attention for storm safety. The storm zones will provide understanding about expected performance of structures during storms and necessary measures to protect these structures.
- The zones will further help the local urban government to introduce and enforce building bylaws and building codes to protect urban infrastructure.
- The map will help national and international NGOs to prioritize DRR strategies.

3.7.4 DATA SOURCES

The current storm track and expected return period maps were developed based on data available from a storm/typhoon- related international agency called the Joint Typhoon Warning Center (JTWC), USA. Additional efforts were made to collect the data from focal departments and established authentic sources. The parameters were classified into the following categories with their sources:

- Main data source for the storm tracking map is from the Joint Typhoon Warning Center (JTWC, USA) (http://www.usno.navy.mil/NOOC/nmfc-ph/RSS/jtwc/best_tracks/wpindex.html).
- TMD, 2006, Storm and typhoon from year 1950-2006 in Thailand, Thai Meteorological Department, Thailand 2006.

3.7.5 METHODOLOGY

The present storm track map for Lao PDR was developed based on the best storm track data provided by JTWC (JTWC, 2010). The World Meteorological Organization (WMO) scale for storm was used to develop the expected return periods maps. Storm in the country of Lao PDR is classified into four storm categories: category 2(154 – 177 km/hr), Category 1 (119 – 153 km/hr), Tropical Storm (63 – 118 km/hr) and Tropical Depression (0-62 km/hr). The methodology used to develop the storm maps of Lao PDR is shown in Figure 3.54.

The definition of sustained winds recommended by the World Meteorological Organization (WMO) and used by most weather agencies including DMH of Lao PDR is that of a 10-minute average at a height of 10 m (33 ft). However, as the Joint Typhoon Warning Center, define sustained winds based on 1-minute average speed, and are also measured 10 m (33 ft) above the surface, therefore to convert the JTWC into WMO, a one-minute wind speed from a tropical cyclone has been converted to a ten minute wind speed, by multiplying the 1 minute speed with 0.88.

The storm tracking map for Lao PDR was developed by converting the points downloaded from the JTWC website into polylines. JTWC provided the best storm track data for 30 years (from 1979 to 2009). Attributes of the track data, such as velocity, name and type of storm, were assigned using GIS tools, for storm tracking map development. The return period maps of storms in Lao PDR were developed based on the 30 years past event by generating a 100 x 100 km grid. The overlaying of the storm points and extraction of the maximum velocity for each grid was done to calculate the return period for the expected storm. The return values of wind velocity for storms of 30 years from 1979 to 2009 were estimated based on Gumbel distribution to come up with the expected storm return period maps. The storm return period map results are shown in Figure 3.57.

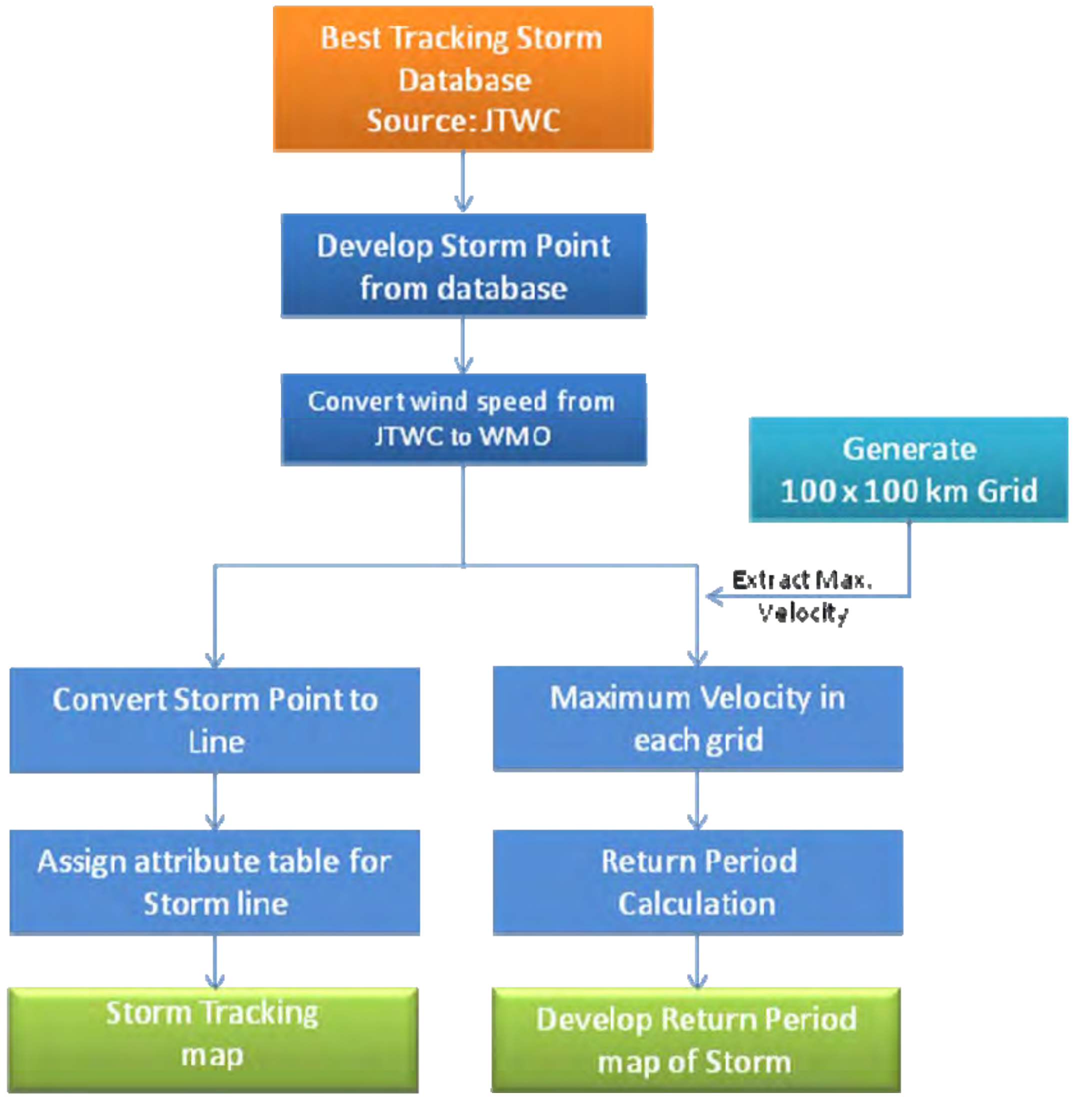


Figure 3.54 Flowchart showing the methodology for storms mapping

3.7.6 HOW TO READ THE MAP

There are two maps which show the storm track and expected return period of storms.The storm track map shows spatial distibution of several storms which hit Lao PDR from 1979 to 2009. The storm return period map consists of 10, 20, 30 and 50 years return period. Provincial boundaries were demarcated for detailed susceptibility in specific regions. Descriptions of the colors are shown in Figure 3.55

Category	Wind speed mph (km/h)	Storm surge ft (m)
Five	≥ 156 (≥ 250)	> 18 (> 5.5)
Four	131-155 (210-249)	13-18 (4.0-5.5)
Three	111-130 (178-209)	9-12 (2.7-3.7)
Two	96-110 (154-177)	6-8 (1.8-2.4)
One	74-95 (119-153)	4-5 (1.2-1.5)
Additional classifications		
Tropical storm	39-73 (36-117)	0-3 (0-0.9)
Tropical depression	0-38 (0-62)	0 (0)

Figure 3.55 WMO Scale adopted from Saffir-Simpson Hurricane

3.7.7 ANALYSIS OF HAZARD ASSESSMENT

The storm return period maps show areas affected by expected storms. These maps were overlaid with a provincial map. Results showed area and the type of storm based on wind velocity covered in respective provinces. For analysis purposes, the four storm return period maps and area covered in various provinces were worked out.

For 10 years return period, there is a 10% of probability that some areas of Khammouane province will be hit by a storm of class 1 (119-153 km/hr). Figure 3.56A. shows the spatial distribution of the area which has a 10% probability of being hit by a certain type of storm within a 10 year return period. The graph shows area percentage of each province in Lao PDR which has a 10% of probability of being hit by a tropical depression (< 62 km/hr), tropical storm (63 -118 km/hr) and class 1 (119-153 km/hr) storm.

Within a 20 year return period, Khammouane province is still the most prone province in the country of Lao PDR. There is a 5% probability that some areas of Khammouane province will be hit by a tropical storm (63 -118 km/hr) , and storm of class 1 (119-153 km/hr). Figure 3.56B shows that within a 20 year return period, most of Lao PDR's provinces are prone to storms categorized as tropical depression and tropical storm. These two types of storm are considered as the lowest class in term of their wind velocity.

Within a 30 year return period, three types of storms are expected to hit some area of Lao PDR. Those are categorized as tropical depression, tropical storm, and storm of class 1. Areas in Khammouane province which falls under the zone affected by storm class 1 is increasing from 35% in a 20 year return period to 45% (Figure 3.56C). The number of provinces which fall under the zone affected by storm class 1 (119 -153 km/hr) is also increased although the probability of being affected is only small (3.3 %). Some areas in Khammouane and a small part of Savannakhet province are located in this class 1 storm zone.

Within a 50 year return period, a damaging storm of class 2 (154 – 177 km/hr) are expected to hit some areas in the Khammouane province. The probability of this type of storm happening, as shown in Figure 3.56D, is 8%. It can concluded from Figure 3.56 (A,B,C,D) that Khammouanne province is the most prone province in the country of Lao PDR. Within a 50 years return period of storm, four types of storm are likely expected to hit Khammouane province.

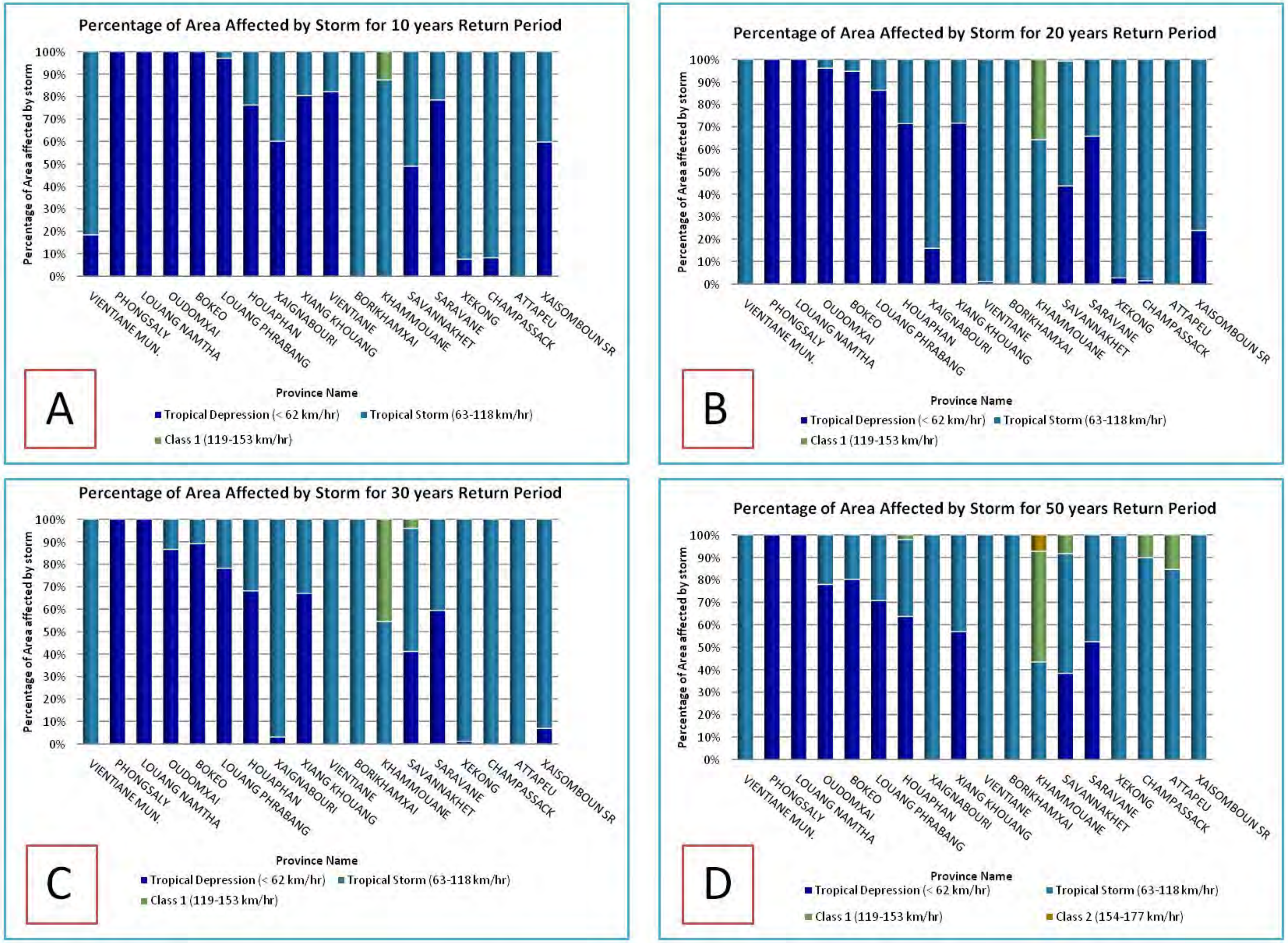


Figure 3.56 Showing Percentage of Area Affected by Storm in different return periods A)10 years return period B) 20 years return period C) 30 years return period and D) 50 years return period

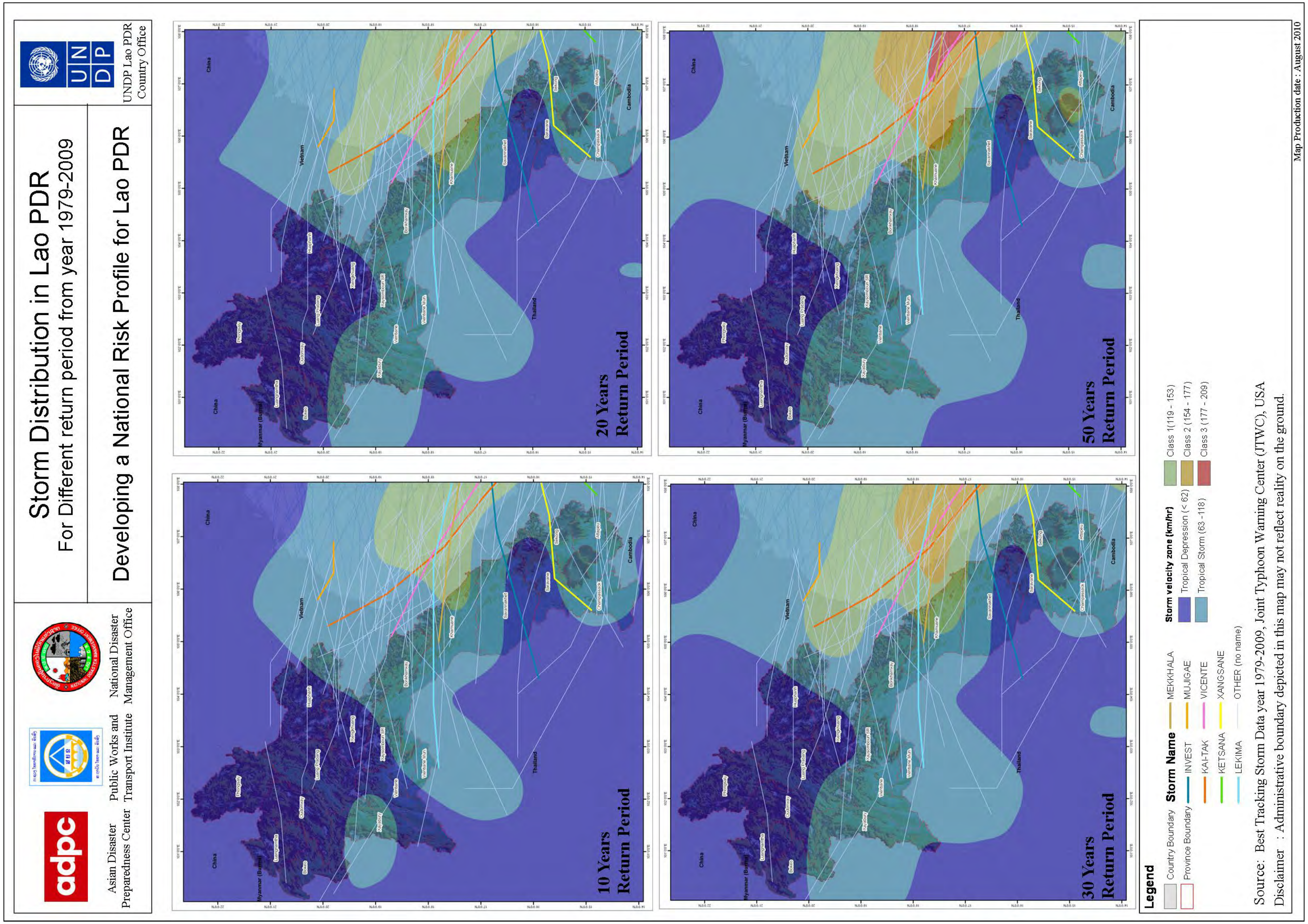


Figure 3.57 Storm distribution in Lao PDR for Different return periods from 1979-2009

3.7.8 RECOMMENDATIONS

- In order to get a clearer and more detailed picture of the storm hazard assessment in Lao PDR, the networking system of storm monitoring and observation which include neighboring countries such as Thailand, Cambodia, Vietnam and China need to be integrated and utilized along with these hazard assessments.
- It is also recommended that detailed studies and mapping on specific locations where the storm are most likely to take place, are carried out, based on the results and methodology mentioned above

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3.8 MULTI-HAZARD ASSESSMENT

3.8.1 BACKGROUND

The multi-hazard assessment was carried out for seven types of hazards. Each of the hazards is discussed in detail in chapter three. The study in earlier sections reveals that Lao PDR is prone to various kinds of hazards including floods, landslides, earthquakes, droughts, epidemics, UXOs and storms. There is a serious need to diagnose all possible hazards in the country and develop strategies to mitigate the negative impacts of these multiple hazards. The idea behind the multi-hazard assessment (Multi-HA) is to identify and compare the severity of various hydro-meteorological, geological and health hazards, as well as understand their distribution in the country. By understanding their causative factors and identifying the regions and districts affected, mitigation interventions can be carried out that are appropriate and region-specific.

3.8.2 APPLICATION OF MULTI-HAZARD ASSESSMENT (MULTI-HA)

- Multi-HA provides necessary background for policy development, awareness and knowledge about DRR.
- Multi-HA provides better understanding about correlation and linkages between various hazards and their causative factors.
- The Multi-HA has been carried out at two scales including provincial and district level. The provincial level hazard assessment is an important tool for national focal agencies and departments involved in DRR interventions. The district level Multi-HA will help provincial governments to introduce appropriate DRR programs and projects.
- The assessment facilitates better cooperation between various agencies working in the area of hazard mitigation and management. For example, NDMO manages disasters overall, but the Department of Mines and Geology, Department of Meteorology and Hydrology, Department of Road and many other agencies work specifically with geological and hydro-meteorological hazards. The Multi-HA provides a platform for communication, cooperation and collaboration towards creating a disaster resilient society.

3.8.3 SCENARIOS AND CRITERIA FOR MULTI HAZARD ASSESSMENT

The Multi-HA was developed based on a certain scenario comprising of criteria selected from the seven hazards in Lao PDR which have been discussed earlier. The scenario and its selected criteria are summarized in Table 3.12. Based on the criteria stated below, a scenario was created.

Table 3.12 Criteria for multi-hazards assessment scenario

Type of Hazard	Criteria to be considered
1. Flood	100 years return period flood where the area is categorized as inundated area with water level > 2 m
2. Landslide	For area categorized as "Very high and High" and > 10 % of its area falling either under “very high” or “high” class
3. Earthquake	Categorized as "Degree VII”at Modified Mercali Intensity Scale
4. Drought	Dry season: Moderate to extreme drought susceptibility where its area falls under 20% or above of probability of having drought
5. Epidemic	Increased number of cases shown in the trend
6. UXO	UXO density is above 1/sq km
7. Storm	50 years return period storm where the area is categorized as class 2 and class 3

3.8.4 METHODOLOGY FOR MULTI HAZARD ASSESSMENT

Multi-hazard scenario maps were done for the seven hazards with selected criteria as mentioned in Table 3.12. Overlaying and weighing were done using GIS tools. The method for the multi-hazard scenario development is presented in Figure 3.58 and the results are presented in Table 3.13.

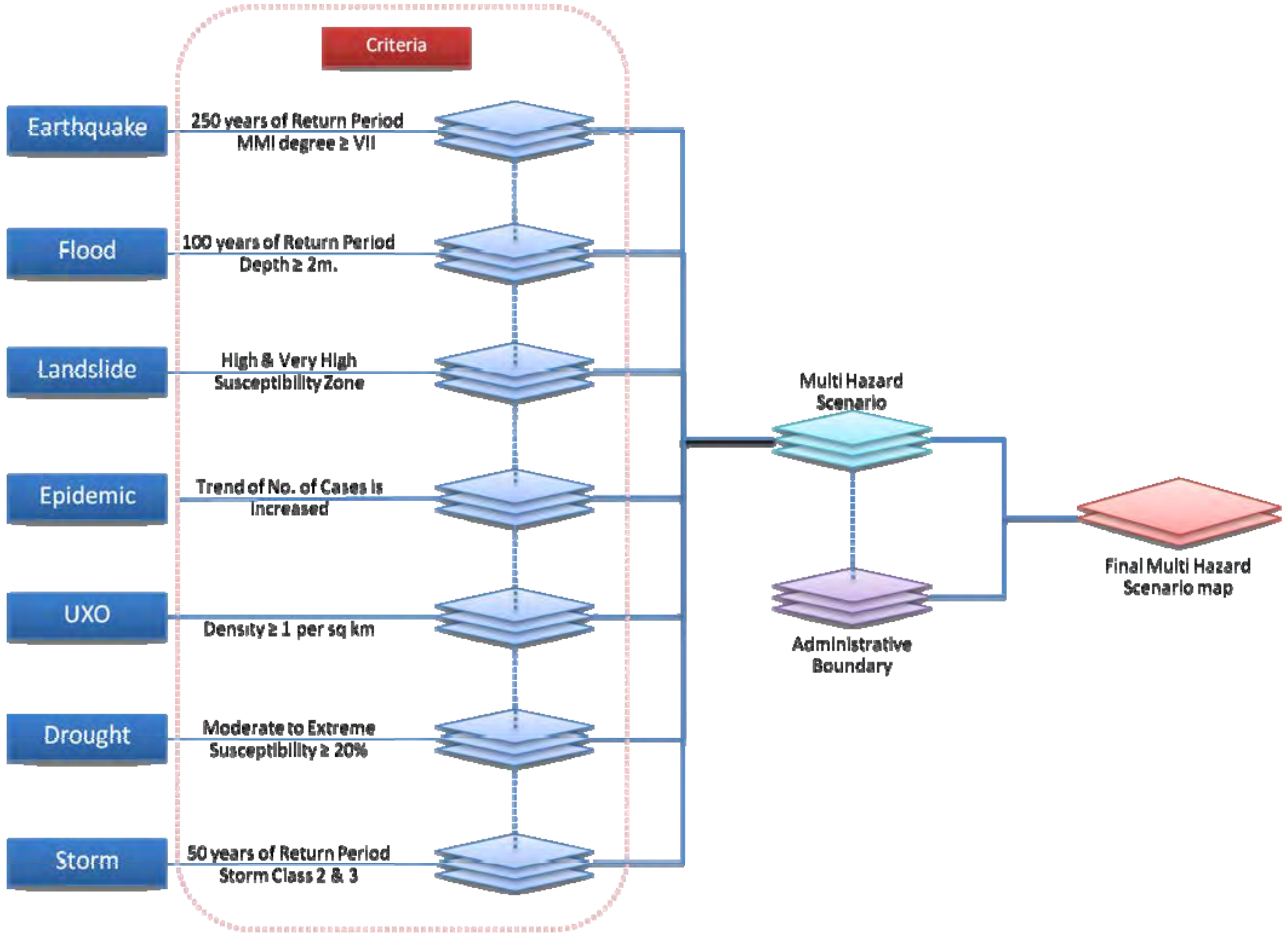

Figure 3.58 Method for multi-hazard assessment (Scenario-based)

3.8.5 ANALYSIS OF MULTI-HAZARD ASSESSMENT

Seven types of hazard criteria were used to develop the Multi-HA, based on a certain scenario as mentioned in the previous section. The results of the scenario-based Multi-HA are presented in Figure 3.59 and Table 3.13. The analysis results show that the total number of hazards in each province range from 1 to 6 types. Khamuane province is the only province in Lao PDR which has the highest number of potential hazards: the six type of hazards being floods, landslides, drought, storms, epidemics and UXOs. Analysis further reveals that there are five provinces in Lao PDR which only have one type of hazard. These provinces are Champassack, Huaphanh,Vientiane Municipality, Xayabury and Xiengkhuang. As shown in Table 3.13, Champassack province and Vientiane Municipality are prone to flooding, Huaphanh and Xiengkhuang are prone to epidemics, while Xayabury province is prone to earthquakes.

The district level Multi-HA shows that out of the 141 districts in Lao PDR, 56% are defined as epidemic-prone areas, 34.7% are flood-prone areas, 29.8% are earthquake-prone areas, 19.1% are landslide-prone areas, 4.9% are storm-prone areas and 4.9% are UXO-prone areas. Details of each district and type of hazard can be found in Table 3.14. Figure 3.60 shows the distribution of multi-hazard maps for the country at district level.

3.8.6 RECOMMENDATIONS

- In this study, multi-hazard zoning was developed based on provincial-level hazard assessments. The results of this study can be used as a reference for the national level. It is recommended that focal technical departments conduct more detailed studies for each hazard, for instance, at district level.
- The multiple hazard prone provinces should be given first priority for disaster mitigation interventions. It is recommended that the focal departments, agencies and ministries give special emphasis for disaster mitigation in multiple hazard provinces/districts.
- Most multiple hazard prone districts in Khamuane province should be given priority for disaster intervention. It is necessary to check the exposure of lives and necessary infrastructure in multiple hazard districts. The details of exposure to lives and infrastructure to multiple hazard prone districts will be discussed in the next chapter.
- The multi-hazard map should be the base map for all necessary DRR interventions.

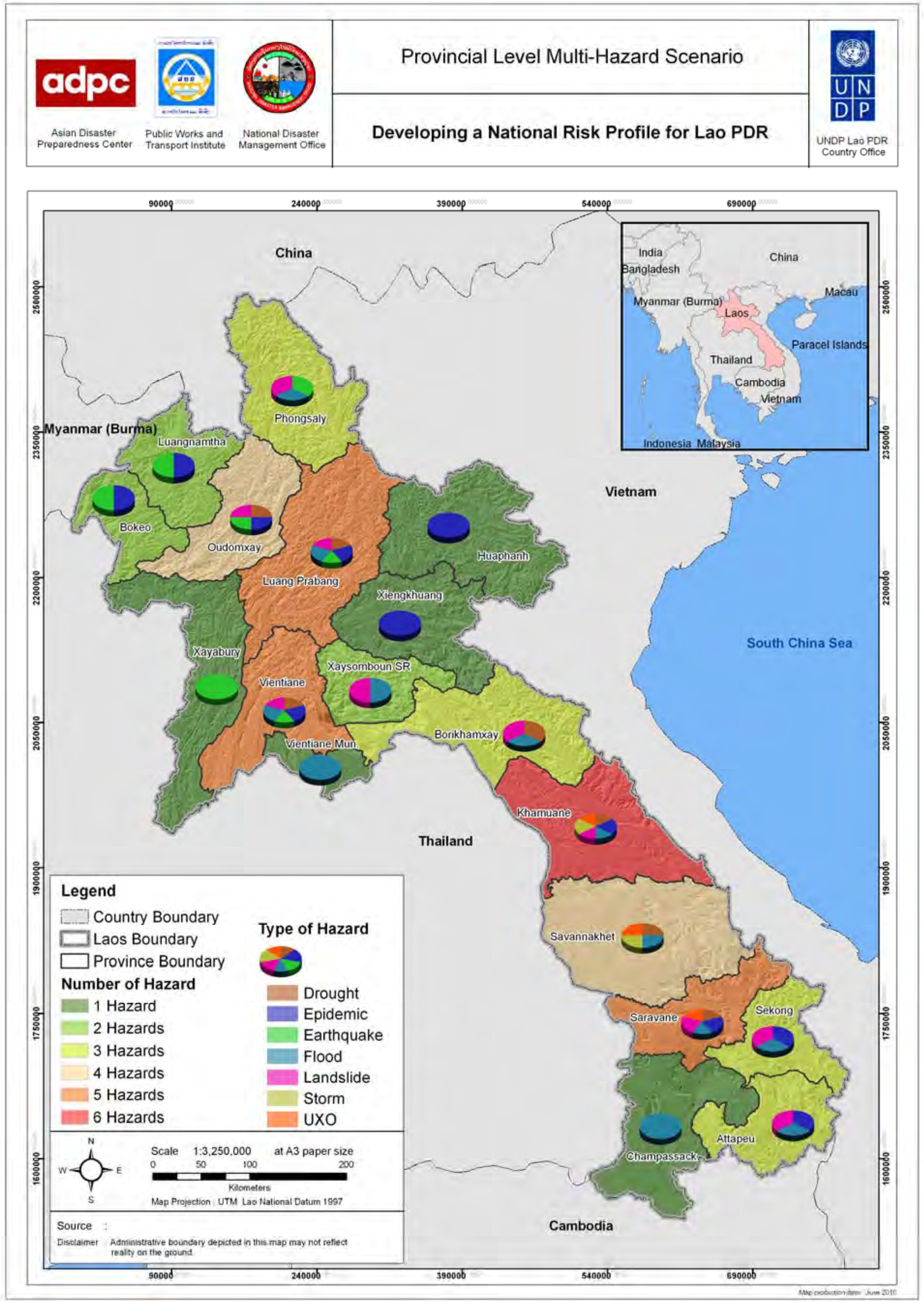

Figure 3.59 Map showing the number and type of hazard at provincial level (scenario based)

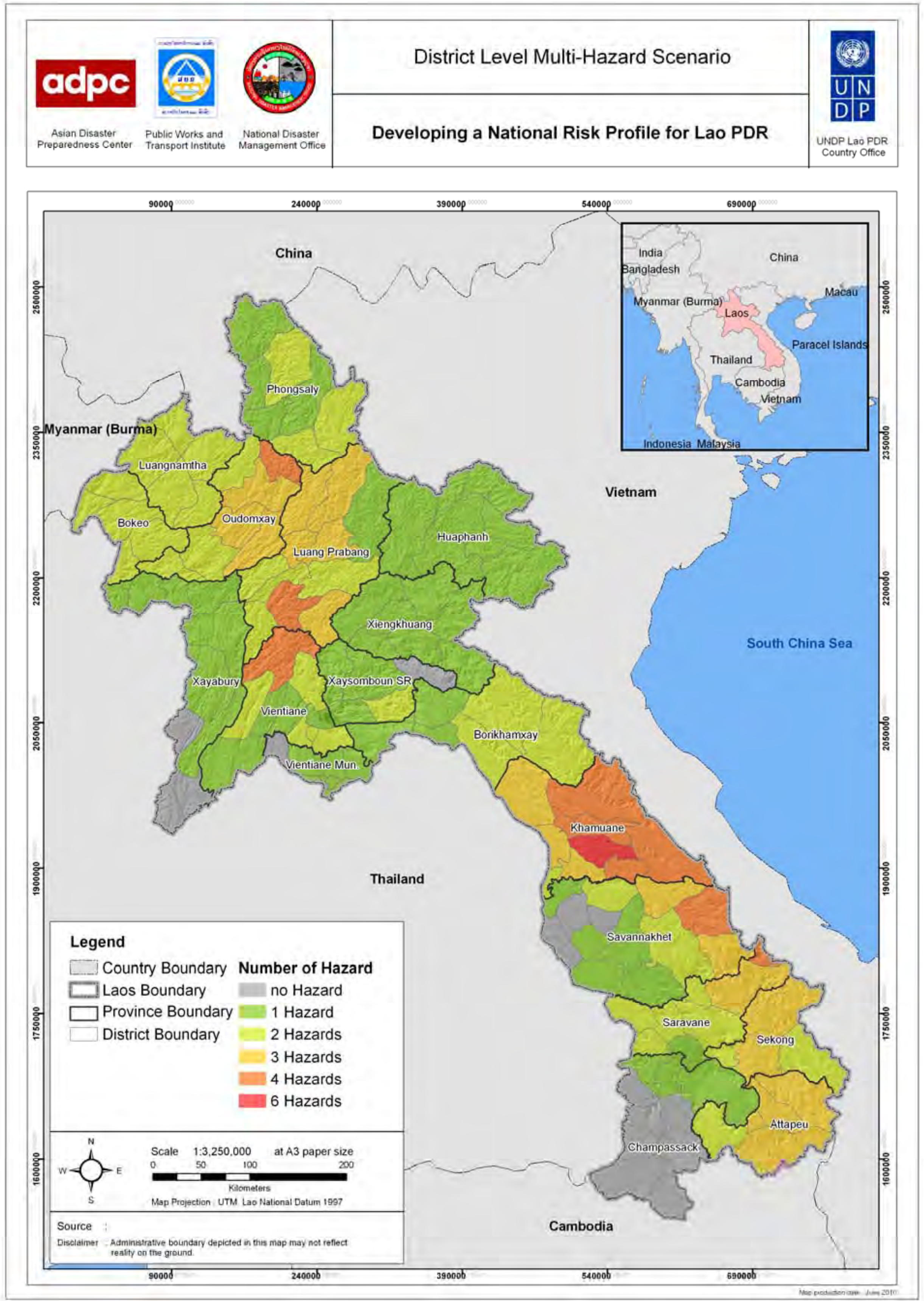

Figure 3.60 Map showing the number of hazard at district level (scenario based)

Table 3.13 Number of hazards at provincial level (scenario based)

Province	Number of Districts	Type of Hazard														Number of Hazard
		Earthquake		Flood		Landslide		Drought		Storm		Epidemic		UXO		
		x	√	x	√	x	√	x	√	x	√	x	√	x	√	
Attapeu	5	5			5	1	4	5		5			5	5		3
Bokeo	5		5	5		5		5		5			5	5		2
Borikhamxay	6	6		3	3	3	3	3	3	6		6		6		3
Champassack	10	10		6	4	10		10		10		10		10		1
Huaphanh	8	8		8		8		8		8			8	8		1
Khamuane	9	9		6	3	4	5	1	8	4	5		9	6	3	6
Luang Prabang	11	2	9	7	4	9	2	9	2	11			11	11		5
Luangnamtha	5		5	5		5		5		5			5	5		2
Oudomxay	7		7	7		6	1	3	4	7			7	7		4
Phongsaly	7		7	5	2	6	1	7		7		7		7		3
Saravane	8	8		3	5	6	2	6	2	8			8	7	1	5
Savannakhet	15	15		6	9	15		9	6	13	2	15		12	3	4
Sekong	4	4		1	3	1	3	4		4			4	4		3
Vientiane	10	8	2	7	3	8	2	9	1	10			10	10		5
Vientiane Mun.	9	9		2	7	9		9		9		9		9		1
Xayabury	10	3	7	10		10		10		10		10		10		1
Xaysomboun SR	5	5		4	1	1	4	5		5		5		5		2
Xiengkhuang	7	7		7		7		7		7			7	7		1
Total	141	99	42	92	49	114	27	115	26	134	7	62	79	134	7	

Note:

x = Number of districts NOT affected by a certain hazard

√ = Number of districts affected by a certain hazard

Table 3.14 Number of hazards at district level (scenario based)

Province	District	Drought	Epidemic	Earthquake	Flood	Landslide	Storm	UXO	Number of Hazard
Vientiane Mun.	Chanthabouri	x	x	x	√	x	x	x	1
	Sikhottabong	x	x	x	√	x	x	x	1
	Xaisettha	x	x	x	√	x	x	x	1
	Sisattanak	x	x	x	x	x	x	x	0
	Naxaythong	x	x	x	√	x	x	x	1
	Xaithani	x	x	x	√	x	x	x	1
	Hatxayfong	x	x	x	√	x	x	x	1
	Sangthong	x	x	x	x	x	x	x	0
	Pak-Ngum	x	x	x	√	x	x	x	1
Phongsaly	Phongsali	x	x	√	x	√	x	x	2
	Mai	x	x	√	√	x	x	x	2
	Khoa	x	x	√	√	x	x	x	2
	Samphan	x	x	√	x	x	x	x	1
	Boun-Nua	x	x	√	x	x	x	x	1
	Gnot-Ou	x	x	√	x	x	x	x	1
	Boun-Tai	x	x	√	x	x	x	x	1
Luangnamtha	Louang-Namtha	x	√	√	x	x	x	x	2
	Sing	x	√	√	x	x	x	x	2
	Long	x	√	√	x	x	x	x	2
	Viangphoukha	x	√	√	x	x	x	x	2
	Nale	x	√	√	x	x	x	x	2
Oudomxay	Xai	√	√	√	x	x	x	x	3
	La	√	√	√	x	√	x	x	4
	Namo	x	√	√	x	x	x	x	2
	Nga	√	√	√	x	x	x	x	3
	Beng	√	√	√	x	x	x	x	3
	Houn	x	√	√	x	x	x	x	2
	Pakbeng	x	√	√	x	x	x	x	2
Bokeo	Houayxay	x	√	√	x	x	x	x	2
	Tonpheung	x	√	√	x	x	x	x	2
	Meung	x	√	√	x	x	x	x	2
	Pha-Oudom	x	√	√	x	x	x	x	2
	Paktha	x	√	√	x	x	x	x	2
Luang Prabang	Louangphrabang	x	√	√	x	x	x	x	2
	Xiang-Ngeun	√	√	√	x	√	x	x	4
	Nan	x	√	√	x	x	x	x	2
	Pak-Ou	x	√	√	√	x	x	x	3
	Nambak	x	√	√	√	x	x	x	3
	Ngoy	x	√	√	√	x	x	x	3
	Pakxeng	x	√	√	√	x	x	x	3
	Phonxai	x	√	√	x	x	x	x	2
	Chomphet	x	√	√	x	x	x	x	2

Province	District	Drought	Epidemic	Earthquake	Flood	Landslide	Storm	UXO	Number of Hazard
	Viangkham	x	√	x	x	x	x	x	1
	Phoukhoun	√	√	x	x	√	x	x	3
Huaphanh	Xam-Nua	x	√	x	x	x	x	x	1
	Xiangkho	x	√	x	x	x	x	x	1
	Viangthong	x	√	x	x	x	x	x	1
	Viangxai	x	√	x	x	x	x	x	1
	Houamuang	x	√	x	x	x	x	x	1
	Xam-Tai	x	√	x	x	x	x	x	1
	Sopbao	x	√	x	x	x	x	x	1
	Et	x	√	x	x	x	x	x	1
Xayabury	Xaignabouri	x	x	√	x	x	x	x	1
	Khop	x	x	√	x	x	x	x	1
	Hongsa	x	x	√	x	x	x	x	1
	Ngeun	x	x	√	x	x	x	x	1
	Xianghon	x	x	√	x	x	x	x	1
	Phiang	x	x	√	x	x	x	x	1
	Paklai	x	x	√	x	x	x	x	1
	Kenthao	x	x	x	x	x	x	x	0
	Thongmixai	x	x	x	x	x	x	x	0
	Boten	x	x	x	x	x	x	x	0
Xiengkhuang	Pek	x	√	x	x	x	x	x	1
	Kham	x	√	x	x	x	x	x	1
	Nonghet	x	√	x	x	x	x	x	1
	Khoun	x	√	x	x	x	x	x	1
	Mok-Mai	x	√	x	x	x	x	x	1
	Phoukout	x	√	x	x	x	x	x	1
	Phaxai	x	√	x	x	x	x	x	1
Vientiane	Phonhong	x	√	x	√	x	x	x	2
	Thourakhom	x	√	x	√	x	x	x	2
	Keo-Oudom	x	√	x	x	x	x	x	1
	Kasi	√	√	√	x	√	x	x	4
	Vangvieng	x	√	x	x	√	x	x	2
	Fuang	x	√	x	x	x	x	x	1
	xanakham	x	√	x	x	x	x	x	1
	Met	x	√	√	x	x	x	x	2
	Hinheup	x	√	x	x	x	x	x	1
	Viangkham	x	√	x	√	x	x	x	2
Borikhamxay	Pakxan	x	x	x	√	x	x	x	1
	Thaphabat	x	x	x	√	x	x	x	1
	Pakkading	√	x	x	x	√	x	x	2
	Borikhan	x	x	x	√	x	x	x	1
	Khamkeut	√	x	x	x	√	x	x	2
	Viangthong	√	x	x	x	√	x	x	2

Province	District	Drought	Epidemic	Earthquake	Flood	Landslide	Storm	UXO	Number of Hazard
Khamuane	Thakhek	√	√	x	x	√	x	x	3
	Mahaxai	√	√	x	√	√	√	√	6
	Nongbok	x	√	x	√	x	x	x	2
	Hinboun	√	√	x	x	√	x	x	3
	Gnommalat	√	√	x	x	√	√	x	4
	Boualapha	√	√	x	x	x	√	√	4
	Nakay	√	√	x	x	√	√	x	4
	Xebangfai	√	√	x	√	x	x	x	3
	Xaibouathong	√	√	x	x	x	√	√	4
Savannakhet	Khanthabouri	x	x	x	x	x	x	x	0
	Outhoumphon	x	x	x	x	x	x	x	0
	Atsaphangthong	x	x	x	x	x	x	x	0
	Phin	√	x	x	√	x	x	x	2
	Xepon	√	x	x	√	x	√	√	4
	Nong	√	x	x	√	x	x	√	3
	Thapangthong	x	x	x	√	x	x	x	1
	Songkhon	x	x	x	√	x	x	x	1
	Champhon	x	x	x	√	x	x	x	1
	Xonbouri	x	x	x	√	x	x	x	1
	Xaibouri	x	x	x	√	x	x	x	1
	Vilabouri	√	x	x	x	x	√	√	3
	Atsaphon	√	x	x	√	x	x	x	2
	Xaiphouthong	x	x	x	x	x	x	x	0
	Phalanxai	√	x	x	x	x	x	x	1
Saravane	Saravan	x	√	x	√	x	x	x	2
	Ta-Oy	√	√	x	x	√	x	x	3
	Toumlan	x	√	x	√	x	x	x	2
	Lakhonpheng	x	√	x	√	x	x	x	2
	Vapi	x	√	x	√	x	x	x	2
	Khongxedon	x	√	x	√	x	x	x	2
	Laongam	x	√	x	x	x	x	x	1
	Samouay	√	√	x	x	√	x	√	4
Sekong	Lamam	x	√	x	√	√	x	x	3
	Karum	x	√	x	√	√	x	x	3
	Dakchung	x	√	x	x	√	x	x	2
	Thateng	x	√	x	√	x	x	x	2
Champassack	Pakxe	x	x	x	√	x	x	x	1
	Xanasomboun	x	x	x	√	x	x	x	1
	Bachiangchareunsouk	x	x	x	√	x	x	x	1
	Pakxong	x	x	x	√	x	x	x	1
	Pathoumphon	x	x	x	x	x	x	x	0
	Phonthong	x	x	x	x	x	x	x	0
	Champasak	x	x	x	x	x	x	x	0

Province	District	Drought	Epidemic	Earthquake	Flood	Landslide	Storm	UXO	Number of Hazard
	Soukhouma	x	x	x	x	x	x	x	0
	Mounlapamok	x	x	x	x	x	x	x	0
	Khong	x	x	x	x	x	x	x	0
Attapeu	Xaisettha	x	√	x	√	√	x	x	3
	Samakkhixai	x	√	x	√	√	x	x	3
	Sanamxai	x	√	x	√	x	x	x	2
	Sanxai	x	√	x	√	√	x	x	3
	Phouvong	x	√	x	√	√	x	x	3
Xaysomboun SR	Xaisomboun	x	x	x	x	√	x	x	1
	Thathom	x	x	x	x	x	x	x	0
	Hom	x	x	x	√	√	x	x	2
	Longxan	x	x	x	x	√	x	x	1
	Phoun	x	x	x	x	√	x	x	1

Note:

x = NOT affected by a certain hazard

√ = Affected by a certain hazard

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