Government of the People's Republic of Bangladesh
Department of Disaster Management
Ministry of Disaster Management and Relief

MULTI HAZARD
RISK AND
VULNERABILITY
ASSESSMENT,
MODELING AND MAPPING

FINAL REPORT OF MULTI HAZARD RISK AND VULNERABILITY ASSESSMENT, MODELING AND MAPPING IN BANGLADESH

VOLUME IV: VULNERABILITY AND RISK ASSESSMENT

FLOOD, STORM SURGE, LANDSLIDE AND DROUGHT

Government of the People's Republic of Bangladesh

Report on Multi-Hazard, Risk and Vulnerability Assessment, Modelling and Mapping in Bangladesh

Volume IV: Vulnerability and Risk Assessment

Flood, Storm Surge, Landslide and Drought

Department of Disaster Management
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Message from Secretary, MoDMR

Government of the Peoples' Republic of Bangladesh had initiated the 'Emergency 2007 Cyclone Recovery and Restoration Project (ECRRP)' under DDM, LGED & BWDB with the assistance of the World Bank for Disaster Risk Mitigation and Reduction. Multi-hazard Risk and Vulnerability Assessment, Modeling and Mapping (MRVAM) is one of the initiatives under ECRRP, D1(DDM component) to assess risk and vulnerability of 8(eight) major hazards like Flood, Cyclone induced Storm Surge, Landslide, Drought, Earthquake, Tsunami, Technological & Health hazards. Component D1 is designed to contribute towards 'building long-term preparedness by strengthening disaster risk management' through strengthening and enhancement of long-term disaster risk mitigation and reduction ability of the DDM. This study is very important, due to the geographical location and topographical features of Bangladesh, exposed the country to almost all kinds of natural disasters and a large-scale disasters in Bangladesh has been observed at a frequency of 5-6 years.

I am very happy to know that ECRRP-D1 project is going to publish comprehensive Report on MRVAM with the help of ADPC, Thailand and IWM, Bangladesh. This study will supplement the efforts of the government to incorporate disaster risk reduction issues in all development programmes to build a safe and disaster resilience nation, referring to the SOD-2010, Disaster Management Act-2012, Disaster Management Policy-2015, and National Disaster Management Plan 2010-15. Alongside by the government, all including non- governmental organizations (NGOs) and civil society should come forward to build an effective disaster management infrastructure to reduce the post-disaster losses. District and local level officials who are frequently involved with the disaster damage assessment, management, preparedness and risk & vulnerability reduction activities will be benefitted by using these national level risk assessment map and database from this project.

Md. Shah Kamal
Secretary
Ministry of Disaster Management and Relief

Message from DG, DDM

Bangladesh has made a strong commitment to implement Hyogo Framework for Action (HFA) during 2005-2015 for critical guidance in efforts to reduce disaster risk and the Multi-Hazard Risk and Vulnerability Assessment, Modeling and Mapping (MRVAM) project initiated under 'Emergency 2007 Cyclone Recovery and Restoration Project (ECRRP)' as D1 component has advanced Bangladesh's progress in Priority Action 2: Identify, assess and monitor disaster risks and enhance early warning. In continuation of this, outcome of this project "Multi-Hazard Risk Assessment at national level" is in line with Priority 1: 'Understanding disaster risk' of Sendai Framework for Disaster Risk Reduction 2015-2030, adopted in the 3rd World Conference on Disaster Risk Reduction, held from 14 to 18 March 2015 in Sendai, Miyagi, Japan.

The findings of MRVAM project has create the basis for "building long term preparedness through strengthening disaster risk management capacity in the country as well as for enhancement of long term disaster risk mitigation and reduction ability of the Department of Disaster Management (DDM)". On the other hand, MRVAM project outcome has created awareness among the district and upazila level officials and will help in contributing towards incorporating appropriate risk-reduction strategies and prioritizing them into the country's development planning process.

In addition to this, the findings of this study 'risk information of population, housing and livelihood at upazila level' will allow decision makers to prioritize risk mitigation investments and measures to strengthen the emergency preparedness and response mechanisms for reducing the losses and damages due to future disaster events.

(Md. Reaz Ahmed)
Director General (Additional Secretary)
Department of Disaster Management

Message from PD, ECRRP-D1, DDM

Multi-Hazard Risk and Vulnerability Assessment, Modeling and Mapping (MRVAM) project implemented as a part of sub-component D1.2 'Emergency 2007 Cyclone Recovery and Restoration Project (ECRRP)', by Department of Disaster Management (DDM) is an efforts towards 'building long-term preparedness through strengthened disaster risk management', through the strengthening and enhancement of the long-term disaster risk mitigation and reduction ability of the DDM.

This project has developed enormous quantity of database representing multi-hazards of Flood, Cyclone induced Storm Surge, Landslides, Drought, Earthquake, Tsunami, Technological and Health along with national level database representing population, housing, livelihood, critical facilities, infrastructure which can be used at Union / Upazila level for development planning process.

DDM has established Multi-Hazard Risk and Vulnerability Assessment (MRVA) Cell, in which geo-database of hazard, exposure and risk assessment at upazila level developed in this project and hosted in the state of the hardware & software facilities. I take this opportunity to state that, this will enhance the capacity of the department to monitor the hazard, exposure and risk assessment, in this way, all the government agencies, professionals and researchers will be benefitted in contributing towards disaster risk reduction in Bangladesh.

(M. Khalid Mahmood)
Joint Secretary and Director (Planning & Development)
Project Director, ECRRP-D1
Department of Disaster Management

Preface

A category IV cyclone *SIDR* struck in the south west coast of Bangladesh on November 15, 2007 evening and moved inland, destroying infrastructure, causing numerous deaths, disrupting economic activities, and affecting social conditions. As most all of Bangladesh is considered as a Delta just above sea level, tidal surge of 15-20 feet and gail-force winds of approximately 150 mph creates havoc in most of the area. The aim of the assessment was to identify priority areas to support the Government of Bangladesh in cyclone recovery efforts as well as to recommend priority interventions for a long-term disaster management strategy. The preparation of Multi-Hazard Risk and Vulnerability Assessment, Modelling and Mapping (MRVAM) project has identified the damage needs and quantified financial and technical requirements and established MRVA Cell in DDM, that will facilitate formulating comprehensive early recovery actions, medium-term recovery and reconstruction plans and a long-term disaster risk management and reduction strategy. The main objective to establish MRVA Cell is to strengthen and enhance country capacity in carrying out systematic multi-hazard risk assessments and consolidating and maintaining hazard risk information at central (national) and disaggregated (district) levels. This will contribute towards the realization of the specific priority attached in the country's disaster management strategy of 'defining and redefining the risk environment' of the country. The Asian Disaster Preparedness Center (ADPC), Thailand, in partnership with the Institute of Water Modeling (IWM), the Norwegian Geotechnical Institute (NGI), the Asian Institute of Technology (AIT), and the Faculty of Geo-Information Science and Earth Observation of the University of Twente (ITC), the Netherlands have been worked together to deliver consulting services on the Multi-Hazard Risk and Vulnerability Assessment, Modeling and Mapping in Bangladesh and finally have prepared the Volume I: Hydro-meteorological Hazard Assessment (Flood, Storm Surge, Landslide, Drought), Volume II: Geological and Environmental Hazard Assessment (Earthquake, Tsunami, Technological, Health), Volume III: Elements at risk, Volume IV: Vulnerability and Risk Assessment (Flood, Storm Surge, Landslide, Drought), Volume V: Vulnerability and Risk Assessment (Earthquake, Tsunami, Technological, Health), Volume VI: Summary and Recommendations.

For flood hazard and vulnerability assessment, Flood Modeling used in this study is MIKE11 Hydrodynamic Model developed by DHI, coupled with Geographic Information System (GIS) to capture the hydraulic response of Bangladesh Rivers, in-depth Flood analysis and its floodplains in extreme flooding conditions. Then a frequency analysis was carried out in the river network at 7617 grid points in order to obtain return period-wise flood levels for 25 year, 50 year, 100 year and 150 years. The model used in MRVAM project for Cyclone induced Storm Surge is called Bay of Bengal Model (BoBM). The model is developed using a MIKE21 FM modelling system, which is a numerical modelling system for the simulation of water levels and flows in estuaries, bays and coastal areas. Storm Surge hazard depth was divided into seven different depth categories in order to find the extent of surge inundation and prepare inundation maps for all return periods: 25, 50 and 100 years for the entire coastal region. The depth categories are <1 m, 1-1.5 m, 1.5-2 m, 2-3 m, 3-4 m, 4-5 m, >5 m. Earthquake hazard maps were developed using the historical data and existing geological setting for 50 year, 100 year, 200 year, 500 year and 1000 years return periods at the sites of investigation derived and interpolated to develop earthquake hazard maps representing spatial variation of Peak Ground Acceleration (PGA) Map in Bangladesh. Simultaneously, to model the tsunamigenic conditions and the possible hazard maps due to Tsunami, have

been generated for 50, 100, 200, 500 and 1000 years return period and the SPI (Standardized Precipitation Index)-Return period plots used to calculate the severity of Drought with different return periods such as the SPI values for 10, 50 and 100 years return period.

The purpose of this Multi-Hazard Risk and Vulnerability Assessment (MRVA) Modelling and Mapping study is to develop a hazard and vulnerability framework using the progression of vulnerability model to identify the root causes (problems) and the underlying pressures within coastal belt as well as whole Bangladesh. The information provided in this study was intended to assist in identifying hazards and vulnerabilities thereby building a disaster resilient Districts and Upazilas by sharing local hazards and also establishing community structures. Combining the results of the theoretical framework and research findings with the argument constructed in these Volumes I-VI about the disaster risk reduction and mitigation; it was found that it is possible to reduce hazard risks, and vulnerability to disasters, through the application of the latest GIS & RS tools and Hydrodynamic modeling and the participation of the grass-root level community in disaster risk management activities.

It is a great pleasure to successfully launch this Scientific MRVA National Document, signifying the needs and opportunities for the protection of the coastal environment as well as overall most vulnerable districts of Bangladesh and associated lives and livelihoods. The Department of Disaster Management (DDM), Ministry of Disaster Management and Relief would like to thank all those involved in the preparation and finalization of this document and would like to believe that materialization of these policies and programmes will improve overall catastrophic environment of the country as a whole and coastal environment in particular.

We would like to express our in-depth gratitude to the prominent experts of Technical Advisory Committee (TAC), the well-known and reverend group of professionals of the Country, specially, Dr. A. S. M. Maksud Kamal, Convener-TAC and Dean, Faculty of Earth and Environmental Sciences, Dhaka University; Dr. Umme Kulsum Navera, Professor, Department of Water Resources Engineering, BUET; Dr. Md. Atiqur Rahman, Joint Secretary (Admin.), Ministry of Disaster Management and Relief (MoDMR), Mr. M. A. Rouf Hawlader, Director, Survey of Bangladesh; Mr. Shamsuddin Ahmed, Director in Charge, Bangladesh Meteorological Department (BMD), Mr. Md. Shahidul Islam, GIS Analyst, CDMP-II; Mr. Mir Ahmed, Member Secretary-TAC & Director-MIM, DDM; Mr. M. Khalid Mahmood, Director (Planning & Development) & PD-ECRRP-D1, DDM; and Mr. Reaz Ahmed, Director General and MRVAM Advisor, DDM & last of all, those associated with MRVA Cell; under whose overall guidance and supervision, these MRVA Volumes were duly checked and scientifically verified, who had worked relentlessly for years to generate scientific information required for these risk and vulnerability assessments. A special appreciation to the World Bank, ERD and PCMU – Planning Commission Team, whose financial and project extension support from the beginning helped us to reach its ultimate destination.

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List of Abbreviations

ARCGIS	ARC Geographic Information System
BWDB	Bangladesh Water Development Board
DDM	Department of Disaster Management
DRR	Disaster Risk Reduction
EA	Exposure Assessment
EVRA	Exposure, Vulnerability and Risk Assessment
GIS	Geographic Information System
MPO	Master Plan Organization
MRVA	Multi-hazard, Risk and Vulnerability Assessment
MRVAM	Multi-Hazard Risk and Vulnerability Assessment Modelling and Mapping
NA	Not Applicable
NGI	Norwegian Geo-technical Institute
PGA	Peak Ground Acceleration
TAC	Technical Advisory Committee
UNISDR	United Nations International Strategy for Disaster Reduction
WARPO	Water Resources Planning Organization

Multi-Hazard Risk and Vulnerability Assessment (MRVA) Report

Volume IV: Vulnerability and Risk Assessment (Flood, Storm Surge, Landslide and Drought)

Chapter 1: Vulnerability and Risk Assessment

1.1 Introduction

Components of risk assessment are hazard, elements at risk, exposure, vulnerability. The first step of a risk assessment is Hazard Assessment, in which natural disaster phenomena are modelled to develop hazardous areas. The exposure, which involves evaluating the elements at risk exposed to different levels of hazards, is a function of the geographic location of the elements at risk and co-existence of hazard at the same location. Vulnerability (damage curves or risk matrices) is assessing the relationship between hazard and *physical damage or monetary value* of exposed elements at risk. Risk can be defined as the total *physical damage or monetary value* of elements at risk *(*properties or assets) that can potentially be affected by hazards. Risk is assessed using damage curves as quantitative risk (*physical damage or loss of monetary value)* or using risk matrices for qualitative risk assessment. A Risk Matrix represents the qualitative relation between the hazard intensity and level of damage expected for each element at risk.

The Exposure, Vulnerability and Risk Assessment approach adopted in this study is based on definitions from United Nations International Strategy for Disaster Reduction (UNISDR, 2009). The basic function of risk can be divided into the three components: hazard, exposure of elements at risk and vulnerability. The definition of these terms are given in Table1.1 and concept of Exposure, Vulnerability and Risk Assessment (EVRA) Approach is shown in figure 1.1.

Table 1.1: The Definition of Exposure, Vulnerability and Risk

Exposure	The degree to which the elements at risk are exposed to a particular hazard.
Vulnerability	The conditions determined by physical, social, economic and environmental factors or processes, which increase the susceptibility of a community to the impact of hazards. Can be subdivided into physical, social, economic and environmental vulnerability.
Risk	The probability of harmful consequences, or expected losses (deaths, injuries, property loss, livelihoods loss, economic activity disruption or environmental damaged) resulting from interactions between (natural and/ or human-induced) hazards and vulnerable conditions in a given area and time period.

Source: UNISDR, 2009

Risk can be presented conceptually with the following basic equation:

Risk = Hazard x Vulnerability x Element at risk

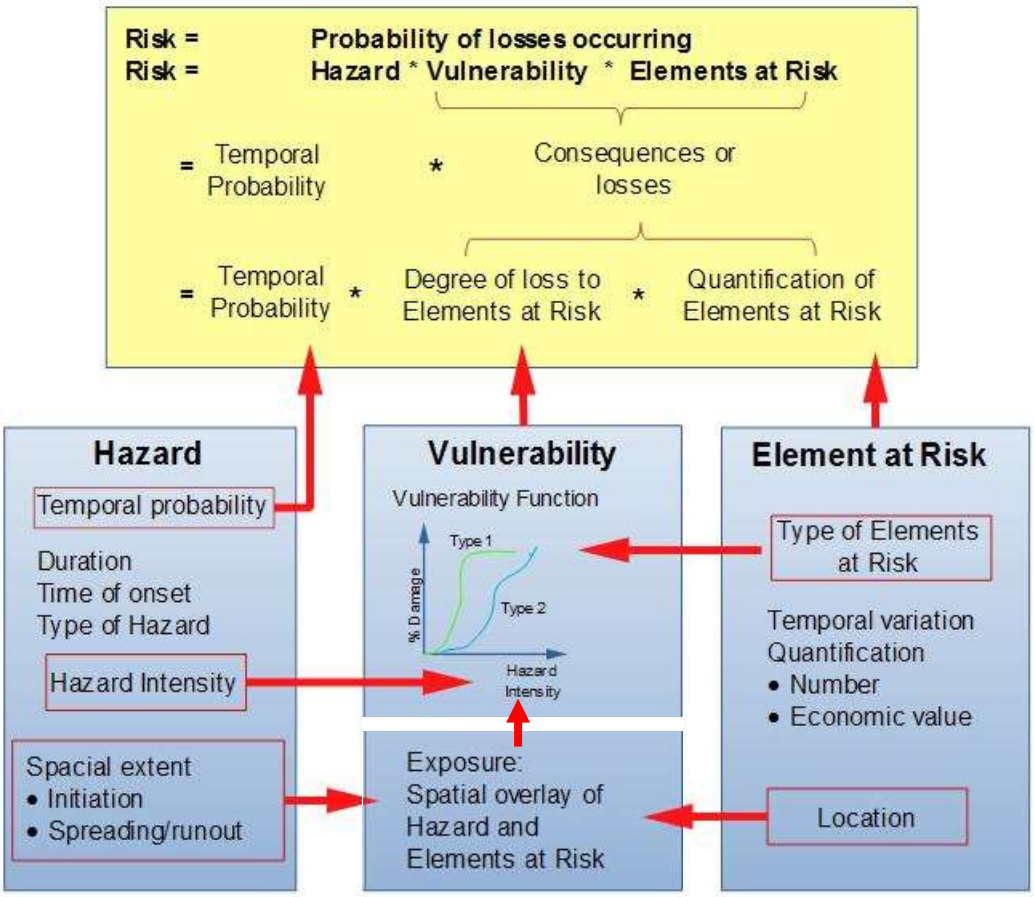


Figure 1.1: Exposure, Vulnerability and Risk Assessment (EVRA) Approach

Source: ADPC, 2014

1.2 Exposure, Vulnerability and Risk Assessment (EVRA) Approach

EVRA results largely depend upon availability of data. The project scope is to develop an EVRA profile based on available authentic secondary information. The elements at risk data is mostly collected from authentic government/non-government and reputed international sources. The risk assessment has been carried out mainly based on data collected from various sources, which is mentioned in detail in table 2.2 (page 18) of Volume – I of this report.

EVRA is developed based on national level hazard assessment of Flood, Cyclone induced storm surge, Earthquake, Tsunami, Landslide, Drought, Technological, Health and Population, Housing, Livelihoods, Critical Facilities and Infrastructure sectors, the elements at risk considered in this project. Hazard assessment was carried out for various return periods as given in table 1.2. The details of hazard assessment used in this report is provided in volume I of this report and elements at risk are presented in volume III of this report.

Table 1.2: Summary of Hazard maps developed in this study

Hazards	Return Period							
	10	**25**	**50**	**100**	**150**	**200**	**500**	**1000**
Flood		√	√	√	√			
Storm Surge		√	√	√				
Earthquake			√	√		√	√	√
Landslide	Not Applicable as there is no return period							
Tsunami			√	√		√	√	√
Drought	√		√	√				
Technological	Not Applicable as there is no return period							
Health	Not Applicable as there is no return period							

1.2.1 Exposure Assessment (EA)

Exposure Assessment (EA) is an intermediate stage of risk assessment, which links hazard assessment with assets under consideration for risk assessment. The objectives of the exposure assessment (EA) under the project are

1) To create an extensive national-level database of Population, Housing, Livelihoods, Critical Facilities and Infrastructure sectors
2) To quantify the number of elements at risk located in each hazard prone areas of Flood, Cyclone induced storm surge, Earthquake, Tsunami, Landslide, Drought, Technological, Health hazards at union/upazila/district/division/national level.

The concept of exposure assessment is given in figure 1.2.

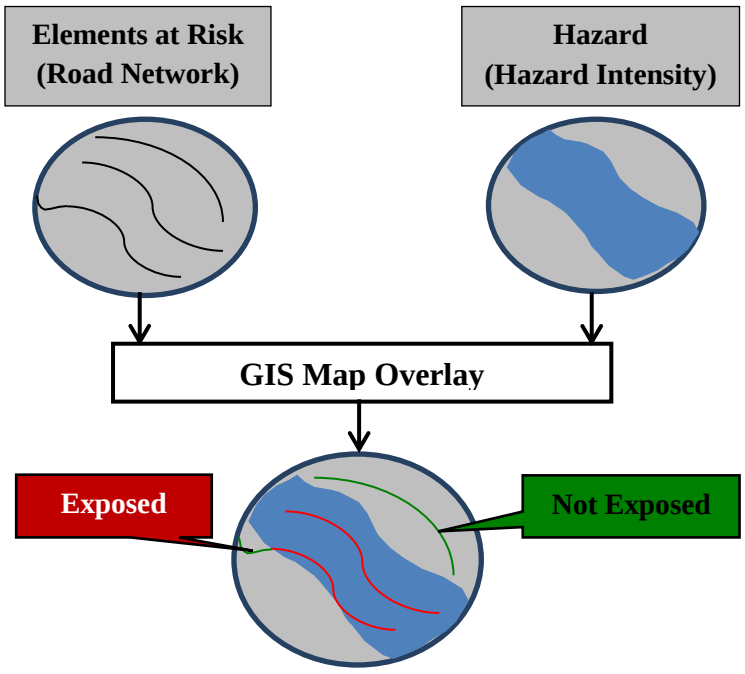


Figure 1.2: Concept of exposure Assessment

The scope of the EA includes:

- All the available elements at risk data for Population, Housing, Livelihoods, Critical Facilities and Infrastructure sectors was collected and compiled as geo-database in GIS environment (Refer to Volume III of this report for more details).
- Hazard assessment is carried out for several return periods (table 1.2), exposure is assessed using the most frequent and damaging hazard maps with relevant return period as approved by Technical Advisory committee (TAC) of this project and is given in table 1.3. Using the hazard maps (Flood, Cyclone induced storm surge, Earthquake, Tsunami, Landslide, Drought, Technological and Health) developed by various experts and elements at risk data is combined in GIS environment to analyze elements at risk located in different hazard zones at union level, which are aggregated to quantify exposed elements at risk at upazila / district / division / national levels.

Table 1.3: Summary of exposure assessment and return period of hazards

Hazard	Return Period for Exposure of Elements at Risk				
	Population	**Housing**	**Livelihood**	**Critical Facilities**	**Infrastructure**
Flood	25	25	25	100	100
Storm Surge	25	25	25	100	100
Landslide	Not Applicable (NA)				
Drought	10	NA	50	NA	NA
Earthquake	50	50	NA	50	50
Tsunami	50	50	50	50	50
Technological	Not Applicable (NA)				
Health	Not Applicable (NA)				

Exposure of elements at risk is assessed based on indicators of hazard levels in each hazard, which is indicated in table 1.4. EA will provide inputs to the vulnerability and risk assessment.

Table 1.4: Hazard level indicators considered for exposure assessment

Hazard	Indicator of Hazard level considered
Flood	Inundation area with different flood depths at 25 and 100 year return period
Storm Surge	Inundation area with different depth due to Cyclone induced storm surge at 25 and 100 year return period
Landslide	Landslide susceptibility category
Drought	Drought hazard category representing severity of 10 year return period
Earthquake	Peak Ground Acceleration (PGA) zones at 50 year return period
Tsunami	Inundation area with different depth due to tsunami at 50 year return period
Technological	Area of influence (3 zones) due to chemical release
Health	Area representing number of cases reported for each disease at district level

1.2.2 Vulnerability Assessment

Based on exposure assessment, damage curves are developed for all hazards and elements at risk for vulnerability and risk assessment, where ever possible. Damage curves represent the relationship between hazard level and % of physical damage. The description and tables given below are the summary of damage curves developed for this study by Norwegian Geo-Technical Institute (NGI) and the full report is attached as Annexure I. In this final report only physical damage of elements at risk is provided.

1.2.2.1 Vulnerability of Population

Based on the area of exposure of the settlements in each union, the vulnerability of population is calculated as number of population affected due to a hazard. All hazards except Technological and health hazards are considered for total population affected at national, district, upzila level is accumulated from union. In case of Technological hazards population affected only in the hazardous area of each industry is assessed. In case of health hazard, affected population at district level is analyzed.

1.2.2.2 Vulnerability of Household structures

Factors affecting vulnerability of household structures are different in each hazard, damage curves are developed accordingly, as indicated in table 1.5.

Table 1.5: Factors affecting used for vulnerability of household structures

Hazard	Factor considered for damage curves	Vulnerability of Household structures
Flood	Inundation depth due to Flood	Damage curves
Cyclone induced Storm surge	Inundation depth due to induced storm surge	Damage curves
Landslide	Landslide susceptible category	Risk matrix
Earthquake	Peak Ground Acceleration (PGA)	Damage curves
Tsunami	Inundation depth due to Tsunami	Damage curves

1.2.2.3 Vulnerability of Livelihood

Elements at risk considered in livelihood is crop (transplanted Aman). Vulnerability of crop is developed using the published literature and technical discussions with concerned authors form Sher-E-Bangla Agricultural University, Dhaka.

Damage curves for crop area are developed using the factors affecting a hazard as given in table 1.6.

Table 1.6: Factors considered for vulnerability for crops

Hazard	Factor considered for damage curves	Vulnerability
Flood	Inundation depth due to Flood	Risk matrix
Cyclone induced Storm surge	Inundation depth due to Storm surge	Risk matrix
Drought	Drought hazard category	Risk matrix
Tsunami	Inundation depth due to Tsunami	Risk matrix

1.2.2.4 Vulnerability of Critical facilities

Elements risk considered in livelihood are Healthcare, Education Institutions, First Responders (Fire and Police stations), and Cyclone Shelters. Keeping in view of the type of data of all critical facilities (only point location and type of critical facility), only exposure i.e. number of critical facilities existing in each hazard category is possible, not damage curves and is indicated in table 1.7.

Table 1.7: Summary of vulnerability assessment of critical facilities

Hazard	Healthcare institutions	Educational institutions	First Responders (Fire and Police stations)	Cyclone Shelters
Flood	Exposure	Exposure	Exposure	Exposure
Cyclone Induced Storm surge	Exposure	Exposure	Exposure	Exposure
Earthquake	Exposure	Exposure	Exposure	Exposure
Tsunami	Exposure	Exposure	Exposure	Exposure

1.2.2.5 Vulnerability of Infrastructure

Elements risk considered in Infrastructure are Road, Bridge, Railway, Air, Sea and River Ports, Power. Damage curves are developed only for road due to earthquake based on the type of road, for other infrastructure only exposure i.e. number/length of infrastructure existing in each hazard category is possible not damage curves, keeping in view of the type of data (only point location and type of infrastructure) available, as indicated in table 1.8.

Table 1.8: Summary of vulnerability assessment of Infrastructure

Hazard	Road	Bridge	Railway	Airports	Sea ports	River ports	Power
Flood	Exposure	Exposure	Exposure	Exposure	Exposure	Exposure	Exposure
Cyclone	Exposure	Exposure	Exposure	Exposure	Exposure	Exposure	Exposure
Earthquake	Damage curves	Exposure	Exposure	Exposure	Exposure	Exposure	Exposure
Tsunami	Exposure	Exposure	Exposure	Exposure	Exposure	Exposure	Exposure

1.2.3 Risk Assessment

Risk defined in table 1.1 (UNISDR, 2009) indicates, the probability of harmful consequences, or expected losses resulting from interactions between hazards and

vulnerable conditions in a given area and time period. The same is pictorially shown in figure 1.3.

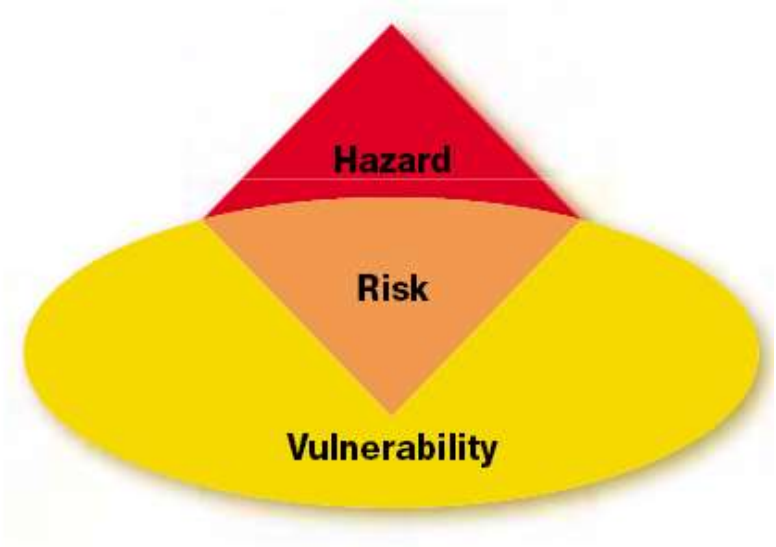


Figure 1.3: Concept of Risk

Using the hazard and vulnerability data, risk is calculated using the damage curves / risk matrix. Risk can be provided as parentage of physical damage or monetary value. In this report, risk is expressed as physical damage only, which will be converted to monetary value later. The parentage of physical damage is grouped into 5 classes and given in table 1.9. These risk classes are used to represent risk in GIS maps at district and upazila level.

Table 1.9: Risk class, Risk level, Range of damage and risk score

Risk class	Risk level	Range of Damage	Risk score
D0	No	No Damage	1
D1	Low	1 - 15%	2
D2	Moderate	15 - 35%	3
D3	High	35 - 60%	4
D4	Very High	Damage >60%	5

Where ever damage curves are not available (refer to section 1.4), the exposure assessed at upazila level is used to derive minimum and maximum exposure at national level, which are categorized into 5 equal levels, as shown in table 1.10 and is used to represent exposure levels in GIS maps at upazila / district level representing upazila exposure levels.

Table 1.10: Exposure class, Exposure level, Range of exposure and risk score

Exposure class	Exposure level	Range of exposure (%)	Exposure score
E 1	Very Low	0 – 20 %	1
E 2	Low	20 – 40 %	2
E 3	Moderate	40 – 60 %	3
E 4	High	60 – 80 %	4
E 5	Very High	80 – 100 %	5

1.3 Application of EVRA

Application of EVRA is,

- VRA provides a basic framework of understanding about linkages between hazards, exposure, vulnerability and risk of various physical and infrastructural assets existing in various parts of the country.
- The vulnerability assessment identifies the characteristics of physical elements with respect to a specific hazard's severity, which reflects the asset's strengths and weaknesses. Vulnerability assessments provide basic understanding about a sector's vulnerability and therefore provide an evidence-based approach for DRR. This volume highlights vulnerability assessment of all elements at risk considered in this study i.e. Population, Housing, Livelihoods, Critical Facilities and Infrastructure, which will further help decision makers, policy makers and planners when it comes to safer sectoral development.
- The risk assessment will provide details of sectoral elements at risk (Population, Housing, Livelihoods, Critical Facilities and Infrastructure) for various types of hazards. This will further enable policy makers and decision makers to understand potential damage and losses to specific sectors. The risk assessment is an essential tool for planning bodies such as the Planning Department and those in charge of allocating funds and resources for DRR.
- VRA will help develop recommendations for sustainable development plans or projects within national DRR planning.

1.4 Key Issues of EVRA

- Though this report is submitted to Government of Bangladesh through Department of Disaster Management (DDM), which leads the disaster related activities in Bangladesh, the respective departments and ministries which are supporting DDM in disaster risk reduction can use these results for the planning, relief and rescue operations in future. However, updation of hazard maps, elements at risk data is a continuous process, which can be co-ordinated by MRVA cell (established as a part of this project) with the support of local scientific / research institutions and relevant government departments using the suggested methodology for carrying out detailed risk assessment in future at local level.
- The characterizing vulnerability of various assets needs extensive technical and scientific inputs. Though significant work has been carried out in the past to characterize vulnerability of Population, Housing, Livelihoods, Critical Facilities and Infrastructure sectors internationally, limited work has been carried out in Bangladesh. An attempt has been made under the scope of the project, to develop damage curves (NGI, 2014) for housing, livelihoods and infrastructure (road) using technical assistance of Norwegian Geo-Technical Institute (NGI), Oslo, Norway using literature available for similar geographical, cultural locations and limited ground data collected (detailed report is attached as Annexure – I).
- But the challenge of validating these damage functions is possible only based on the detailed data collected during or after the disaster events affecting the elements at

risk, which was not possible earlier due to non-availability of compiled scientific data for this purpose. It is proposed to validate these damage functions based on the necessary relevant field data to be collected in future, as well as expert opinions and field-based judgment.

- The results are represented in more simplistic terms so as to be understood by various stakeholders. This report will be largely used by policy-makers, decision makers, planners, community and non-government agencies involved in DRR planning.
- The scale of VRA is at national / division / district / upazila / union levels based on the results presented in this report. However, the entire GIS database will be hosted in MRVA cell in DDM, which can be used to view the results at much larger scale than what is presented in this report, using the latest ARCGIS software provided in MRVA cell.

1.5 Structure of this report

Hydro-meteorological hazards considered in this study are Flood, Cyclone induced storm surge, Landslide and Drought. Volume I of this report consists of the methodology and results of hazard assessment. Elements at Risk considered in this study are discussed in volume III of this report. In this volume, Vulnerability and Risk Assessment of elements at risk to Hydro-meteorological hazards is given.

Exposure, Vulnerability and Risk Assessment is carried out for all the elements at risk (as explained in sections 1.2.1 and 1.2.2) to Flood, Cyclone induced storm surge, Landslide, Drought hazards. Risk due to Flood hazard is given in chapter 2, in chapter 3 risk due to Cyclone induced storm surge is given, in chapter 4 risk due to Landslide hazard is given, risk due to Drought hazard is given in chapter 5.

Chapter 2: Exposure, Vulnerability & Risk Assessment to Flood hazard

2.1 Exposure Assessment

Flood hazard maps consist of flood inundation depth of 5 categories and not affected area. These flood inundation depth categories are Very Shallow (< 0.3 m), Shallow (0.3 – 0.9 m), Medium (0.9 – 1.8 m), Deep (1.8 – 3.6 m), Very Deep (> 3.6). The flood depth classification is based on MPO, (1986) and adopted by BWDB.

As explained in section 1.4, flood hazard map of 25 year return period is used for exposure assessment of elements at risk i.e. population, housing, livelihoods, critical facilities and infrastructure. For pictorial representation, exposure to flood depth more than 1.8 m i.e. deep and very deep categories are only considered.

2.1.1 Population

As explained in section 1.5, based on the area of exposure of the settlements in each union, number of population exposed is calculated as affected population for flood hazard at division / district / upzila level.

2.1.1.1 Gender

Total population (male) exposed to flood at division level is given in table 2.1 and figure 2.1. Population (male) exposed to more than 1.8 m flood depth at district level is shown in figure 2.2.

Table 2.1: Population (male) exposed to flood at division level

Division	Flood depth (m) / Population exposed					Not affected	Total
	< 0.3	0.3 - 0.9	0.9 - 1.8	1.8 - 3.6	> 3.6		
Barisal	54,358	410,429	973,481	254,215	3,371	2,393,655	4,089,508
Chittagong	268,278	882,259	2,111,590	2,533,086	473,954	7,664,148	13,933,314
Dhaka	530,420	1,263,945	2,809,815	6,276,659	2,163,035	5,672,902	18,716,775
Khulna	22,273	63,569	209,124	227,335	22,439	7,297,792	7,842,533
Mymensingh	248,616	645,602	1,270,360	1,600,539	301,983	1,388,442	5,455,542
Rajshahi	121,440	363,954	1,005,142	1,687,118	256,928	5,822,328	9,256,910
Rangpur	101,056	183,875	258,359	623,990	368,507	6,346,037	7,881,824
Sylhet	35,955	97,164	287,095	1,689,581	1,983,285	840,309	4,933,390
Total	1,382,394	3,910,797	8,924,965	14,892,524	5,573,502	37,425,614	72,109,796

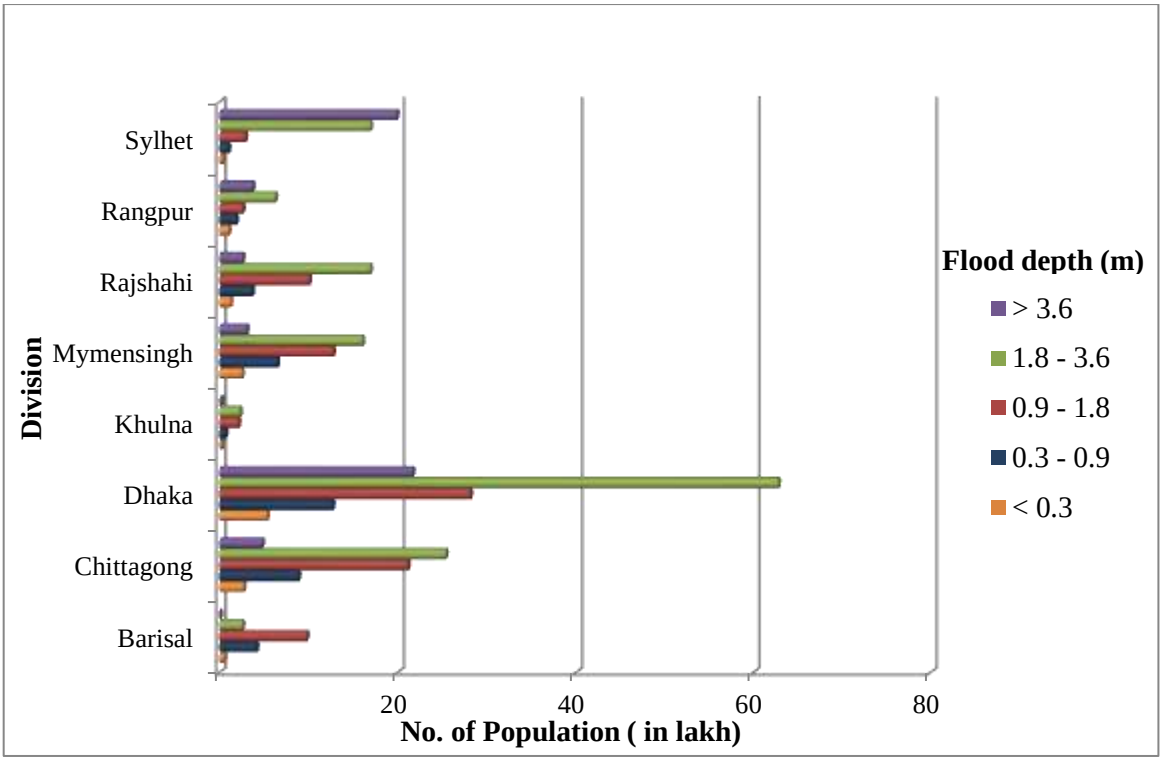


Figure 2.1: Population (male) exposed to different flood depth at division level

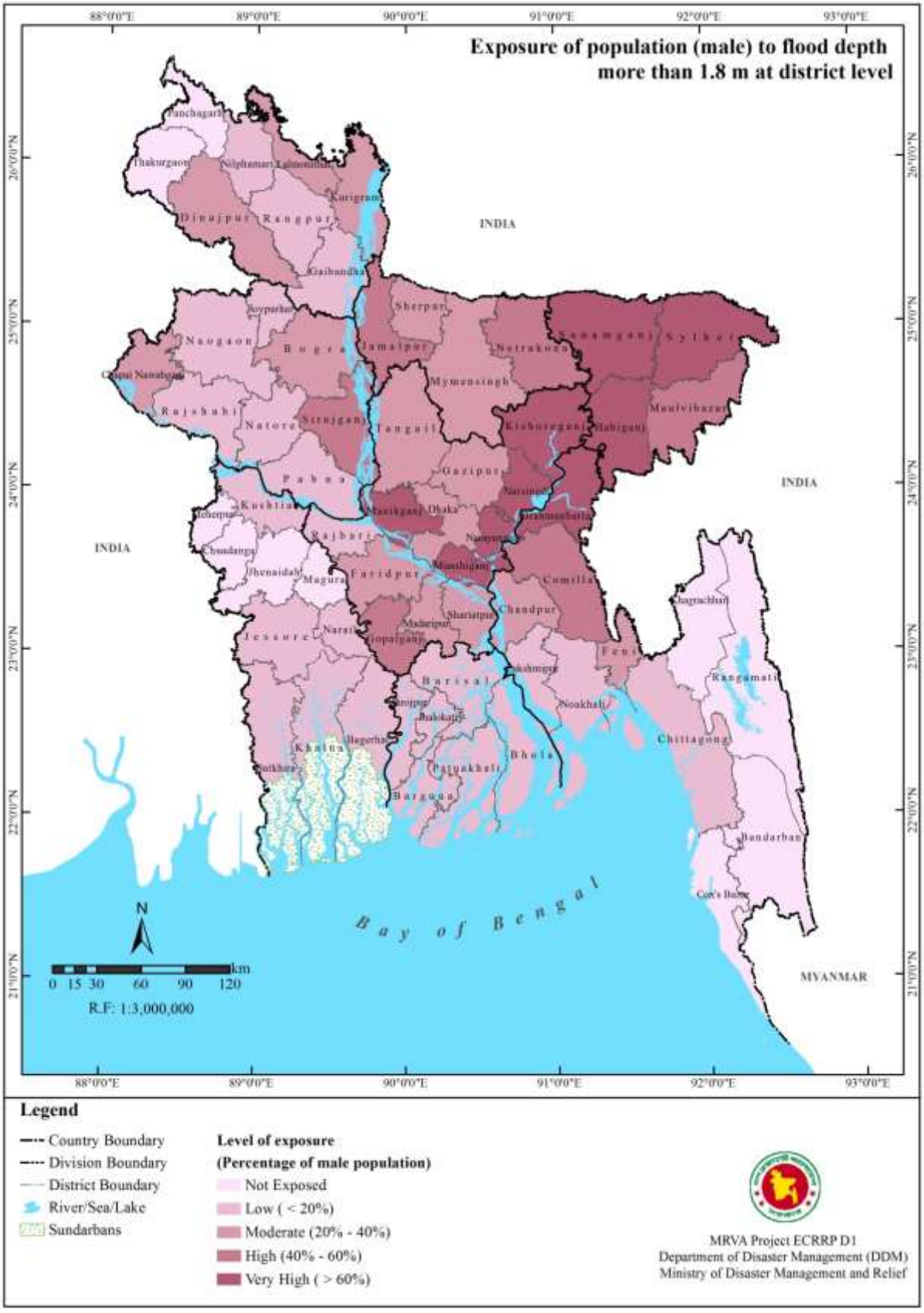


Figure 2.2: Population (male) exposed to flood depth more than 1.8 m at district level

Total population (female) exposed to flood at division level is given in table 2.2 and figure 2.3. Population (female) exposed to more than 1.8 m flood inundation depth at district level is shown in figure 2.4.

Table 2.2: Population (female) exposed to flood at division level

Division	Flood inundation Depth (m) / Population exposed					Not affected	Total
	< 0.3	0.3 - 0.9	0.9 - 1.8	1.8 - 3.6	> 3.6		
Barisal	56,662	427,619	1,024,389	267,516	3,485	2,456,487	4,236,158
Chittagong	293,729	971,914	2,345,966	2,748,703	502,723	7,626,669	14,489,705
Dhaka	483,045	1,195,648	2,762,953	6,164,777	2,022,070	5,672,902	18,301,395
Khulna	22,574	63,779	207,764	226,683	22,639	7,301,787	7,845,226
Mymensingh	252,345	656,533	1,292,894	1,629,247	304,114	1,388,442	5,523,575
Rajshahi	119,437	360,133	997,070	1,690,665	257,268	5,803,375	9,227,948
Rangpur	99,968	182,181	260,407	630,912	368,369	6,364,097	7,905,934
Sylhet	36,222	98,225	290,950	1,713,607	1,993,300	844,525	4,976,829
Total	1,363,983	3,956,033	9,182,393	15,072,109	5,473,967	36,885,415	71,933,901

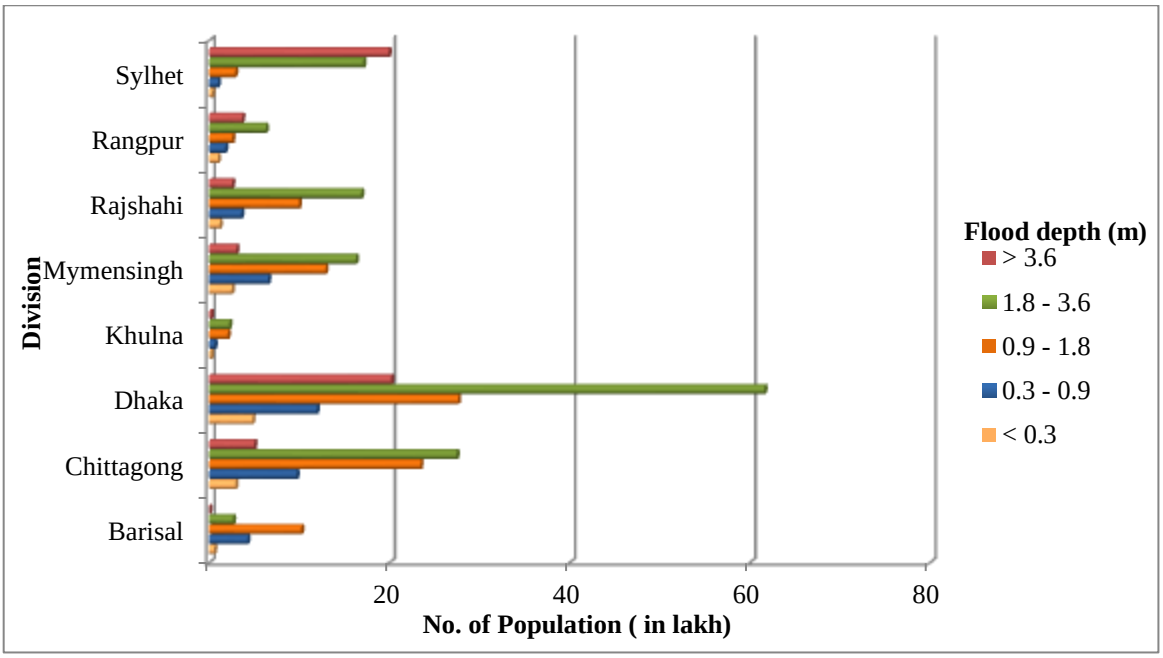


Figure 2.3: Population (female) exposed to different flood depth at division level

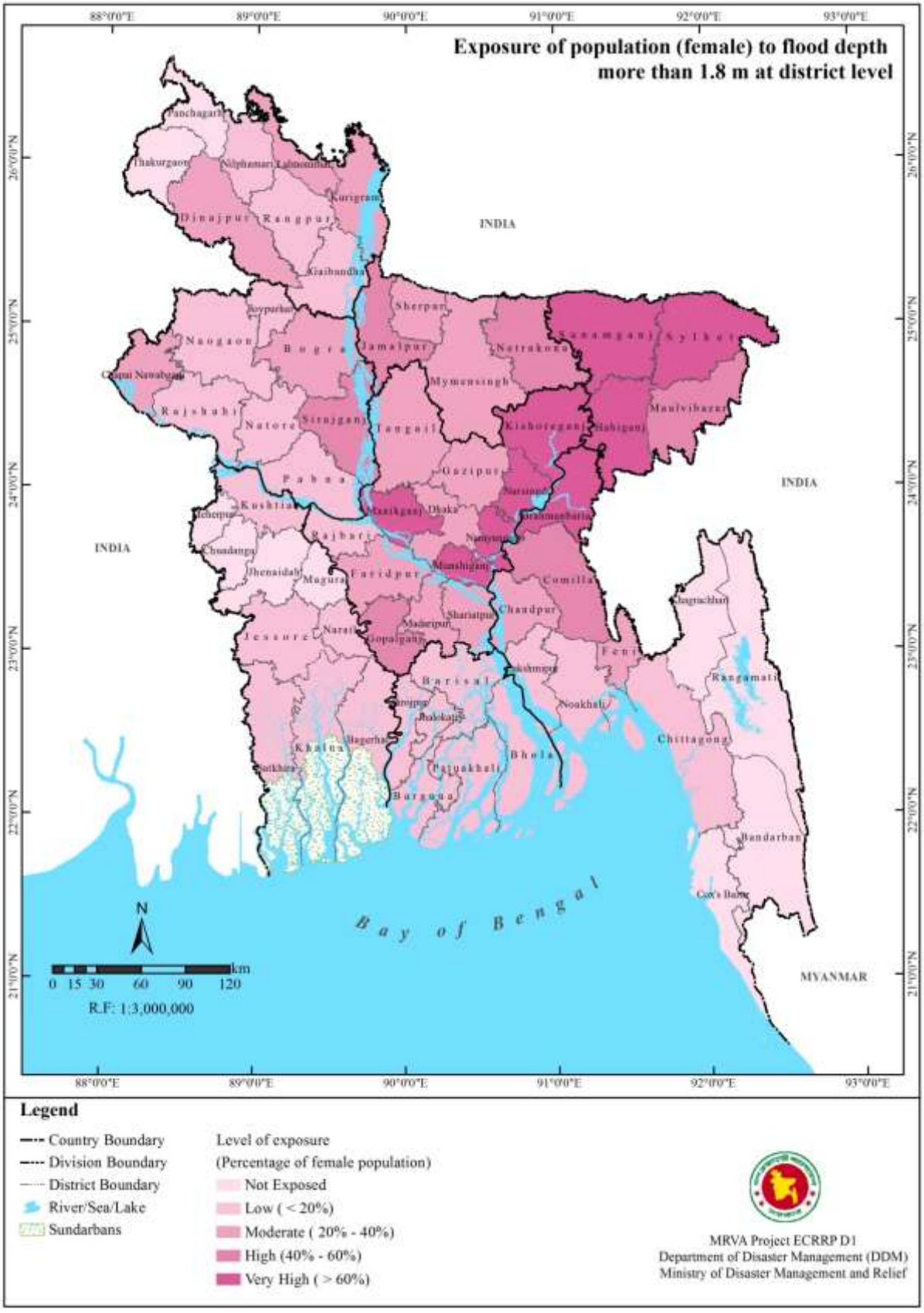


Figure 2.4: Population (female) exposed to flood depth more than 1.8 m at district level

2.1.1.2 Age

As explained in section 1.1.2, population by age is regrouped into 0-14 years, 14 - 59 years and more than 59 years. Population in the age group of 0 - 14 years exposed to flood in each division is given table 2.3 and figure 2.5. Population exposed to flood inundation depth of more than 1.8 m and in the age group of 0 – 14 years at district level is shown in figure 2.6. Population in the age group of 14 - 59 years exposed to flood in each division is given table 2.4 and figure 2.7. Population exposed to flood inundation depth of more than 1.8 m and in the age group of 14 - 59 years at district level is shown in figure 2.8. Population in the age of more than 59 years exposed to flood in each division is given table 2.5 and figure 2.9. Population exposed to flood inundation depth of more than 1.8 m and in the age of > 59 years at district level is shown in figure 2.10.

Table 2.3: Population (0 - 14 years) exposed to flood at division level

Division	Flood inundation Depth (m) / Population exposed					Not affected	Total
	< 0.3	0.3 - 0.9	0.9 - 1.8	1.8 - 3.6	> 3.6		
Barisal	39,816	303,021	699,884	179,959	2,579	1,802,566	3,027,825
Chittagong	218,189	720,775	1,723,628	2,083,682	397,136	5,672,464	10,815,874
Dhaka	301,613	779,268	1,872,635	4,184,922	1,343,531	3,151,973	11,633,941
Khulna	13,719	38,831	128,552	146,343	13,729	4,535,995	4,877,169
Mymensingh	189,685	496,651	979,761	1,246,849	239,252	1,040,836	4,193,034
Rajshahi	74,452	225,939	645,490	1,136,098	176,357	3,627,558	5,885,895
Rangpur	66,310	121,608	179,655	436,430	257,869	4,423,345	5,485,217
Sylhet	28,815	77,833	231,641	1,367,216	1,603,791	654,728	3,964,024
Total	932,599	2,763,926	6,461,246	10,781,500	4,034,244	24,909,465	49,882,979

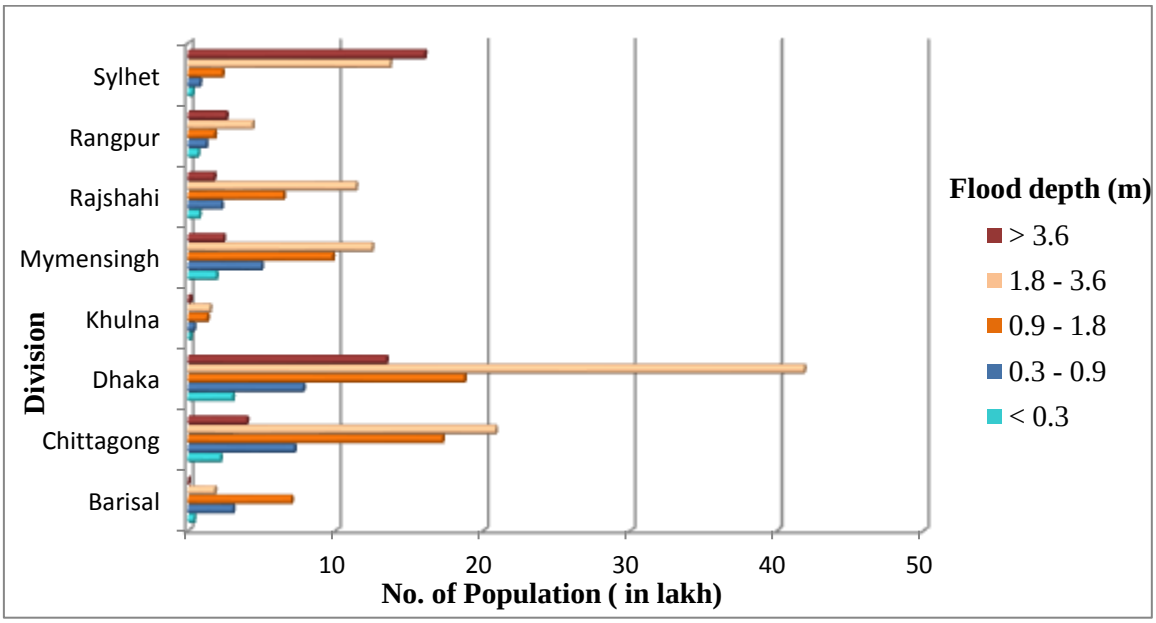


Figure 2.5: Population (0 - 14 years) exposed to flood depth more than 1.8 m at division level

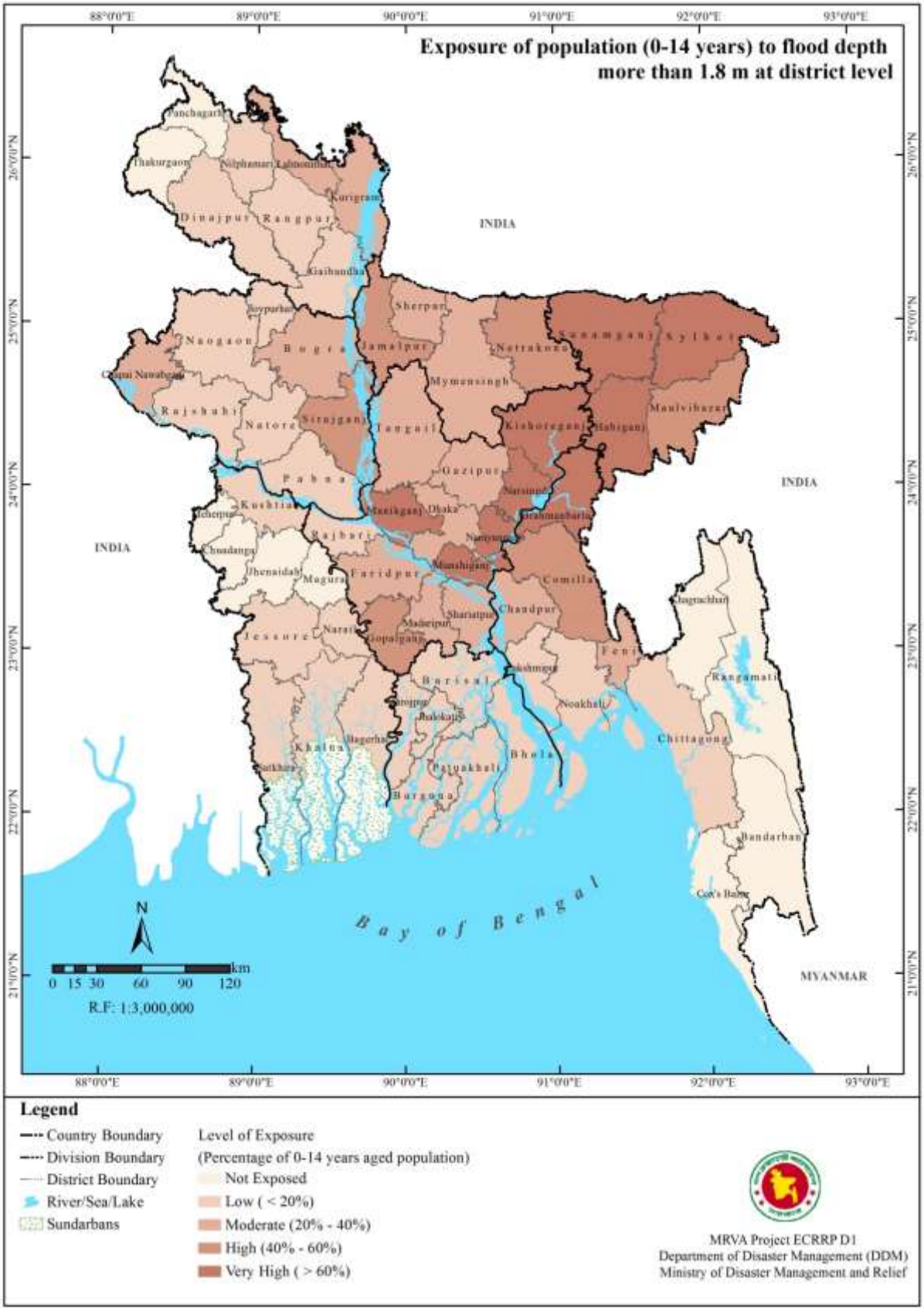


Figure 2.6: Population (0 - 14 years) exposed to different flood depth at district level

Table 2.4: Population (15 – 59 years) exposed to flood at division level

Division	Flood inundation Depth (m) / Population exposed					Not affected	Total
	< 0.3	0.3 - 0.9	0.9 - 1.8	1.8 - 3.6	> 3.6		
Barisal	61,159	459,810	1,106,678	290,347	3,694	2,627,531	4,549,220
Chittagong	299,150	982,945	2,363,998	2,774,630	506,377	8,634,818	15,561,917
Dhaka	653,031	1,517,444	3,291,693	7,363,405	2,587,310	6,941,281	22,354,164
Khulna	27,312	77,581	251,790	269,464	27,384	8,842,617	9,496,148
Mymensingh	268959	695503	1368807	1711887	315621	1516203	5876980
Rajshahi	148,099	442,558	1,203,091	1,982,464	299,601	7,109,902	11,185,716
Rangpur	118,903	215,884	299,006	723,541	424,101	7,339,099	9,120,535
Sylhet	38,334	103,762	304,961	1,793,141	2,092,219	913,293	5,245,711
Total	1,614,947	4,495,488	10,190,025	16,908,879	6,256,308	43,924,745	83,390,391

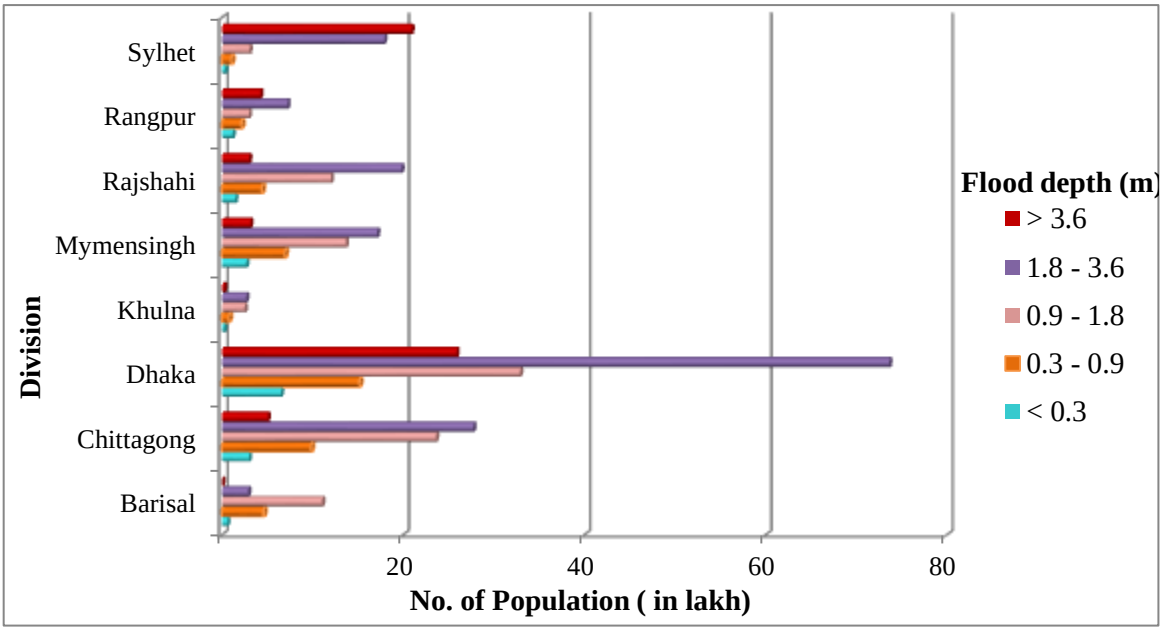


Figure 2.7: Population (15 - 59 years) exposed to different flood depth at division level

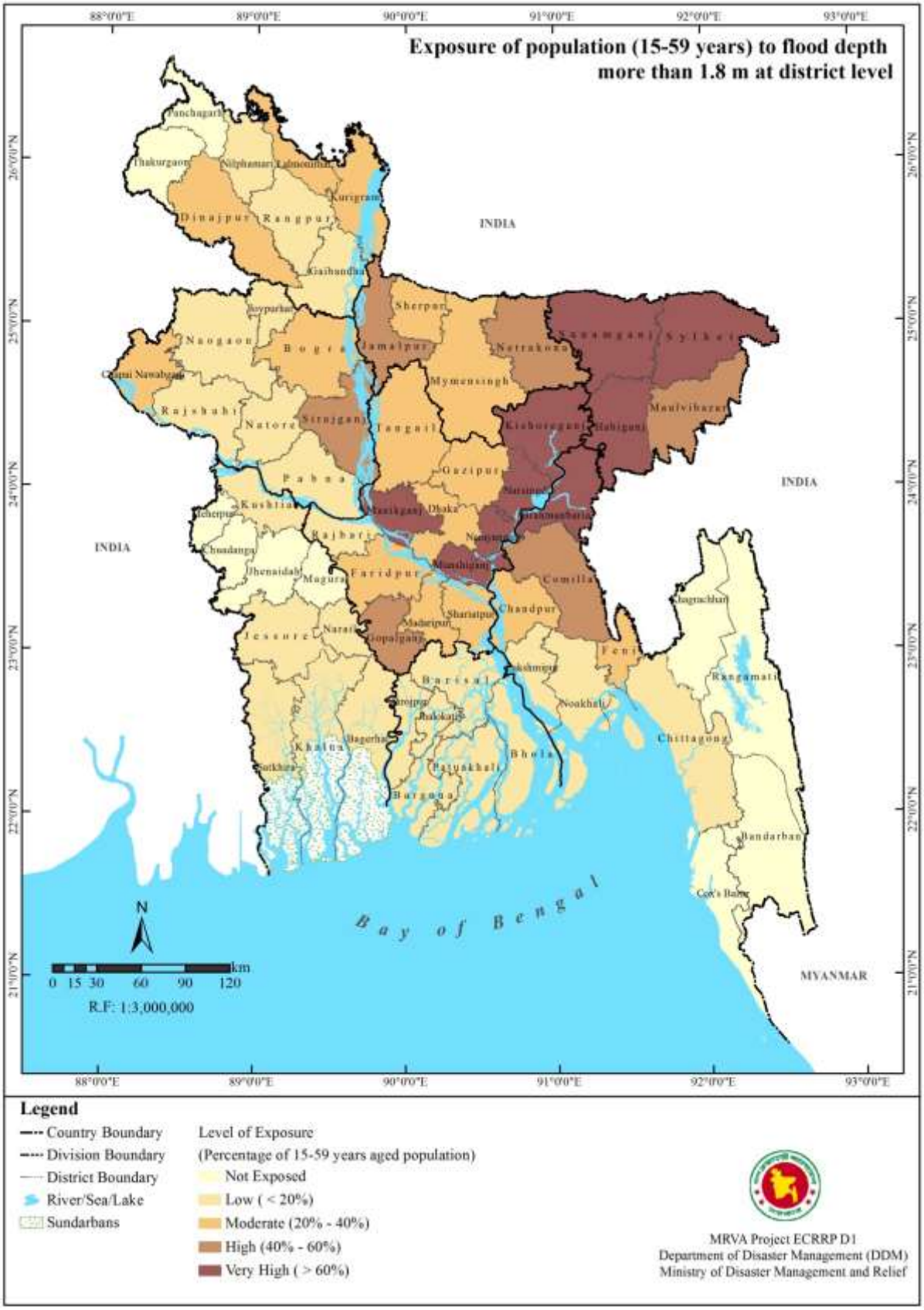


Figure 2.8: Population (15 - 59 years) exposed to flood depth more than 1.8 m at district level

Table 2.5: Population (over 59 years) exposed to flood at division level

Division	Flood inundation depth (m) / population exposed					Not affected	Total
	< 0.3	0.3 - 0.9	0.9 - 1.8	1.8 - 3.6	> 3.6		
Barisal	10,045	75,217	191,306	51,423	583	420,048	748,621
Chittagong	44,668	150,453	369,930	423,477	73,164	983,539	2,045,232
Dhaka	58,820	162,880	408,438	893,111	254,264	667,890	2,445,405
Khulna	3,816	10,936	36,546	38,211	3,965	1,220,969	1,314,443
Mymensingh	42,317	109,980	214,685	271,048	51,224	231,641	920,895
Rajshahi	18,324	55,585	153,630	259,219	38,237	888,047	1,413,042
Rangpur	15,811	28,563	40,104	94,931	54,906	947,688	1,182,004
Sylhet	5,028	13,794	41,443	242,830	280,575	116,812	700,483
Total	198,829	607,410	1,456,083	2,274,251	756,919	5,476,634	10,770,125

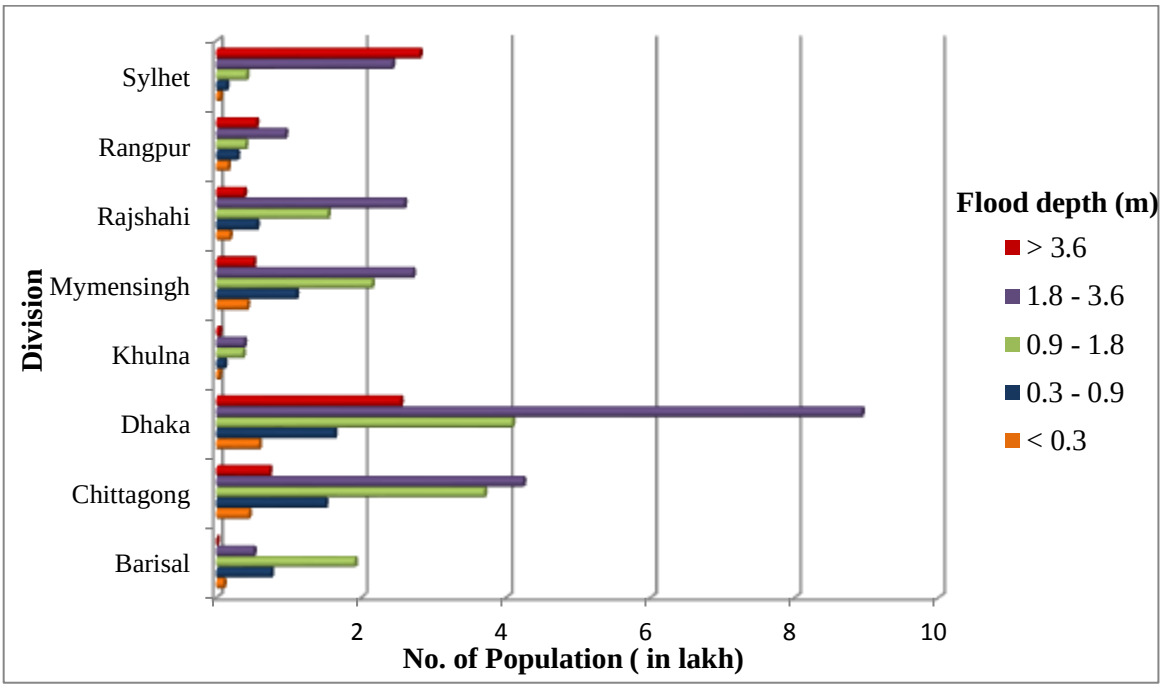


Figure 2.9: Population (over 59 years) exposed to different flood depth at division level

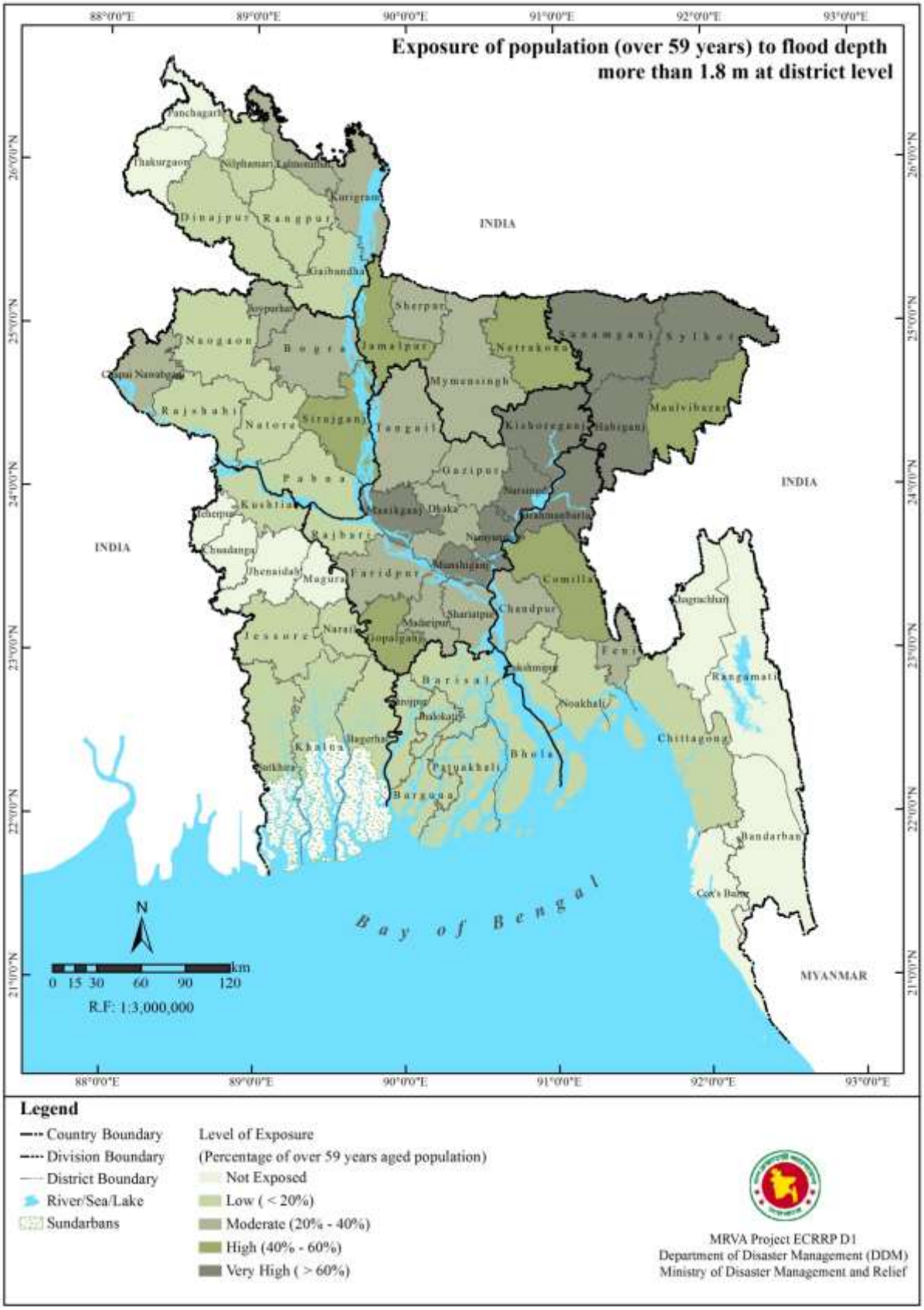


Figure 2.10: Population (over 59 years) exposed to flood depth more than 1.8 m at district level

2.1.1.3 Ethnicity

As the ethnicity population is very less, exposure to flood hazard is not considered.

2.1.1.4 Employment

As explained in section 1.1.4, the employment types considered are agriculture and industry. Population employed in Agriculture sector at division level is given table 2.6 and figure 2.11. Population exposed to flood inundation depth of more than 1.8 m and employed in agriculture sector at district level is shown in figure 2.12. Population employed in industry sector at division level is given table 2.7 and figure 2.13. Population exposed to flood inundation depth of more than 1.8 m and employed in industry sector at district level is shown in figure 2.14.

Table 2.6: Employed (Agriculture) Population exposed to flood at division level

Division	Flood inundation depth (m) / Population exposed					Not affected	Total
	< 0.3	0.3 - 0.9	0.9 - 1.8	1.8 - 3.6	> 3.6		
Barisal	5,552	42,336	74,606	19,136	393	316,011	458,034
Chittagong	28,018	86,684	185,544	296,347	62,536	832,528	1,491,657
Dhaka	35,308	118,745	318,127	650,998	192,773	477,695	1,793,646
Khulna	3,472	8,693	24,533	34,762	4,617	1,172,873	1,248,951
Mymensingh	56,590	151,263	310,037	402,231	82,810	292,479	1,295,410
Rajshahi	21,382	67,205	191,491	346,118	56,430	1,180,660	1,863,286
Rangpur	19,551	36,119	56,477	130,389	78,068	1,325,356	1,645,959
Sylhet	5,617	14,594	42,648	261,245	327,438	128,098	779,640
Total	175,490	525,638	1,203,464	2,141,226	805,066	5,725,699	10,576,583

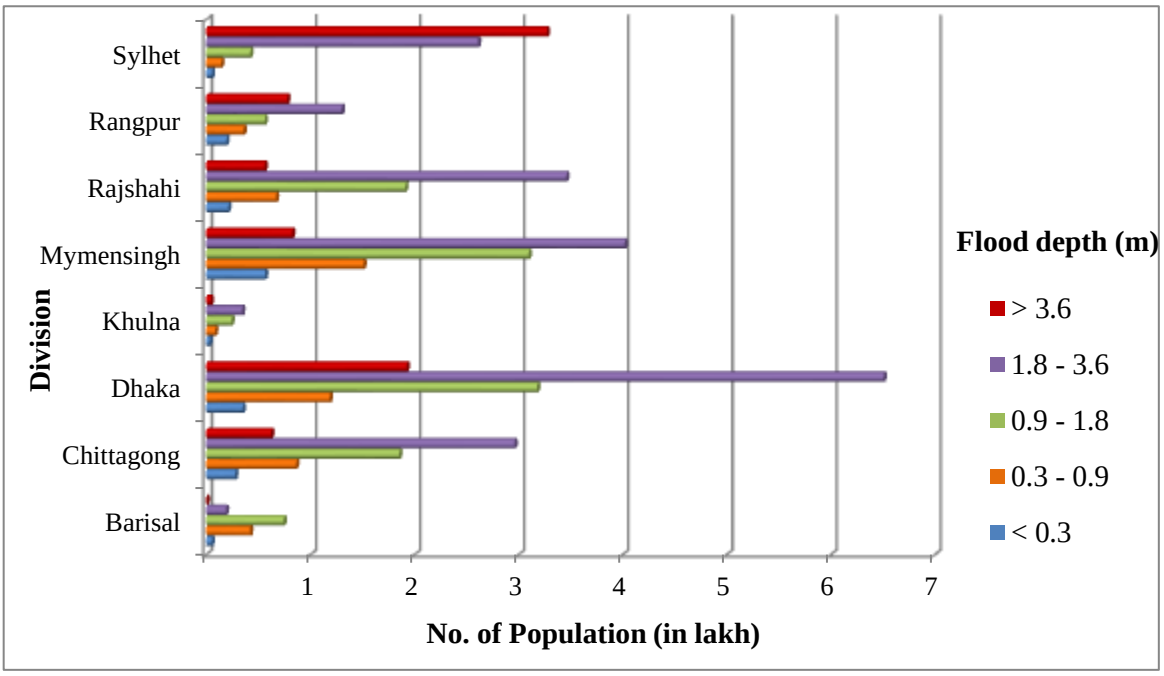


Figure 2.11: Employed (Agriculture) Population exposed to different flood depth at division level

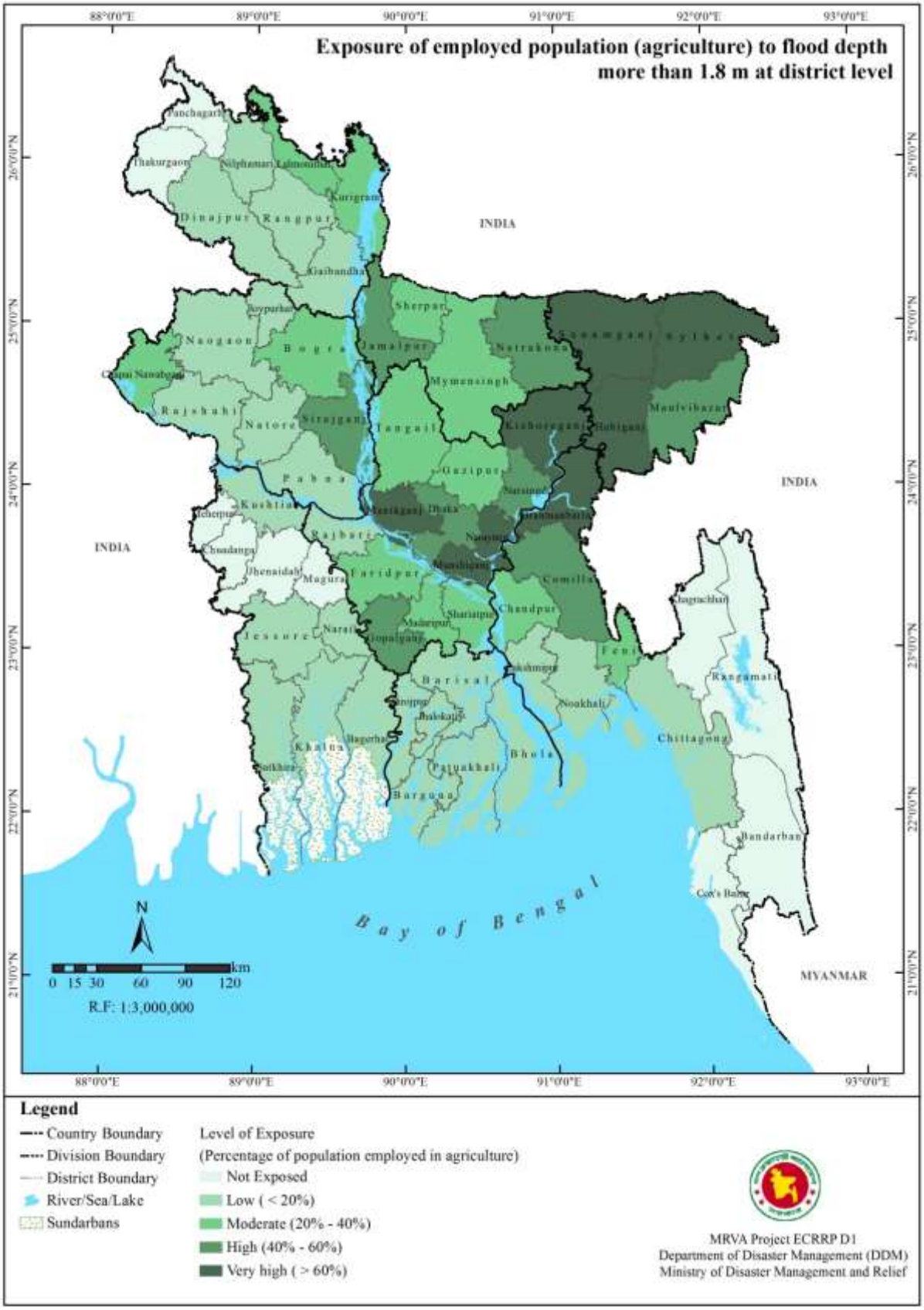


Figure 2.12: Employed (Agriculture) Population exposed to flood depth more than 1.8m at district level

Table 2.7: Employed (Industry) Population exposed to flood at division level

Division	Flood inundation depth (m) /Population exposed					Not affected	Total
	< 0.3	0.3 - 0.9	0.9 - 1.8	1.8 - 3.6	> 3.6		
Barisal	491	3,721	7,507	1,571	30	20,116	33,435
Chittagong	3,153	9,334	22,225	34,738	6,900	148,152	224,502
Dhaka	22,747	47,963	99,057	258,845	97,465	205,945	732,022
Khulna	287	968	4,141	4,926	267	91,699	102,288
Mymensingh	3,830	9,363	17,636	20,592	2,953	25,751	80,125
Rajshahi	2,630	8,217	29,708	55,886	7,303	93,391	197,136
Rangpur	852	1,502	2,091	6,602	3,328	66,169	80,543
Sylhet	765	1,896	4,536	26,540	33,684	19,491	86,912
Total	34,755	82,963	186,901	409,700	151,930	670,713	1,536,963

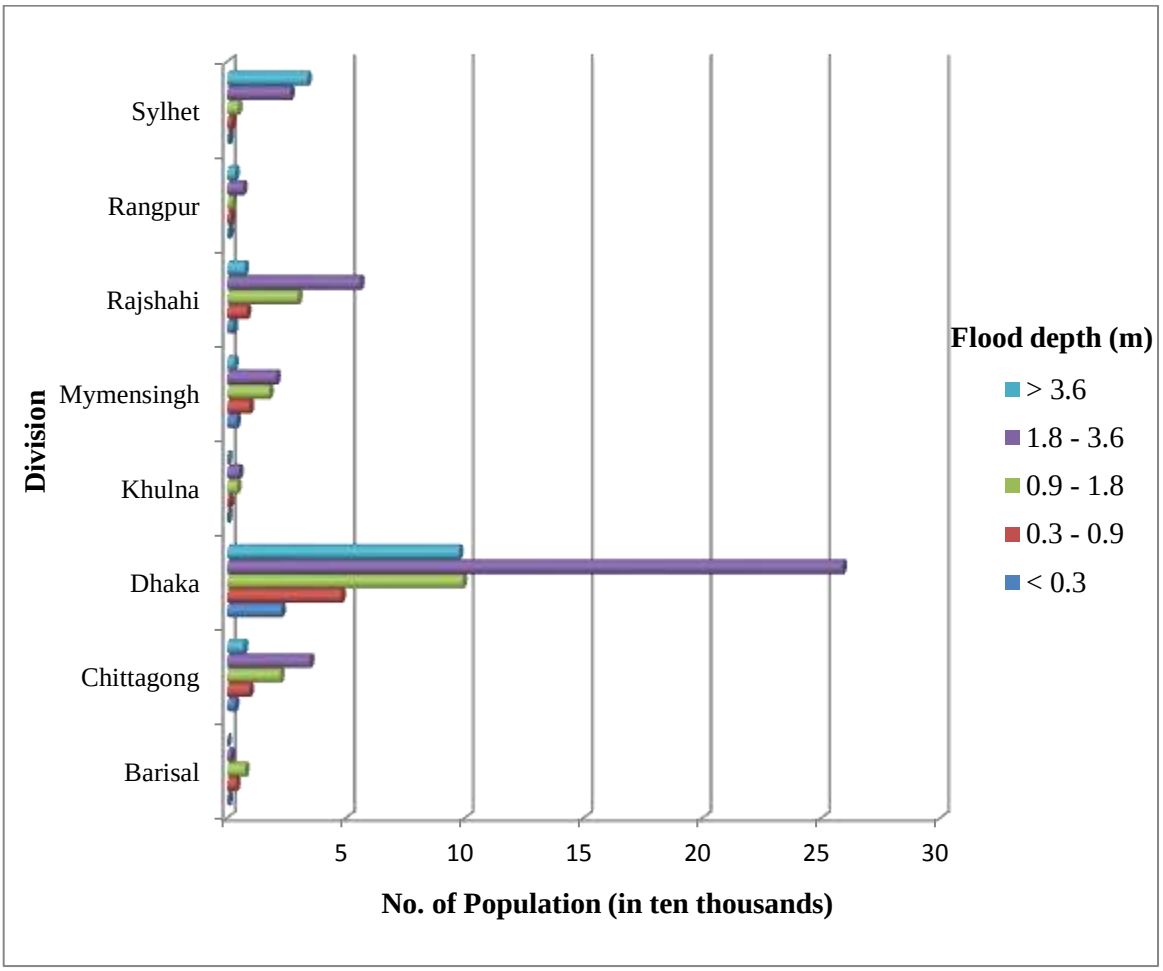


Figure 2.13: Employed (Industry) Population exposed to different flood depth at division level

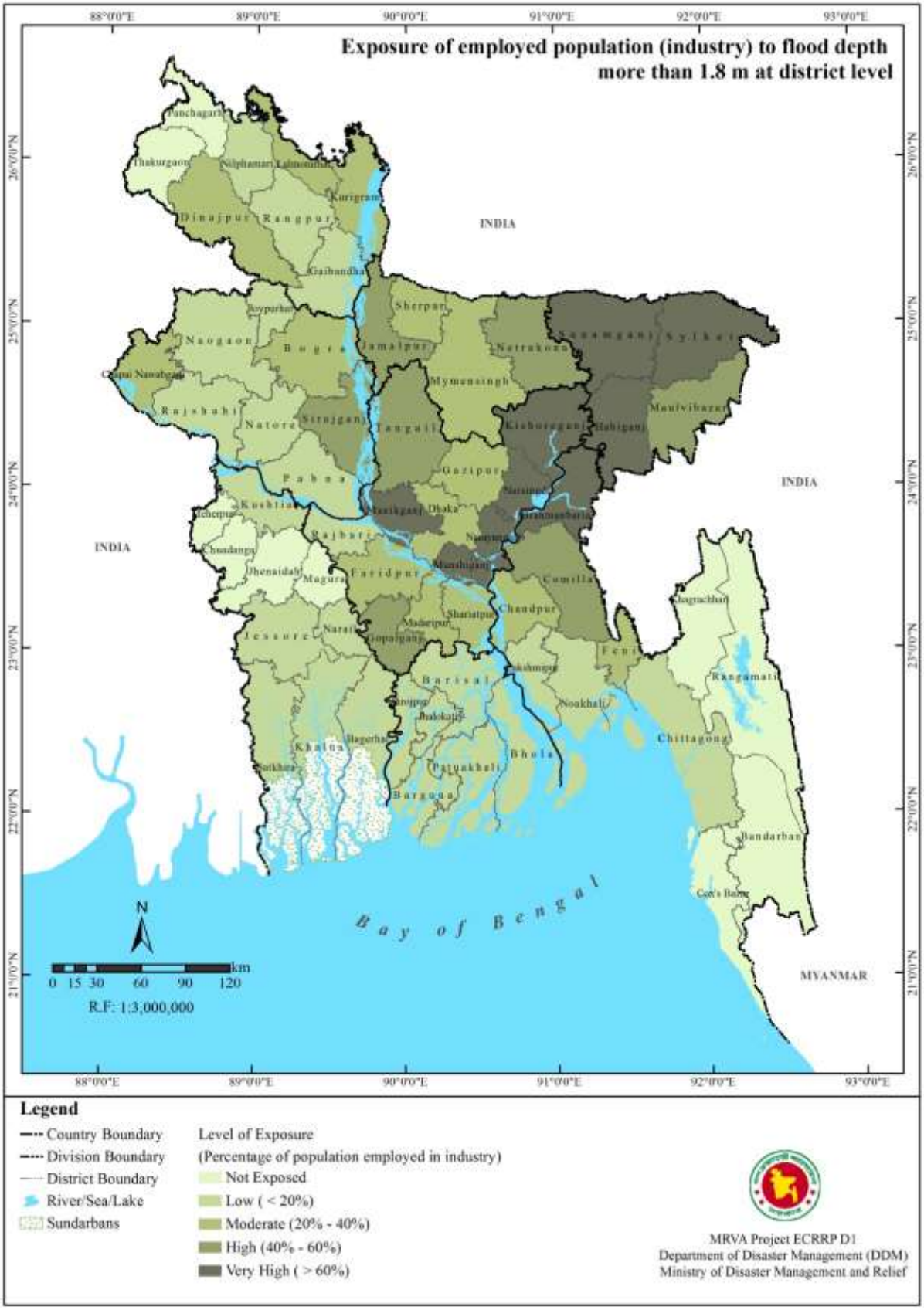


Figure 2.14: Employed (Industry) Population exposed to flood depth more than 1.8 m at district level

2.1.1.5 Education

Literate Population (male) exposed to flood is given in table 2.8 and figure 2.15. Literate Population (female) exposed to flood is given in table 2.9 and figure 2.16.

Table 2.8: Literate Population (male) exposed to flood at division level

Division	Flood inundation depth (m) Vs Population exposed					Not affected	Total
	< 0.3	0.3 - 0.9	0.9 - 1.8	1.8 - 3.6	> 3.6		
Barisal	33,247	248,123	626,073	164,863	1,893	1,273,714	2,347,912
Chittagong	143,721	478,568	1,179,505	1,315,232	237,119	4,007,389	7,361,533
Dhaka	352,304	779,232	1,607,197	3,559,860	1,303,504	3,731,572	11,333,670
Khulna	12,509	36,502	120,544	122,125	11,501	4,062,809	4,365,990
Mymensingh	108,242	276,807	534,269	663,756	117,924	623,563	2,324,561
Rajshahi	65,860	193,144	512,038	806,513	115,940	2,983,728	4,677,222
Rangpur	52,035	93,988	123,663	310,956	185,501	3,201,232	3,967,376
Sylhet	17,020	46,465	134,914	785,005	907,222	412,230	2,302,855
Total	784,939	2,152,829	4,838,202	7,728,310	2,880,604	20,296,236	38,681,119

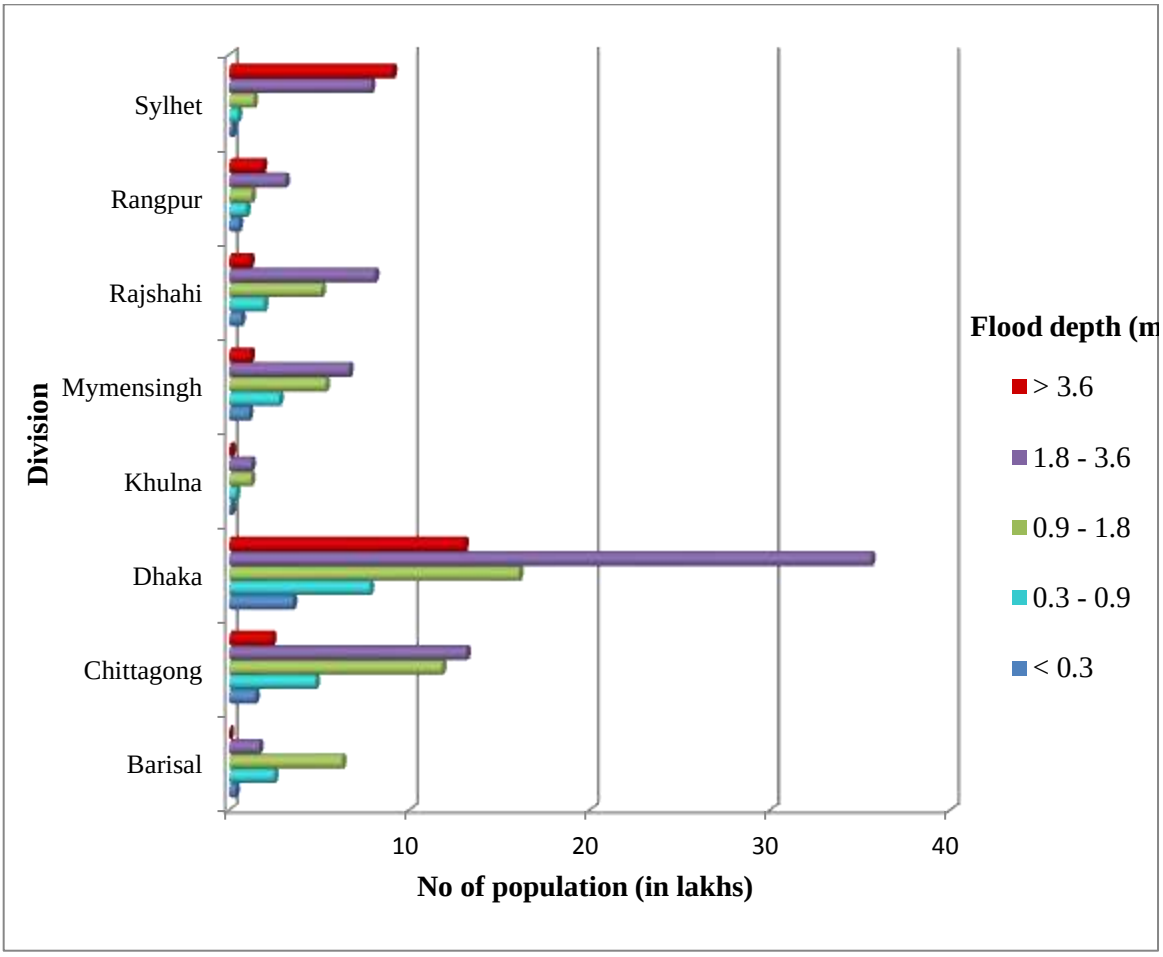


Figure 2.15: Literate Population (male) exposed to different flood depth at division level

Table 2.9 : Literate Population (female) exposed to flood at division level

Division	Flood inundation depth (m) / Population exposed					Not affected	Total
	< 0.3	0.3 - 0.9	0.9 - 1.8	1.8 - 3.6	> 3.6		
Barisal	34,017	253,887	637,842	167,711	1,935	1,265,421	2,360,813
Chittagong	155,875	526,164	1,315,393	1,387,433	242,486	3,705,540	7,332,891
Dhaka	288,490	665,537	1,442,535	3,210,152	1,099,639	2,987,883	9,694,235
Khulna	11,428	33,213	109,540	110,797	10,236	3,704,599	3,979,814
Mymensingh	101,297	259,628	498,126	620,027	110,108	576,707	2,165,893
Rajshahi	57,068	167,981	446,976	715,118	106,269	2,718,247	4,211,659
Rangpur	45,581	81,744	94,190	256,188	160,395	2,751,611	3,389,709
Sylhet	15,680	43,184	125,914	734,722	838,820	374,359	2,132,679
Total	709,435	2,031,339	4,670,517	7,202,148	2,569,887	18,084,367	35,267,693

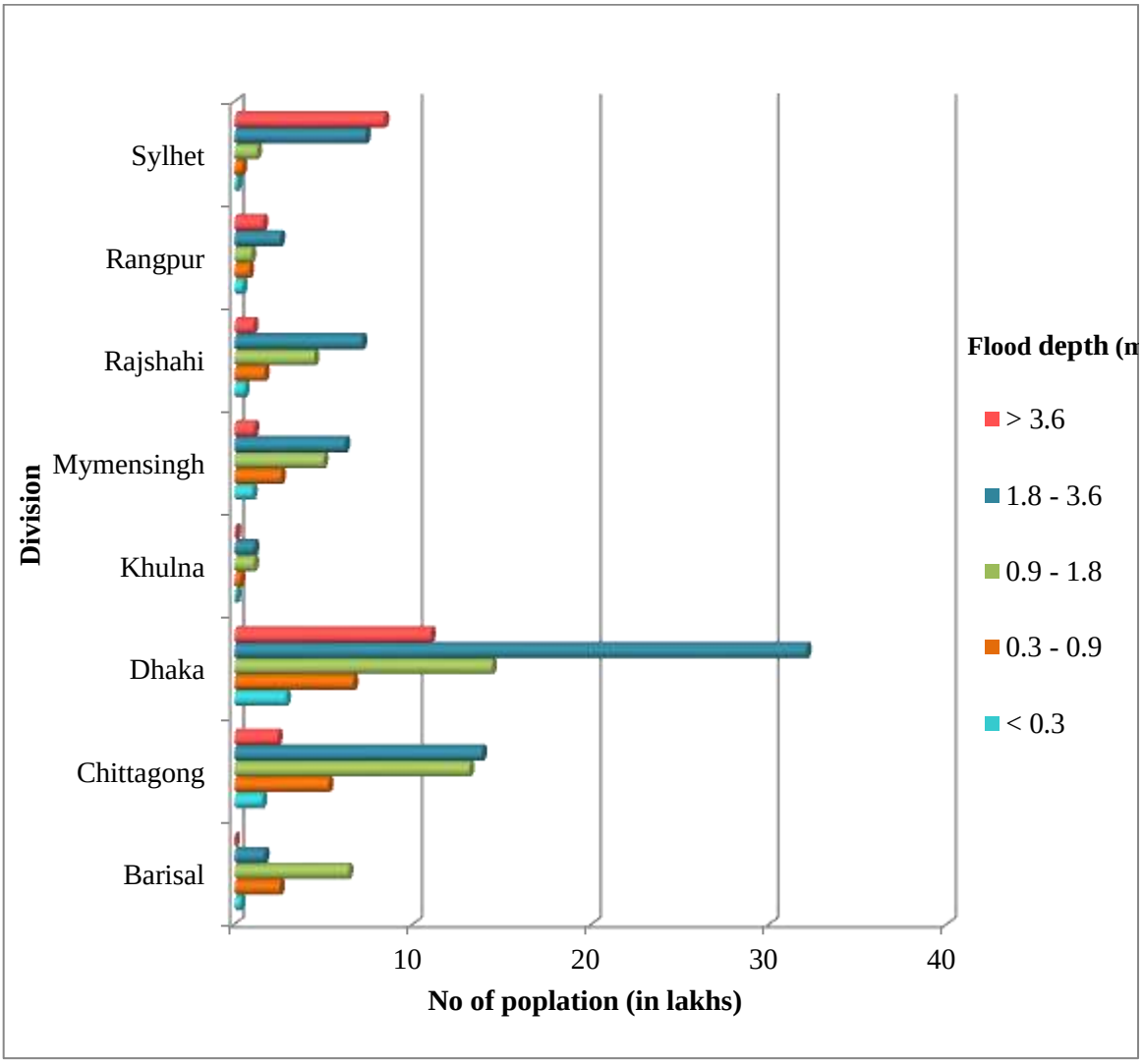


Figure 2.16: Literate Population (female) exposed to different flood depth at division level

2.1.1.6 Disability

Details of population with disability are given in section 1.1.6. Disabilities of population mentioned are Speech, Vision, Hearing, Physical, Mental, and Autism. Population with disability of Vision exposed to flood at division level is given table 2.10 and figure 2.17. Population with disability of Physical exposed to flood at division level is given table 2.11 and figure 2.18. Population with disability of Mental exposed to flood at division level is given table 2.12 and figure 2.19. Population with disability of Autism exposed to flood at division level is given table 2.13 and figure 2.20. Disable population exposed to flood inundation depth more than 1.8 m at district level is shown in figure 2.21.

Table 2.10: Disable Population (Vision) exposed to flood at division level

Division	Flood depth (m) / Population exposed					Not affected	Total
	< 0.3	0.3 - 0.9	0.9 - 1.8	1.8 - 3.6	> 3.6		
Barisal	271	2,144	5,619	1,528	20	17,163	26,746
Chittagong	1,342	4,396	12,158	12,527	2,312	38,285	71,022
Dhaka	1,971	5,331	13,184	28,743	8,685	22,809	80,723
Khulna	110	327	1,290	1,436	122	41,857	45,141
Mymensingh	1,423	3,631	7,112	9,144	2,006	6,934	30,251
Rajshahi	809	2,442	7,003	11,499	1,771	35,847	59,370
Rangpur	697	1,225	1,691	4,017	2,221	41,500	51,352
Sylhet	203	543	1,677	10,745	12,256	4,912	30,336
Total	6,827	20,040	49,735	79,639	29,393	209,307	394,941

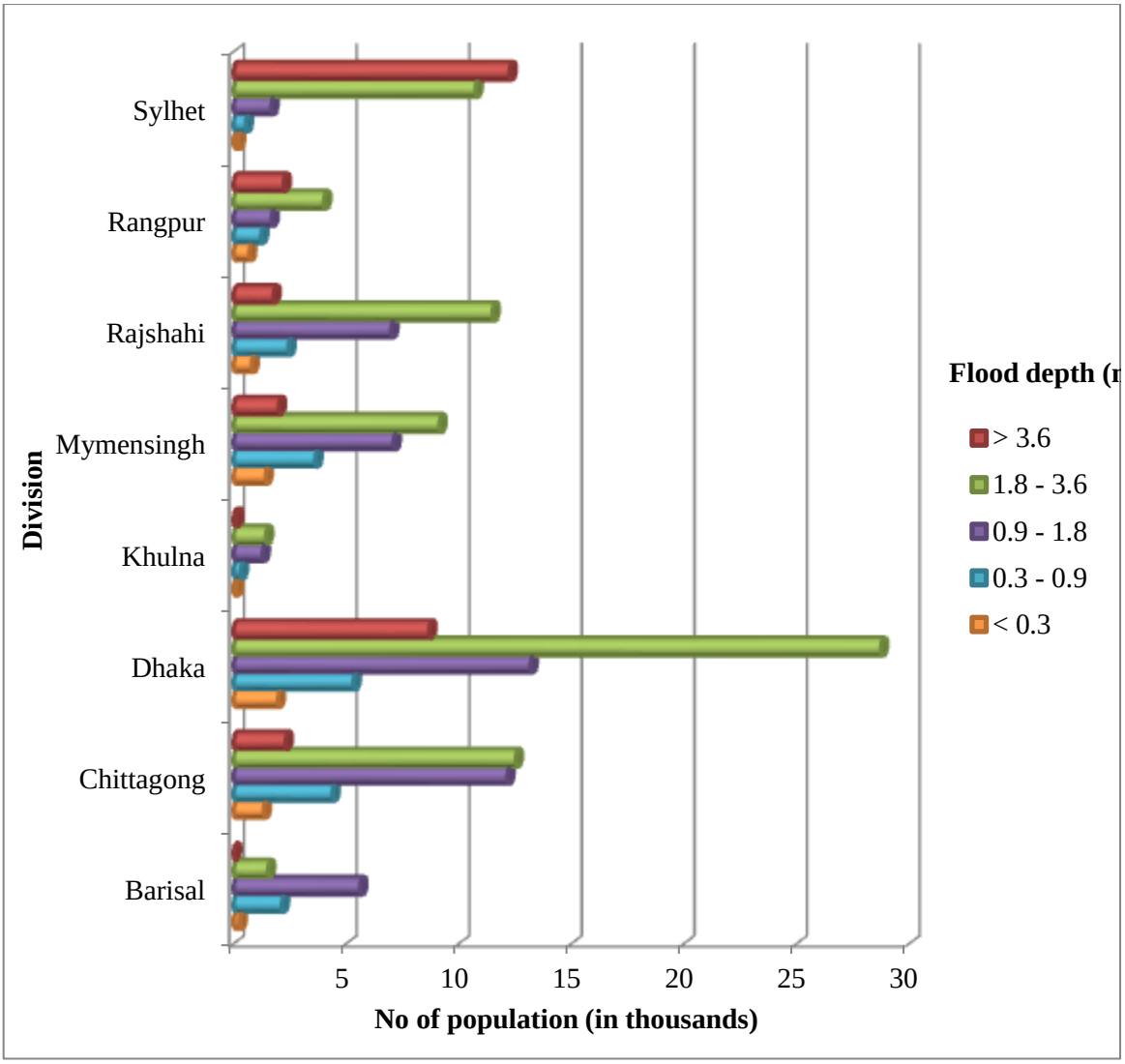


Figure 2.17: Disable Population (Vision) exposed to different flood depth at division level

Table 2.11: Disable Population (Physical) exposed to flood at division level

Division	Flood inundation depth (m) / Population exposed					Not affected	Total
	< 0.3	0.3 - 0.9	0.9 - 1.8	1.8 - 3.6	> 3.6		
Barisal	569	4,457	13,004	3,695	40	34,663	56,427
Chittagong	3,057	10,994	28,869	28,399	4,489	78,286	154,095
Dhaka	3,886	10,268	25,104	55,955	17,106	46,304	158,623
Khulna	284	819	2,769	2,942	317	96,071	103,202
Mymensingh	2,750	6,989	13,594	17,200	3,387	14,099	58,018
Rajshahi	1,409	4,277	11,853	19,664	3,073	72,484	112,761
Rangpur	1,316	2,378	3,264	7,571	4,237	80,939	99,705
Sylhet	360	987	3,042	18,770	21,199	8,620	52,977
Total	13,631	41,168	101,500	154,197	53,848	431,465	795,808

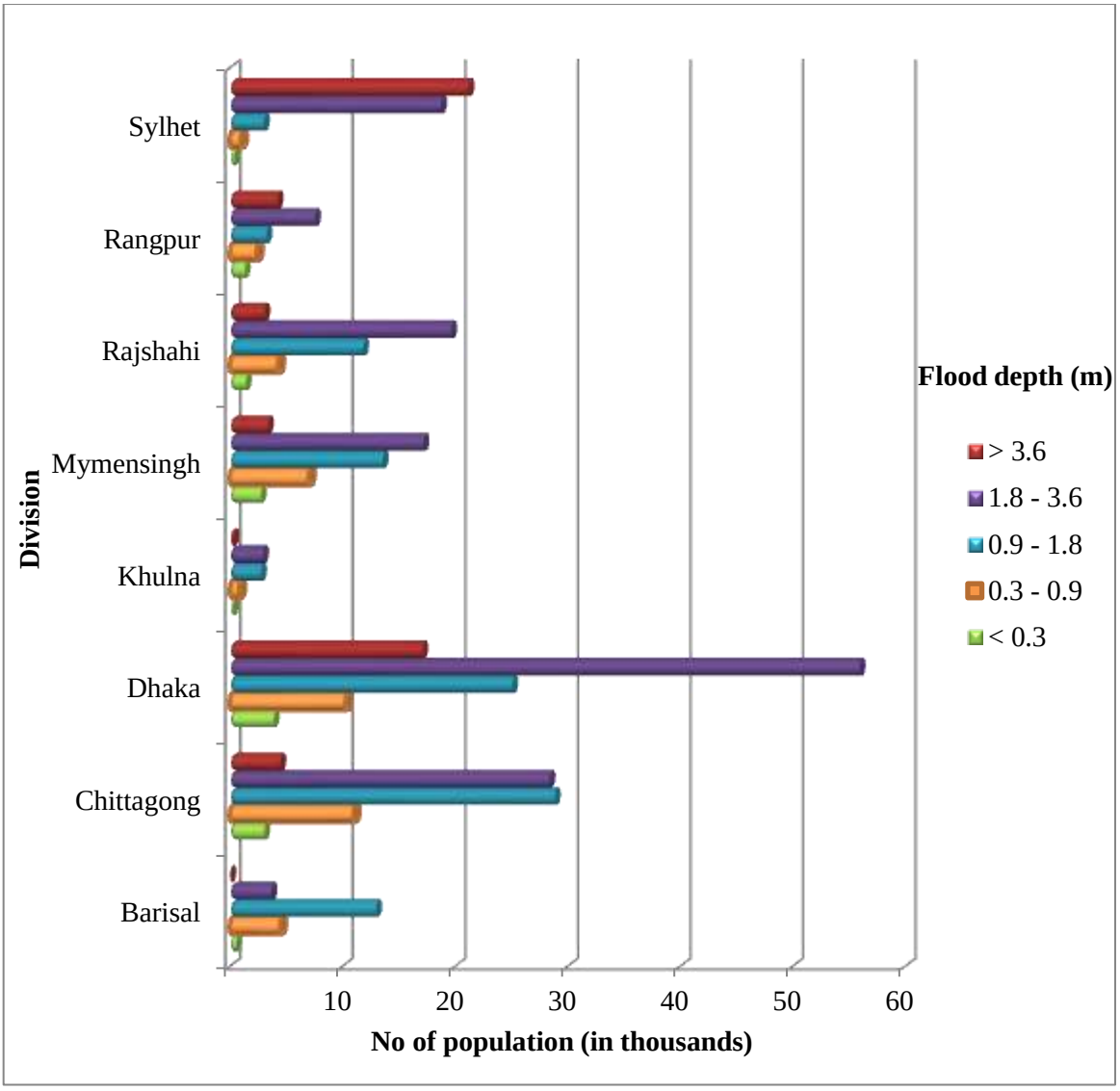


Figure 2.18: Disable Population (Physical) exposed to different flood depth at division level

Table 2.12: Disable Population (Mental) exposed to flood at division level

Division	Flood inundation depth (m) / Population exposed					Not affected	Total
	< 0.3	0.3 - 0.9	0.9 - 1.8	1.8 - 3.6	> 3.6		
Barisal	181	1,335	3,541	968	10	8,529	14,564
Chittagong	892	3,022	7,688	7,747	1,287	26,688	47,324
Dhaka	1,401	3,670	8,873	19,188	6,086	15,984	55,203
Khulna	111	297	875	852	94	29,626	31,856
Mymensingh	955	2,469	4,875	6,156	1,064	5,447	20,966
Rajshahi	487	1,481	3,989	6,656	1,017	23,690	37,320
Rangpur	377	679	975	2,423	1,404	24,742	30,599
Sylhet	131	360	1,097	6,506	7,383	3,133	18,611
Total	4,537	13,313	31,911	50,497	18,346	137,839	256,443

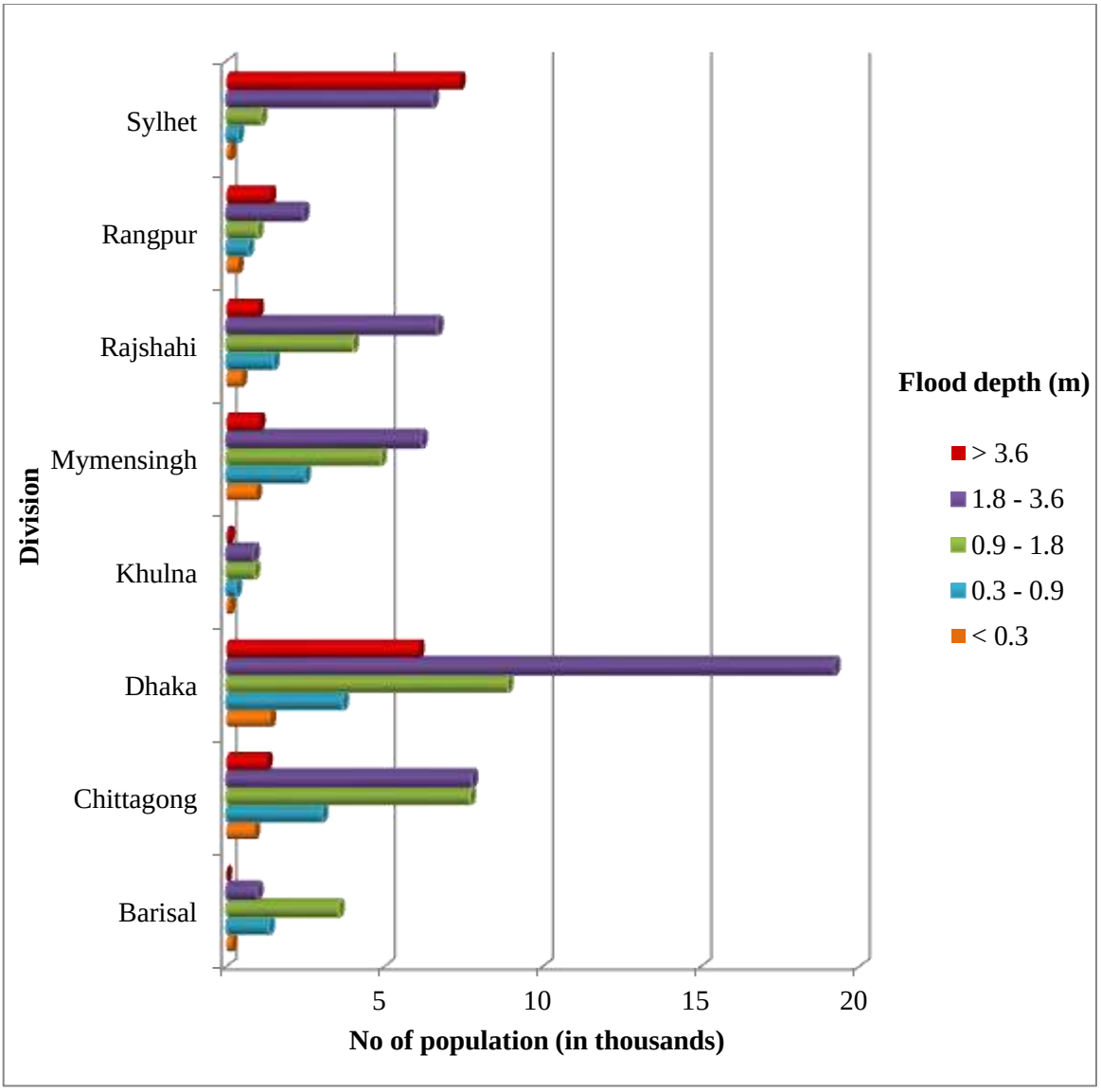


Figure 2.19: Disable Population (Mental) exposed to different flood depth at division level

Table 2.13: Disable Population (Autism) exposed to flood at division level

Division	Flood inundation depth (m) /Population exposed					Not affected	Total
	< 0.3	0.3 - 0.9	0.9 - 1.8	1.8 - 3.6	> 3.6		
Barisal	111	838	1,997	521	7	4,851	8,325
Chittagong	562	1,854	4,451	5,177	975	15,575	28,594
Dhaka	1,009	2,430	5,540	12,510	4,373	10,563	36,425
Khulna	45	127	415	455	45	14,492	15,578
Mymensingh	501	1,302	2,563	3,229	605	2,788	10,989
Rajshahi	240	704	1,945	3,139	511	10,874	17,414
Rangpur	180	319	511	1,151	635	12,976	15,772
Sylhet	72	195	578	3,403	3,976	1,685	9,910
Total	2,719	7,769	18,000	29,585	11,129	73,804	143,007

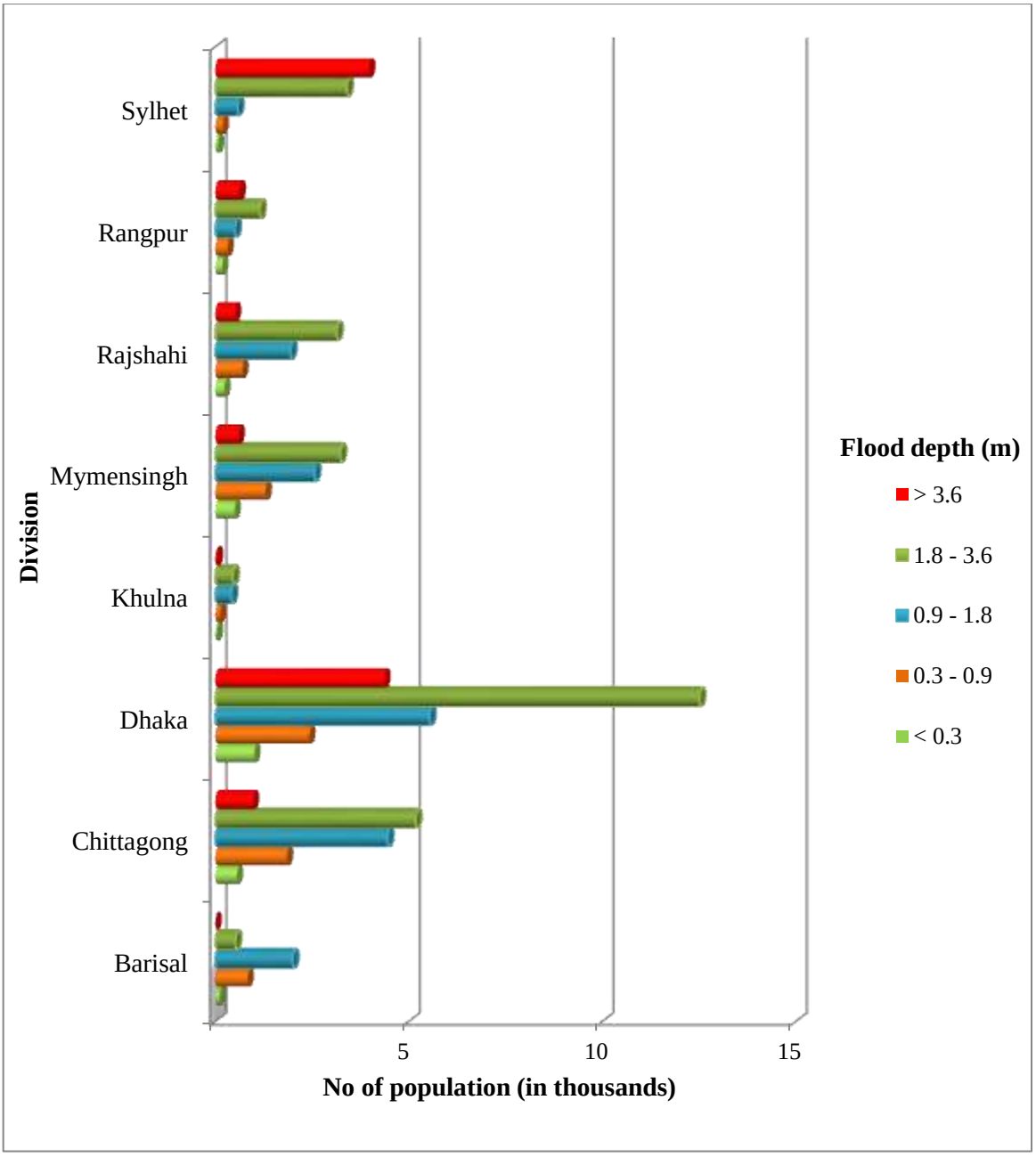


Figure 2.20: Disable Population (Autism) exposed to different flood depth at division level

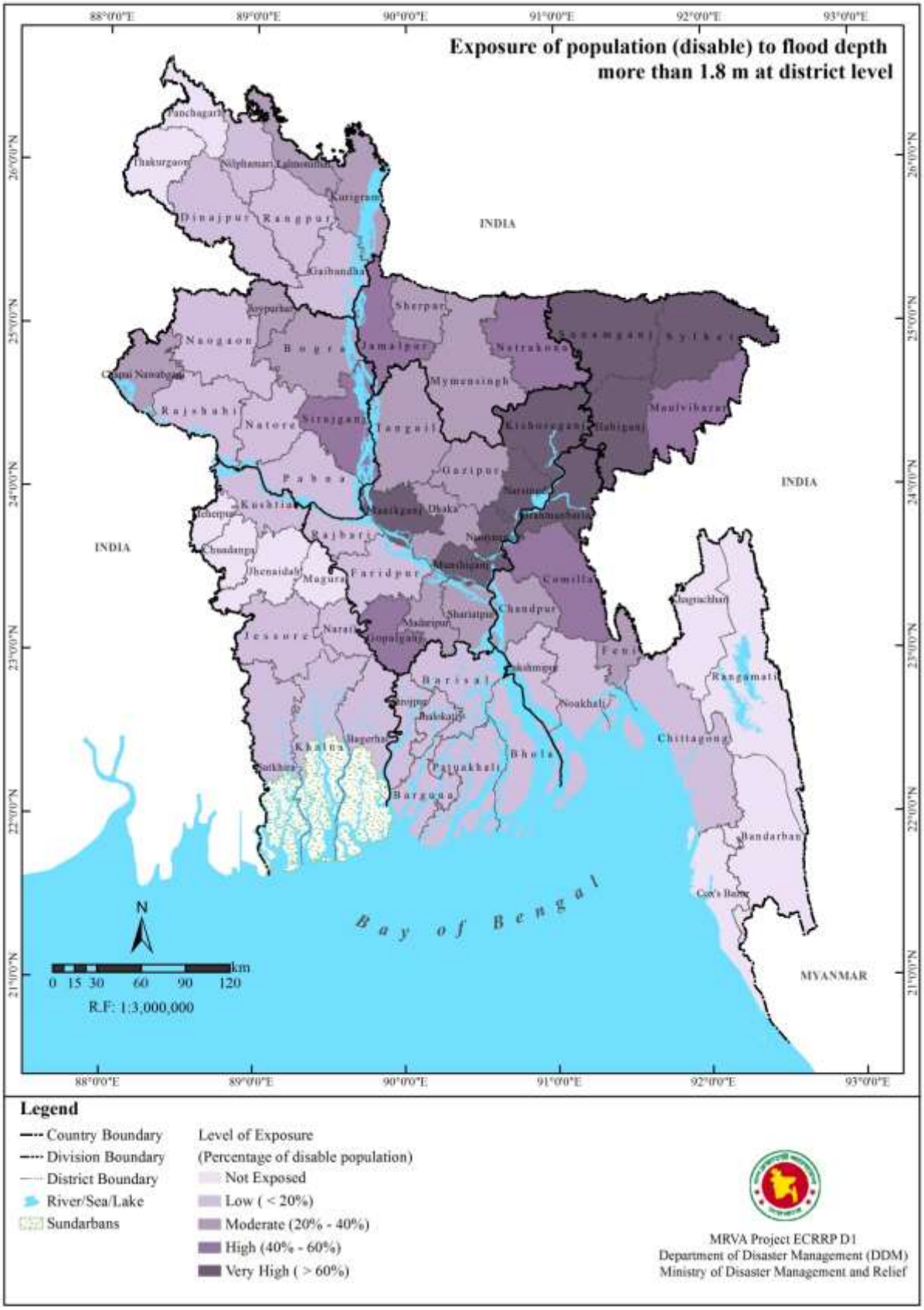


Figure 2.21: Disable Population exposed to flood depth more than 1.8 m at district level

2.1.1.7 Poverty

The exposure of population in poverty (extreme poor) to flood at division level is provided in table 2.14 and figure 2.22. At district level shown in figure 2.23.

Table 2.14: Population (extreme poor) exposed to flood at division level

Division	Flood inundation depth (m) / Population exposed					Not affected	Total
	< 0.3	0.3 - 0.9	0.9 - 1.8	1.8 - 3.6	> 3.6		
Barisal	42,313	307,680	640,235	170,720	2,291	963,296	2,126,534
Chittagong	102,042	295,745	761,243	982,225	166,467	1,476,252	3,783,975
Dhaka	88,978	284,308	813,931	1,682,480	444,041	1,130,961	4,444,700
Khulna	11,085	30,115	89,062	89,769	7,609	2,357,197	2,584,837
Mymensingh	152,420	397,608	788,959	984,906	158,793	789,731	3,272,418
Rajshahi	28,768	80,791	260,349	550,056	93,287	1,631,917	2,645,168
Rangpur	44,531	84,284	153,842	382,777	196,029	3,146,011	4,007,474
Sylhet	14,750	37,476	104,543	669,665	813,381	357,747	1,997,561
Total	484,887	1,518,009	3,612,164	5,512,597	1,881,898	11,853,112	24,862,667

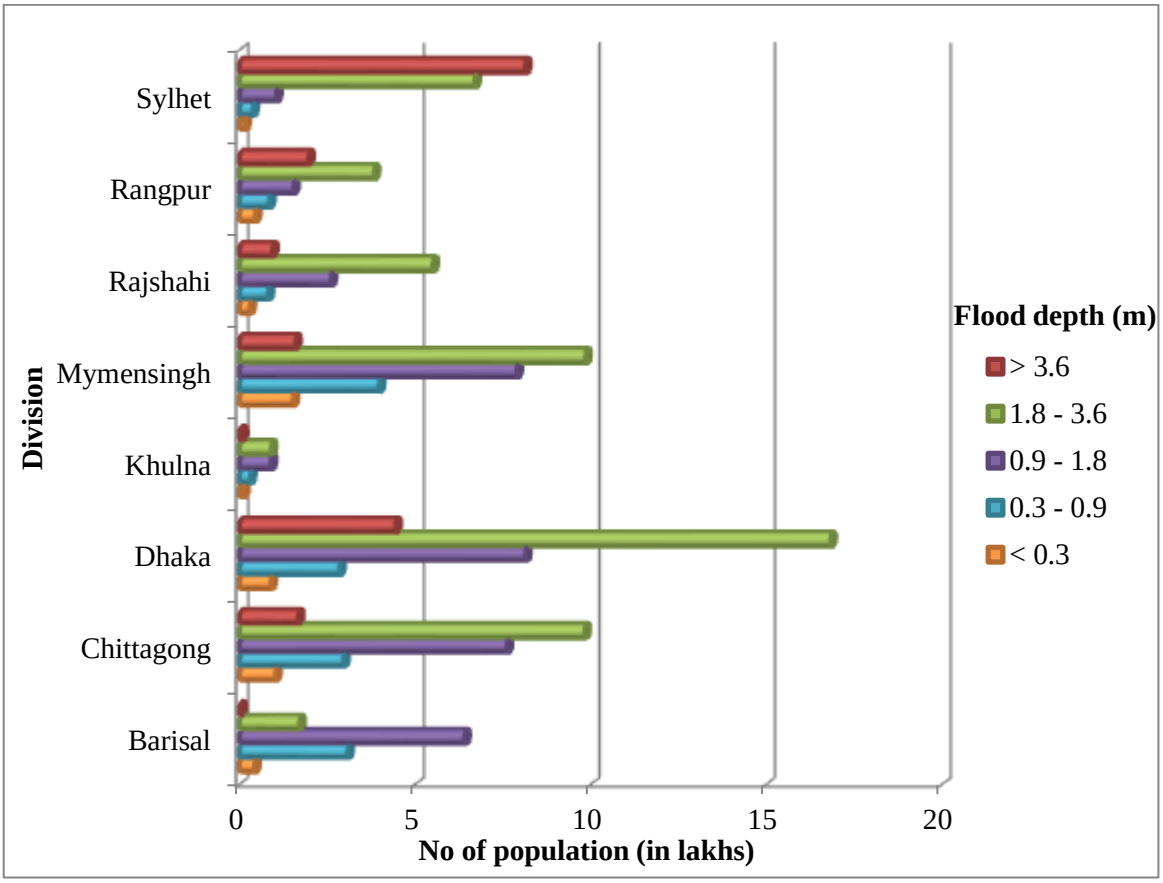


Figure 2.22: Population (extreme poor) exposed to different flood depth at division level

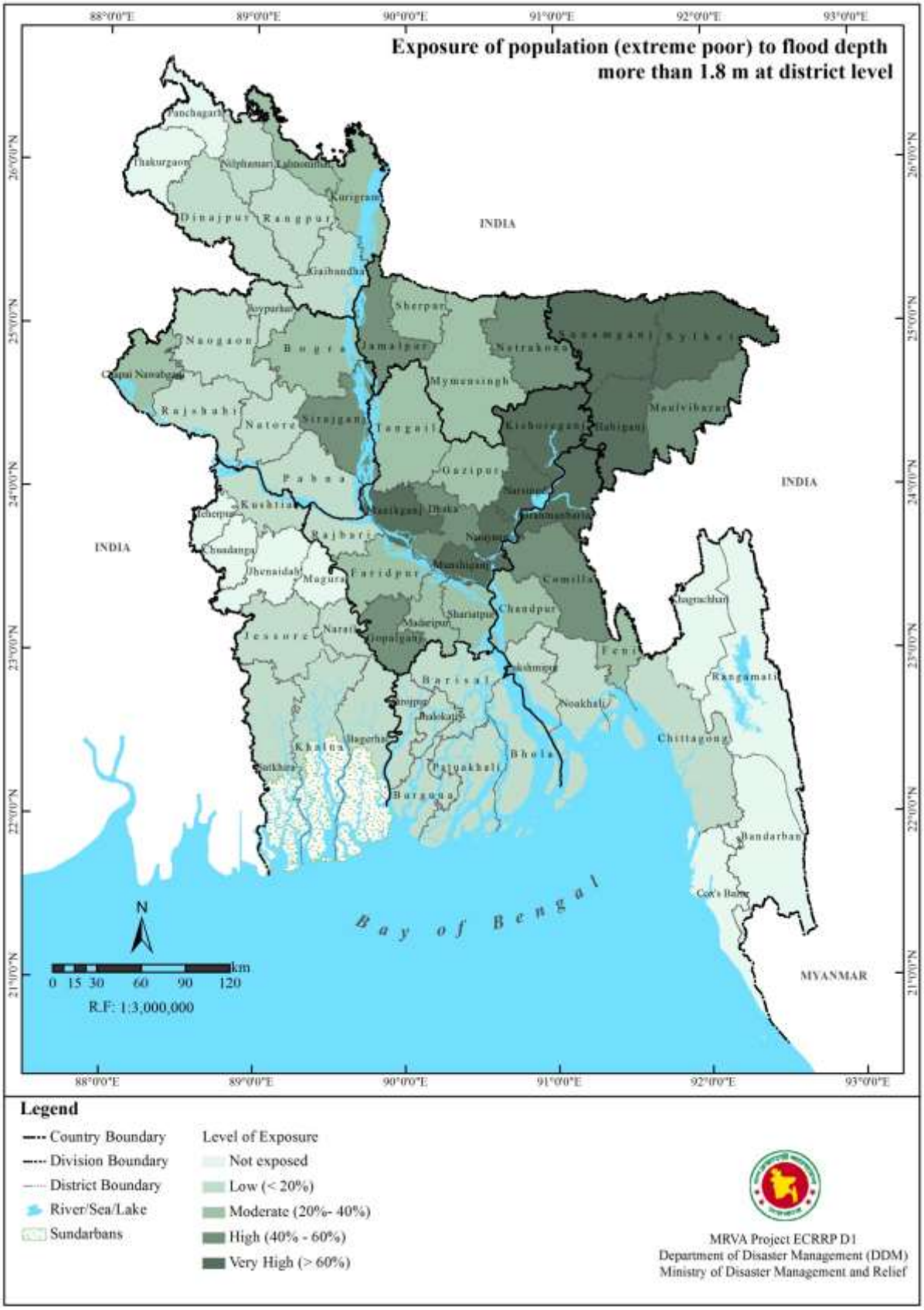


Figure 2.23: Population (extreme poor) exposed to different flood depth at district level

The exposure of population in poverty (poor) to flood at division level is provided in table 2.15 and figure 2.24. At district level shown in figure 2.25.

Table 2.15: Population (poor) exposed to flood at division level

Division	Flood inundation depth (m) / Population exposed					Not affected	Total
	< 0.3	0.3 - 0.9	0.9 - 1.8	1.8 - 3.6	> 3.6		
Barisal	58,947	431,274	914,159	243,305	3253	1,544,782	3,195,719
Chittagong	181,788	537,213	1,369,982	1,799,608	31,7193	3,175,427	7,381,212
Dhaka	208,219	592,260	1,577,819	3,387,796	980,216	2,331,029	9,077,338
Khulna	18,765	51,890	158,008	155,540	12,819	4,605,549	5,002,570
Mymensingh	241,156	626,326	1,236,687	1,548,205	26,2011	1,279,237	5,193,623
Rajshahi	58,490	167,784	511,075	1,017,251	168,524	3,145,916	5,069,040
Rangpur	78,812	146,999	245,740	596,575	325,964	5,234,005	6,628,094
Sylhet	18,328	46,723	130,915	836,109	1,010,605	441,392	2,484,072
Total	864,505	2,600,469	6,144,385	9,584,389	3,080,585	21,757,337	44,031,668

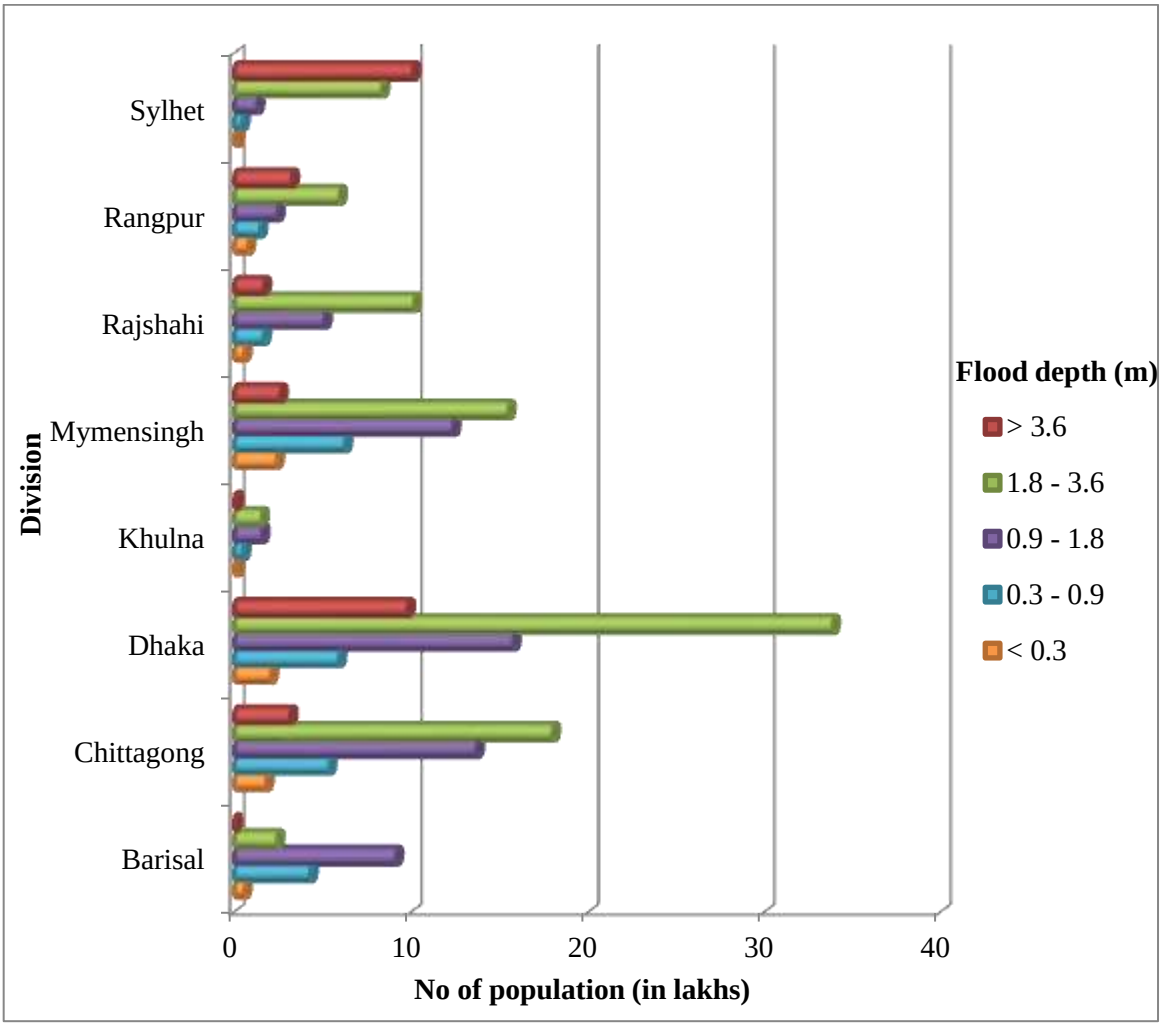


Figure 2.24: Population (poor) exposed to different flood depth at division level

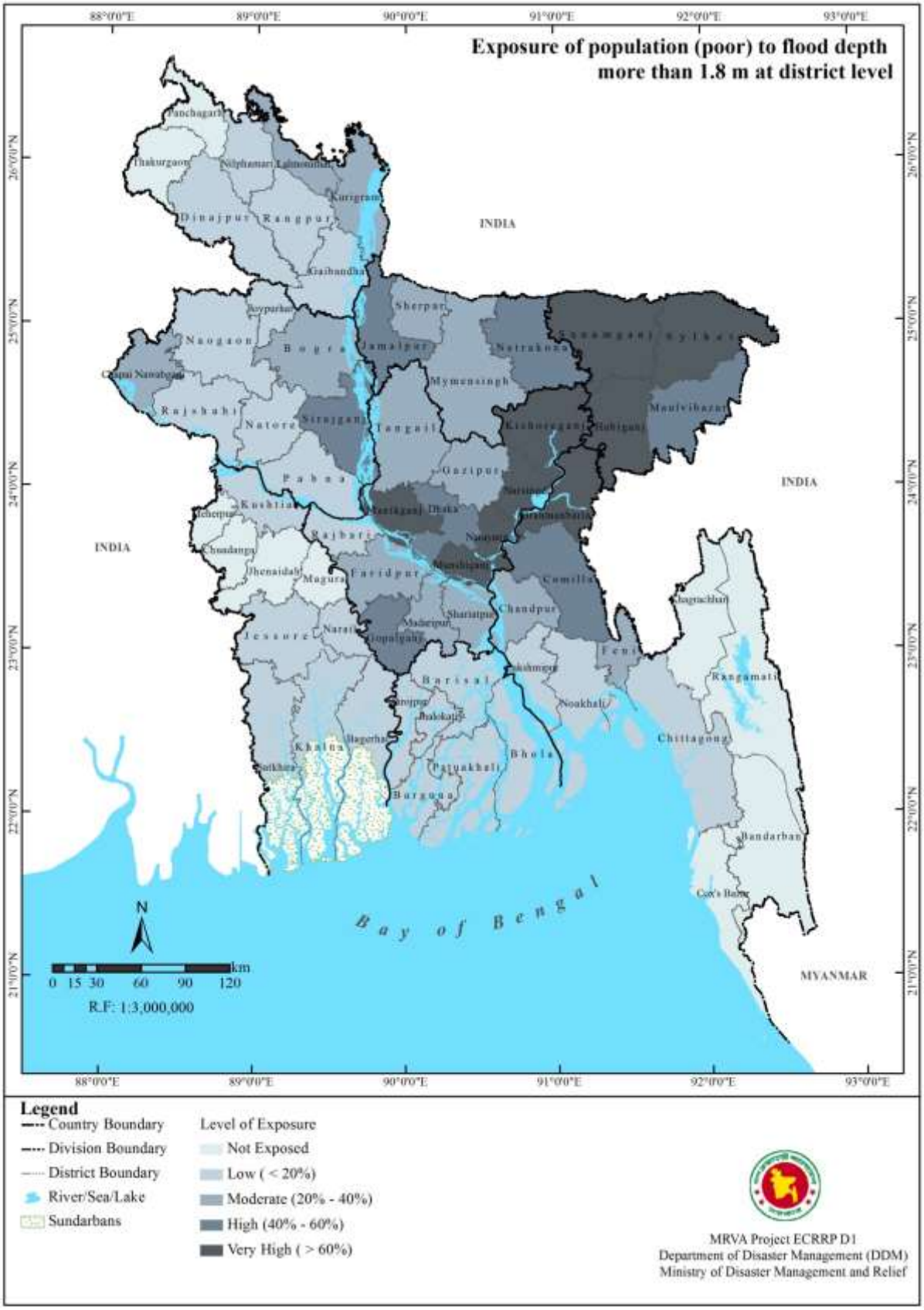


Figure 2.25: Population (poor) exposed to different flood depth at district level

2.1.2 Housing

As mentioned in section 1.2.1, household structure types are Pucca, Semi-Pucca, Katcha, Jhupri. Exposure of the household structures to flood inundation depths is assessed by combining flood hazard map and household structure maps. Number of Pucca household structures in each flood inundation depth category in each division is given in table 2.16 and figure 2.26. Number of semi-Pucca household structures in each flood inundation depth category in each division is given in table 2.17 and figure 2.27. Number of Katcha household structures in each flood inundation depth category in each division is given in table 2.18 and figure 2.28. Number of Jhupri household structures in each flood inundation depth category in each division is given in table 2.19 and figure 2.29.

Table 2.16: Number of Pucca household structures exposed to flood in each division

Division	Flood inundation depth (m) / household structures exposed					Not affected
	< 0.3	0.3 - 0.9	0.9 - 1.8	1.8 - 3.6	> 3.6	
Barisal	1,922	13,981	26,243	5,939	95	29,713
Chittagong	11,196	36,029	87,322	94,577	20,513	478,561
Dhaka	70,472	124,700	182,232	399,427	192,812	722,370
Khulna	1,600	4,021	9,596	9,440	1,073	485,037
Mymensingh	3,427	8,166	14,340	16,266	1,749	20,941
Rajshahi	3,816	11,434	27,183	40,797	8,185	216,970
Rangpur	1,732	3,147	3,966	12,041	6,760	83,426
Sylhet	1,614	4,702	15,123	78,498	85,831	38,202
Total	95,779	206,179	366,005	656,984	317,019	2,075,220

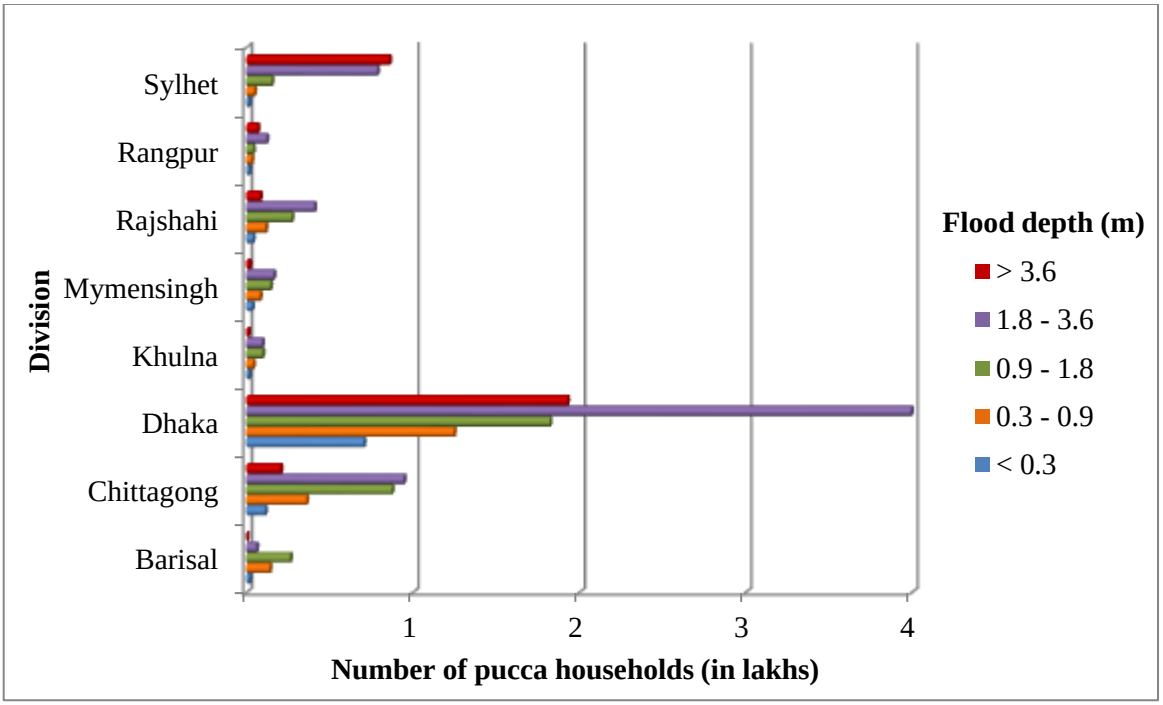


Figure 2.26: Number of Pucca household structures exposed to different flood depth in each division

Table 2.17: Number of semi-Pucca household structures exposed to flood in different division

Division	Flood depth (m) / household structures exposed					Not affected
	< 0.3	0.3 - 0.9	0.9 - 1.8	1.8 - 3.6	> 3.6	
Barisal	2,834	21,201	43,736	10,390	175	74,963
Chittagong	14,058	43,373	105,827	145,984	30,867	456,102
Dhaka	71,207	147,167	286,203	670,412	309,513	672,754
Khulna	3,199	8,546	22,721	29,374	3,906	956,700
Mymensingh	12,910	31,969	58,842	69,006	10,146	75,296
Rajshahi	14,065	40,152	100,047	140,308	24,610	647,584
Rangpur	10,266	17,918	18,724	42,375	23,230	452,600
Sylhet	3,063	8,416	23,941	143,467	159,831	76,966
Total	131,602	318,742	660,042	1,251,317	562,279	3,412,966

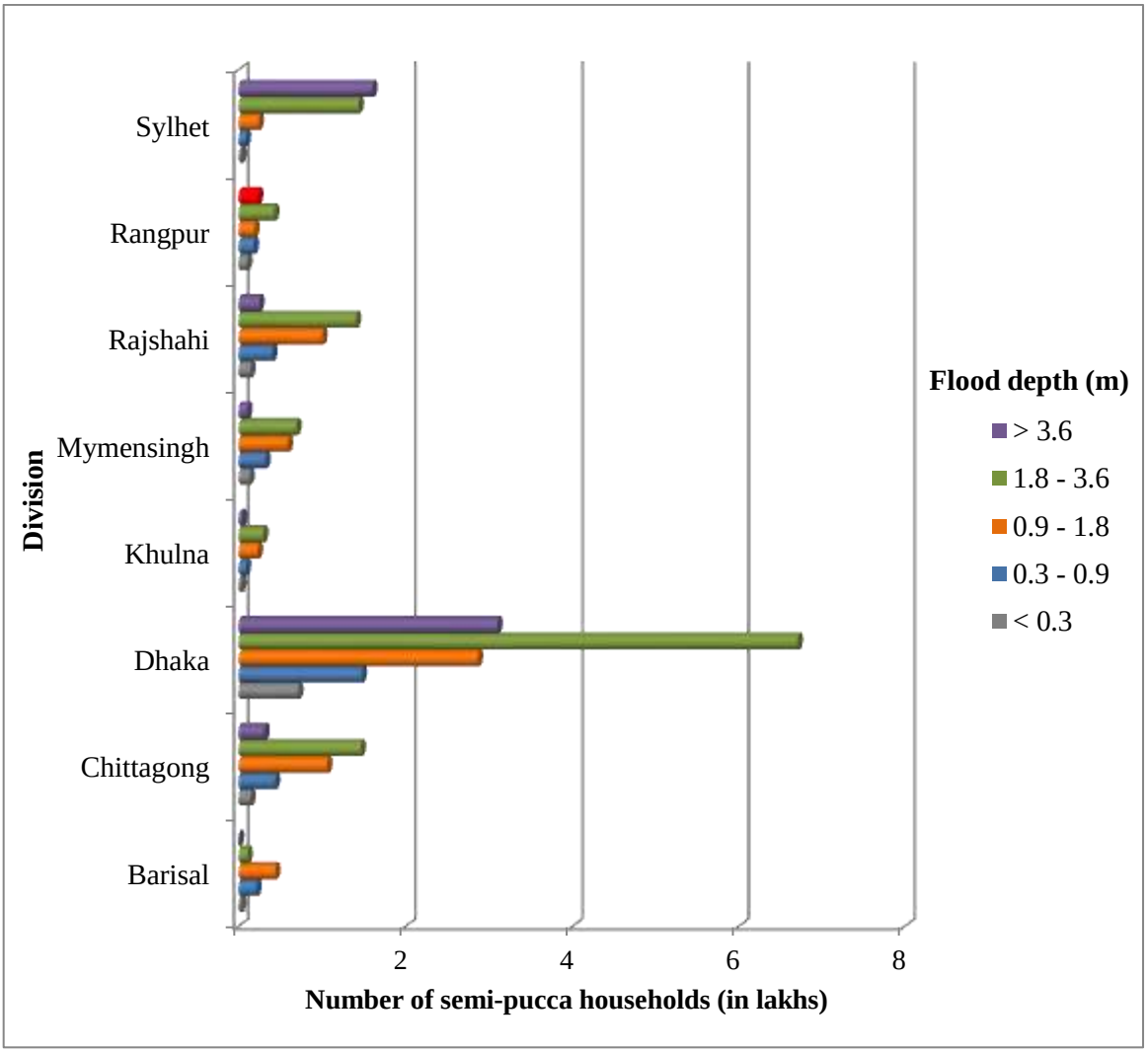


Figure 2.27: Number of semi-Pucca household structures exposed to flood in each division

Table 2.18: Number of Katcha household structures exposed to flood in each division

Division	Flood depth (m) / household structures exposed					Not affected
	< 0.3	0.3 - 0.9	0.9 - 1.8	1.8 - 3.6	> 3.6	
Barisal	19,172	145,367	370,980	99,067	1,174	936,413
Chittagong	84,658	280,361	667,507	775,367	132,794	1,935,891
Dhaka	92,923	290,615	777,284	1,694,862	446,746	1,025,975
Khulna	5,755	17,176	63,625	66,690	5,926	1,934,029
Mymensingh	95,325	248,500	497,572	628,918	117,697	529,189
Rajshahi	40,232	125,356	355,915	611,554	81,908	1,868,233
Rangpur	34,426	63,421	98,476	237,585	139,640	2,450,390
Sylhet	8,180	21,205	60,239	367,174	448,853	192,554
Total	380,671	1,192,003	2,891,598	4,481,215	1,374,738	10,872,675

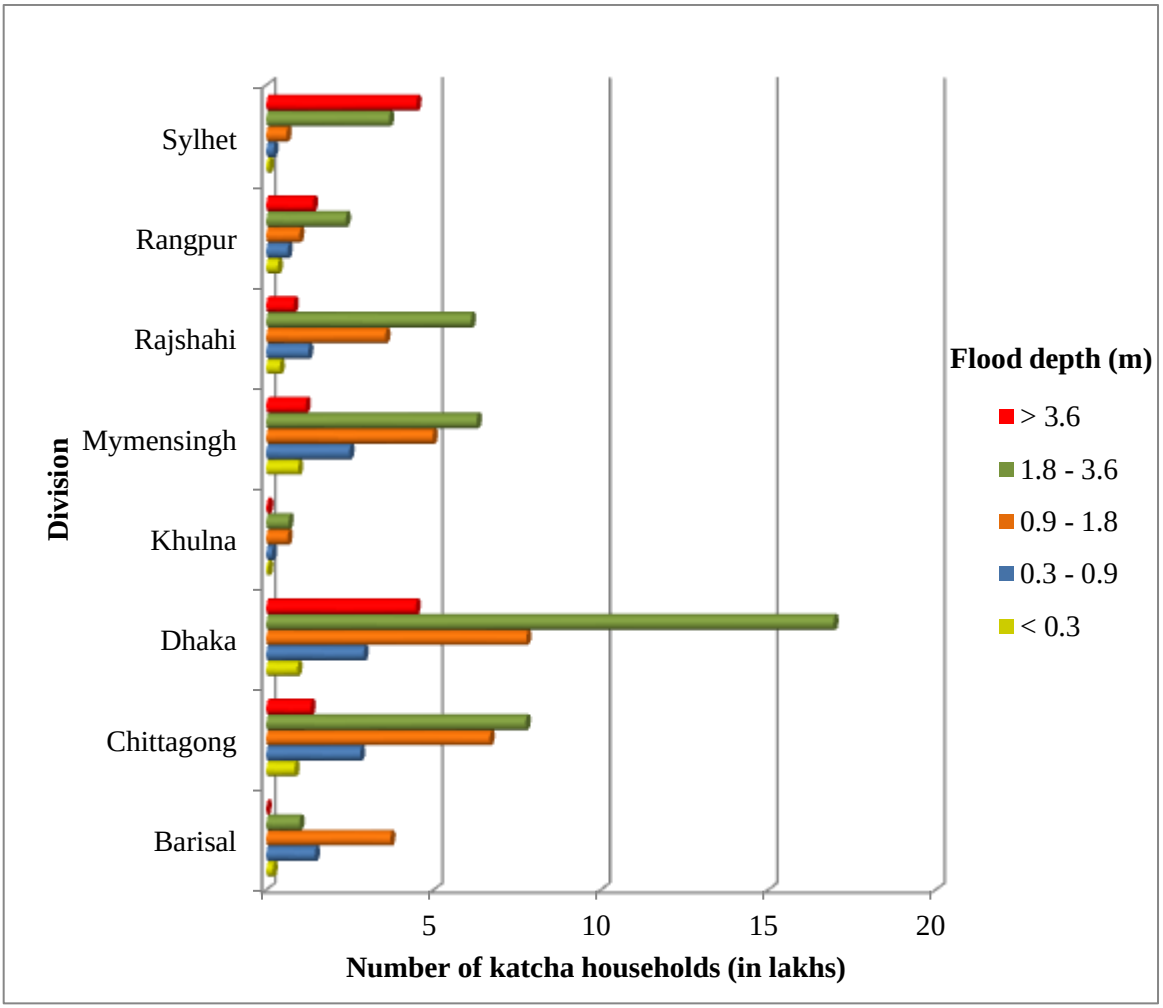


Figure 2.28: Number of Katcha household structures exposed to flood in each division

Table 2.19: Number of Jhupri household structures exposed to flood in each division

Division	Flood depth (m) / household structures exposed					Not affected
	< 0.3	0.3 - 0.9	0.9 - 1.8	1.8 - 3.6	> 3.6	
Barisal	453	3,259	8,125	2,563	26	45,041
Chittagong	2,041	6,609	10,335	10,798	3,183	192,353
Dhaka	4,077	8,852	17,367	37,500	15,475	48,997
Khulna	251	830	3,569	2,266	174	104,269
Mymensingh	4,593	12,715	23,916	29,651	6,703	21,556
Rajshahi	1,752	4,090	8,763	15,465	3,873	94,543
Rangpur	2,388	4,301	4,590	9,645	6,106	90,508
Sylhet	513	1,263	3,128	16,188	21,303	10,636
Total	16,068	41,919	79,793	124,074	56,842	607,904

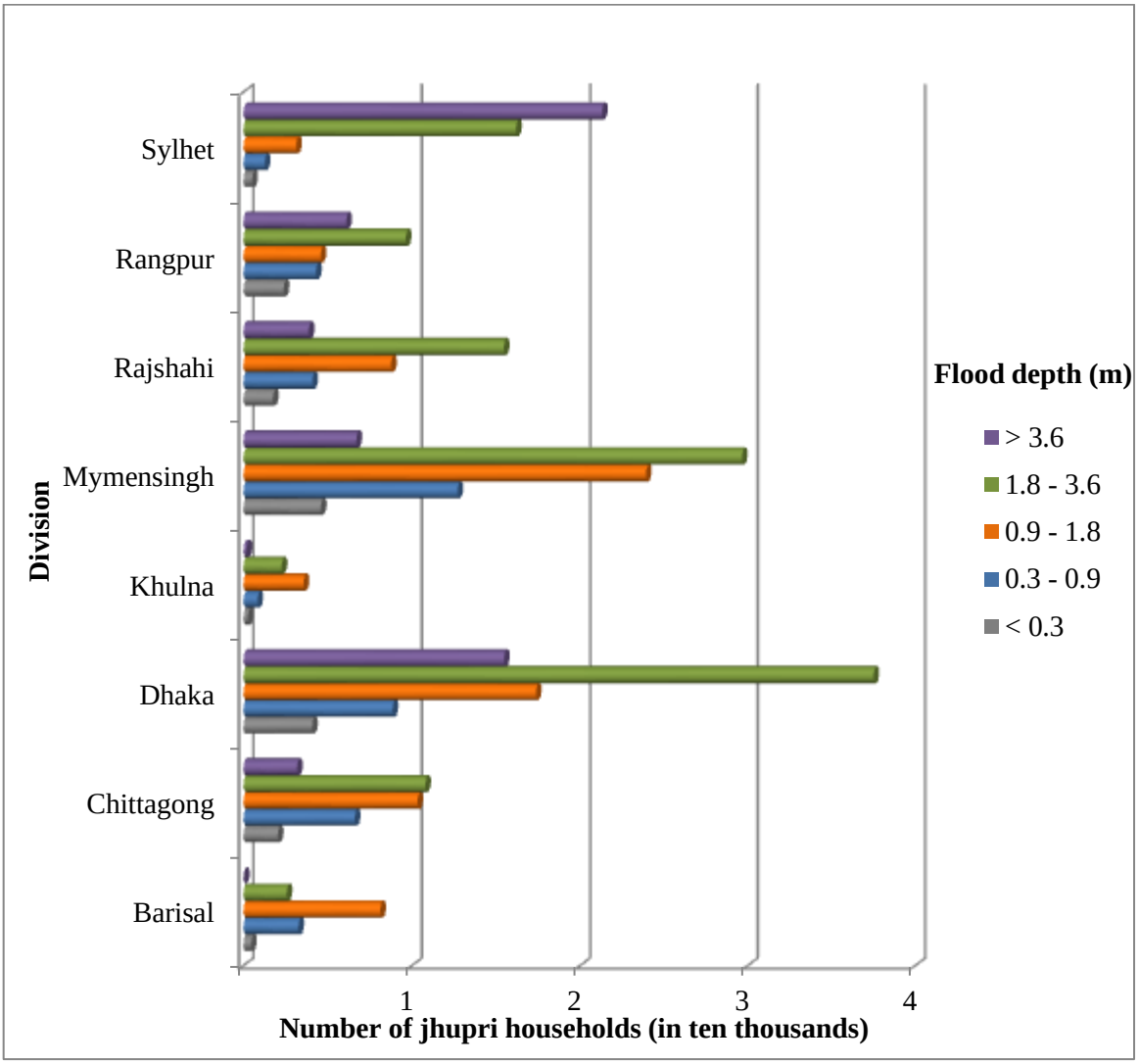


Figure 2.29: Number of Jhupri household structures exposed to different flood depth in different division

2.1.3 Livelihood

Elements at risk considered in livelihood are Agriculture (transplanted Aman crop) and industries.

2.1.3.1 Agriculture

As explained in section 1.3.1, transplanted Aman crop data is used for assessing the exposure of livelihood. Flood hazard map of 25 years and transplanted aman crop map are combined for exposure assessment. Exposed transplanted aman crop area (km^2) in each district is given table 2.20 and at division level shown in figure 2.30.

Table 2.20: Exposed transplanted aman crop area (km^2) in each district

Division	District	Transplanted aman crop area (km^2) exposed to flood depth (m)		
		0.9 - 1.8	**1.8 - 3.6**	**> 3.6**
Barisal	Barguna	55.98	28.15	0
	Barisal	798.53	158.24	0.97
	Bhola	48.3	6.08	0.58
	Jhalokati	372.91	120.37	0.65
	Patuakhali	346.81	13.02	0.62
	Pirojpur	387.29	91.12	0
Chittagong	Brahmanbaria	39.83	81.97	5.02
	Chandpur	75.13	16.21	0.56
	Chittagong	1.83	1.15	0
	Comilla	426.64	433.29	139.27
	Feni	242.4	273.64	1.27
	Lakshmipur	101.33	17.27	2.26
	Noakhali	331.62	105.38	0.08
Dhaka	Dhaka	1.45	1.41	1.26
	Faridpur	0	0.02	0
	Gazipur	29.8	20.74	15.39
	Gopalganj	5.79	0.44	0
	Kishoreganj	267.36	397.43	54.17
	Madaripur	26.96	2.28	0
	Manikganj	6.85	17.31	0.81
	Narayanganj	0.03	20.42	1.16
	Narsingdi	194.3	351.99	66.82
	Shariatpur	0	0.01	0
	Tangail	283.12	211.06	5.19
Mymensingh	Jamalpur	395.42	367.94	6.77
	Mymensingh	583.46	717.36	86.54
	Netrakona	233.51	282.39	32.77
	Sherpur	246.73	278.01	155.2
Khulna	Bagerhat	176.12	26.72	0
	Jessore	1.15	5.35	4.44
	Khulna	83.92	62.42	0
	Kushtia	0.09	3.06	0
	Narail	0.15	0	0
	Satkhira	70.34	94.86	24.81
Rajshahi	Bogra	673.85	628.02	8.54
	Chapai	0.33	3.89	0.68

Division	District	Transplanted aman crop area (km^2) exposed to flood depth (m)		
		0.9 - 1.8	1.8 - 3.6	> 3.6
	Nawabganj			
	Joypurhat	185.79	165.88	14.3
	Naogaon	3.04	42.53	13.14
	Natore	35.49	95.54	25.14
	Pabna	7.79	23.36	1.81
	Rajshahi	8.75	3.59	2.22
	Sirajganj	270.94	423.9	13.41
Rangpur	Dinajpur	249.81	292.29	190.16
	Gaibandha	12.67	69.16	15.36
	Kurigram	106.57	196.29	18.05
	Lalmonirhat	13.97	66.02	138.35
	Nilphamari	16.28	22.57	5.8
	Rangpur	6.21	31.73	60.36
	Thakurgaon	2.52	0	0
Sylhet	Habiganj	34.65	265.57	232.43
	Maulvibazar	62.89	363.93	545.76
	Sunamganj	80.72	126.72	88.35
	Sylhet	191.09	1030.32	867.24

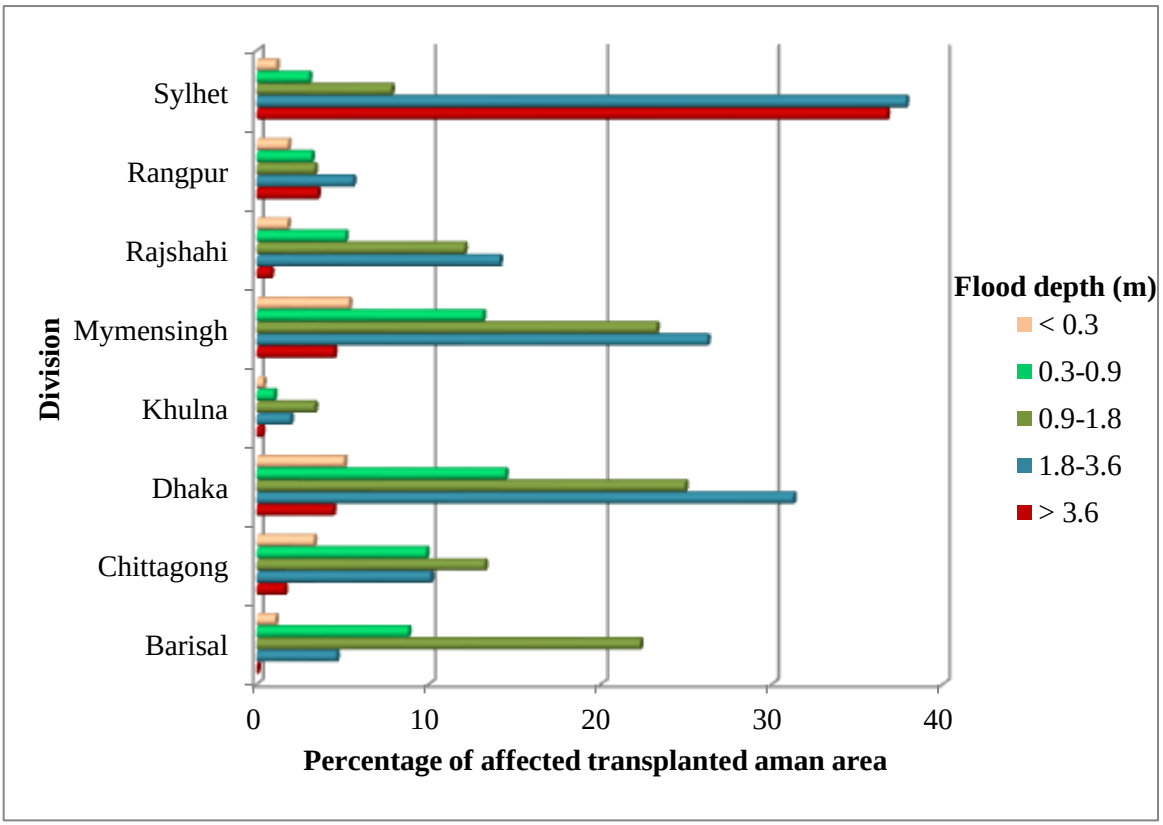


Figure 2.30: Percentage of exposed transplanted aman crop at division level

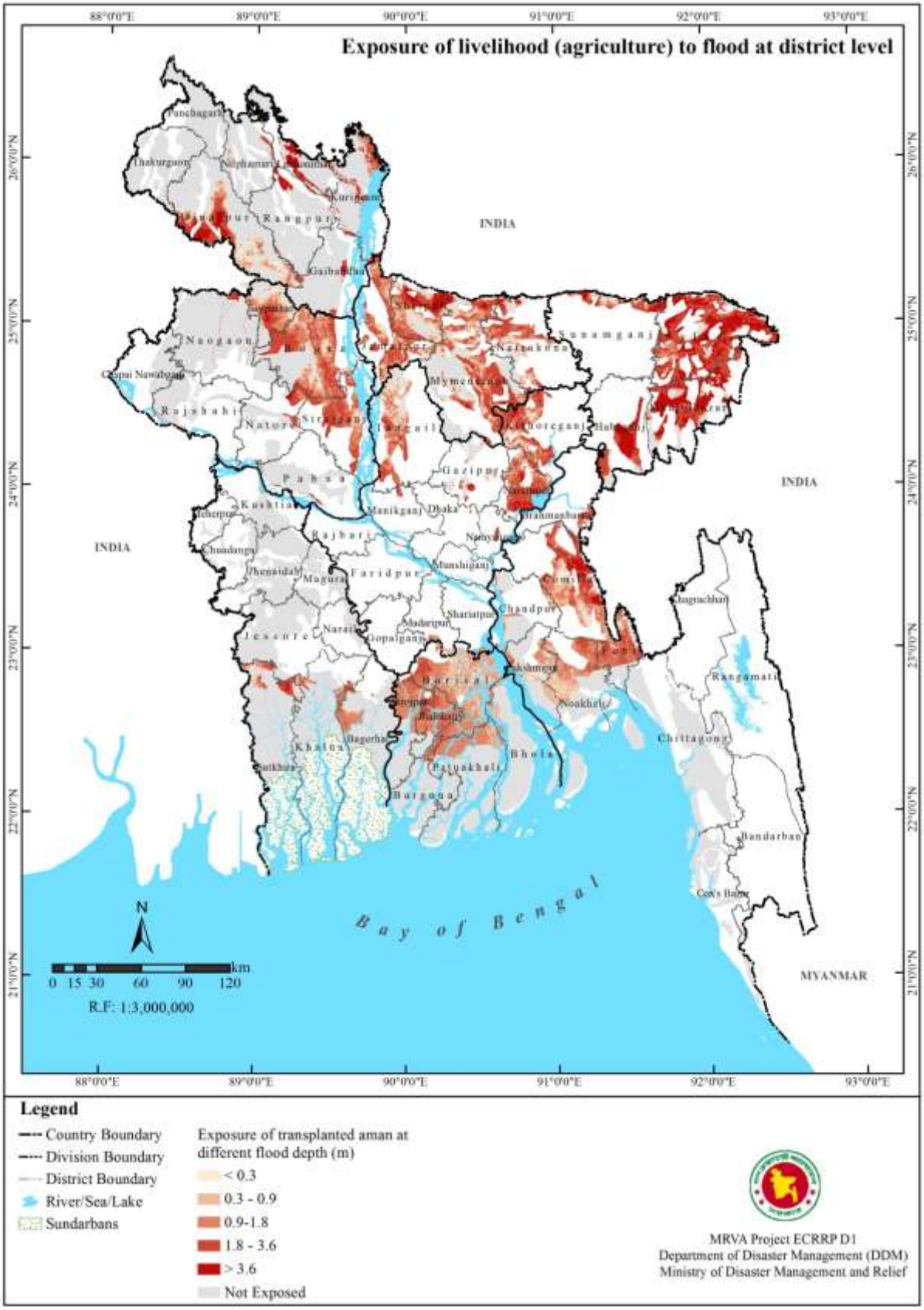


Figure 2.31: Exposure of livelihood (agriculture) to flood at district level

2.1.3.2 Industries

The different types of industries (Food Godowns, Mills, Gas Field, Cold Storage, Cottage Industries, Rice/Oil/Grain mills) existing in the database are assessed for their existence in flood hazard areas.

The number of food godowns existing in different flood inundation depths at division level is given in table 2.21 and figure 2.32.

Table 2.21: Number of food godowns exposed to flood at division level

Division	Flood inundation depth (m) / number of food godowns					Not affected
	< 0.3	0.3 - 0.9	0.9 - 1.8	1.8 - 3.6	> 3.6	
Barisal	1	7	14			42
Chittagong	1	7	12	25	5	67
Dhaka	5	14	42	64	19	10
Khulna	3	7	3	12	2	45
Mymensingh	2	12	12	20	5	10
Rajshahi		7	13	36	26	13
Rangpur	3	5	12	21	7	66
Sylhet			4	23	26	5
Total	15	59	112	201	90	258

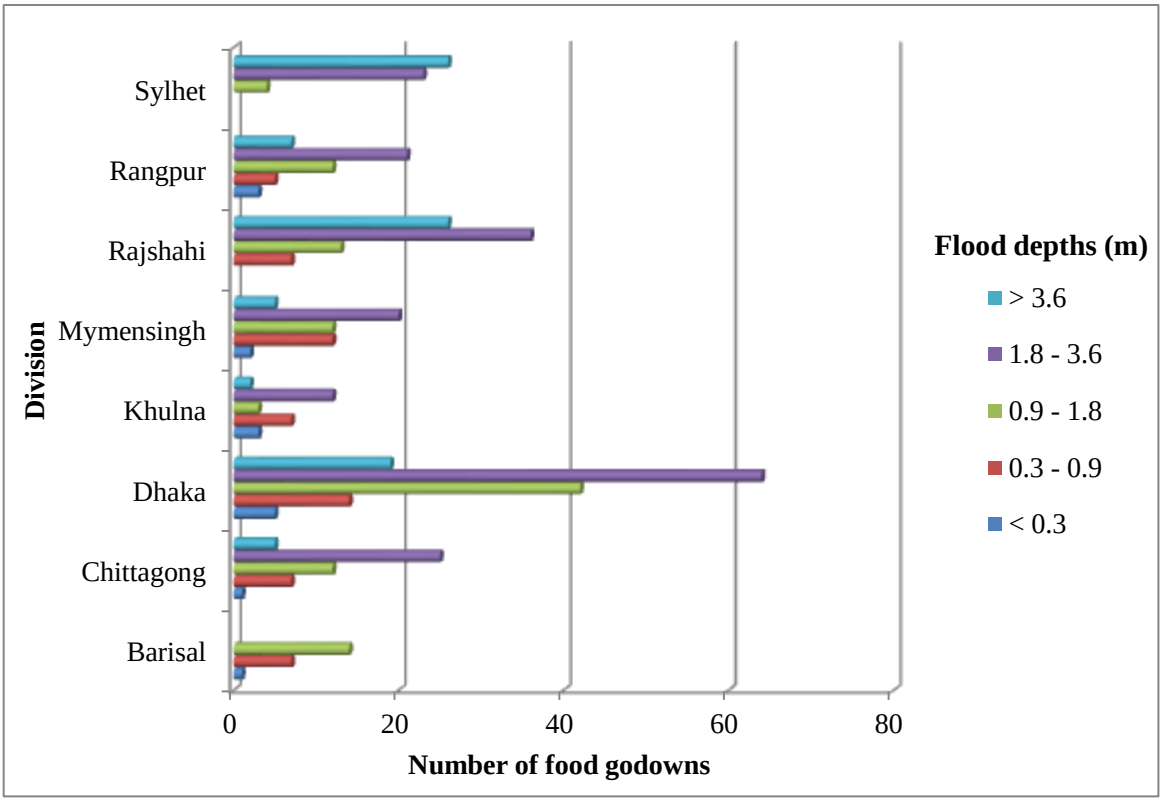


Figure 2.32: Number of food godowns exposed to different flood depth at division level

The number of Mills existing in different flood inundation depths at division level is given in table 2.22 and figure 2.33.

Table 2.22: Number of mills exposed to flood at division level

Division	Flood inundation depth (m) / number of mills					Not affected
	< 0.3	0.3 - 0.9	0.9 - 1.8	1.8 - 3.6	> 3.6	
Barisal		4	2			
Chittagong	1		3	1		22
Dhaka			3	21	7	2
Khulna			3	6		15
Mymensingh			2			
Rajshahi		1	3	7	10	2
Rangpur	1	2	1			6
Sylhet			1	1	4	
Total	2	7	18	36	21	47

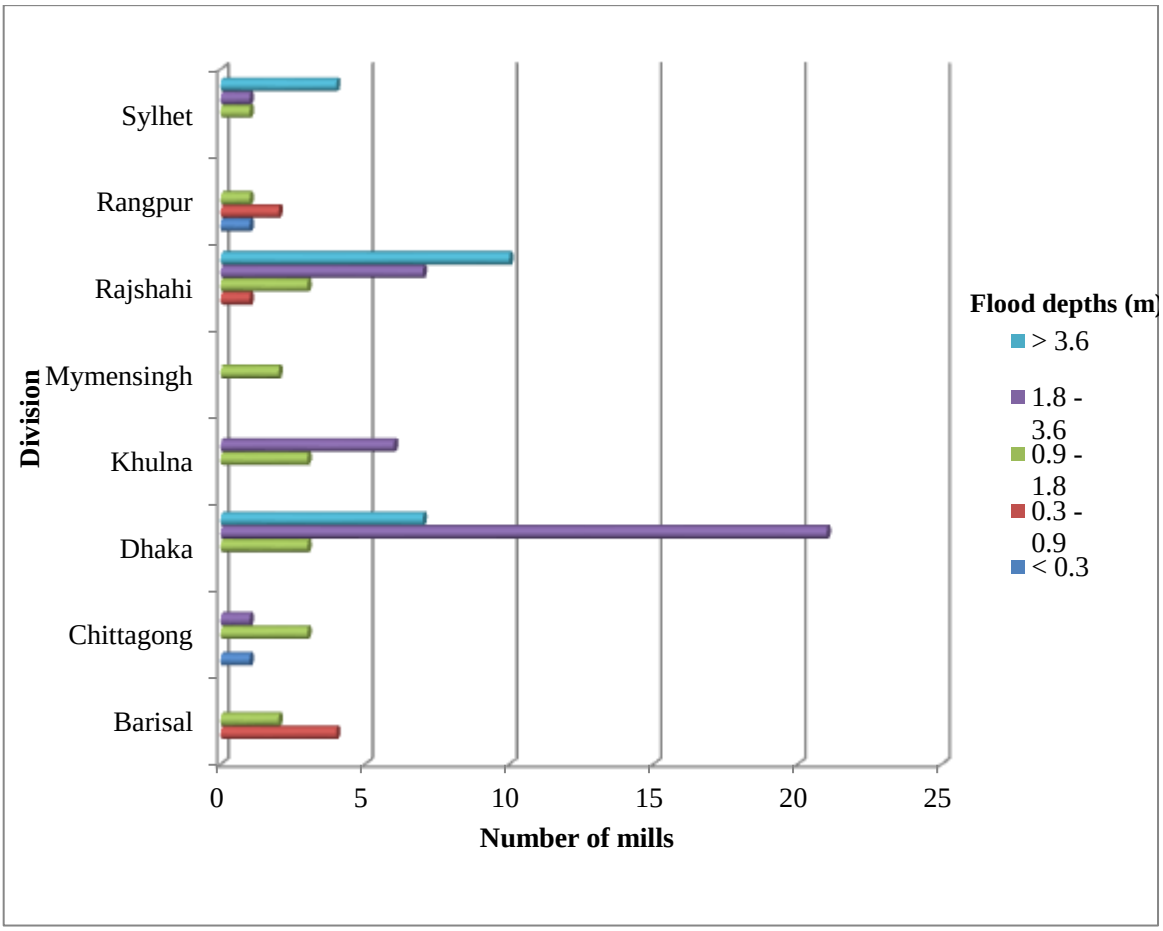


Figure 2.33: Number of mills exposed to different flood depth at division level

The number of Cold Storage existing in different flood inundation depths at division level is given in table 2.23.

Table 2.23: Number of Cold Storage exposed to flood at division level

Division	Flood inundation depth (m) / Cold Storage					Not affected
	< 0.3	0.3 - 0.9	0.9 - 1.8	1.8 - 3.6	> 3.6	
Barisal						
Chittagong						2
Dhaka						1
Khulna						
Mymensingh			1			
Rajshahi			4	1		
Rangpur						
Sylhet					1	
Total	0	0	5	1	1	3

The number of Cottage Industry existing in different flood inundation depths at division level is given in table 2.24 and figure 2.34.

Table 2.24: Number of Cottage Industry exposed to flood at division level

Division	Flood inundation depth (m) / Cottage Industry					Not affected
	< 0.3	0.3 - 0.9	0.9 - 1.8	1.8 - 3.6	> 3.6	
Barisal						
Chittagong			2	1		
Dhaka				45	3	1
Khulna						1
Mymensingh						
Rajshahi	1		2			
Rangpur						
Sylhet					1	
Total	1	0	4	46	4	2

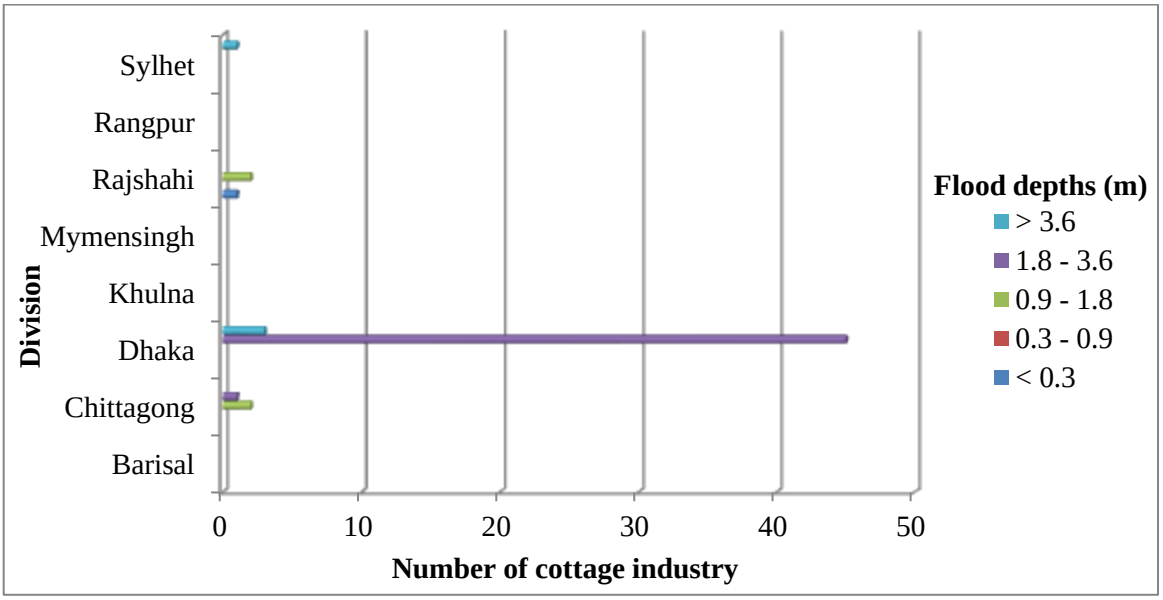


Figure 2.34: Number of cottage industry exposed to different flood depth at division level

The number of Rice/Oil/Grain Mill existing in different flood inundation depths at division level is given in table 2.25 and figure 2.35.

Table 2.25: Number of Rice/Oil/Grain Mill exposed to flood at division level

Division	Flood inundation depth (m) / Rice/Oil/Grain Mill					Not affected
	< 0.3	0.3 - 0.9	0.9 - 1.8	1.8 - 3.6	> 3.6	
Barisal						
Chittagong						21
Dhaka			1			
Khulna						
Mymensingh						
Rajshahi						
Rangpur						4
Sylhet				3	2	
Total	0	0	1	3	2	25

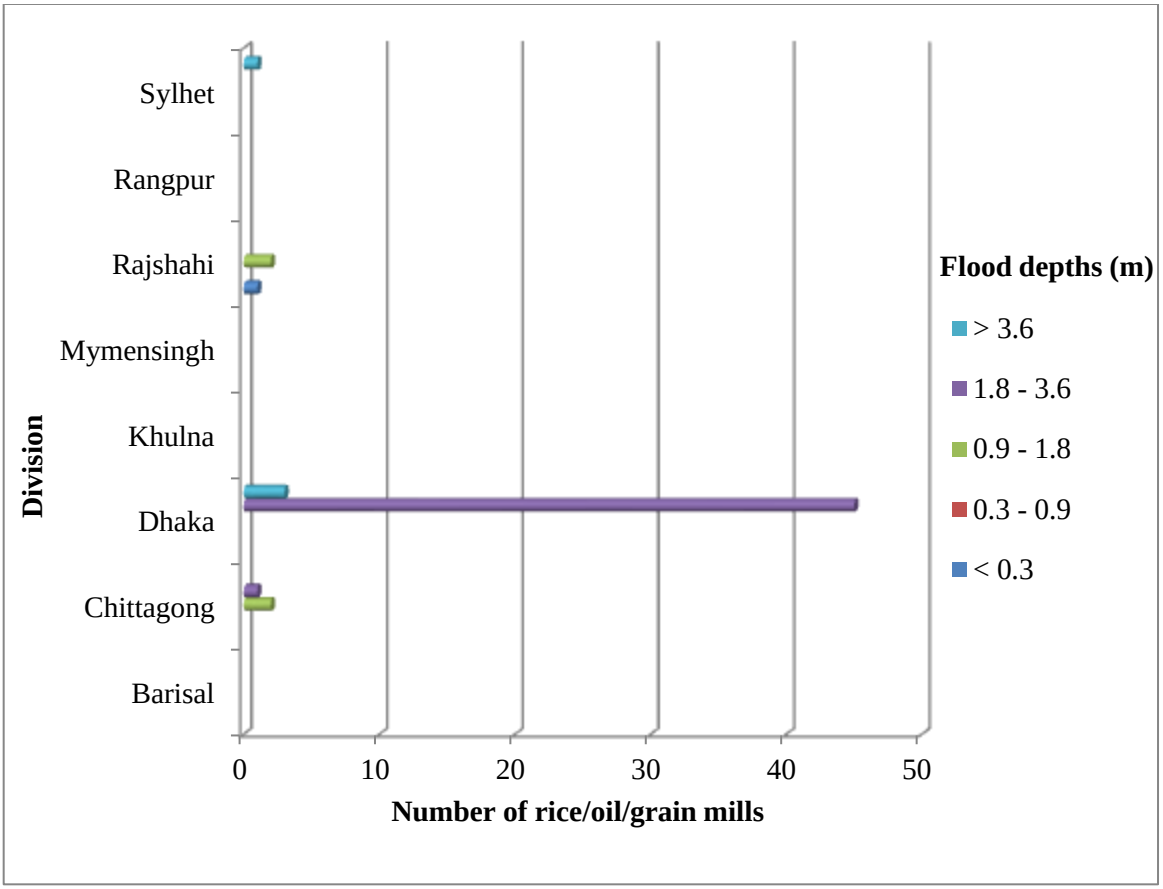


Figure 2.35: Number of rice / oil / grain mills exposed to different flood depth at division level

Exposure of all industries to different flood inundation depths at district level is shown in Figure 2.36.

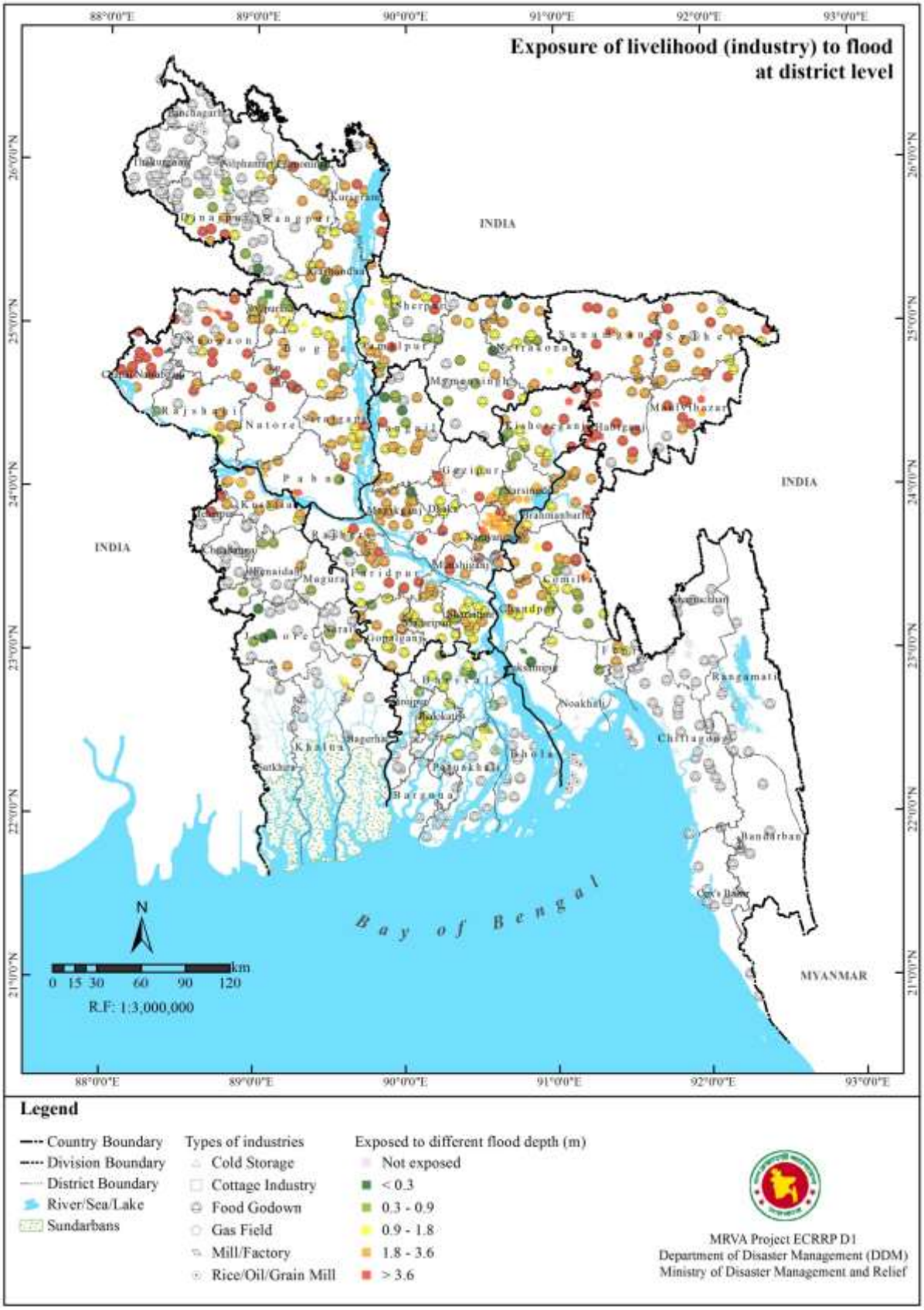


Figure 2.36: Exposure of industries to flood at district level

2.1.4 Critical Facilities

2.1.4.1 Health care facilities

Combining flood hazard map and health care facility map will provide existing hospitals and family welfare centers in flood prone areas.

The number of hospitals existing in different flood prone areas at division level is given in table 2.26 and figure 2.37. Hospitals existing in different flood prone areas at district level is shown in figure 2.38.

Table 2.26: Number of hospitals exposed to flood at division level

Division	Flood inundation depth (m) / number of hospitals					Not affected	Total
	< 0.3	0.3 - 0.9	0.9 - 1.8	1.8 - 3.6	> 3.6		
Barisal	1	3	9			23	36
Chittagong	1	4	10	9	3	68	95
Dhaka	6	6	27	49	9	5	102
Khulna	2	4	6	14		40	66
Mymensingh		2	5	7	4	6	24
Rajshahi	2	4	10	20	10	7	53
Rangpur	1	4	3	7	3	20	38
Sylhet	1			16	11	6	34
Total	14	27	70	122	40	175	448

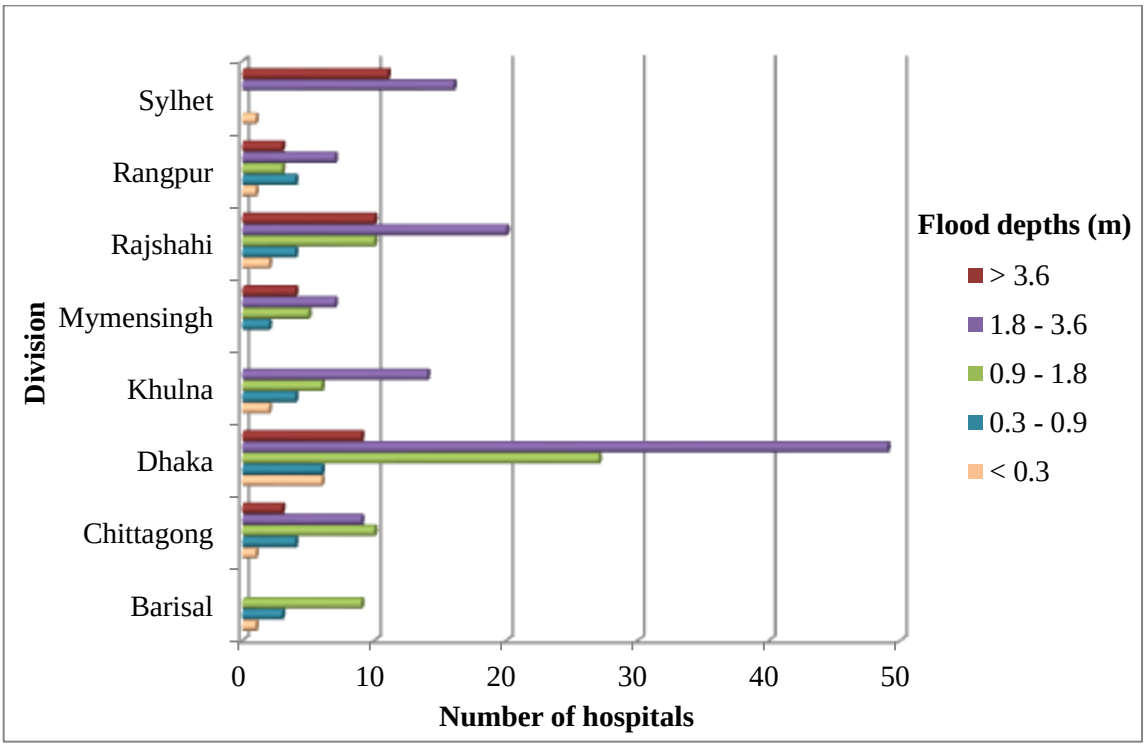


Figure 2.37: Number of hospitals exposed to different flood depth at division level

Figure 2.38: Exposure of hospitals to flood at district level

The number of Family Welfare centres existing in different flood prone areas at division level is given in table 2.27 and figure 2.39. Family Welfare centres existing in different flood prone areas at district level is shown in figure 2.40.

Table 2.27: Number of Family Welfare centres exposed to flood at division level

Division	Flood Flood inundation depth (m) / number of family welfare centers					Not affected	Total
	< 0.3	0.3 - 0.9	0.9 - 1.8	1.8 - 3.6	> 3.6		
Barisal	4	19	58	21		105	207
Chittagong	7	26	66	100	13	140	352
Dhaka	14	44	140	315	68	45	626
Khulna	15	26	48	45	9	199	342
Mymensingh	7	22	35	54	11	50	179
Rajshahi	2	21	74	189	53	52	391
Rangpur	7	28	54	83	34	158	364
Sylhet		3	12	66	58	15	154
Total	**56**	**189**	**487**	**873**	**246**	**764**	**2,615**

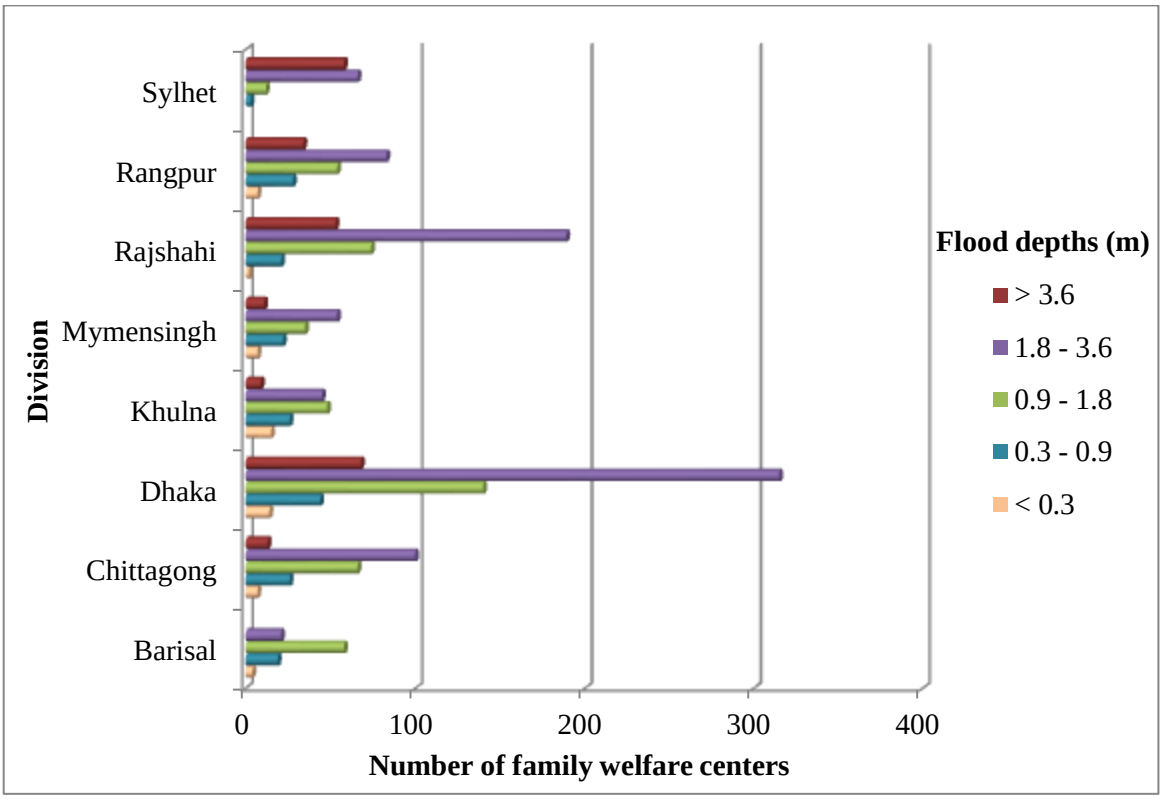


Figure 2.39: Number of Family Welfare centres exposed to different flood depth at division level

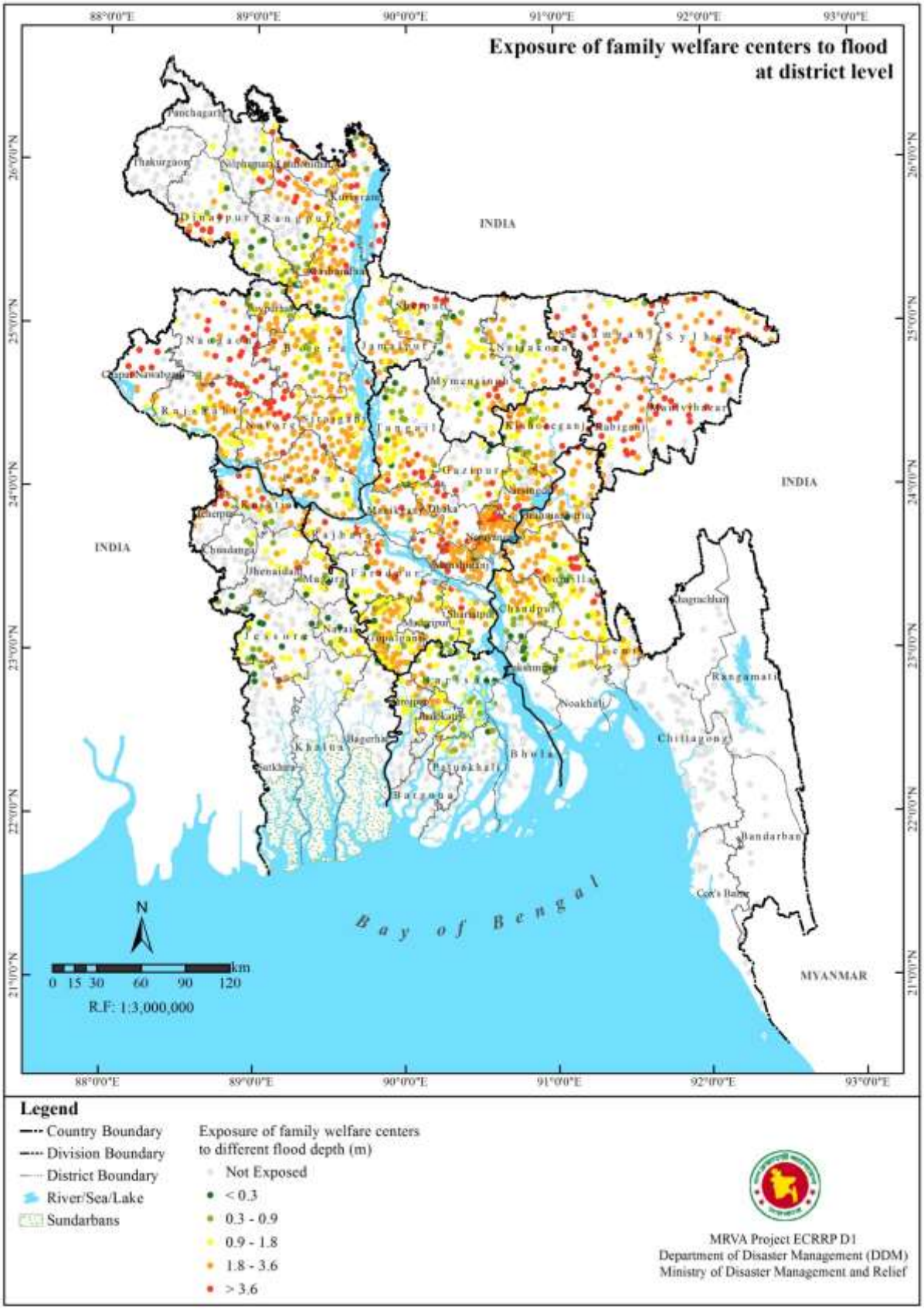


Figure 2.40: Exposure of Family Welfare centres to flood at district level

2.1.4.2 Educational Institutions

Educational institutions database consists of categories of educational institutions as University, College, High School, Madrasa, Primary Schools. Combining flood hazard map and Educational institutions map will provide existing Educational institutions in flood prone areas.

The number of High Schools existing in different flood prone areas at division level is given in table 2.28 and figure 2.41. High Schools existing in different flood prone areas at district level is shown in figure 2.42.

Table 2.28: Number of High Schools exposed to flood at division level

Division	Flood inundation depth (m) / High Schools					Not affected	Total
	< 0.3	0.3 - 0.9	0.9 - 1.8	1.8 - 3.6	> 3.6		
Barisal	11	74	255	94	1	400	835
Chittagong	28	84	247	292	48	547	1,246
Dhaka	40	156	391	805	170	273	1,835
Khulna	37	80	119	153	21	638	1,048
Mymensingh	8	26	44	58	10	24	170
Rajshahi	10	38	148	446	186	124	952
Rangpur	40	76	115	224	60	404	919
Sylhet	5	11	31	182	147	51	427
Total	179	545	1,350	2,254	643	2,461	7,432

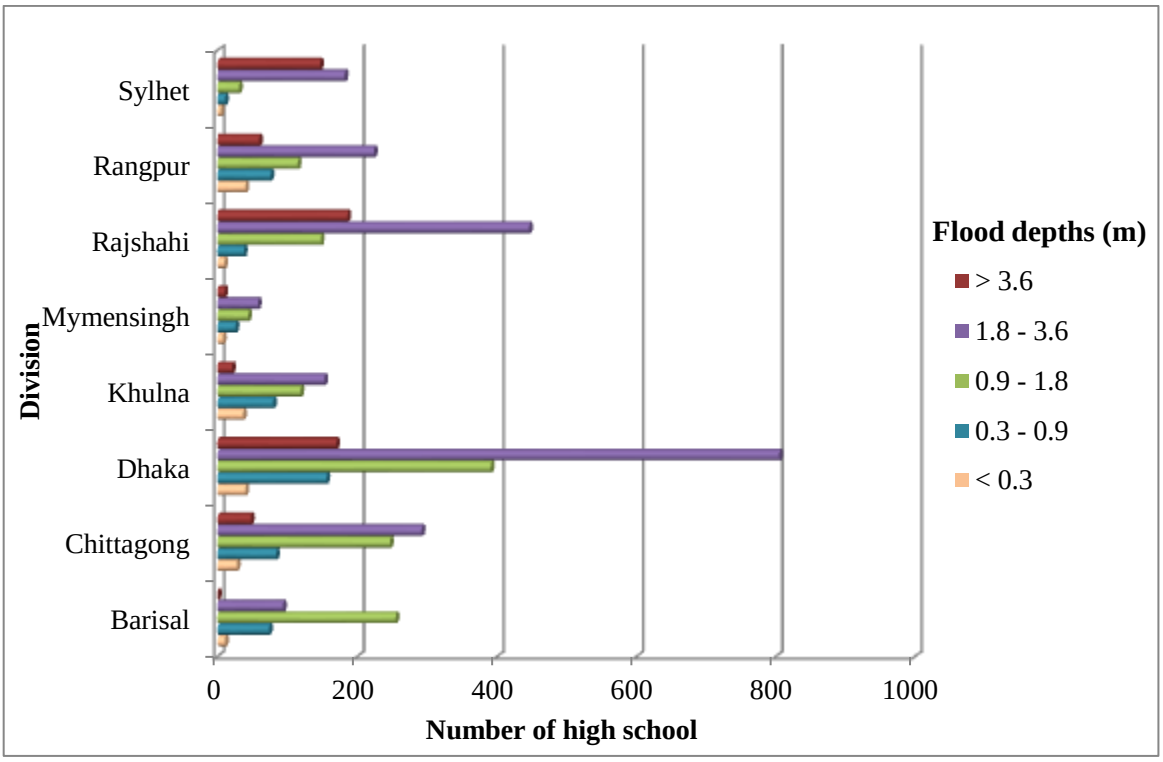


Figure 2.41: Number of High Schools exposed to different flood depth at division level

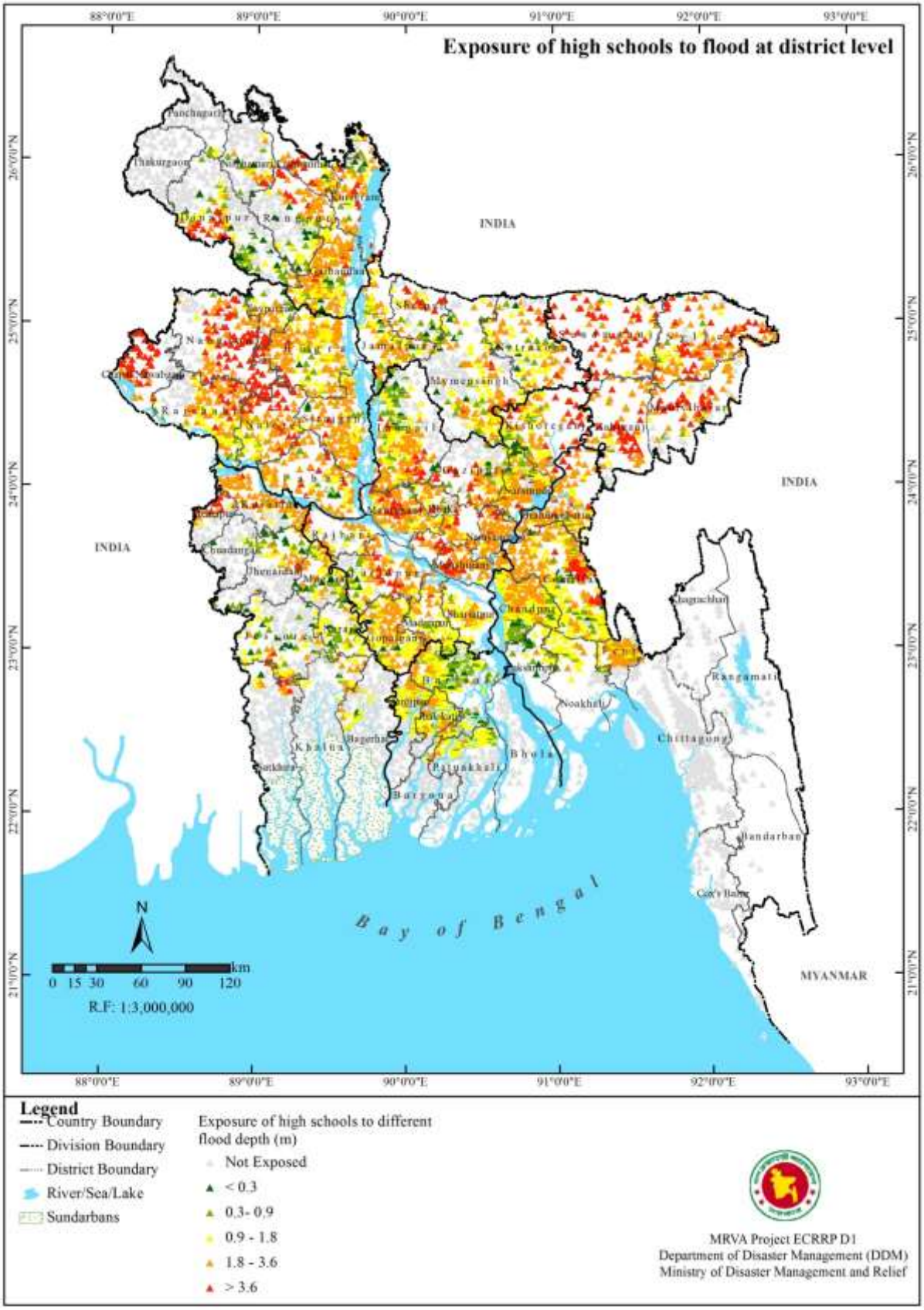


Figure 2.42: Exposure of High Schools to flood at district level

The number of Madrasa existing in different flood prone areas at division level is given in table 2.29 and figure 2.43. Madrasa existing in different flood prone areas at district level is shown in figure 2.44.

Table 2.29: Number of Madrasa exposed to flood at division level

Division	Flood inundation depth (m) / Madrasas					Not affected	Total
	< 0.3	0.3 - 0.9	0.9 - 1.8	1.8 - 3.6	> 3.6		
Barisal	1	27	92	21		174	315
Chittagong	16	48	103	179	67	262	675
Dhaka	30	78	230	447	128	166	1,079
Khulna	8	51	70	74	10	294	507
Mymensingh	7	20	37	46	5	13	128
Rajshahi	11	45	102	308	120	77	663
Rangpur	22	43	66	128	15	256	530
Sylhet	4	8	23	178	157	49	419
Total	99	320	723	1,381	502	1,291	4,316

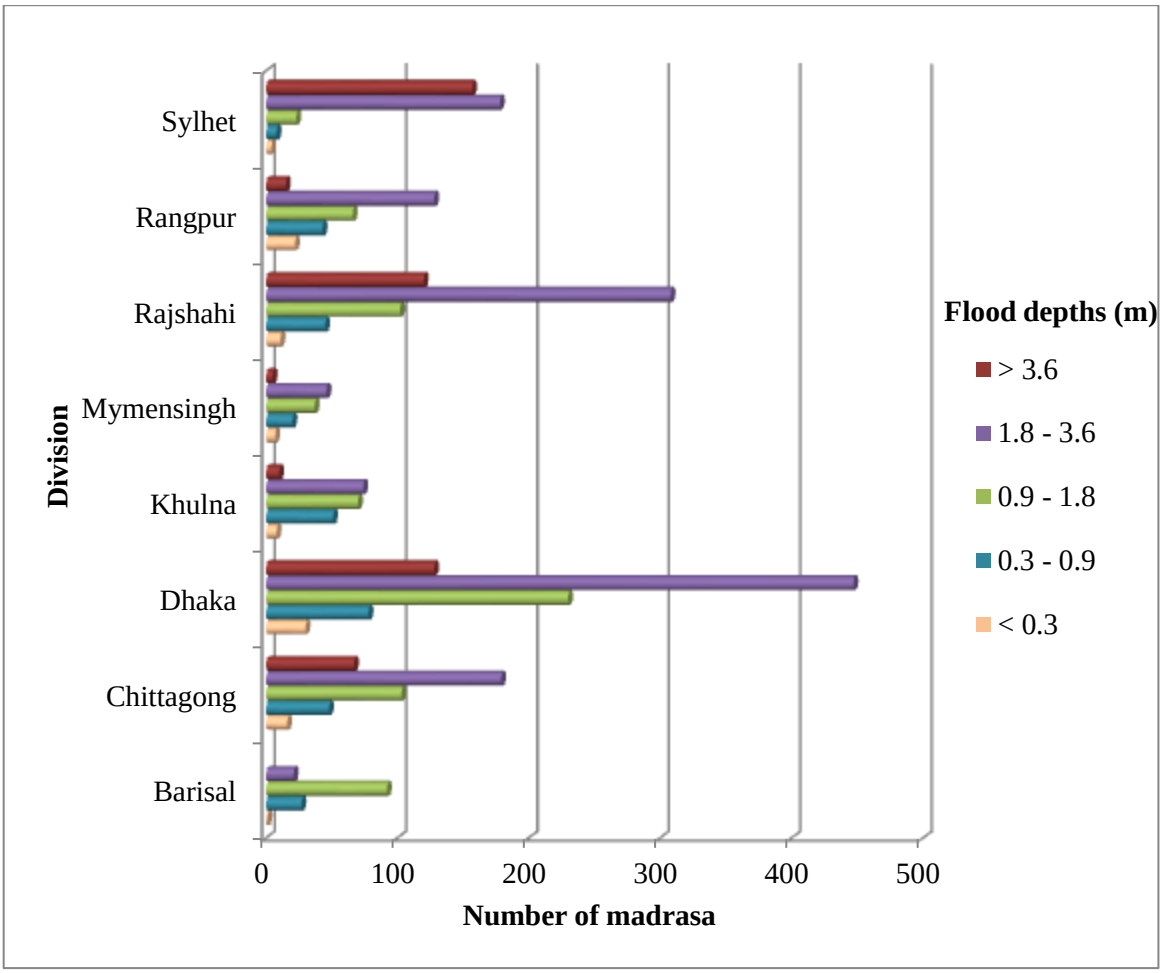


Figure 2.43: Number of Madrasa exposed to different flood depth at division level

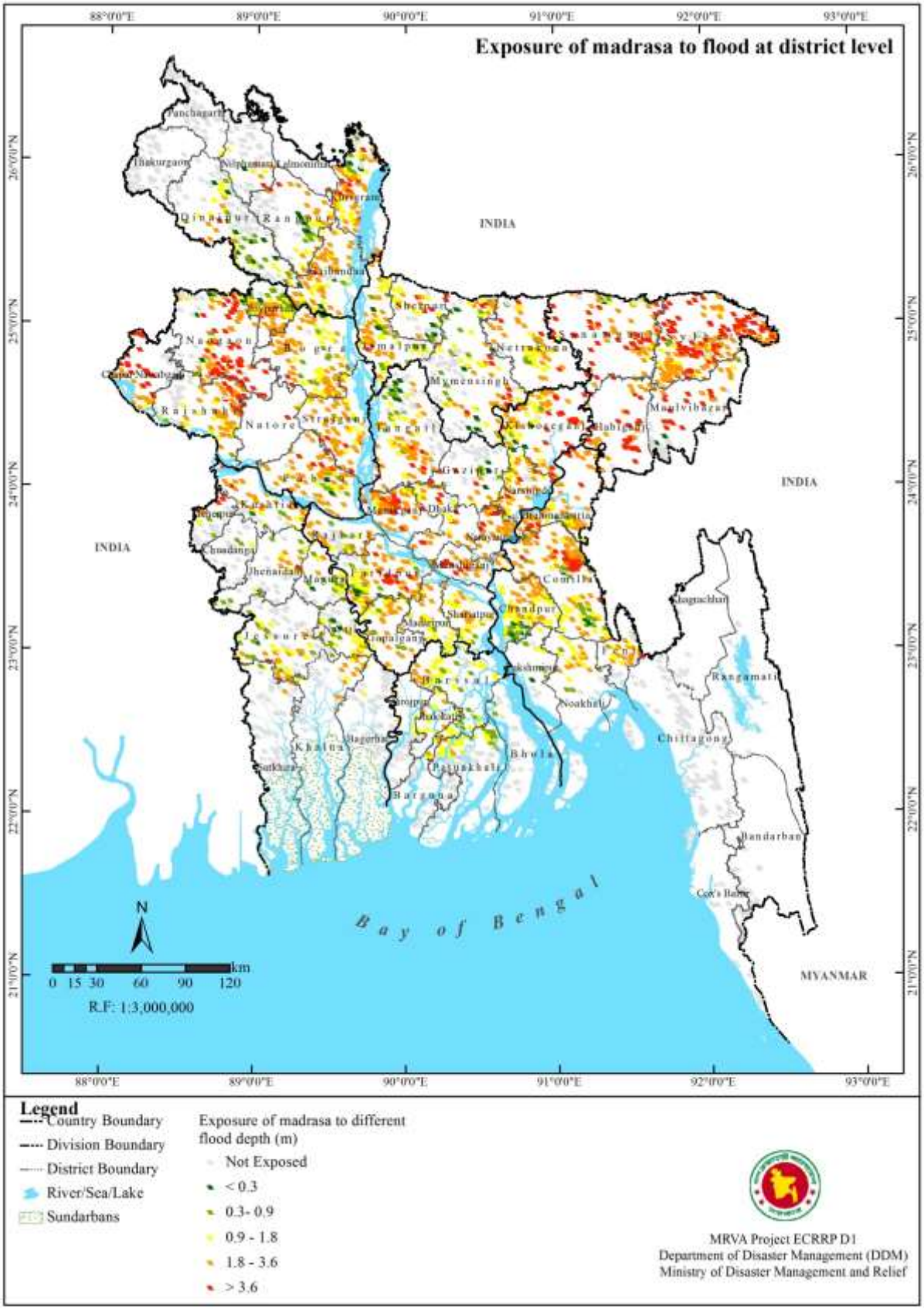


Figure 2.44: Exposure of Madrasa to flood at district level

The number of Primary Schools existing in different flood prone areas at division level is given in table 2.30 and figure 2.45. Primary Schools existing in flood prone areas at district level is shown in figure 2.46.

Table 2.30: Number of Primary School exposed to flood at division level

Division	Flood inundation depth (m) / Primary Schools					Not affected	Total
	< 0.3	0.3 - 0.9	0.9 - 1.8	1.8 - 3.6	> 3.6		
Barisal	28	244	663	198		1,124	2,257
Chittagong	99	380	1,027	1,534	230	3,051	6,321
Dhaka	175	616	1,723	4,484	1,196	1,115	9,309
Khulna	156	365	581	629	108	2,352	4,191
Mymensingh	43	95	228	398	84	99	947
Rajshahi	43	154	575	1,961	986	603	4,322
Rangpur	118	263	407	876	304	2,031	3,999
Sylhet	32	51	184	1,295	1,376	281	3,219
Total	694	2,168	5,388	11,375	4,283	10,655	34,563

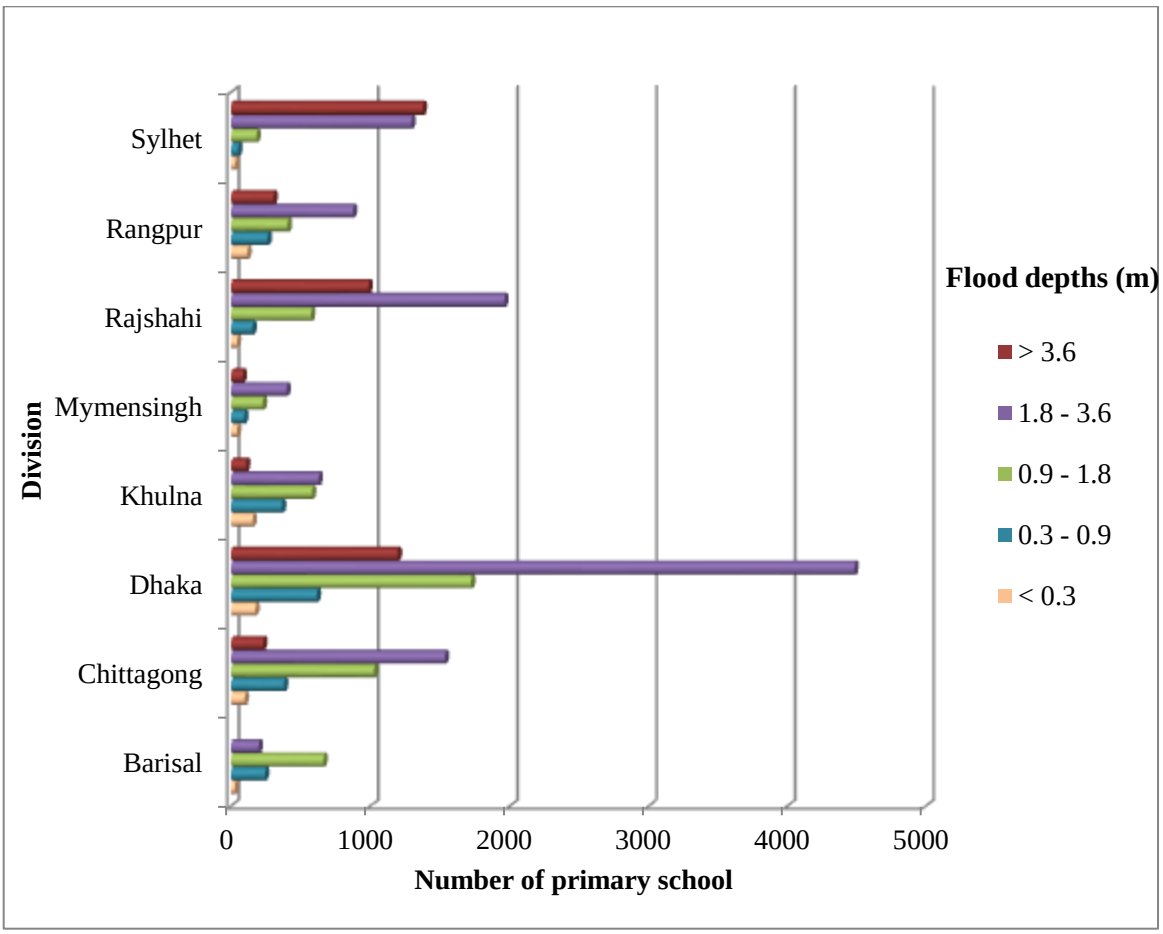


Figure 2.45: Number of Primary School exposed to different flood depth at division level

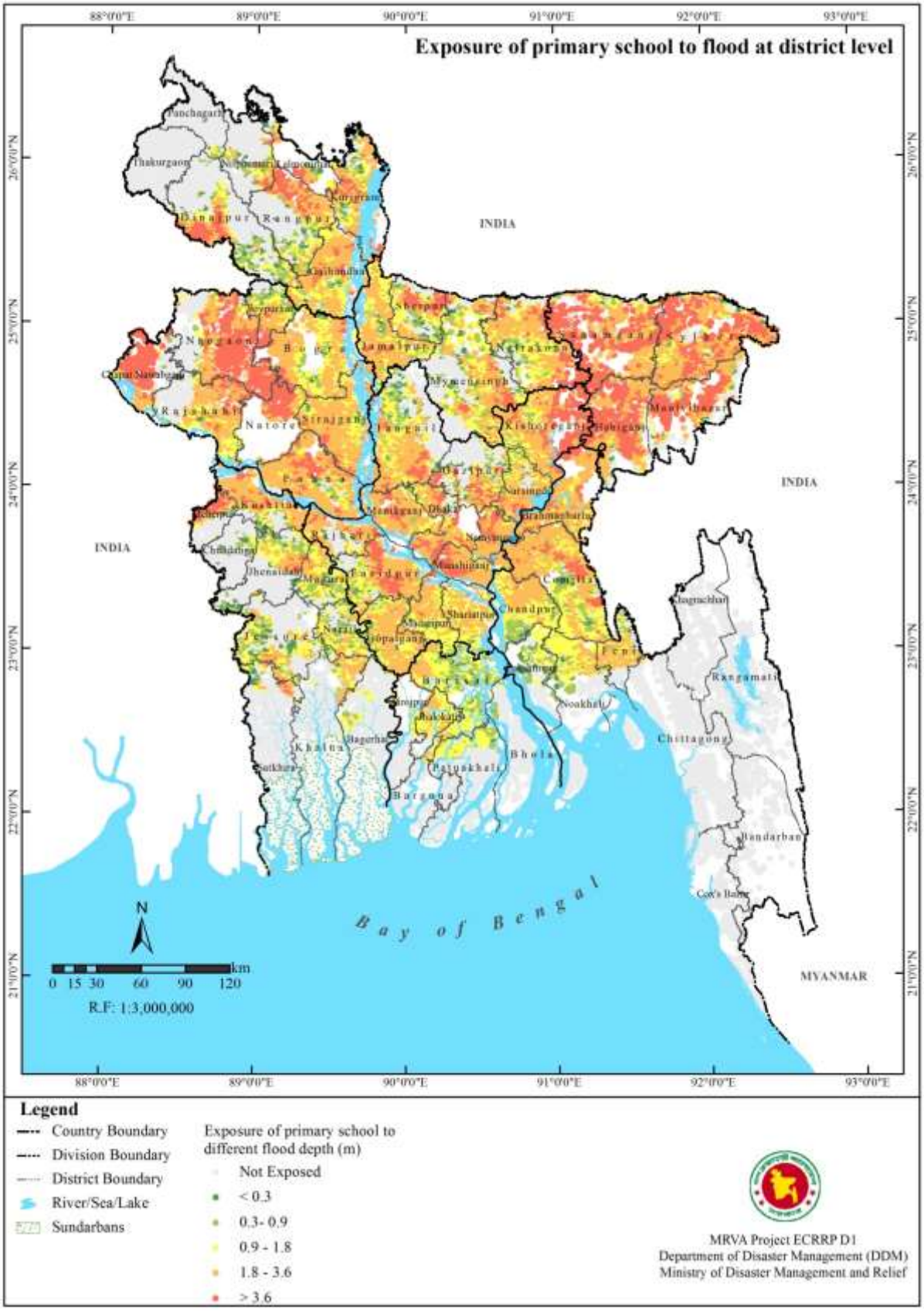


Figure 2.46: Exposure of Primary schools to flood at district level

2.1.4.3 First Responders

Fire stations

The number of Fire stations existing in different flood prone areas at division level is given in table 2.31 and figure 2.47. A fire station existing in different flood prone areas at district level is shown in figure 2.48.

Table 2.31: Number of Fire stations exposed to flood at division level

Division	Flood inundation depth (m) / Fire stations					Not affected	Total
	< 0.3	0.3 - 0.9	0.9 - 1.8	1.8 - 3.6	> 3.6		
Barisal		1	2			5	8
Chittagong		4	3	3	2	12	24
Dhaka	1	4	5	6	3	10	29
Khulna	1			4		11	16
Mymensingh		2		3		1	6
Rajshahi	2	1	7	7		2	19
Rangpur		1	1	1	3	5	11
Sylhet		1		4	3		8
Total	4	14	18	28	11	46	121

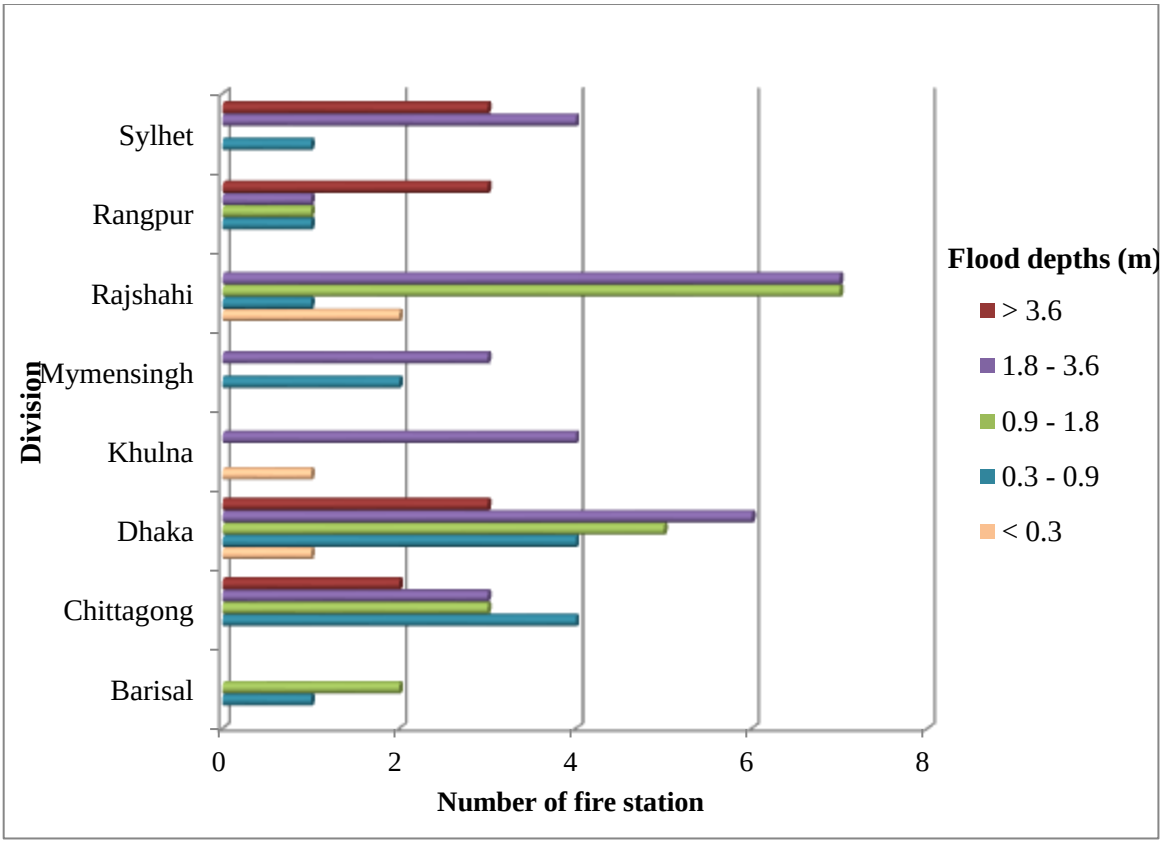


Figure 2.47: Number of Fire stations exposed to different flood depth at division level

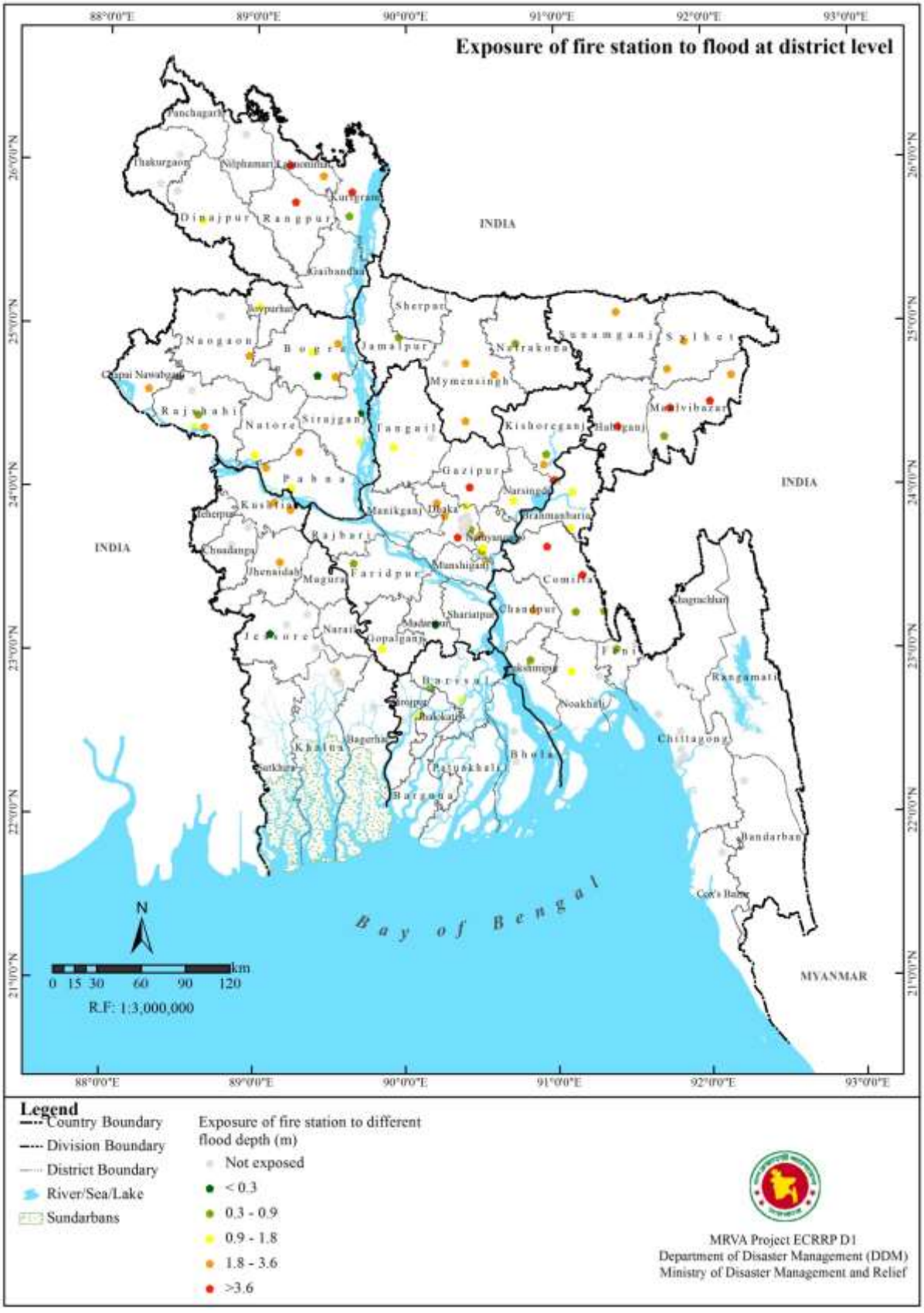


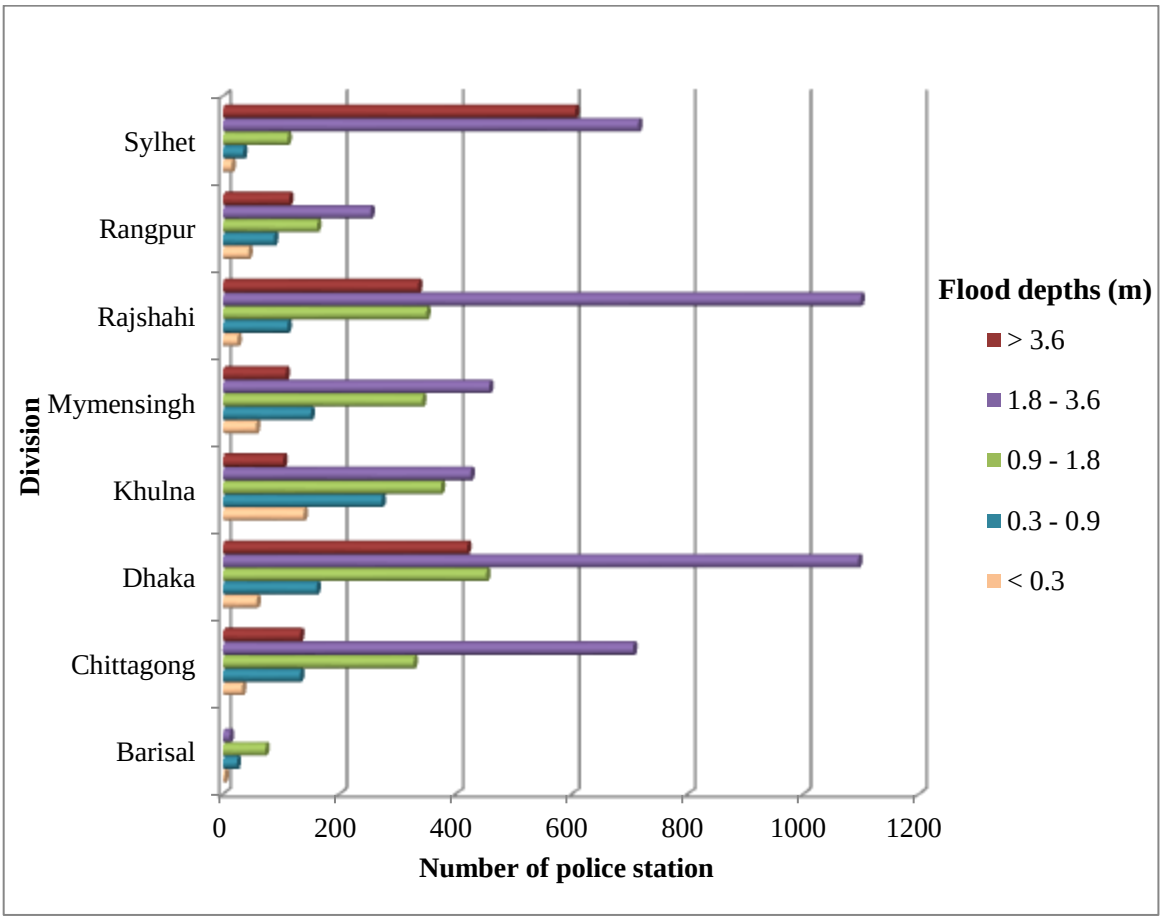
Figure 2.48: Exposure of Fire stations to flood at district level

Police stations

The number of Police stations existing in different flood prone areas at division level is given in table 2.32 and figure 2.49. A police station existing in different flood prone areas at district level is shown in figure 2.50.

Table 2.32: Number of Police stations exposed to flood at division level

Division	Flood inundation depth (m) / Police stations					Not affected	Total
	< 0.3	0.3 - 0.9	0.9 - 1.8	1.8 - 3.6	> 3.6		
Barisal	3	24	73	12		457	569
Chittagong	33	133	328	706	133	1,376	2,709
Dhaka	58	161	453	1,095	420	457	2,644
Khulna	139	273	375	426	104	1,746	3,063
Mymensingh	57	151	343	458	108	185	1,302
Rajshahi	25	111	350	1,099	336	292	2,213
Rangpur	44	88	162	254	114	729	1,391
Sylhet	15	35	111	715	606	104	1,586
Total	374	976	2,195	4,765	1,821	5,346	15,477



Future 2.49: Number of Police stations exposed to different flood depth at division level

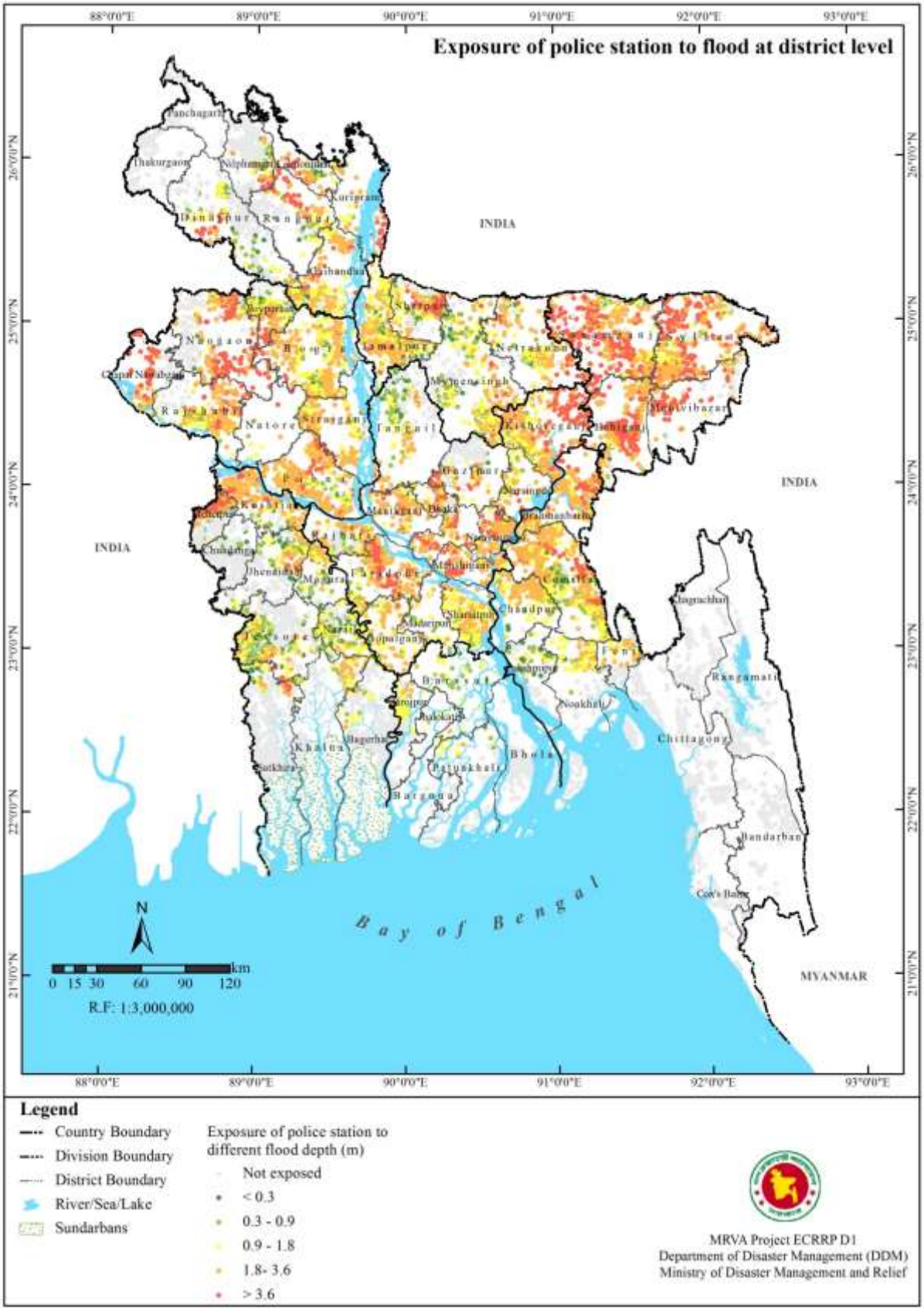


Figure 2.50: Exposure of Police stations to flood at district level

2.1.4.4 Cyclone Shelters

The number of Cyclone Shelters existing in different flood prone areas at division level is given in table 2.33 and figure 2.51. Cyclone Shelters existing in different flood prone areas at district level is shown in figure 2.52.

Table 2.33: Number of Cyclone Shelters exposed to flood at division level

Division	Flood inundation depth (m) Vs Cyclone Shelters					Not affected	Total
	< 0.3	0.3 - 0.9	0.9 - 1.8	1.8 - 3.6	> 3.6		
Barisal	3	38	83	28		1,217	1,369
Chittagong	28	53	66	49	1	1801	1,998
Dhaka		3	24	13	1		41
Khulna	1	3	16	7		342	369
Total	32	97	189	97	2	3,360	3,777

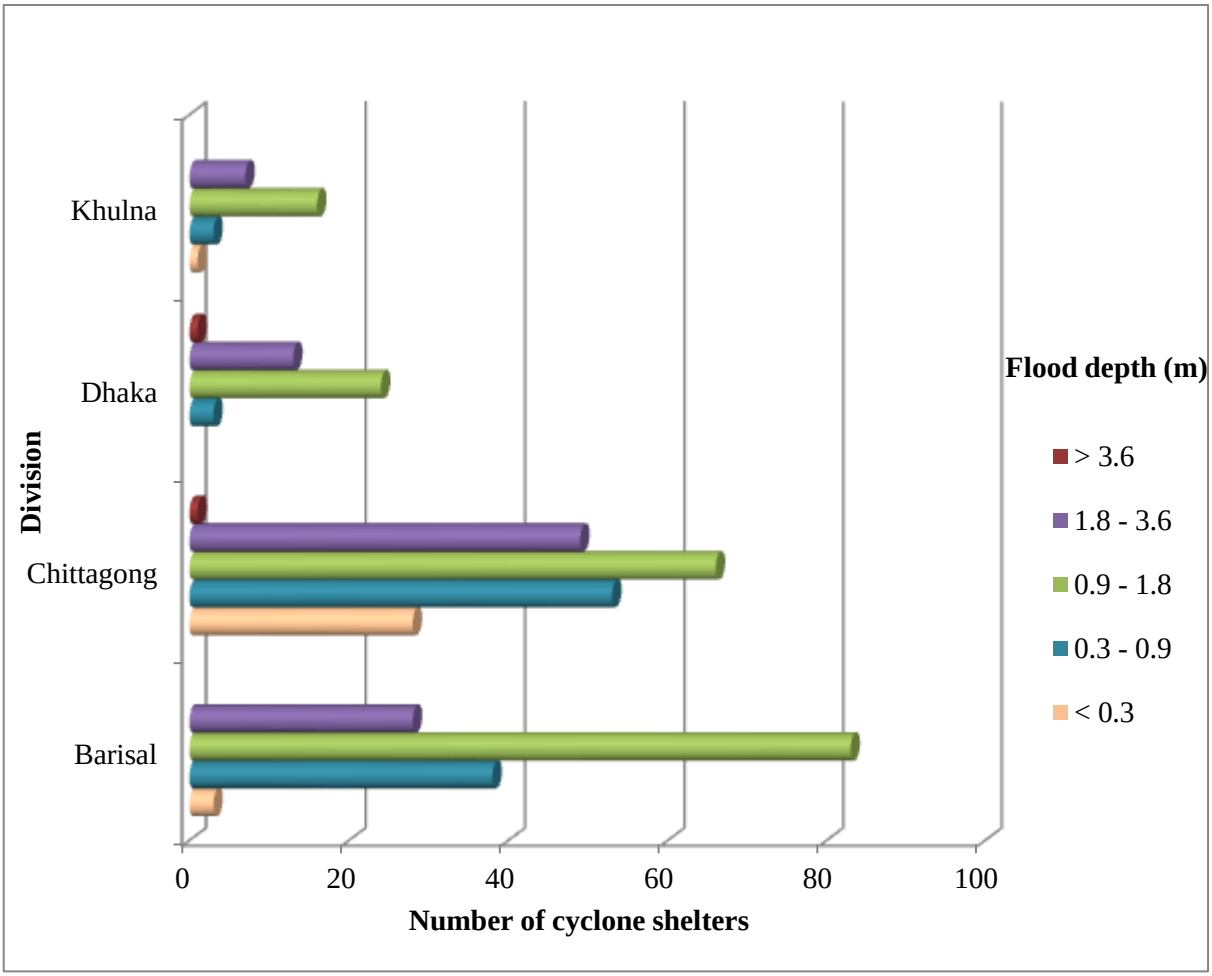


Figure 2.51: Number of Cyclone Shelters exposed to different flood depth at division level

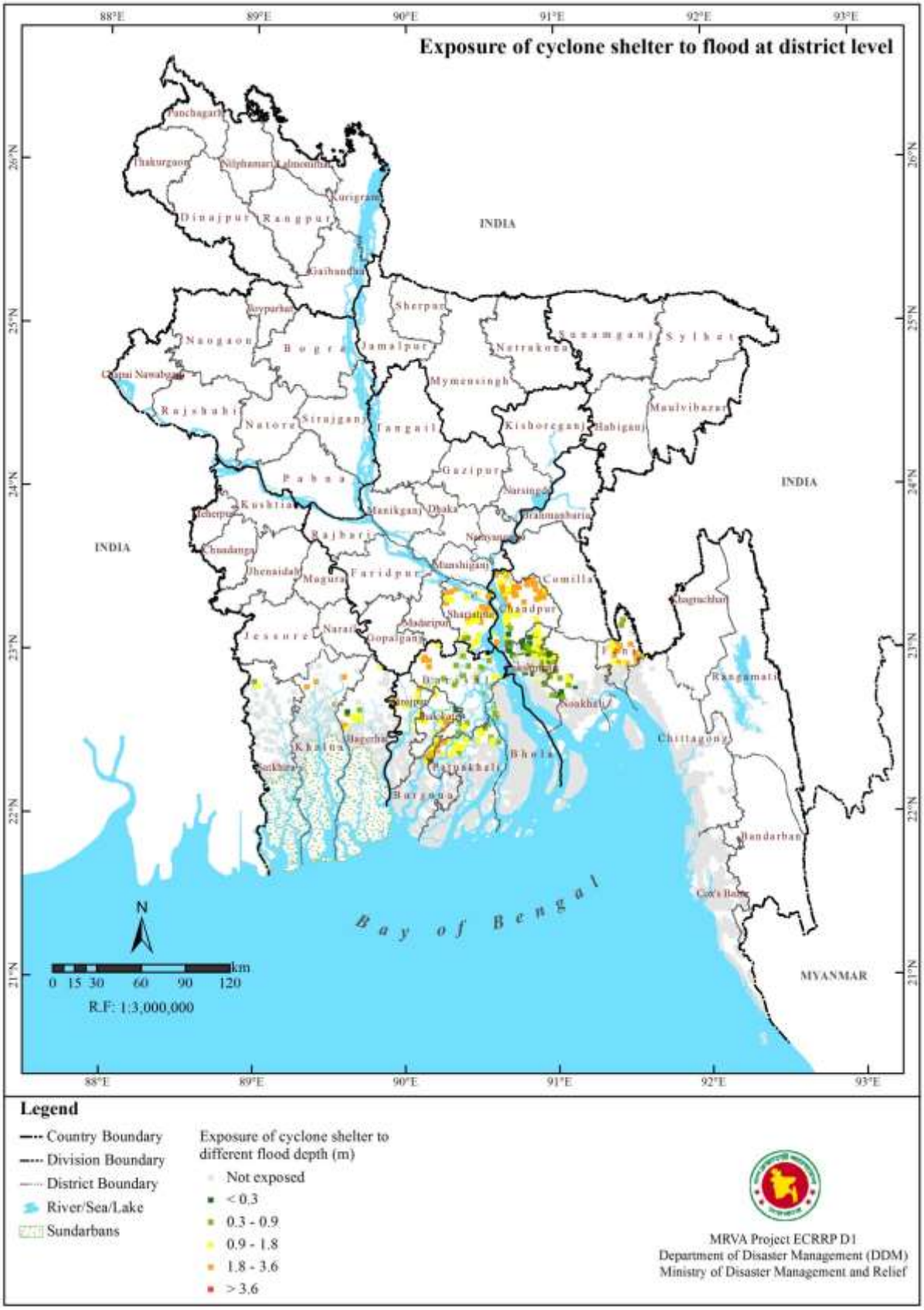


Figure 2.52: Exposure of Cyclone Shelters to flood at district level

2.1.5 Infrastructure

2.1.5.1 Road

The types of roads existing in the database are, National Highway, Regional Highway, Municipal road, Upazila road, Union road and Village roads. Combining flood hazard map and road network map will provide existing type of roads in flood prone areas.

The length of all road categories existing in different flood prone areas at division level is given in table 2.34. The length of National Highway existing in different flood prone areas at division level is given in table 2.35 and figure 2.53.

Table 2.34: Length of road (Km) exposed to flood at national level

Flood Depth (m) / Road Category	National High Way	Regional High Way	Union Road	Upazila Road	Village Road
< 0.3	80.25	276.37	895.07	800.85	3,048.94
0.3 -0.9	242.50	780.20	2,620.99	2,392.66	9,142.24
0.9 -1.8	564.02	1,755.02	5,983.46	5,495.38	20,914.89
1.8 -3.6	1,099.32	3,348.75	11,273.28	10,153.95	36,459.45
> 3.6	356.19	1,205.98	4,487.08	4,046.05	14,217.90
Not Affected	1,299.83	4,151.60	13,631.07	11,620.35	53,530.11
Total	3,642.11	11,517.91	38,890.96	34,509.24	137,313.53

Table 2.35: Length of National Highway exposed to flood at division level

Division	Flood inundation depth (m) / road length (km)					Not affected	Total
	< 0.3	0.3-0.9	0.9-1.8	1.8-3.6	> 3.6		
Barisal	4.92	12.10	44.44	4.91	0.00	92.84	159.22
Chittagong	4.28	19.72	68.76	128.15	32.45	423.83	677.20
Dhaka	17.92	66.16	152.98	370.31	101.19	129.11	837.67
Khulna	19.40	56.78	78.79	103.76	11.15	298.63	568.52
Mymensingh	1.87	9.22	33.70	61.63	7.28	21.43	135.11
Rajshahi	18.60	55.41	133.36	258.97	66.96	79.91	613.21
Rangpur	11.49	20.99	39.54	76.83	43.67	211.00	403.52
Sylhet	1.77	2.11	12.46	94.76	93.49	43.09	247.67
Total	80.25	242.50	564.02	1,099.32	356.19	1,299.83	3,642.11

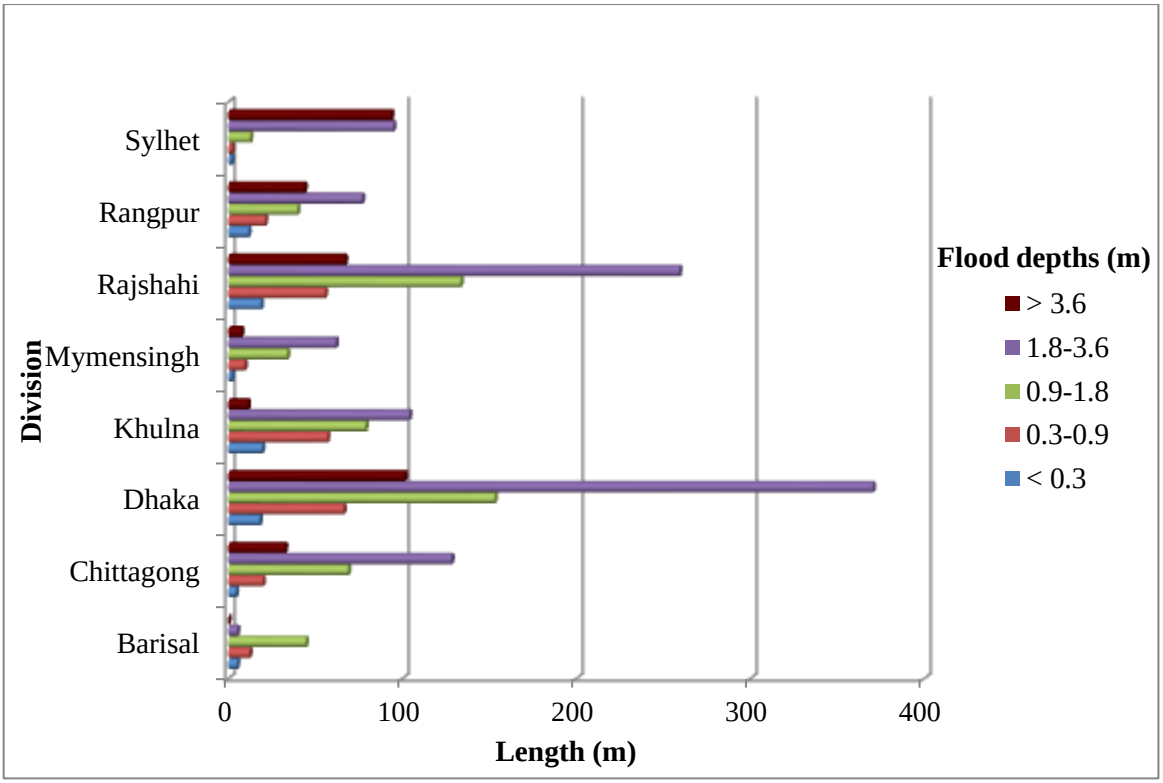


Figure 2.53: Length of National Highway exposed to flood at division level

The length of Regional highway existing in different flood prone areas at division level is given in table 2.36 and figure 2.54.

Table 2.36: Length of Regional Highway exposed to flood at division level

Division	Flood inundation depth (m) / length (km)					Not affected	Total
	< 0.3	0.3-0.9	0.9-1.8	1.8-3.6	> 3.6		
Barisal	7.99	55.34	228.37	78.81	0.31	442.07	812.90
Chittagong	38.68	169.45	371.26	572.79	85.83	1443.07	2,681.08
Dhaka	36.50	112.85	333.88	795.58	200.72	187.57	1,667.104
Khulna	51.92	95.58	133.68	154.82	20.04	801.36	1,257.40
Mymensingh	53.05	147.19	267.59	302.27	87.08	239.75	1,096.924
Rajshahi	23.36	91.59	259.82	810.17	290.51	277.24	1,752.70
Rangpur	58.66	98.81	122.53	265.75	155.50	692.77	1,394.01
Sylhet	6.22	9.39	37.87	368.55	365.99	67.78	855.79
Total	276.37	780.20	1,755.02	3,348.75	1,205.98	4,151.60	11,517.91

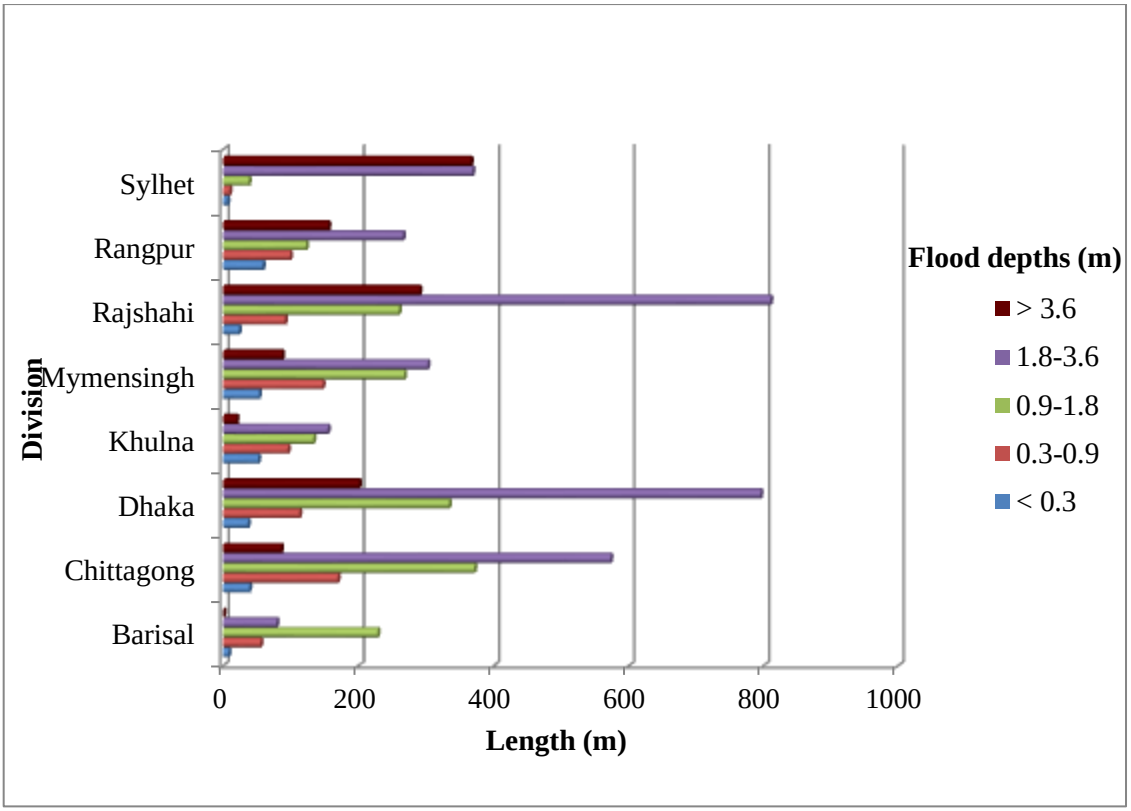


Figure 2.54: Length of Regional Highway exposed to flood at district level

Exposure of road network to flood at district level is shown in figure 2.55.

Figure 2.55: Exposure of road network for flood at district level

2.1.5.2 Bridge

The number of bridges existing in different flood prone areas at division level is given in table 2.37 and figure 2.56. Exposure of bridges to flood at district level is shown in figure 2.57.

Table 2.37: Number of Bridges exposed to flood at division level

Bridges	Flood inundation depth (m) / number of bridges					Not affected	Total
	< 0.3	0.3 - 0.9	0.9 - 1.8	1.8 - 3.6	> 3.6		
Barisal		25	346	135		406	912
Chittagong	1	8	54	248	71	2,012	2,394
Dhaka	353	1,206	2,505	8,138	1,956	1,468	15,626
Khulna	178	359	490	304	17	1,932	3,280
Mymensingh	267	914	1,818	3,027	578	1,180	7,784
Rajshahi	5	58	307	682	46	269	1,367
Rangpur	103	236	202	9		667	1,217
Sylhet	116	226	466	3,473	4,434	1,702	10,417
Total	1,023	3,032	6,188	16,016	7,102	9,636	42,997

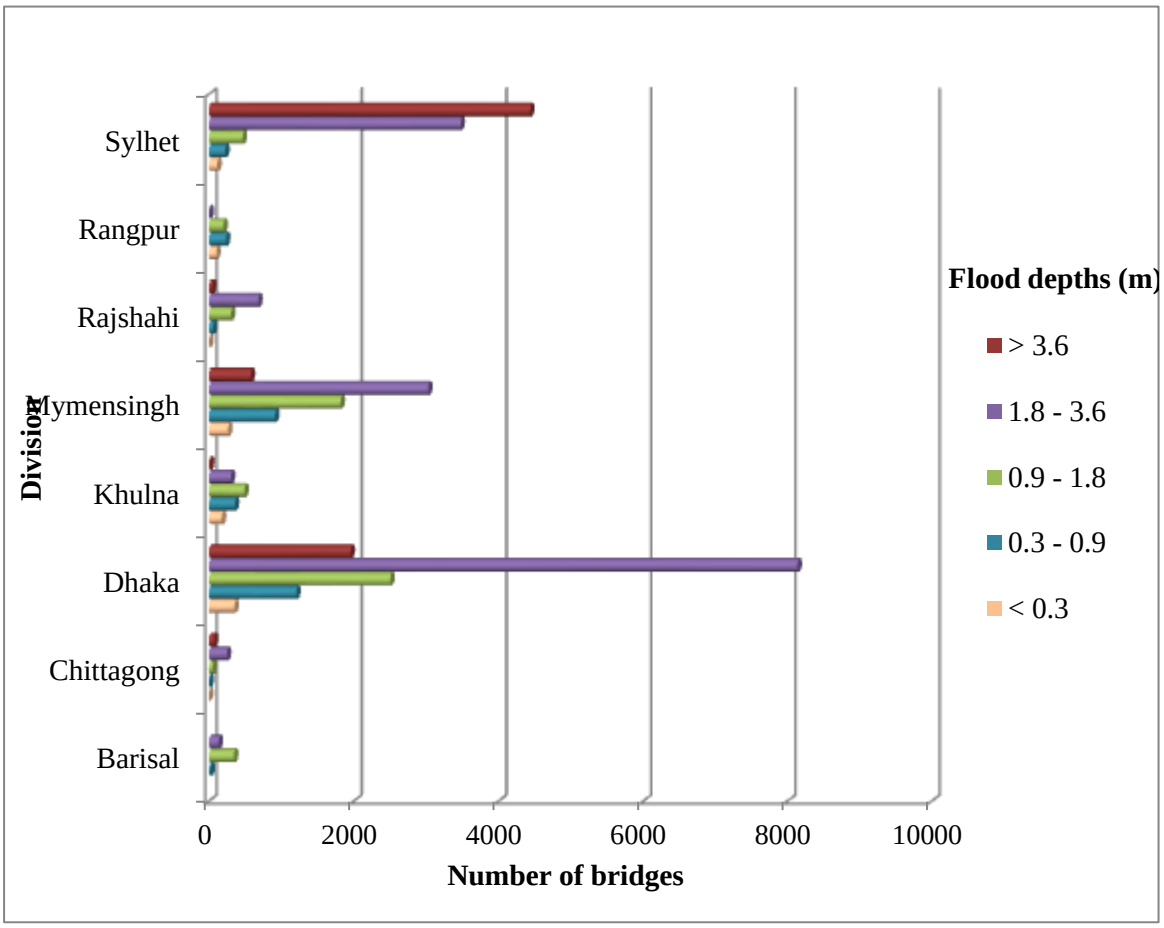


Figure 2.56: Number of Bridges exposed to flood at division level

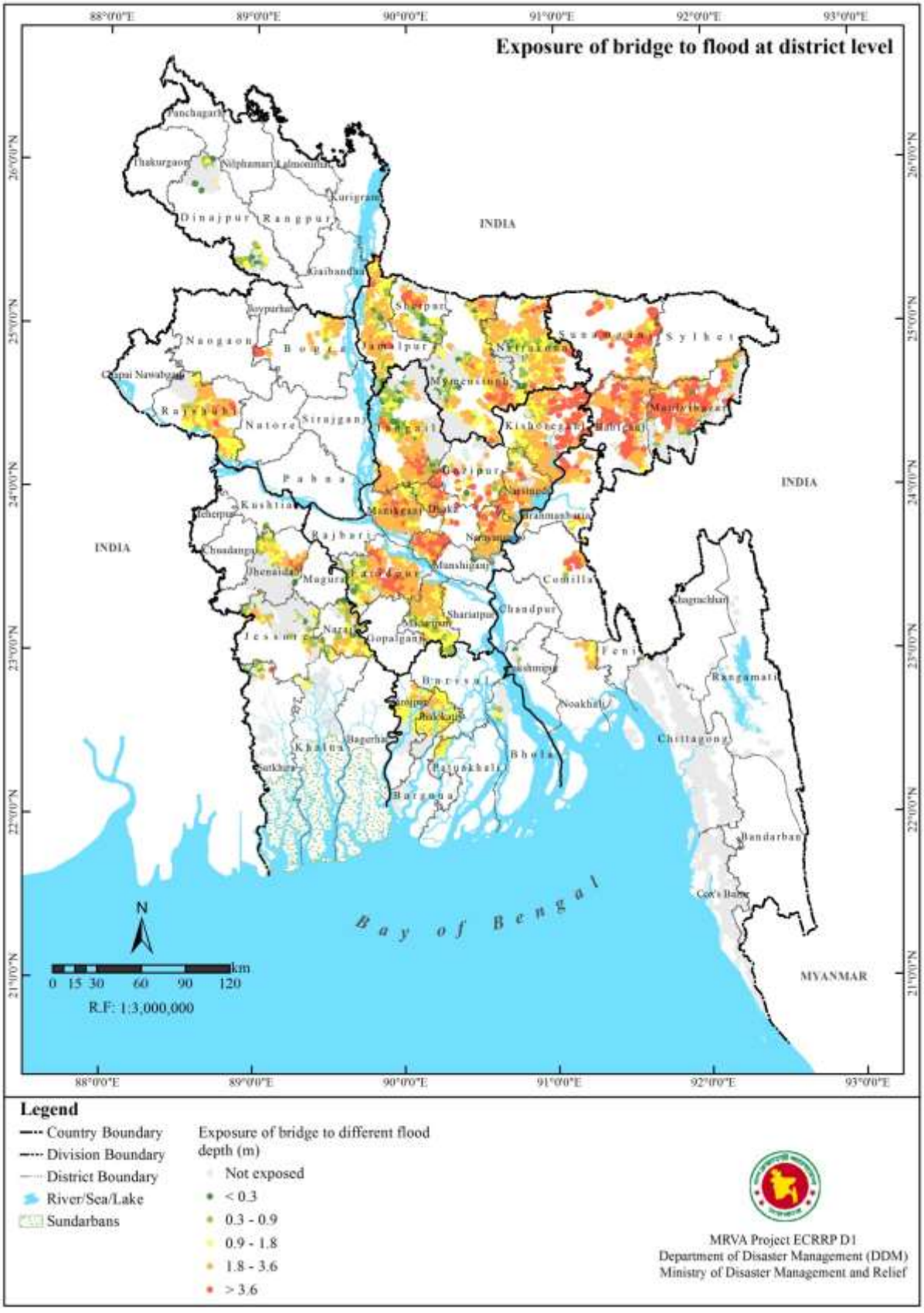


Figure 2.57: Number of Bridges exposed to flood at district level

2.1.5.3 Railway

Combining flood hazard map and railway network map will provide the length of railway network (broad gauge and narrow gauge) exposed to flood. The length of railway network (Broad, narrow gauge) existing in flood prone areas at national level is given in table 2.38. The length of railway network (Broad gauge) existing in flood prone areas at division level is given in table 2.39 and figure 2.58.

Table 2.38: Length of railway network inundated in flood depth

Flood Depth (m)	Broad Gauge	Narrow Gauge
< 0.3	24.01	47.04
0.3 - 0.9	43.08	132.06
0.9 - 1.8	112.90	340.17
1.8 - 3.6	301.78	601.41
> 3.6	135.61	230.81
Not Affected	378.14	468.36
Total length (km)	995.52	1,819.85

Table 2.39: Length of Railway (Broad gauge) exposed to flood at division level

Division	Flood inundation depth (m) / length (km)					Not affected	Total
	< 0.3	0.3 - 0.9	0.9 - 1.8	1.8 - 3.6	> 3.6		
Barisal	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Chittagong	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Dhaka	3.49	13.28	29.85	100.24	45.22	40.56	232.65
Khulna	5.40	12.27	31.45	63.66	6.37	168.75	287.90
Mymensingh	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Rajshahi	3.08	11.94	48.58	133.95	84.03	74.93	356.51
Rangpur	12.03	5.59	3.02	3.93	0.00	93.90	118.46
Sylhet	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	24.01	43.08	112.90	301.78	135.61	378.14	995.52

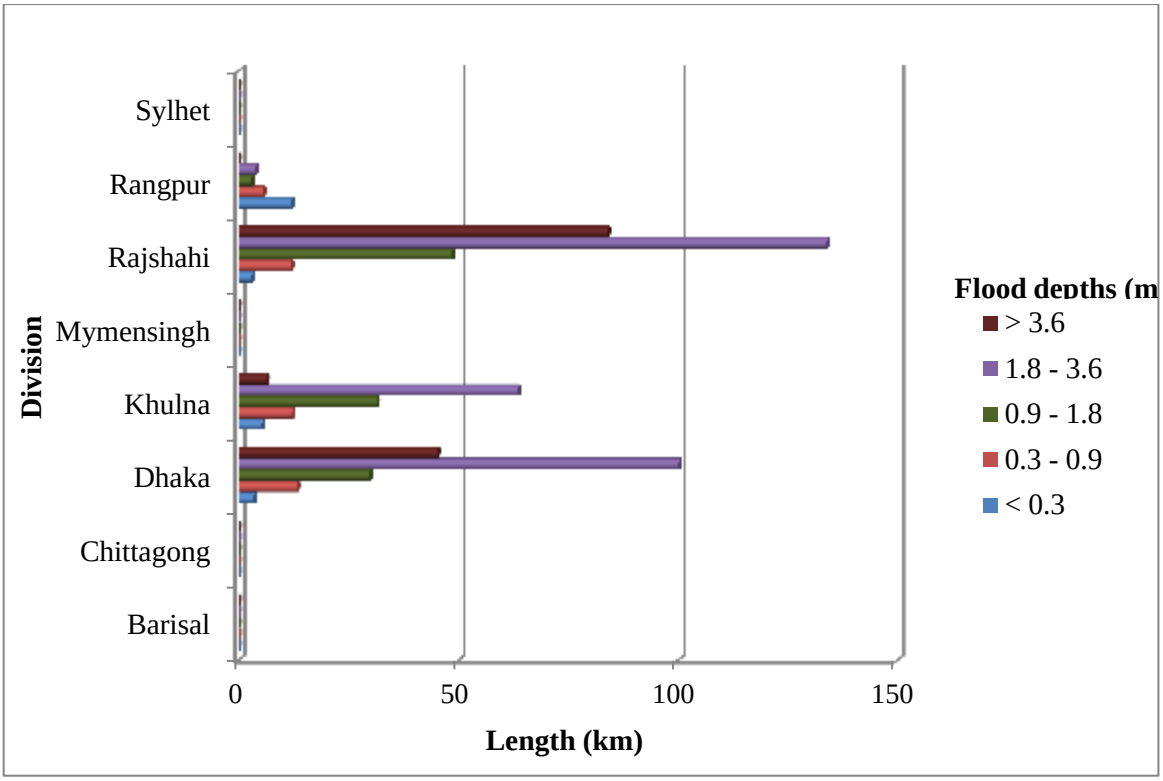


Figure 2.58: Length of Railway (Broad gauge) exposed to flood in division level

The length of railway network (narrow gauge) existing in flood prone areas at division level is given in table 2.40 and figure 2.59.

Table 2.40: Length of Railway (narrow gauge) exposed to flood in each Division

Division	Flood inundation depth (m) / length (Km)					Not affected	Total
	< 0.3	0.3 - .9	0.9 - 1.8	1.8 - 3.6	> 3.6		
Barisal	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Chittagong	4.16	37.87	111.76	124.55	19.12	160.39	457.85
Dhaka	7.50	10.97	33.33	118.95	29.74	34.82	235.30
Khulna	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mymensingh	18.70	51.54	96.73	89.82	13.47	46.04	316.31
Rajshahi	2.91	3.12	13.64	34.06	10.48	4.12	68.33
Rangpur	7.07	16.57	61.63	159.20	46.71	170.73	461.91
Sylhet	6.70	11.99	23.09	74.83	111.29	52.26	280.17
Total	47.04	132.06	340.17	601.41	230.81	468.36	1,819.85

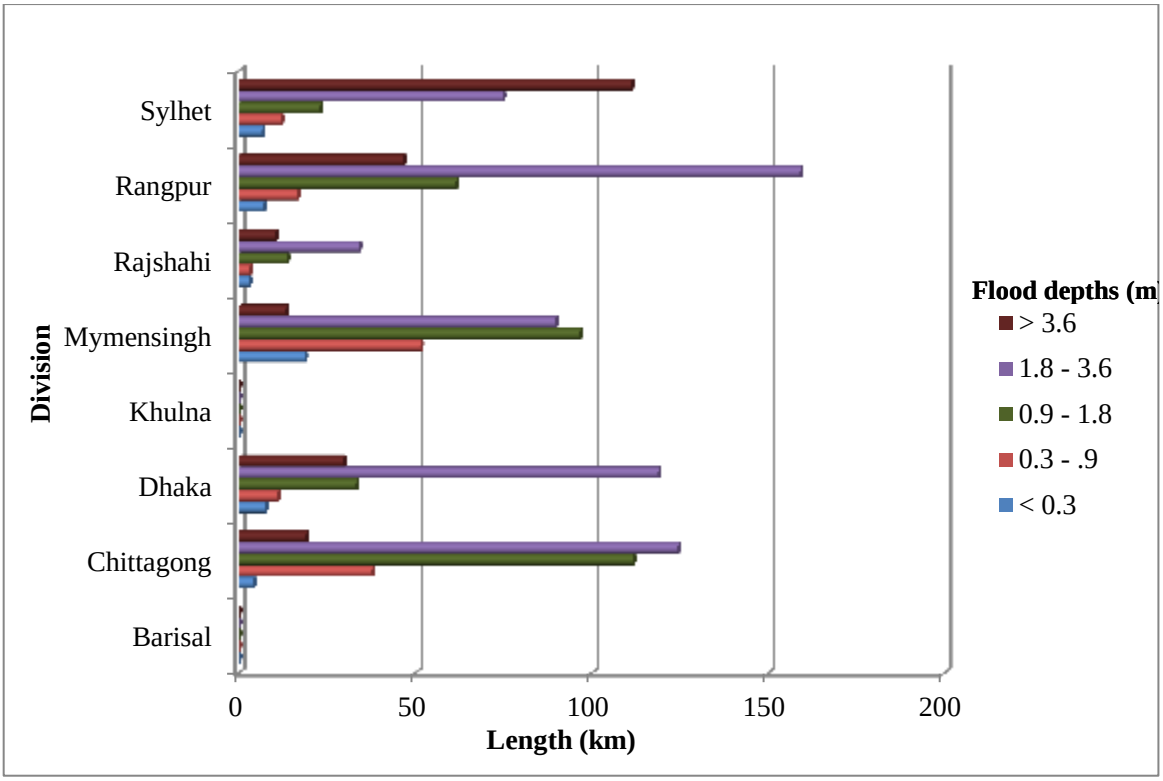


Figure 2.59: Length of Railway (narrow gauge) exposed to flood in each Division

Exposure of railway network to flood at district level is shown in figure 2.60.

Figure 2.60: Exposure of railway network to flood at district level

2.1.5.4 Air, Sea and River Ports

Combining flood hazard map and Air, Sea and River ports map will provide the number of ports exposed to flood.

The number of Air, Sea and River ports existing in different flood prone areas at division level is given in table 2.41. Exposure of Air, Sea and River ports to flood at district level is shown in figure 2.61.

Table 2.41: Number of Air, Sea and river ports exposed to flood in each division

Division	Flood inundation depth (m) / number of ports					Not affected
	< 0.3	0.3 - 0.9	0.9 - 1.8	1.8 - 3.6	> 3.6	
Barisal		1	3			0
Chittagang				1		3
Dhaka	1			1		1
Khulna						2
Mymensingh						
Rajshahi		1	1	1		
Rangpur						3
Sylhet			1	1		
Total	1	2	5	4	0	9

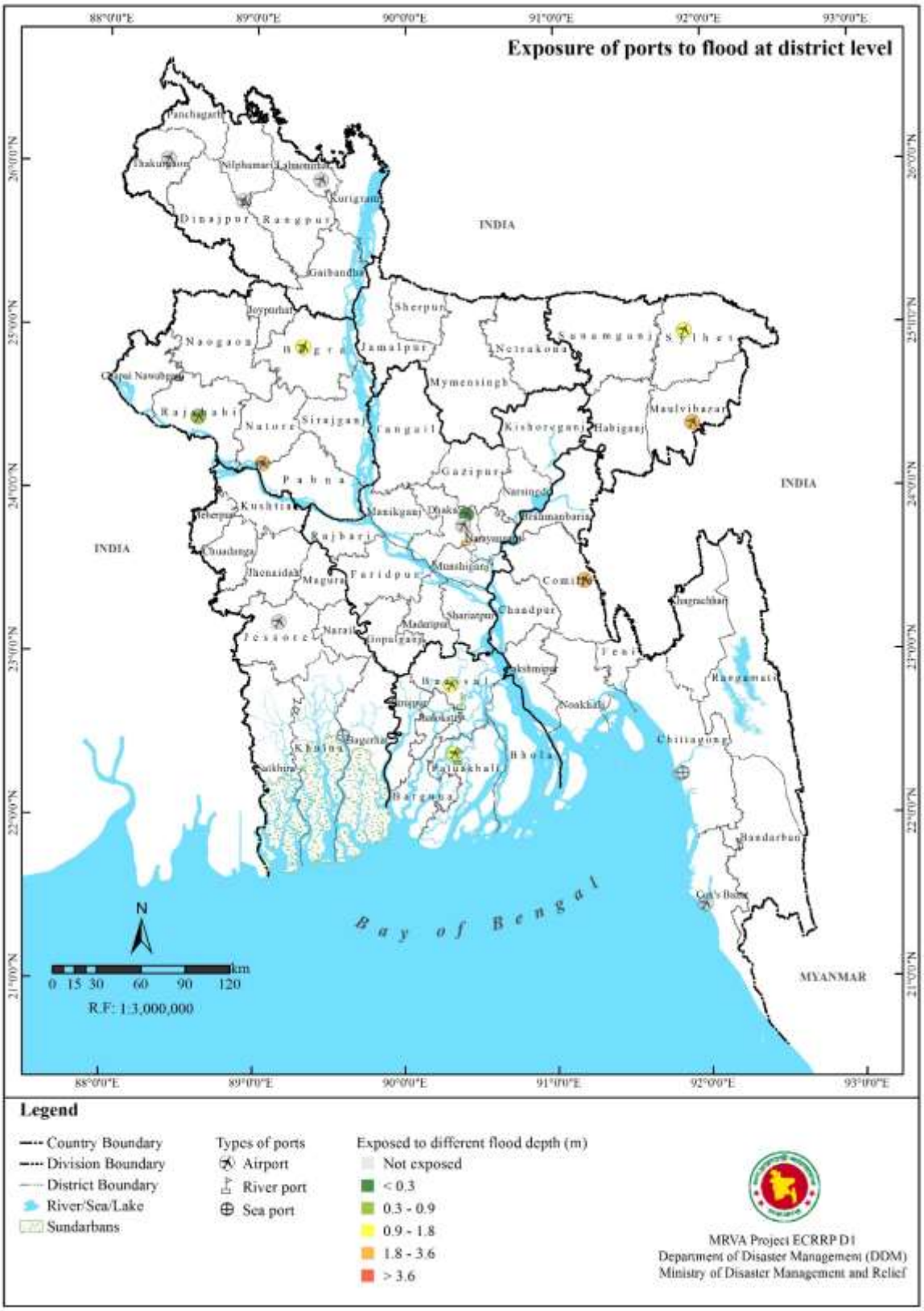


Figure 2.61: Number of Air, Sea and river ports exposed to flood at district level

2.1.5.5 Power

Combining flood hazard map and Power sector (Power stations, Power sub-stations) will provide the number of power stations, power sub-stations exposed to flood.

The number of Power stations exposed to flood at division level is given in table 2.42 and figure 2.62.

Table 2.42: Number of Power Stations exposed to flood at division level

Division	Flood inundation depth (m) / number of power stations					Not Affected
	< 0.3	0.3 - 0.9	0.9 - 1.8	1.8 - 3.6	> 3.6	
Barisal						1
Chittagong			1	1		3
Dhaka		1		2		
Khulna				1		1
Mymensingh				1		
Rajshahi					1	
Rangpur					1	3
Sylhet				1	1	1
Total	0	1	1	6	3	9

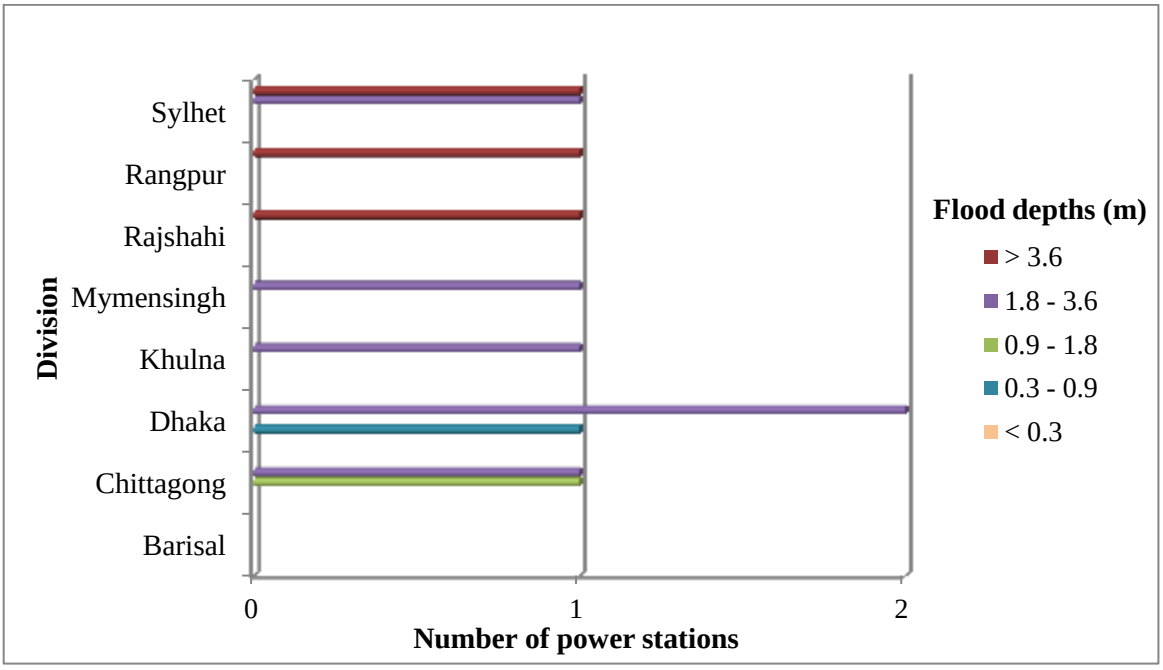


Figure 2.62: Number of Power stations exposed to flood at division level

The number of Power sub-stations existing in different flood hazard levels at division level is given in table 2.43 and figure 2.63.

Table 2.43: Number of Power sub-stations exposed to flood at division level

Division	Flood inundation depth (m) / number of sub-stations					Not affected
	< 0.3	0.3 - 0.9	0.9 - 1.8	1.8 - 3.6	> 3.6	
Barisal			1			2
Chittagong			2	2		9
Dhaka	2	2	3	3	4	4
Khulna		1	3	1		6
Mymensingh		2		1		
Rajshahi		2	4	2	2	
Rangpur	1			1		2
Sylhet	1			2		
Total	4	7	13	12	6	23

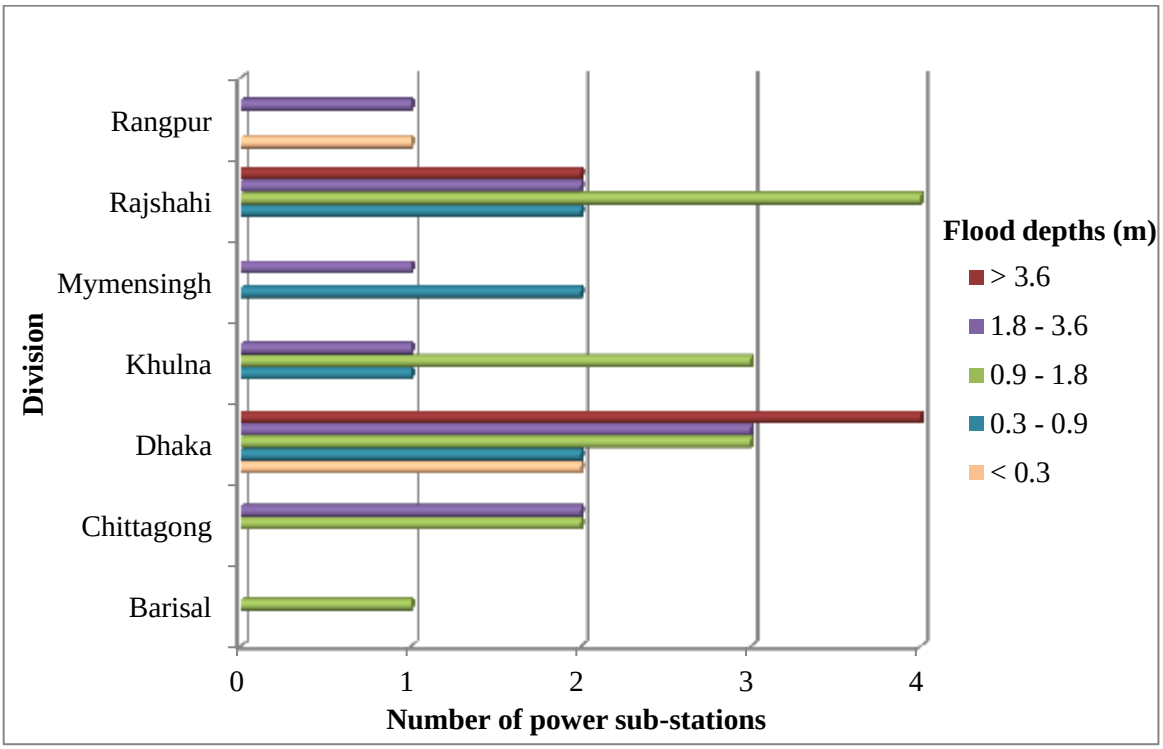


Figure 2.63: Number of Power sub-stations exposed to flood at division level

Exposure of Power stations to flood at district level is shown in figure 2.64.

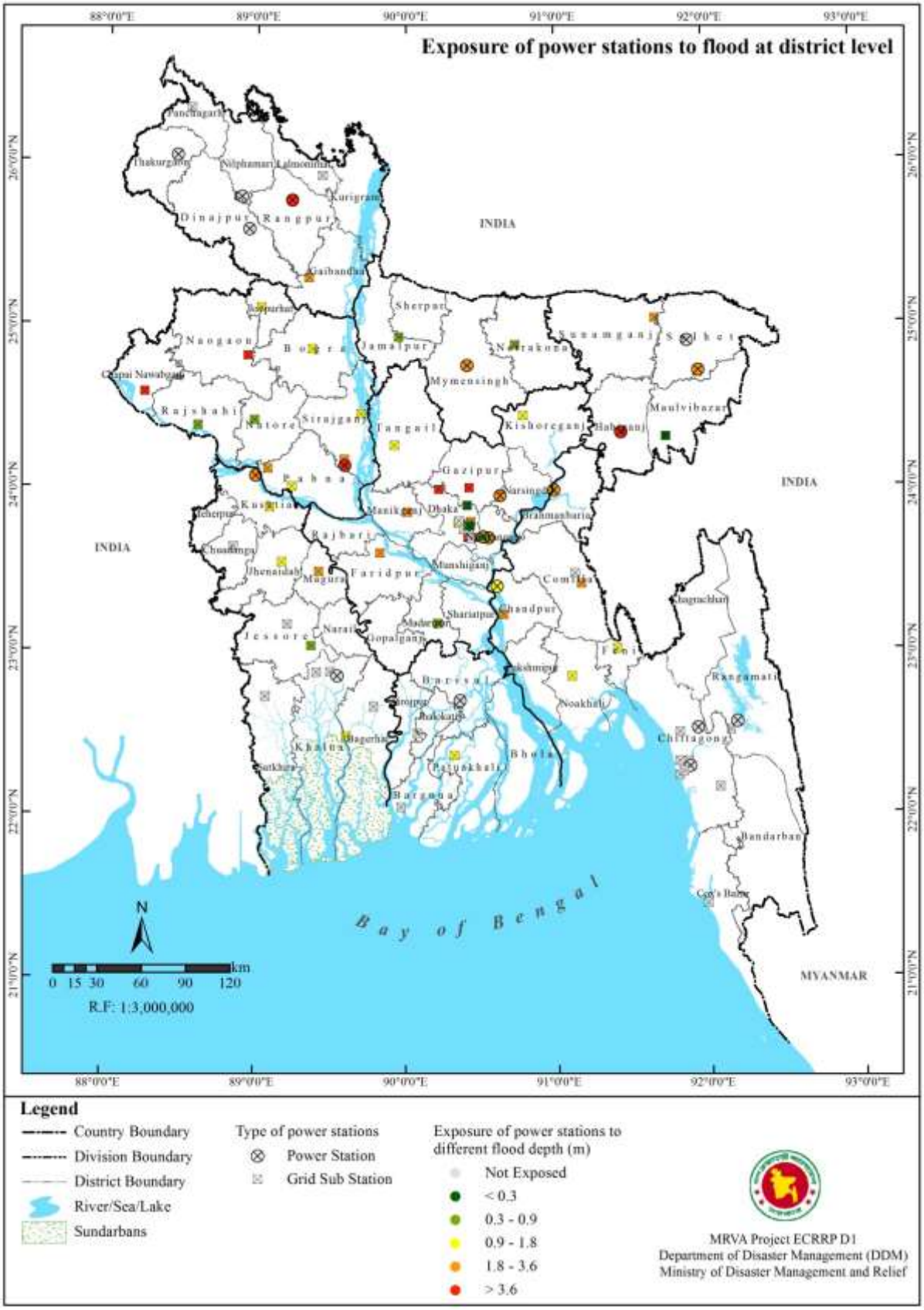


Figure 2.64: Exposure of Power infrastructure to flood prone areas at district level

2.2 Vulnerability / Damage Assessment

2.2.1 Household structures

The damage curves representing the vulnerability of household structure types is developed based on the literature and limited field data analysis (more details in Annexure – I: Probabilistic damage functions report). The damage curves developed for household structure types due to flood inundation depth is given as table 2.44 and figure 2.65.

Table 2.44: Damage function table for household structures due to flood inundation depth

Flood Depth (m)	Damage ratio (%)			
	Jhupri	Katcha	Semi- Pucca	Pucca
0 – 0.3	0.1	0.1	0.0	0.0
0.3 - 0.9	6.8	6.8	3.3	1.7
0.9 – 1.8	50.0	50.0	30.0	20.0
1.8 – 3.6	95.1	95.1	58.2	39.3
>3.6	100.0	100.0	60.0	40.0

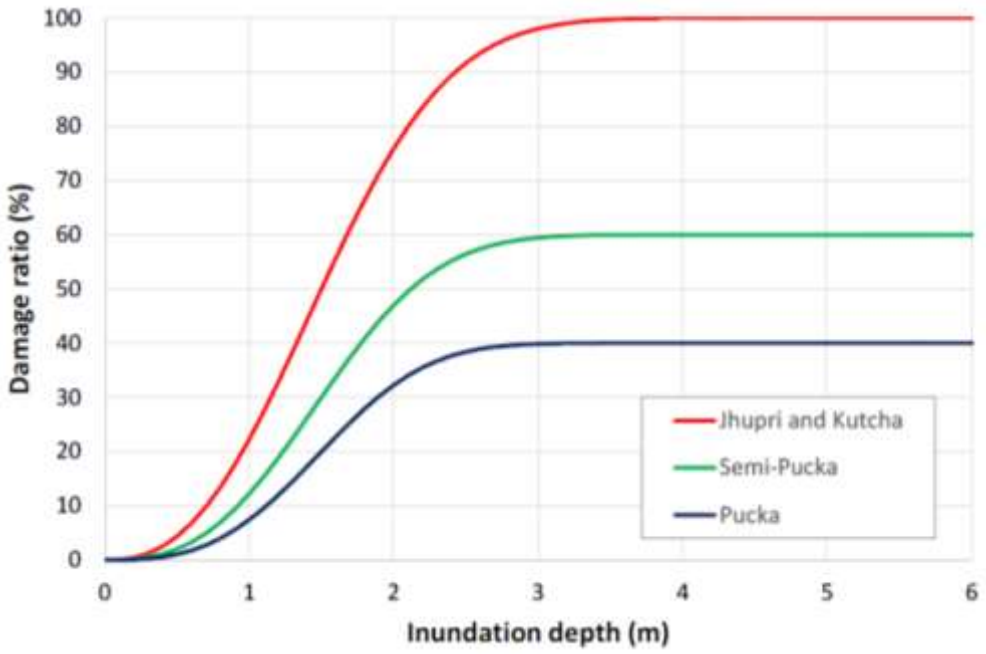


Figure 2.65: Damage functions for household structure types due to flood inundation depth

Using the above damage function table and exposure of household structure types to flood inundation depth, possible % of damage of household structure is calculated. The percentage of damage is classified into 5 risk levels (D0: 0, D1: 1-15 %, D2: 15-35%, D3: 35-60%, D4: >60%) as explained in section 1.5. The number of Pucca household

structures at different risk levels at division level is given table 2.45 and figure 2.66. Pucca household structures at different risk levels at district level is given in figure 2.67.

Table 2.45: Number of Pucca household structures at different risk levels due to flood at division level

Division	Risk levels (%) / number of household structures				
	0	0-15	15-35	35-60	>60
Barisal	31,635	13,981	26,243	6,034	0
Chittagong	489,757	36,029	87,322	115,090	0
Dhaka	792,842	124,700	182,232	592,238	0
Khulna	486,637	4,021	9,596	10,513	0
Mymensingh	24,368	8,166	14,340	18,015	0
Rajshahi	220,785	11,434	27,183	48,983	0
Rangpur	85,159	3,147	3,966	18,801	0
Sylhet	39,815	4,702	15,123	164,329	0
Total Pucca households	2,170,999	206,179	366,005	974,003	0

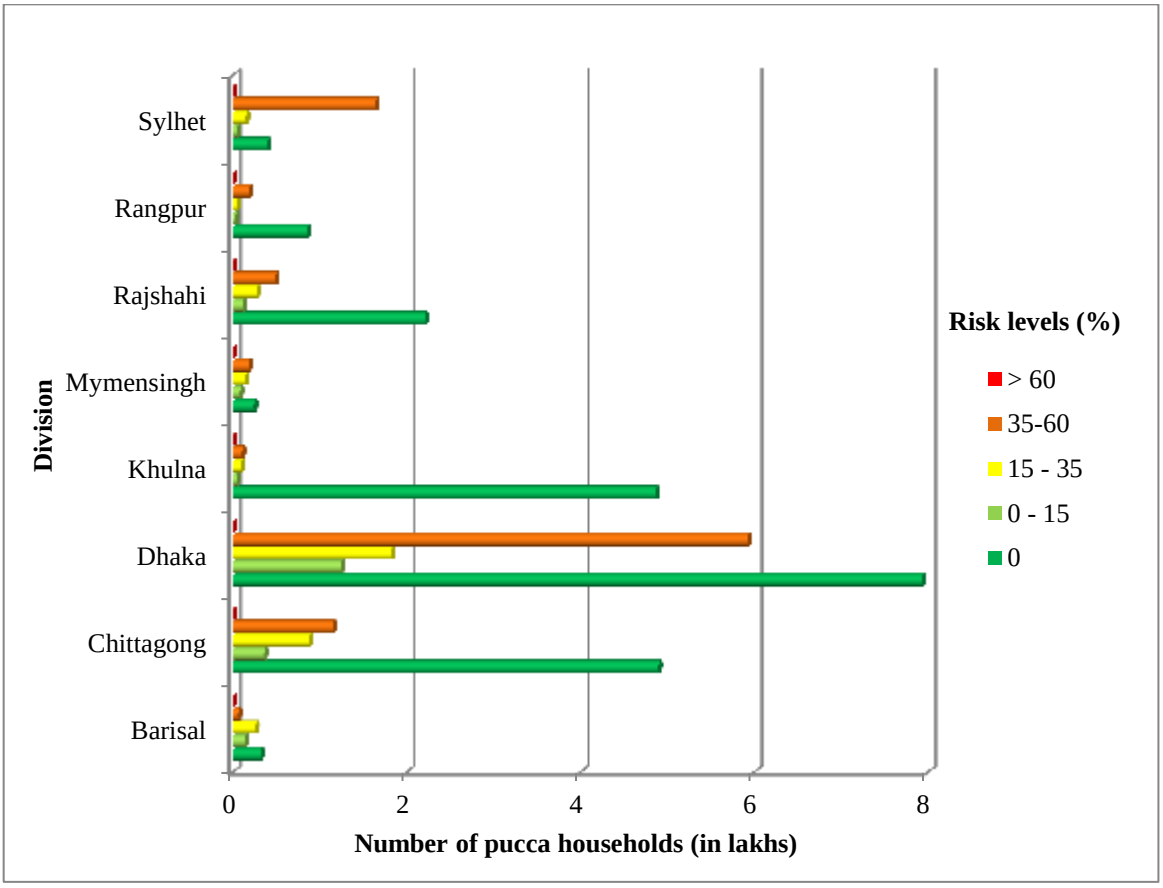


Figure 2.66: Number of Pucca household structures at different risk levels due to flood at division level.

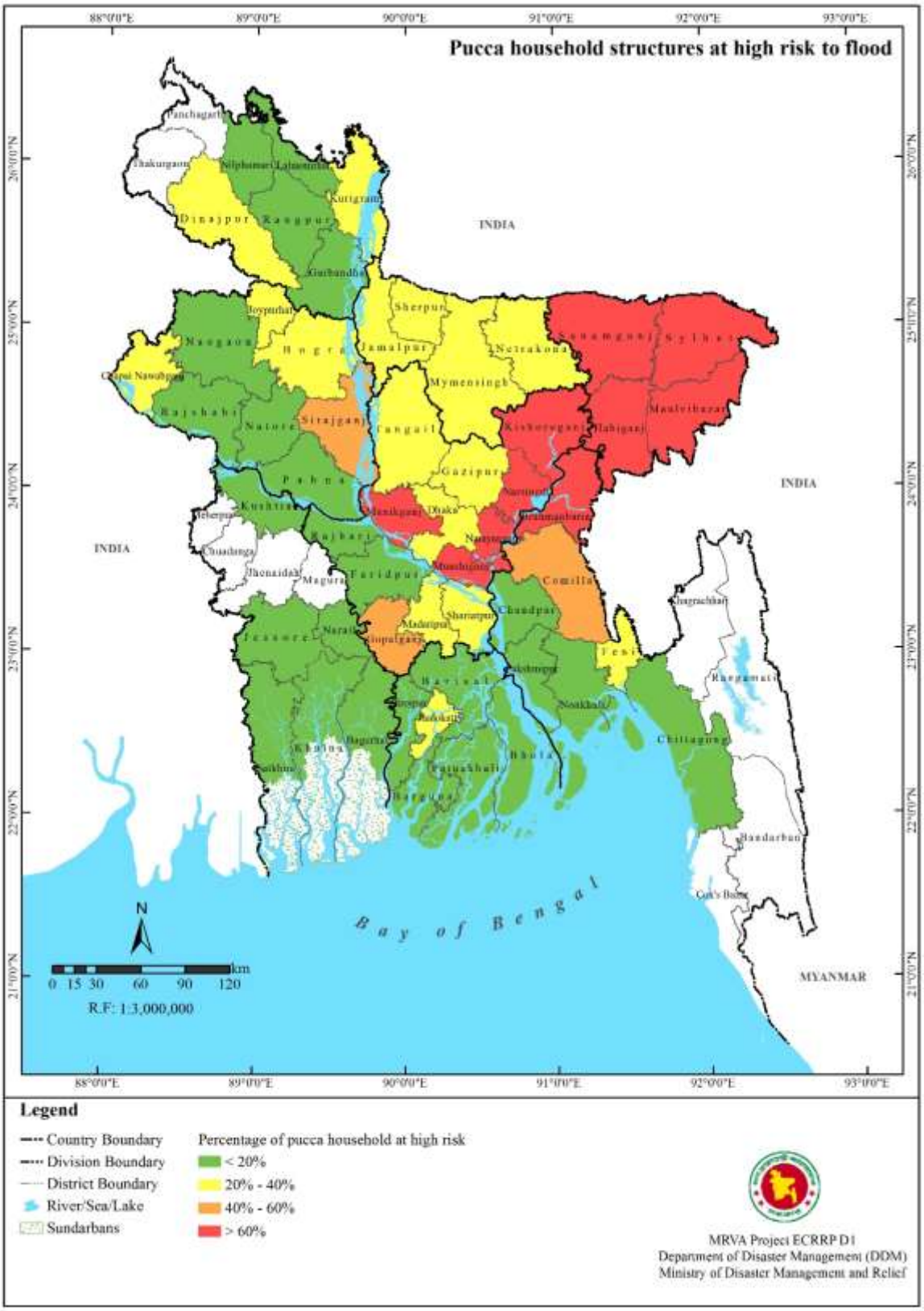


Figure 2.67: Pucca household structures at different risk levels due to flood at district level

The number of semi-Pucca household structures at different risk levels at division level is given table 2.46 and figure 2.68. Semi-Pucca household structures at different risk levels at district level is given in figure 2.69

Table 2.46: Number of semi-Pucca household structures at different risk levels due to flood at division level

Division	Risk level (%)/ number of household structures				
	0	0-15	15-35	35-60	>60
Barisal	77,797	21,201	43,736	10,565	0
Chittagong	470,160	43,373	105,827	176,852	0
Dhaka	743,961	147,167	286,203	979,926	0
Khulna	959,899	8,546	22,721	33,280	0
Mymensingh	88,206	31,969	58,842	79,152	0
Rajshahi	661,649	40,152	100,047	164,918	0
Rangpur	462,866	17,918	18,724	65,605	0
Sylhet	80,029	8,416	23,941	303,298	0
Total semi-Pucca households	3,544,568	318,742	660,042	1,813,596	0

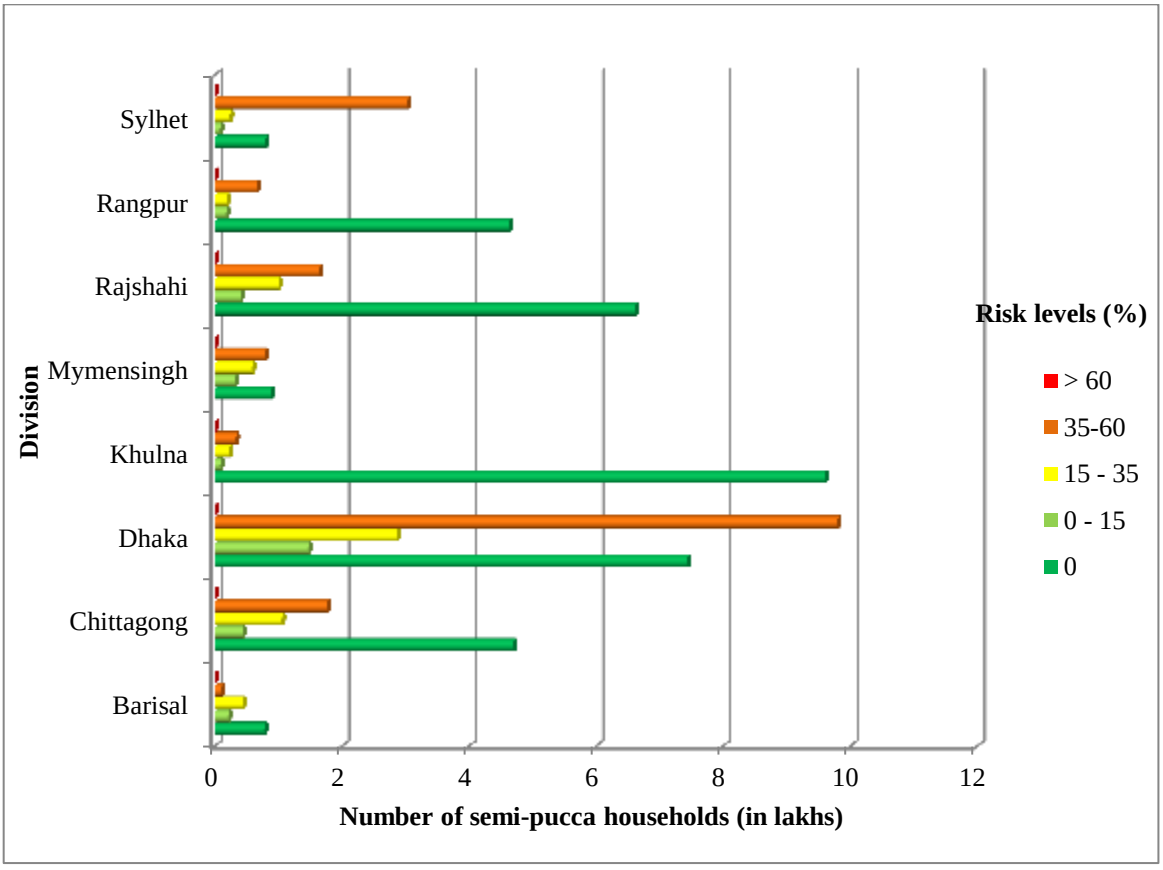


Figure 2.68: Number of semi-pucca household structures at different risk levels due to flood at division level

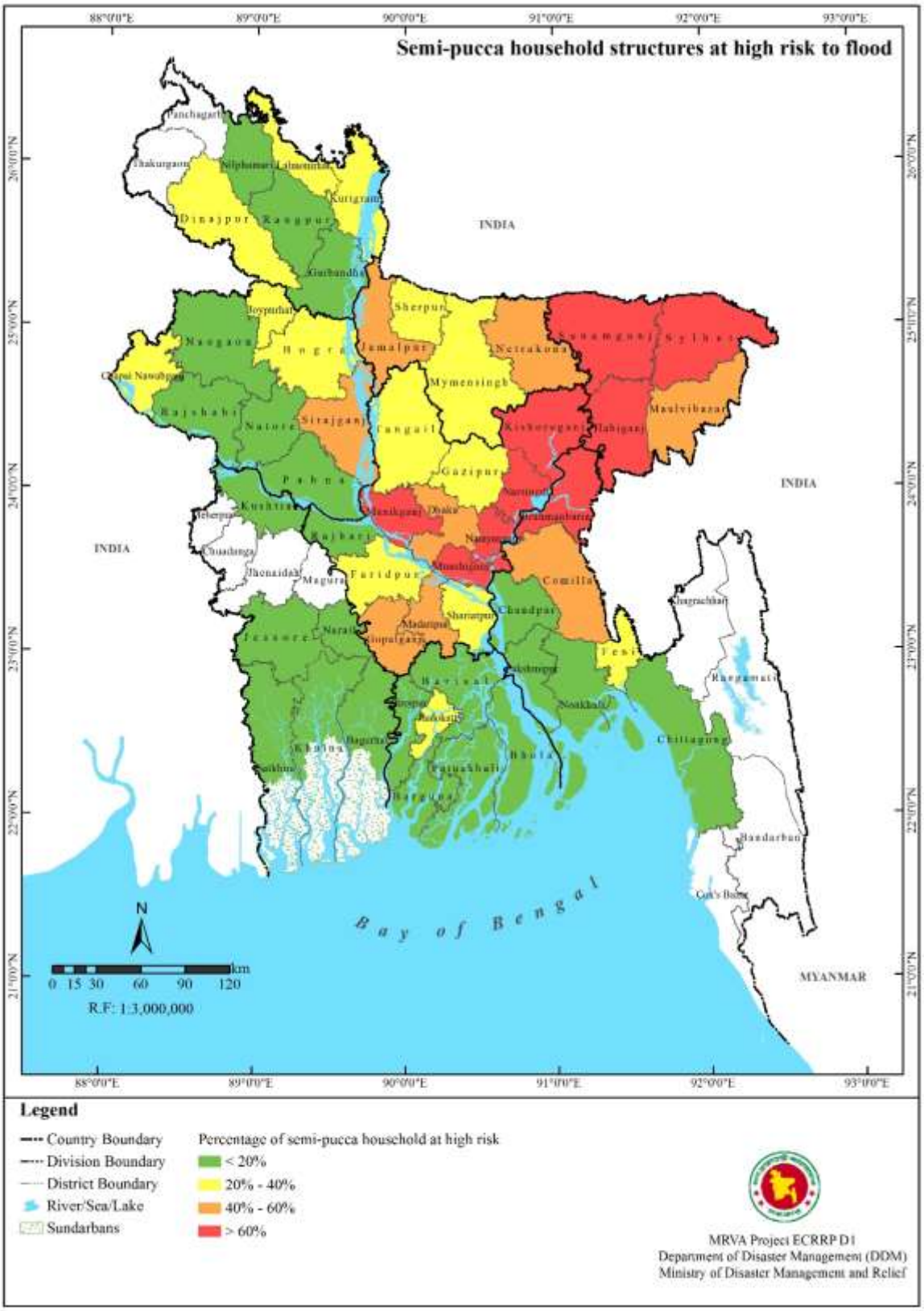


Figure 2.69: Semi-Pucca household structures at different risk levels due to flood at district level

The number of Katcha household structures at different risk levels at division level is given table 2.47 and figure 2.70. Katcha household structures at different risk levels at district level is given in figure 2.71.

Table 2.47: Number of Katcha household structures at different risk levels due to flood at division level

Division	Risk levels (%) / number of household structures				
	0	0-15	15-35	35-60	>60
Barisal	955,586	145,367	0	370,980	100,241
Chittagong	2,020,549	280,361	0	667,507	908,161
Dhaka	1,118,898	290,615	0	777,284	2,141,608
Khulna	1,939,784	17,176	0	63,625	72,615
Mymensingh	624,514	248,500	0	497,572	746,615
Rajshahi	1,908,465	125,356	0	355,915	693,462
Rangpur	2,484,816	63,421	0	98,476	377,225
Sylhet	200,734	21,205	0	60,239	816,027
Total Kutcha households	11,253,346	1,192,003	0	2,891,598	5,855,953

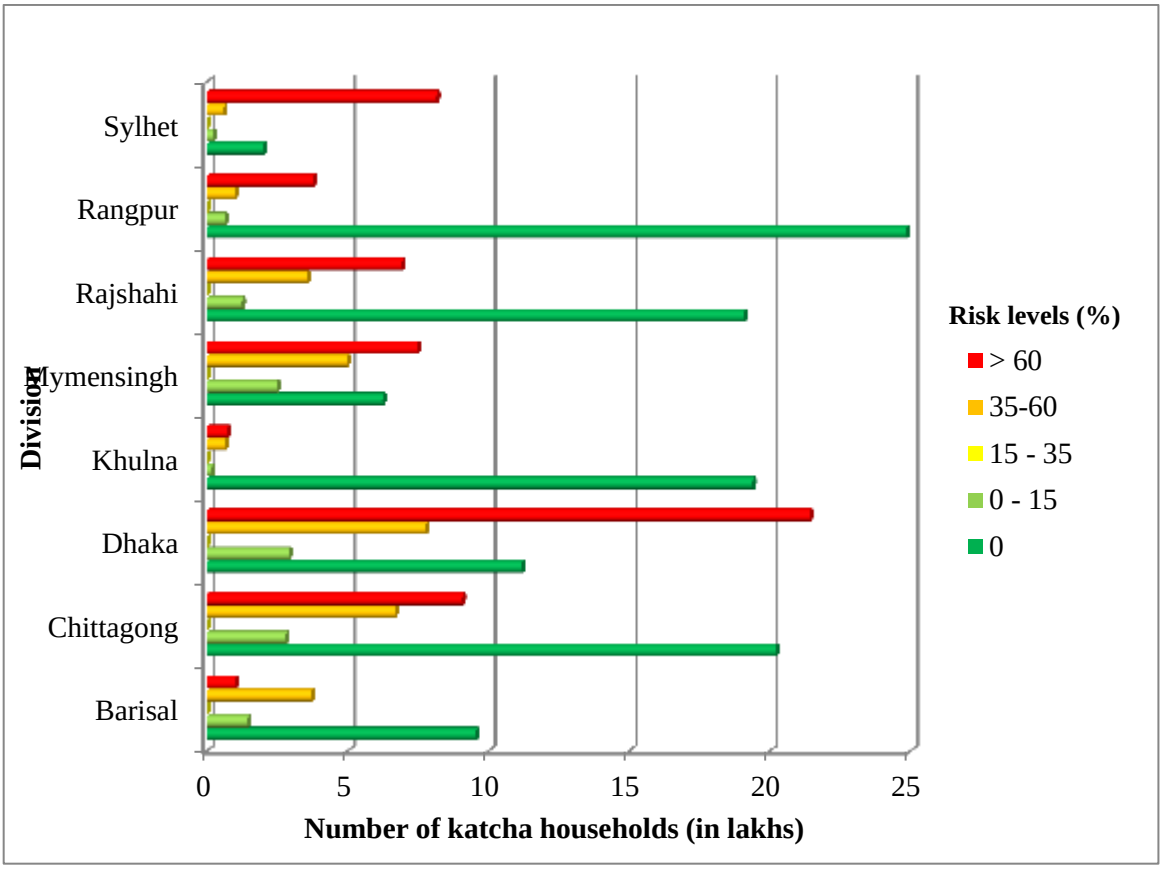


Figure 2.70: Number of Katcha household structures at different risk levels due to flood at division level.

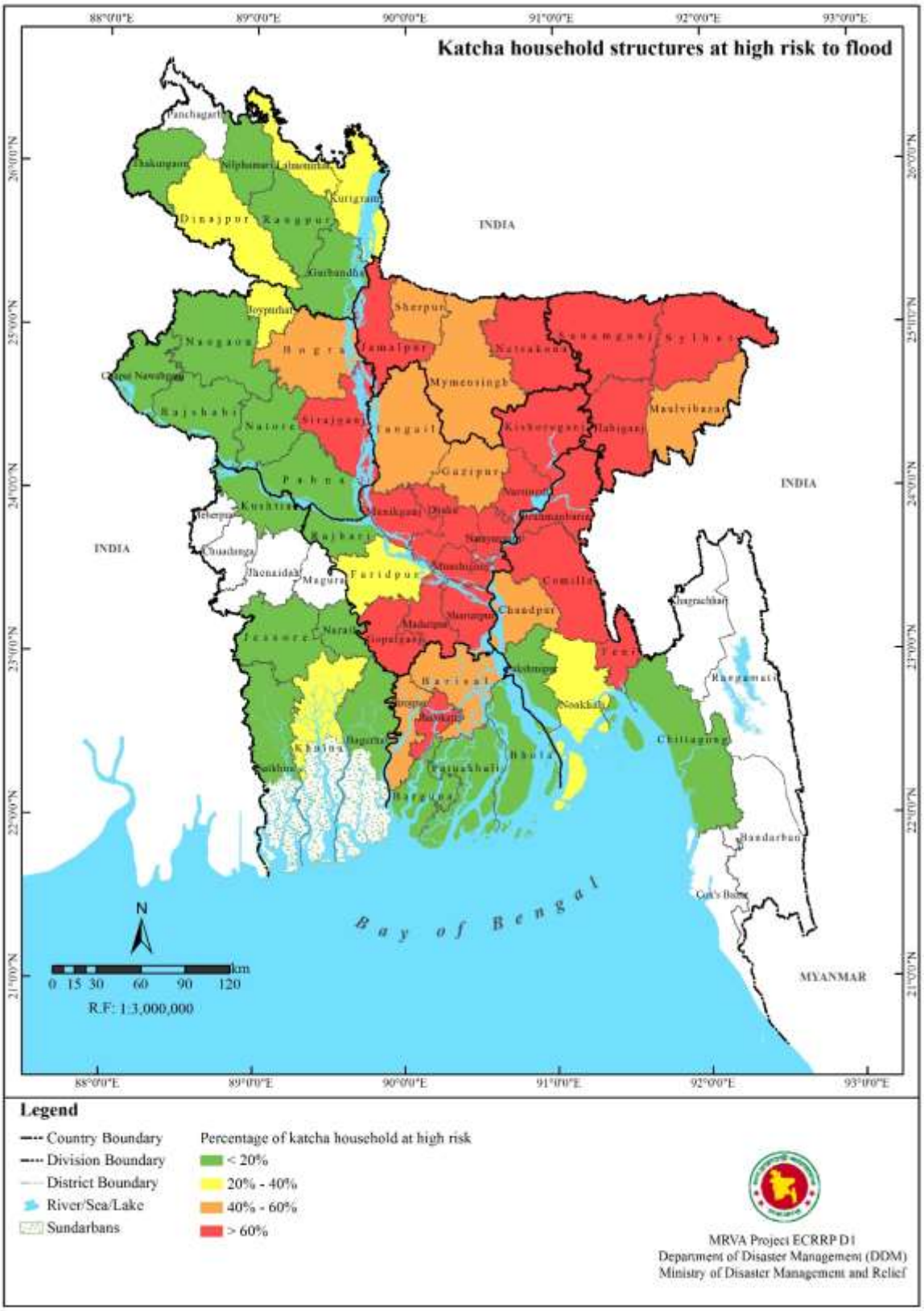


Figure 2.71 : Katcha household structures at different risk levels due to flood at district level

The number of Jhupri household structures at different risk levels at division level is given table 2.48 and figure 2.72. Jhupri household structures at different risk levels at district level is given in figure 2.73.

Table 2.48: Number of Jhupri household structures at different risk levels due to flood at division level

Division	Risk levels (%) / number of household structures				
	0	0-15	15-35	35-60	>60
Barisal	45,494	3,259	0	8,125	2,589
Chittagong	194,395	6,609	0	10,335	13,980
Dhaka	53,074	8,852	0	17,367	52,975
Khulna	104,520	830	0	3,569	2,439
Mymensingh	26,149	12,715	0	23,916	36,354
Rajshahi	96,295	4,090	0	8,763	19,338
Rangpur	92,896	4,301	0	4,590	15,750
Sylhet	11,149	1,263	0	3,128	37,490
Total Jhupri households	623,972	41,919	0	79,793	180,917

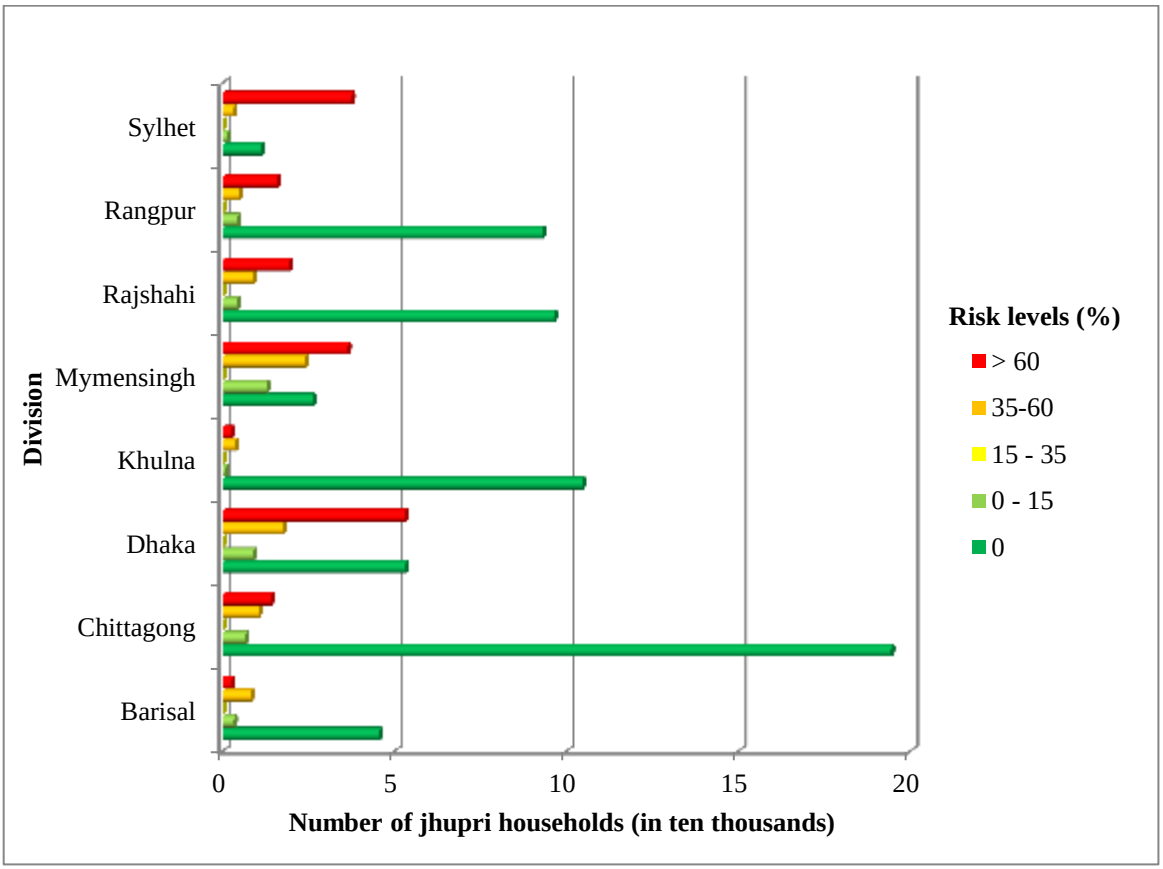


Figure 2.72: Number of Jhupri household structures at different risk levels due to flood at division level.

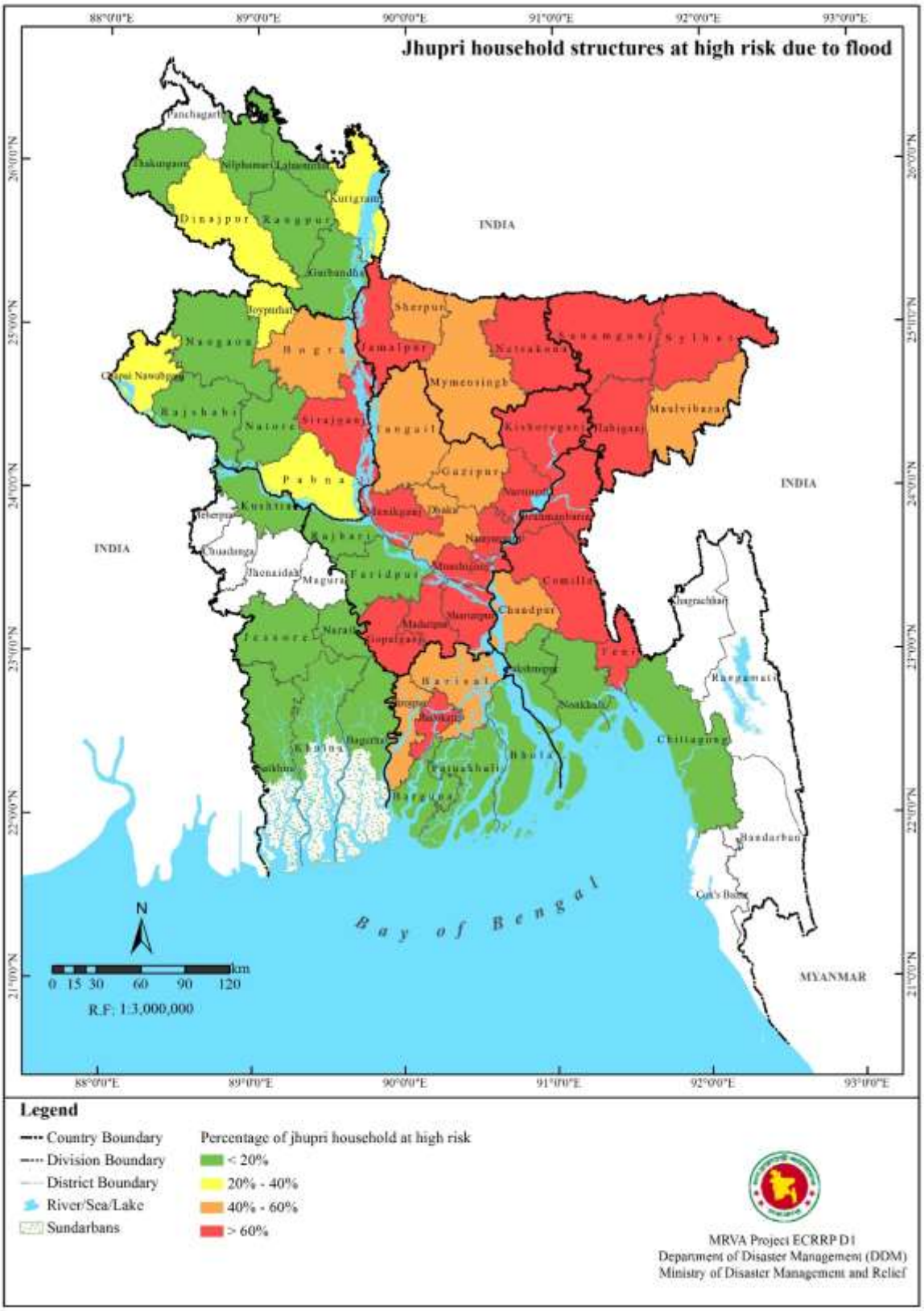


Figure 2.73: Jhupri household structures at different risk levels due to flood at district level

2.2.2 Livelihood (Agriculture)

The exposure map of livelihood (agriculture) i.e. transplanted Aman to flood hazard is used for risk assessment. Since crop duration of paddy is approximately 110 days, it is divided into 4 crop growth stages (seedling, vegetative stage, reproductive stage and mature). The number of days from the date of sowing is given in table 2.49, based on the literature and also discussion with Prof. Mirza, Share-e-Bangla Agriculture University, Dhaka.

Table 2.49 : Crop growth stages of Transplanted Aman crop

Crop	Crop growth stages in days				Total days (90- 110)
	Seedling (7-10)	Vegetative state (45-50)	Reproductive stage (60-75)	Mature (90-110)	
Transplanted (Aman Rice)	9	47	68	100	110
Height of the crop (m)	0.15	0.7 (0.6 - 0.8)	1.05 (0.9 - 1.20)	1.05 (0.9 - 1.20)	
Period of season (Jul./ Aug. to Nov. /Dec.)	Jul / Aug	Aug / Sep	Sep / Oct	Nov / Dec	

Vulnerability/ damage curves of Transplanted Aman (Rice) crop

The risk levels of transplanted Aman to flood depends upon the time of flooding and crop growth stage at the time of flooding. Risk matrices for transplanted Aman for each month of flooding is developed. For July is given in table 2.50, August is given table 2.51, September in table 2.52 and October in table 2.53.

Table 2.50: Risk matrix of Transplanted Aman crop to flood in July

Floods in July	Crop growth stages (cumulative days)			
	Seedling (7-10)	Vegetative state (45-50)	Reproductive stage (60-75)	Mature (90-110)
Planting date:	Jul / Aug	Aug / Sep	Sep / Oct	Nov / Dec
Height of the crop (m) / Flood depth (m)	0.15	0.7 (0.6 - 0.8)	1.05 (0.9 - 1.20)	1.05 (0.9 - 1.20)
< 0.3	D2	D2	D3	D3
0.3 - 0.9	D3	D3	D3	D3
0.9 - 1.8	D4	D4	D4	D4
1.8 - 3.6	D4	D4	D4	D4
> 3.6	D4	D4	D4	D4

Table 2.51: Risk matrix of Transplanted Aman crop to flood in August

Floods in August	Crop growth stages (cumulative days)			
	Seedling (7-10)	**Vegetative state (45-50)**	**Reproductive stage (60-75)**	**Mature (90-110)**
Planting date:	Jul / Aug	Aug / Sep	Sep / Oct	Nov / Dec
Height of the crop (m) / Flood Depth (m)	0.15	0.7 (0.6 - 0.8)	1.05 (0.9 - 1.20)	1.05 (0.9 - 1.20)
< 0.3	D2	D2	D3	D3
0.3 - 0.9	D3	D3	D3	D3
0.9 - 1.8	D4	D4	D4	D4
1.8 - 3.6	D4	D4	D4	D4
> 3.6	D4	D4	D4	D4

Table 2.52: Risk matrix of Transplanted Aman crop to flood in September

Floods in September	Crop growth stages (cumulative days)			
	Seedling (7-10)	**Vegetative state (45-50)**	**Reproductive stage (60-75)**	**Mature (90-110)**
Planting date:	Jul / Aug	Aug / Sep	Sep / Oct	Nov / Dec
Height of the crop (m) / Flood Depth (m)	0.15	0.7 (0.6 - 0.8)	1.05 (0.9 - 1.20)	1.05 (0.9 - 1.20)
< 0.3	D0	D1	D2	D3
0.3 - 0.9	D0	D2	D3	D3
0.9 - 1.8	D0	D3	D4	D4
1.8 - 3.6	D0	D4	D4	D4
> 3.6	D0	D4	D4	D4

Table 2.53: Risk matrix of Aman rice crop to flood in October

Floods in October	Crop growth stages (cumulative days)			
	Seedling (7-10)	**Vegetative state (45-50)**	**Reproductive stage (60-75)**	**Mature (90-110)**
Planting date:	Jul / Aug	Aug / Sep	Sep / Oct	Nov / Dec
Height of the crop (m) / Flood Depth (m)	0.15	0.7 (0.6 - 0.8)	1.05 (0.9 - 1.20)	1.05 (0.9 - 1.20)
< 0.3	D0	D0	D1	D2
0.3 - 0.9	D0	D0	D2	D3
0.9 - 1.8	D0	D0	D3	D4
1.8 - 3.6	D0	D0	D4	D4
> 3.6	D0	D0	D4	D4

Based on the frequency analysis of observed water level data in the rivers in Bangladesh, time of flood occurrence at district level on monthly basis is derived. Using this data and

above risk matrix tables (Table 2.50 to 2.53) are used to derive the risk levels of transplanted aman crop at district level in 5 risk levels and is given in table 2.54.

Table 2.54: Risk levels of Transplanted Aman crop at district level

Division	District	Transplanted Aman Area (km2) in different flood risk levels				
		D0	D1	D2	D3	D4
Barisal	Barguna	1141.9	0.1	1.8	56.0	28.1
	Barisal	264.4	82.8	578.8	798.5	159.2
	Bhola	1600.4	4.6	62.9	48.3	6.7
	Jhalokati	186.3	1.5	21.2	372.9	121.0
	Patuakhali	1882.7	7.6	100.3	346.8	13.6
	Pirojpur	621.1	0.6	28.3	387.3	91.1
Chittagong	Bandarban	4.4	0.0	0.0	0.0	0.0
	Brahmanbaria	19.2	0.0	2.0	10.0	126.8
	Chandpur	423.1	1.8	38.8	75.1	16.8
	Chittagong	2381.8	0.0	0.0	1.8	1.1
	Comilla	64.3	128.5	290.7	426.6	572.6
	Cox's Bazar	899.1	0.0	0.0	0.0	0.0
	Feni	271.1	15.3	66.5	242.4	274.9
	Lakshmipur	657.7	92.0	212.3	101.3	19.5
	Noakhali	956.4	65.2	286.6	331.6	105.5
	Rangamati	13.9	0.0	0.0	0.0	0.0
Dhaka	Dhaka	1.9	0.8	1.1	1.4	2.7
	Faridpur	45.6	0.0	0.0	0.0	0.0
	Gazipur	264.8	0.0	14.5	26.3	65.9
	Gopalganj	7.0	2.1	6.0	5.8	0.4
	Kishoreganj	49.8	0.0	30.2	115.9	719.0
	Madaripur	2.1	3.7	24.9	27.0	2.3
	Manikganj	0.4	0.0	0.3	6.8	18.1
	Narayanganj	0.0	0.0	0.0	0.0	21.6
	Narsingdi	49.8	0.0	16.1	61.0	613.1
	Shariatpur	9.2	0.0	0.0	0.0	0.0
	Tangail	220.7	0.0	98.8	237.3	499.4
Khulna	Bagerhat	1365.2	3.7	24.5	176.1	26.7
	Chuadanga	281.0	0.0	0.0	0.0	0.0
	Jessore	1534.3	0.3	1.0	1.2	9.8
	Jhenaidah	1242.8	0.0	0.0	0.0	0.0
	Khulna	1361.7	7.0	17.2	83.9	62.4
	Kushtia	477.7	0.0	0.0	0.1	3.2
	Magura	611.8	0.0	0.0	0.0	0.0
	Meherpur	82.7	0.0	0.0	0.0	0.0
	Narail	247.0	0.1	0.2	0.2	0.0
	Satkhira	1973.2	25.9	54.6	70.3	119.7
Mymensingh	Jamalpur	111.7	0.0	47.9	154.9	770.1
	Mymensingh	1187.7	0.0	155.9	371.3	1387.4
	Netrakona	228.4	0.0	54.6	126.8	548.7
	Sherpur	202.1	0.0	77.9	171.0	679.9
Rajshahi	Bogra	698.6	0.0	77.5	271.6	1310.4
	Chapai Nawabganj	530.0	0.0	0.1	0.1	4.9
	Joypurhat	379.5	0.0	69.8	143.6	366.0
	Naogaon	2650.1	0.0	2.2	3.3	58.7

Division	District	Transplanted Aman Area (km2) in different flood risk levels				
		D0	D1	D2	D3	D4
	Natore	570.9	0.0	0.1	4.0	156.2
	Pabna	806.9	0.0	0.2	7.8	25.2
	Rajshahi	795.5	0.0	5.8	11.4	14.6
	Sirajganj	64.8	0.0	20.7	70.6	708.3
Rangpur	Dinajpur	1940.5	0.0	187.8	321.4	732.3
	Gaibandha	1304.7	0.0	2.5	8.3	97.2
	Kurigram	1033.3	0.0	11.1	22.2	320.9
	Lalmonirhat	705.6	0.0	4.5	5.9	218.3
	Nilphamari	1049.0	0.0	9.7	19.9	44.7
	Panchagarh	1057.0	0.0	0.1	0.0	0.0
	Rangpur	1678.6	0.0	2.0	2.6	98.3
	Thakurgaon	1247.8	0.0	3.1	5.1	2.5
Sylhet	Habiganj	119.3	0.0	5.5	12.5	532.7
	Maulvibazar	282.7	0.0	15.3	37.4	972.6
	Sunamganj	75.2	0.0	18.2	42.3	295.8
	Sylhet	159.2	0.0	14.7	51.1	2088.7

Risk levels of transplanted Aman at division level is shown in figure 2.74.

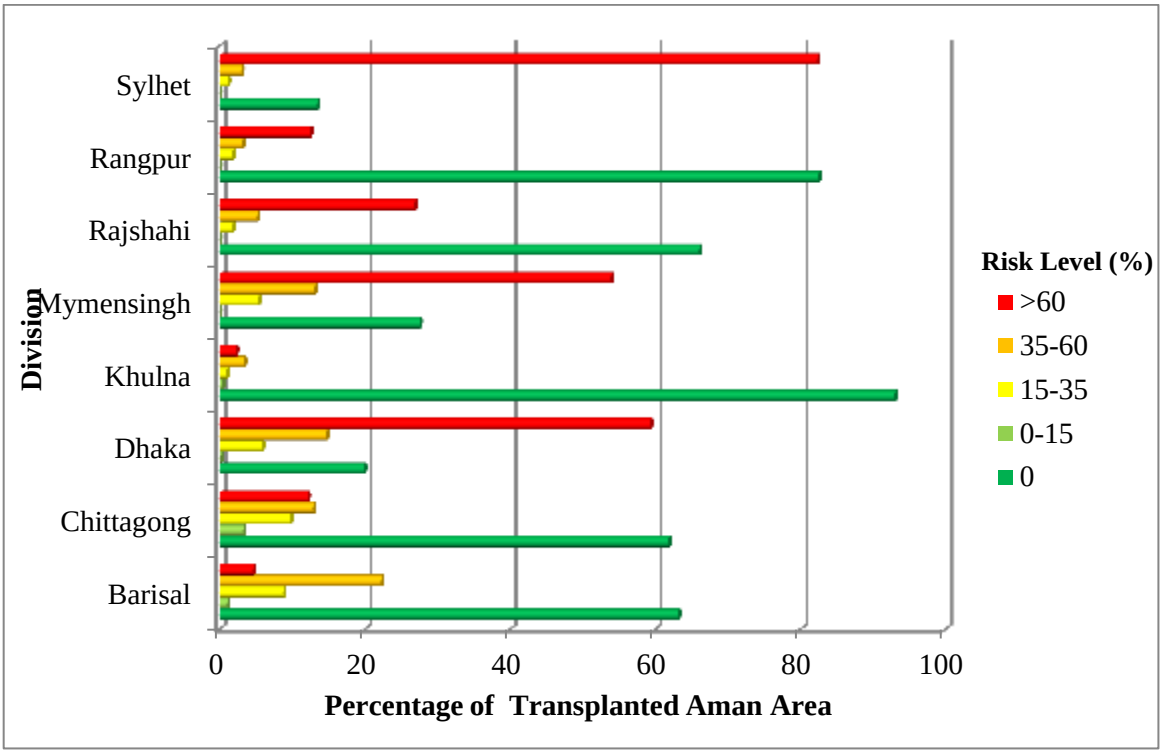


Figure 2.74: Percentage of risk level of transplanted Aman crop area at division level

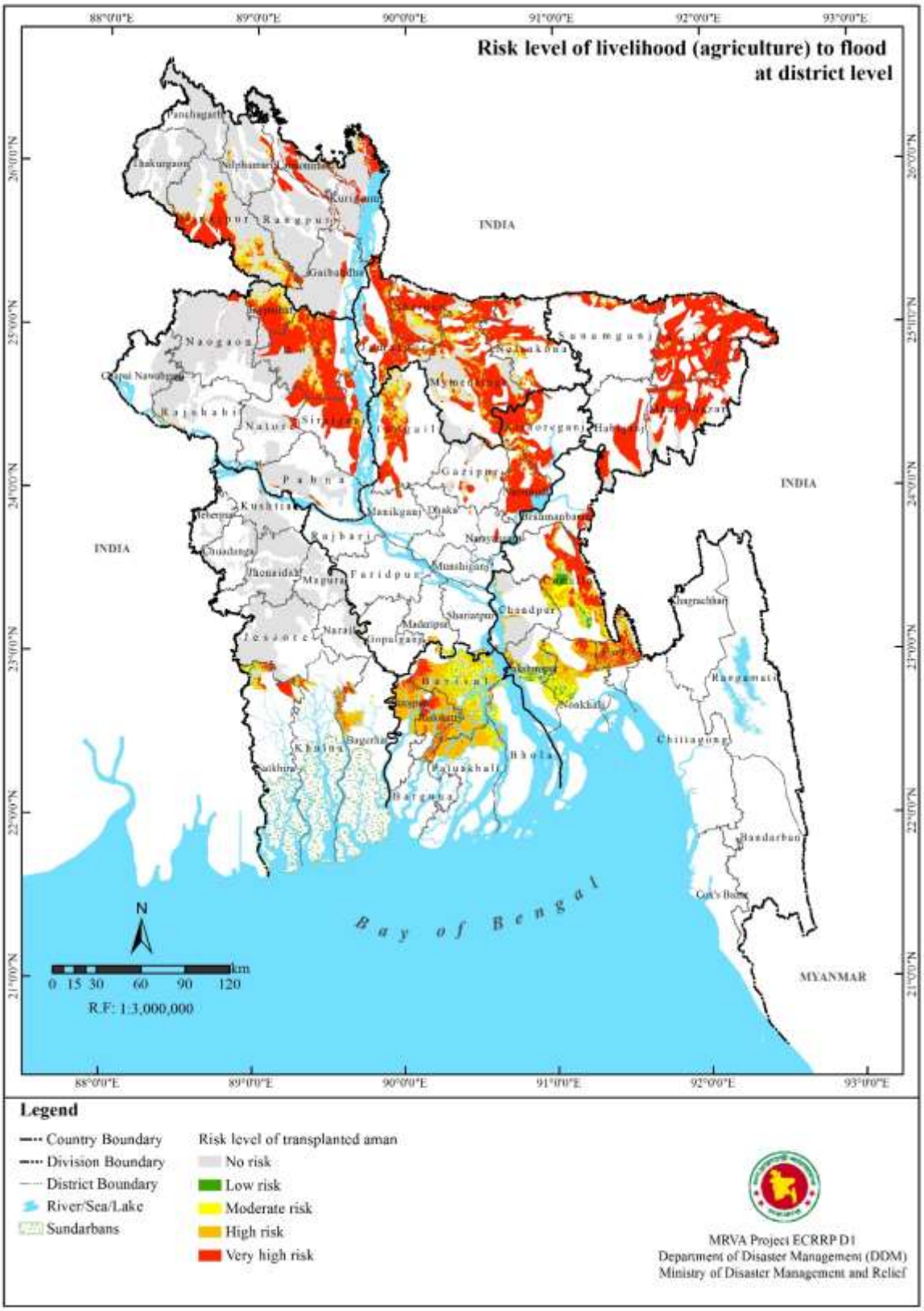


Figure 2.75: Risk level of livelihood (agriculture) to flood at district level

Chapter 3: Exposure, Vulnerability & Risk Assessment to Storm Surge

3.1 Exposure Assessment

The storm surge hazard map consists of inundation depth in 5 categories and not affected. The inundation depth categories are < 1.0 m, 1.0 – 1.5 m, 1.5 – 2.0 m, 2.0 – 3.0 m, 3.0 – 4.0 m 4.0 – 5.0 m, > 5.0 m.

As explained in section 1.4, storm surge hazard map for 25 year return period is selected for exposure assessment of elements at risk.

3.1.1 Population

As explained in section 1.5, based on the area of exposure of the settlements in each union, the vulnerability of population is calculated as affected population for storm surge hazard at division / district / upazila level.

3.1.1.1 Gender

Total population (male) exposed to storm surge inundation depth at division level is given in table 3.1 and figure 3.1. Population (male) exposed to more than 3.0 m Storm surge inundation depth at district level is shown in figure 3.2.

Table 3.1: Population (male) exposed to storm surge at division level

Division	Inundation Depth (m) / Population							Not Affected
	< 1.0	1.0 - 1.5	1.5 - 2.0	2.0 - 3.0	3.0 - 4.0	4.0 - 5.0	> 5.0	
Barisal	1,037,467	528,409	253,382	183,603	68,777	16,256	-	2,001,618
Chittagong	662,362	337,576	269,442	362,949	115,549	50,578	43,151	12,091,692
Dhaka	109,211	38,990	23,399	22,093	2,973	2,490	-	23,973,161
Khulna	846,123	263,399	116,218	54,655	5,239	-	-	6,556,907
Total	2,655,163	1,168,375	662,442	623,300	192,538	69,323	43,151	44,623,378

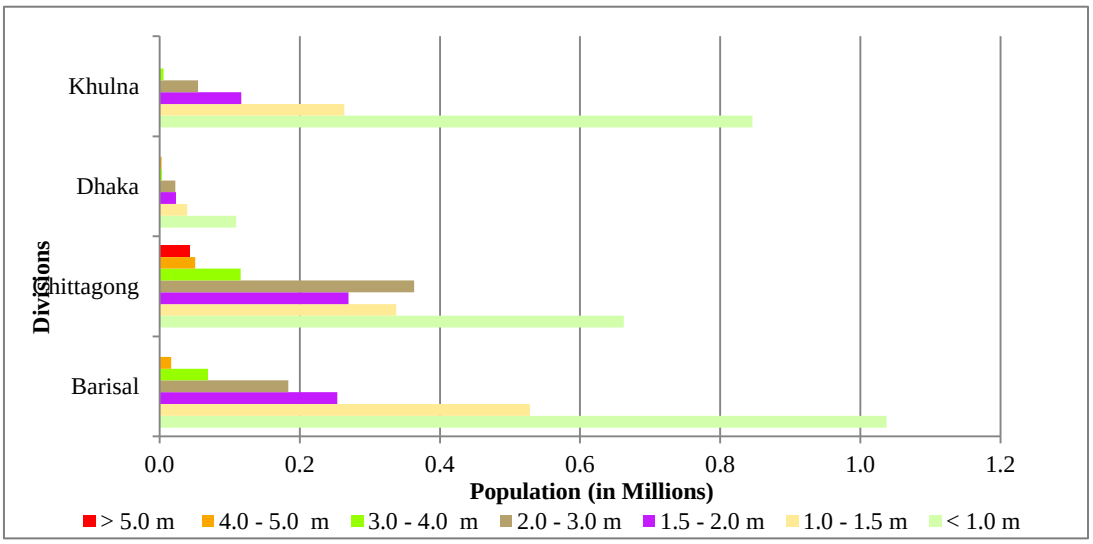


Figure 3.1: Population (male) exposed to different Storm surge inundation depth at division level

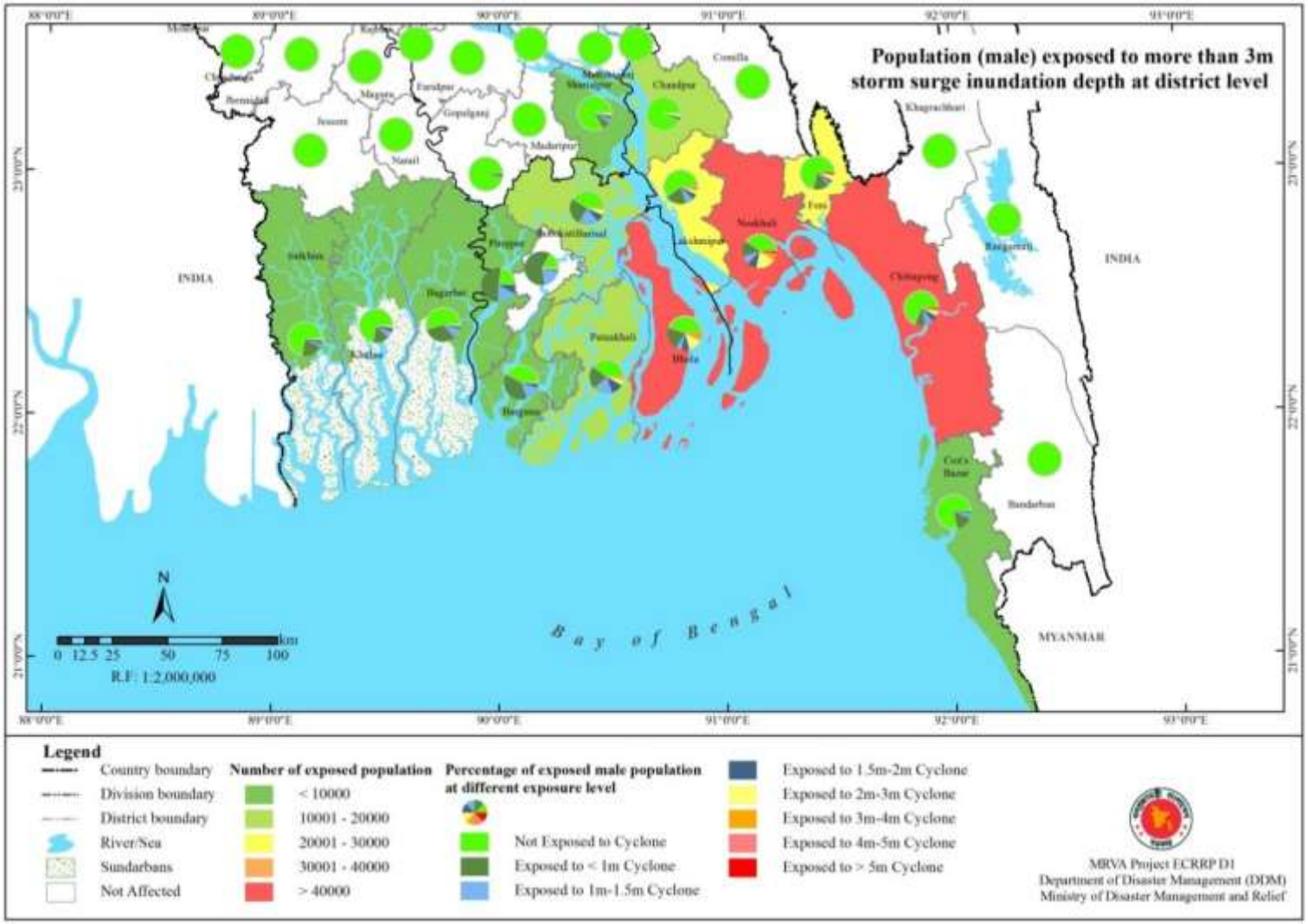


Figure 3.2: Population (male) exposed to more 3.0 m storm surge inundation depth at district level

Total population (female) exposed to storm surge inundation depth at division level is given in table 3.2 and figure 3.3. Population (female) exposed to storm surge inundation depth more 3.0 m at district level is shown in figure 3.4.

Table 3.2: Population (female) exposed to storm surge at division level

Division	Inundation Depth (m) / Population							Not Affected
	< 1.0	1.0 - 1.5	1.5 - 2.0	2.0 - 3.0	3.0 - 4.0	4.0 - 5.0	> 5.0	
Barisal	1,074,671	262,468	547,358	190,187	71,244	16,839	-	2,073,396
Chittagong	688,812	280,202	351,057	377,442	120,163	52,598	44,875	12,574,543
Dhaka	105,053	22,508	37,506	21,252	2,860	2,395	-	23,060,527
Khulna	846,414	116,258	263,490	54,673	5,241	-	-	6,559,158
Total	2,714,949	681,436	1,199,410	643,555	199,507	71,831	44,875	44,267,624

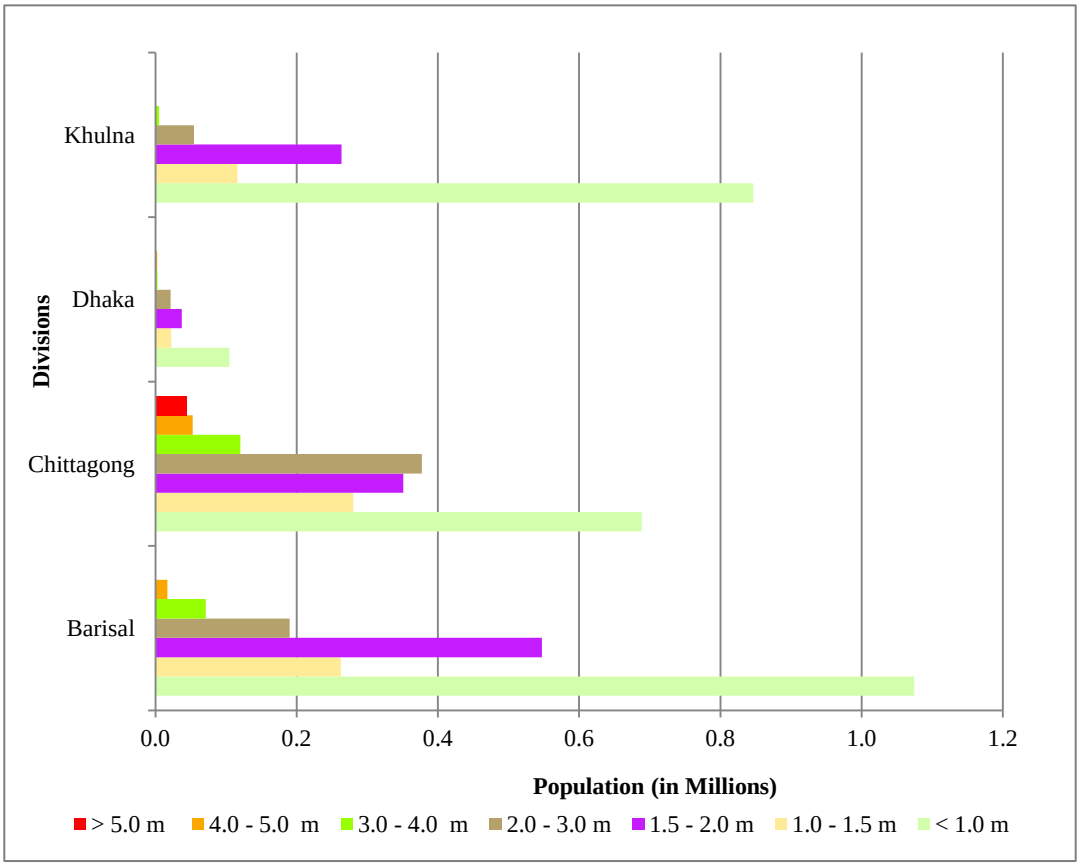


Figure 3.3: Population (female) exposed to different Storm surge inundation depth at division level

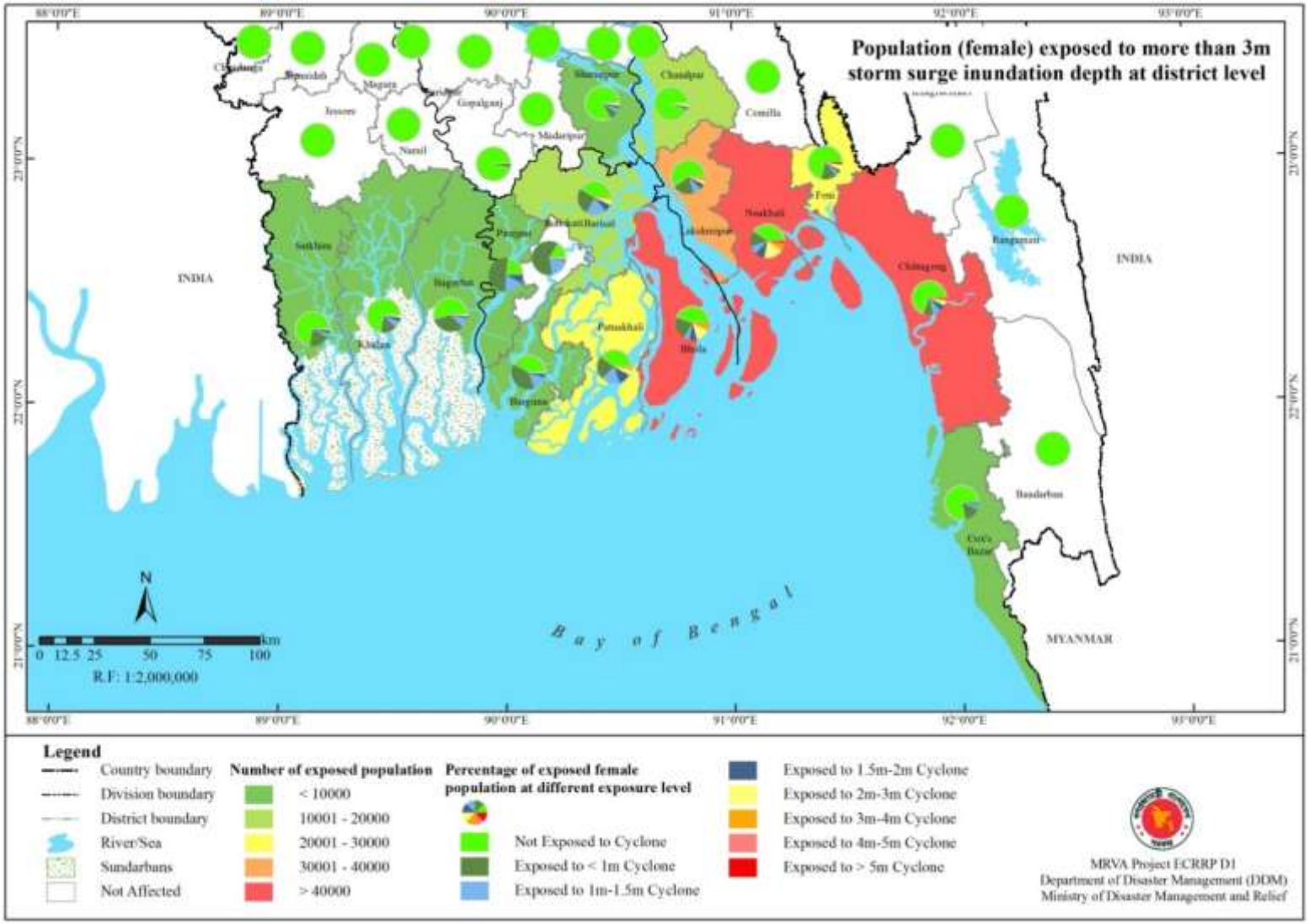


Figure 3.4: Population (female) exposed to more 3.0 m storm surge inundation depth at district level

3.1.1.2 Age

As explained in section 4.1.2, population by age is regrouped into 0-14 years, 14 - 59 years and more than 59 years. Population in the age group of 0 - 14 years exposed to storm surge in each division is given table 3.3 and figure 3.5. Population in the age group of 0 - 14 years exposed to more than 3.0 m of storm surge at district level is given figure 3.6. Population in the age group of 14 - 59 years exposed to storm surge in each division is given table 3.4 and figure 3.7. Population in the age group of 14 – 59 years exposed to more than 3.0 m of storm surge at district level is given figure 3.8. Population in the age of more than 59 years exposed to storm surge in each division is given table 3.5 and figure 3.9. Population in the age more than 59 years exposed to more than 3.0 m of storm surge at district level is given figure 3.10.

Table 3.3: Population (0 - 14 years) exposed to storm surge at division level

Division Name	Inundation Depth (m) / Population							Not Affected
	< 1.0	1.0 - 1.5	1.5 - 2.0	2.0 - 3.0	3.0 - 4.0	4.0 - 5.0	> 5.0	
Barisal	767,941	391,133	187,555	135,904	50,910	12,033	-	1,481,613
Chittagong	514,060	261,993	209,115	281,685	89,678	39,254	33,490	9,384,377
Dhaka	71,486	25,522	15,316	14,462	1,946	1,630	-	15,692,231
Khulna	526,251	163,823	72,283	33,993	3,258	-	-	4,078,104
Total	1,879,739	842,471	484,269	466,044	145,792	52,916	33,490	30,636,325

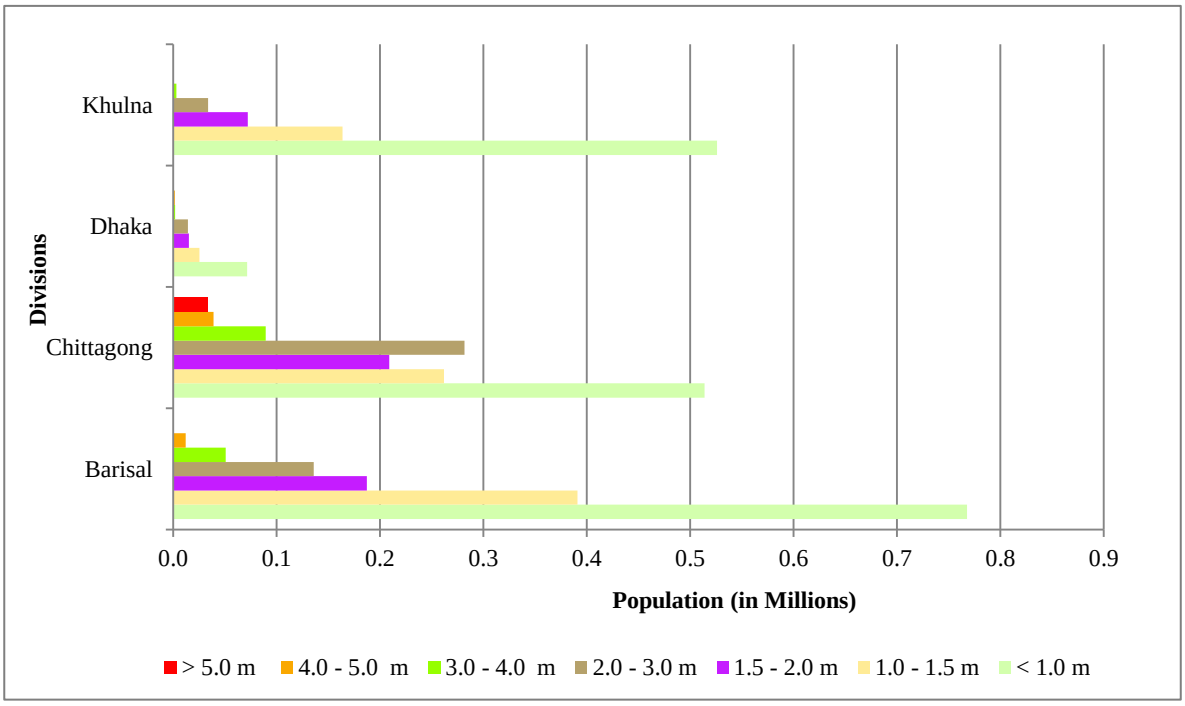


Figure 3.5: Population (0 - 14 years) exposed to storm surge inundation depth at division level

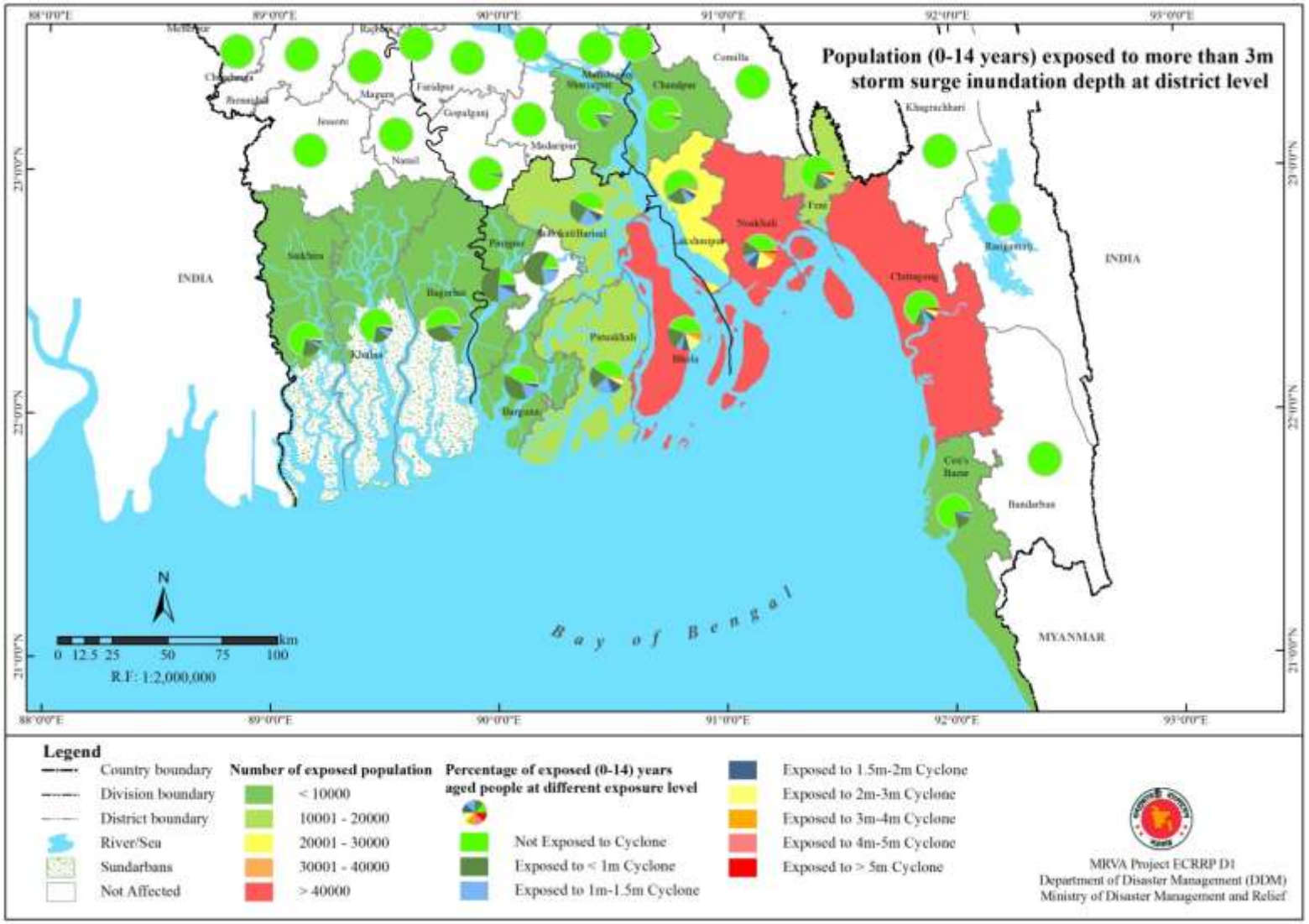


Figure 3.6: Population (0 - 14 years) exposed to more than 3.0 m storm surge inundation depth at district level

Table 3.4: Population (15 - 59 years) exposed to storm surge at division level

Name	Inundation Depth (m) / Population							Not Affected
	< 1.0	1.0 - 1.5	1.5 - 2.0	2.0 - 3.0	3.0 - 4.0	4.0 - 5.0	> 5.0	
Barisal	1,154,693	588,116	282,012	204,348	76,549	18,093	-	2,227,786
Chittagong	739,791	377,039	300,940	405,377	129,056	56,490	48,196	13,505,193
Dhaka	127,526	45,529	27,323	25,799	3,472	2,907	-	27,993,734
Khulna	1,024,335	318,877	140,697	66,166	6,342	-	-	7,937,938
Total	3,046,346	1,329,560	750,972	701,690	215,419	77,490	48,196	51,664,651

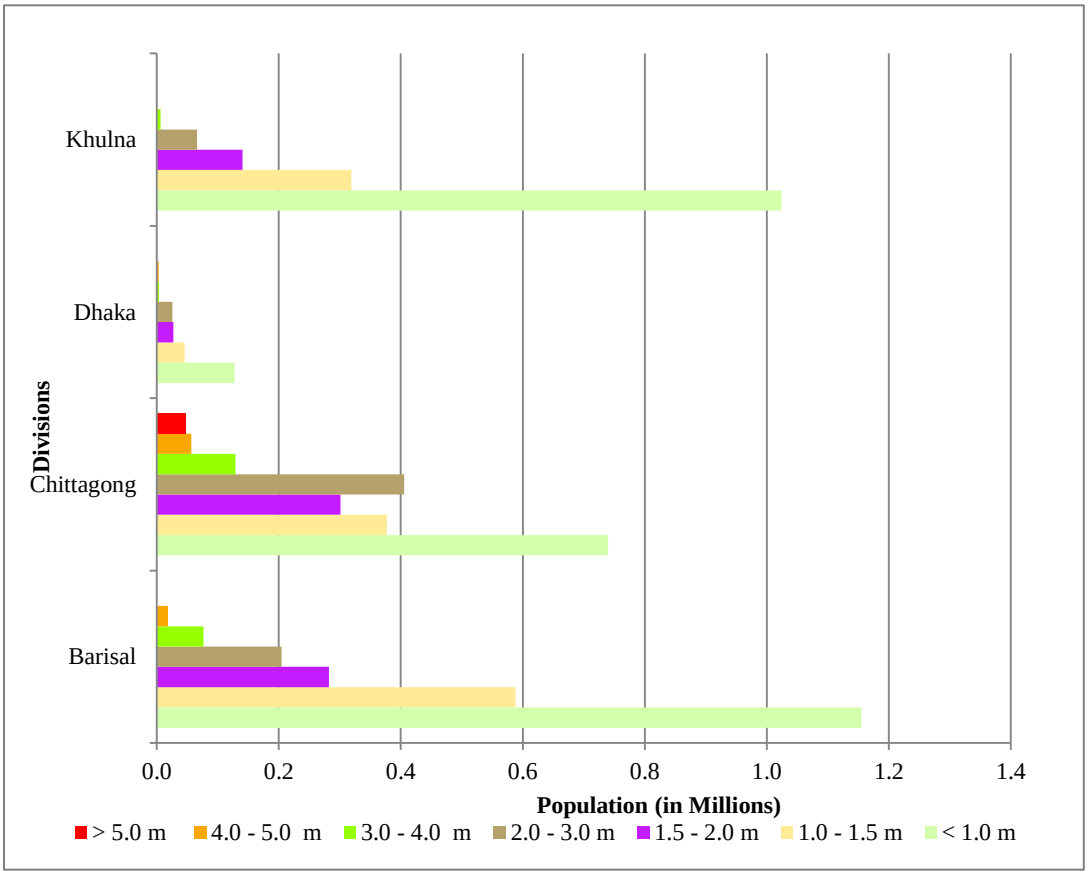


Figure 3.7: Population (15 - 59 years) exposed to different Storm surge inundation depth at division level

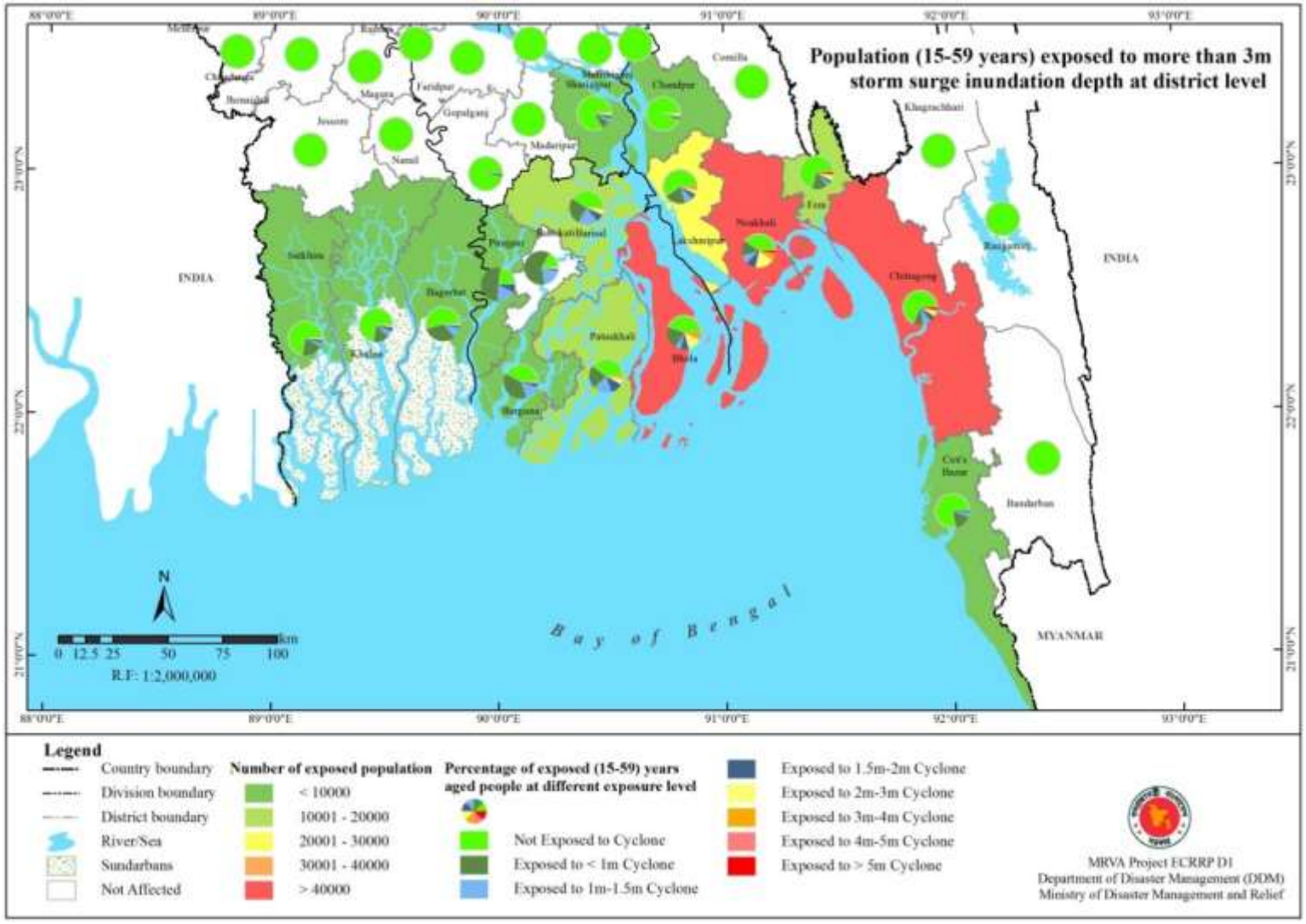


Figure 3.8: Population (15 - 59 years) exposed to more than 3.0 m Storm surge inundation depth at district level

Table 3.5: Population (more than 59 years) exposed to storm surge at division level

Division	Inundation Depth (m) / Population							Not Affected
	< 1.0	1.0 - 1.5	1.5 - 2.0	2.0 - 3.0	3.0 - 4.0	4.0 - 5.0	> 5.0	
Barisal	189,503	96,519	46,283	33,537	12,563	2,969	-	365,614
Chittagong	97,323	49,601	39,590	53,329	16,978	7,432	6,340	1,776,665
Dhaka	15,251	5,445	3,268	3,085	415	348	-	3,347,721
Khulna	141,950	44,189	19,497	9,169	879	-	-	1,100,022
Total	444,026	195,754	108,637	99,120	30,835	10,748	6,340	6,590,022

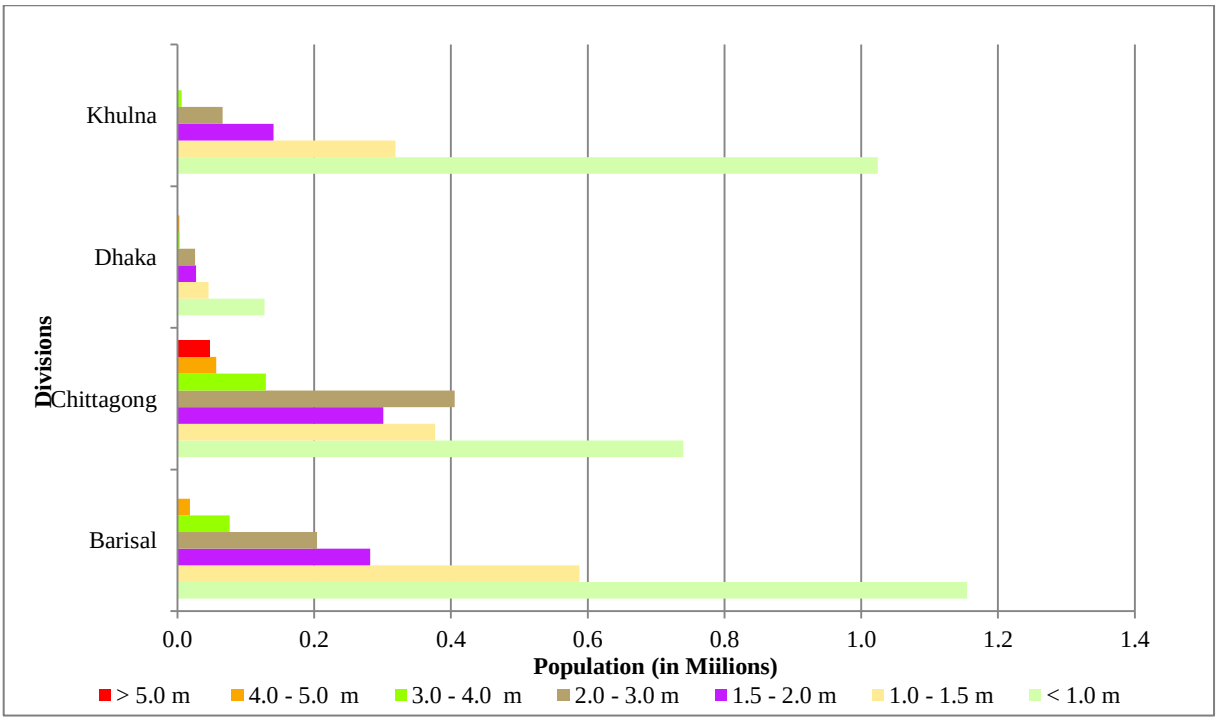


Figure 3.9: Population (more than 59 years) exposed to different storm surge inundation depth at division level

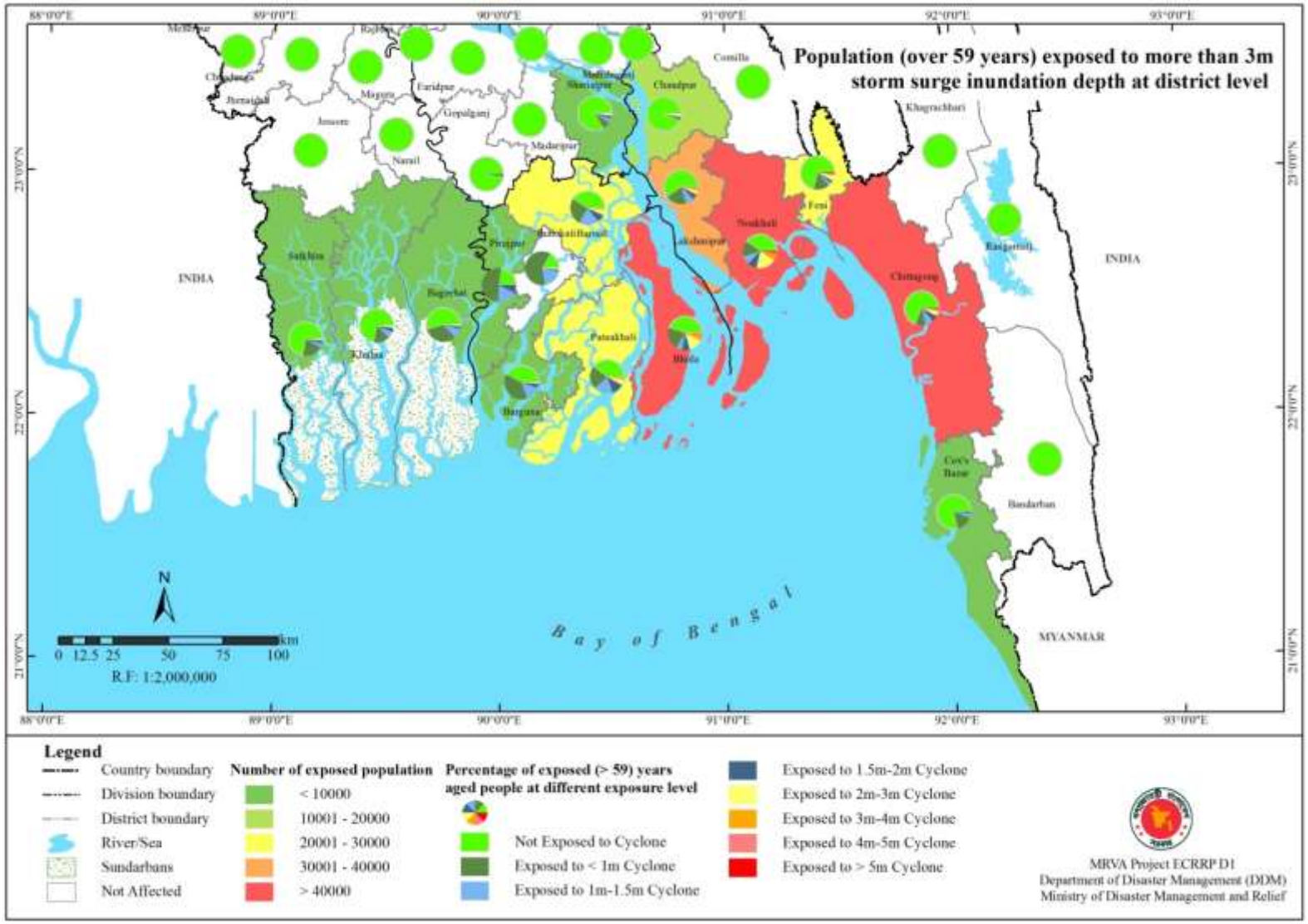


Figure 3.10: Population (over 59 years) exposed to more than 3.0 m storm surge inundation depth at district level

3.1.1.3 Ethnicity

As the ethnicity population is very less, exposure to storm surge is not considered.

3.1.1.4 Employment

The employment types considered are agriculture and industry. Population employed in Agriculture sector affected due to storm surge at division level is given table 3.6 and figure 3.11. Population exposed to storm surge inundation depth of more than 3.0 m and employed in agriculture sector at district level is shown in figure 3.12 and Population employed in industry sector affected due to storm surge at division level is given table 3.7 and figure 3.13. Population exposed to storm surge inundation depth of more than 3.0 m and employed in industry sector at district level is shown in figure 3.14.

Table 3.6: Employed (Agriculture) Population exposed to storm surge at division level

Division Name	Inundation Depth (m) / Population							Not Affected
	< 1.0	1.0 - 1.5	1.5 - 2.0	2.0 - 3.0	3.0 - 4.0	4.0 - 5.0	> 5.0	
Barisal	116,199	59,183	28,379	20,564	7,703	1,821	-	224,186
Chittagong	70,910	36,140	28,846	38,856	12,370	5,415	4,620	1,294,499
Dhaka	13,956	4,983	2,990	2,823	380	318	-	3,063,605
Khulna	134,748	41,947	18,508	8,704	834	-	-	1,044,210
Total	335,813	142,253	78,723	70,947	21,288	7,554	4,620	5,626,500

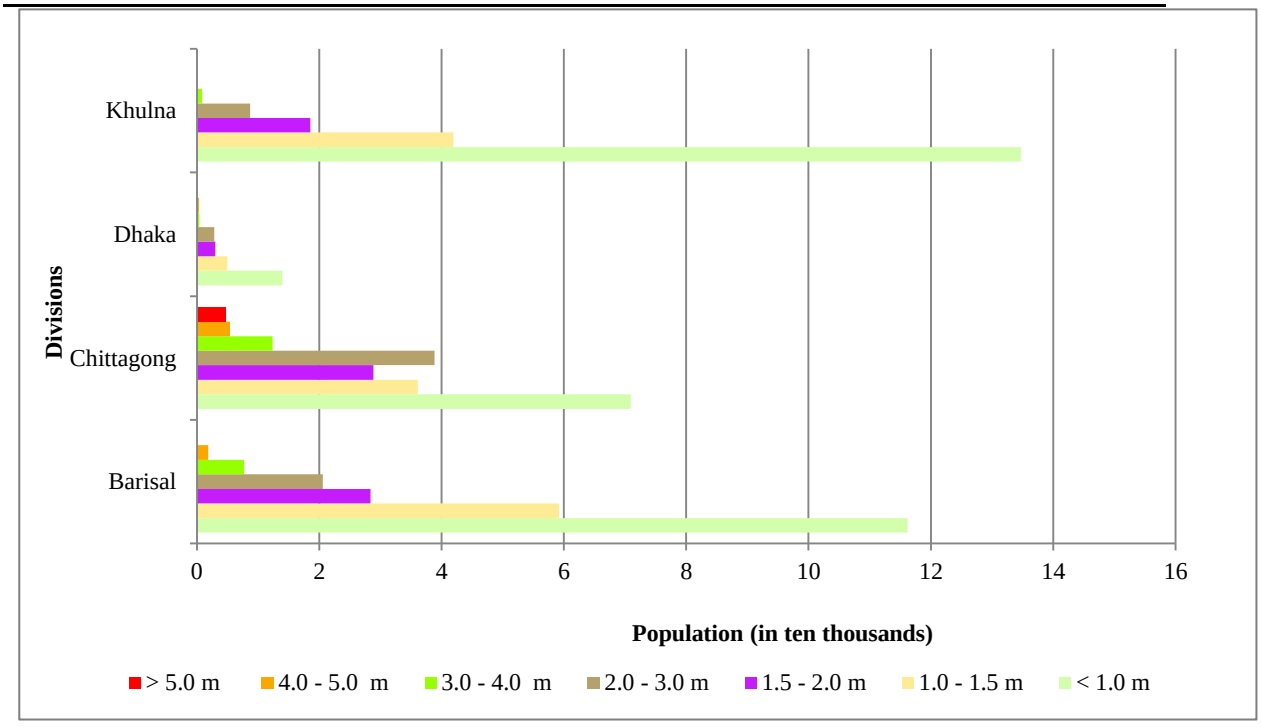


Figure 3.11: Employed (Agriculture) Population exposed to different Storm surge inundation depth at division level

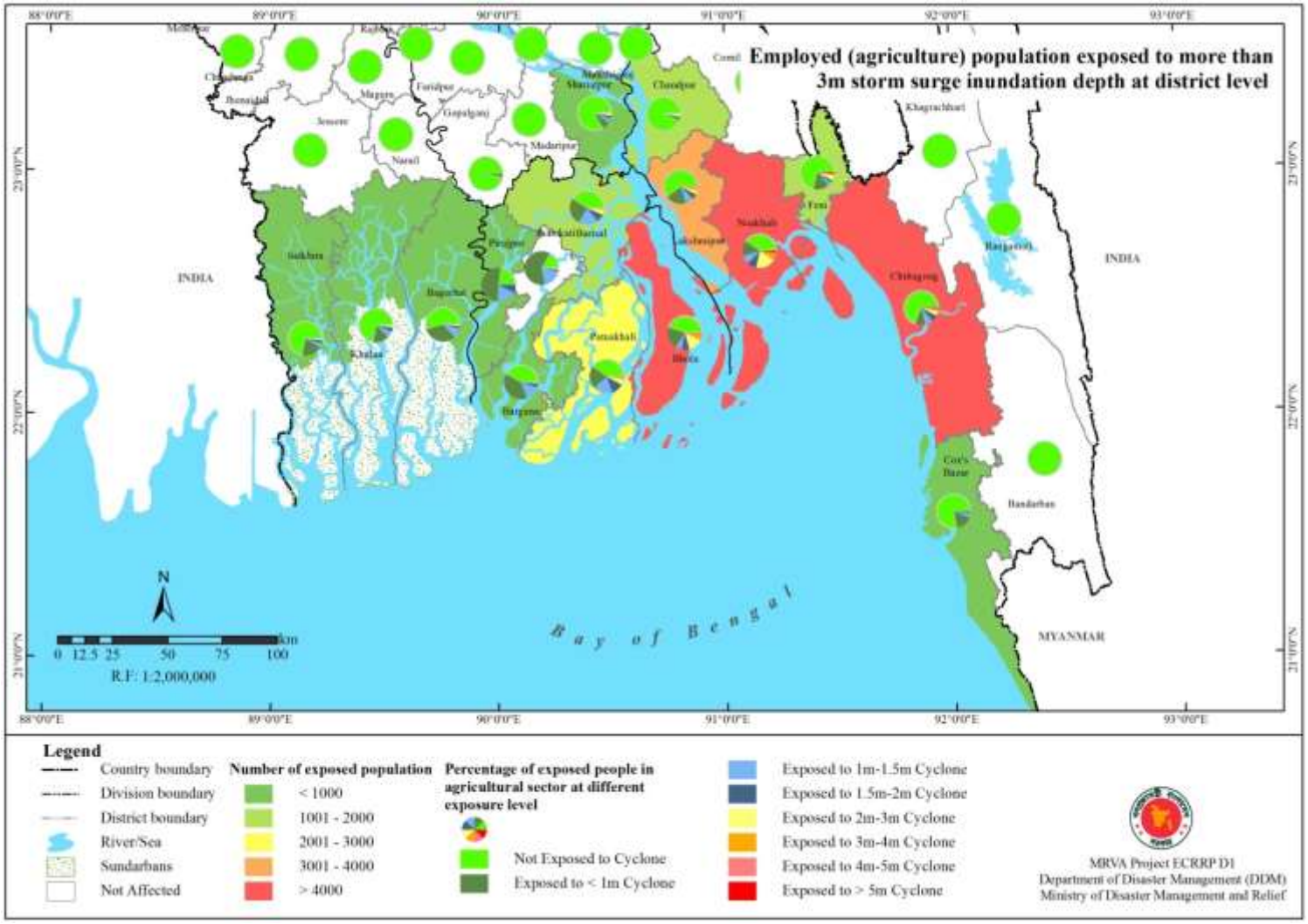


Figure 3.12: Employed (Agriculture) Population exposed to more than 3.0 m storm surge inundation depth at district level

Table 3.7: Employed (Industry) Population exposed to storm surge at division level

Division	Inundation Depth (m) / Population							Not Affected
	< 1.0	1.0 - 1.5	1.5 - 2.0	2.0 - 3.0	3.0 - 4.0	4.0 - 5.0	> 5.0	
Barisal	8,482	4,320	2,072	1,501	562	133	-	16,365
Chittagong	10,672	5,439	4,341	5,848	1,862	815	695	194,829
Dhaka	3,669	1,310	786	742	100	84	-	805,456
Khulna	11,036	3,435	1,516	713	68	-	-	85,520
Total	33,860	14,505	8,715	8,804	2,592	1,031	695	1,102,169

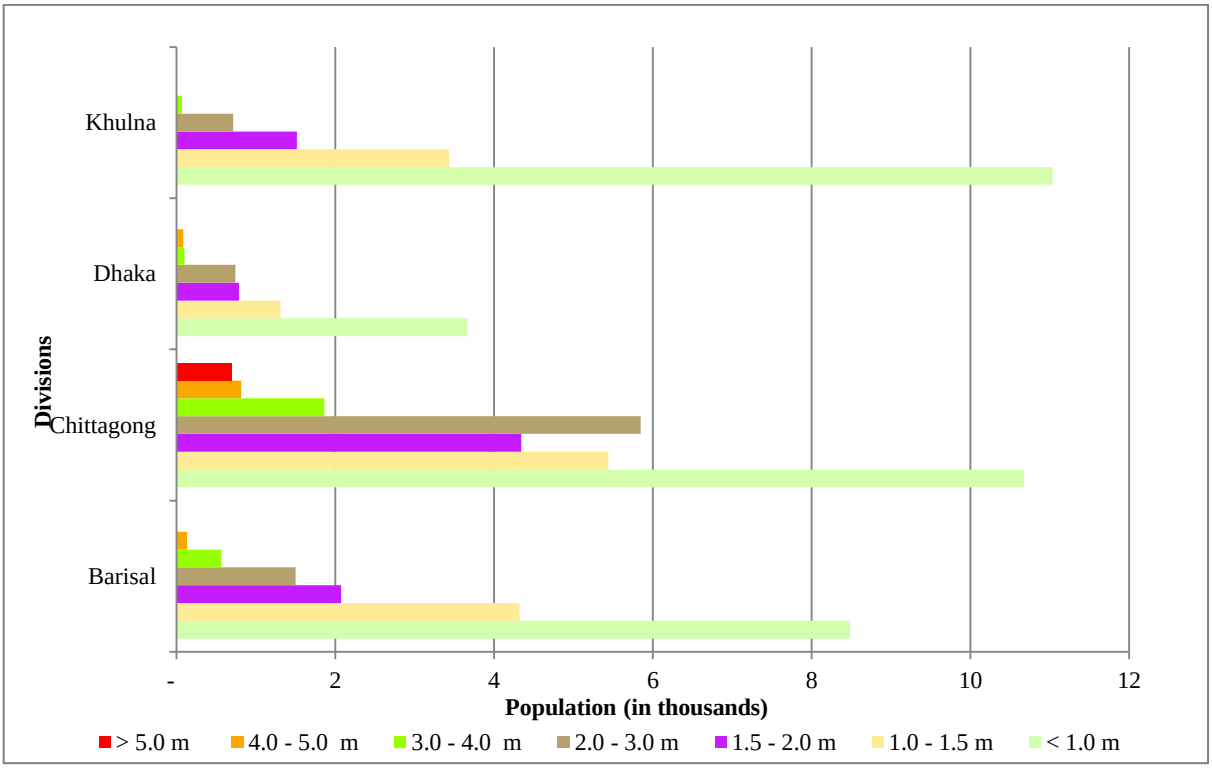


Figure 3.13: Employed (Industry) Population exposed to different storm surge inundation depth at division level

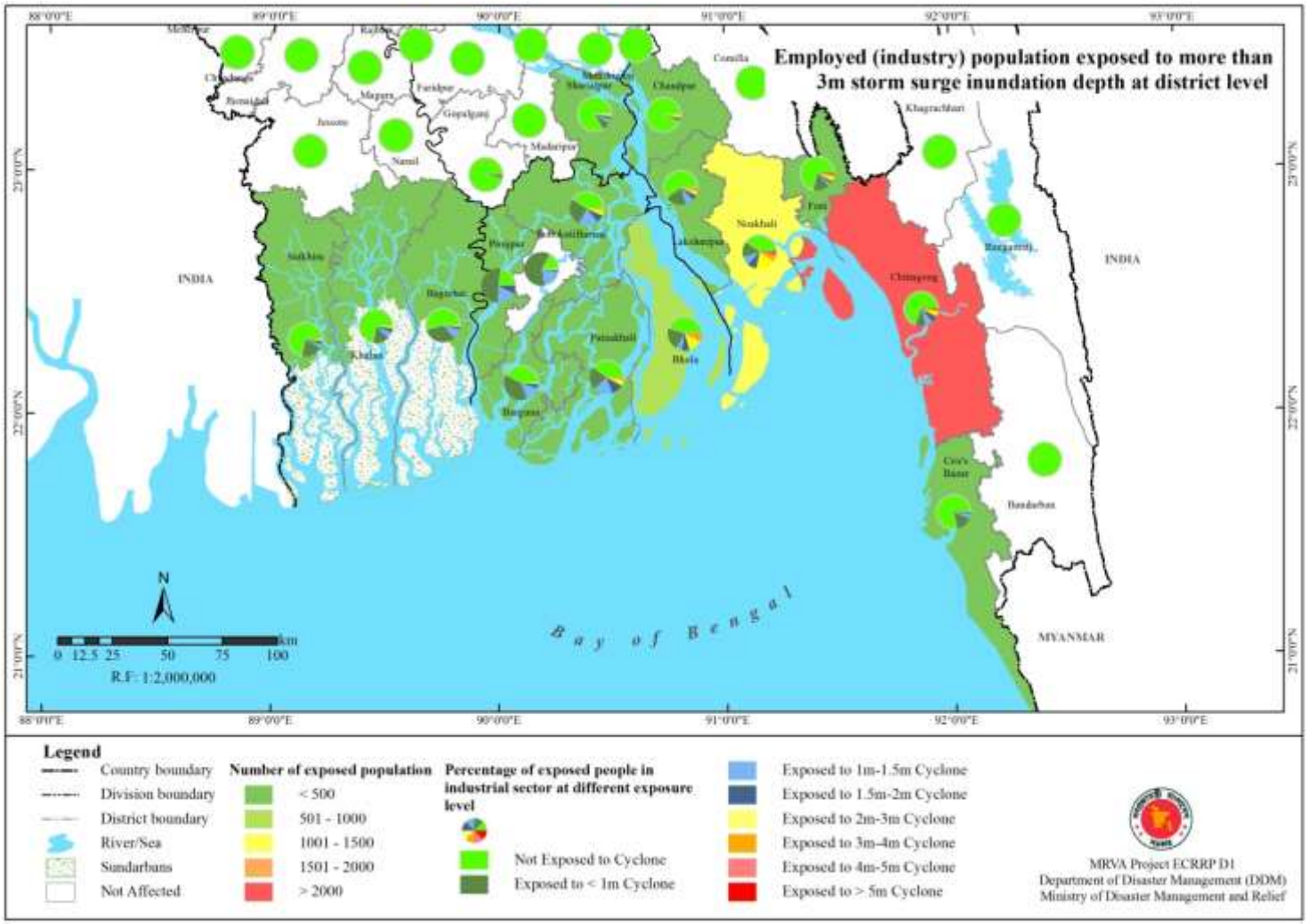


Figure 3.14: Employed (Industry) Population exposed to more than 3.0 m storm surge inundation depth at district level

3.1.1.5 Education

Details of population with education are given in section 1.1.5. Literate Population (male) exposed to storm surge is given in table 3.8 and figure 3.15. Literate Population (female) exposed to storm surge is given in table 3.9 and figure 3.16.

Table 3.8: Literate Population (male) exposed to storm surge at division level

Division	Inundation Depth (m) / Population							Not Affected
	< 1.0	1.0 - 1.5	1.5 - 2.0	2.0 - 3.0	3.0 - 4.0	4.0 - 5.0	> 5.0	
Barisal	596,329	303,726	145,642	105,533	39,533	9,344	-	1,150,516
Chittagong	356,109	181,493	144,862	195,134	62,123	27,192	23,200	6,500,911
Dhaka	61,832	22,075	13,248	12,509	1,683	1,410	-	13,572,970
Khulna	471,506	146,780	64,763	30,457	2,919	-	-	3,653,865
Total	1,485,775	654,074	368,515	343,633	106,259	37,946	23,200	24,878,262

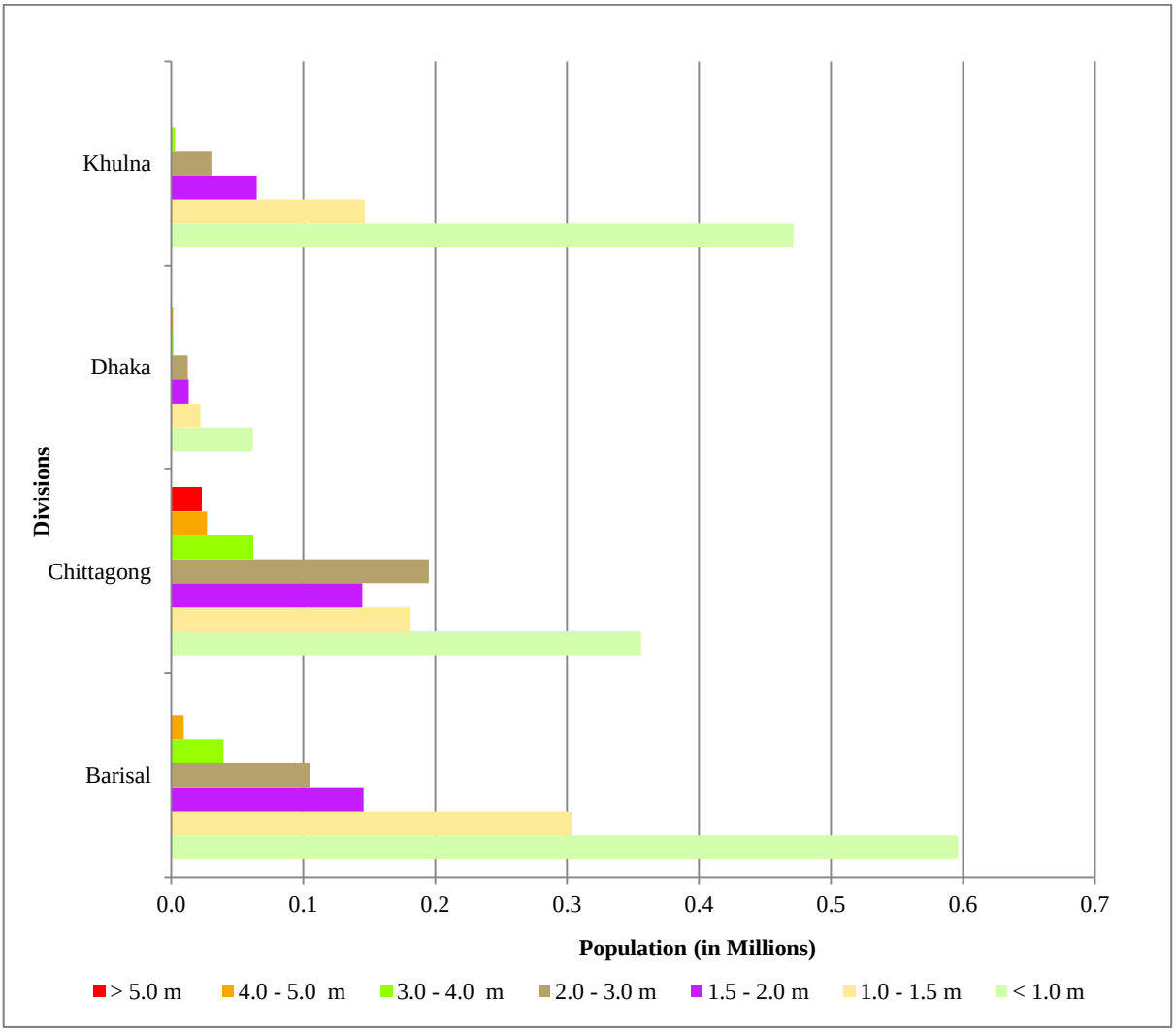


Figure 3.15: Literate Population (male) exposed to different storm surge inundation depth at division level

Table 3.9: Literate Population (female) exposed to storm surge at division level

Division Name	Inundation Depth (m) / Population							Not Affected
	< 1.0	1.0 - 1.5	1.5 - 2.0	2.0 - 3.0	3.0 - 4.0	4.0 - 5.0	> 5.0	
Barisal	599,436	305,309	146,401	106,083	39,739	9,392	-	1,156,511
Chittagong	354,108	180,473	144,048	194,038	61,774	27,040	23,069	6,464,393
Dhaka	53,672	19,162	11,500	10,858	1,461	1,224	-	11,781,801
Khulna	429,699	133,766	59,021	27,756	2,661	-	-	3,329,888
Total	1,436,916	638,710	360,969	338,735	105,635	37,656	23,069	22,732,594

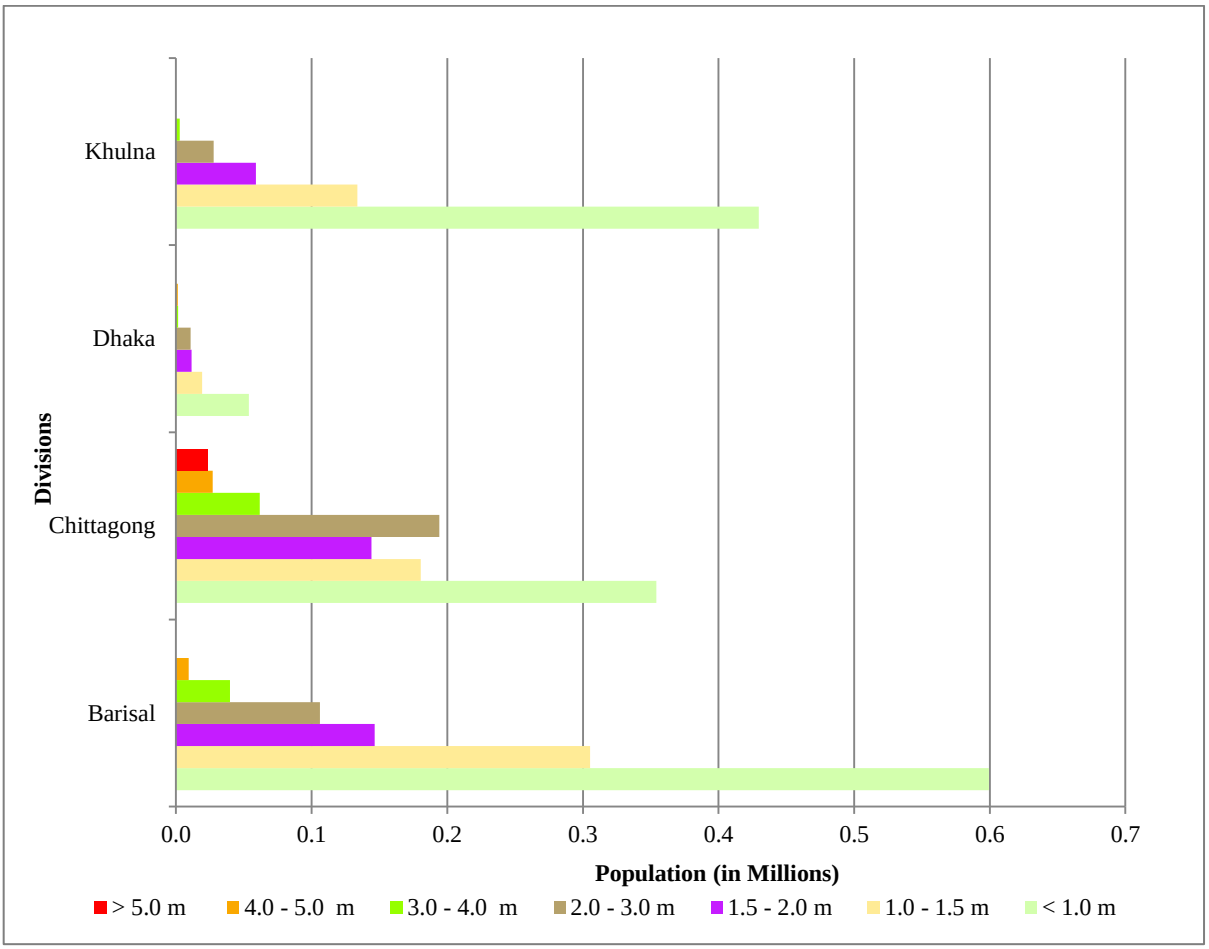


Figure 3.16: Literate Population (female) exposed to different storm surge inundation depth at division level

3.1.1.6 Disability

Details of population with disability are given in section 4.1.6 (Volume – I of this report). Disabilities of population available are Speech, Vision, Hearing, Physical, Mental, Autism. Population with disability of Vision exposed to storm surge at division level is given table 3.10 and figure 3.17. Population with disability of Physical exposed to storm surge at division level is given table 3.11 and figure 3.18. Population with disability of Mental exposed to storm surge at division level is given table 3.12 and figure 3.19. Population with disability of Autism exposed to storm surge at division level is given

table 3.13 and figure 3.20. Disable population exposed to storm surge inundation depth more than 3.0 m at district level is shown in figure 3.21.

Table 3.10: Disable Population (Vision) exposed to storm surge at division level

Division Name	Inundation Depth (m) / Population							Not Affected
	< 1.0	1.0 - 1.5	1.5 - 2.0	2.0 - 3.0	3.0 - 4.0	4.0 - 5.0	> 5.0	
Barisal	6,429	3,274	1,570	1,138	426	101	-	12,404
Chittagong	3,145	1,603	1,279	1,723	549	240	205	57,418
Dhaka	467	167	100	94	13	11	-	102,475
Khulna	4,720	1,469	648	305	29	-	-	36,580
Total	14,761	6,514	3,598	3,261	1,017	352	205	208,876

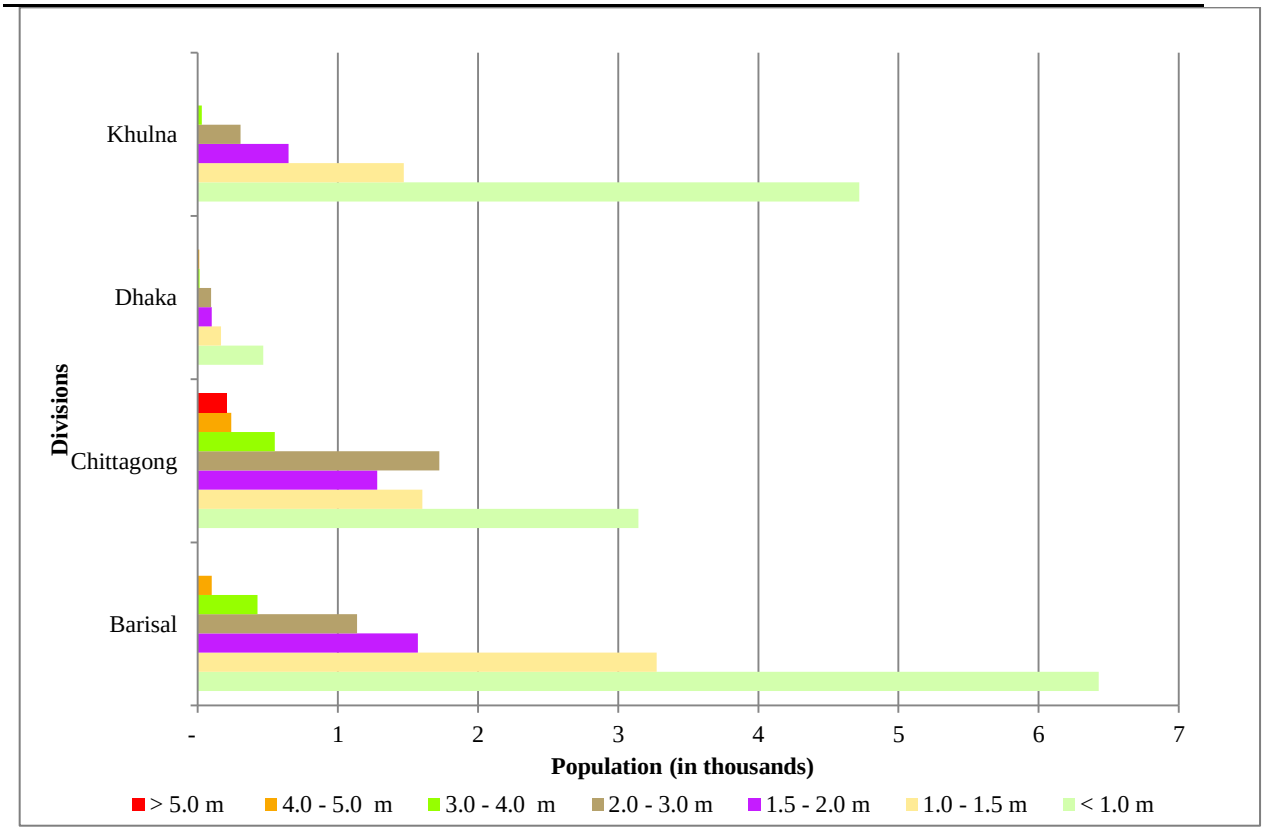


Figure 3.17: Disable Population (Vision) exposed to different storm surge inundation depth at division level

Table 3.11: Disable Population (Physical) exposed to storm surge at division level

Division Name	Inundation Depth (m) / Population							Not Affected
	< 1.0	1.0 - 1.5	1.5 - 2.0	2.0 - 3.0	3.0 - 4.0	4.0 - 5.0	> 5.0	
Barisal	14,346	7,307	3,504	2,539	951	225	-	27,678
Chittagong	7,354	3,748	2,991	4,030	1,283	562	479	134,247
Dhaka	939	335	201	190	26	21	-	206,189
Khulna	11,212	3,490	1,540	724	69	-	-	86,886
Total	33,851	14,880	8,236	7,483	2,329	808	479	455,001

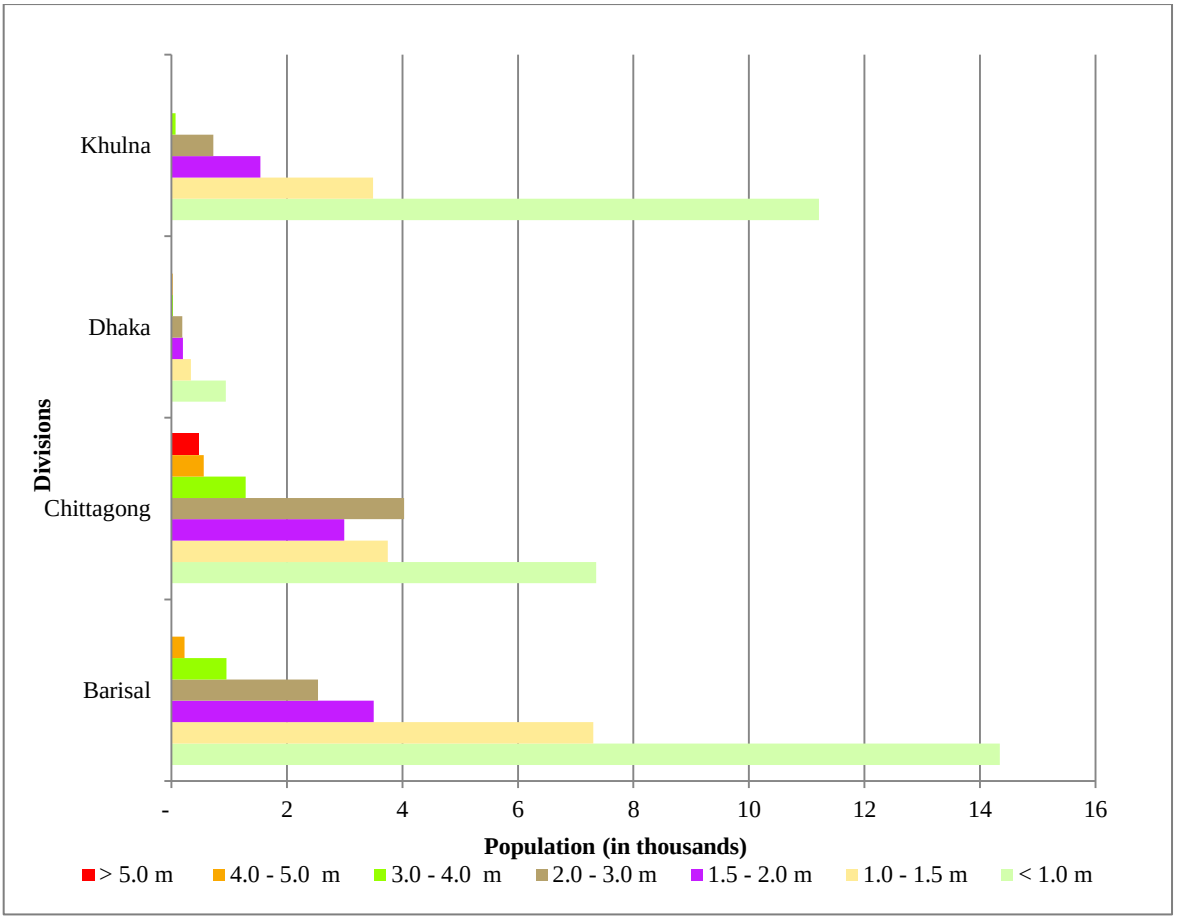


Figure 3.18: Disable Population (Physical) exposed to different storm surge inundation depth at division level

Table 3.12: Disable Population (Mental) exposed to storm surge at division level

Division Name	Inundation Depth (m) / Population							Not Affected
	< 1.0	1.0 - 1.5	1.5 - 2.0	2.0 - 3.0	3.0 - 4.0	4.0 - 5.0	> 5.0	
Barisal	2,112	1,076	516	374	140	33	-	4,075
Chittagong	1,351	689	550	740	236	103	88	24,664
Dhaka	214	76	46	43	6	5	-	47,034
Khulna	1,693	527	232	109	10	-	-	13,116
Total	5,370	2,368	1,344	1,267	392	141	88	88,890

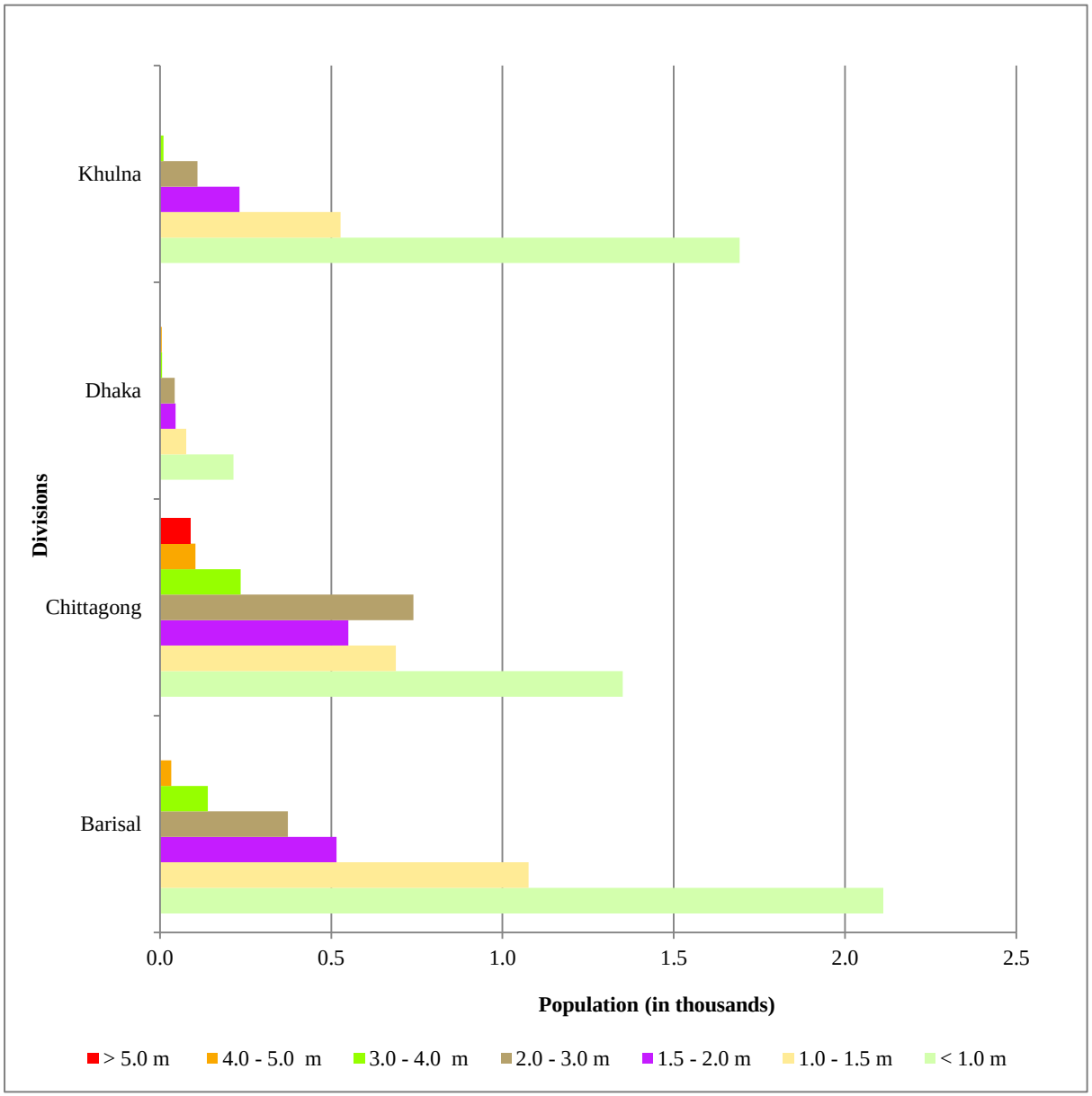


Figure 3.19: Disable Population (Mental) exposed to different storm surge inundation depth at division level

Table 3.13: Disable Population (Autism) exposed to storm surge at division level

Division Name	Inundation Depth (m) / Population							Not Affected
	< 1.0	1.0 - 1.5	1.5 - 2.0	2.0 - 3.0	3.0 - 4.0	4.0 - 5.0	> 5.0	
Barisal	3,774	1,922	922	668	250	59	-	7,281
Chittagong	2,448	1,248	996	1,341	427	187	159	44,688
Dhaka	325	116	70	66	9	7	-	71,407
Khulna	3,385	1,054	465	219	21	-	-	26,233
Total	9,932	4,340	2,452	2,294	707	253	159	149,608

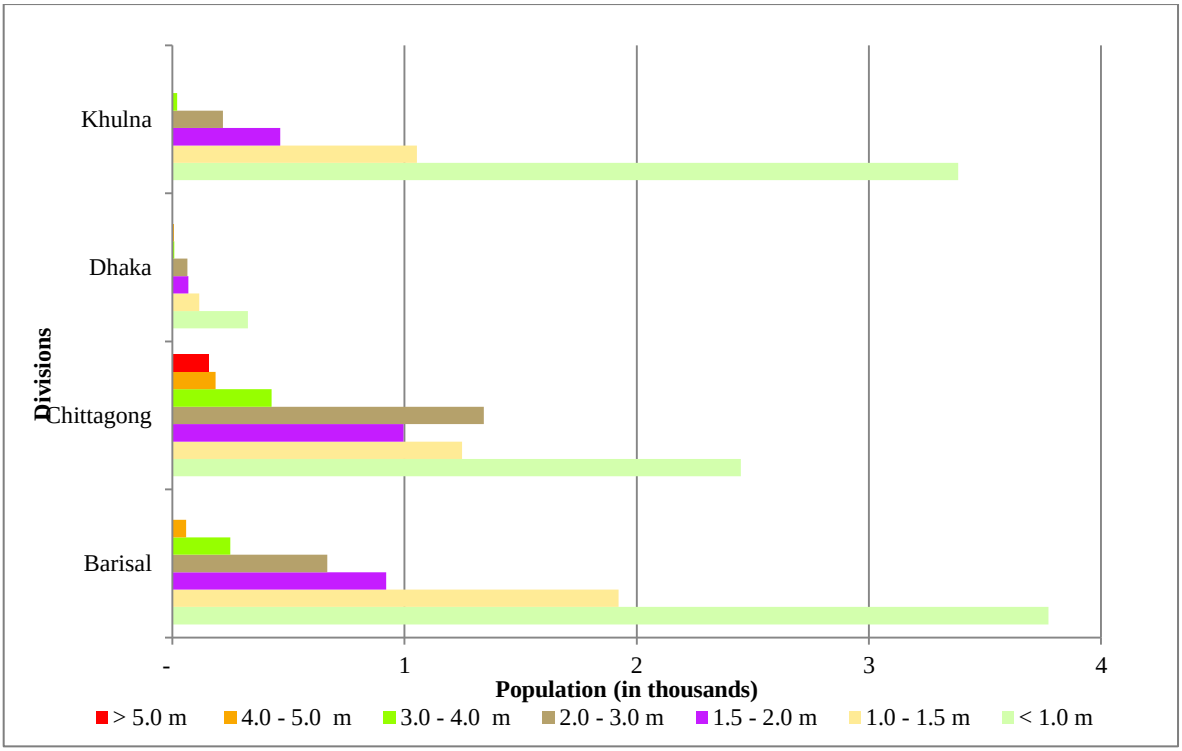


Figure 3.20: Disable Population (Autism) exposed to different storm surge inundation depth at division level

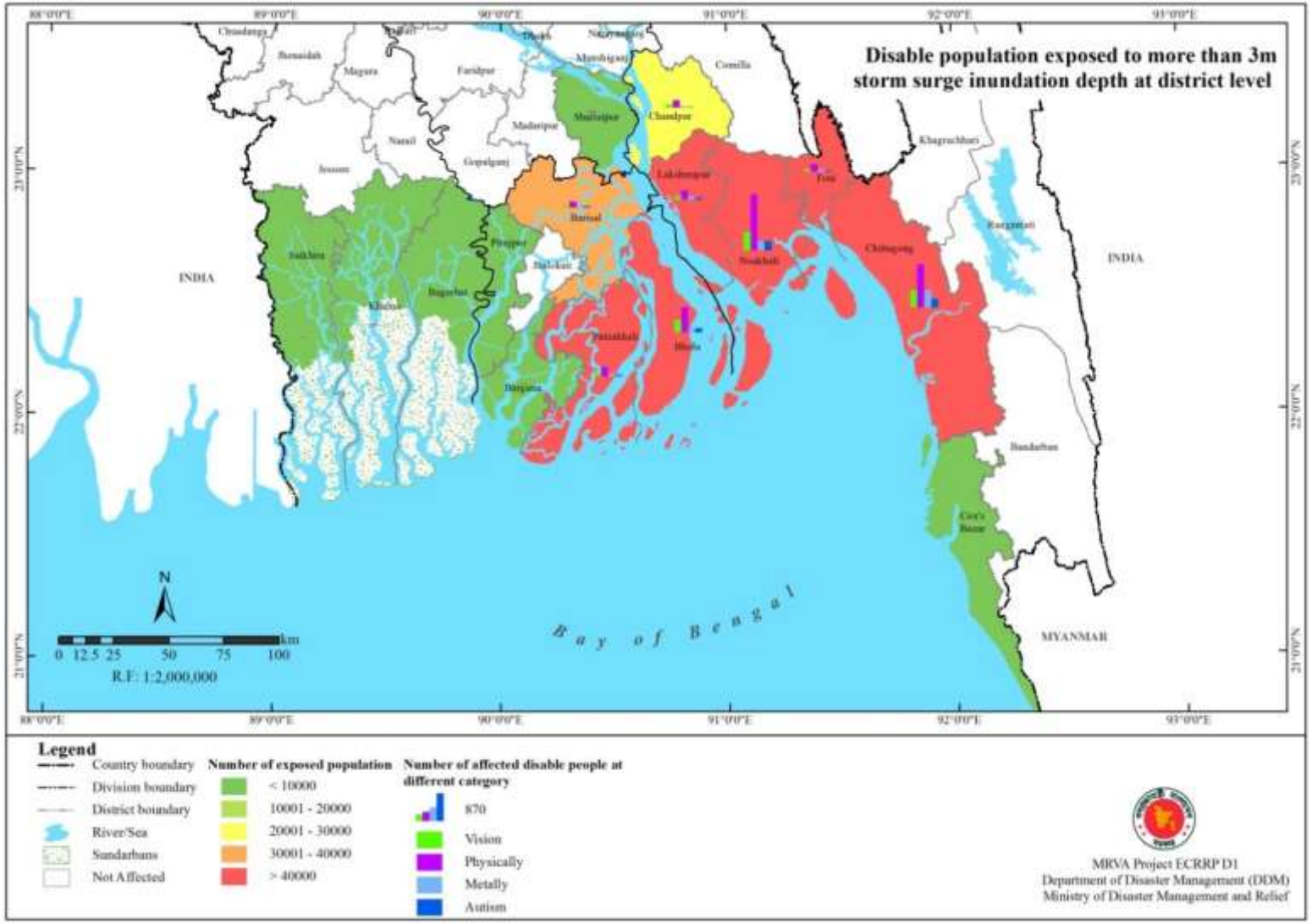


Figure 3.21: Disable Population exposed to more than 3.0 m storm surge inundation depth at district level

3.1.1.7 Poverty

As explained in section 3.1.7, population in extreme poor and poor population exposed to different inundation depth is given in table 3.14 and 3.15.

Table 3.14: Number of extreme poor population exposed to storm surge at division level

Division Name	Inundation Depth (m) / extreme poor population							Not Affected
	< 1.0	1.0 - 1.5	1.5 - 2.0	2.0 - 3.0	3.0 - 4.0	4.0 - 5.0	> 5.0	
Barisal	540,207	275,142	131,935	95,601	35,812	8,464	-	1,042,239
Chittagong	179,951	91,713	73,202	98,606	31,392	13,741	11,723	3,285,073
Dhaka	34,997	12,494	7,498	7,080	953	798	-	7,682,230
Khulna	278,979	86,847	38,319	18,020	1,727	-	-	2,161,910
Total	1,034,134	466,196	250,955	219,308	69,885	23,003	11,723	14,171,452

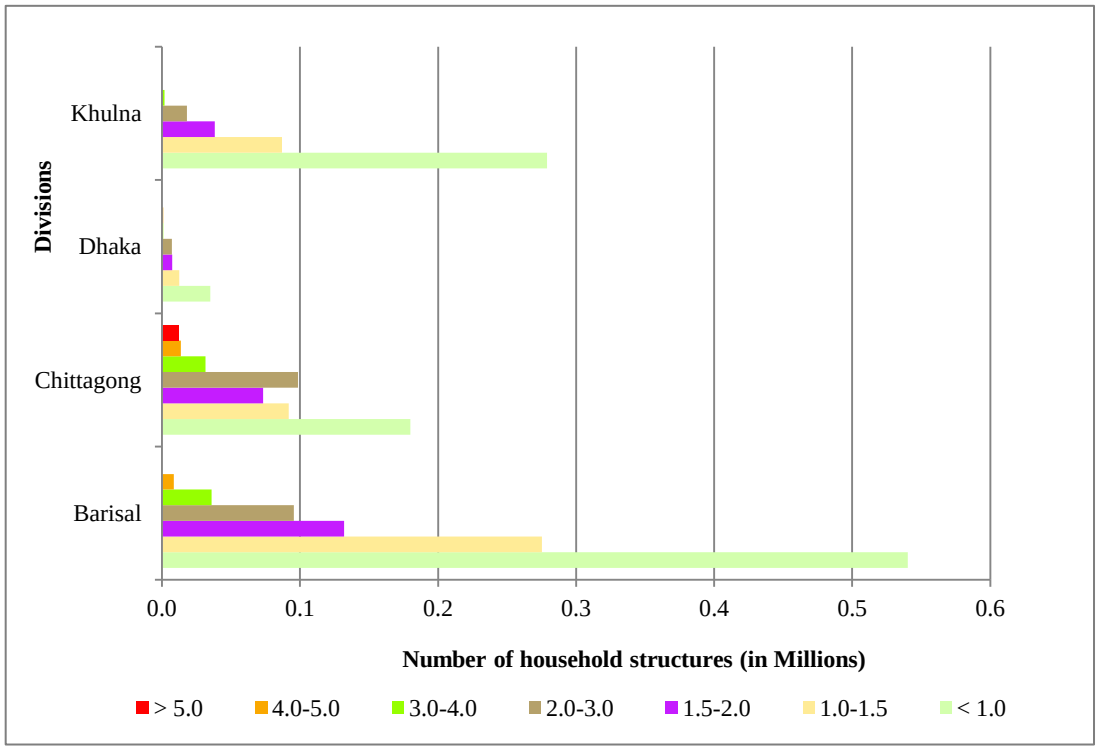


Figure 3.22: Number of extreme poor population exposed to different storm surge inundation depth at division level

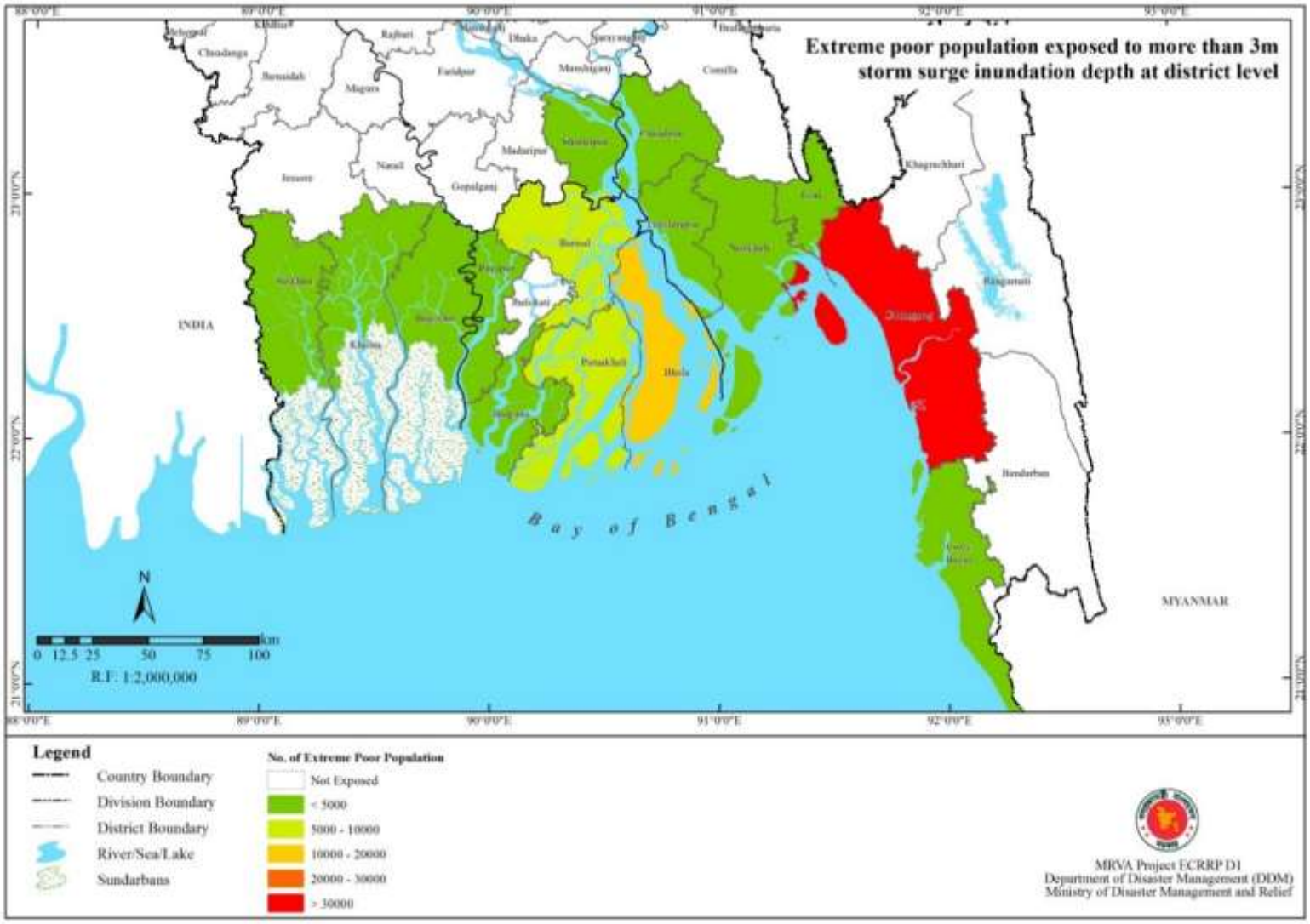


Figure 3.23: Number of extreme poor population exposed to more than 3.0 m storm surge inundation depth at district level

Table 3.15: Number of poor population exposed to storm surge at division level

Division Name	Inundation Depth (m) / poor population							Not Affected
	< 1.0	1.0 - 1.5	1.5 - 2.0	2.0 - 3.0	3.0 - 4.0	4.0 - 5.0	> 5.0	
Barisal	811,027	413,078	198,078	143,529	53,766	12,708	-	1,564,740
Chittagong	351,507	179,147	142,990	192,612	61,320	26,841	22,900	6,416,900
Dhaka	64,699	23,098	13,862	13,089	1,761	1,475	-	14,202,180
Khulna	540,554	168,275	74,247	34,917	3,347	-	-	4,188,943
Total	1,767,786	783,598	429,177	384,146	120,194	41,024	22,900	26,372,763

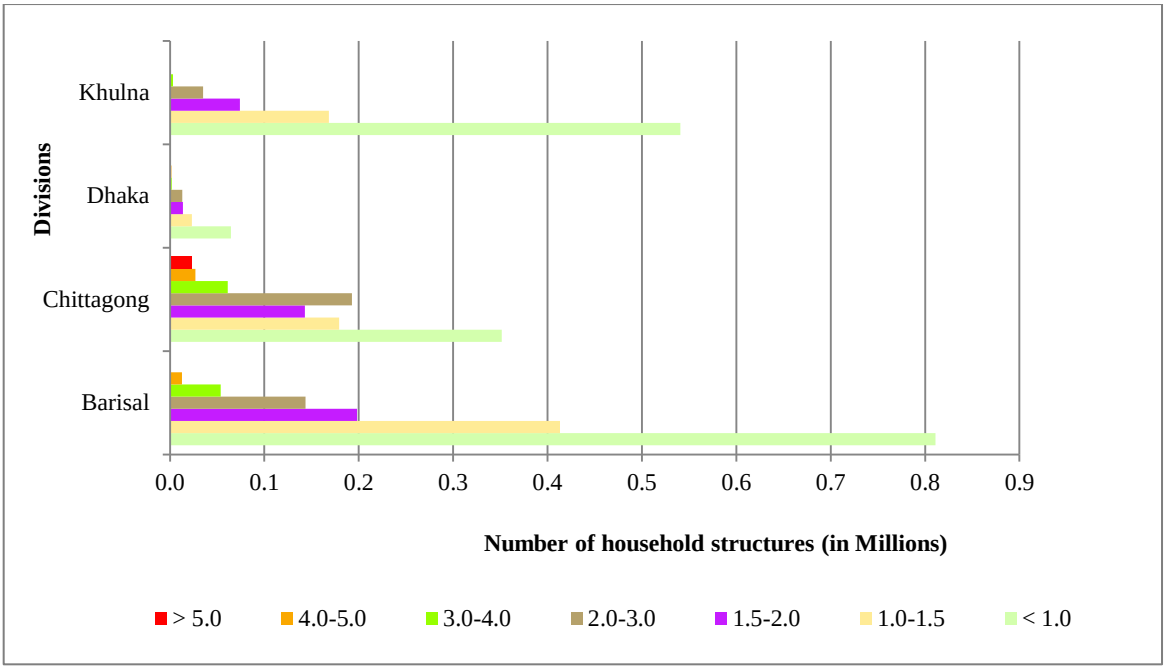


Figure 3.24: Number of poor population exposed to different storm surge inundation depth at division level

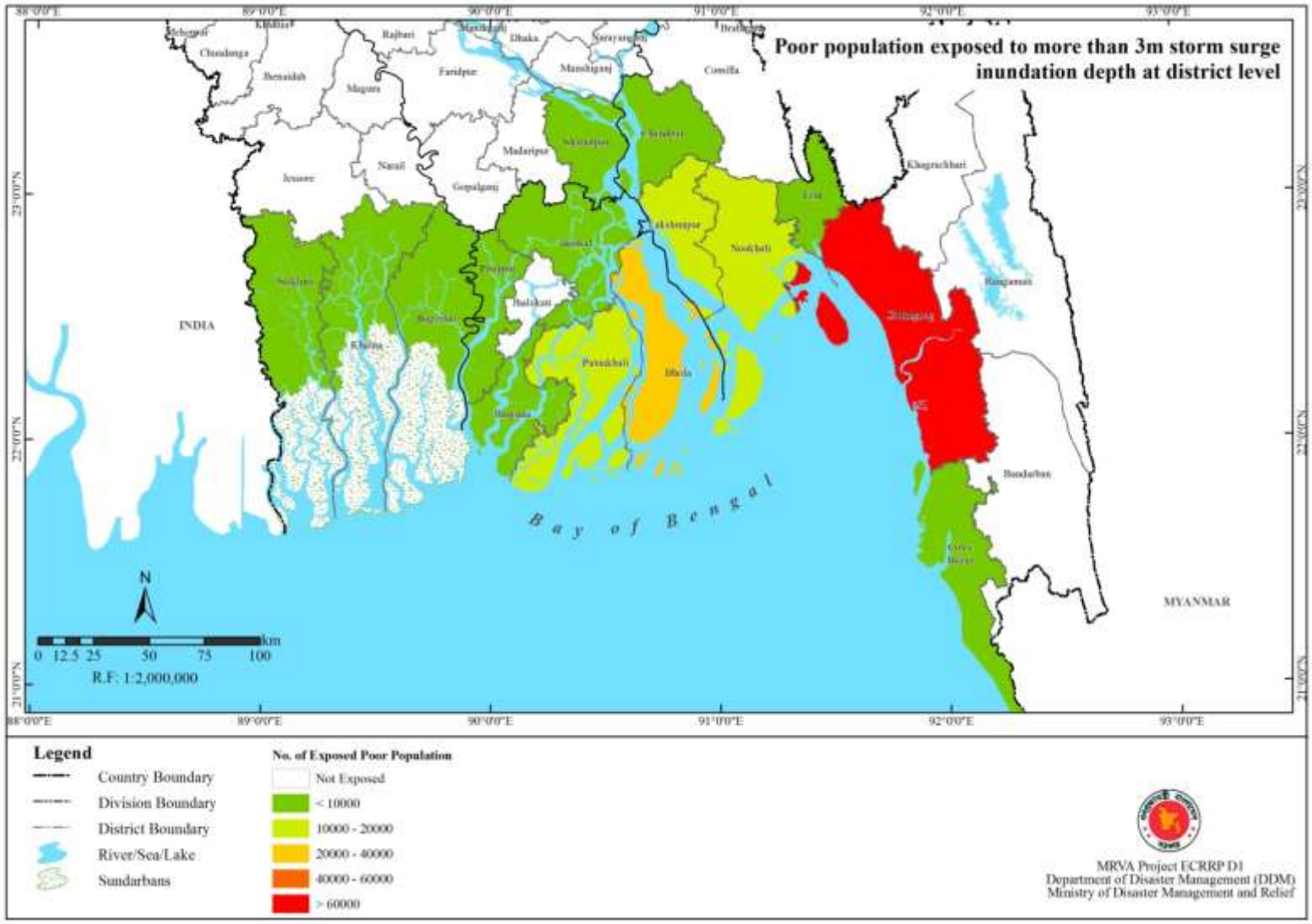


Figure 3.25: Number of poor population exposed to more than 3.0 m storm surge inundation depth at district level

3.1.2 Housing

As mentioned in section 1.2.1 (Volume III of this report), household structure types are Pucca, Semi-Pucca, Katcha, Jhupri. Exposure of the household structure to storm surge inundation depth is assessed by combining storm surge hazard map and household structure maps. Number of Pucca household structures in each storm surge inundation depth category in each division is given in table 3.16 and figure 3.26. Number of semi-Pucca household structures in each storm surge inundation depth category in each division is given in table 3.17 and figure 3.27. Number of Katcha household structures in each storm surge inundation depth category in each division is given in table 3.18 and figure 3.28. Number of Jhupri household structures in each storm surge inundation depth category in each division is given in table 3.19 and figure 3.29.

Table 3.16: Number of Pucca household structures exposed to storm surge at division level

Name	Inundation Depth (m) / household structures							Not Affected
	< 1.0	1.0 - 1.5	1.5 - 2.0	2.0 - 3.0	3.0 - 4.0	4.0 - 5.0	> 5.0	
Barisal	19,786	10,078	4,832	3,502	1,312	310	-	38,174
Chittagong	34,477	17,572	14,025	18,892	6,015	2,633	2,246	629,397
Dhaka	7,857	2,805	1,683	1,589	214	179	-	1,724,697
Khulna	54,952	17,107	7,548	3,550	340	-	-	425,844
Total	117,073	47,561	28,089	27,533	7,880	3,122	2,246	2,818,112

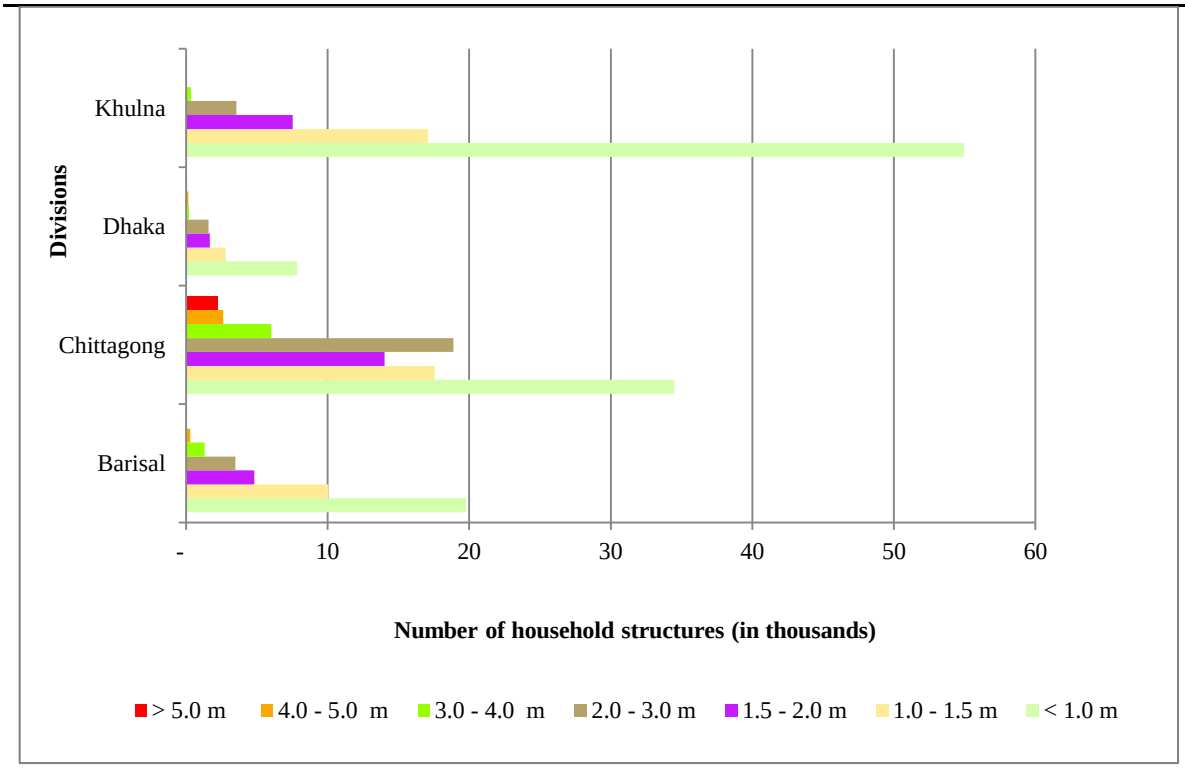


Figure 3.26: Number of Pucca household structures exposed to different storm surge inundation depth at division level

Table 3.17: Number of semi-Pucca household structures exposed to storm surge at division level

Name	Inundation Depth (m) / household structures							Not Affected
	< 1.0	1.0 - 1.5	1.5 - 2.0	2.0 - 3.0	3.0 - 4.0	4.0 - 5.0	> 5.0	
Barisal	38,798	19,761	9,476	6,866	2,572	608	-	74,853
Chittagong	37,721	19,225	15,345	20,670	6,580	2,880	2,457	688,611
Dhaka	10,946	3,908	2,345	2,214	298	250	-	2,402,852
Khulna	110,475	34,391	15,174	7,136	684	-	-	856,112
Total	197,940	77,284	42,340	36,886	10,134	3,738	2,457	4,022,429

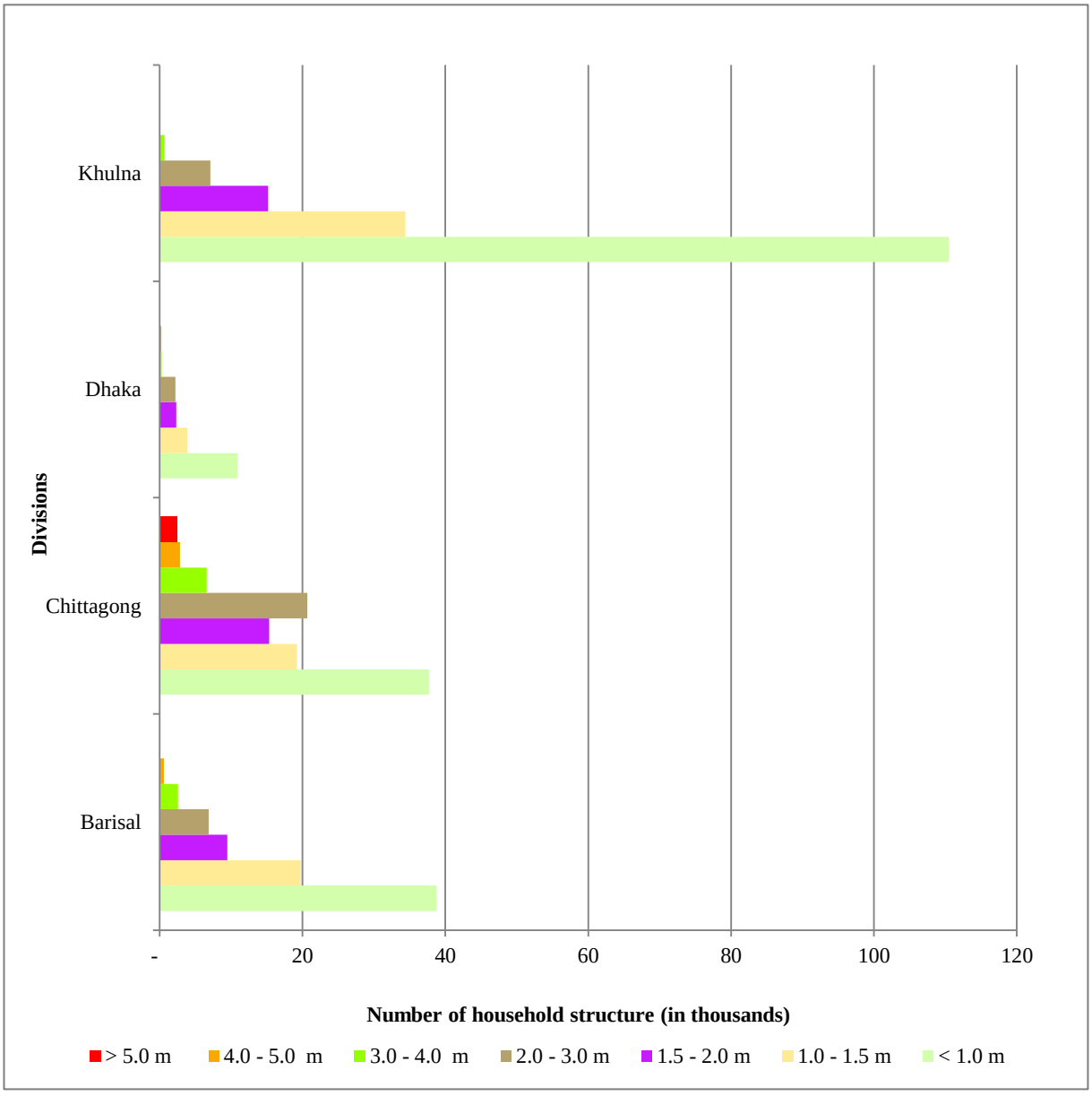


Figure 3.27: Number of semi-Pucca household structures exposed to different storm surge inundation depth at division level

Table 3.18: Number of Katcha household structures exposed to storm surge at division level

Division	Inundation Depth (m) / household structures							Not Affected
	< 1.0	1.0 - 1.5	1.5 - 2.0	2.0 - 3.0	3.0 - 4.0	4.0 - 5.0	> 5.0	
Barisal	398,861	203,150	97,414	70,587	26,442	6,250	-	769,535
Chittagong	184,545	94,054	75,071	101,123	32,194	14,092	12,023	3,368,943
Dhaka	29,178	10,417	6,251	5,903	794	665	-	6,404,943
Khulna	226,045	70,368	31,048	14,601	1,400	-	-	1,751,702
Total	838,629	377,990	209,785	192,215	60,830	21,007	12,023	12,295,123

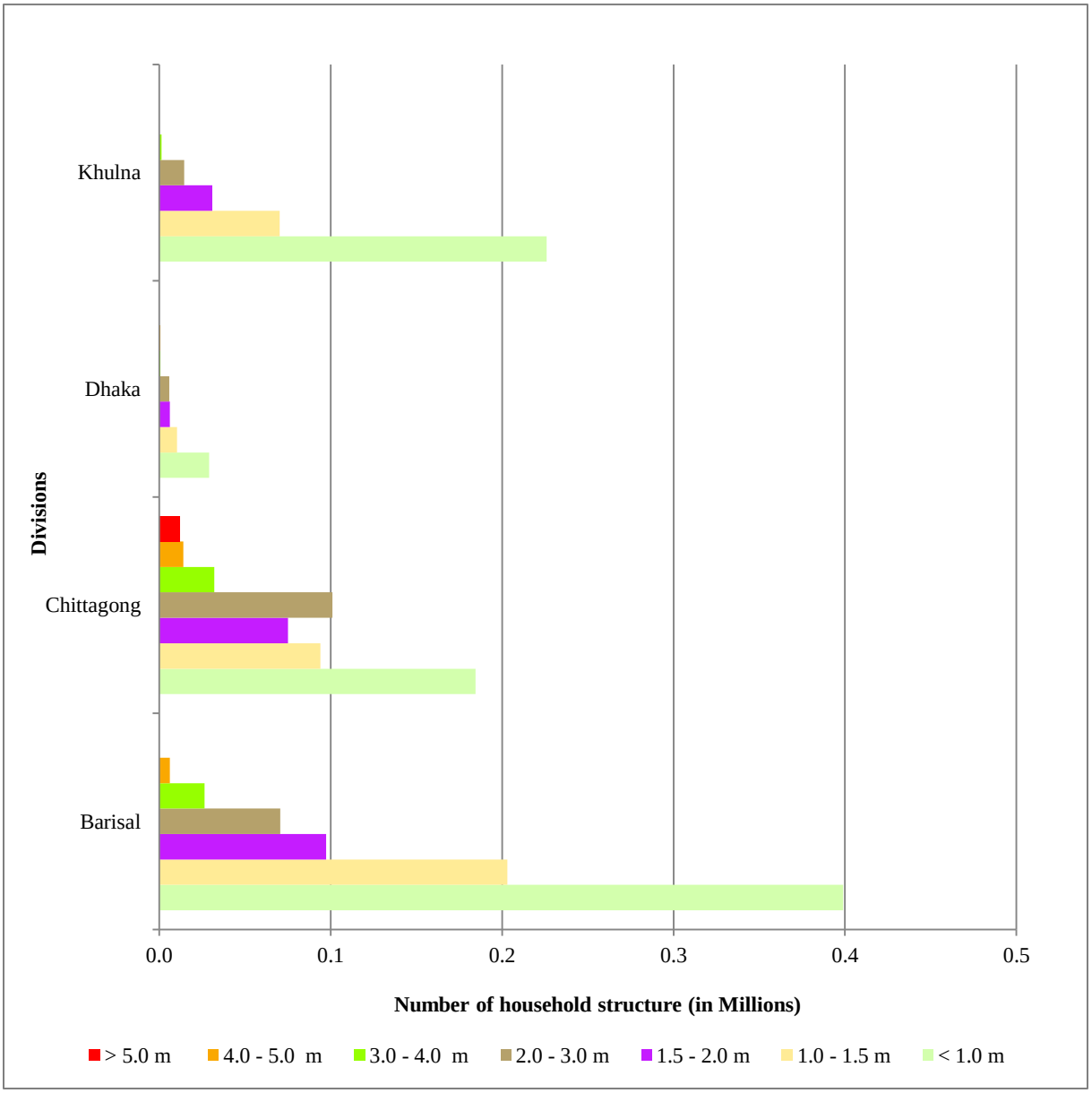


Figure 3.28: Number of Katcha household structures exposed to different storm surge inundation depth at division level

Table 3.19: Number of Jhupri household structures exposed to storm surge at division level

Division	Inundation Depth (m) / household structures							Not Affected
	< 1.0	1.0 - 1.5	1.5 - 2.0	2.0 - 3.0	3.0 - 4.0	4.0 - 5.0	> 5.0	
Barisal	15,138	7,710	3,697	2,679	1,004	237	-	29,207
Chittagong	10,721	5,464	4,361	5,874	1,870	819	698	195,708
Dhaka	1,036	370	222	210	28	24	-	227,437
Khulna	12,009	3,738	1,649	776	74	-	-	93,062
Total	38,904	17,283	9,930	9,539	2,976	1,079	698	545,414

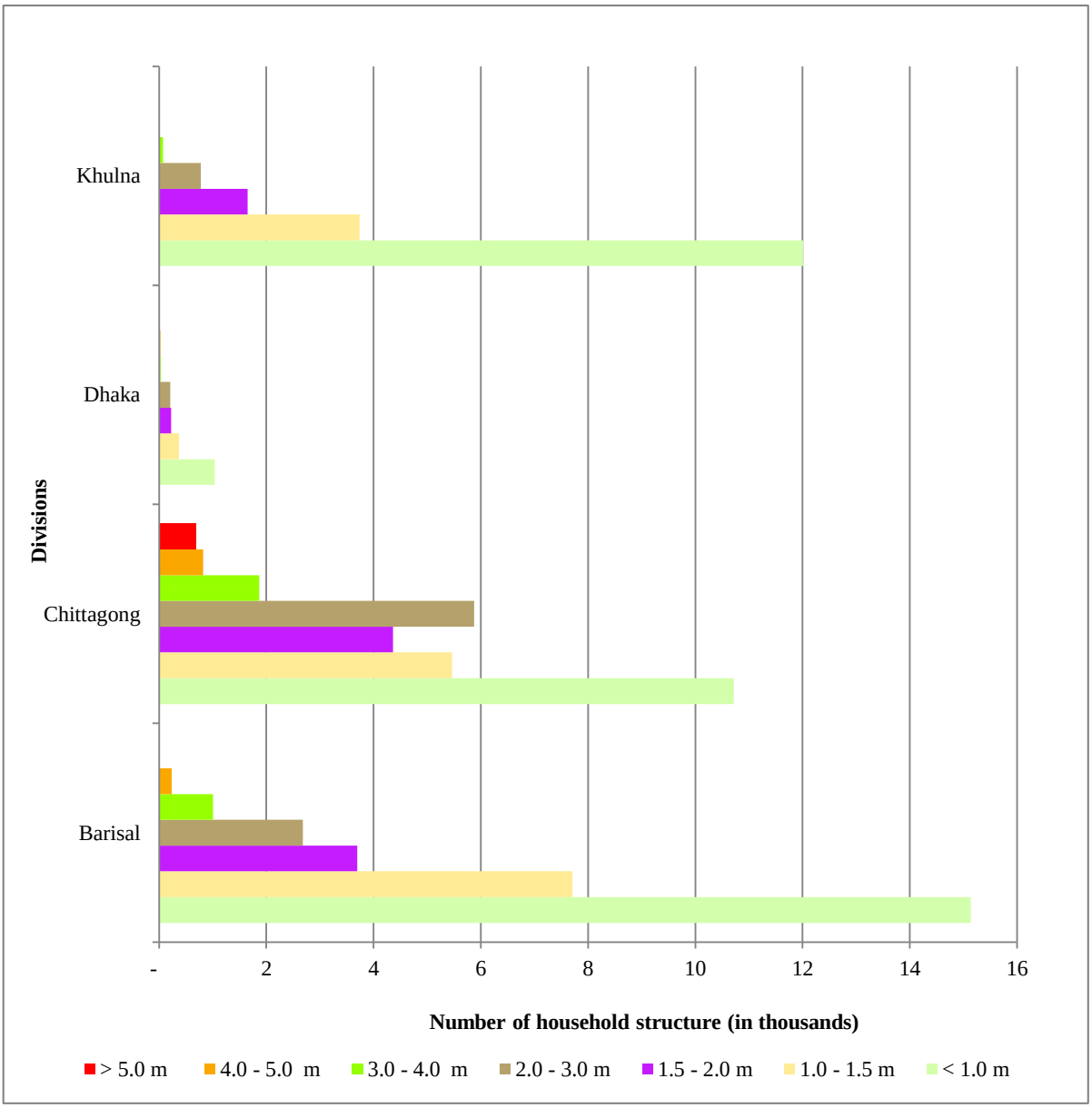


Figure 3.29: Number of Jhupri household structures exposed to different storm surge inundation depth at division level

3.1.3 Livelihood

Elements at risk considered in livelihood are crop (transplanted Aman) and industries.

3.1.3.1 Agriculture

The exposure of transplanted Aman crop area to storm surge is given in table 3.20.

Table 3.20: Exposure of transplanted Aman crop area to storm surge

District	Upazila	Transplanted aman area (km^2) exposed to inundation depth (m) due to storm surge						
		< 1.0	1.0-1.5	1.5-2.0	2.0-3.0	3.0-4.0	4.0-5.0	> 5.0
Barisal	Barguna	501.6	194.2	47.9	11.5	1.6	0.1	
	Barisal	495.5	402.1	144.0	85.5	22.3	1.7	
	Bhola	391.6	97.7	113.2	164.7	33.8	6.4	
	Jhalokati	447.1	137.8	12.4	8.5			
	Patuakhali	538.8	469.2	287.3	108.0	27.7	1.5	
	Pirojpur	602.4	222.9	95.0	7.8	1.0		
Chittagong	Chandpur	40.3	6.9	4.2	10.8	4.0	0.7	
	Chittagong	371.8	298.0	209.0	162.3	27.7	6.7	5.0
	Cox's Bazar	242.4	87.2	20.8	5.7	0.2		
	Feni	134.1	32.5	19.8	31.6	6.4	2.1	3.0
	Lakshmipur	206.1	93.5	58.9	33.7	21.5	8.6	0.2
	Noakhali	362.3	175.5	162.2	256.8	15.9	4.8	3.0
Dhaka	Shariatpur				0.0		1.1	
Khulna	Bagerhat	256.6	94.2	25.2	3.1	0.4		
	Khulna	2.7	1.0	1.4	2.7	0.2		
	Satkhira	6.9	5.2	3.4	7.2	1.4		
Total		4600.2	2318.0	1204.7	899.8	164.1	33.5	11.1

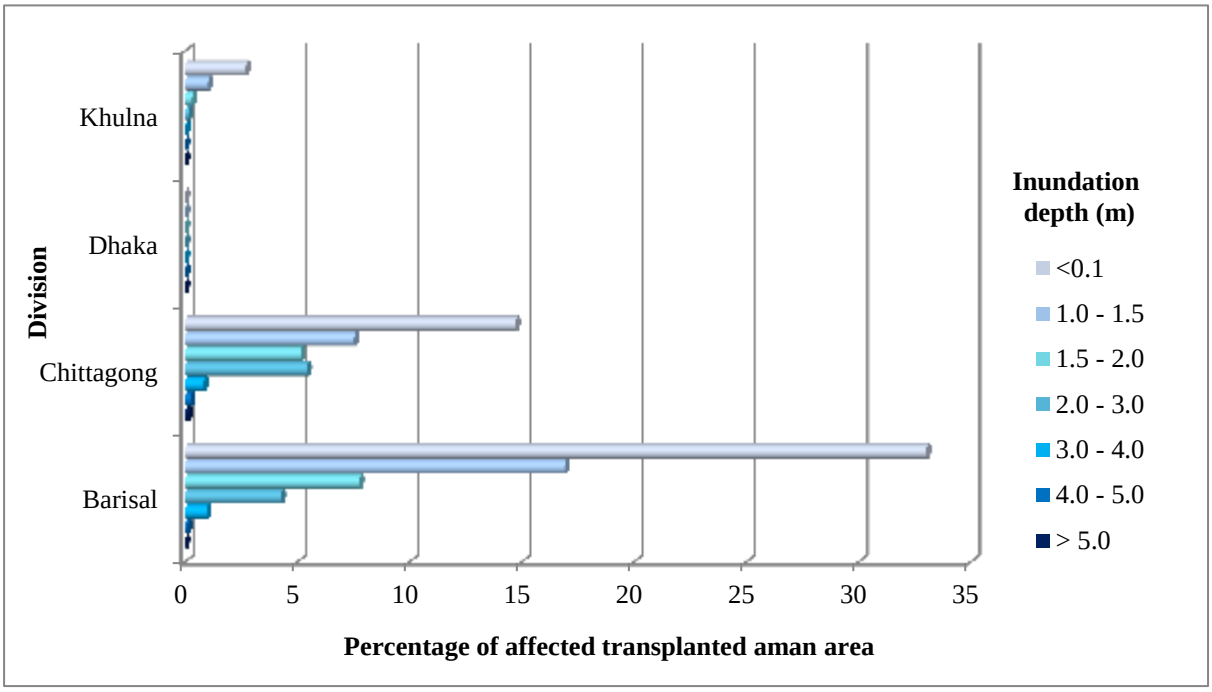


Figure 3.30: Exposure of transplanted Aman crop area to storm surge at division level

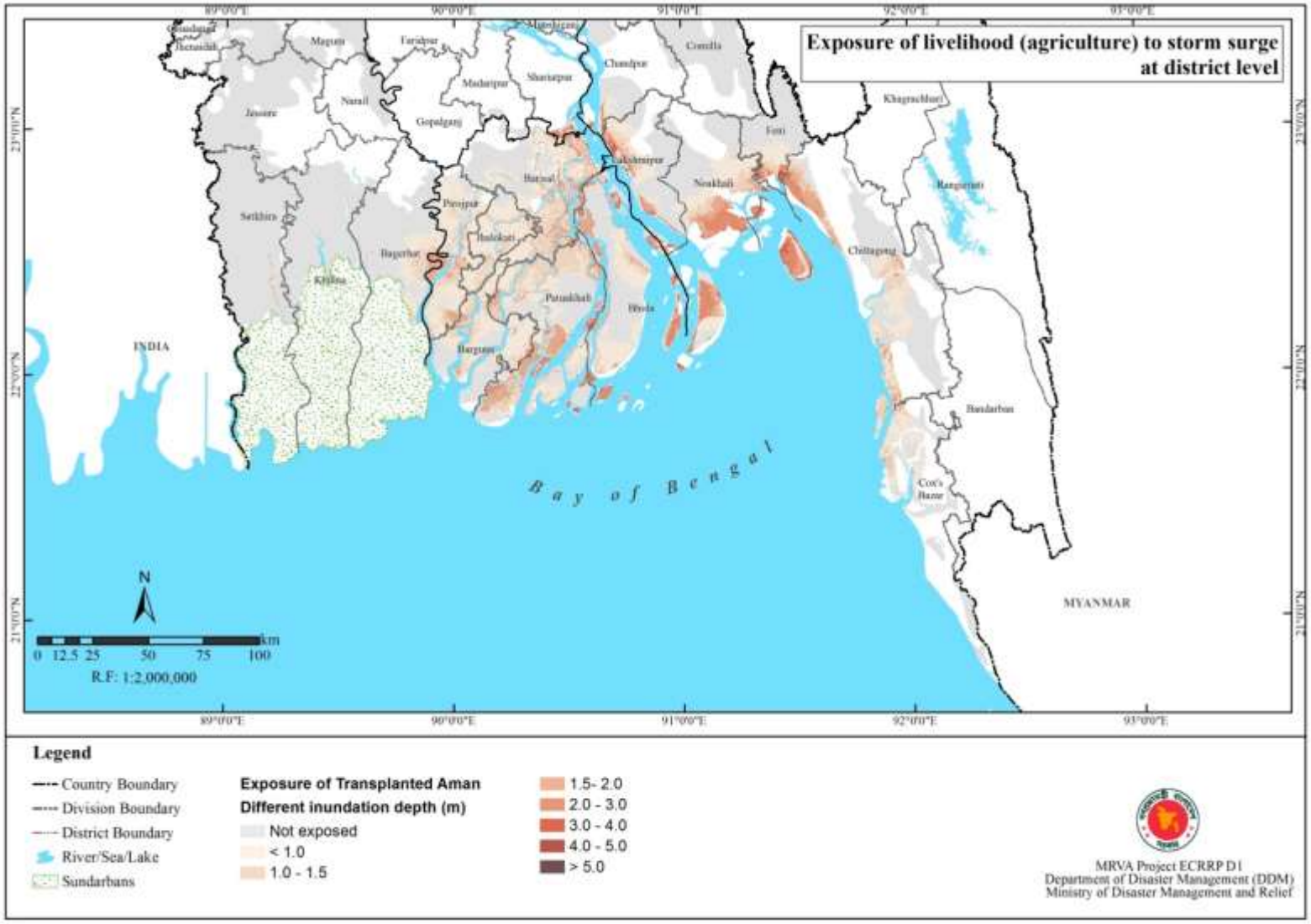


Figure 3.31: Exposure of transplanted Aman crop area to storm surge at district level

3.1.3.2 Industries

The different types of industries (Food Godowns, Mills, Gas Field, Cold Storage, Cottage Industries, Rice/Oil/Grain mills) existing in the database are assessed for their existence in storm surge inundation prone areas.

The number of food godowns existing in different storm surge inundation depths at division level is given in table 3.21 and figure 3.32.

Table 3.21: Number of Food godowns exposed to storm surge at division level

Name	Inundation Depth (m) / number of industries							Not Affected
	< 1.0	1.0 - 1.5	1.5 - 2.0	2.0 - 3.0	3.0 - 4.0	4.0 - 5.0	> 5.0	
Barisal	-	13	13	10	13	6	1	8
Chittagong	1	1	3	6	3	5	3	95
Dhaka	5	4	1	1	-	-	-	179
Khulna	-	2	-	-	-	-	-	70
Total	6	20	17	17	16	11	4	352

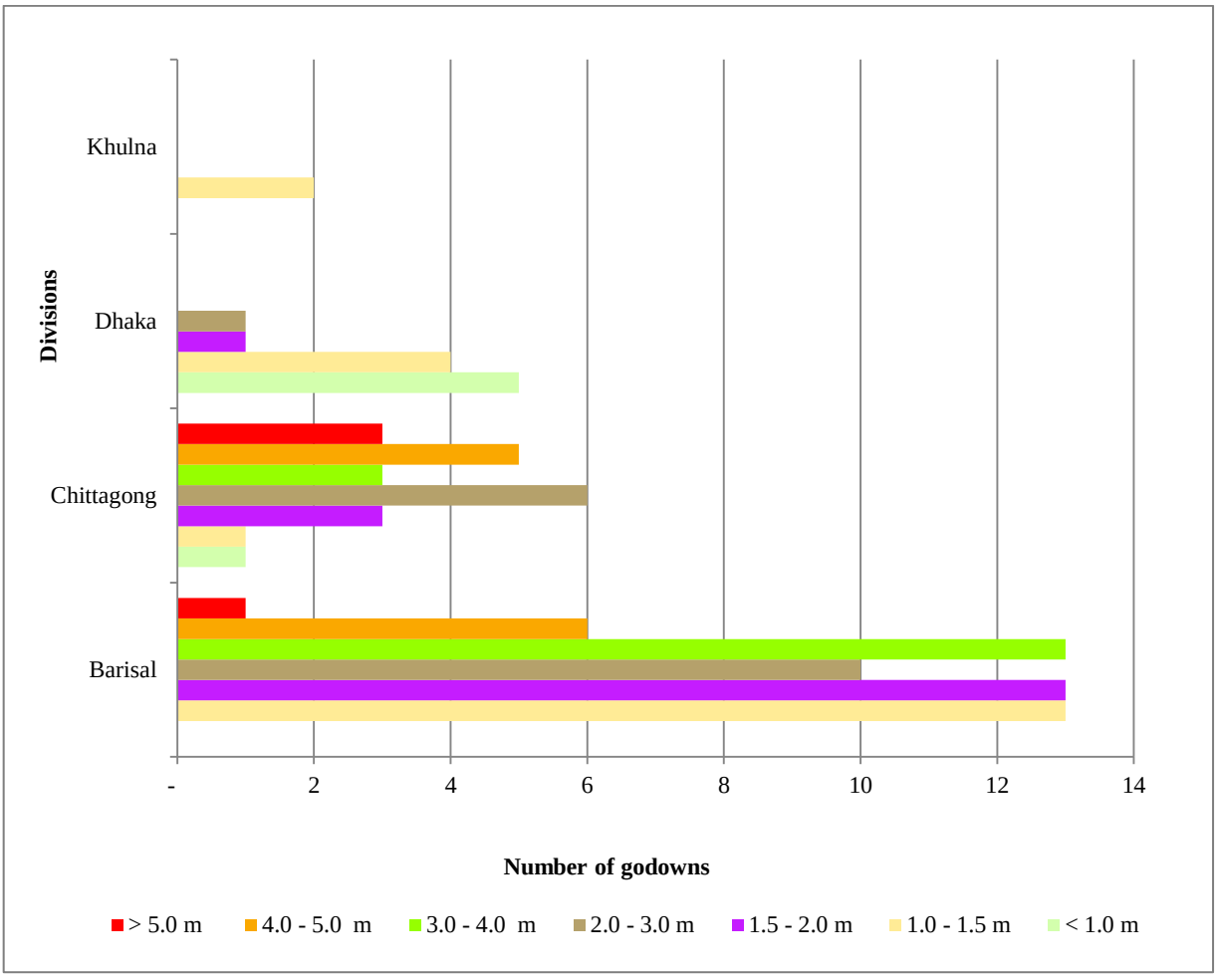


Figure 3.32: Number of Food godowns exposed to different storm surge inundation depth at division level

The number of Mills existing in different storm surge inundation depths at division level is given in table 3.22 and figure 3.33.

Table 3.22: Number of Mills exposed to storm surge at division level

Division	Inundation Depth (m) / number of industries							Not Affected
	< 1.0	1.0 - 1.5	1.5 - 2.0	2.0 - 3.0	3.0 - 4.0	4.0 - 5.0	> 5.0	
Barisal	1	-	1	4	-	-	-	-
Chittagong	-	1	3	7	2	1	-	13
Dhaka	-	-	-	-	-	-	-	35
Khulna	2	2	3	-	1	-	-	16
Total	3	3	7	11	3	1	-	64

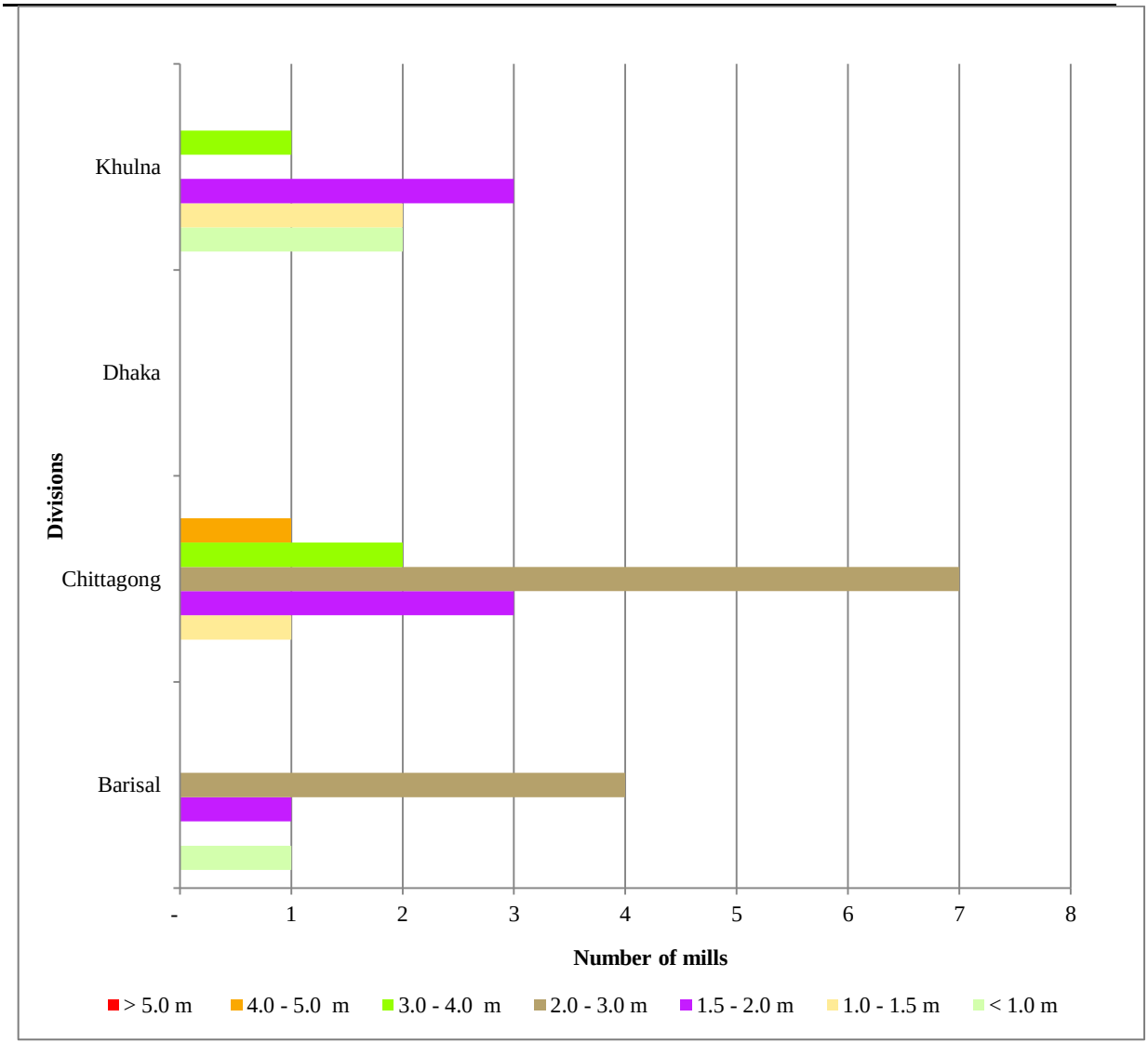


Figure 3.33: Number of Mills exposed to different storm surge inundation depth at division level

The existing 13 Gas Fields are not exposed to storm surge inundation depth.

The number of Cold Storage existing in different storm surge inundation depths at division level is given in table 3.23.

Table 3.23: Number of Cold Storage exposed to storm surge at division level

Division	Inundation Depth (m) / number of industries							Not Affected
	< 1.0	1.0 - 1.5	1.5 - 2.0	2.0 - 3.0	3.0 - 4.0	4.0 - 5.0	> 5.0	
Barisal	-	-	-	-	-	-	-	-
Chittagong	-	-	-	1	-	1	-	-
Dhaka	-	-	-	-	-	-	-	2
Khulna	-	-	-	-	-	-	-	-
Total	-	-	-	1	-	1	-	2

The existing 53 Cottage Industry are not exposed to storm surge inundation depth.

The number of Rice/Oil/Grain Mill existing in different storm surge inundation depths at division level is given in table 3.24.

Table 3.24: Number of Rice/Oil/Grain Mill exposed to storm surge at division level

Division Name	Inundation Depth (m) / number of industries							Not Affected
	< 1.0	1.0 - 1.5	1.5 - 2.0	2.0 - 3.0	3.0 - 4.0	4.0 - 5.0	> 5.0	
Barisal	-	-	-	-	-	-	-	-
Chittagong	-	-	-	-	-	8	4	9
Dhaka	-	-	-	-	-	-	-	1
Khulna	-	-	-	-	-	-	-	-
Total	-	-	-	-	-	8	4	10

3.1.4 Critical Facilities

3.1.4.1 Health care facilities

Combining storm surge hazard map and Health care facility map will provide existing hospitals and family welfare centers in storm surge prone areas.

The number of hospitals exposed to storm surge at division level is given in table 3.25 and figure 3.34 Hospitals exposed to storm surge at district level is shown in figure 3.35.

Table 3.25: Number of hospitals exposed to storm surge at division level

Division	Inundation Depth (m) / number of hospitals							Not Affected
	< 1.0	1.0 - 1.5	1.5 - 2.0	2.0 - 3.0	3.0 - 4.0	4.0 - 5.0	> 5.0	
Barisal	1	10	8	5	8	2	0	2
Chittagong	0	3	8	6	5	2	1	70
Dhaka	2	0	0	0	0	0	0	124
Khulna	3	2	3	2	0	0	0	56
Total	6	15	19	13	13	4	1	252

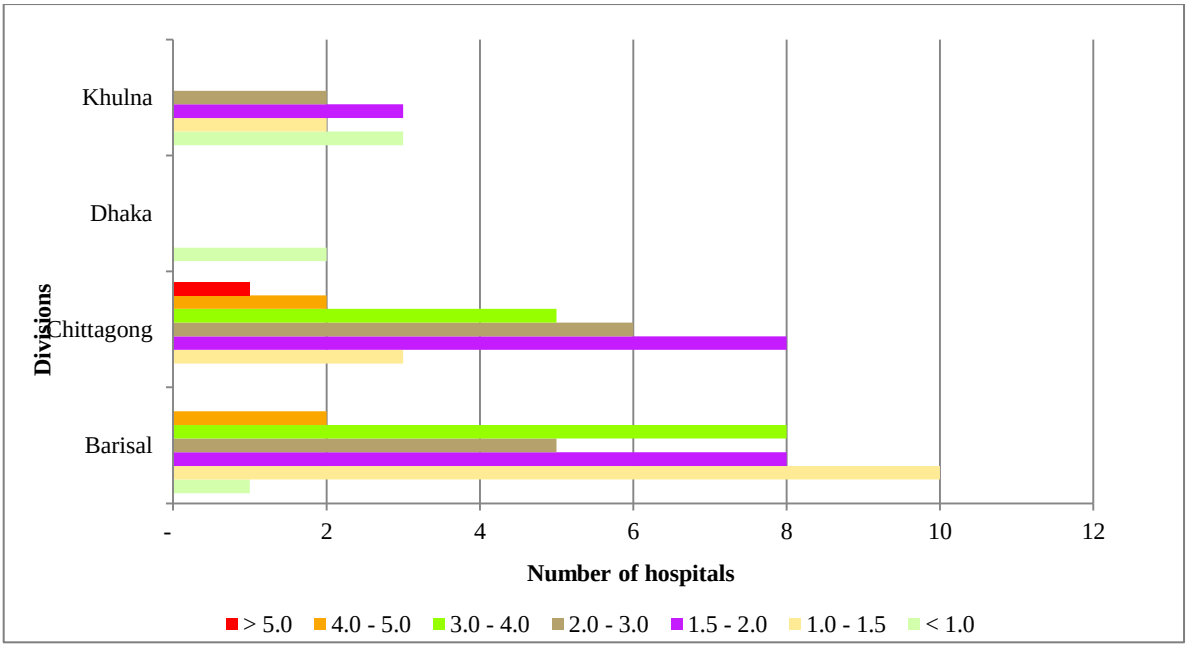


Figure 3.34: Number of hospitals exposed to different storm surge inundation depth at division level

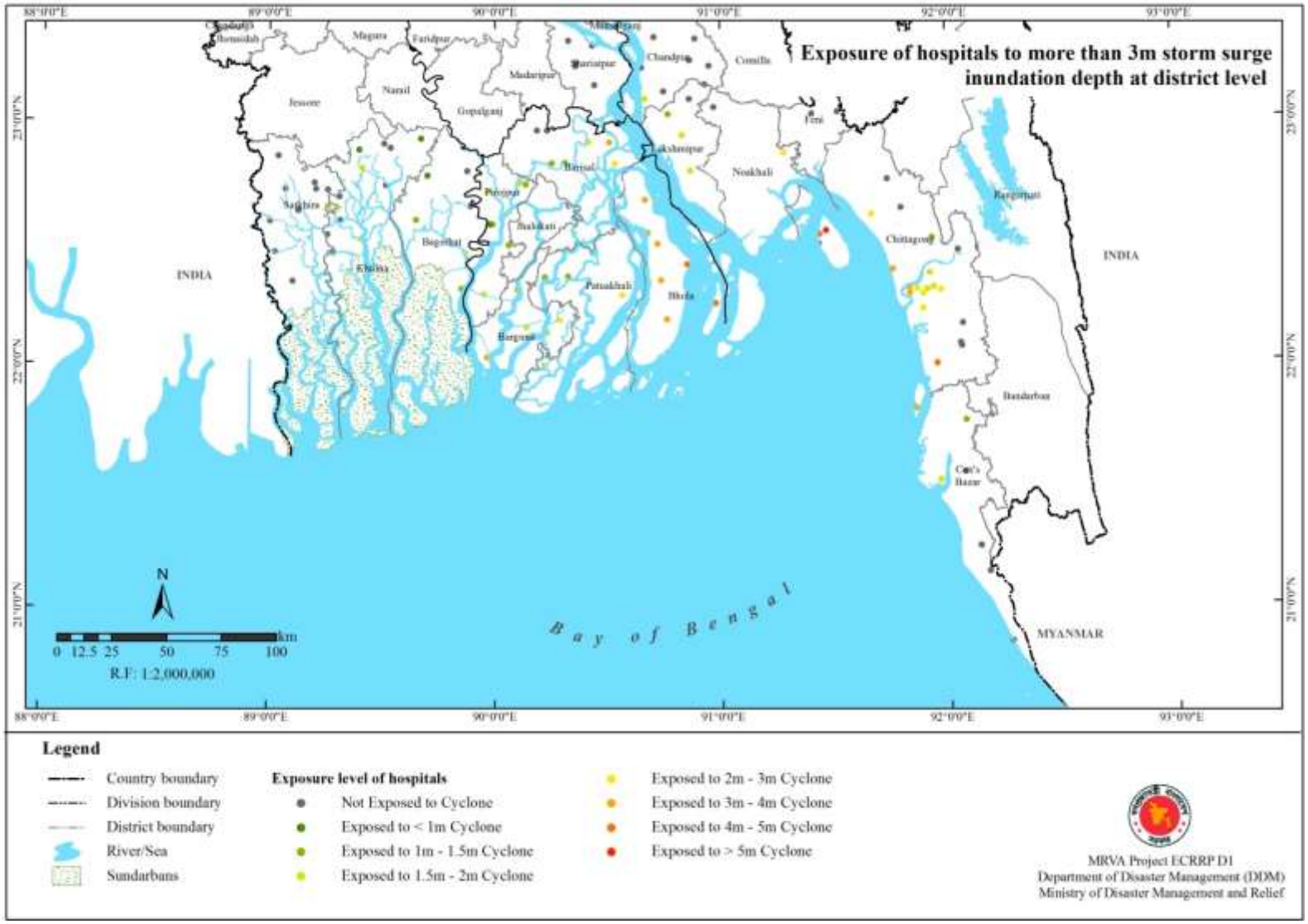


Figure 3.35: Exposure of hospitals to more than 3m storm surge inundation depth at district level

The number of Family Welfare centres existing in different storm surge inundation depth at division level is given in table 3.26 and figure 3.36. Family Welfare centres existing in different storm surge inundation depth at district level is shown in figure 3.37.

Table 3.26: Number of Family Welfare centres exposed to storm surge at division level

Division	Inundation Depth (m) / number of family welfare centers							Not Affected
	< 1.0	1.0 - 1.5	1.5 - 2.0	2.0 - 3.0	3.0 - 4.0	4.0 - 5.0	> 5.0	
Barisal	3	43	74	45	20	9	1	12
Chittagong	3	10	13	22	13	10	9	272
Dhaka	9	22	-	2	-	-	-	772
Khulna	11	10	6	2	-	-	-	313
Total	26	85	93	71	33	19	10	1,369

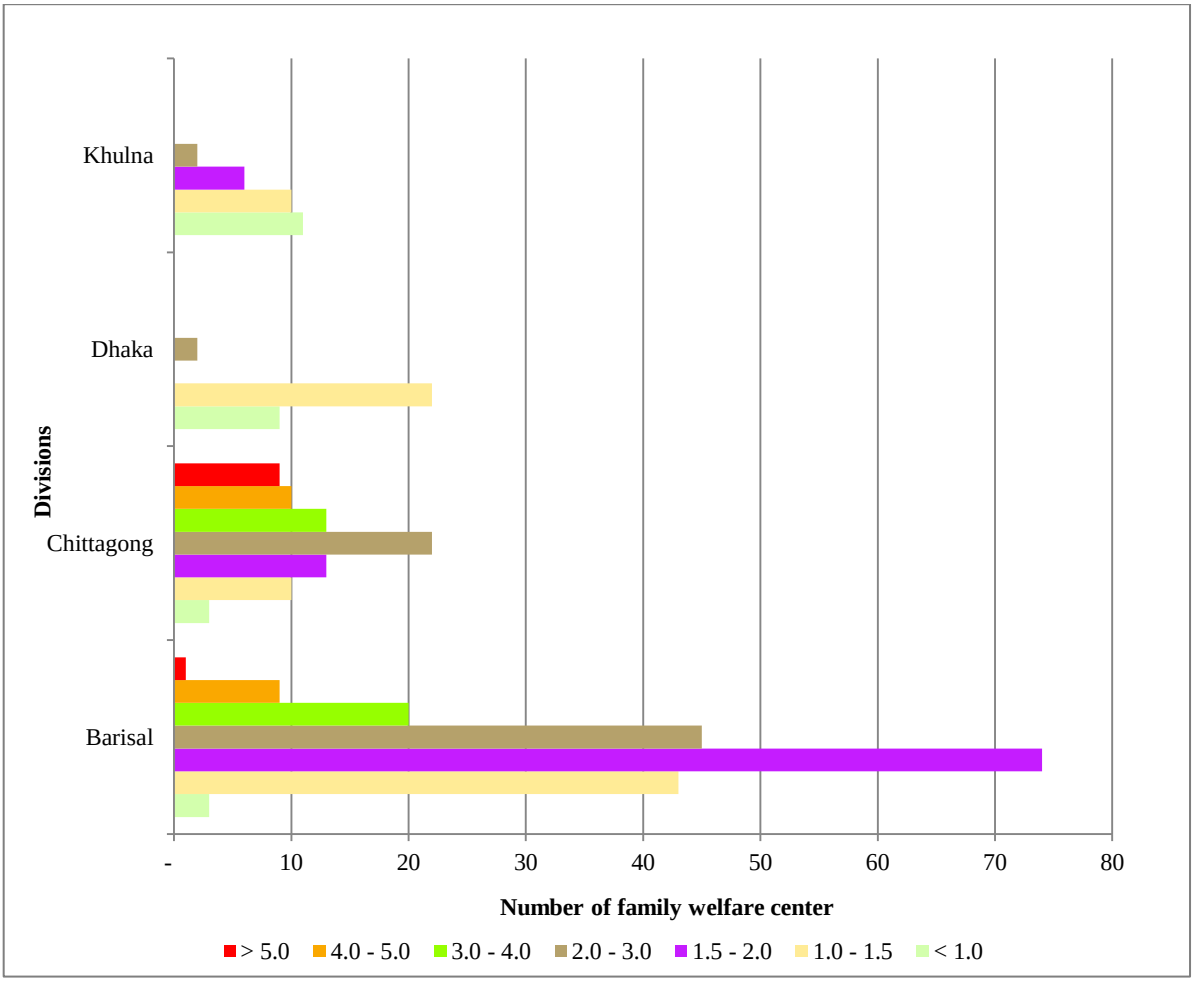


Figure 3.36 : Number of Family Welfare centres exposed to different storm surge inundation depth at division level

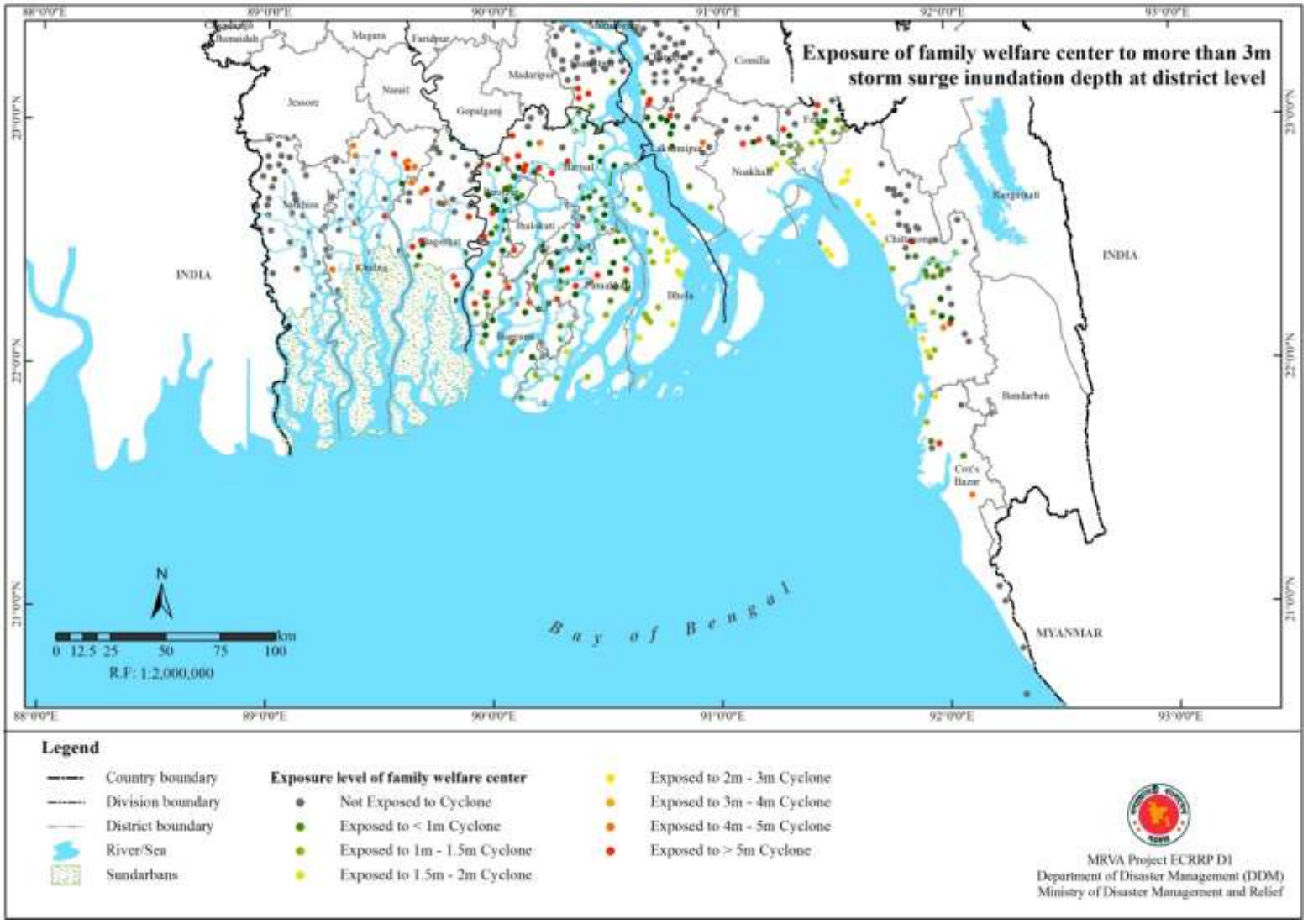


Figure 3.37: Exposure of family welfare center to more than 3m storm surge inundation depth at district level

3.1.4.2 Educational Institutions

Educational institutions database consists of categories of educational institutions as University, College, High School, Madrasa, Primary Schools. Combining storm surge hazard map and Educational institutions map will provide existing Educational institutions in storm surge prone areas.

The number of High Schools existing in different storm surge prone areas at division level is given in table 3.27 and figure 3.38. High Schools existing in different storm surge inundation depth at district level is shown in figure 3.39.

Table 3.27: Number of High Schools exposed to storm surge at division level

Division	Inundation Depth (m) / number of High schools							Not Affected
	< 1.0	1.0 - 1.5	1.5 - 2.0	2.0 - 3.0	3.0 - 4.0	4.0 - 5.0	> 5.0	
Barisal	19	179	301	191	59	27	9	50
Chittagong	3	30	48	116	47	28	50	924
Dhaka	13	19	5	1				1967
Khulna	37	55	25	10	1			920
Total	72	283	379	318	107	55	59	3861

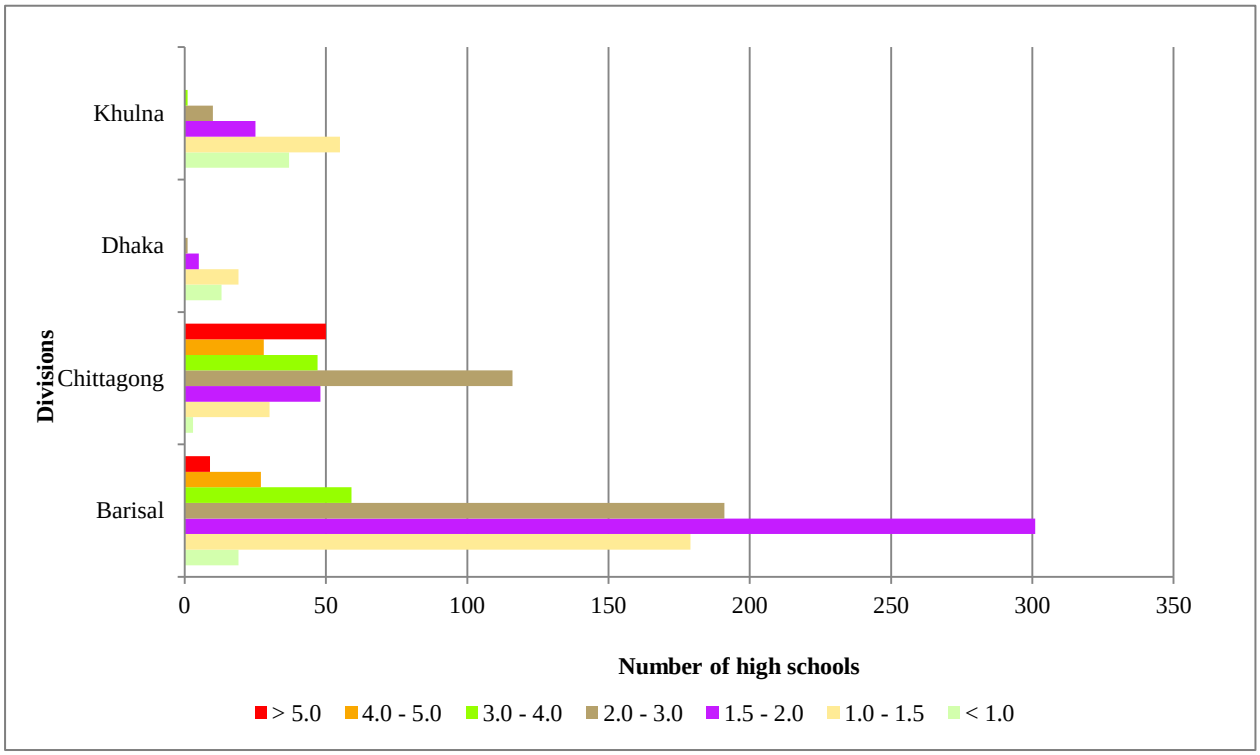


Figure 3.38: Number of High Schools exposed to different Storm surge inundation depth at division level

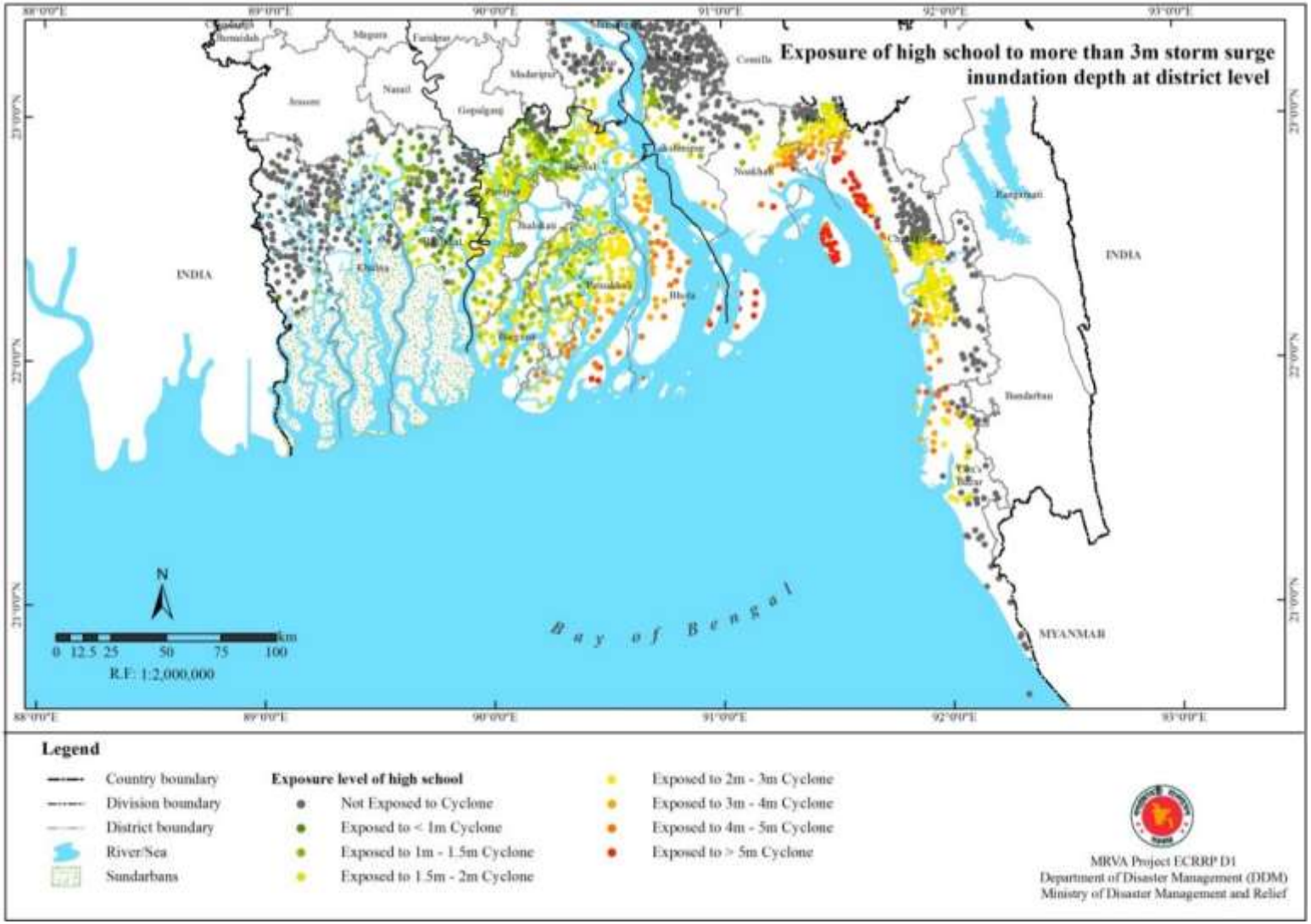


Figure 3.39: Exposure of High Schools to more than 3m storm surge inundation depth at district level

The number of Madrasa existing in different storm surge prone areas at division level is given in table 3.28 and figure 3.40. Madrasa existing in different storm surge inundation depth at district level is shown in figure 3.41.

Table 3.28: Number of Madrasa exposed to storm surge at division level

Division	Inundation Depth (m) / number of Madrasa							Not Affected
	< 1.0	1.0 - 1.5	1.5 - 2.0	2.0 - 3.0	3.0 - 4.0	4.0 - 5.0	> 5.0	
Barisal	5	60	109	73	26	18	5	19
Chittagong	3	17	14	27	24	16	25	549
Dhaka	3	7	3	4				1190
Khulna	12	23	19	12		1		440
Total	23	107	145	116	50	35	30	2198

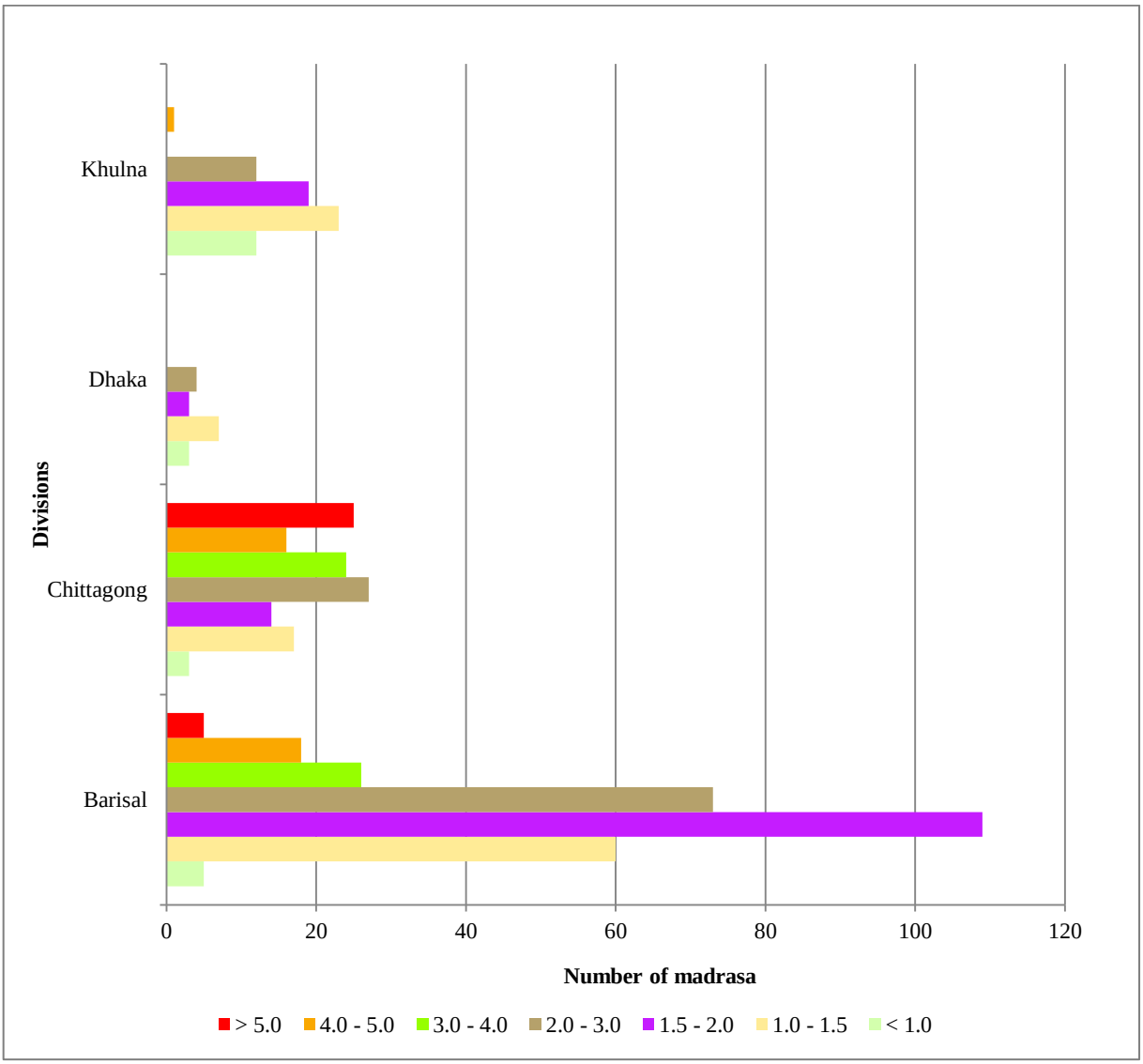


Figure 3.40: Number of Madrasa exposed to different storm surge inundation depth at division level

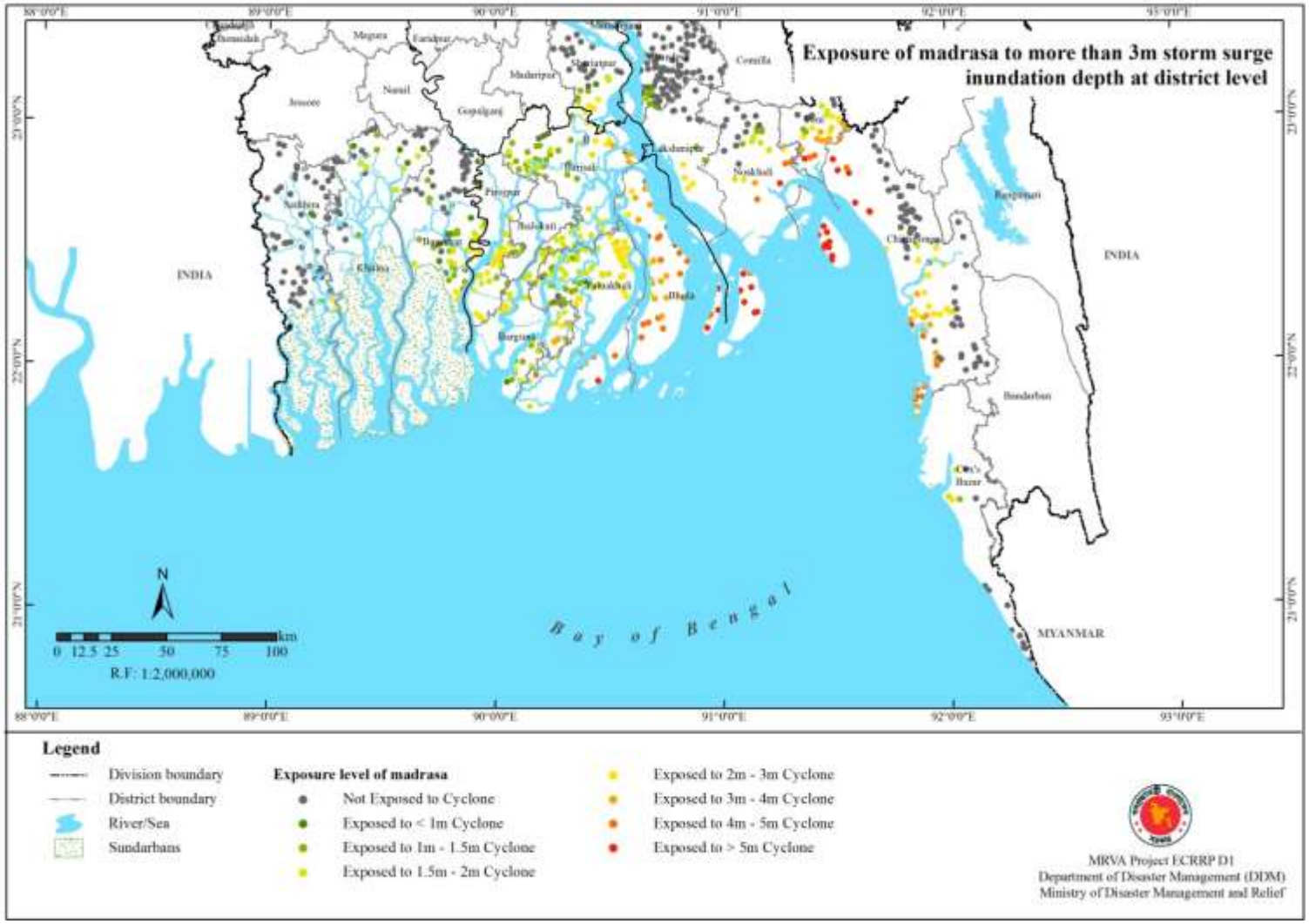


Figure 3.41: Exposure of Madrasa to more than 3m storm surge inundation depth at district level

The number of Primary Schools existing in different storm surge prone areas at division level is given in table 3.29 and figure 3.42. Primary Schools existing in storm surge prone areas at district level is shown in figure 3.43.

Table 3.29: Number of Primary Schools exposed to storm surge at division level

Division	Inundation Depth (m) / number of Primary schools							Not Affected
	< 1.0	1.0 - 1.5	1.5 - 2.0	2.0 - 3.0	3.0 - 4.0	4.0 - 5.0	> 5.0	
Barisal	38	376	755	479	218	149	26	216
Chittagong	25	155	202	379	219	193	234	4914
Dhaka	45	108	39	13	9	1		10039
Khulna	146	188	86	32	2			3737
Total	254	827	1082	903	448	343	260	18906

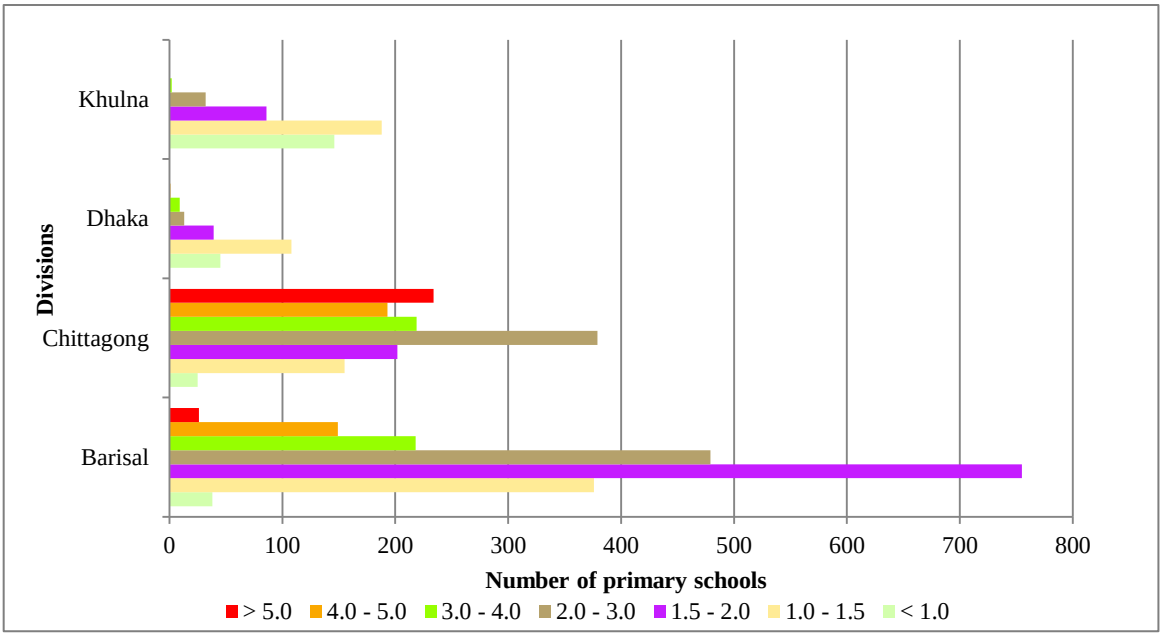


Figure 3.42: Number of Primary Schools exposed to different surge inundation depth at division level

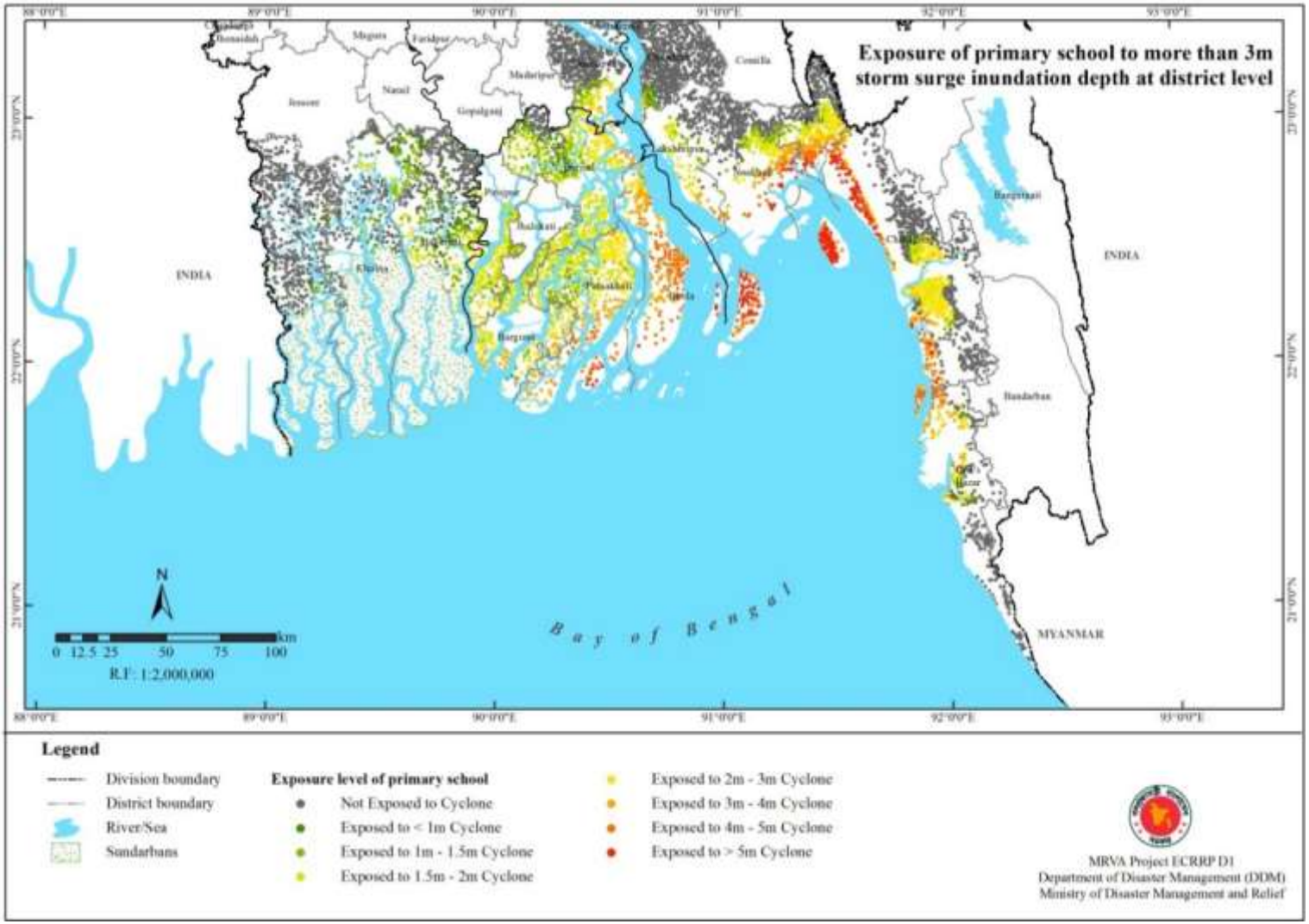


Figure 3.43: Exposure of Primary Schools more than 3m storm surge inundation depth at district level

3.1.4.3 First Responders

Fire stations

The number of Fire stations existing in different storm surge prone areas at division level is given in table 3.30 and figure 3.44. Fire stations existing in different storm surge prone areas at district level is shown in figure 3.45.

Table 3.30: Number of Fire stations exposed to storm surge at division level

Division	Inundation Depth (m) / Fire stations							Not Affected
	< 1.0	1.0 - 1.5	1.5 - 2.0	2.0 - 3.0	3.0 - 4.0	4.0 - 5.0	> 5.0	
Barisal	-	2	2	1	2	1	-	-
Chittagong	-	-	1	1	2	1	-	19
Dhaka	-	-	-	-	-	-	-	35
Khulna	2	3	-	-	-	-	-	11
Total	2	5	3	2	4	2	-	65

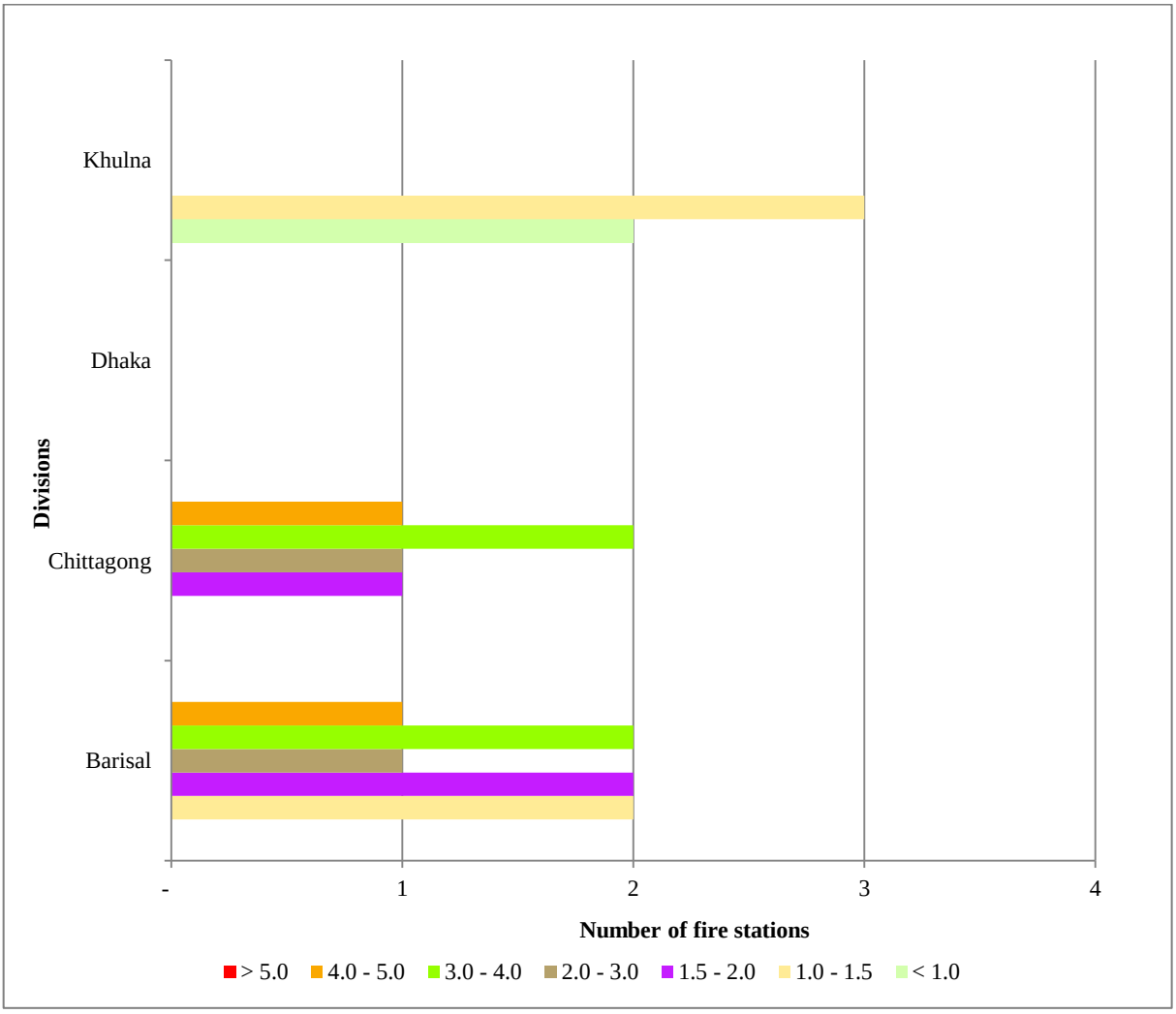


Figure 3.44: Number of Fire stations exposed to different Storm surge inundation depth at division level

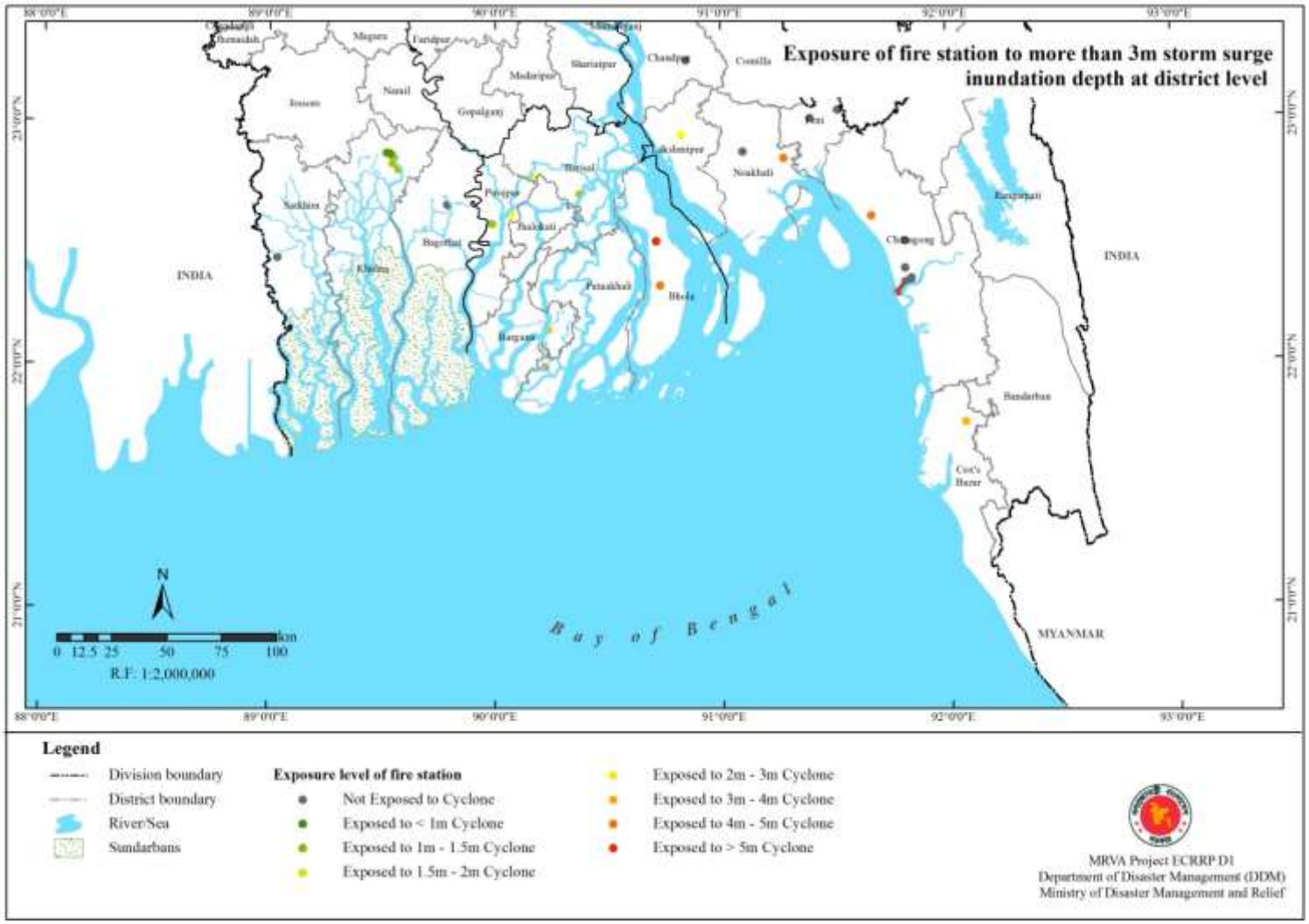


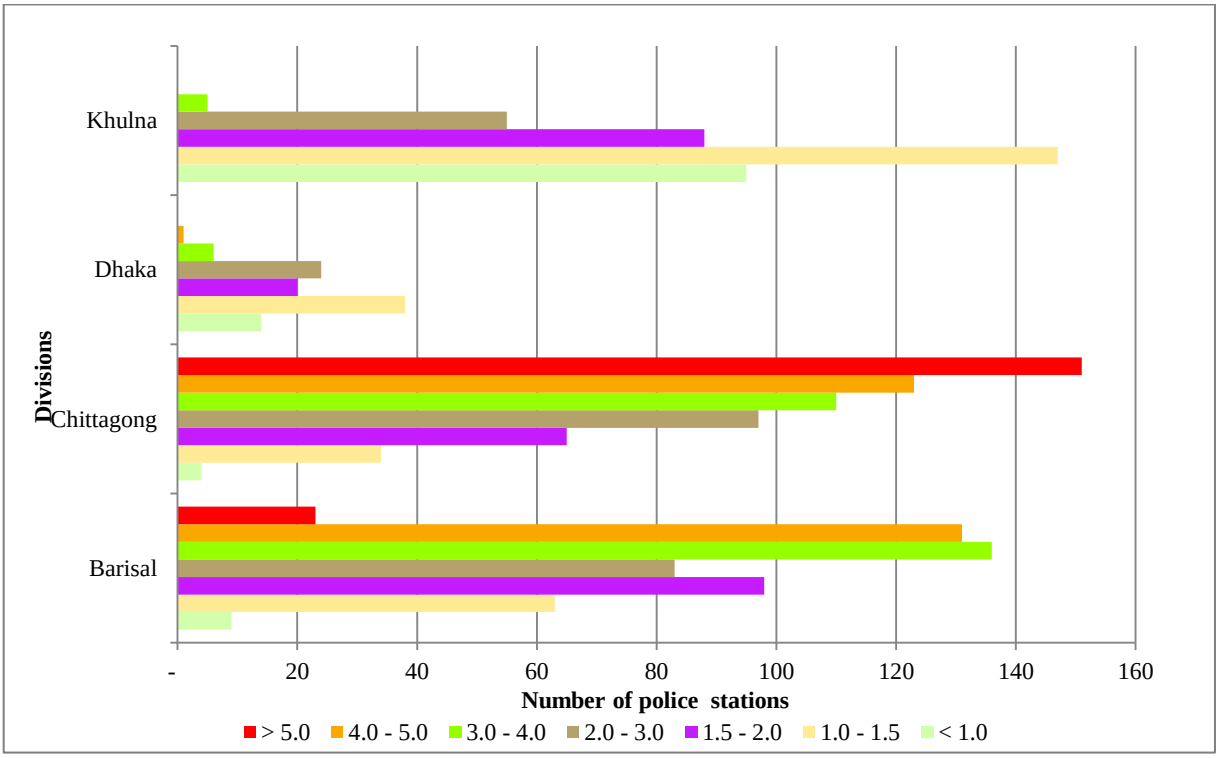
Figure 3.45: Exposure of Fire stations to more than 3m storm surge inundation depth at district level

Police stations

The number of Police stations existing in different storm surge prone areas at division level is given in table 3.31 and figure 3.46. Fire stations existing in different storm surge prone areas at district level is shown in figure 3.47.

Table 3.31: Number of Police stations exposed to storm surge at division level

Division	Inundation Depth (m) / Police stations							Not Affected
	< 1.0	1.0 - 1.5	1.5 - 2.0	2.0 - 3.0	3.0 - 4.0	4.0 - 5.0	> 5.0	
Barisal	9	63	98	83	136	131	23	26
Chittagong	4	34	65	97	110	123	151	2,125
Dhaka	14	38	20	24	6	1	-	3,843
Khulna	95	147	88	55	5	-	-	2,673
Total	122	282	271	259	257	255	174	8,667



Future 3.46: Number of Police stations exposed to different Storm surge inundation depth at division level

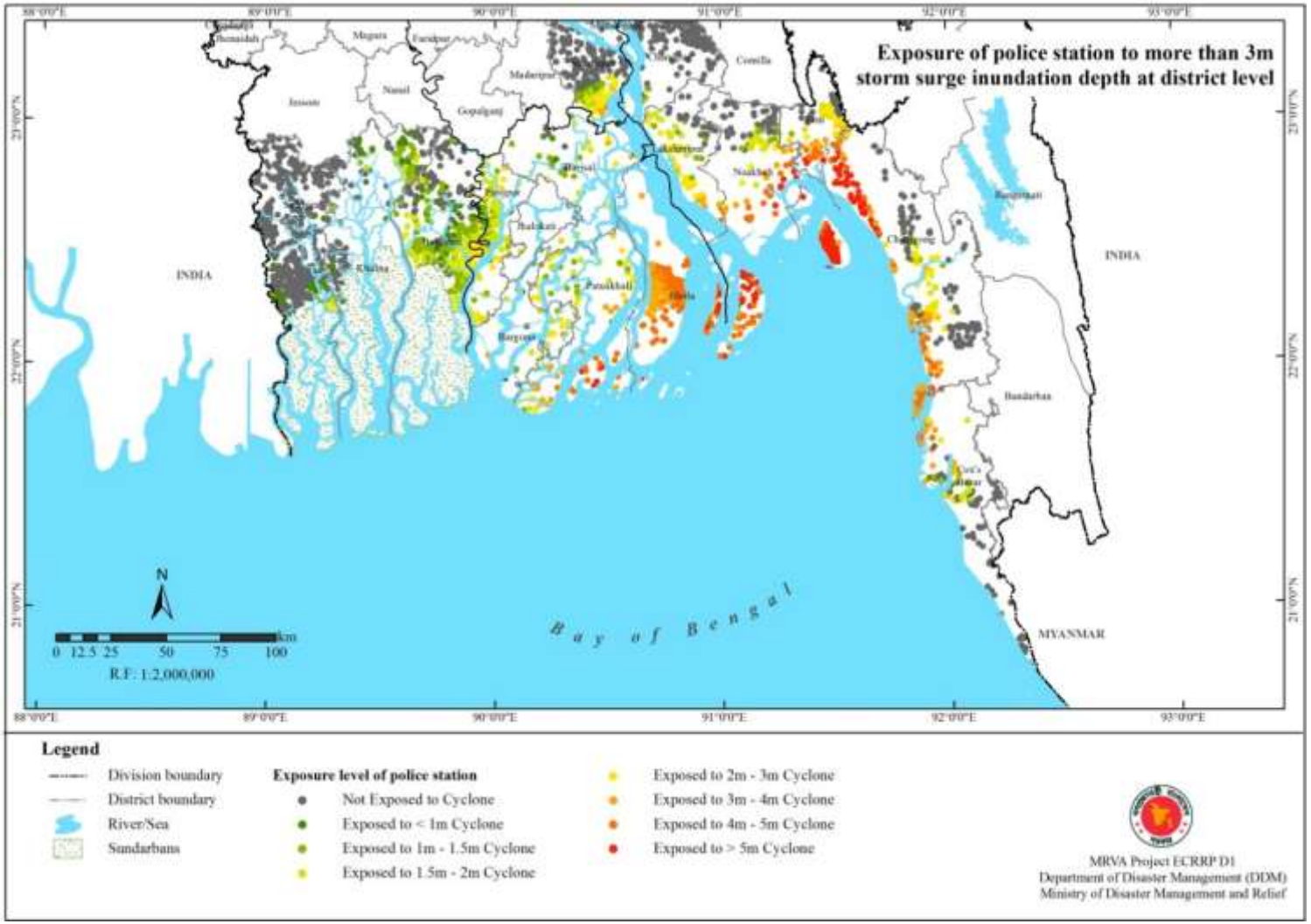


Figure 3.47: Exposure of Police stations to more than 3m storm surge inundation depth at district level

3.1.4.4 Cyclone Shelters

The number of Cyclone Shelters existing in different storm surge prone areas at division level is given in table 3.32 and figure 3.48. Cyclone Shelters existing in different storm surge prone areas at district level is shown in figure 3.49.

Table 3.32: Number of Cyclone Shelters exposed to storm surge at division level

Division Name	Inundation Depth (m) / cyclone shelters							Not Affected
	< 1.0	1.0 - 1.5	1.5 - 2.0	2.0 - 3.0	3.0 - 4.0	4.0 - 5.0	> 5.0	
Barisal	5	121	291	268	318	323	41	59
Chittagong	14	60	74	146	265	253	247	439
Dhaka	1	15	3	4	2			211
Khulna	35	102	67	61	4	2		180
Total	55	298	435	479	589	578	288	889

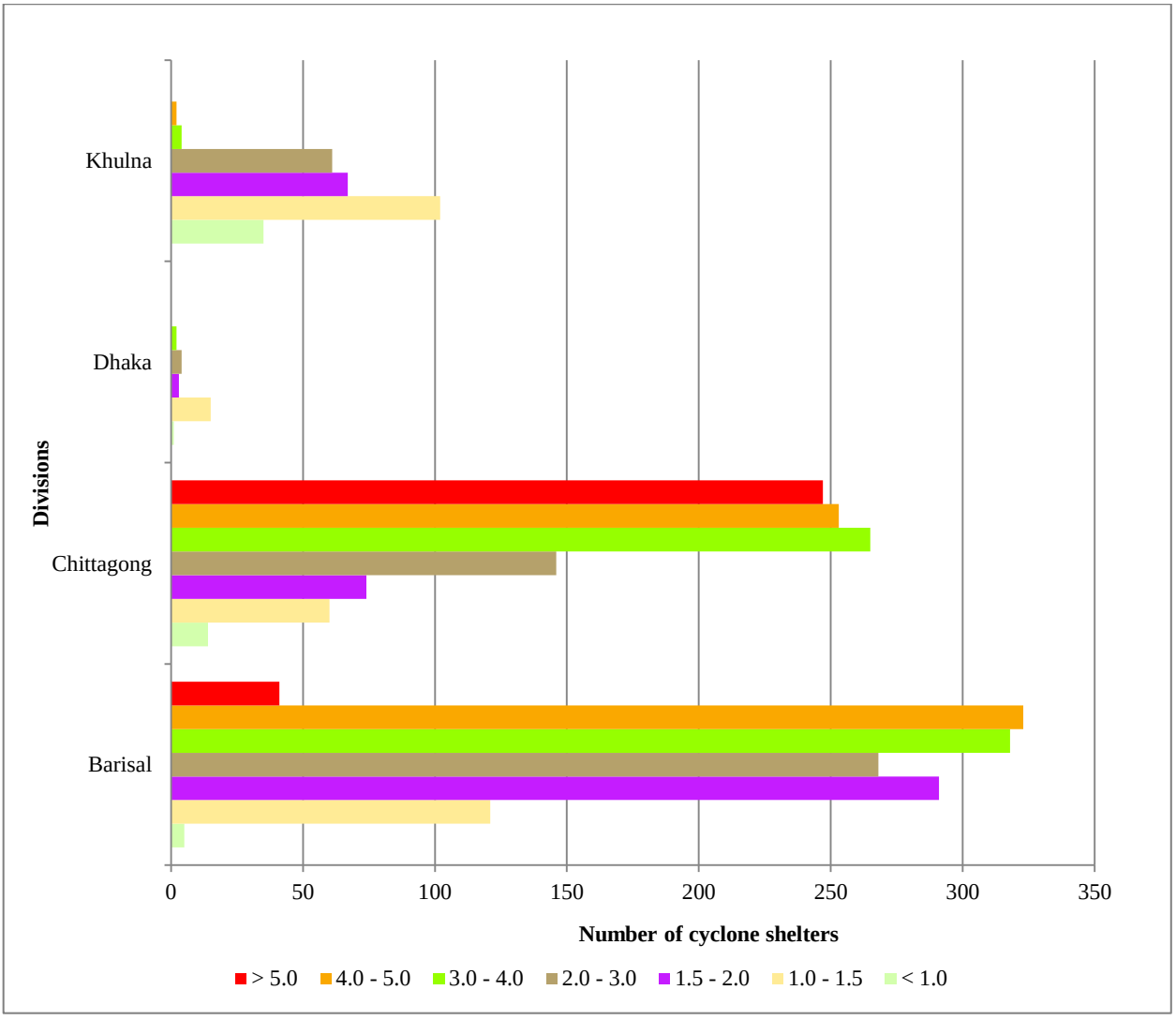


Figure 3.48: Number of Cyclone Shelters exposed to different Storm surge inundation depth at division level

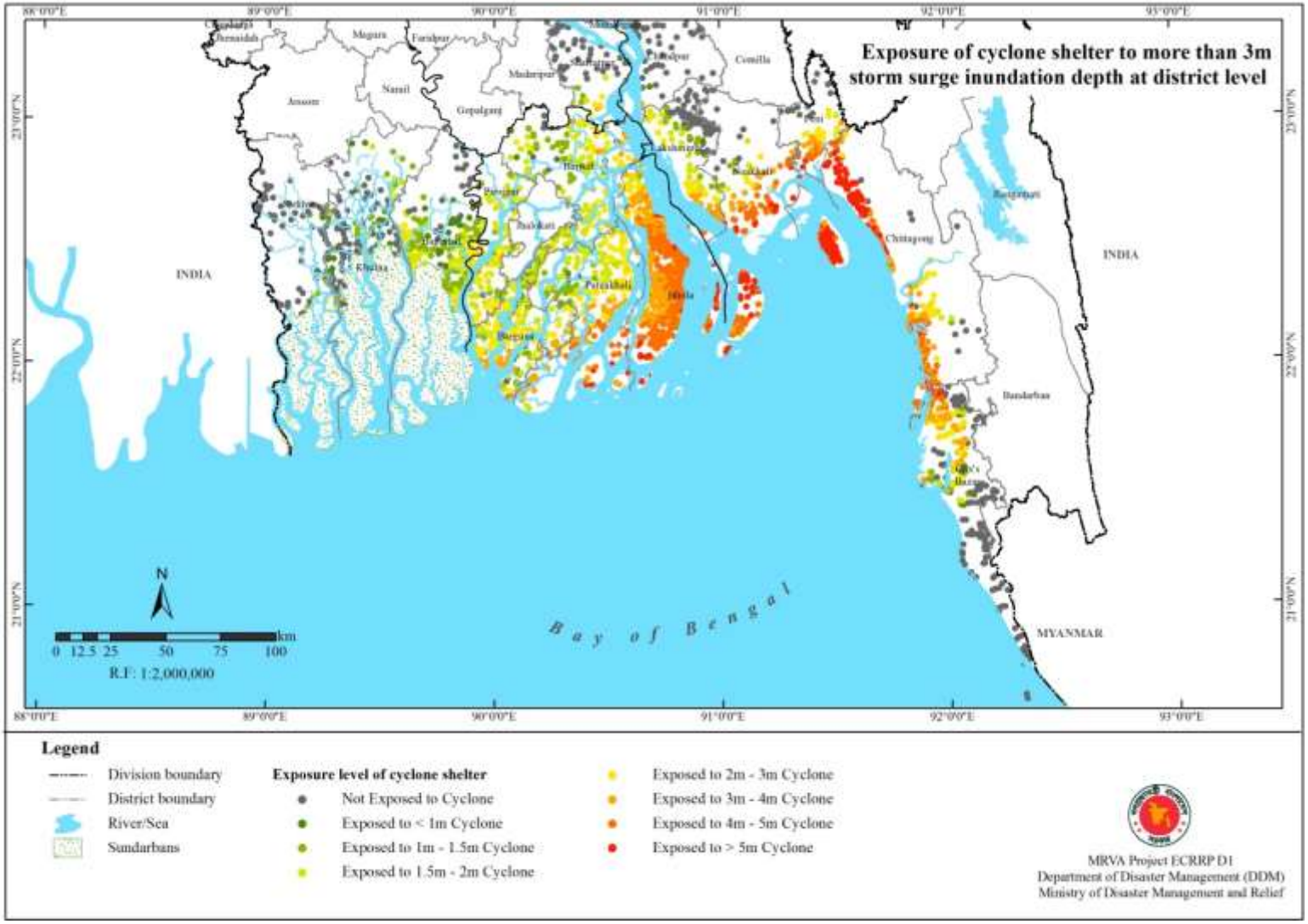


Figure 3.49: Exposure of Cyclone Shelters to more than 3m storm surge inundation depth at district level

Based on the cyclone shelter data and the exposure of cyclone shelters to storm surge, analysis was carried out to assess the population exposed and the capacity of the cyclone shelters. Table 3.33 provide the details of population exposed to storm surge and capacity of existing cyclone shelters at upazila level. Upazila where cyclone shelters are not available for most exposed population are Barisal Sadar, Bakerganj, Mehendiganj upazila in Barisal district, Patiya Chandgaon, Banshkhali upazilas in Chittagong district, Subarnachar, Companiganj upazails in Noakhali district, Lakshmipur Sadar upazaila in Lakshmipur district, Morrelganj upazaila in Bagerhat district.

Table 3.33 : Population exposed and capacity of cyclone shelters in storm surge exposed upazilas

Division	District	Upazila	Exposed Population	Number of Cyclone Shelters	Total Capacity of cyclone shelters	Deficient capacity	Excess Capacity
Barisal	Barguna	Amtali	147683	56	48350	99333	
		Bamna	73875	11	13600	60275	
		Barguna Sadar	164140	37	37515	126625	
		Betagi	112364	43	36450	75914	
		Patharghata	70796	55	56525	14271	
	Barisal	Babuganj	25141	3	2050	23091	
		Bakerganj	299397	7	9150	290247	
		Banari Para	98060	4	4025	94035	
		Barisal Sada	466377	0	0	466377	
		Gaurnadi	141	0	0	141	
		Hizla	132930	9	12600	120330	
		Mehendiganj	214577	14	13725	200852	
		Muladi	117730	5	4400	113330	
		Wazirpur	39557	2	1425	38132	
	Bhola	Bhola Sadar	67375	76	76250		8875
		Burhanuddin	141982	76	70600	71382	
		Char Fasson	260148	164	149350	110798	
		Daulat Khan	37962	73	63775		25813
		Lalmohan	20746	157	135750		115004
		Manpura	63209	60	51450	11759	
		Tazumuddin	102973	65	59850	43123	
	Jhalokati	Jhalokati Sadar	142495	2	1400	141095	
		Kanthalia	116472	3	1350	115122	
		Nalchity	188318	6	4450	183868	
		Rajapur	136637	5	3625	133012	
	Patuakhali	Bauphal	175178	32	27300	147878	
		Dashmina	11201	39	39550		28349
		Dumki	67253	5	3375	63878	
		Galachipa	222089	100	95750	126339	

Division	District	Upazila	Exposed Population	Number of Cyclone Shelters	Total Capacity of cyclone shelters	Deficient capacity	Excess Capacity
		Kala Para	187479	110	98510	88969	
		Mirzaganj	116570	13	11475	105095	
		Patuakhali Sadar	198533	31	26275	172258	
	Pirojpur	Bhandaria	140301	19	16325	123976	
		Kawkhali	66681	3	4050	62631	
		Mathbaria	215588	29	25450	190138	
		Nazirpur	128910	1	750	128160	
		Nesarabad	160725	7	5250	155475	
		Pirojpur Sadar	134292	9	7000	127292	
		Zianagar	73107	0	0	73107	
	Chittagong	Anowara	134326	74	89600	44726	
		Bakalia	81692	5	7500	74192	
		Banshkhali	370759	148	155910	214849	
		Bayejid Bosta	2246	0	0	2246	
		Boalkhali	205208	6	8200	197008	
		Chandanaish	36222	0	0	36222	
		Chandgaon	237185	14	21000	216185	
		Chittagong Port	91882	5	6400	85482	
		Halishahar	40709	1	1500	39209	
		Hathazari	57018	0	0	57018	
		Mirsharai	272601	90	105110	167491	
		Pahartali	41102	3	3825	37277	
		Panchlai	239	0	0	239	
		Patenga	84967	9	10950	74017	
		Patiya	267327	3	4200	263127	
		Rangunia	13848	0	0	13848	
		Raozan	155728	2	1750	153978	
		Sandwip	242470	183	176730	65740	
		Satkania	20990	0	0	20990	
		Sitakunda	179517	84	104300	75217	
Chittagong	Cox's Bazar	Chakoria	115359	155	182480		67121
		Cox's Bazar Sadar	40285	62	71175		30890
		Kutubdia	125279	112	118660	6619	
		Maheshkhali	111154	77	72825	38329	
		Pekua	141835	0	0	141835	
	Feni	Chhagalnaiya	24	7	5600		5576
		Daganbhuiyan	50037	0	0	50037	
		Feni Sadar	86069	4	6000	80069	
		Sonagazi	246141	53	47950	198191	
	Lakshmipur	Kamalnagar	78179	0	0	78179	
		Lakshmipur Sadar	241642	33	32025	209617	

Division	District	Upazila	Exposed Population	Number of Cyclone Shelters	Total Capacity of cyclone shelters	Deficient capacity	Excess Capacity
		Ramgati	34090	127	116575		82485
		Roypur	161633	21	18400	143233	
	Noakhali	Begumganj	31108	0	0	31108	
		Companiganj	249426	40	38860	210566	
		Hatiya	290217	130	152459	137758	
		Kabirhat	189466	0	0	189466	
		Noakhali Sadar	80805	124	113218		32413
		Senbagh	23086	0	0	23086	
		Subarnachar	224387	0	0	224387	
Dhaka	Shariatpur	Bhedarganj	31086	1	825	30261	
		Damudya	32277	0	0	32277	
		Gosairhat	121458	6	6950	114508	
Khulna	Bagerhat	Bagerhat Sadar	2949	1	500	2449	
		Chitalmari	614	1	825		211
		Kachua	8083	1	825	7258	
		Mollahat	1303	0	0	1303	
		Mongla	4587	52	46234		41647
		Morrelganj	221824	28	23000	198824	
		Rampal	130	12	8525		8395
	Khulna	Sarankhola	58143	46	39050	19093	
		Dacope	74	21	19377		19303
		Koyra	10597	7	6100	4497	
	Satkhira	Assasuni	4198	2	1120	3078	
		Shyamnagar	8254	13	9675		1421

3.1.5 Infrastructure

3.1.5.1 Road

The type of roads existing in the database are, National Highway, Regional Highway, Municipal road, Upazilla road, Union road and Village roads. Combining storm surge hazard map and road network map will provide existing type of roads in storm surge prone areas.

The length of National Highway existing in different storm surge inundation depth at division level is given in table 3.34 and figure 3.50.

Table 3.34: Length of National Highway exposed to storm surge at division level

Division	Inundation Depth (m) / length of road (Km)							Not Affected
	< 1.0	1.0 - 1.5	1.5 - 2.0	2.0 - 3.0	3.0 - 4.0	4.0 - 5.0	> 5.0	
Barisal	2.56	31.47	36.07	27.58	3.75	39.45	-	18.33
Chittagong	0.23	17.54	21.24	40.98	31.30	26.92	16.82	522.18
Dhaka	0.66	0.17	0.62	0.06	-	-	-	971.27
Khulna	6.14	30.06	33.86	5.13	0.15	-	-	493.18
Total	9.58	79.24	91.80	73.75	35.20	66.36	16.82	2,004.96

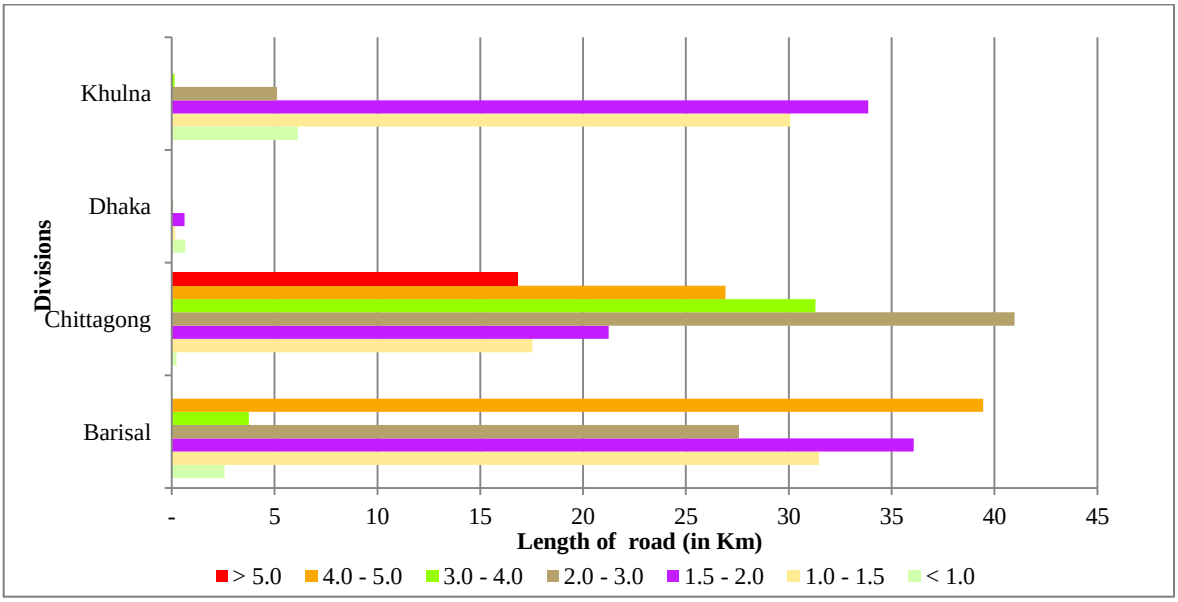


Figure 3.50: Length of National Highway exposed to different Storm surge inundation depth at division level

The length of Regional Highway existing in different storm surge prone areas at division level is given in table 3.35 and figure 3.51.

Table 3.35: Length of Regional Highway exposed to storm surge at division level

Division	Inundation Depth (m) / length of road (Km)							
	< 1.0	1.0 - 1.5	1.5 - 2.0	2.0 - 3.0	3.0 - 4.0	4.0 - 5.0	> 5.0	Not Affected
Barisal	12.19	173.98	288.76	137.05	83.57	67.16	4.47	45.73
Chittagong	10.37	108.97	110.19	195.72	127.21	86.10	77.77	1,964.75
Dhaka	12.32	11.93	7.79	1.17	-	-	-	2,730.82
Khulna	67.30	42.49	23.15	17.68	0.39	-	-	1,106.40
Total	102.18	337.36	429.87	351.61	211.17	153.26	82.24	5,847.70

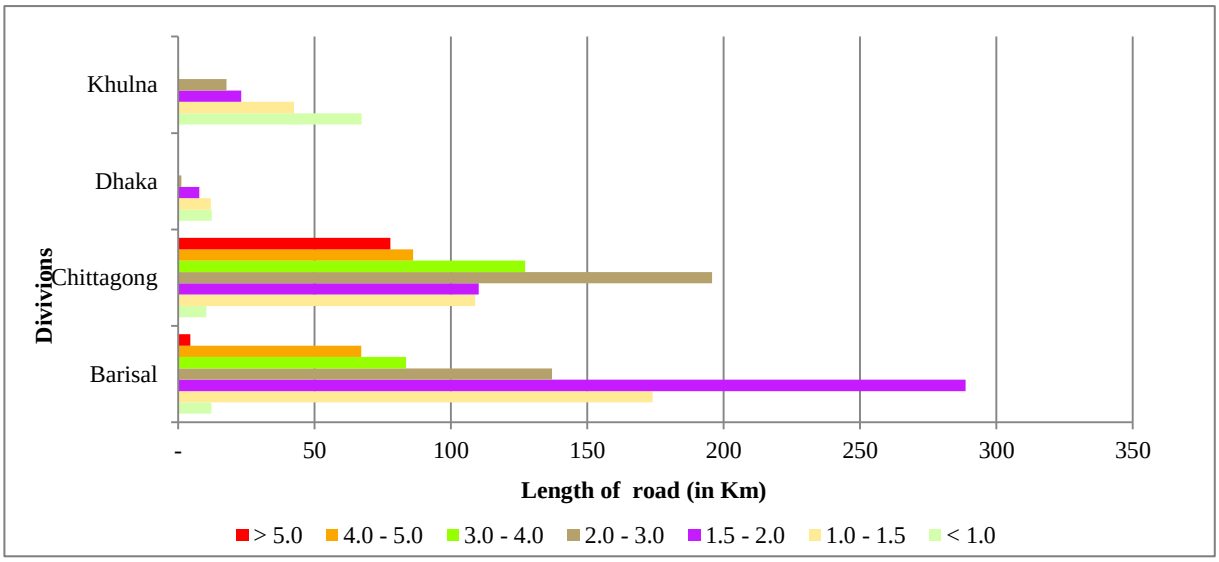


Figure 3.51: Length of Regional Highway exposed to different Storm surge inundation depth at division level

The length of Upazila Road existing in different storm surge prone areas at division level is given in table 3.36 and figure 3.52.

Table 3.36: Length of Upazila Road exposed to storm surge at division level

Division	Inundation Depth (m) / length of road (Km)							
	< 1.0	1.0 - 1.5	1.5 - 2.0	2.0 - 3.0	3.0 - 4.0	4.0 - 5.0	> 5.0	Not Affected
Barisal	51.29	482.07	889.83	650.95	323.41	265.25	24.79	234.19
Chittagong	19.80	150.54	179.35	425.12	218.61	172.99	222.44	3,798.85
Dhaka	49.24	113.70	36.85	35.51	11.51	-	-	8,320.19
Khulna	239.44	285.12	160.14	49.57	5.05	2.07	-	4,790.12
Total	359.77	1,031.43	1,266.16	1,161.14	558.59	440.30	247.23	17,143.36

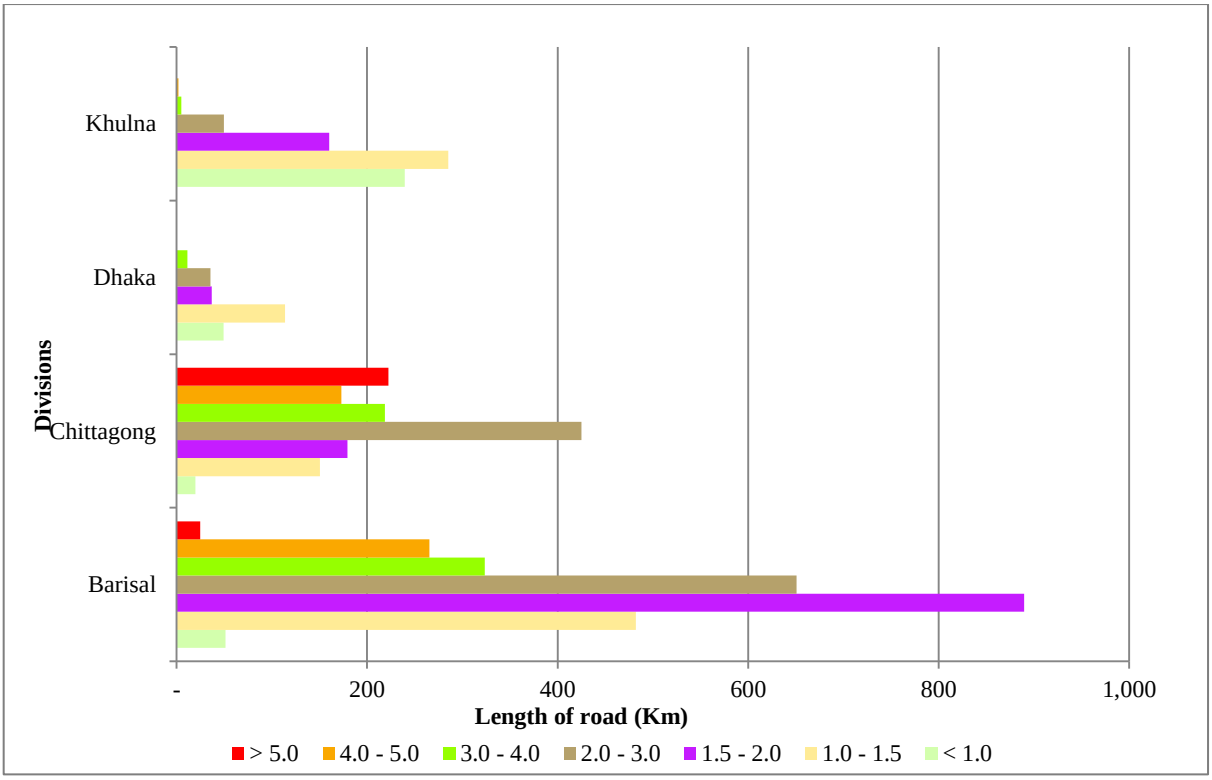


Figure 3.52: Length of Upazila Road exposed to different Storm surge inundation depth at division level

The length of Union Road existing in different storm surge prone areas at division level is given in table 3.37 and figure 3.53.

Table 3.37: Length of Union Road exposed to storm surge at division level

Division	Inundation Depth (m) / length of road (km) / length of road (km)							
	< 1.0	1.0 - 1.5	1.5 - 2.0	2.0 - 3.0	3.0 - 4.0	4.0 - 5.0	> 5.0	Not Affected
Barisal	66.76	617.72	1,212.67	893.66	422.60	289.76	54.14	288.52
Chittagong	22.27	201.46	245.15	357.72	310.01	229.20	259.11	4,887.71
Dhaka	28.32	70.34	30.64	28.61	6.18	0.07	-	9,896.59
Khulna	203.67	199.16	108.31	42.46	2.03	0.22	-	4,026.35
Total	321.03	1,088.69	1,596.78	1,322.45	740.82	519.26	313.25	19,099.17

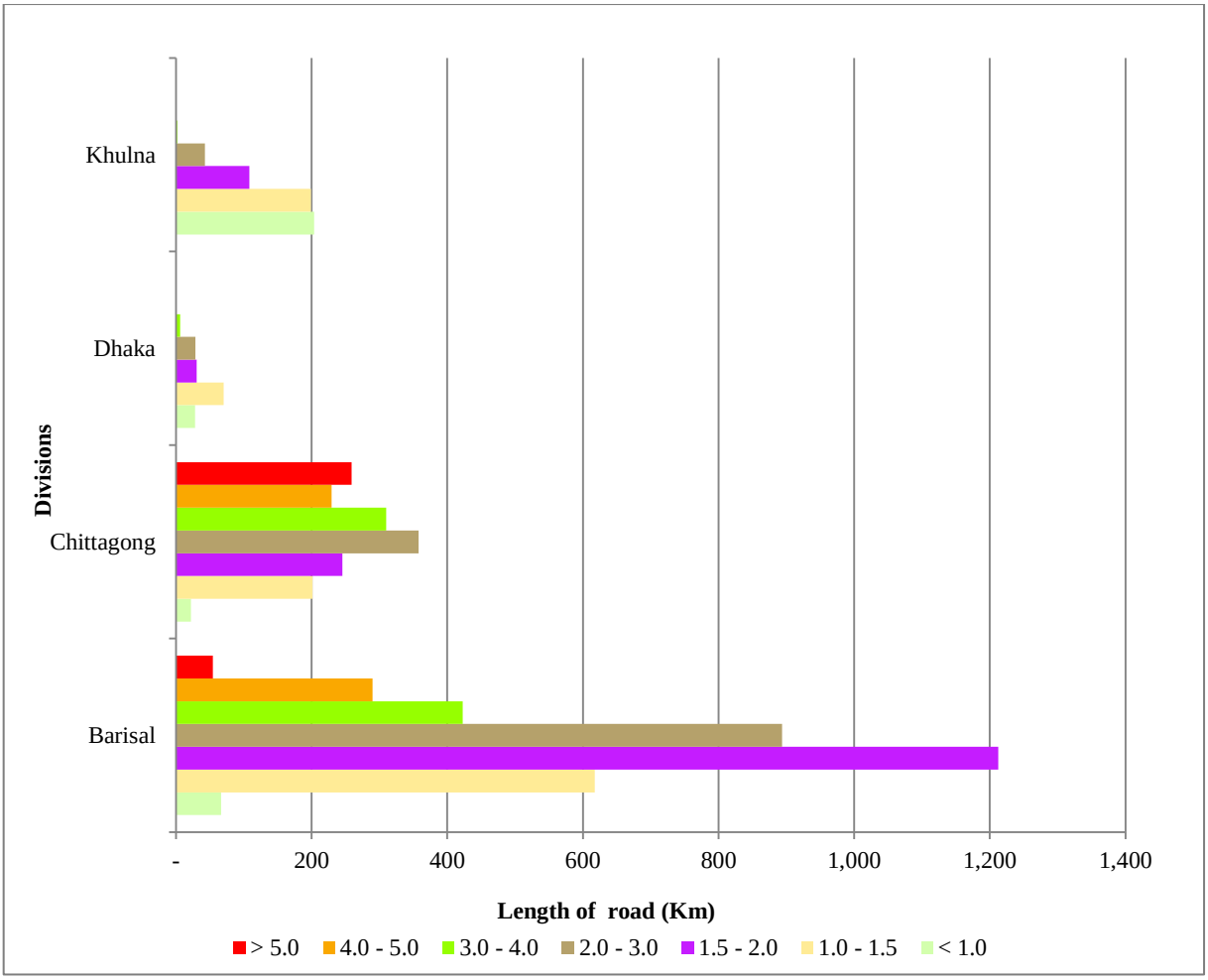


Figure 3.53: Length of Union Road exposed to different Storm surge inundation depth at division level

The length of Village Road exposed to storm surge at division level is given in table 3.38 and figure 3.54.

Table 3.38: Length of Village Road exposed to storm surge at division level

Division	Inundation Depth (m) / length of road (Km)							
	< 1.0	1.0 - 1.5	1.5 - 2.0	2.0 - 3.0	3.0 - 4.0	4.0 - 5.0	> 5.0	Not Affected
Barisal	192.07	2,323.06	4,851.29	3,067.15	1,743.48	1,321.14	204.09	1,003.70
Chittagong	102.35	1,162.08	1,208.31	2,001.21	1,247.66	1,215.62	1,406.75	19,182.91
Dhaka	91.01	240.81	114.74	115.61	46.79	12.01	0.22	32,515.43
Khulna	959.38	1,253.75	744.56	257.99	27.88	2.01	-	17,346.36
Total	1,344.81	4,979.70	6,918.90	5,441.96	3,065.81	2,550.78	1,611.07	70,048.39

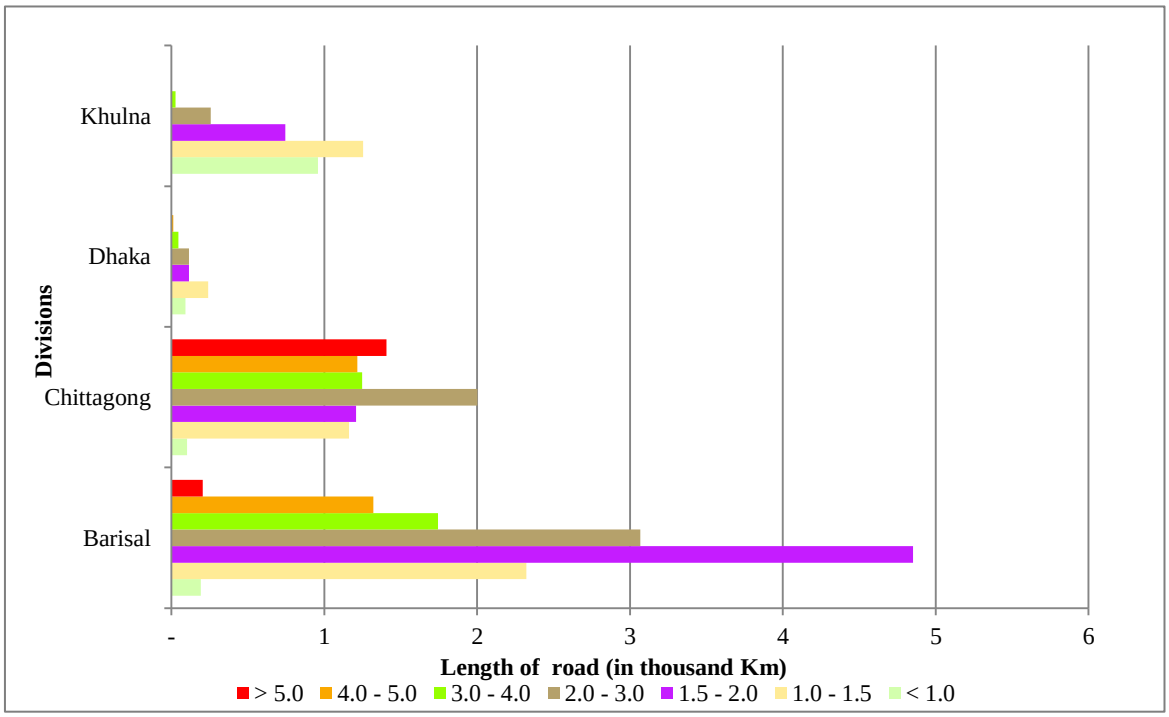


Figure 3.54: Length of Village Road exposed to different Storm surge inundation depth at division level

Exposure of road network to storm surge inundation depth at district level is shown in figure 3.55.

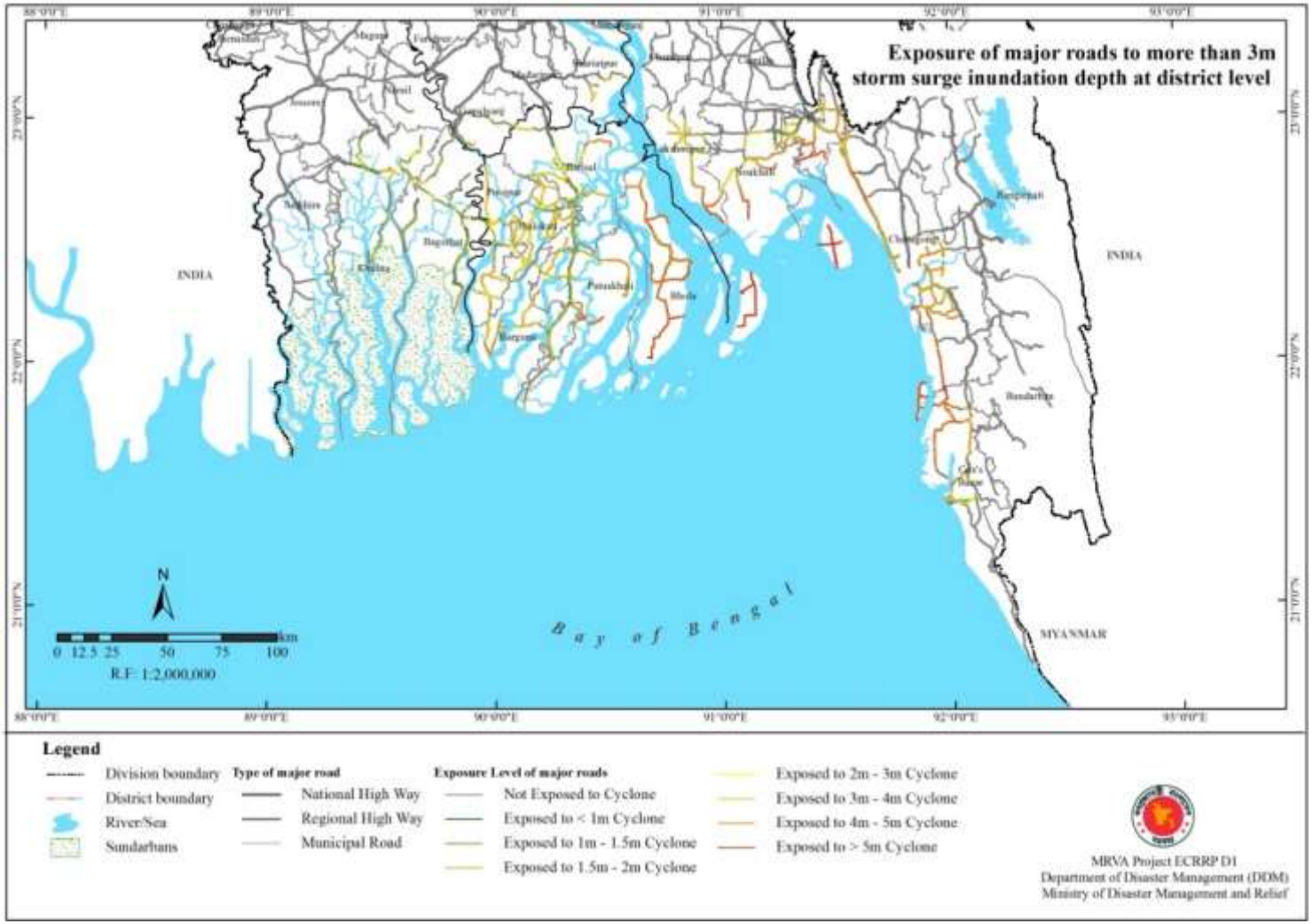


Figure 3.55: Exposure of Road network to more than 3m storm surge inundation depth at district level

3.1.5.2 Bridge

The number of bridges exposed to storm surge at division level is given in table 3.39 and figure 3.56. Exposure of all bridges for storm surge at district level is shown in figure 3.57.

Table 3.39: Number of Bridges exposed to storm surge at division level

Division	Inundation Depth (m) / number of bridges							Not Affected
	< 1.0	1.0 - 1.5	1.5 - 2.0	2.0 - 3.0	3.0 - 4.0	4.0 - 5.0	> 5.0	
Barisal	8	189	454	156	57	4	0	44
Chittagong	24	83	108	270	150	151	288	1320
Dhaka	8	60	0	0	0	0	0	23342
Khulna	15	20	13	3	0	0	0	3229
Total	55	352	575	429	207	155	288	27935

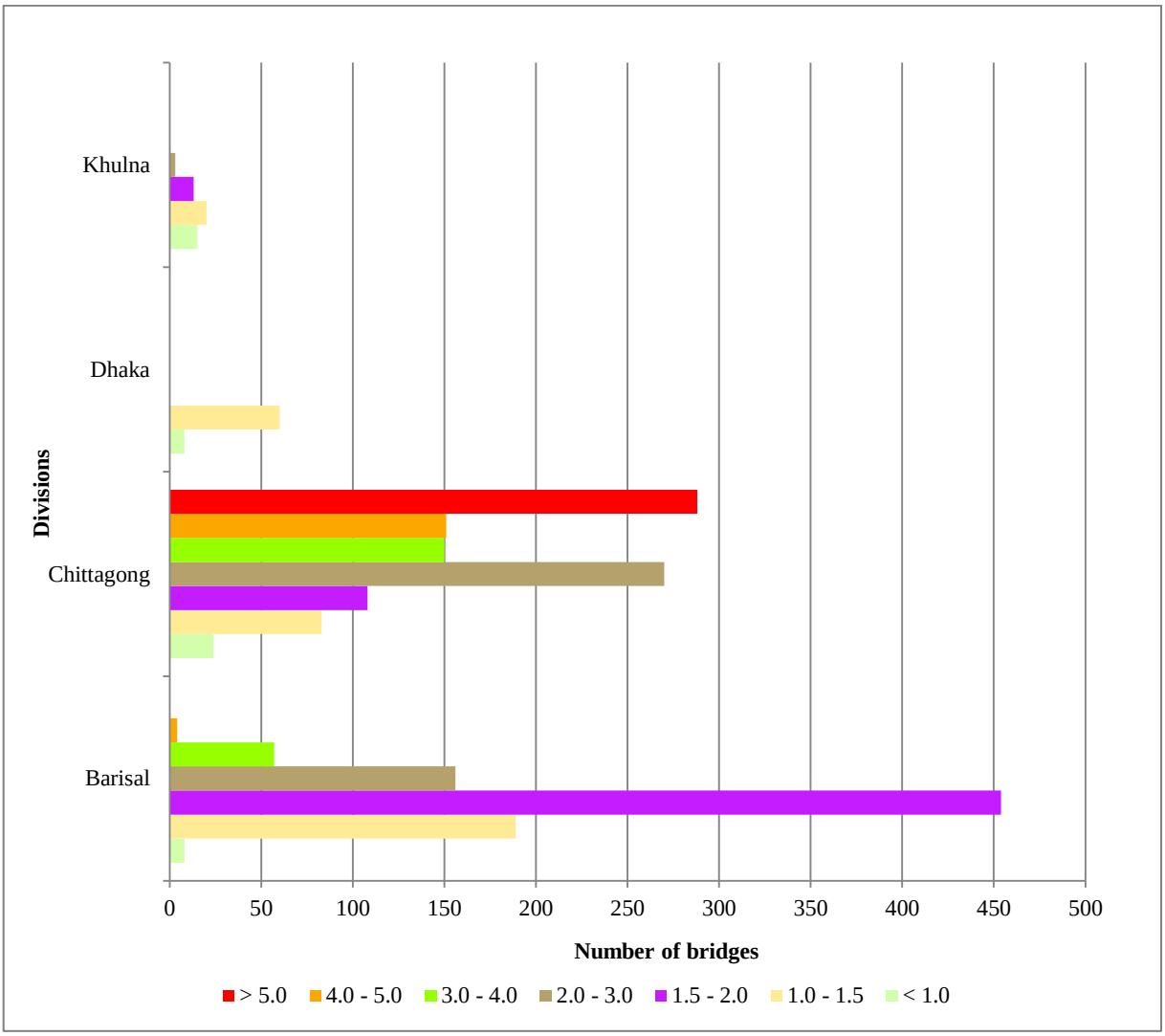


Figure 3.56: Number of Bridges exposed to different storm surge inundation depth at division level

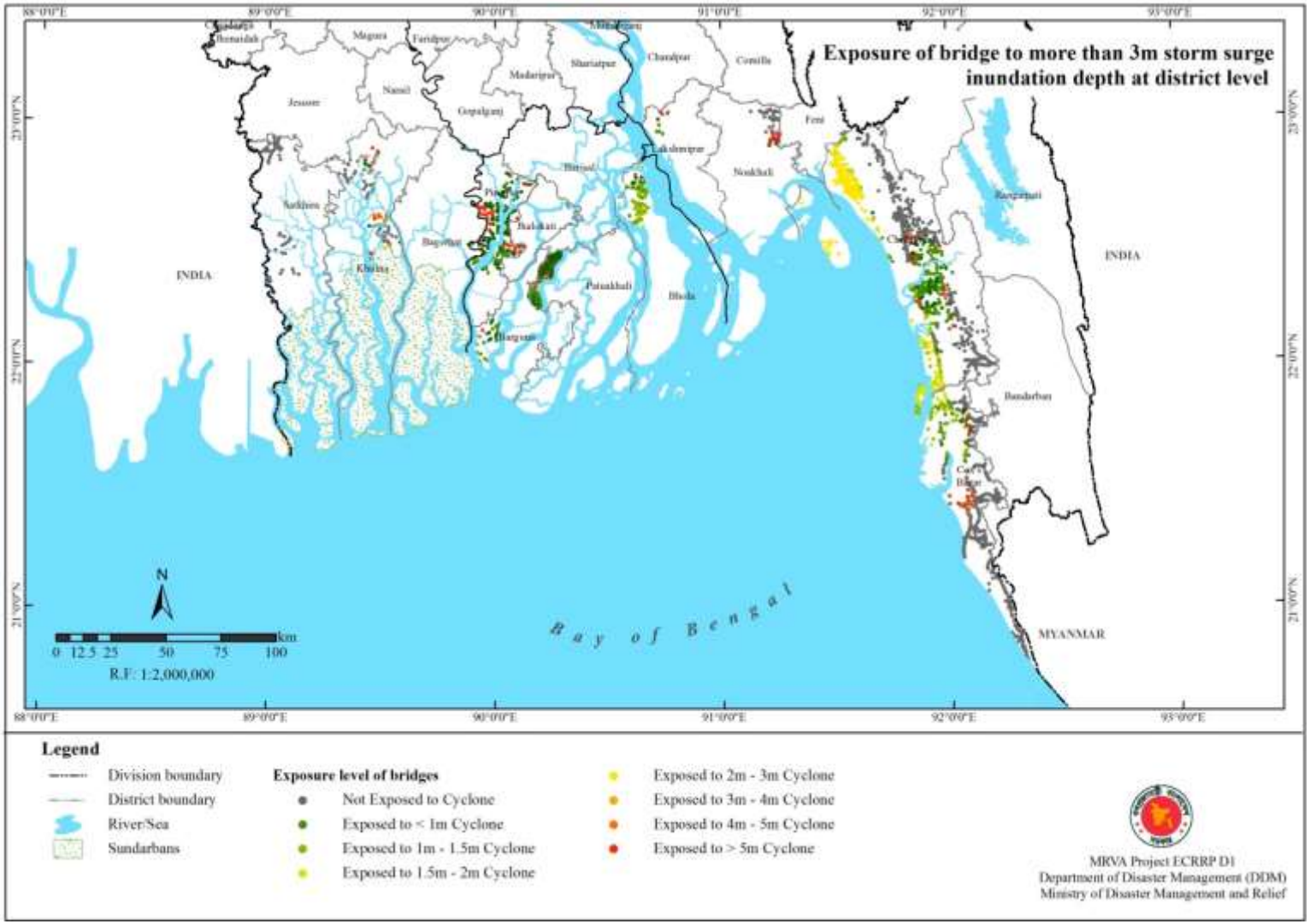


Figure 3.57: Number of Bridges exposed to more than 3m storm surge inundation depth at district level

3.1.5.3 Railway

Combining storm surge hazard map and railway network map will provide the length of railway network (broad gauge and narrow gauge) exposed to storm surge inundation depth. The length of railway network (Broad gauge) existing in storm surge prone areas at division level is given in table 3.40 and figure 3.58.

Table 3.40: Length of Railway (Broad gauge) exposed to Storm surge inundation depth in each Division

Division	Inundation Depth (m) / length of railway (Km)							Not Affected
	< 1.0	1.0 - 1.5	1.5 - 2.0	2.0 - 3.0	3.0 - 4.0	4.0 - 5.0	> 5.0	
Dhaka	-	-	-	-	-	-	-	232.65
Khulna	6.24	16.39	2.01	0.10	-	-	-	263.17
Total	6.24	16.39	2.01	0.10	-	-	-	495.81

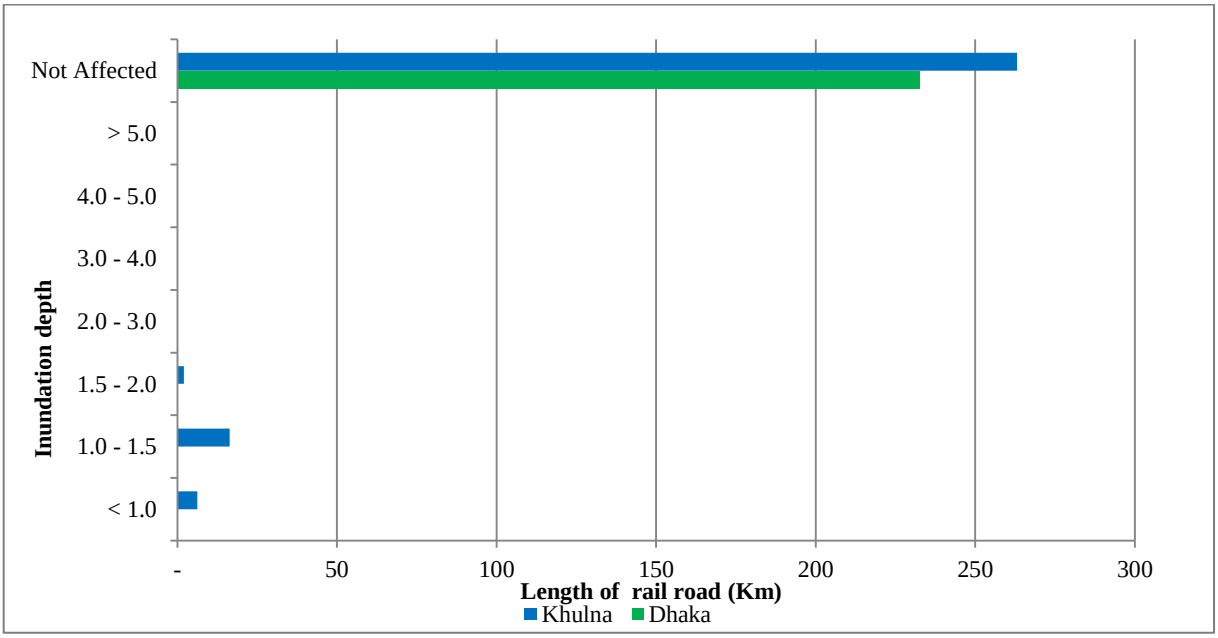


Figure 3.58: Length of Railway (Broad gauge) exposed to different Storm surge inundation depth at division level

The length of railway network (narrow gauge) existing in storm surge prone areas at division level is given in table 3.41 and figure 3.59.

Table 3.41: Length of Railway (narrow gauge) exposed to storm surge at division level

Division	Inundation Depth (m) / length of railway (Km)							Not Affected
	< 1.0	1.0 - 1.5	1.5 - 2.0	2.0 - 3.0	3.0 - 4.0	4.0 - 5.0	> 5.0	
Chittagong	-	12.80	14.33	48.38	14.73	5.66	0.81	361.14
Dhaka	-	-	-	-	-	-	-	551.61
Total	-	12.80	14.33	48.38	14.73	5.66	0.81	912.75

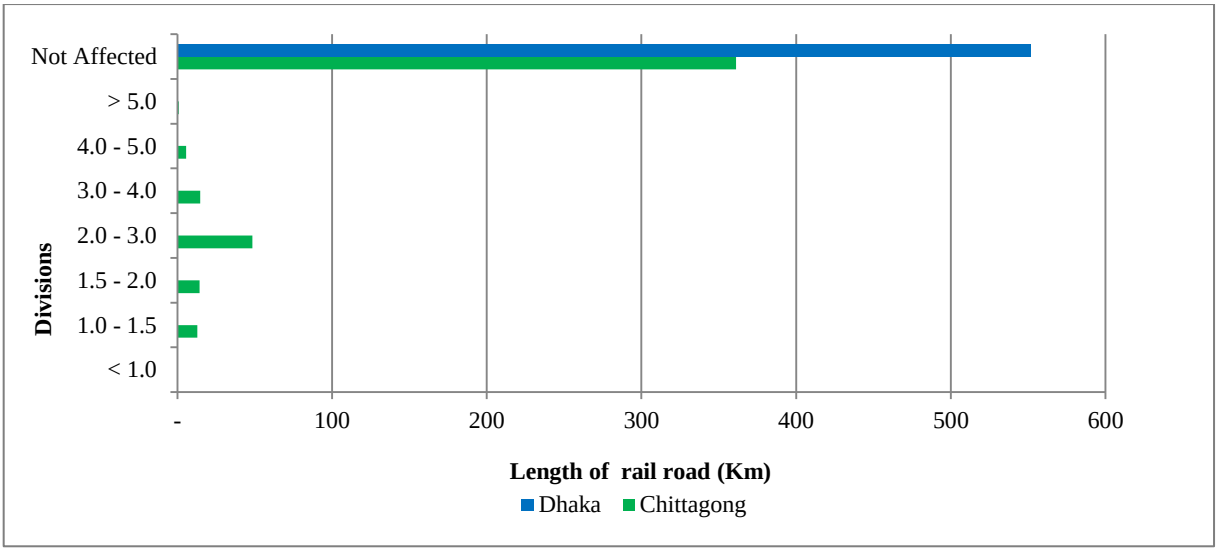


Figure 3.59: Length of Railway (narrow gauge) exposed to different Storm surge inundation depth at division level

Exposure of railway network to storm surge at district level is shown in figure 3.60.

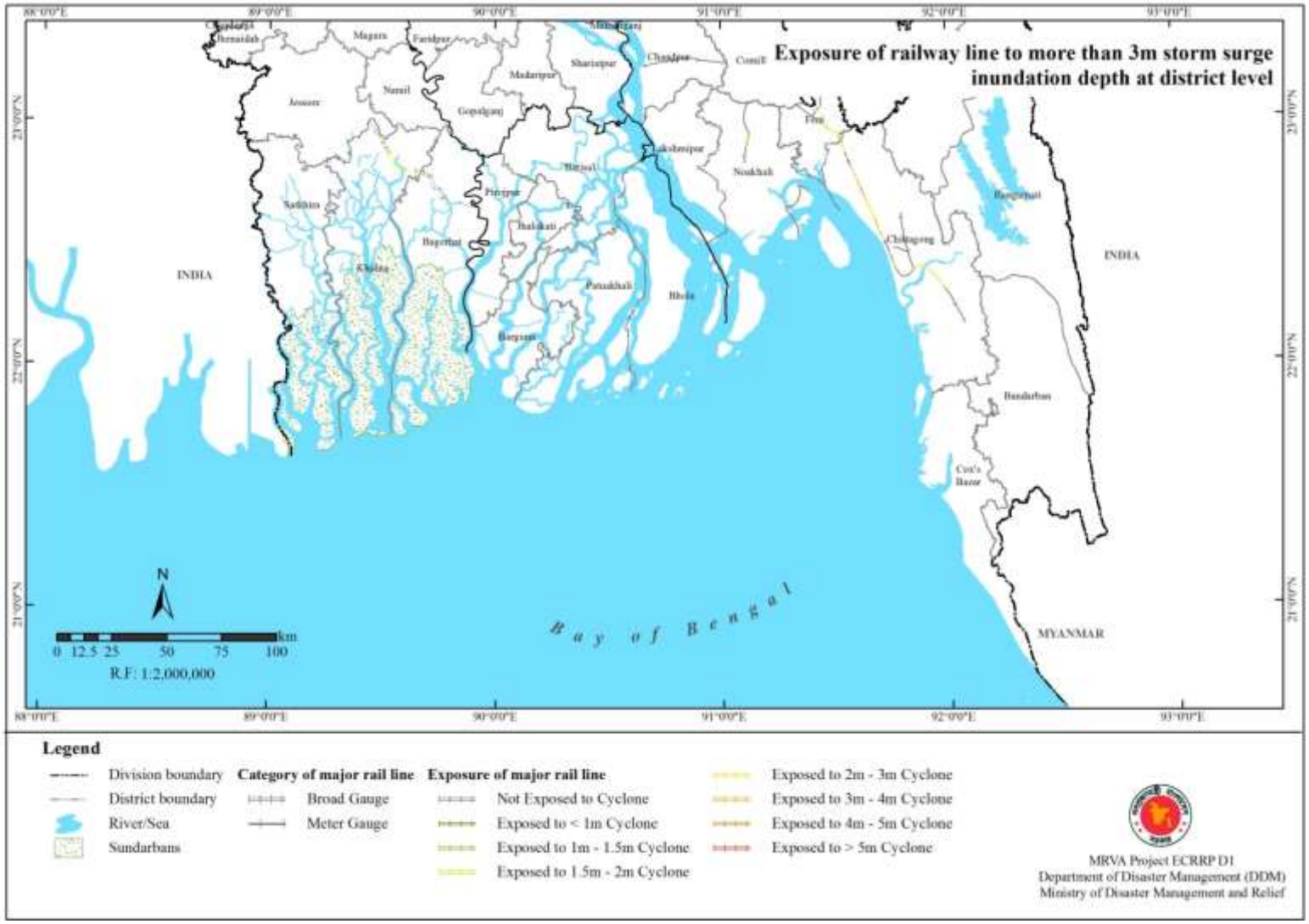


Figure 3.60: Exposure of Railway network to more than 3m storm surge inundation depth at district level

3.1.5.4 Air, Seas and River Ports

Combining storm surge hazard map and Air, Sea and River ports map will provide the number of ports exposed to storm surge inundation depth.

The number of Air ports existing in different storm surge prone areas at division level is given in table 3.42.

Table 3.42: Number of Airports exposed to storm surge at division level

Division	Inundation Depth (m) / number of air ports							Not Affected
	< 1.0	1.0 - 1.5	1.5 - 2.0	2.0 - 3.0	3.0 - 4.0	4.0 - 5.0	> 5.0	
Barisal	-	1	1	-	-	-	-	-
Chittagong	-	-	-	1	-	1	-	1
Dhaka	-	-	-	-	-	-	-	2
Khulna	-	-	-	-	-	-	-	1
Total	-	1	1	1	-	1	-	4

The number of River ports existing in different storm surge prone areas at division level is given in table 3.43.

Table 3.43: Number of River ports exposed to storm surge at division level

Division	Inundation Depth (m) / number of river ports							Not Affected
	< 1.0	1.0 - 1.5	1.5 - 2.0	2.0 - 3.0	3.0 - 4.0	4.0 - 5.0	> 5.0	
Barisal	-	-	1	-	-	-	-	1
Chittagong	-	-	-	-	-	-	-	-
Dhaka	-	-	-	-	-	-	-	1
Khulna	-	-	-	-	-	-	-	-
Total	-	-	1	-	-	-	-	2

The number of Sea ports existing in different storm surge prone areas at division level is given in table 3.44.

Table 3.44: Number of Sea ports exposed to storm surge at division level

Division	Inundation Depth (m) / number of sea ports							Not Affected
	< 1.0	1.0 - 1.5	1.5 - 2.0	2.0 - 3.0	3.0 - 4.0	4.0 - 5.0	> 5.0	
Barisal	-	-	-	-	-	-	-	-
Chittagong	-	-	-	-	-	-	1	-
Dhaka	-	-	-	-	-	-	-	-
Khulna	-	-	-	-	-	-	-	1
Total	-	-	-	-	-	-	1	1

Exposure of Air, Sea and River ports to Storm surge inundation depth in each districts is given in figure 3.61.

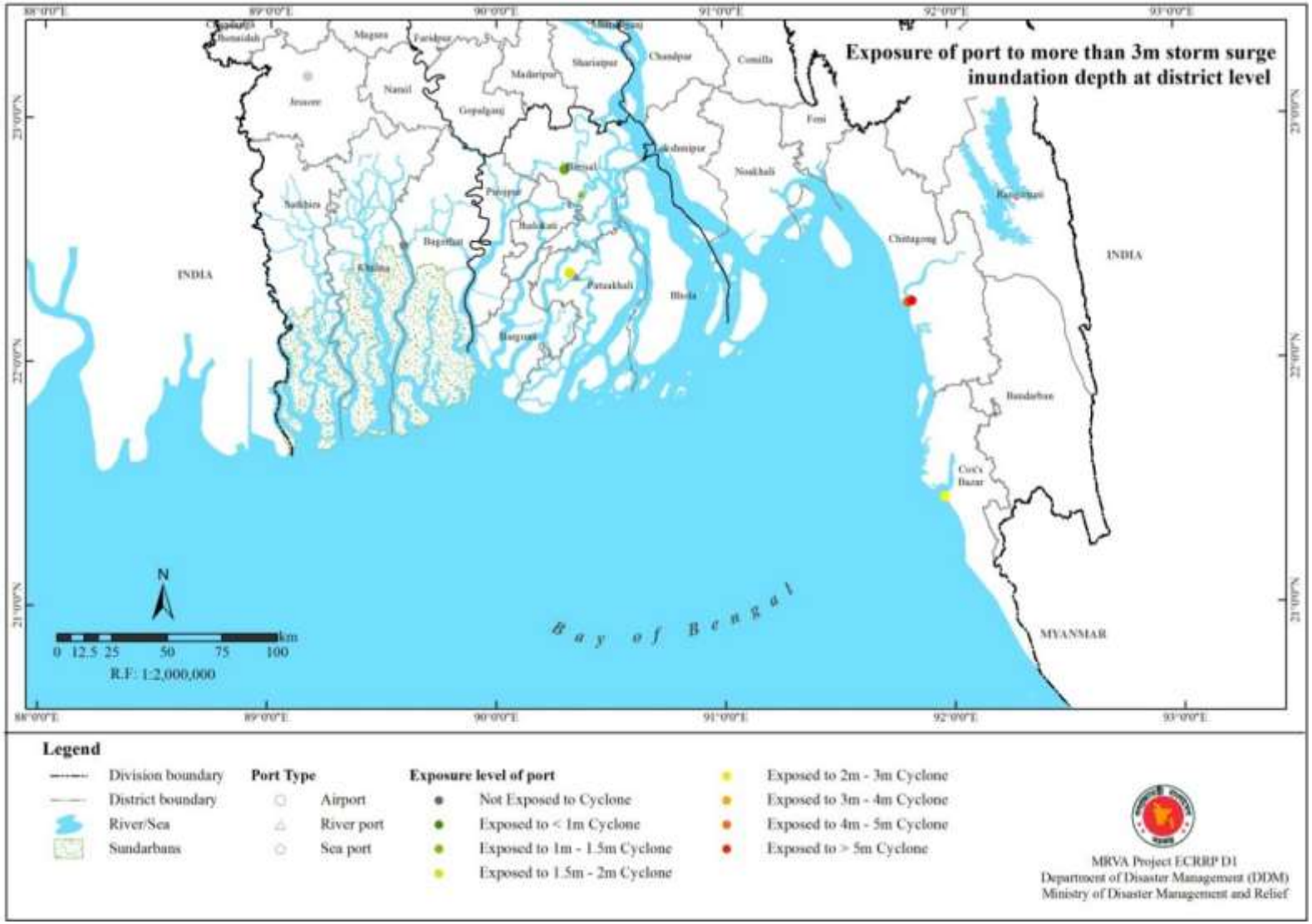


Figure 3.61: Exposure of Air, Sea and River ports to more than 3m storm surge inundation depth at district level

3.1.5.5 Power

Combining storm surge hazard map and Power sector (Power stations, Power sub-stations) will provide the number of power stations, grid sub-stations exposed to storm surge inundation depth.

The number of Power stations existing in different storm surge inundation depth at division level is given in table 3.45.

Table 3.45: Number of Power Stations exposed to storm surge at division level

Division	Inundation Depth (m) / number of power stations							Not Affected
	< 1.0	1.0 - 1.5	1.5 - 2.0	2.0 - 3.0	3.0 - 4.0	4.0 - 5.0	> 5.0	
Barisal	0	1	0	0	0	0	0	0
Chittagong	0	1	0	1	0	0	0	3
Dhaka	0	0	0	0	0	0	0	4
Khulna	0	1	0	0	0	0	0	1
Total	0	3	0	1	0	0	0	8

Exposure of Power stations to storm surge at district level is shown in figure 3.62.

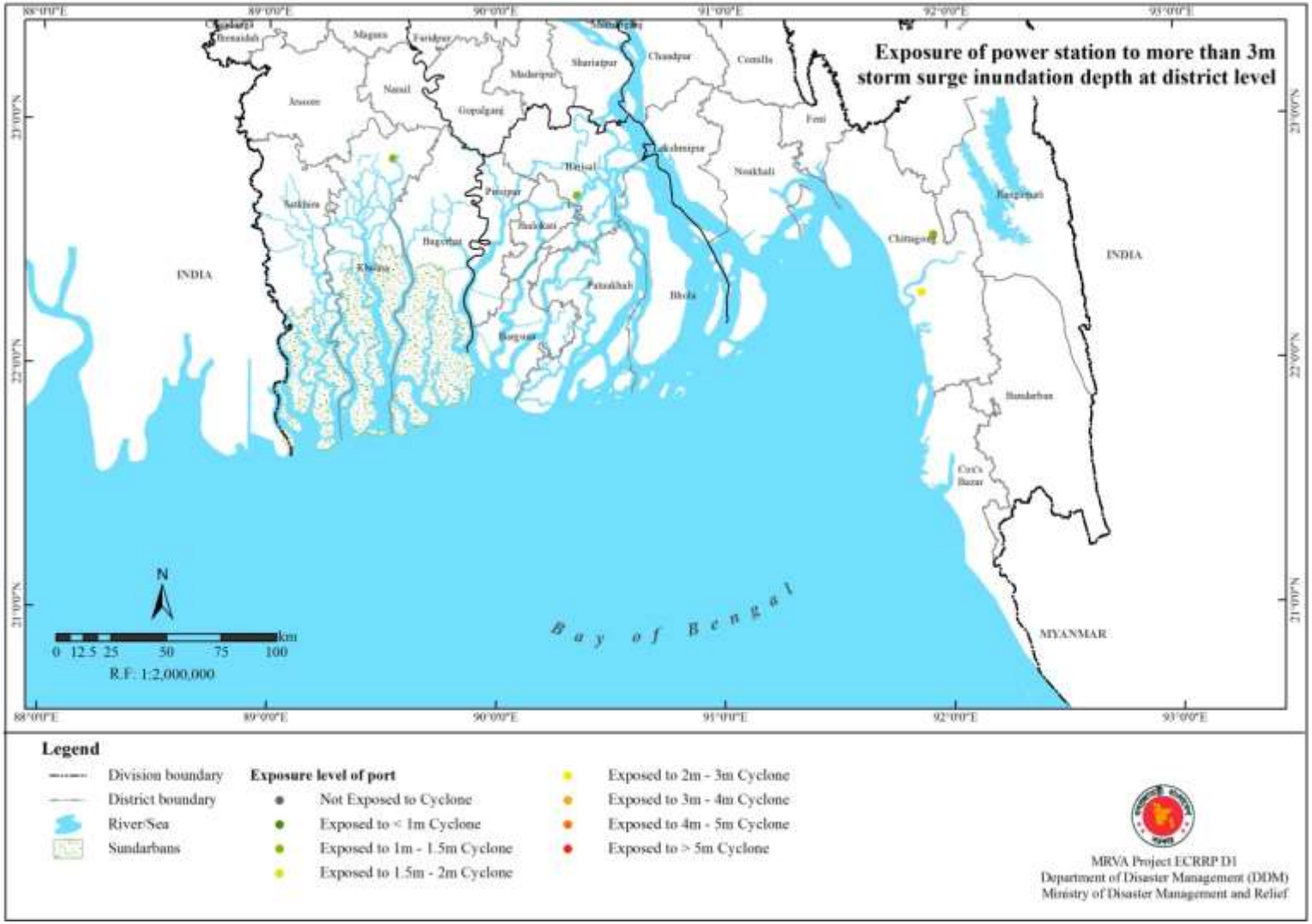


Figure 3.62: Exposure of Power stations to more than 3m storm surge inundation depth at district level

The number of Power Sub-Stations existing in different storm surge hazard levels at division level is given in table 3.46.

Table 3.46: Number of Power Sub-Stations exposed to storm surge at division level

Division	Inundation Depth (m) / number of power sub-stations							Not Affected
	< 1.0	1.0 - 1.5	1.5 - 2.0	2.0 - 3.0	3.0 - 4.0	4.0 - 5.0	> 5.0	
Barisal	1	-	1	-	1	-	-	-
Chittagong	-	-	-	-	3	1	-	9
Dhaka	-	-	-	-	-	-	-	21
Khulna	-	-	1	-	-	-	-	10
Total	1	0	2	0	4	1	0	40

Exposure of Power Sub-Stations to storm surge at district level is shown in figure 3.63.

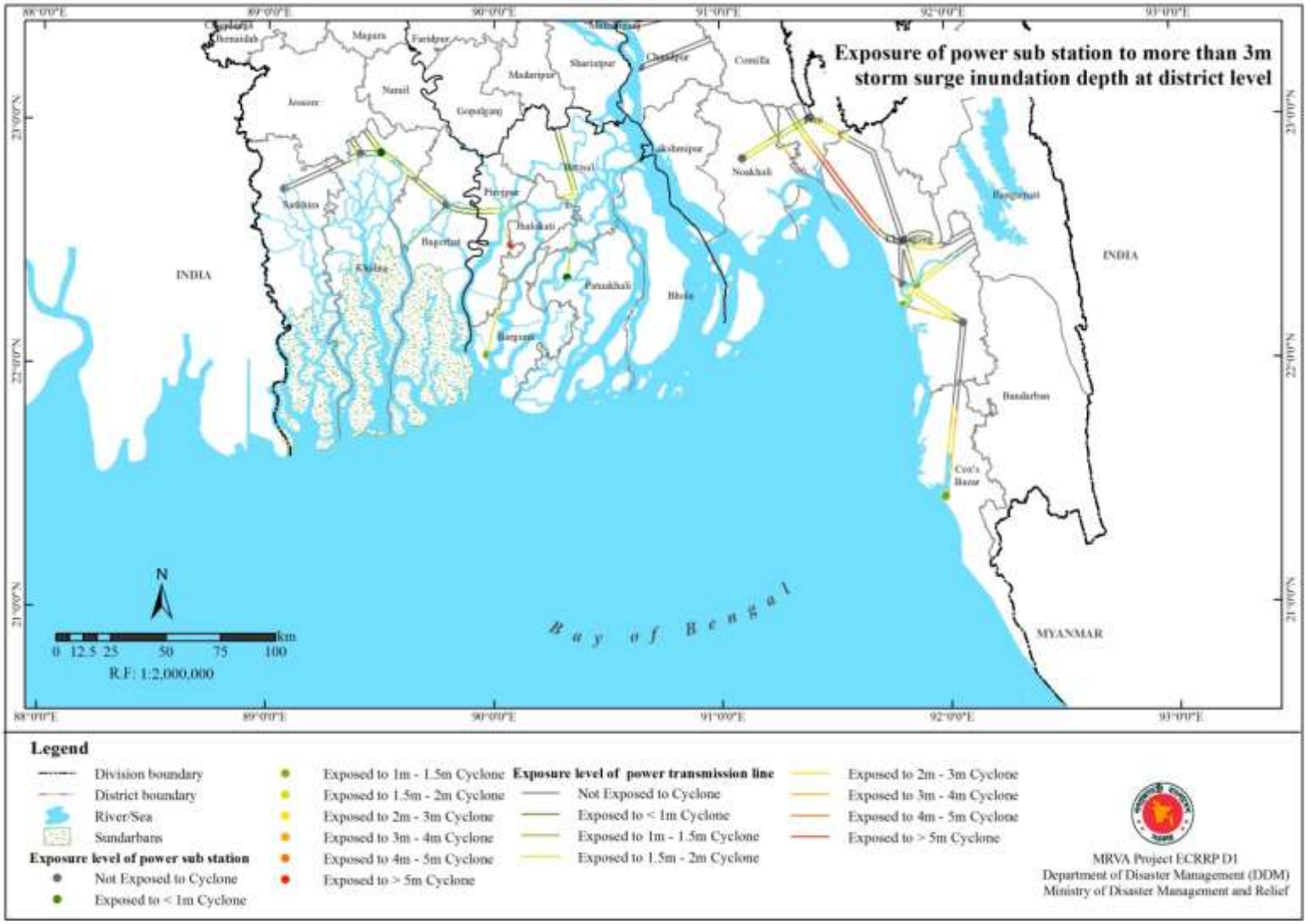


Figure 3.63: Exposure of Power sub-stations to more than 3m storm surge inundation depth at district level

3.2 Vulnerability / Risk (Damage) Assessment

3.2.1 Household structures

The damage curves representing the vulnerability of household structures is developed based on the literature and limited field data analysis (more details in Annexure I: Probabilistic damage functions report). The damage curves developed for housing structures types due to storm surge inundation depth is given as table 3.47 and figure 3.64.

Table 3.47: Damage function table for housing structures types to storm surge inundation depth

Inundation Depth (m)	Damage ratio (%)			
	Jhupri	Katcha	Semi- Pucca	Pucca
< 1.0	1.2	1.2	0.5	0.2
1.0 – 1.5	25.0	25.0	15.0	10.0
1.5 – 2.0	50.0	50.0	30.0	20.0
2.0 – 3.0	91.7	91.7	56.4	38.4
3.0 – 4.0	99.7	99.7	60.0	40.0
> 4.0	100.0	100.0	60.0	40.0

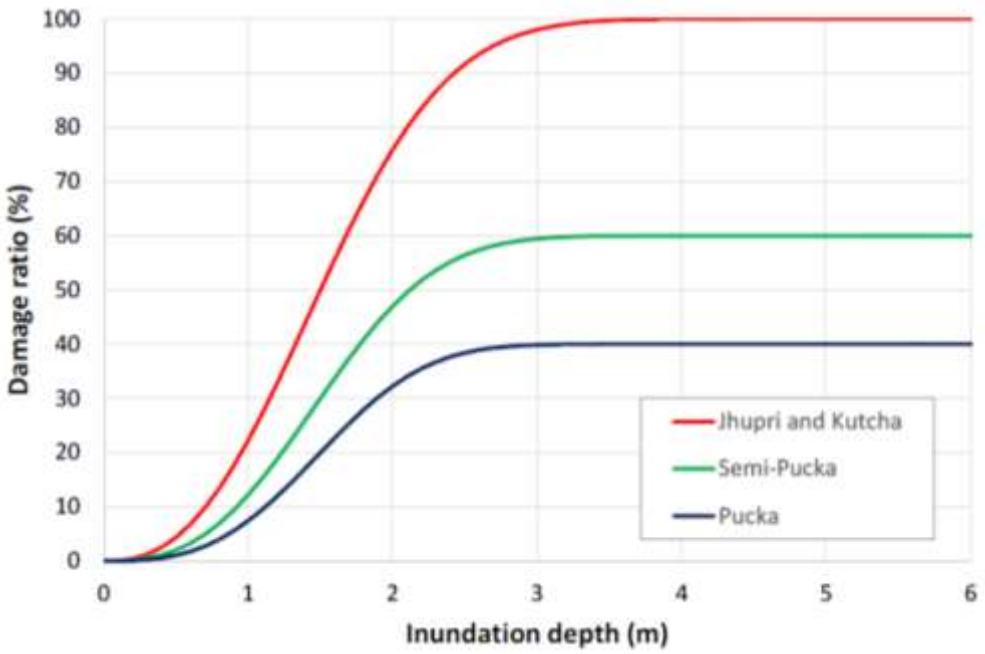


Figure 3.64: Damage functions for housing types due to storm surge inundation depth

Using the above damage function table and exposure of household structure types to storm surge inundation depth, possible % of damage of household structures is calculated. The percentage of damage is grouped into 5 risk levels (No Damage (D0): 0, Low Damage (D1): 1-15 %, Moderate Damage (D2): 15-35%, High Damage (D3): 35-60%, Very High (D4): >60%) as explained in section 1.3.2.

The number of Pucca household structures in different risk levels at division level is given table 3.48 and figure 3.65. Pucca household structures at high risk levels due to storm surge at district level is given in figure 3.66.

Table 3.48: Number of Pucca household structures in different risk levels at division level

Division	Risk levels (%) / number of household structures				
	0	0-15	15-35	35-60	>60
Barisal	38,174	29,864	4,832	5,123	-
Chittagong	629,397	52,049	14,025	29,786	-
Dhaka	1,724,697	10,662	1,683	1,982	-
Khulna	425,844	72,059	7,548	3,890	-
Total	2,818,112	164,634	28,089	40,781	-

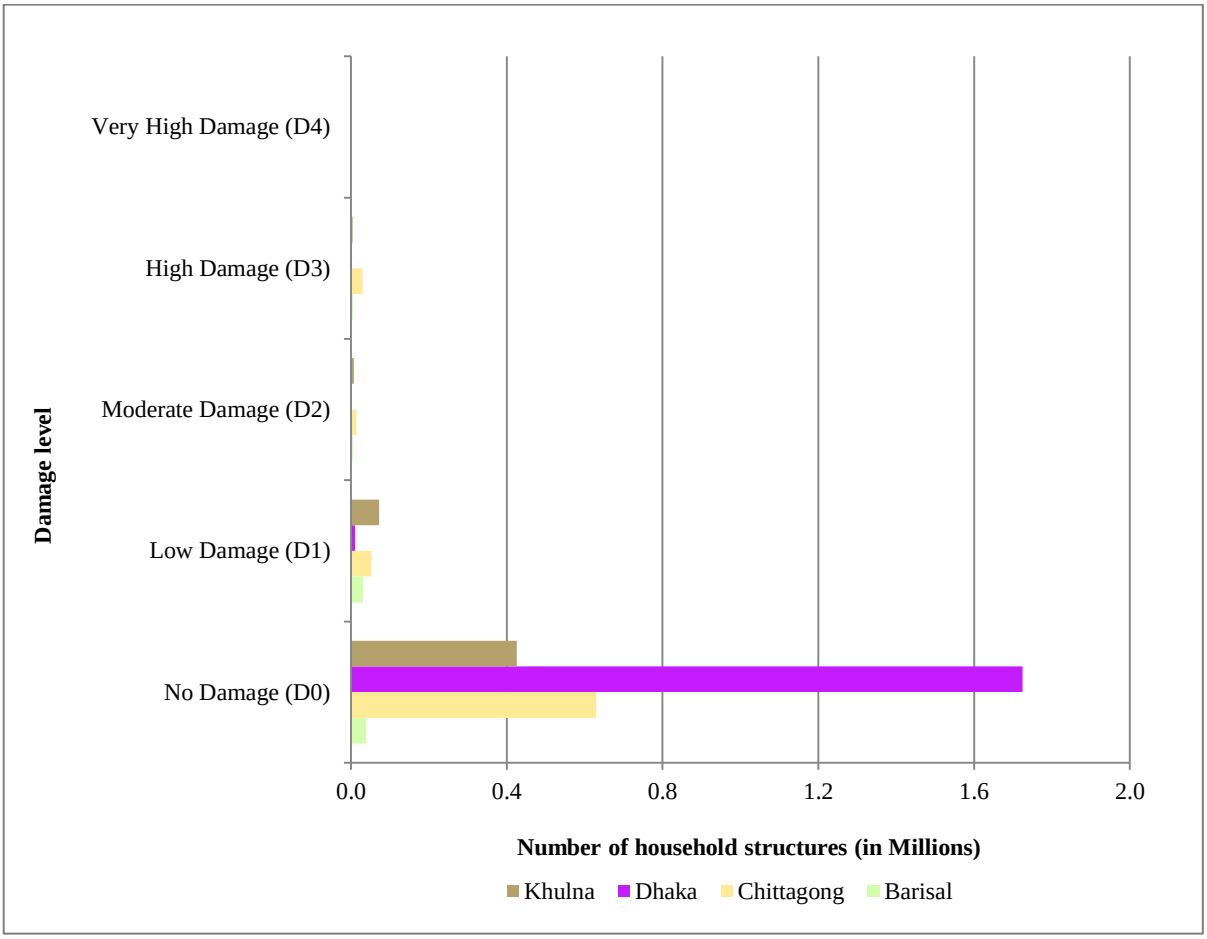


Figure 3.65: Number of Pucca household structures in different risk levels at division level

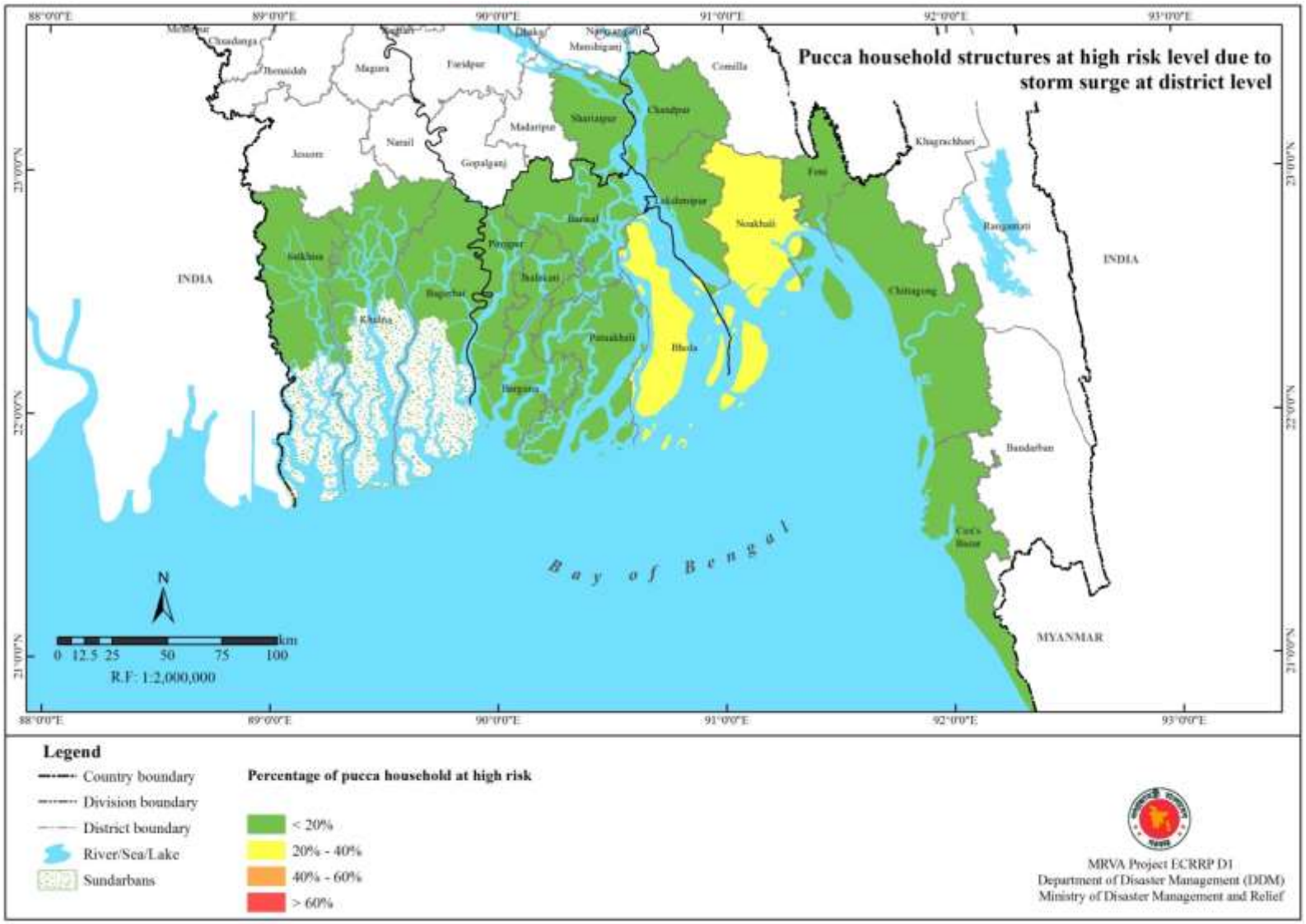


Figure 3.66: Pucca household structures at high risk levels due to storm surge at district level

The number of semi-Pucca household structures in different risk levels at division level is given table 3.49 and figure 3.67. Semi-Pucca household structures at high risk levels due to storm surge at district level is given in figure 3.68.

Table 3.49: Number of semi-Pucca household structures in different risk levels at division level

Division	Risk levels (%) / number of household structures				
	0	0-15	15-35	35-60	>60
Barisal	74,853	38,798	19,761	19,522	-
Chittagong	688,611	37,721	19,225	47,932	-
Dhaka	2,402,852	10,946	3,908	5,107	-
Khulna	856,112	110,475	34,391	22,994	-
Total	4,022,429	197,940	77,284	95,556	-

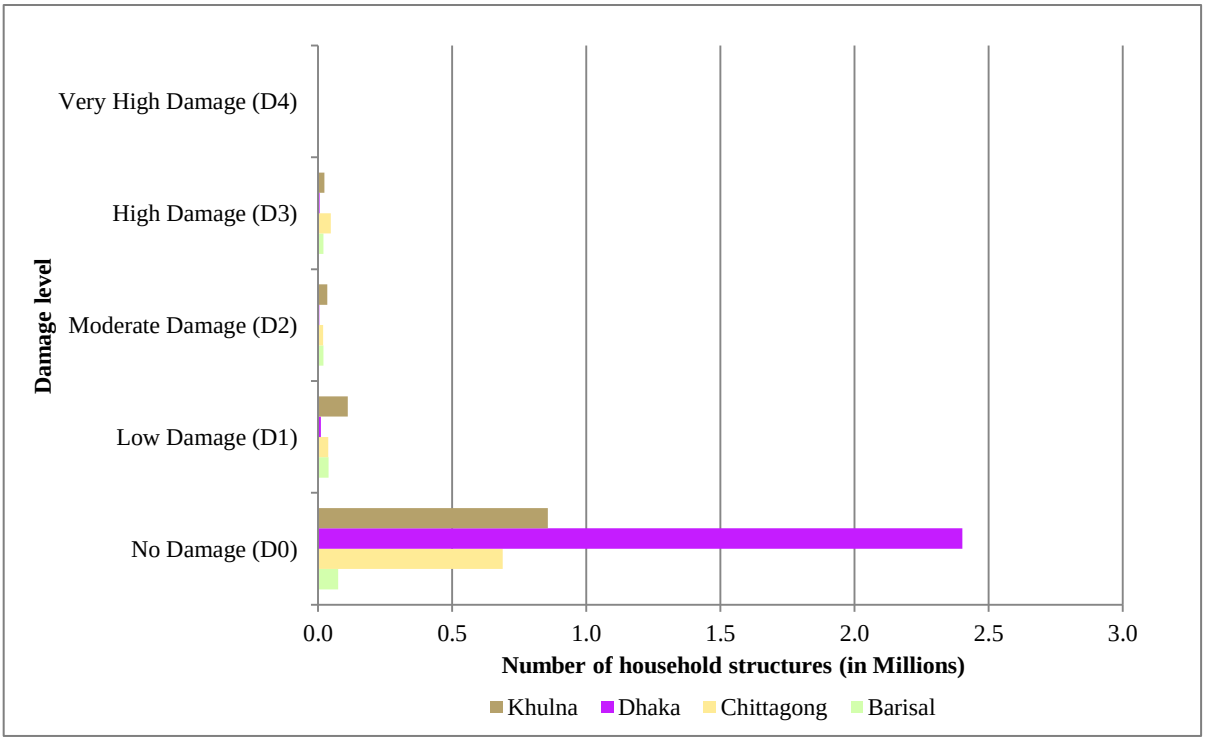


Figure 3.67: Number of semi-Pucca household structures in different risk levels at division level

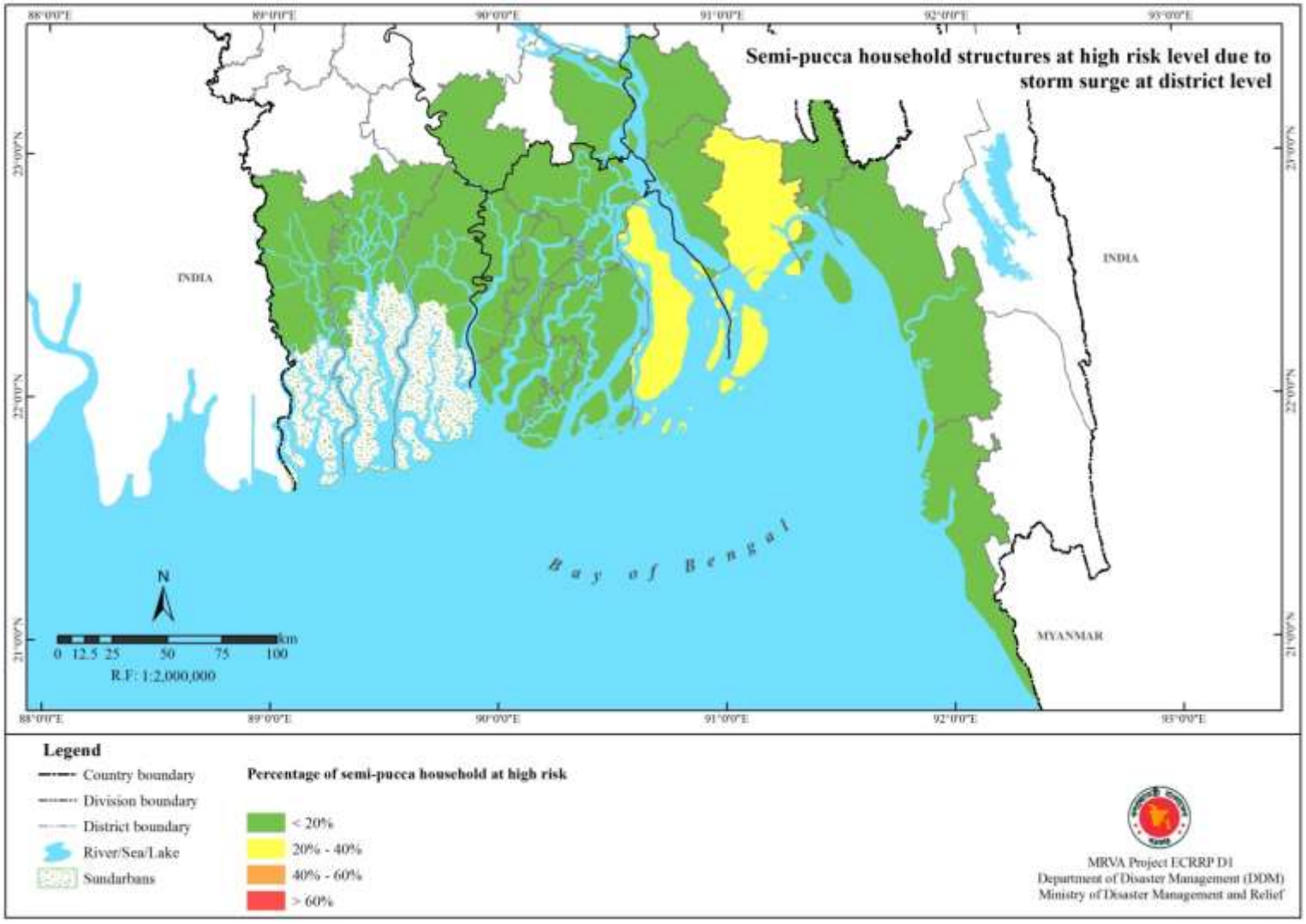


Figure3.68: Semi-Pucca household structures at high risk levels due to storm surge at district level

The number of Kutcha households in different risk levels at division level is given table 3.50 and figure 3.69. Kutcha household structures at high risk levels due to storm surge at district level is given in figure 3.70.

Table 3.50: Number of Kutcha household structures in different risk levels at division level

Division	Risk levels (%) / number of household structures				
	0	0-15	15-35	35-60	>60
Barisal	769,535	398,861	203,150	-	200,693
Chittagong	3,368,943	184,545	94,054	-	234,503
Dhaka	6,404,943	29,178	10,417	-	13,614
Khulna	1,751,702	226,045	70,368	-	47,049
Total	12,295,123	838,629	377,990	-	495,859

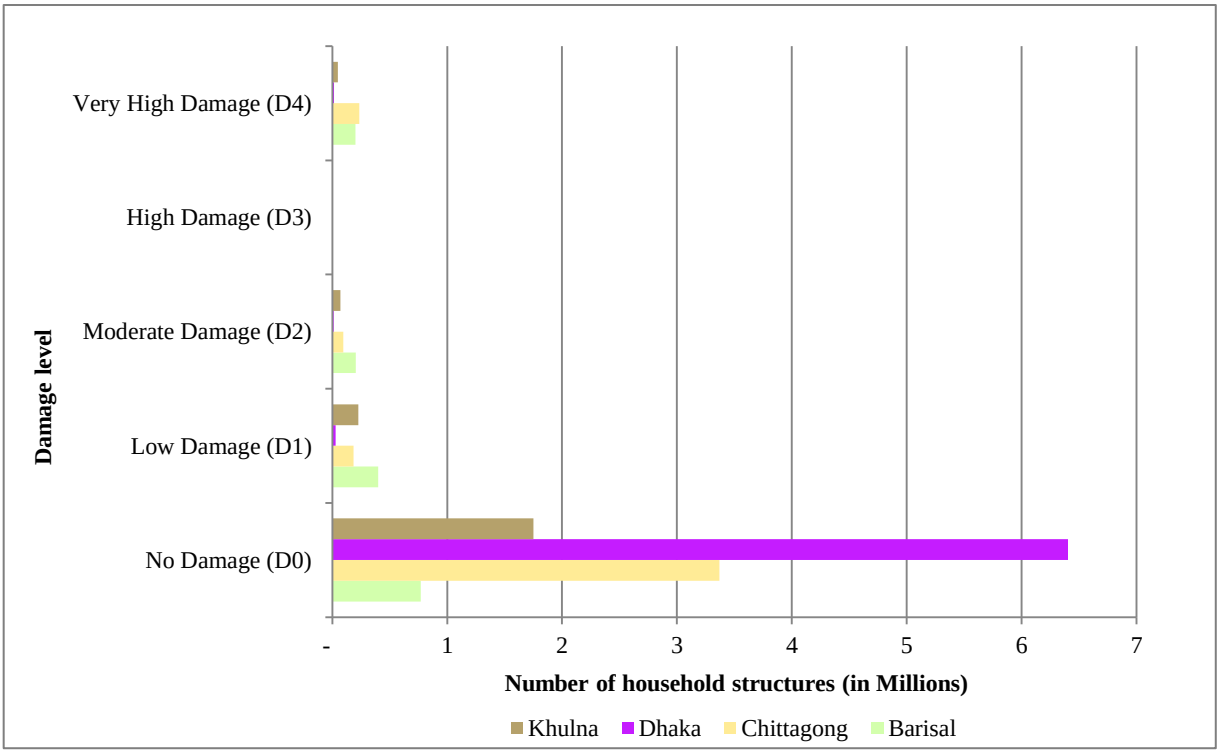


Figure 3.69: Number of Kutcha household structures in different risk levels at division level

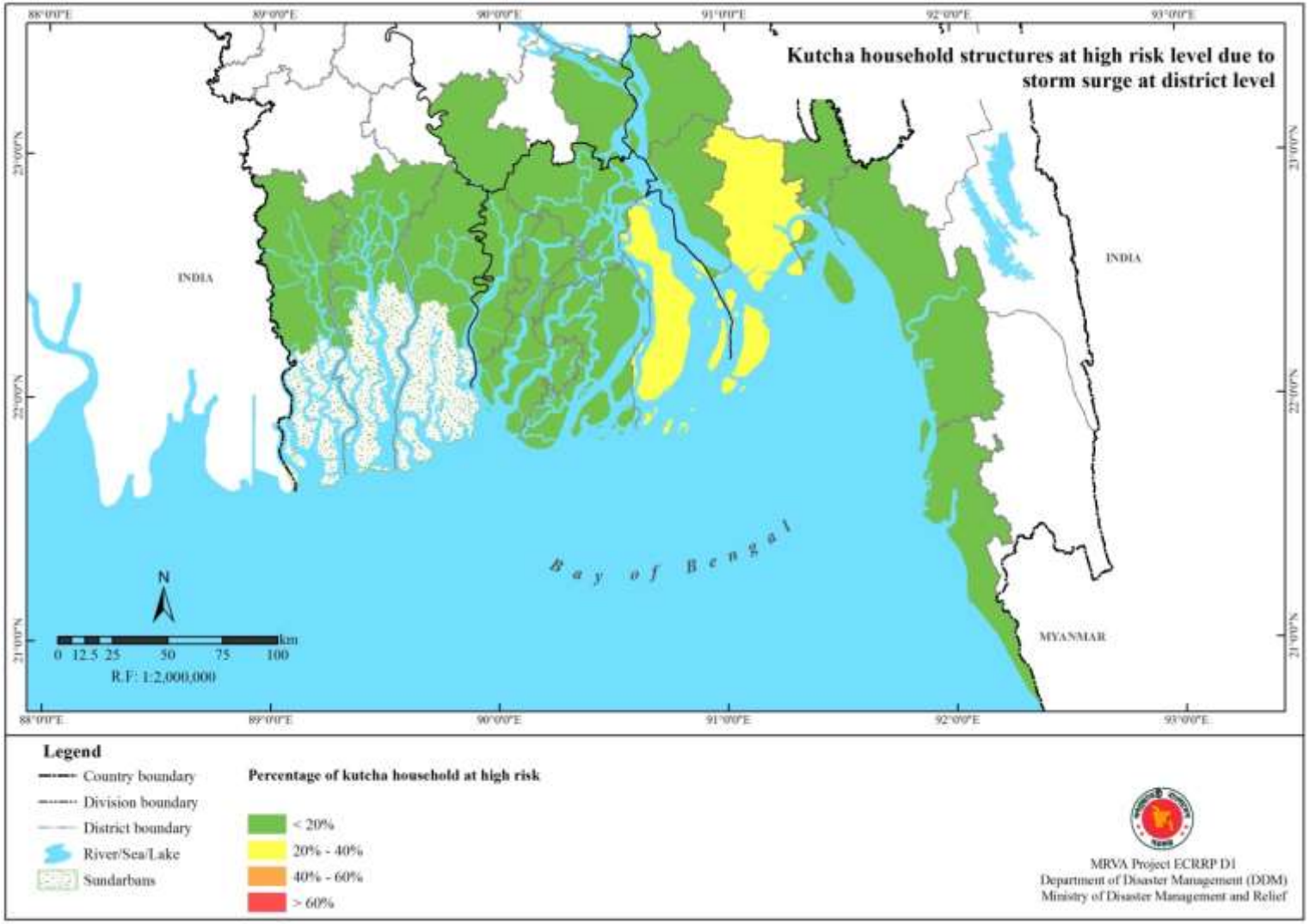


Figure3.70: Kutcha household structures at high risk levels due to storm surge at district level

The number of Jhupri household structures in different risk levels at division level is given table 3.51 and figure 3.71. Jhupri household structures at high risk levels due to storm surge at district level is given in figure 3.72.

Table 3.51: Number of Jhupri household structures in different risk levels at division level

Division	Risk levels (%) / number of household structures				
	0	0-15	15-35	35-60	>60
Barisal	29,207	15,138	7,710	-	7,617
Chittagong	195,708	10,721	5,464	-	13,623
Dhaka	227,437	1,036	370	-	483
Khulna	93,062	12,009	3,738	-	2,500
Total	545,414	38,904	17,283	-	24,223

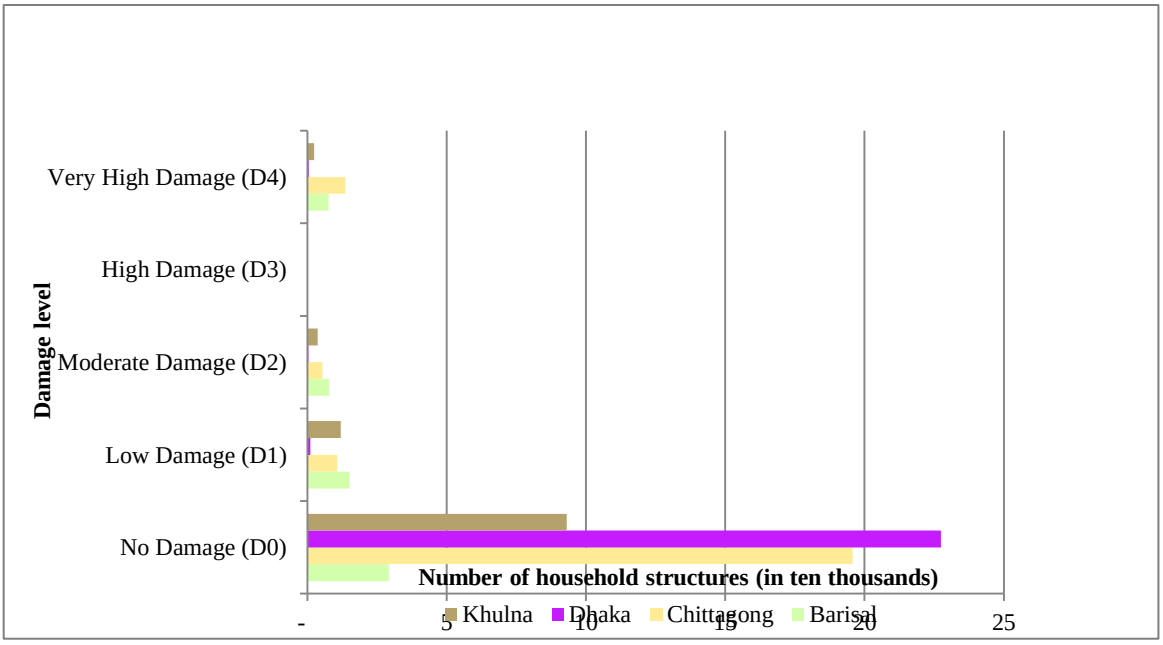


Figure 3.71: Number of Jhupri household structures in different risk levels at division level

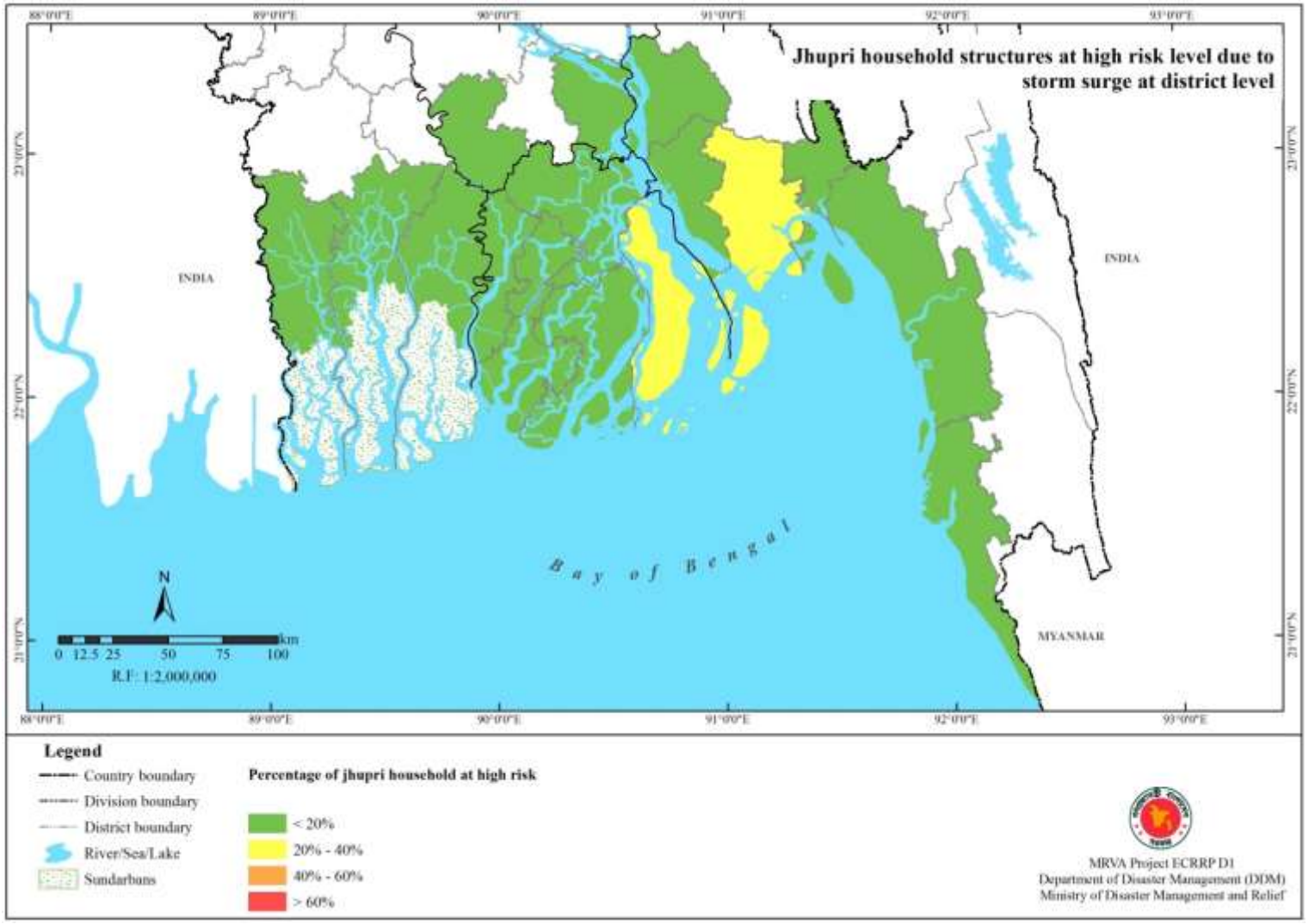


Figure 3.72: Jhupri household structures at different risk level due to storm surge at district level

3.2.2 Livelihood (Agriculture)

The exposure map of livelihood (agriculture) i.e. transplanted Aman to storm surge hazard is used for risk assessment. Since crop duration of paddy is approximately 110 days, it is divided into 4 crop growth stages (seedling, vegetative stage, reproductive stage and mature). The number of days from the date of sowing is given in table 3.52, based on the literature and also discussion with Prof. Mirza, Share-e-Bangla Agriculture University, Dhaka.

Table 3.52: Crop growth stages of Transplanted Aman crop

Crop	Crop growth stages in days				Total days (90- 110)
	Seedling (7-10)	Vegetative state (45-50)	Reproductive stage (60-75)	Mature (90-110)	
Transplanted (Aman Rice)	9	47	68	100	110
Height of the crop (m)	0.15	0.7 (0.6 - 0.8)	1.05 (0.9 - 1.20)	1.05 (0.9 - 1.20)	
Period of season (Jul./ Aug. to Nov. /Dec.)	Jul / Aug	Aug / Sep	Sep / Oct	Nov / Dec	

Vulnerability/ damage curves of Transplanted Aman (Rice) crop

The risk levels of transplanted Aman to storm surge depends upon the time of occurrence of storm surge and crop growth stage at the time of storm surge. Storm surges usually occur during pre-monsoon (April-May) or post-monsoon (October-November). During pre-monsoon, transplanted Aman crop is still not sown. During post-monsoon period, if transplanted Aman crop is not harvested, which may be subjected to damage due to storm surge. Risk matrix of transplanted Aman due to storm surge in the month of October is developed and is given in table 3.53.

Table 3.53: Risk matrix of Aman rice crop to Storm surge in October

Storm surge in October	Crop growth stages (cumulative days)			
	Seedling (7-10)	Vegetative state (45-50)	Reproductive stage (60-75)	Mature (90-110)
Planting date:	Jul / Aug	Aug / Sep	Sep / Oct	Nov / Dec
Height of the crop (m) / Storm surge inundation depth (m)	0.15	0.7 (0.6 - 0.8)	1.05 (0.9 - 1.20)	1.05 (0.9 - 1.20)
< 1.0	D0	D0	D2	D3
1.0 - 1.5	D0	D0	D3	D4
1.5 - 2.0	D0	D0	D4	D4
2.0 - 3.0	D0	D0	D4	D4
3.0 - 4.0	D0	D0	D4	D4
4.0 – 5.0	D0	D0	D4	D4
> 5.0	D0	D0	D4	D4

Using the above risk matrix and exposure of transplanted Aman crop, crop area at different risk levels is assessed and given in table 3.54.

Table 3.54: Transplanted Aman crop at different risk levels due to Storm surge

District	Upazila	Transplanted Aman Area (km2) in different risk (damage) levels				
		Low (D1)	Moderate (D2)	High (D3)	Very High (D4)	No Risk (D0)
Barisal	Barguna	0	501.6	194.2	61.0	471.1
	Barisal	0	495.5	402.1	253.4	732.8
	Bhola	0	391.6	97.7	318.1	915.4
	Jhalokati	0	447.1	137.8	20.9	97.2
	Patuakhali	0	538.8	469.2	424.4	918.6
	Pirojpur	0	602.4	222.9	103.9	199.2
Chittagong	Chandpur	0	40.3	6.9	19.6	488.8
	Chittagong	0	371.8	298.0	410.7	1304.2
	Cox's Bazar	0	242.4	87.2	26.8	542.8
	Feni	0	134.1	32.5	62.9	640.7
	Lakshmipur	0	206.1	93.5	122.8	660.4
	Noakhali	0	362.3	175.5	442.6	764.9
Dhaka	Shariatpur	0	0.0	0.0	1.1	8.1
Khulna	Bagerhat	0	256.6	94.2	28.7	1216.6
	Khulna	0	2.7	1.0	4.3	1524.2
	Satkhira	0	6.9	5.2	11.9	2219.7

Transplanted Aman crop at different risk levels in percentage is shown in figure 3.73 and figure 3.74.

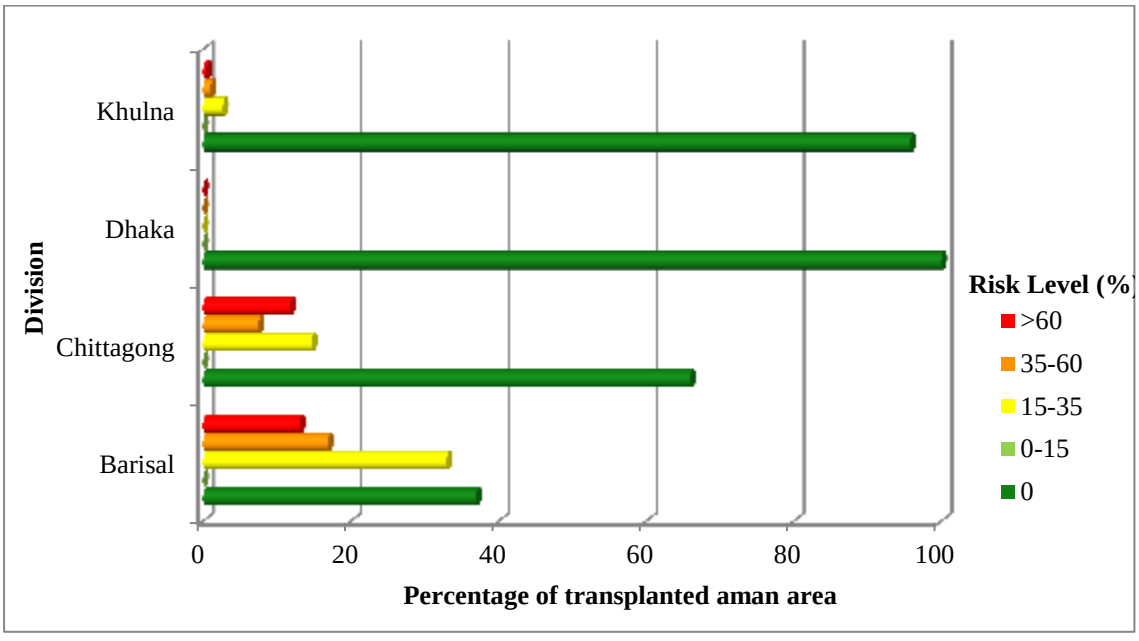


Figure 3.73: Percentage of risk levels of transplanted Aman crop at division level

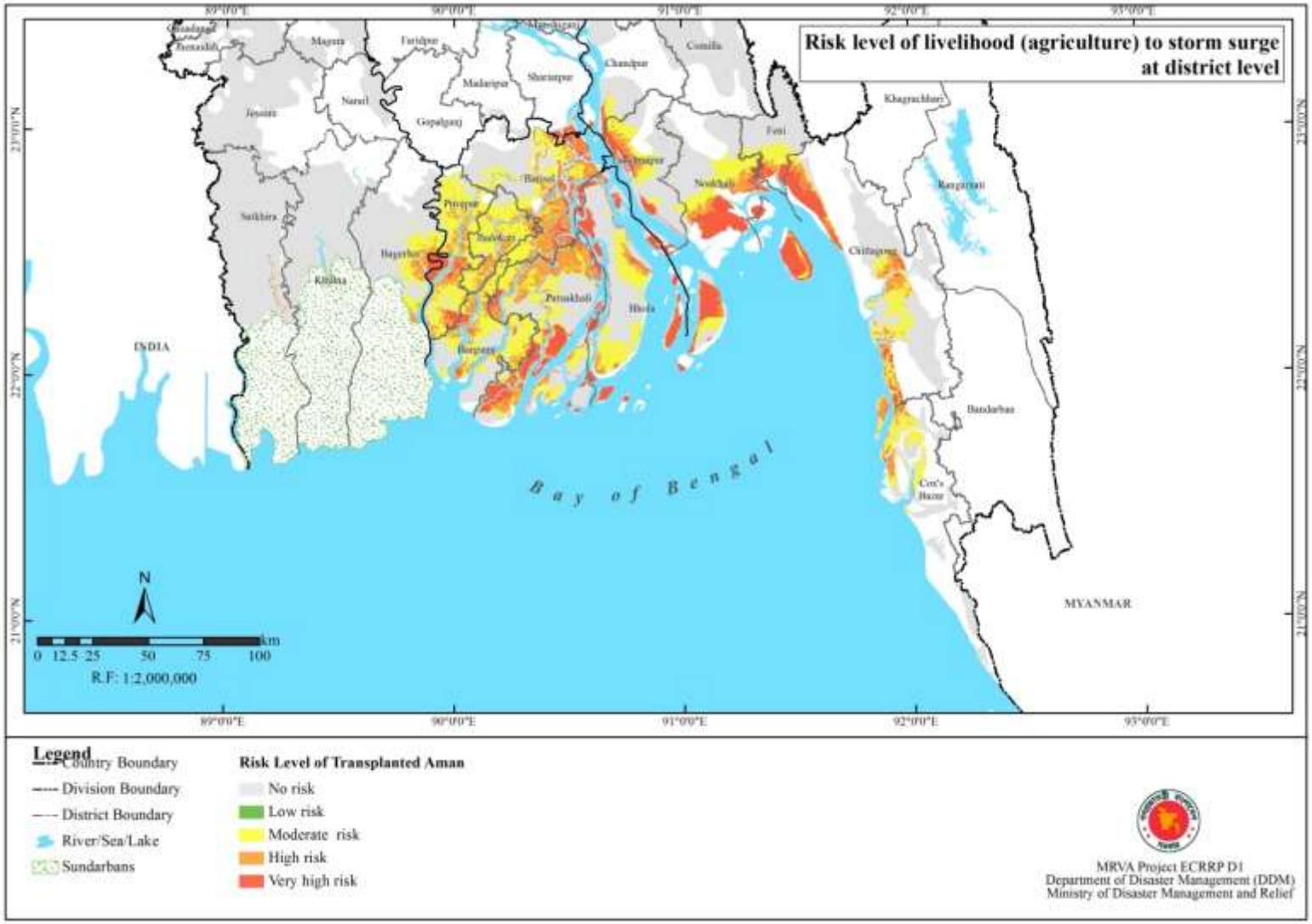


Figure 3.74: Risk level of livelihood (agriculture) to storm surge at district level

Chapter 4: Exposure, Vulnerability & Risk Assessment to Landslide

Although, landslide susceptibility maps are available from two triggering factors i.e. rainfall and earthquake, since rainfall triggered landslides are predominant in Bangladesh, only rainfall susceptibility map due to rainfall is used for exposure and also risk assessment. The rainfall induced landslide susceptibility map consists of 5 categories of landslide susceptibility, they are very low, low, moderate, high and very high categories.

4.1 Exposure Assessment

Landslide susceptibility maps due to rainfall and earthquake indicates spatial distribution of landslide susceptibility zones in 5 categories. They are low, moderate, high and very high. As explained in section 1.4, Landslide susceptibility map will not have a return period. Although rainfall and earthquake induced landslide susceptibility maps are developed, only rainfall induced landslide susceptibility map is used (as rainfall is the predominant triggering factor for landslides in Bangladesh) for exposure assessment of elements at risk i.e. population, housing, livelihoods, critical facilities and infrastructure.

4.1.1 Population

As explained in section 1.5, based on the area of exposure of the settlements in each union, number of population exposed is calculated as affected population due to landslide susceptibility at division / district / upazila level. The settlement area (km^2) and percentage exposed to high and very high category of land slide hazard at district level is given in table 4.1. Table 4.1 indicates that settlement area existing in Bandarban (96.1%), Khagrachhari (84.9%), Rangamati (81.1%), Cox's Bazar (51%) is highest exposed.

Table 4.1: Settlement area exposed to landslide susceptibility

Division	District	Settlement Area in Landslide susceptibility				Total	
		High		Very High			
		Km^2	Percentage	Km^2	Percentage	Km^2	Percentage
Chittagong	Bandarban	57.86	75.65	15.67	20.49	73.5	96.1
	Chittagong	85.51	14.68	1.83	0.31	87.3	15.0
	Comilla	4.82	0.82	0.00	0.00	4.8	0.8
	Cox's Bazar	41.44	45.86	4.65	5.14	46.1	51.0
	Feni	0.05	0.04	0.00	0.00	0.05	0.04
	Khagrachhari	57.93	82.19	1.89	2.68	59.83	84.87
	Rangamati	18.29	75.00	1.48	6.07	19.8	81.1
Sylhet	Habiganj	9.99	6.15	0.00	0.00	10.0	6.1
	Maulvibazar	44.71	23.36	5.09	2.66	49.8	26.0
	Sunamganj	2.66	1.77	0.01	0.01	2.7	1.8
	Sylhet	28.75	10.81	9.12	3.43	37.9	14.2

4.1.1.1 Gender

Based on the settlement area population exposed to landslide susceptibility (high and very high) at division/district level based on gender (male and female) is calculated and given in table 4.2, shown at division level in figure 4.1 and population (male) at district level in figure 4.2 and population (female) in figure 4.3.

Table 4.2: Population based on gender exposed to landslide susceptibility

Division	District	Population (gender) exposed to Landslide susceptibility			
		High		Very High	
		Male	Female	Male	Female
Chittagong	Bandarban	153,841	139,947	41,669	37,905
	Chittagong	563,494	554,488	12,091	11,898
	Comilla	20,997	22,931	-	-
	Cox's Bazar	536,342	513,772	60,121	57,591
	Feni	245	263	-	-
	Khagrachhari	257,900	246,665	8,424	8,057
	Rangamati	234,807	212,178	18,994	17,163
Sylhet	Habiganj	63,050	65,375	-	-
	Maulvibazar	220,692	227,608	25,126	25,914
	Sunamganj	21,875	21,800	63	63
	Sylhet	186,724	184,589	59,209	58,532

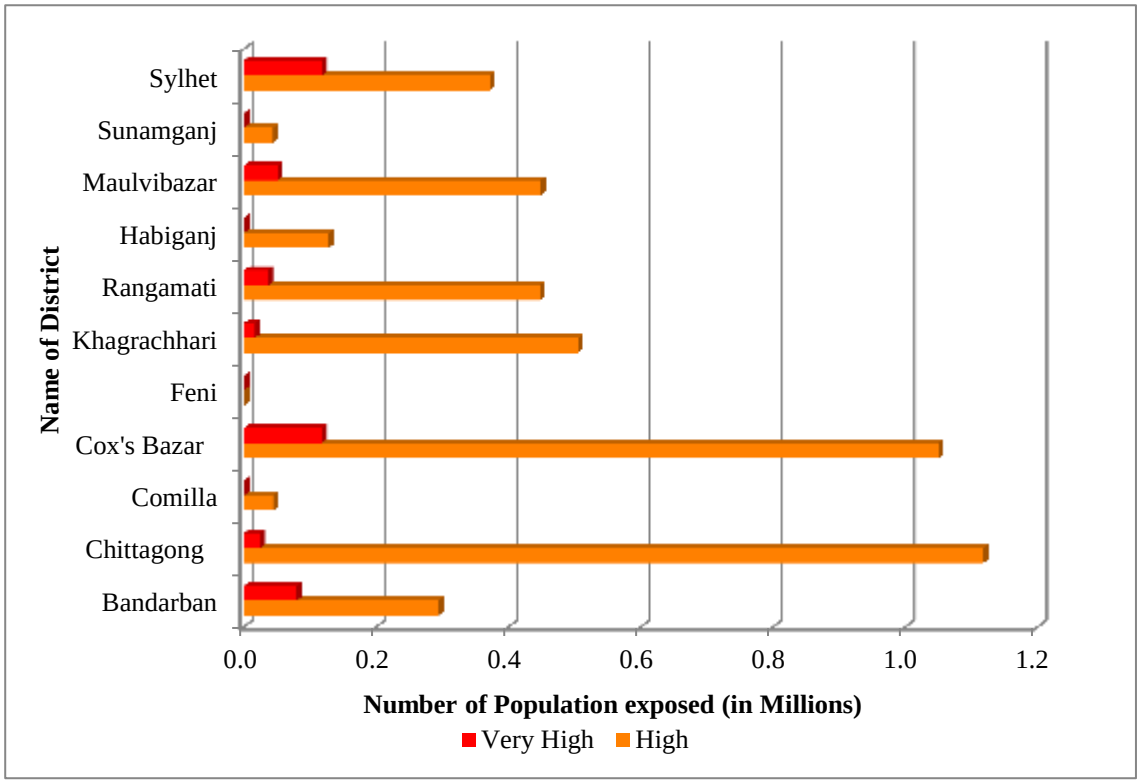


Figure 4.1: Population exposed to landslide susceptibility at district level

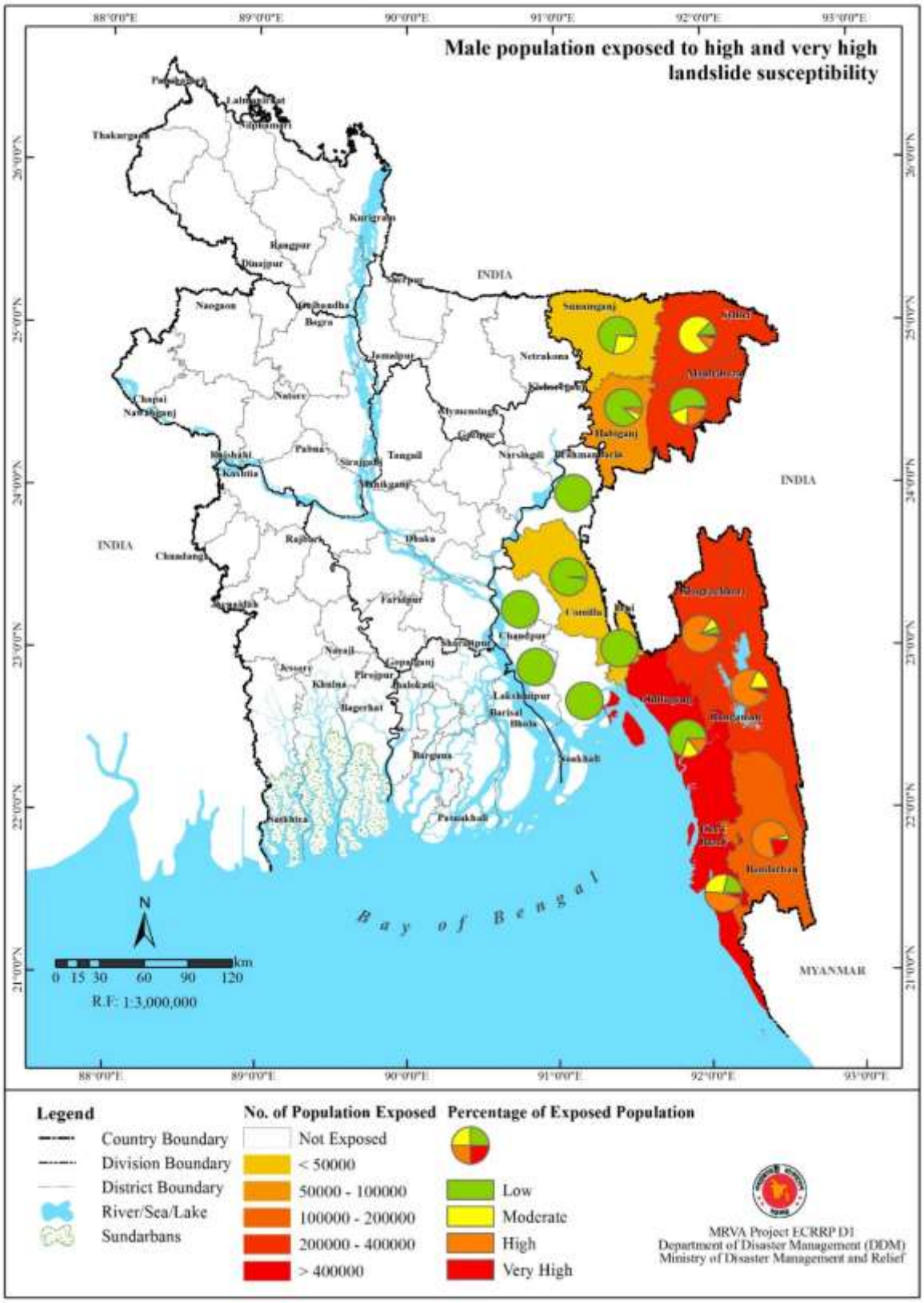


Figure 4.2: Male Population exposed to high and very high landslide susceptibility

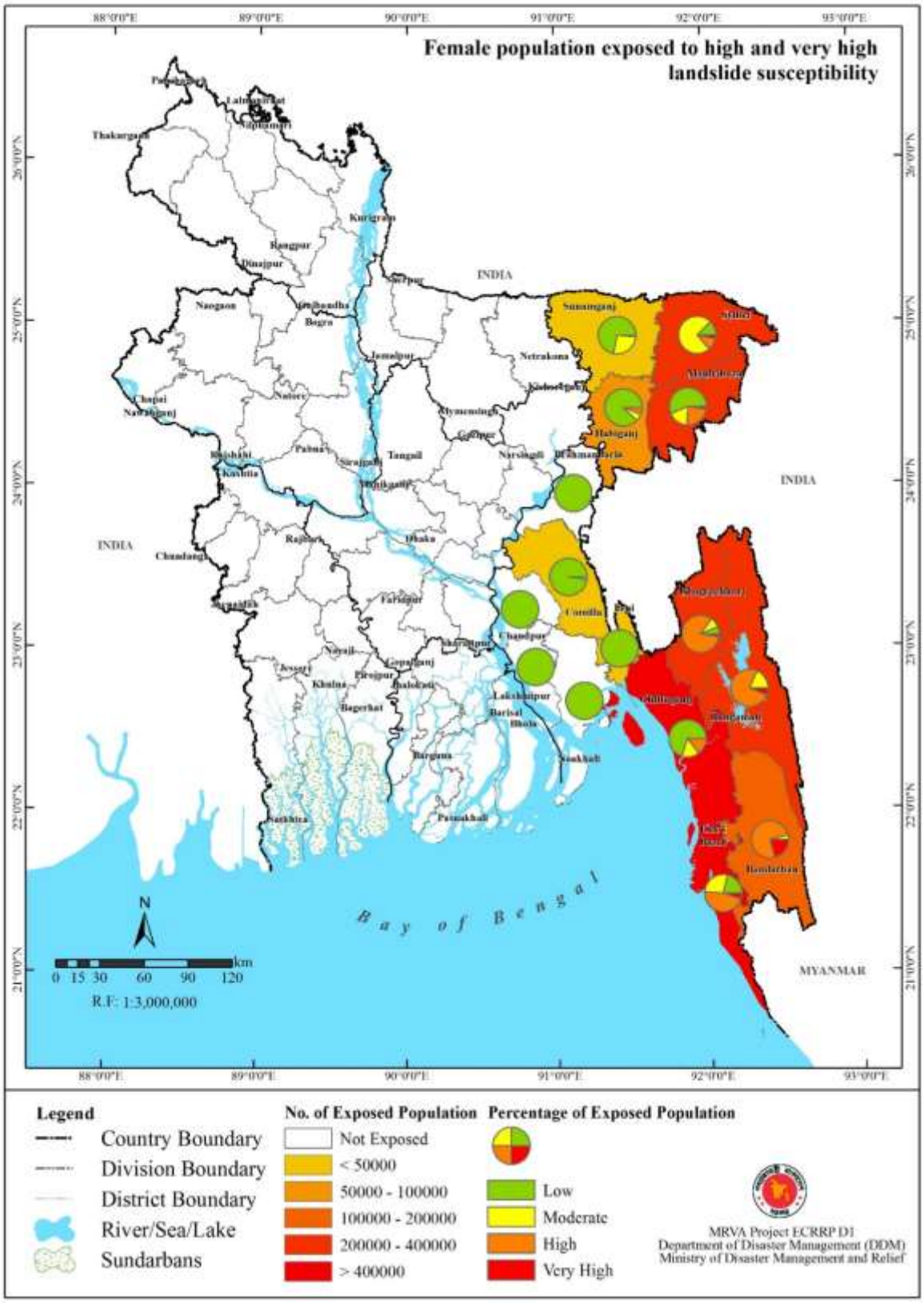


Figure 4.3: Female Population exposed to high and very high landslide susceptibility

4.1.1.2 Age

As explained in section 1.1.2, population by age is regrouped into 0 - 14 years, 14 - 59 years and more than 59 years. Population based on age groups of 0 - 14 years, 14 - 59 years and more than 59 years, exposed to high and very high landslide susceptibility categories is given in table 4.3 and at district level shown in figure 4.4. Population distribution at age group of 0 - 14 years and more than 59 years is shown in figure 4.5, at 14 - 59 years shown in figure 4.6.

Table 4.3: Population based on age exposed to landslide susceptibility

Division	District	Population (age) exposed to Landslide susceptibility					
		High			Very High		
		0 - 14	14 - 59	> 59	0 - 14	14 - 59	> 59
Chittagong	Bandarban	117,515	160,702	15,571	31,830	43,527	4,217
	Chittagong	378,996	669,671	69,315	8,132	14,369	1,487
	Comilla	17,044	23,370	3,514	-	-	-
	Cox's Bazar	450,499	546,060	53,556	50,499	61,210	6,003
	Feni	181	285	43	-	-	-
	Khagrachhari	192,239	278,520	33,805	6,279	9,098	1,104
	Rangamati	160,020	259,251	27,713	12,944	20,971	2,242
Sylhet	Habiganj	52,269	66,524	9,632	-	-	-
	Maulvibazar	168,113	247,910	32,278	19,140	28,225	3,675
	Sunamganj	18,605	21,837	3,232	53	63	9
	Sylhet	145,183	201,994	24,135	46,037	64,051	7,653

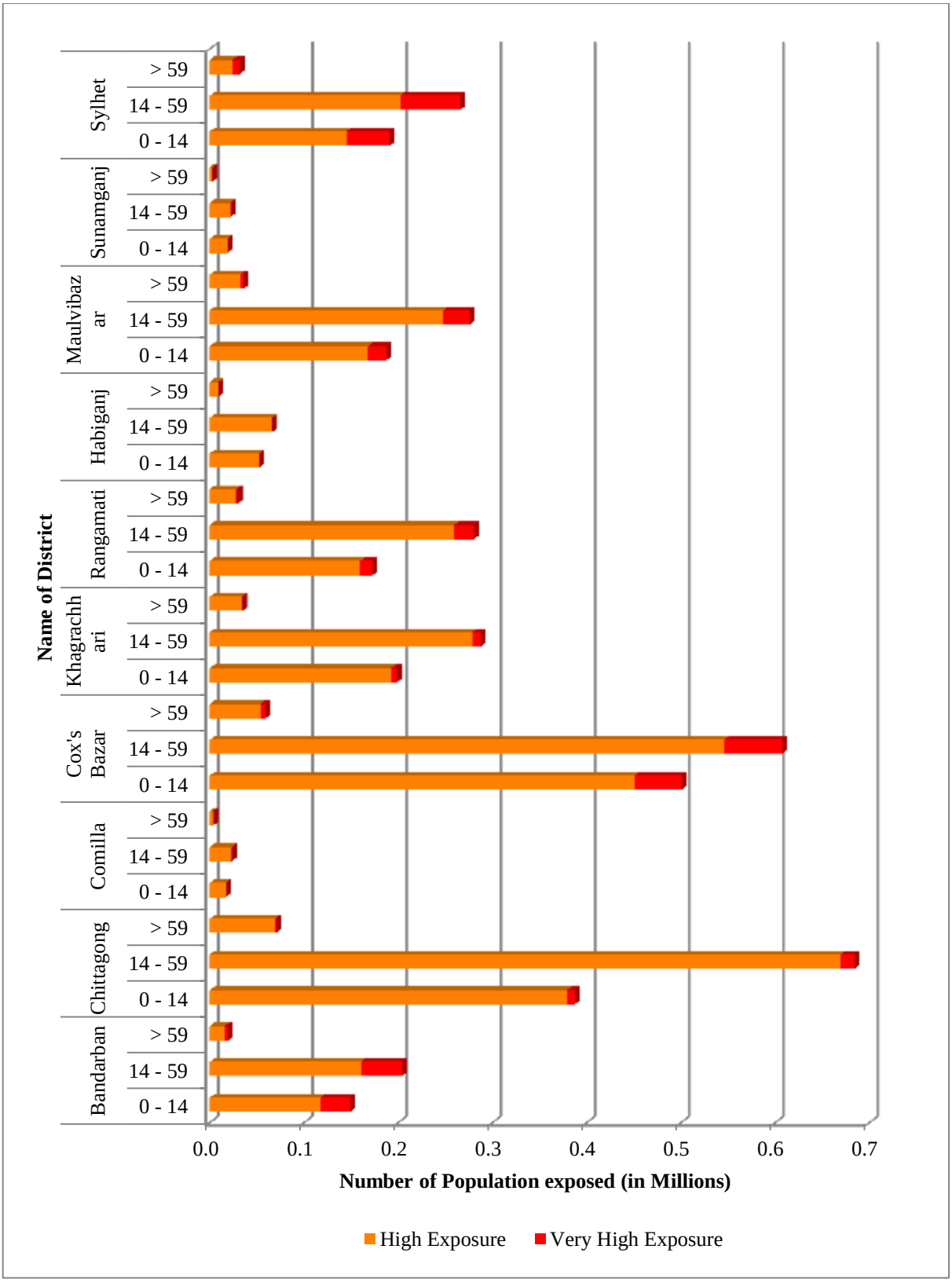


Figure 4.4: Population based on age exposed to landslide susceptibility at district level

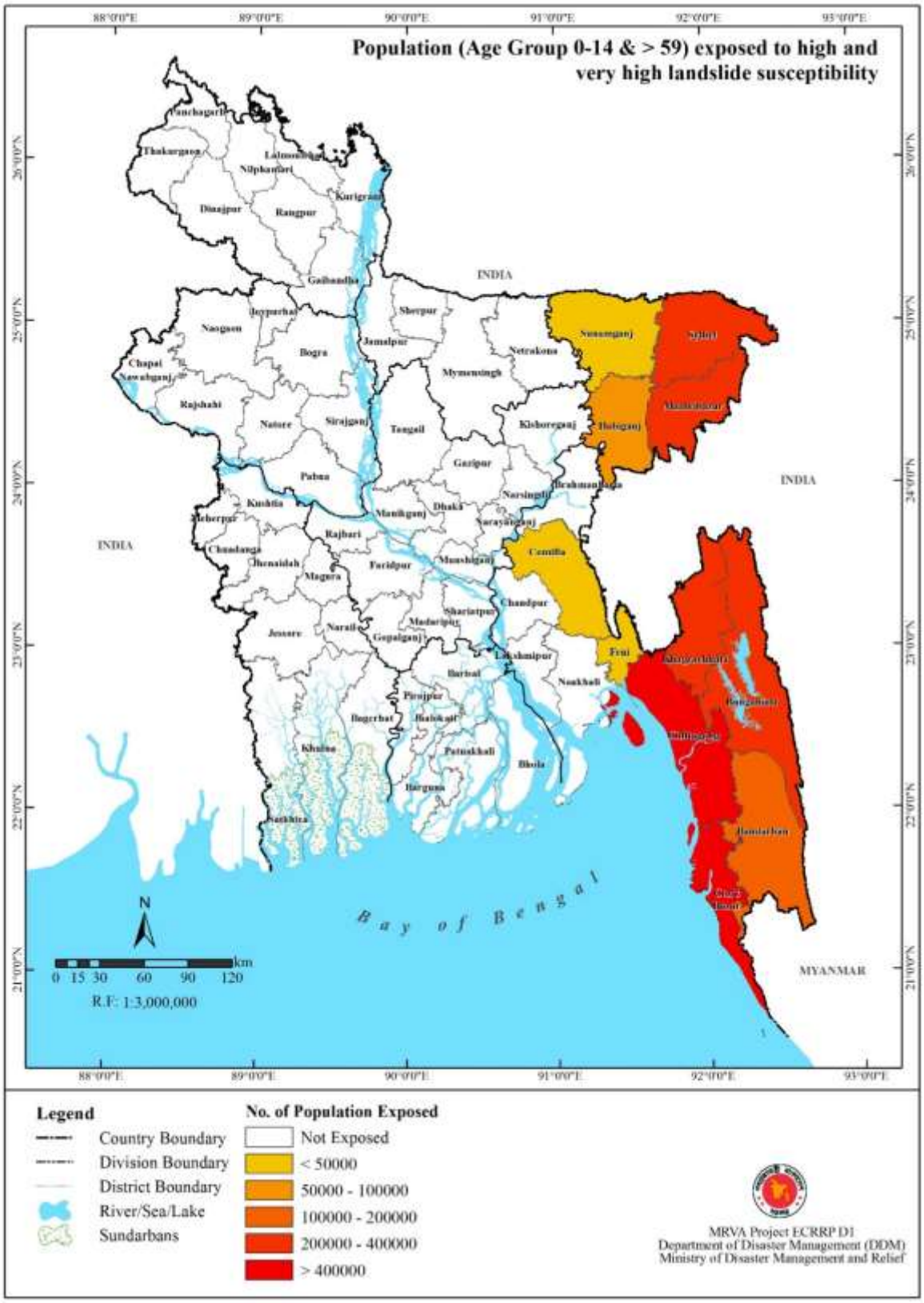


Figure 4.5: Population (Age group 0-14 and more than 59) exposed to landslide susceptibility at district level

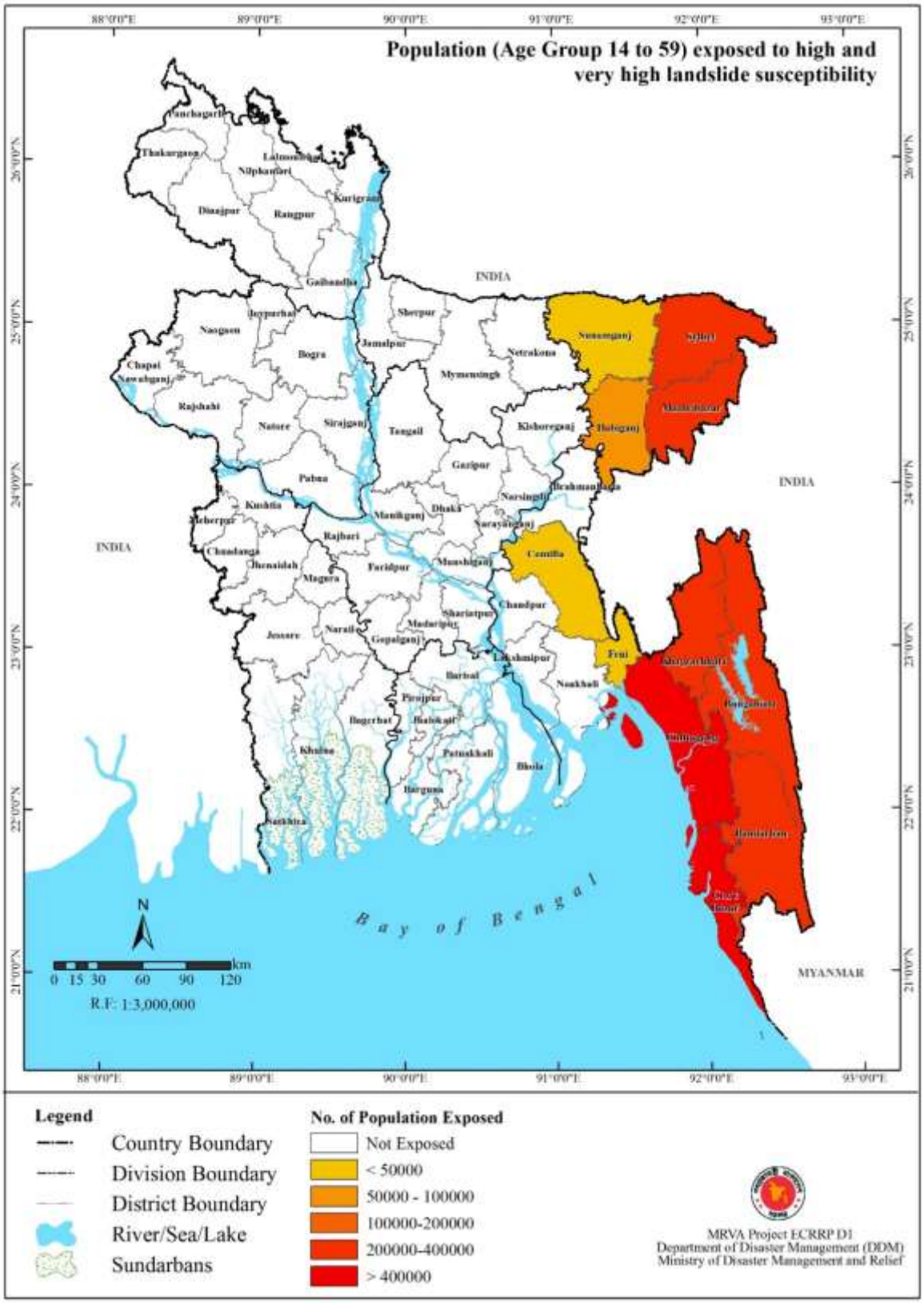


Figure 4.6: Population (Age group 14-59) exposed to landslide susceptibility at district level

4.1.1.3 Ethnicity

Details of ethnic population are given in section 1.1.3 of Volume III of this report. Since most of the ethnic population are living in hill track region of Bangladesh, exposure of ethnic population to high and very high landslide susceptibility is given in table 4.4 and at district level shown in figure 4.7. Distribution of Ethnic population is shown in figure 4.8.

Table 4.4: Ethnic population exposed to landslide susceptibility

Division	District	Number of Ethnic Population exposed to Landslide susceptibility			
		High		Very High	
		Male	Female	Male	Female
Chittagong	Bandarban	66,325	64,102	17,965	17,362
	Chittagong	2,397	2,325	51	50
	Comilla	14	11	-	-
	Cox's Bazar	3,231	3,442	362	386
	Khagrachhari	130,933	129,591	4,277	4,233
	Rangamati	136,365	130,750	11,031	10,576
Sylhet	Habiganj	2,031	2,014	-	-
	Maulvibazar	7,340	7,486	836	852
	Sunamganj	62	60	0	0
	Sylhet	700	682	222	216

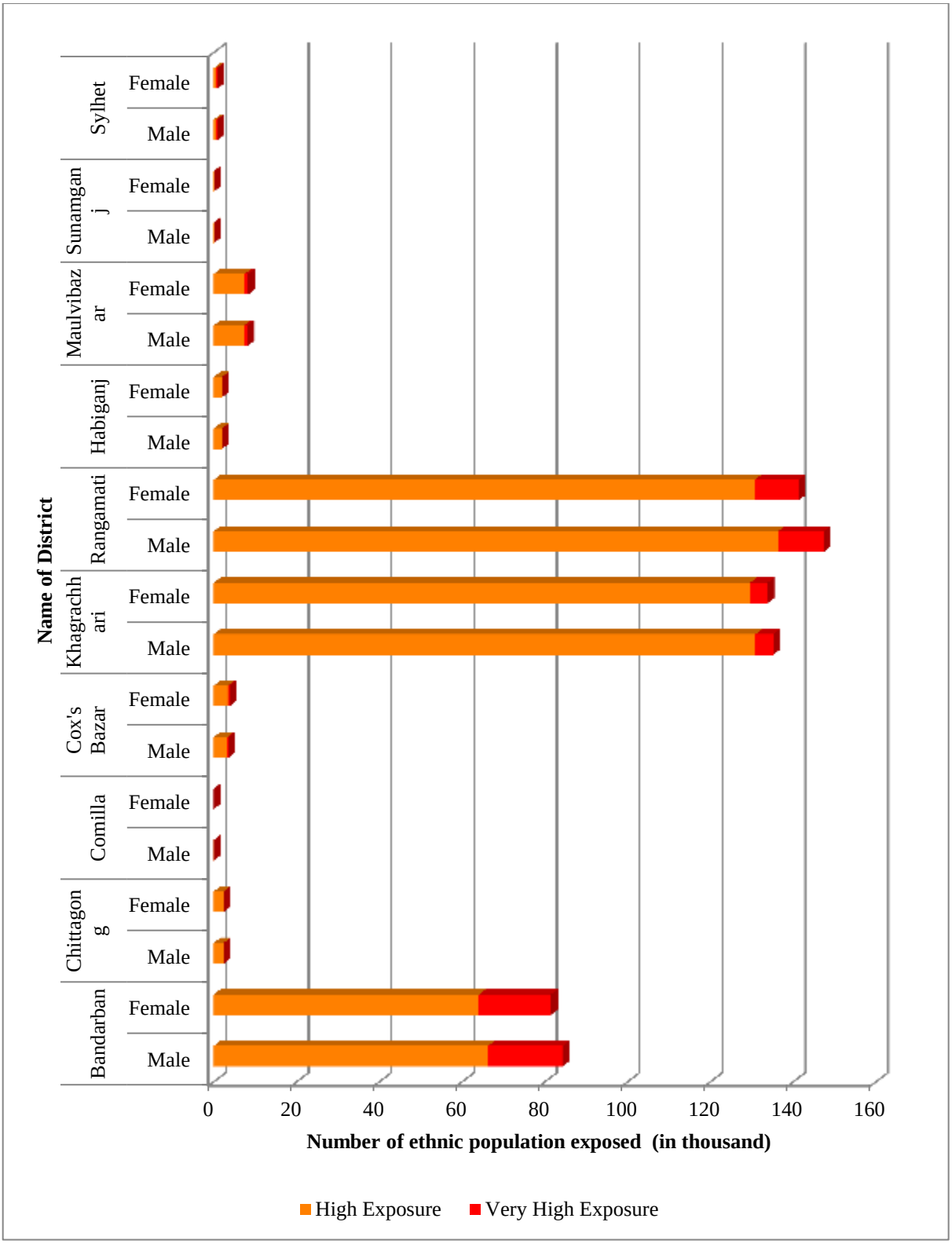


Figure 4.7: Ethnic population exposed to landslide susceptibility at district level

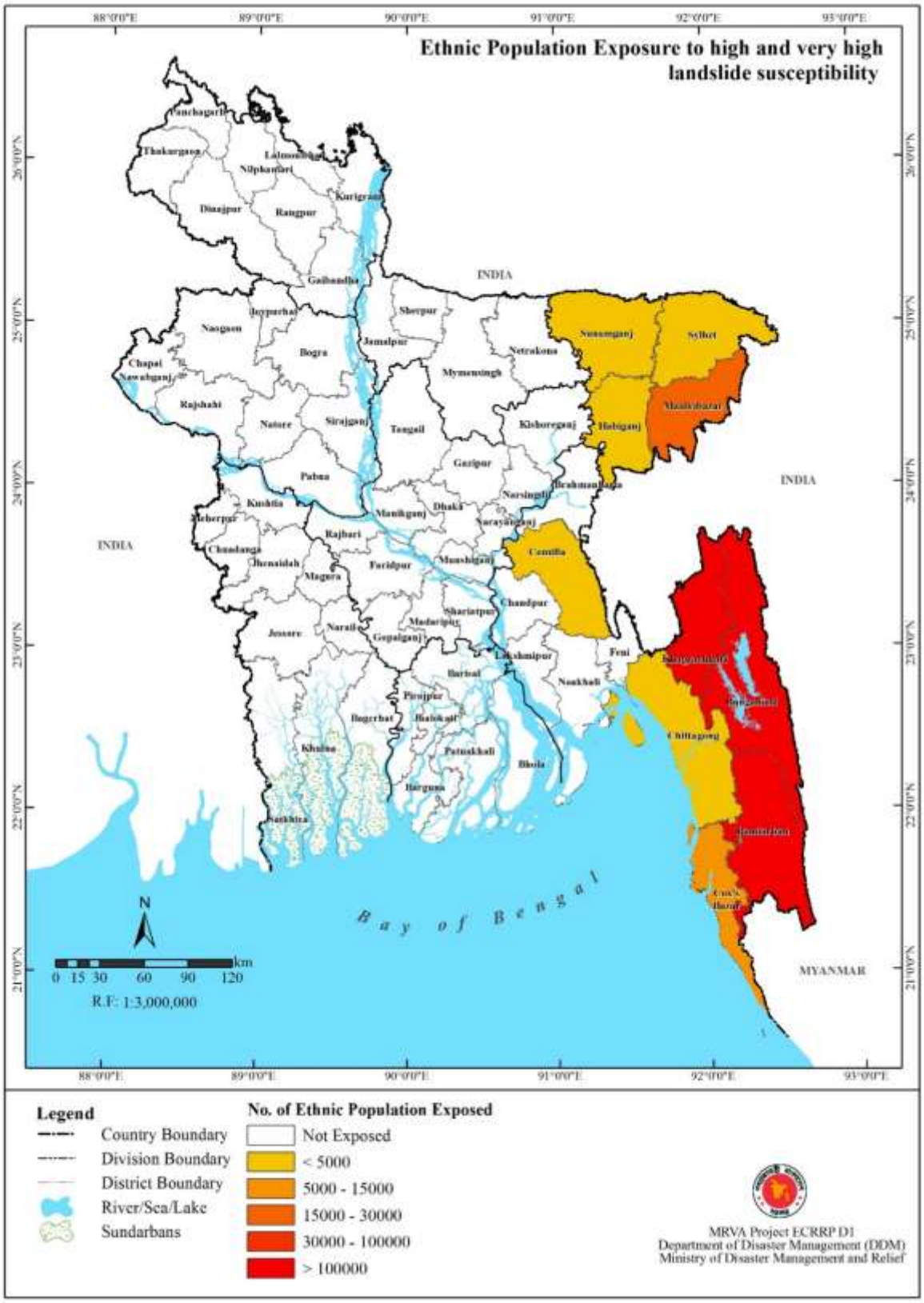


Figure 4.8: Ethnic population exposed to landslide susceptibility at district level

4.1.1.4 Employment

As explained in section 1.1.4 of Volume III of this report, the employment types considered are agriculture and industry. Employed Population in Agriculture and Industry sectors exposed to high and very high landslide susceptibility categories is given in table 4.5 and shown in figure 4.9. Employed population distribution at district level is shown in figure 4.10.

Table 4.5: Employed Population (Agriculture and Industry) exposed to Landslide susceptibility

Division	District	Population in employment (Agriculture and Industry) exposed to Landslide susceptibility			
		High		Very High	
		Agriculture	Industry	Agriculture	Industry
Chittagong	Bandarban	54,321	2,411	14,713	653
	Chittagong	29,112	15,550	625	334
	Comilla	2,331	269	-	-
	Cox's Bazar	86,891	7,266	9,740	814
	Feni	14	3	-	-
	Khagrachhari	55,047	1,534	1,798	50
	Rangamati	50,359	1,916	4,074	155
Sylhet	Habiganj	12,359	823	-	-
	Maulvibazar	28,848	5,620	3,284	640
	Sunamganj	5,048	184	14	1
	Sylhet	18,366	4,222	5,824	1,339

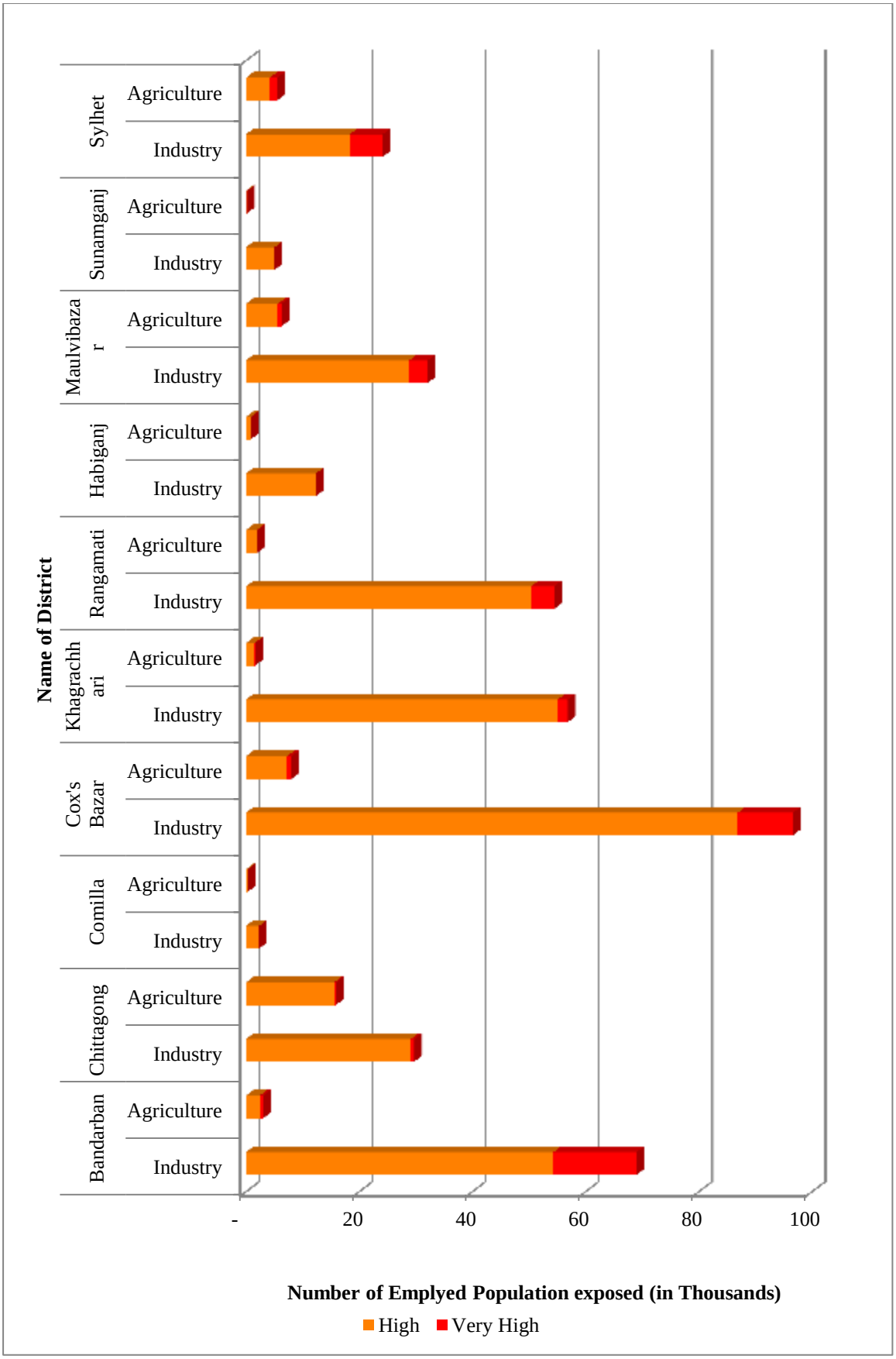


Figure 4.9: Employed population exposed to landslide susceptibility at district level

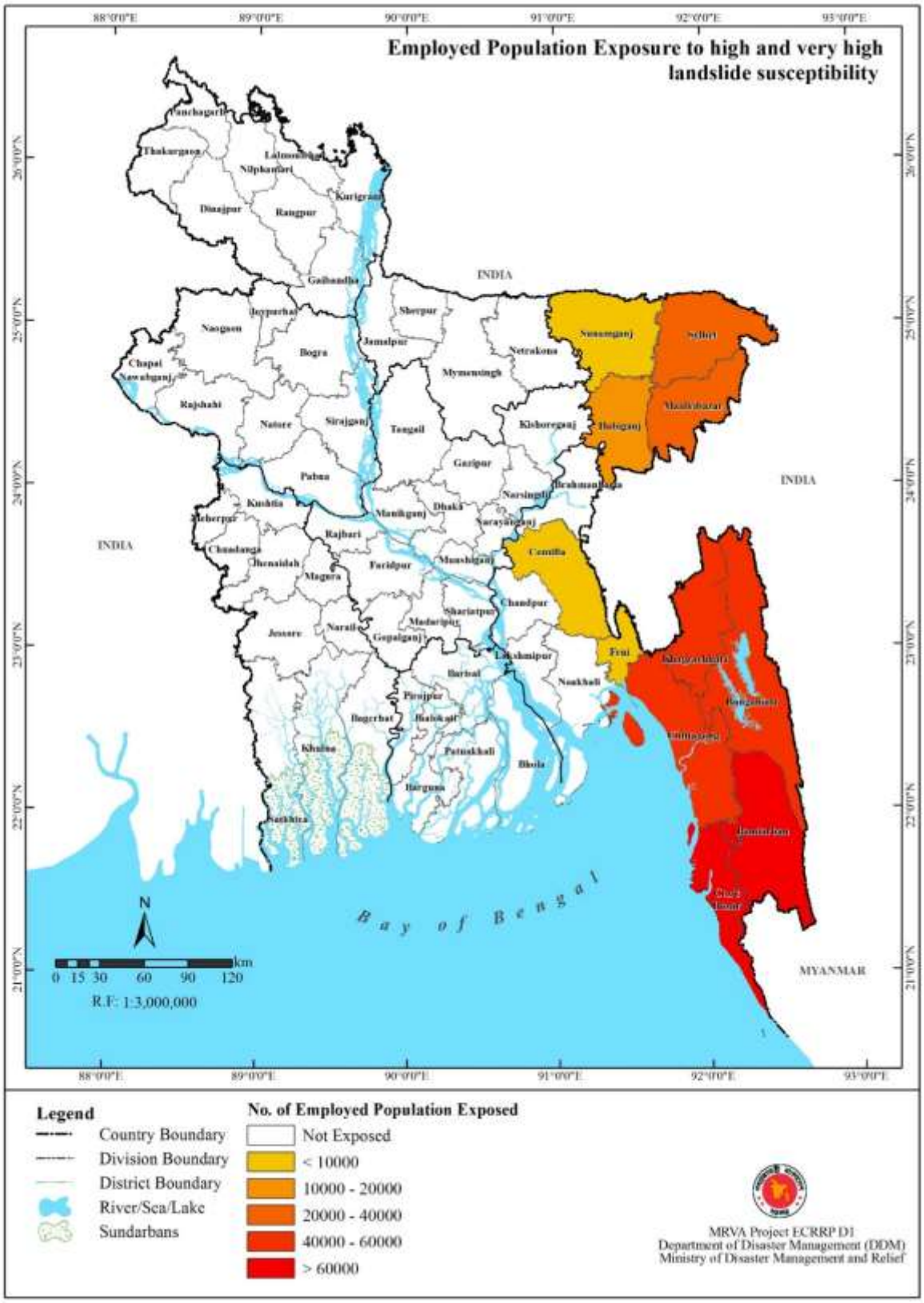


Figure 4.10: Employed population exposed to landslide susceptibility at district level

4.1.1.5 Education

Details of literate population are given in section 1.1.5 of Volume III of this report, Literate Population (male and female) exposed to high and very high landslide susceptibility at district level is given in table 4.6 and shown in figure 4.11. Total literate population distribution at district level is shown in figure 4.12.

Table 4.6: Literate population exposed to landslide susceptibility

Division	District	Number of Literate Population exposed to Landslide susceptibility			
		High		Very High	
		Male	Female	Male	Female
Chittagong	Bandarban	61,998	43,243	16,792	11,713
	Chittagong	344,295	314,395	7,388	6,746
	Comilla	11,359	12,062	-	-
	Cox's Bazar	216,146	196,261	24,229	22,000
	Feni	150	153	-	-
	Khagrachhari	133,850	98,913	4,372	3,231
	Rangamati	132,431	89,751	10,712	7,260
Sylhet	Habiganj	26,607	25,431	-	-
	Maulvibazar	116,305	112,666	13,241	12,827
	Sunamganj	8,072	7,216	23	21
	Sylhet	99,897	90,264	31,677	28,622

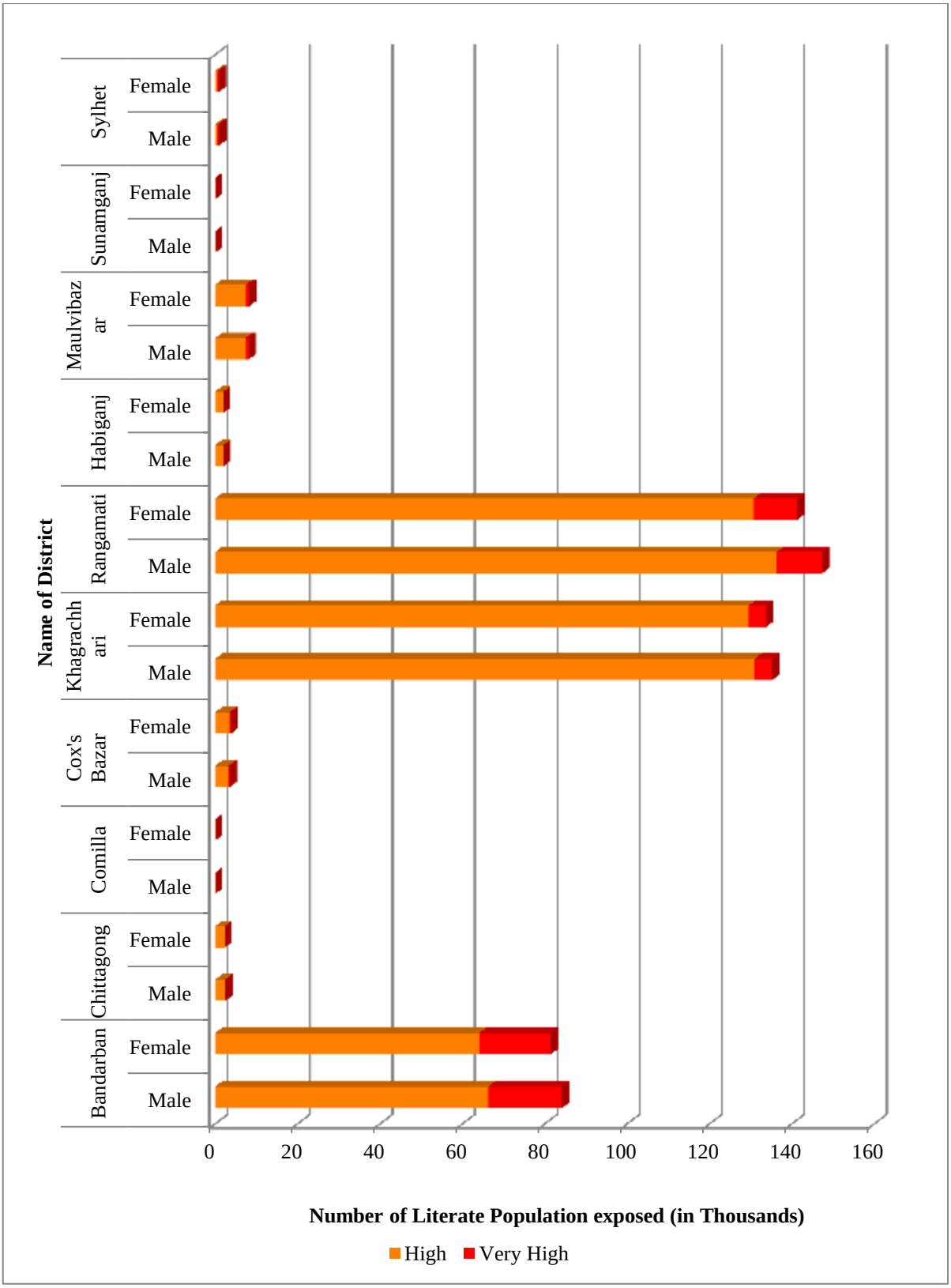


Figure 4.11: Literate population exposed to landslide susceptibility at district level

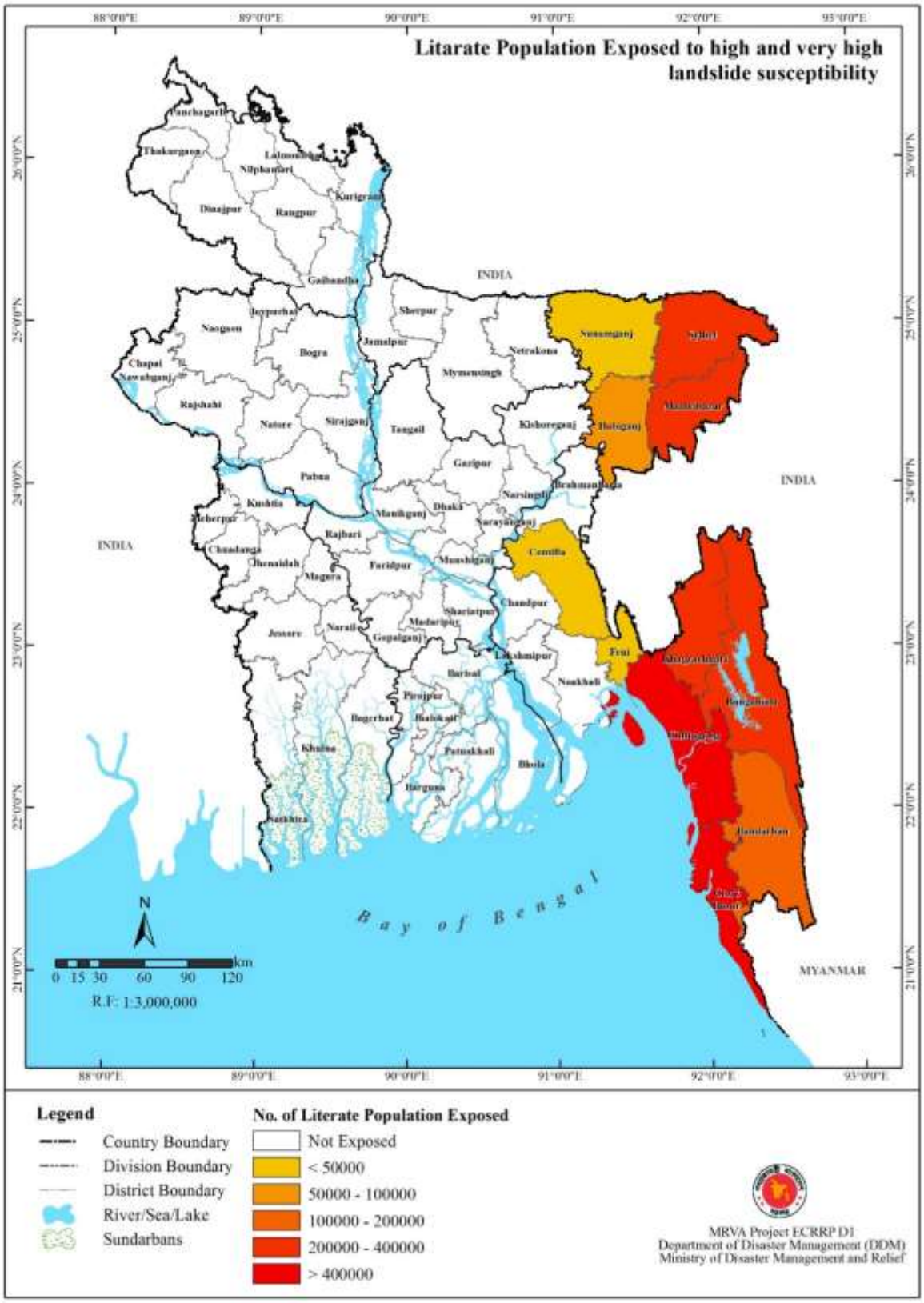


Figure 4.12: Literate population exposed to landslide susceptibility at district level

4.1.1.6 Disability

Details of population with disability are given in section 1.1.6 of Volume – III of this report, Disability of population mentioned are Speech, Vision, Hearing, Physical, Mental, and Autism. Population with disability exposed to high and very high categories landslide susceptibility at division/district level is given table 4.7 and figure 4.13. Total disabled population exposed to high and very high landslide susceptibility in figure 4.14.

Table 4.7: Population with disability exposed to Landslide susceptibility

Division	District	Number of Population with disability exposed to Landslide susceptibility							
		High				Very High			
		Vision	Physical	Mental	Autism	Vision	Physical	Mental	Autism
Chittagong	Bandarban	881	1,469	588	294	239	398	159	80
	Chittagong	2,236	5,590	2,236	1,118	48	120	48	24
	Comilla	88	220	88	44	-	-	-	-
	Cox's Bazar	3,150	5,251	2,100	1,050	353	589	235	118
	Feni	1	3	1	1	-	-	-	-
	Khagrachhari	1,514	3,028	1,009	505	49	99	33	16
	Rangamati	1,788	2,682	1,341	447	145	217	108	36
Sylhet	Habiganj	385	642	257	128	-	-	-	-
	Maulvibazar	1,345	2,690	897	448	153	306	102	51
	Sunamganj	175	218	87	44	1	1	0	0
	Sylhet	743	1,857	743	371	235	589	235	118

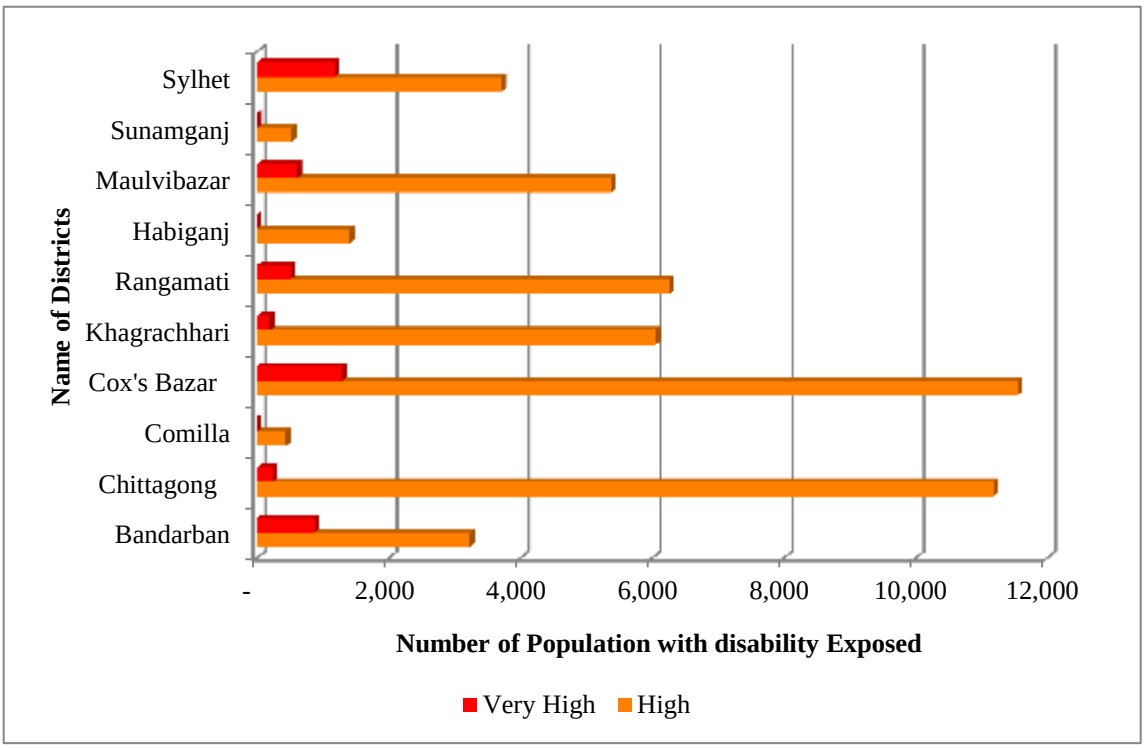


Figure 4.13: Population with disability exposed to landslide susceptibility at district level

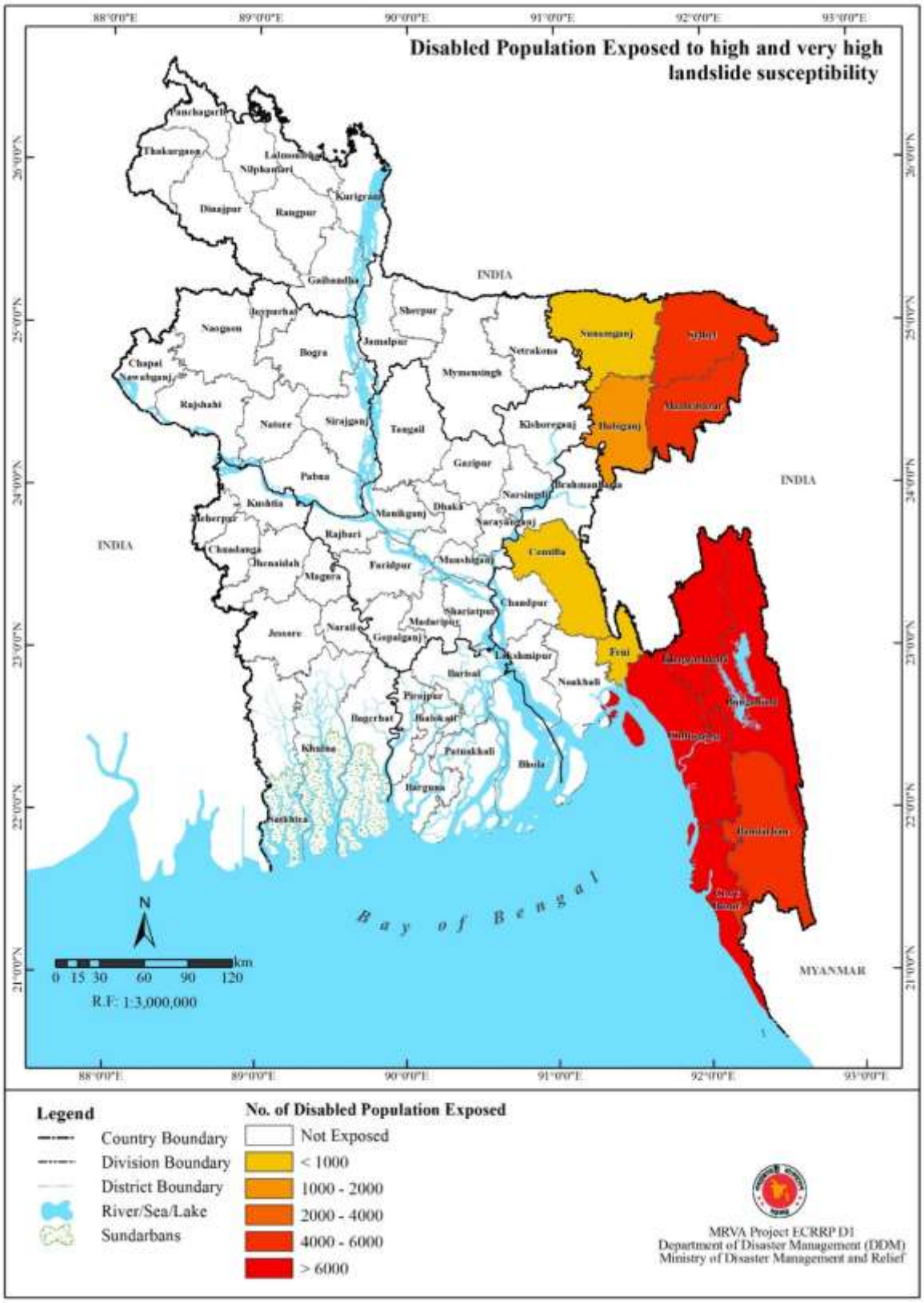


Figure 4.14: Number of disabled people exposed to landslide susceptibility at district level

4.1.1.7 Poverty

As explained in section 1.1.7 of volume III of this report, population in extreme poor and poor categories exposed to high and very high landslide susceptibility categories is given in table 4.8 and shown in figure 4.15. Poor population exposed to high and very high landslide susceptibility categories at district level is shown in figure 4.16 and for extreme poor population in figure 4.17.

Table 4.8: Population (extreme poor and poor) exposed to Landslide susceptibility

Division	District	Number of Population exposed to Landslide susceptibility			
		High		Very High	
		Extreme Poor	Poor	Extreme Poor	Poor
Chittagong	Bandarban	322,340	644,680	87,307	174,614
	Brahmanbaria	-	-	-	-
	Chandpur	-	-	-	-
	Chittagong	166,856	299,707	3,580	6,431
	Comilla	3,025	6,106	-	-
	Cox's Bazar	96,233	170,715	10,787	19,136
	Feni	22	55	-	-
	Khagrachhari	257,234	443,409	8,402	14,484
	Lakshmipur	-	-	-	-
	Noakhali	-	-	-	-
	Rangamati	442,617	1,418,181	35,803	114,717
Sylhet	Habiganj	24,893	30,320	-	-
	Maulvibazar	118,765	149,897	13,522	17,066
	Sunamganj	11,851	14,646	34	42
	Sylhet	100,273	137,718	31,796	43,669

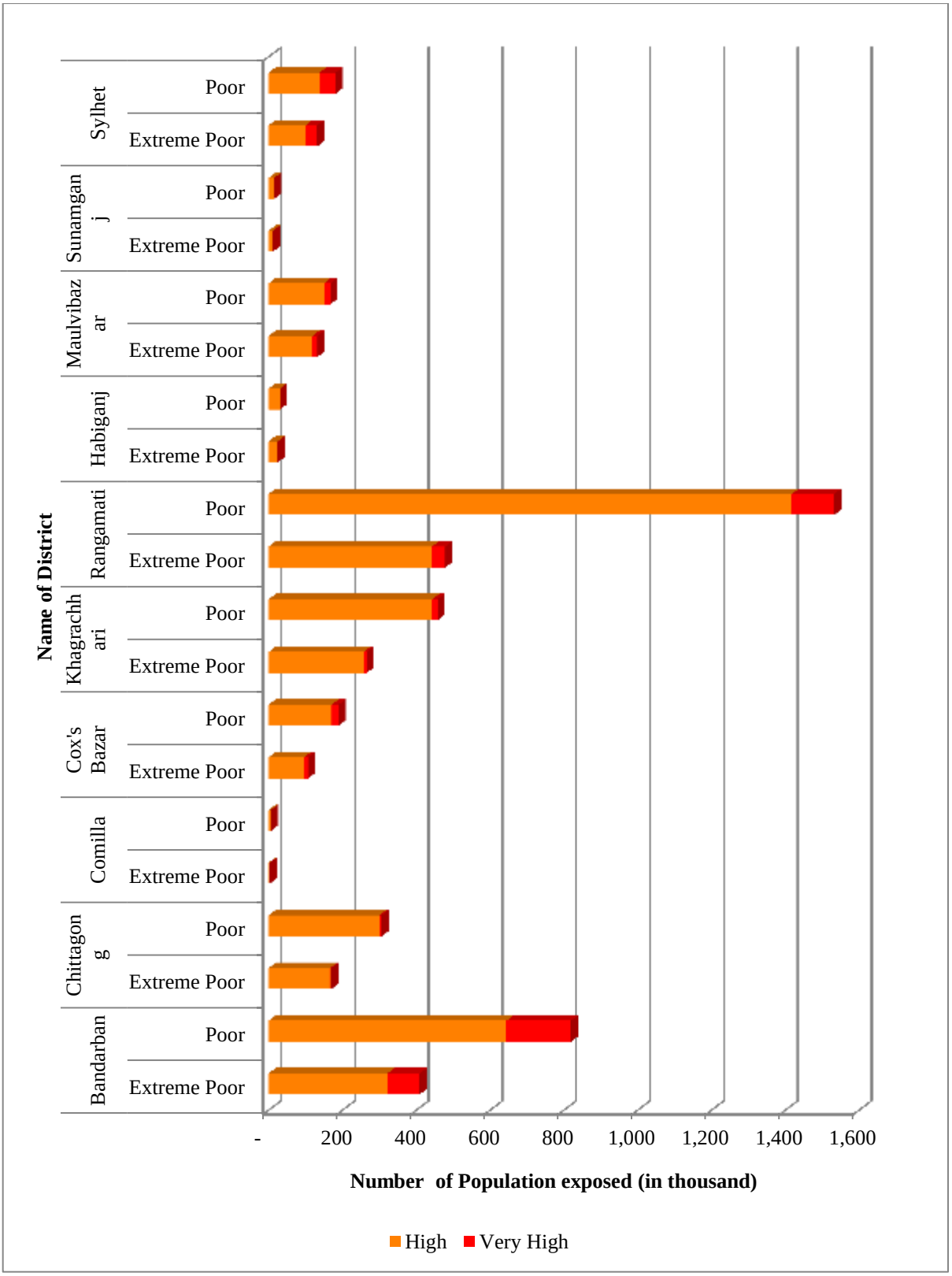


Figure 4.15: Number of Population (extreme poor and poor) exposed to landslide susceptibility at district level

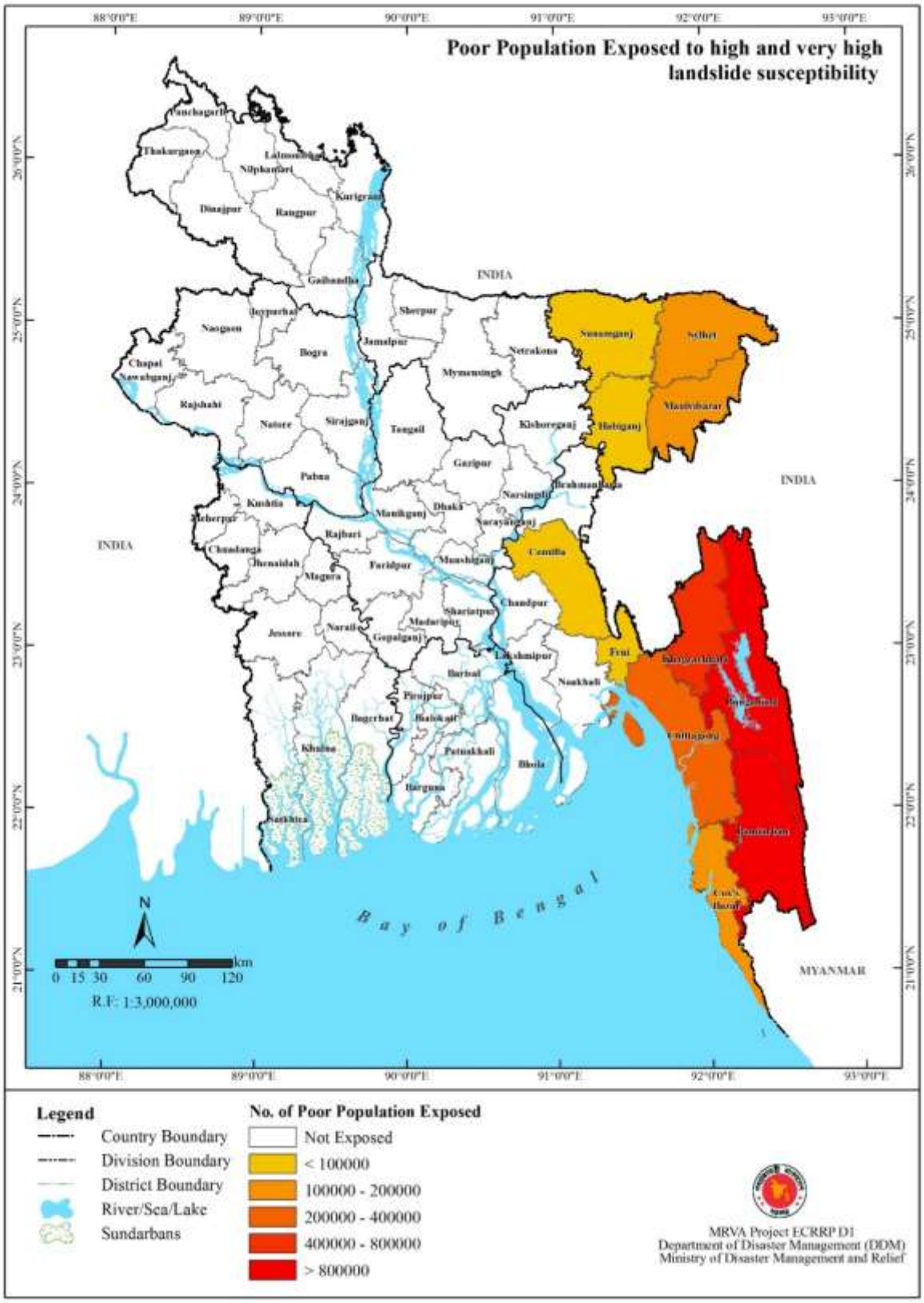


Figure 4.16: Poor Population exposed to landslide susceptibility at district level

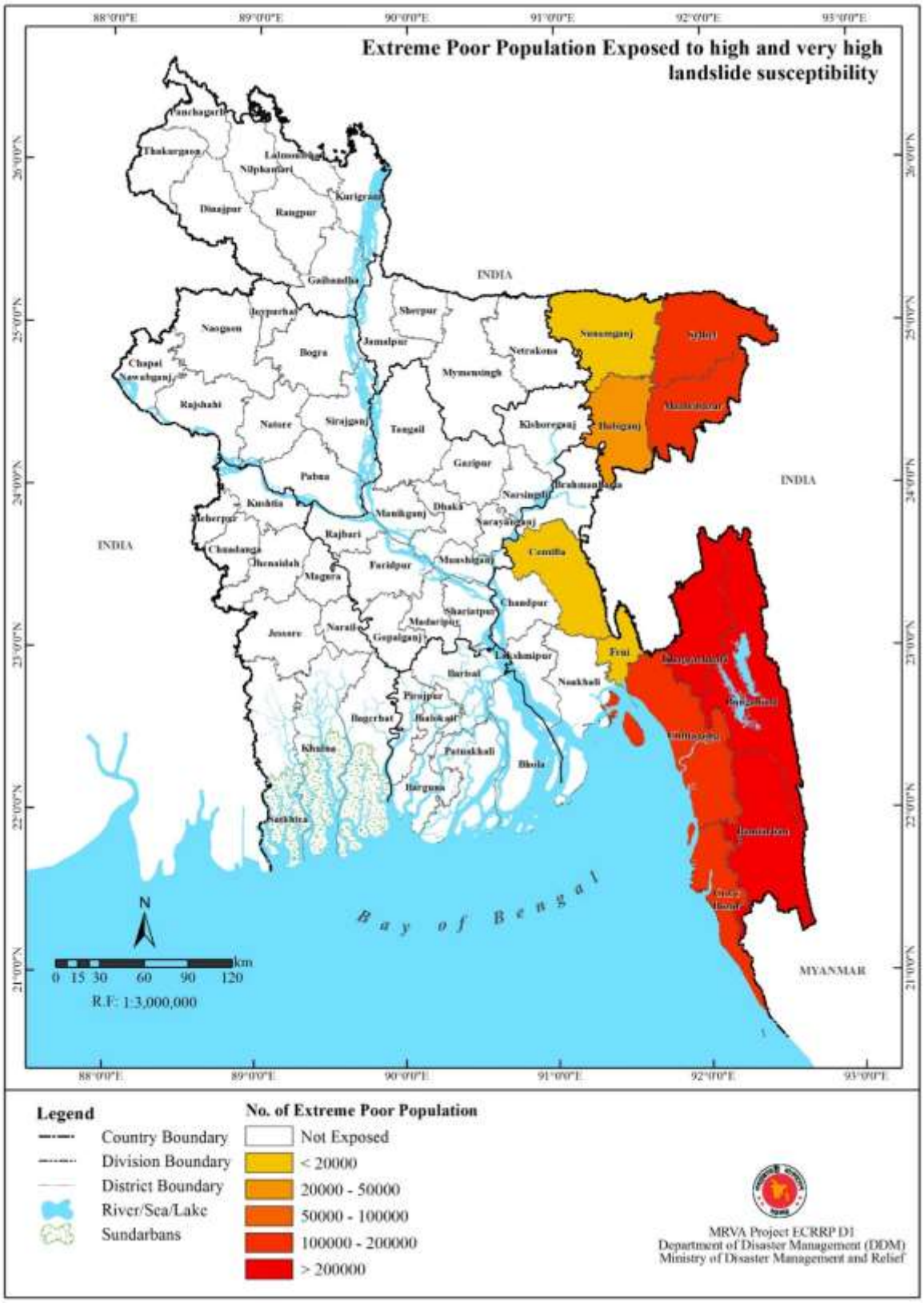


Figure 4.17: Extreme Poor Population exposed to landslide susceptibility at district level

4.1.2 Housing

As mentioned in section 1.2.1 of volume III of this report, household structure types are Pucca, Semi-Pucca, Katcha, Jhupri. Exposure of the household structures to landslide susceptibility is assessed by combining landslide susceptibility and household structure maps. Number of Pucca, Semi-Pucca, Katcha, Jhupri household structures in high and very high landslide susceptibility category in each division/district is given in table 4.9 and shown figure 4.18. Distribution of exposed pucca household structures to high ad very high landslide susceptibility at district level is shown in figure 4.19, semi-pucca in figure 4.20, katcha in figure 4.21, jhupri in figure 4.22.

Table 4.9: Number of household structures exposed to landslide susceptibility

Division	District	Number of household structures exposed to Landslide susceptibility							
		High				Very High			
		Pucca	Semi-Pucca	Katcha	Jhupri	Pucca	Semi-Pucca	Katcha	Jhupri
Chittagong	Bandarban	2,182	3,273	51,571	3,575	591	886	13,968	968
	Chittagong	56,220	46,325	108,617	13,718	1,206	994	2,331	294
	Comilla	850	1,349	6,280	112	-	-	-	-
	Cox's Bazar	11,826	22,126	131,422	25,369	1,326	2,480	14,732	2,844
	Feni	16	17	63	1	-	-	-	-
	Khagrachhari	2,419	7,697	95,556	4,289	79	251	3,121	140
	Rangamati	4,626	7,903	78,736	5,108	374	639	6,369	413
Sylhet	Habiganj	1,306	4,425	17,651	798	-	-	-	-
	Maulvibazar	10,209	24,637	47,417	2,109	1,162	2,805	5,399	240
	Sunamganj	514	912	6,039	327	1	3	17	1
	Sylhet	13,986	20,108	29,002	1,353	4,435	6,376	9,196	429

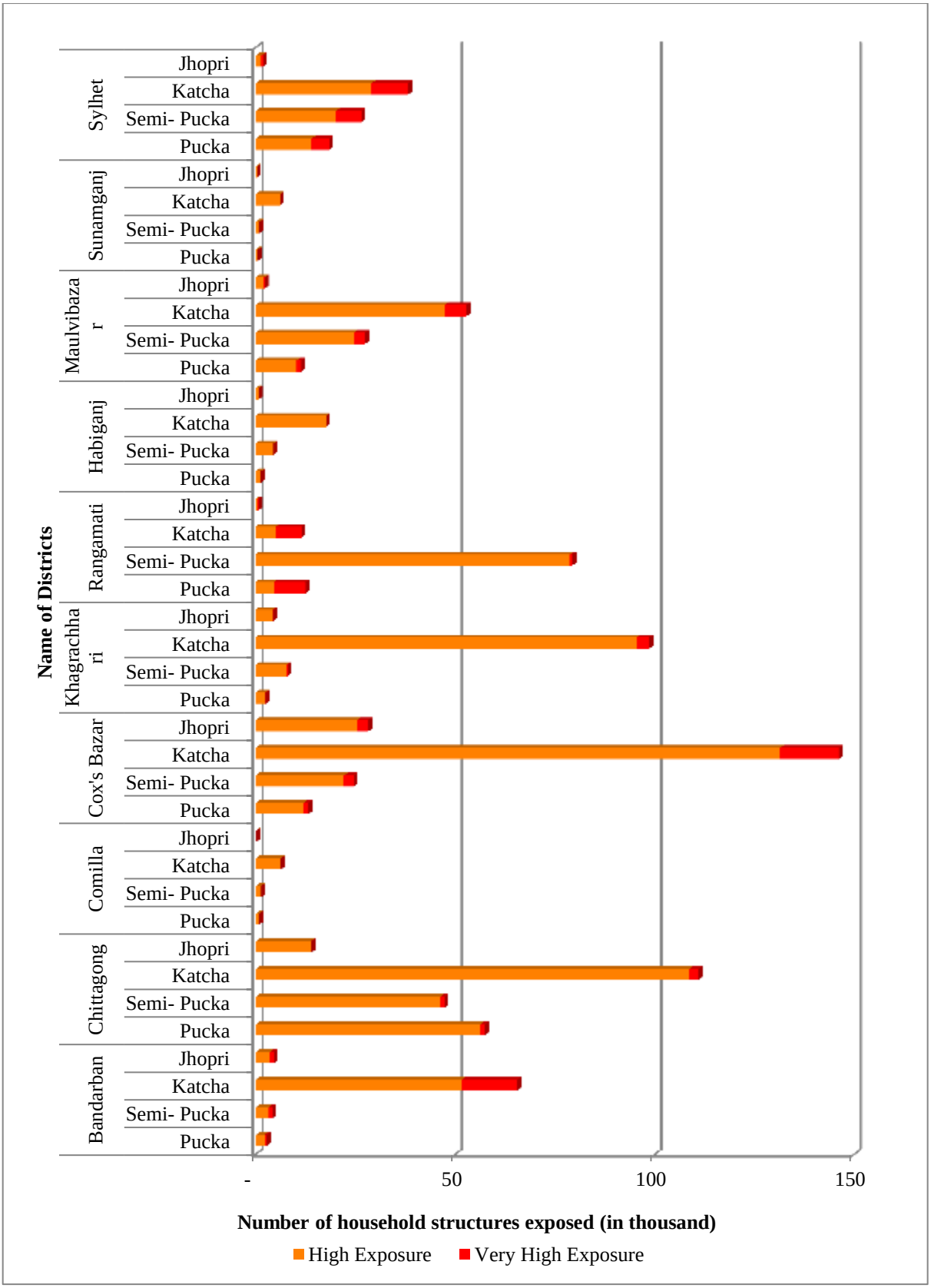


Figure 4.18: Number of household structures exposed to landslide susceptibility at district level

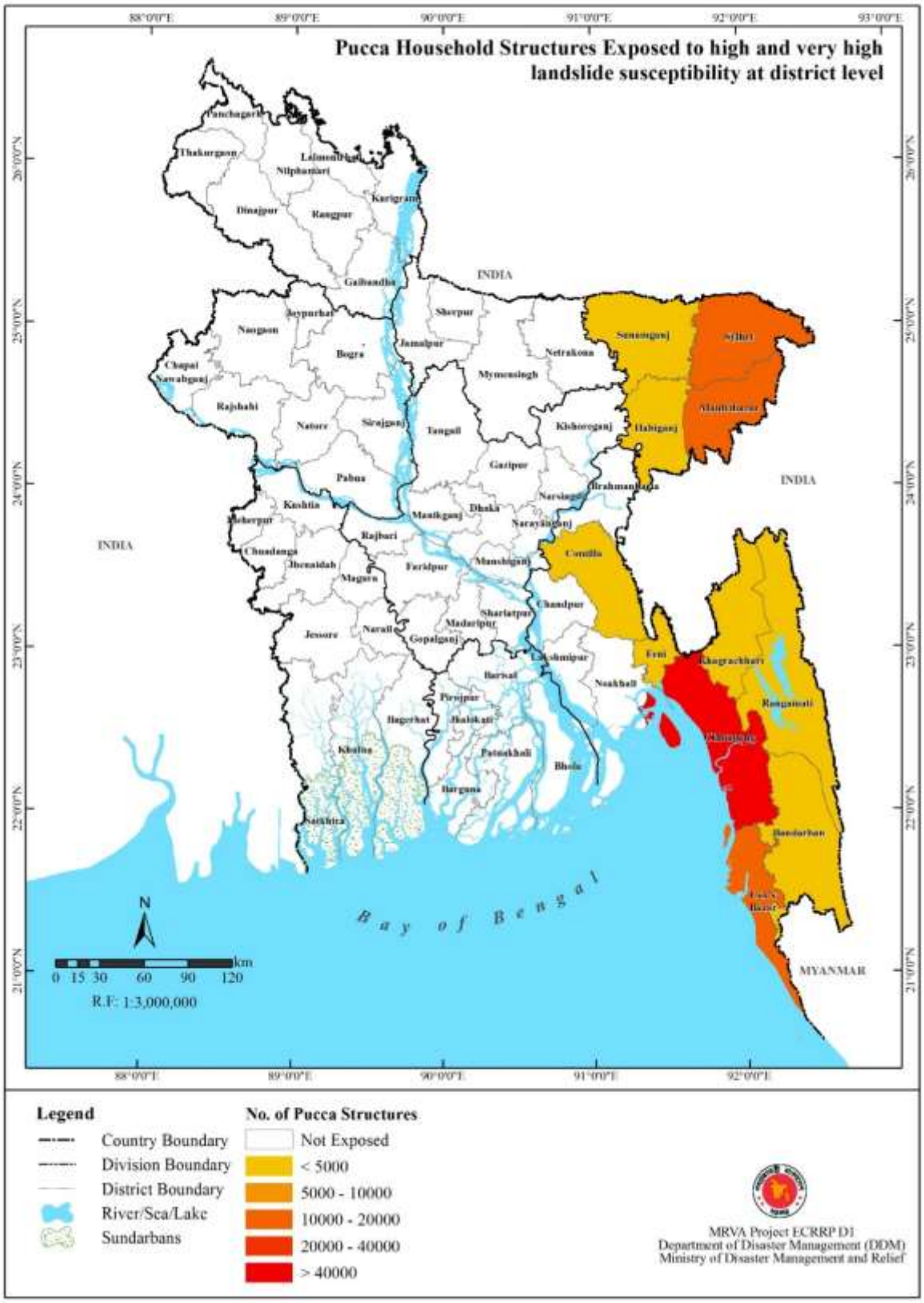


Figure 4.19: Pucca household structures exposed to high and very high landslide susceptibility at district level

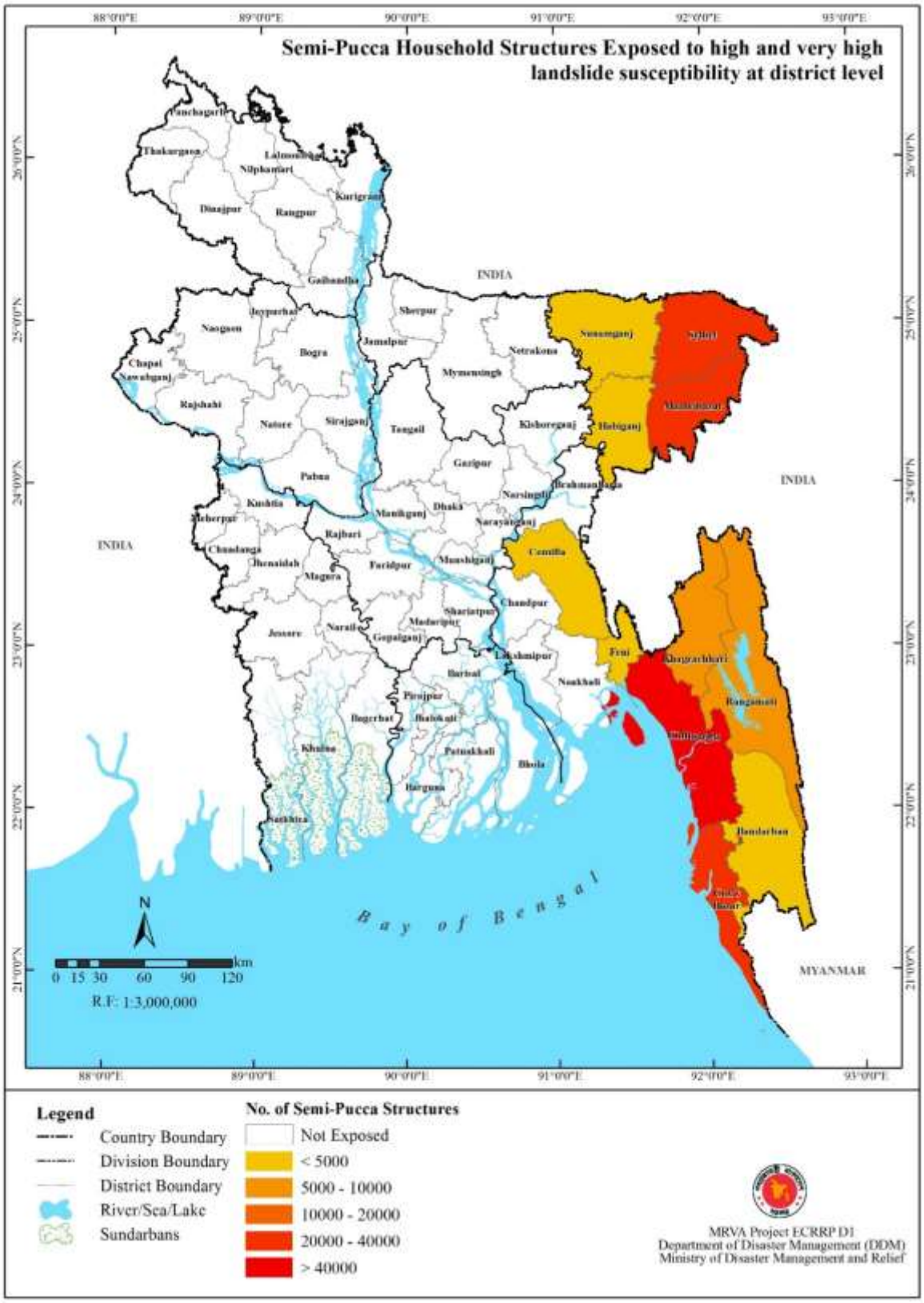


Figure 4.20: Semi-Pucca household structures exposed to high and very high landslide susceptibility at district level

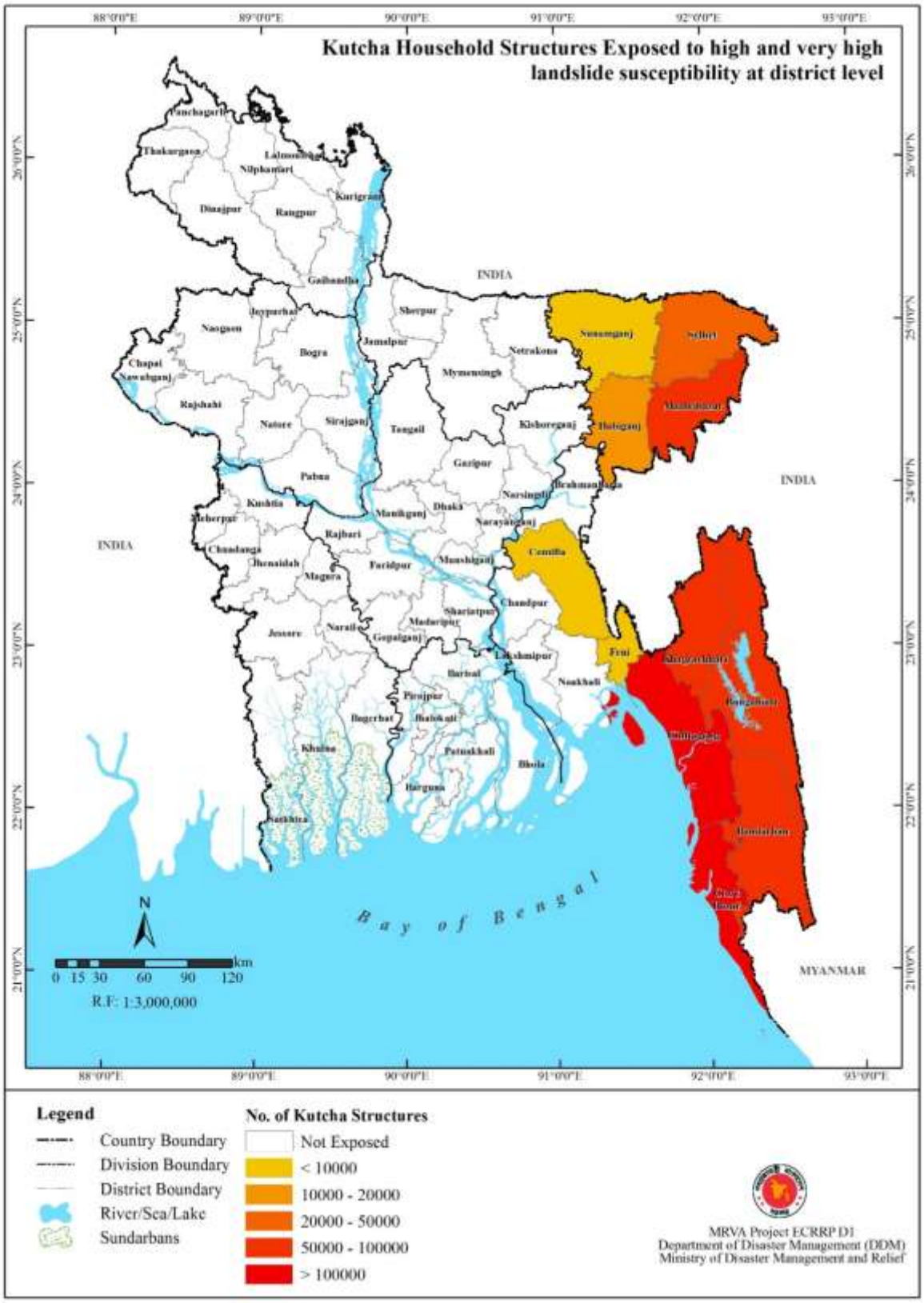


Figure 4.21: Kutcha household structures exposed to high and very high landslide susceptibility at district level

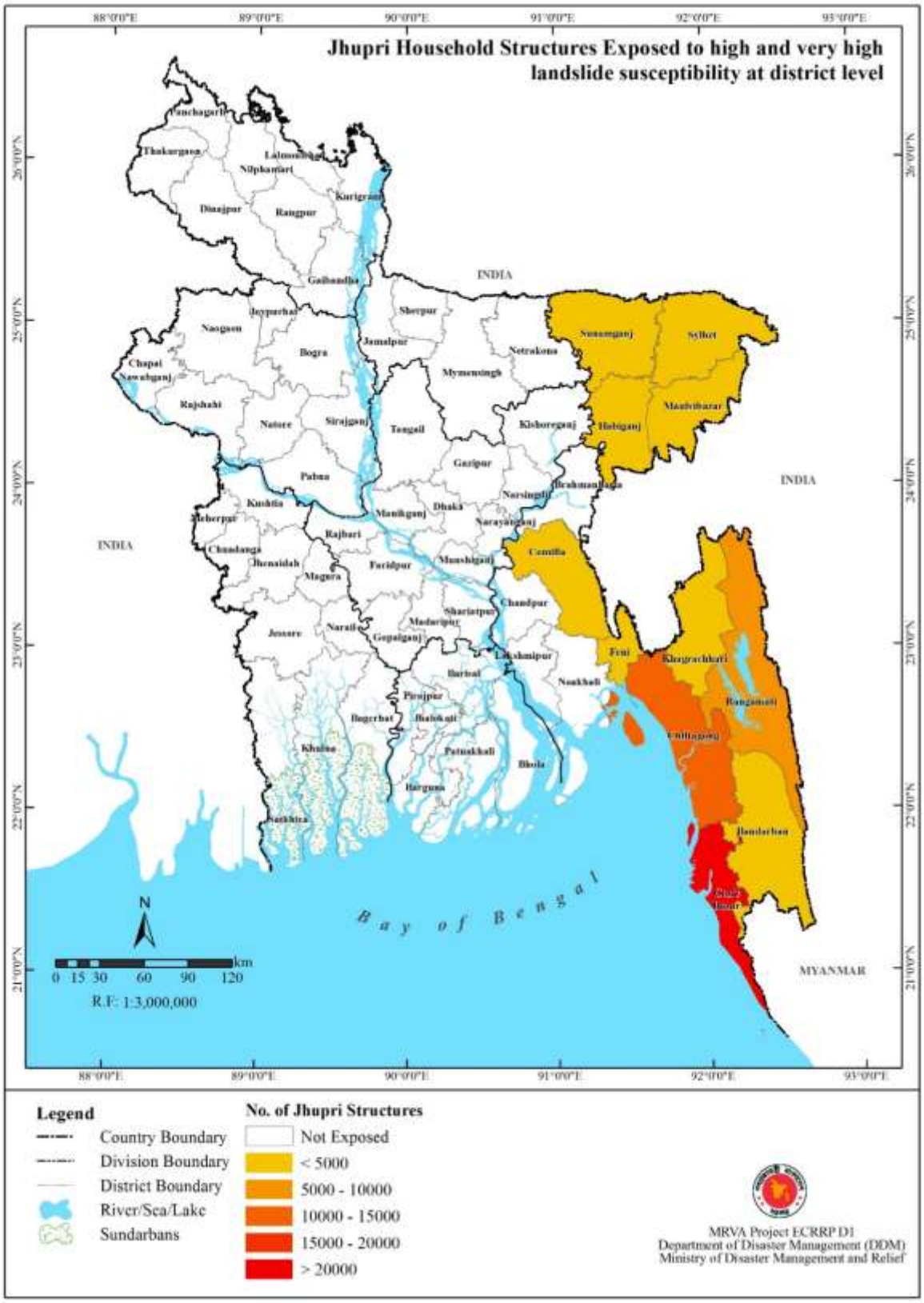


Figure 4.22: Jhupri household structures exposed to high and very high landslide susceptibility at district level

4.1.3 Livelihood

Elements at risk considered in livelihood are crop (transplanted Aman) and industries.

4.1.3.1 Agriculture

As explained in section 1.3.1, transplanted Aman crop data is used for assessing the exposure of livelihood. Landslide susceptibility map and transplanted aman crop map were overlaid for exposure assessment. Exposed transplanted aman crop area (km^2) to high and very high landslide susceptibility category in each division / district is given table 4.10 and shown in figure 4.23. Distribution of exposed transplanted aman crop is shown in figure 4.24.

Table 4.10: Exposed transplanted aman crop area (Km^2) in each district

Division	District	Transplanted aman crop area (Km^2) exposed to Landslide susceptibility	
		High	Very High
Chittagong	Bandarban	2.36	0.11
	Chittagong	309.15	2.62
	Comilla	22.67	-
	Cox's Bazar	240.57	14.64
	Feni	3.99	-
	Rangamati	12.91	0.82
Sylhet	Habiganj	3.24	-
	Maulvibazar	156.10	0.46
	Sunamganj	35.48	0.13
	Sylhet	231.87	45.95

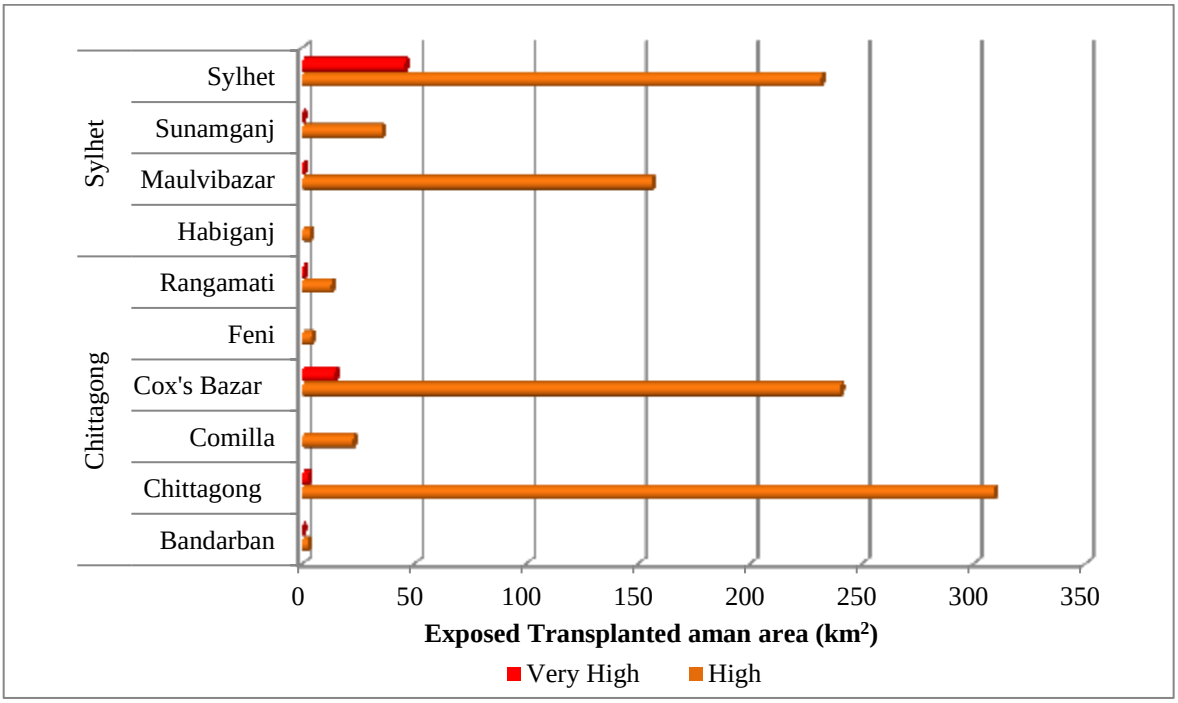


Figure 4.23: Transplanted aman crop area (km^2) exposed to landslide susceptibility at district level

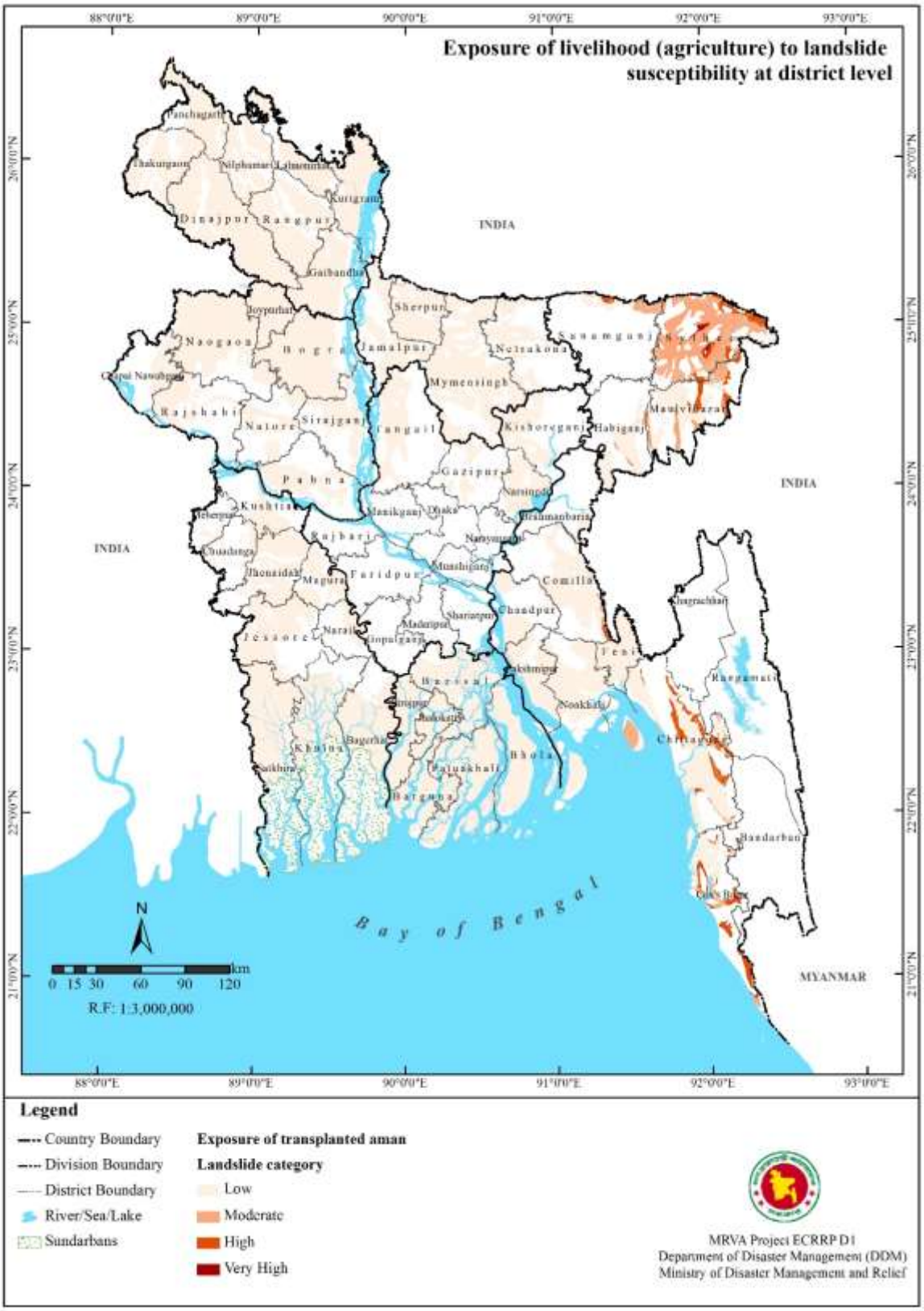


Figure 4.24: Exposure of Livelihood (agriculture) aman area to landslide susceptibility at district level

4.1.3.2 Industries

The different types of industries (Food Godowns, Mills, Gas Field, Cold Storage, Cottage Industries, Rice/Oil/Grain mills) existing in the database are assessed for their existence in landslide susceptible areas.

The number of food godowns existing in high and very high landslide susceptible categories at district / division level is given in table 4.11 and figure 4.25.

Table 4.11: Number of food godowns exposed to landslide susceptibility

Division	District	Number of food godowns exposed to Landslide susceptibility	
		High	Very High
Chittagong	Bandarban	7	1
	Chittagong	5	0
	Cox's Bazar	4	0
	Khagrachhari	7	0
	Rangamati	5	0
Sylhet	Habiganj	1	0
	Maulvibazar	4	0
	Sylhet	2	0

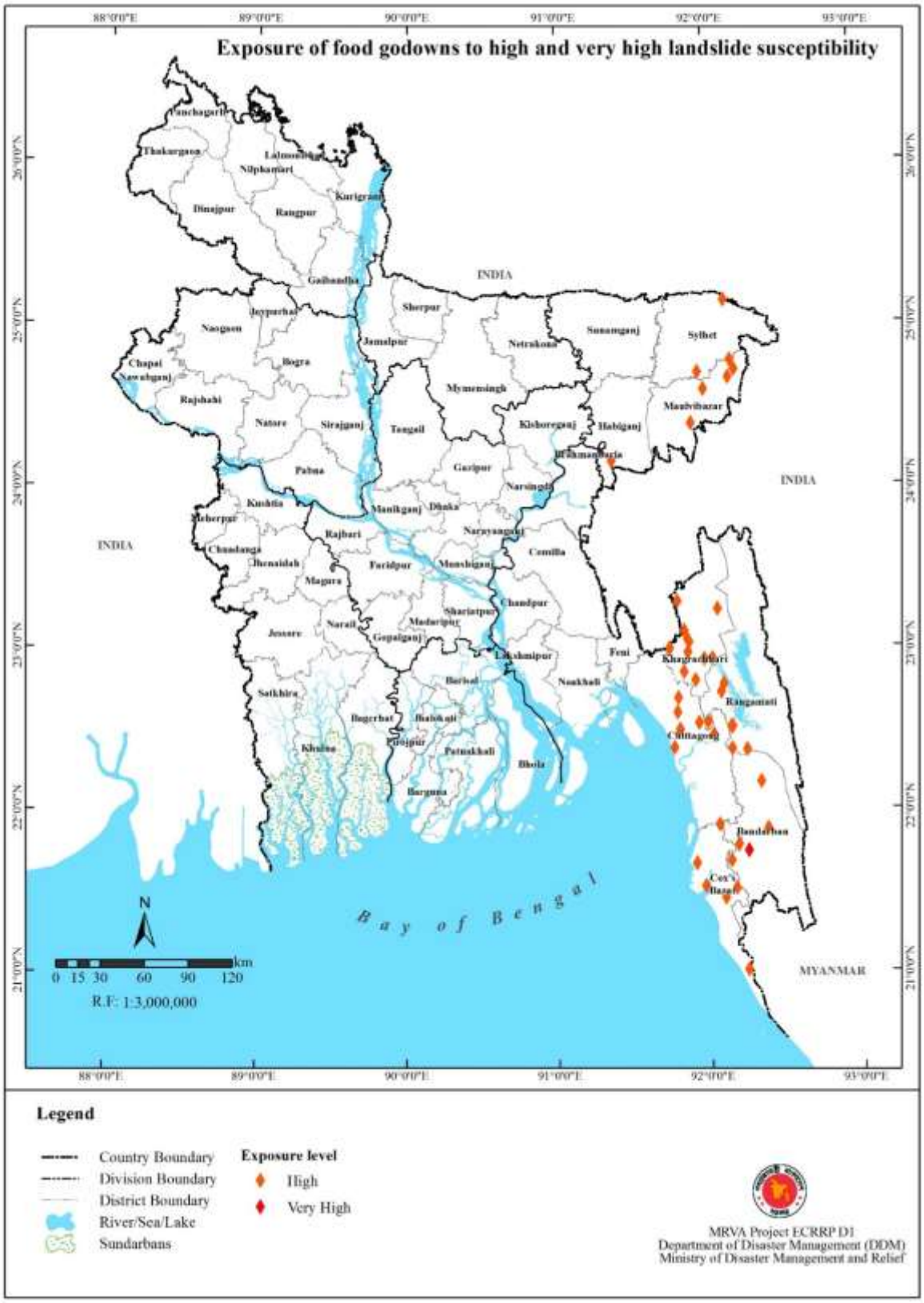


Figure 4.25: Exposure of food godowns to high and very high landslide susceptibility

4.1.4 Critical Facilities

4.1.4.1 Health care facilities

Combining landslide susceptibility map and health care facility map will provide existing hospitals and family welfare centers in landslide susceptibility prone areas.

The number of hospitals and family welfare centres existing in high and very high landslide susceptibility areas at division/district level is given in table 4.12. Hospitals existing in different landslide susceptibility prone areas at district level is shown in figure 4.26 and family welfare centres in figure 4.27.

Table 4.12: Number of health care facilities exposed to Landslide susceptibility

Division	District	Number of hospital facilities exposed to Landslide susceptibility			
		High		Very High	
		Hospitals	Family Welfare Centre	Hospitals	Family Welfare Centre
Chittagong	Bandarban	6	8		2
	Chittagong		8		
	Comilla		1		
	Cox's Bazar	4	6	1	
	Khagrachhari	4	5		
	Rangamati	8	9	1	
Sylhet	Habiganj		2		
	Maulvibazar	2	8		
	Sunamganj		1		
	Sylhet	2	4		

Figure 4.26: Exposure of hospitals to high and very high landslide susceptibility

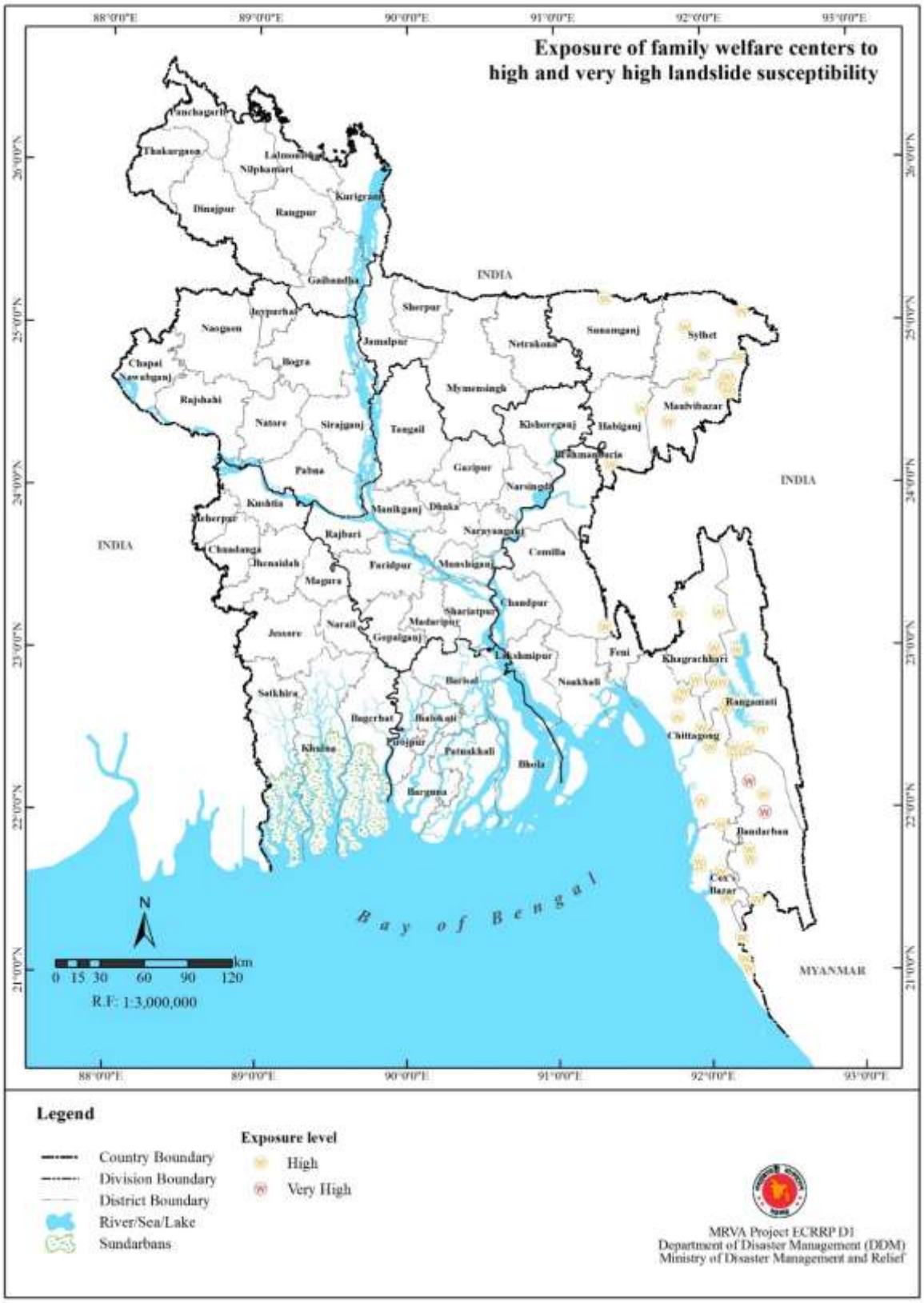


Figure 4.27: Exposure of family welfare centers to high and very high landslide susceptibility

4.1.4.2 Educational Institutions

Educational institutions database consists of categories of educational institutions as University, College, High School, Madrasa, Primary Schools. Combining landslide susceptibility map and educational institutions map will provide existing Educational institutions in landslide susceptible areas. No University, College exists in landslide susceptible areas. The number of High School, Madrasa, Primary Schools existing in high and very high landslide susceptible areas at division/district level is given in table 4.13. High School, Madrasa, Primary Schools existing in different landslide susceptible areas at district level is shown in figures 4.28, 4.29, 4.30.

Table 4.13: Number of educational institutions exposed to Landslide susceptibility

Division	District	Number of Educational Institutions exposed to Landslide susceptibility					
		High			Very High		
		High School	Madrasa	Primary School	High School	Madrasa	Primary School
Chittagong	Bandarban	18	38	242	5	17	67
	Brahmanbaria	0	0	0	0	0	0
	Chandpur	0	0	0	0	0	0
	Chittagong	43	19	192	0	0	1
	Comilla	5	2	15	0	0	0
	Cox's Bazar	31	6	133	1	1	18
	Feni	0	0	0	0	0	0
	Khagrachhari	33	11	283	0	0	7
	Lakshmipur	0	0	0	0	0	0
	Noakhali	0	0	0	0	0	0
	Rangamati	21	7	298	1	0	19
Sylhet	Habiganj	2	1	17	0	0	0
	Maulvibazar	18	28	99	4	1	18
	Sunamganj	1	3	14	0	0	0
	Sylhet	16	18	99	5	4	34

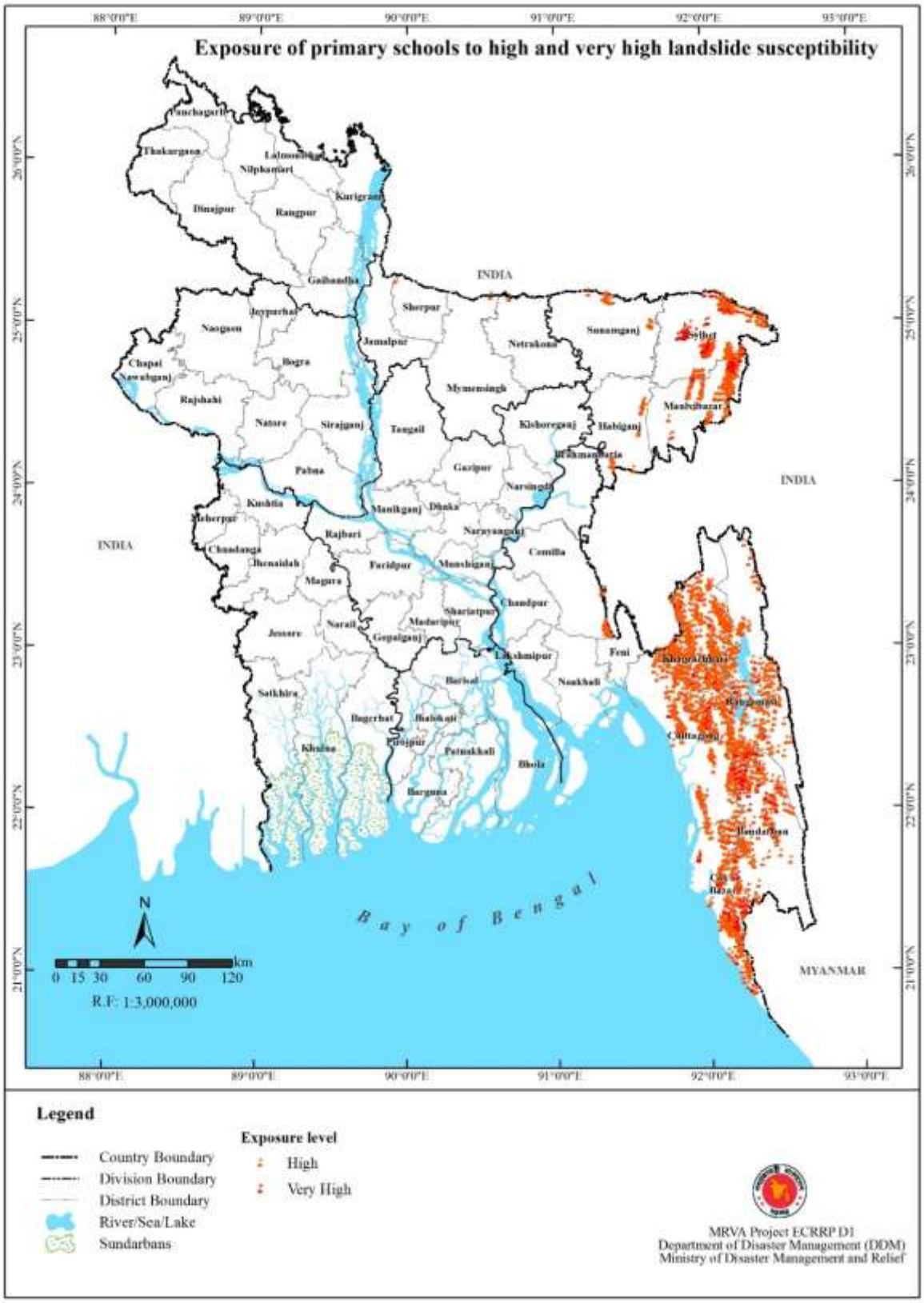


Figure 4.28: Exposure of primary schools to high and very high landslide susceptibility

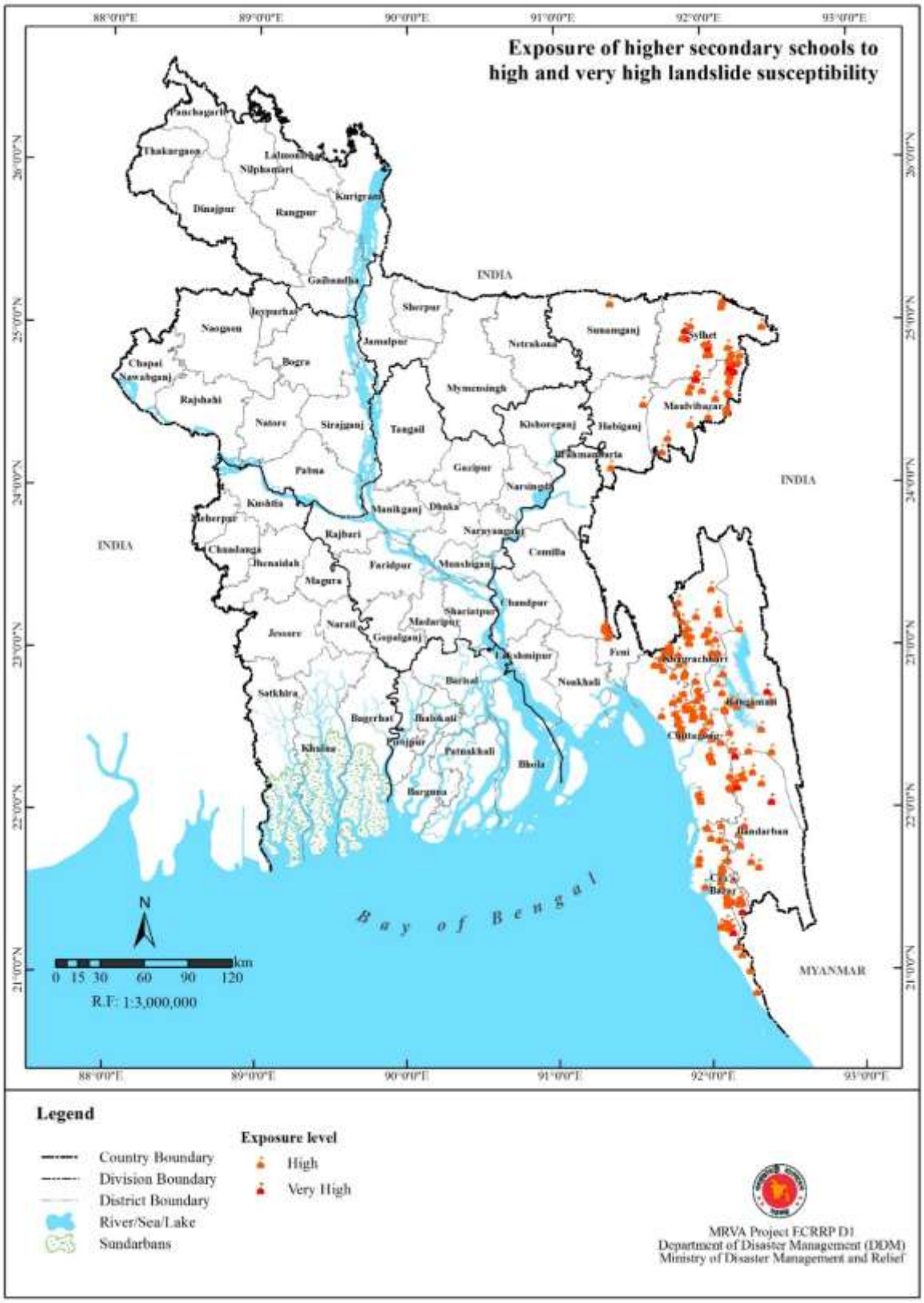


Figure 4.29: Exposure of high schools to high and very high landslide susceptibility

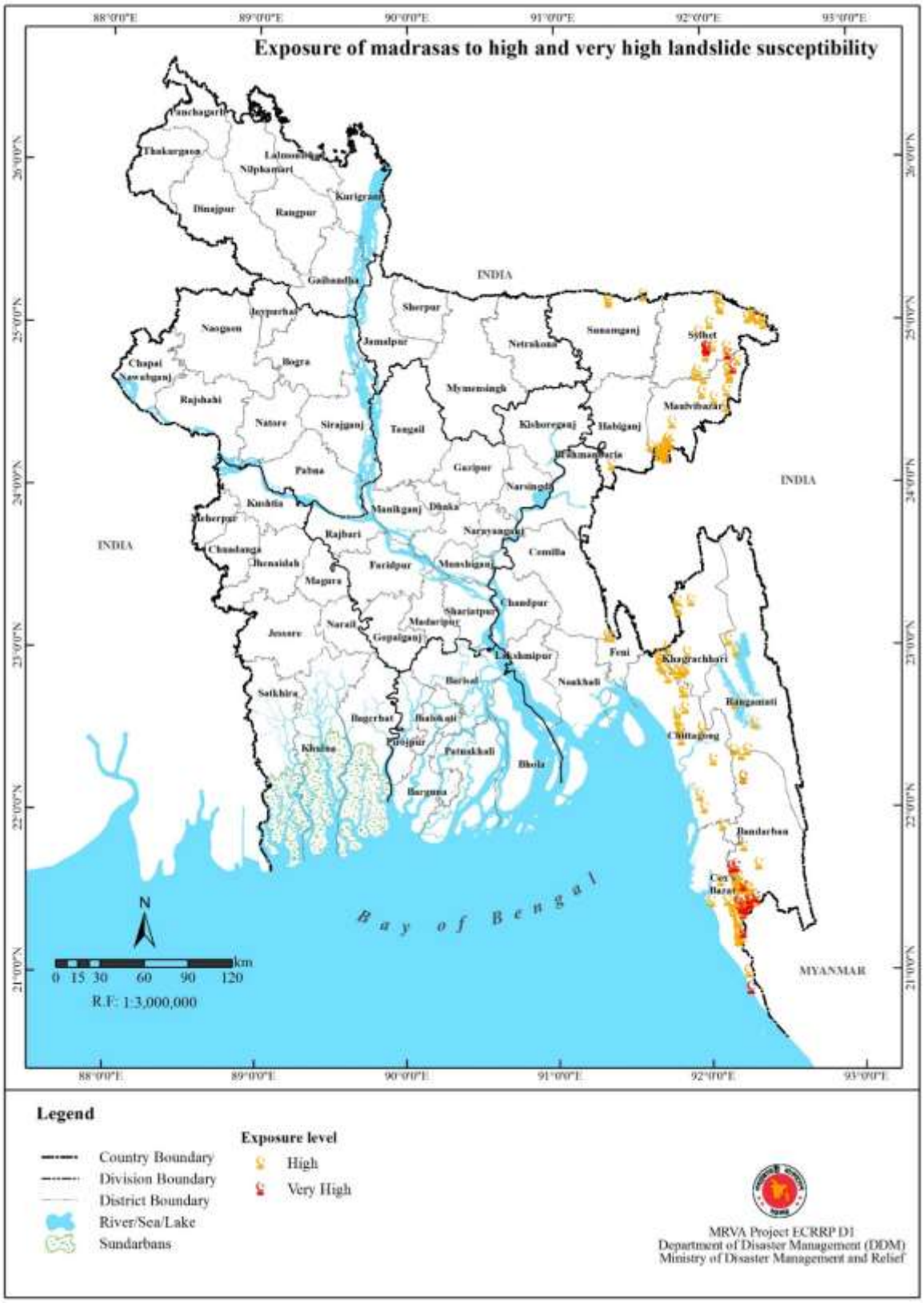


Figure 4.30: Exposure of madrasas stations to high and very high landslide susceptibility

4.1.4.3 First Responders

Fire and police stations

The number of Fire and Police stations existing in high and very high landslide susceptible areas at division/district level is given in table 4.14. Distribution of Fire and Police stations existing in high and very high landslide susceptible prone areas at district level is shown in figure 4.31 and figure 4.32.

Table 4.14: Number of fire and police stations exposed to Landslide susceptibility

Division	District	Number of Fire and Police stations exposed to Landslide susceptibility			
		High		Very High	
		Fire stations	Police Stations	Fire stations	Police Stations
Chittagong	Bandarban	1	192	0	49
	Brahmanbaria	0	0	0	0
	Chandpur	0	0	0	0
	Chittagong	2	30	0	0
	Comilla	0	19	0	0
	Cox's Bazar	0	41	0	4
	Feni	0	1	0	0
	Khagrachhari	0	137	0	4
	Lakshmipur	0	0	0	0
	Noakhali	0	0	0	0
	Rangamati	0	133	0	9
Sylhet	Habiganj	0	11	0	0
	Maulvibazar	1	34	0	5
	Sunamganj	0	16	0	0
	Sylhet	0	42	0	9

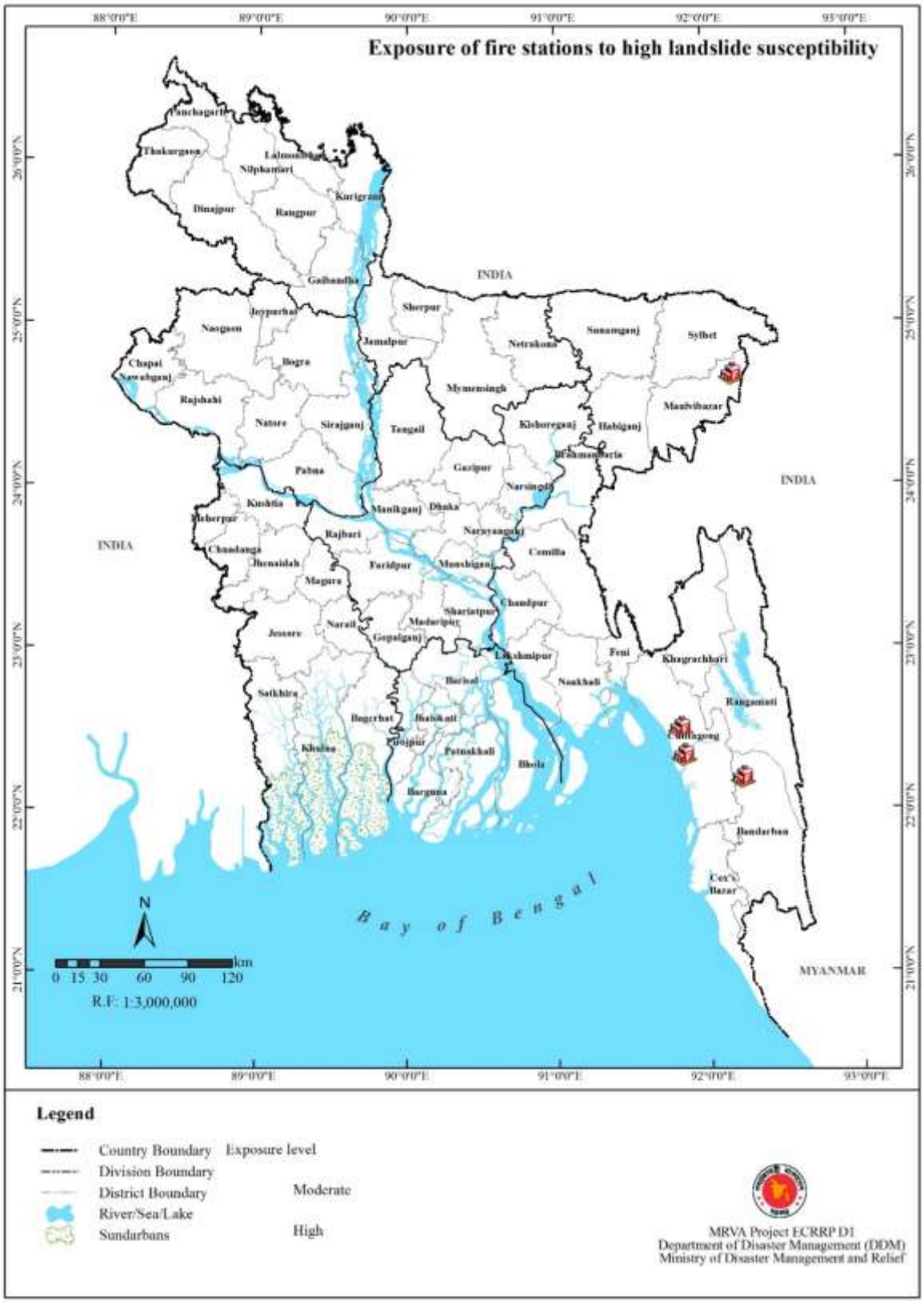


Figure 4.31: Exposure of fire stations to high and very high landslide susceptibility

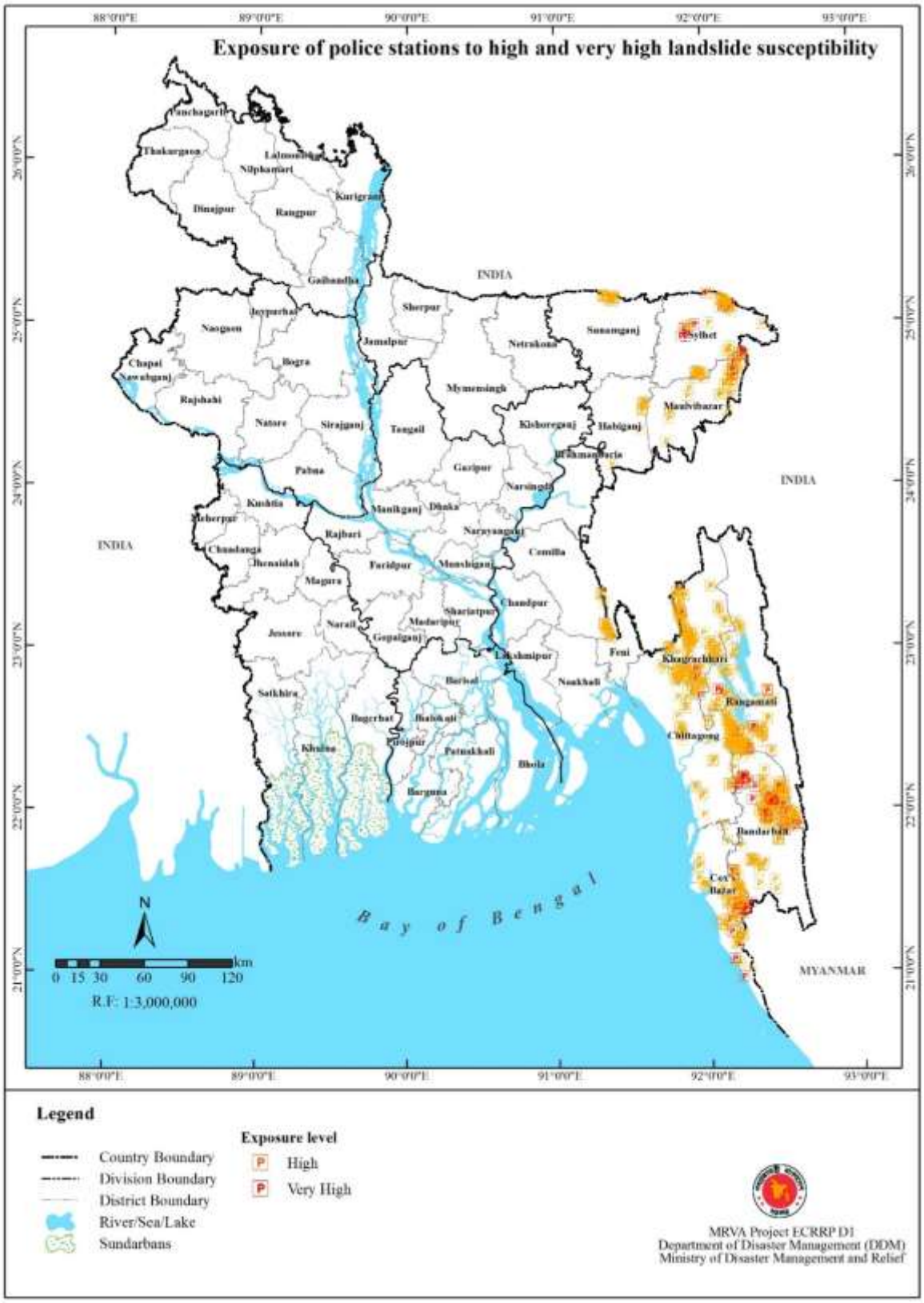


Figure 4.32: Exposure of police stations to high and very high landslide susceptibility

4.1.4.4 Cyclone Shelters

The number of Cyclone Shelters existing in high and very high landslide susceptible areas at division/district level is given in table 4.15. Cyclone Shelters existing in high and very high landslide susceptible areas at district level are shown in figure 4.33.

Table 4.15: Number of cyclone shelters exposed to Landslide susceptibility

Division	District	Number of Cyclone Shelters exposed to Landslide susceptibility	
		High	Very High
Chittagong	Chittagong	3	1
	Cox's Bazar	206	22

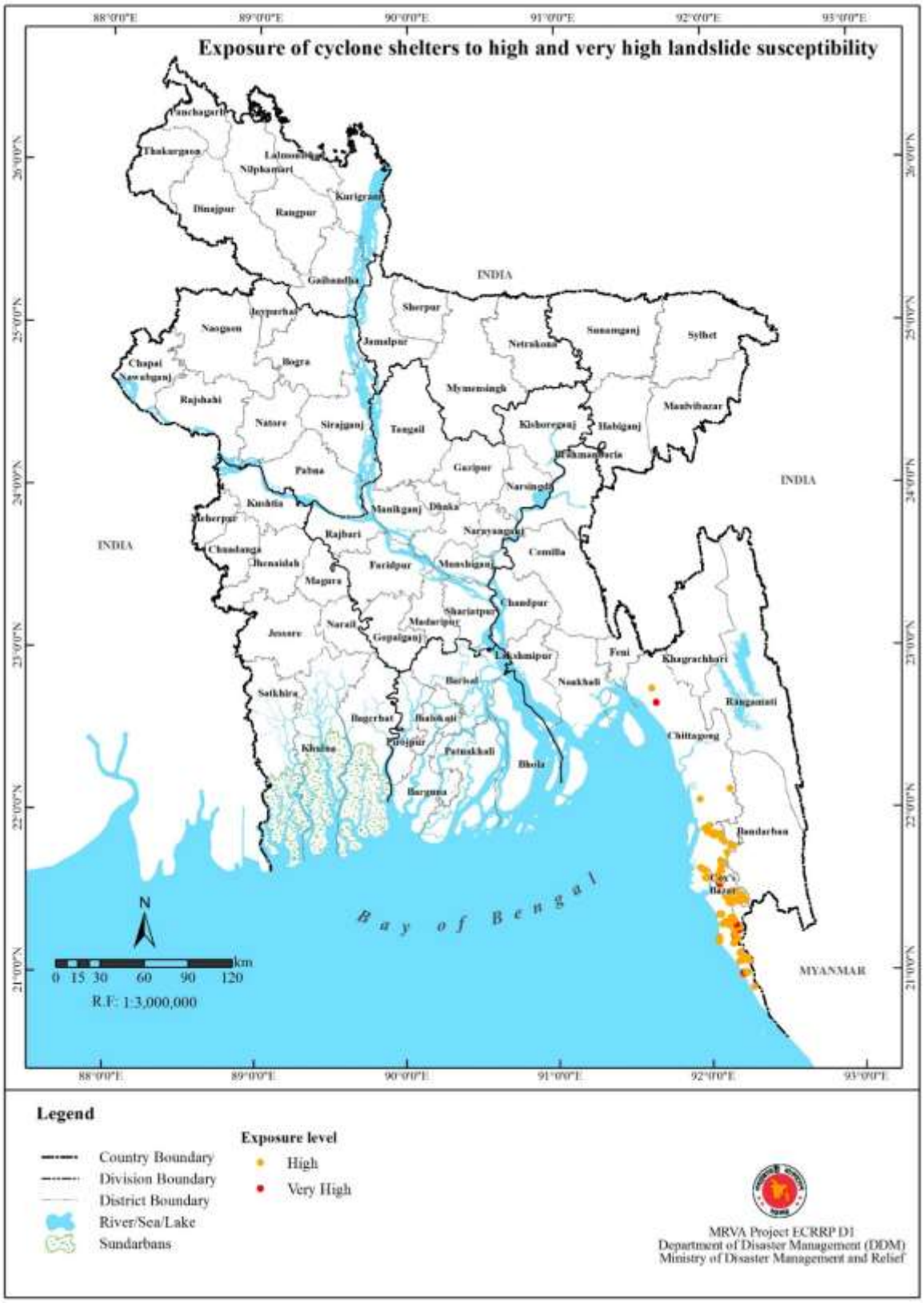


Figure 4.33: Exposure of cyclone shelters to high and very high landslide susceptibility

4.1.5 Infrastructure

4.1.5.1 Road

The type of roads existing in the database are, National Highway, Regional Highway, Municipal road, Upazila road, Union road and Village roads. Combining landslide susceptibility map and road network map will provide existing type of roads in landslide susceptibile areas.

The length of all categories of road existing in high and very high landslide susceptible areas at division/district level is given in table 4.16 and figure 4.34.

Table 4.16: Length of types of Road exposed to high and very high Landslide susceptibility

Division	District	Length of types of road exposed to Landslide susceptibility									
		High					Very High				
		National High Way	Regional High Way	Union Road	Upazilla Road	Village Road	National High Way	Regional High Way	Union Road	Upazilla Road	Village Road
Chittagong	Bandarban	2.2	116.7	336.9	204.1	972.4	1.4	36.5	73.6	51.9	220.0
	Chittagong	52.5	85.8	167.2	110.5	1359.2	0.8	2.2	1.5	1.4	22.7
	Comilla	6.8	1.9	13.2	8.4	82.4	0.0	0.0	0.0	0.0	0.0
	Cox's Bazar	14.9	165.4	138.9	167.6	945.1	2.7	12.1	14.5	17.4	104.2
	Feni	0.6	0.0	3.5	1.1	11.5	0.0	0.0	0.0	0.0	0.0
	Khagrachhari	58.1	157.0	199.9	165.6	1576.6	1.5	6.2	8.7	3.9	61.6
	Rangamati	63.6	74.3	331.8	301.8	1108.3	5.9	3.3	30.0	20.7	87.7
Sylhet	Habiganj	8.6	12.3	8.7	14.6	103.4	0.0	0.0	0.0	0.0	0.1
	Maulvibazar	0.2	58.4	139.1	100.0	587.8	0.0	2.8	20.1	9.0	72.1
	Sunamganj	0.0	0.0	18.7	9.0	34.7	0.0	0.0	0.2	0.0	0.3
	Sylhet	3.1	31.2	84.3	76.9	346.7	15.7	7.5	17.9	22.6	151.2

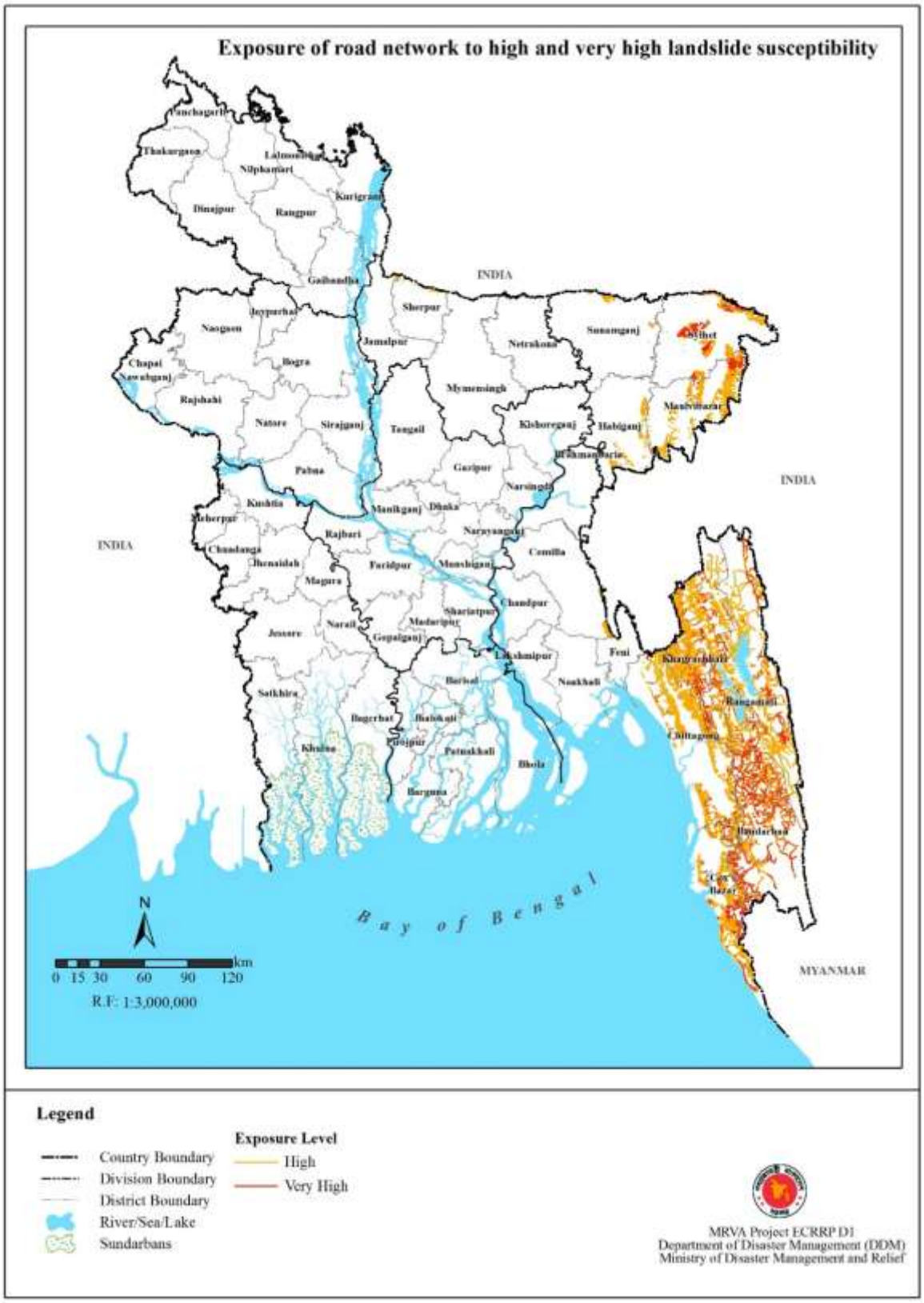


Figure 4.34: Exposure of road network to high and very high landslide susceptibility

4.1.5.2 Bridge

The number of bridges existing in high and very high landslide susceptible areas at division/district level is given in table 4.17. Exposure of bridges to landslide susceptibility at district level is shown in figure 4.35.

Table 4.17: Number of bridges exposed to Landslide susceptibility

Division	District	Number of Bridges exposed to Landslide susceptibility	
		High	Very High
Chittagong	Bandarban	8	0
	Chittagong	186	2
	Cox's Bazar	389	25
	Khagrachhari	2	0
	Rangamati	15	1
Sylhet	Habiganj	221	0
	Maulvibazar	1516	138
	Sunamganj	12	0
	Sylhet	0	5

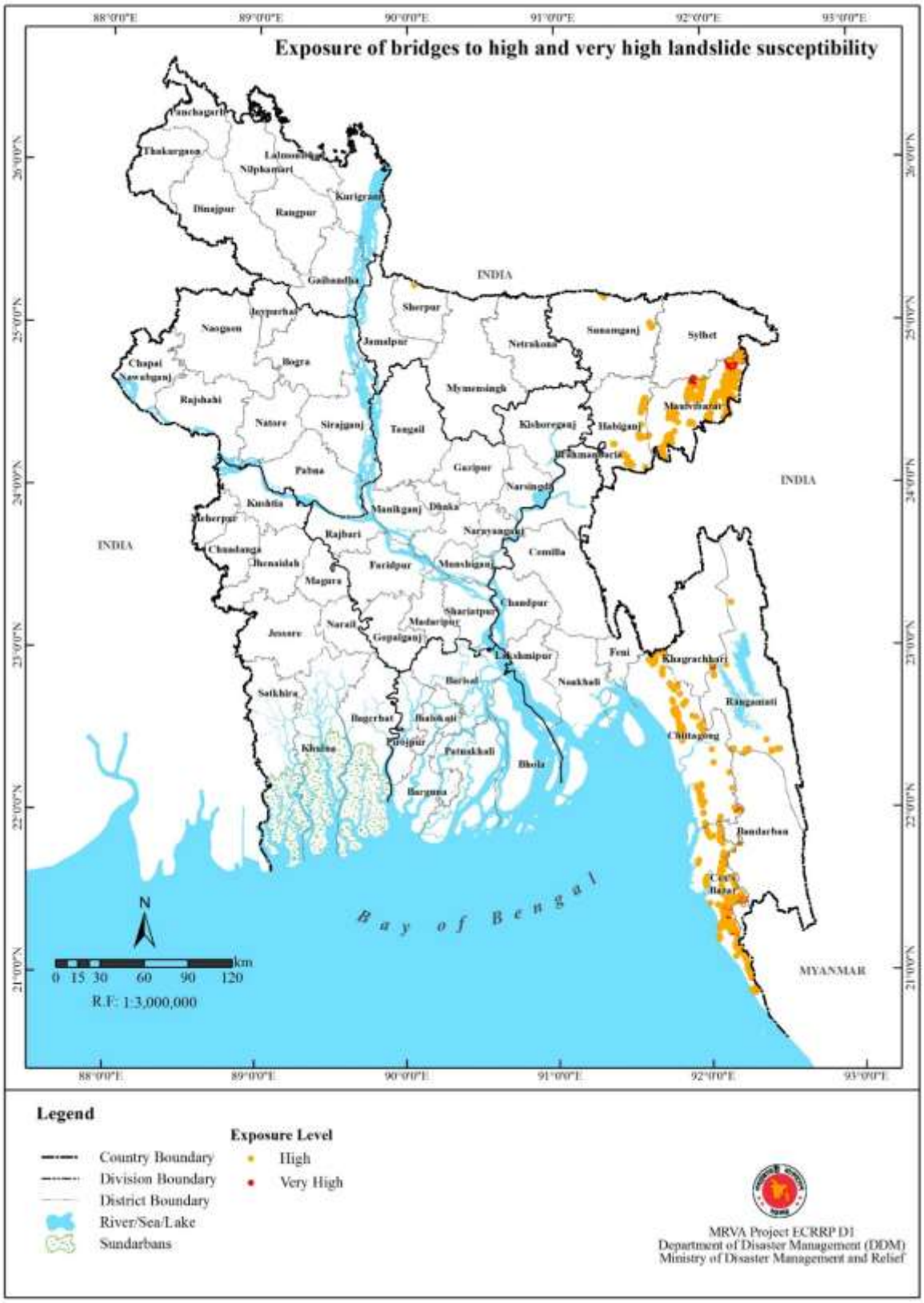


Figure 4.35: Exposure of bridges to high and very high landslide susceptibility

4.1.5.3 Railway

Combining landslide susceptible map and railway network map will provide the length of railway network (broad gauge and narrow gauge) exposed to landslide susceptibility. Existing broad gauge railway network is not exposed to landslide. The length of railway network (narrow gauge) existing in high and very high landslide susceptible areas at division/district level is given in table 4.18 and figure 4.36.

Table 4.18: Narrow gauge railway line exposed to Landslide susceptibility

Division	District	Railway Line exposed to Landslide susceptibility	
		High	Very High
		Narrow Gauge	
Chittagong	Chittagong	33.4	2.4
Sylhet	Habiganj	14.5	0.0
	Maulvibazar	40.0	5.3
	Sunamganj	0.0	0.0
	Sylhet	10.5	0.5

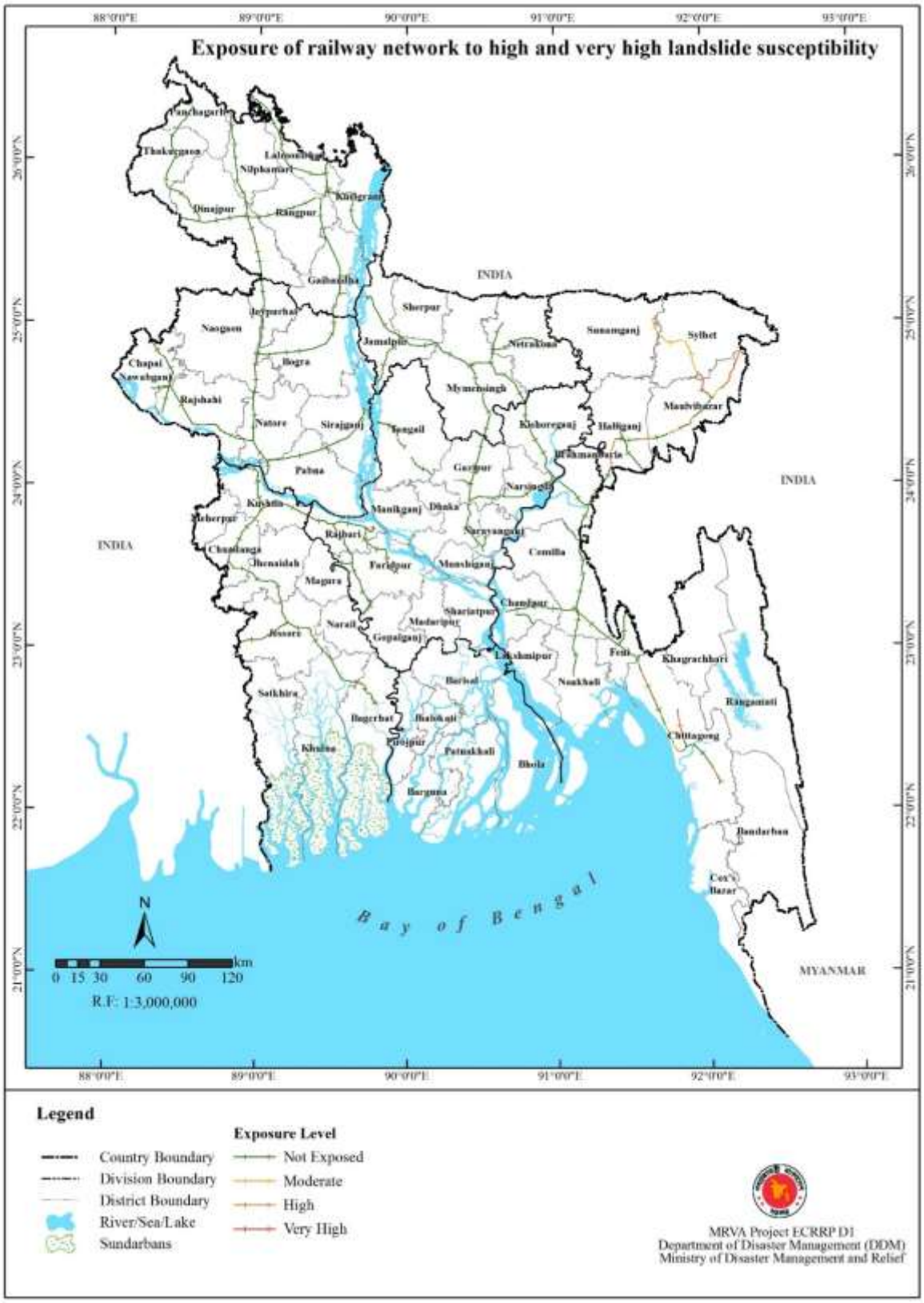


Figure 4.36: Exposure of railway network to high and very high landslide susceptibility

4.1.5.4 Air, Sea and River Ports

Combining landslide susceptibility map and Air, Sea and River ports map will provide the number of ports exposed to landslide susceptibility. The number of Air, Sea and River ports existing in high and very high landslide susceptible areas at division/district level is given in table 4.19.

Table 4.19: Number of Air ports exposed to Landslide susceptibility

Division	District	Number of Air, River and Sea ports exposed to Landslide susceptibility	
		High	Very High
		Airport	Airport
Sylhet	Maulvibazar	1	
	Sylhet		1

4.1.5.5 Power

Combining landslide susceptibility map and Power sector (Power stations, Power sub-stations) will provide the number of power stations, power sub-stations exposed to landslide susceptibility. The number of Power stations existing in high and very high landslide susceptible at division/district level is given in table 4.20 and figure 4.37.

Table 4.20: Number of power stations exposed to Landslide susceptibility

Division	**District**	**Number of Power Sector exposed to Landslide susceptibility**			
		High		**Very High**	
		Grid Sub Station	**Power Station**	**Grid Sub Station**	**Power Station**
Chittagong	Chittagong	1	0	0	0
	Rangamati	1	0	0	0

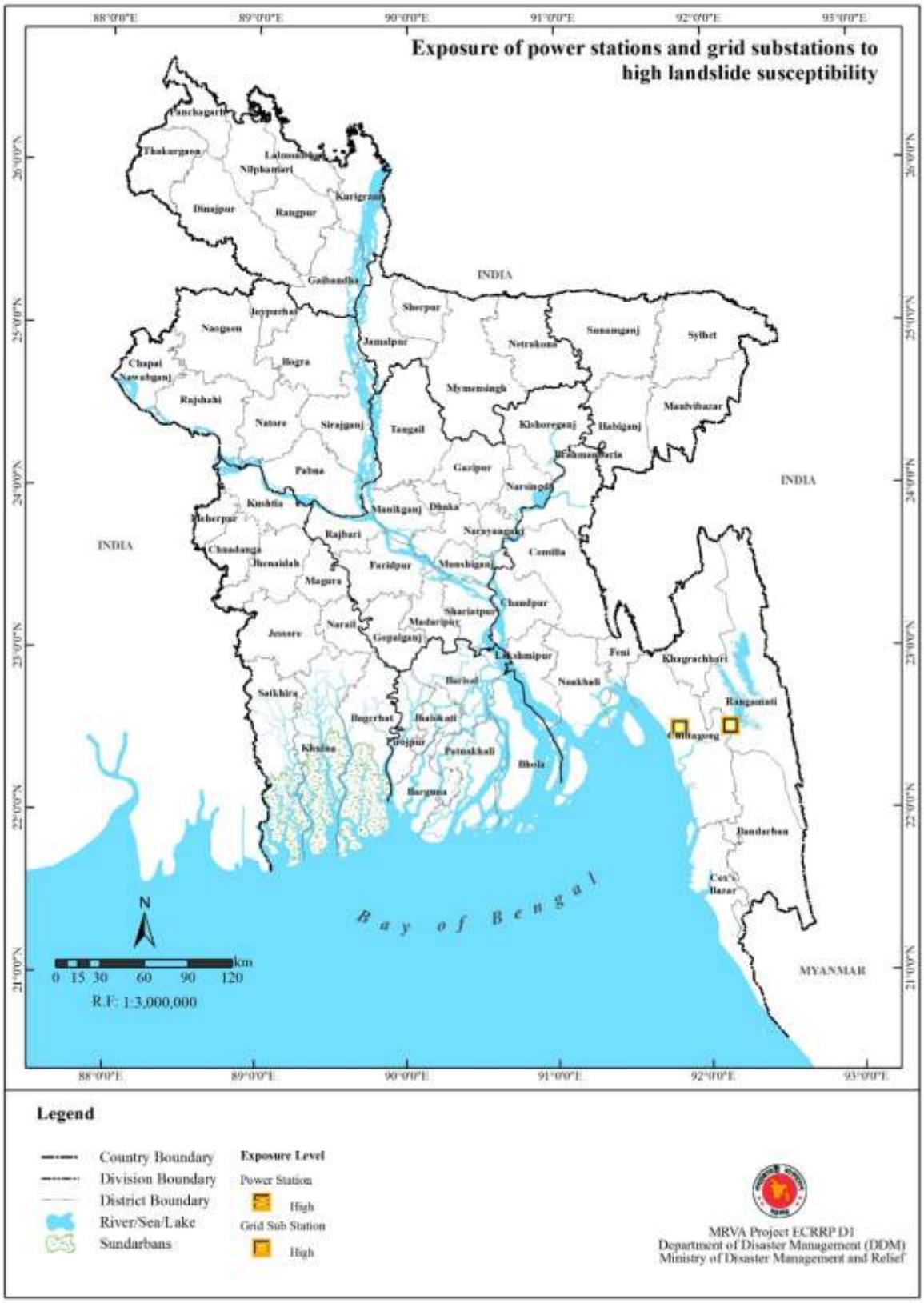


Figure 4.37: Exposure of power and grid sub stations to landslide susceptibility

4.2 Vulnerability / Damage Assessment

4.2.1 Household structures

Settlement area which represent the location of the household structures and landslide susceptibility maps are combined to know areal extent of settlements existing in each landslide susceptibility category. Based on the area, number of different type of household structures existing in each landslide susceptibility category are assessed. Risk of the household structures due to each landslide susceptibility is represented by a risk matrix, which is given in table 4.21.

Table 4.21: Vulnerability / Risk Matrix for household structure types

Landslide category	Types of households vs Risk level			
	Pucca	Semi- Pucca	Katcha	Jhupri
Very Low	D0	D1	D1	D1
Low	D1	D1	D2	D2
Medium	D2	D3	D4	D4
High	D3	D4	D4	D4
Very High	D4	D4	D4	D4

D0	No Risk	No Damage
D1	Slight Risk	1-15% Damage
D2	Moderate Risk	15-35% Damage
D3	High Risk	35-60% Damage
D4	Very High Risk	Damage >60%

Using the exposure assessment results and above risk matrix, number of household structures at risk due to landslide susceptibility are assessed at district level and given here. Number of pucca household structures at risk are given in table 4.22 and figure 4.38. Distribution of pucca household structures is given in figure 4.39. Number of semi-pucca household structures at risk are given in table 4.23 and figure 4.40. Distribution of semi-pucca household structures is given in figure 4.41. Number of katcha household structures at risk are given in table 4.24 and figure 4.42. Distribution of katcha household structures is given in figure 4.43. Number of jhupri household structures at risk are given in table 4.25 and figure 4.44. Distribution of pucca household structures is given in figure 4.45.

Table 4.22: Pucca household structures at different risk levels due to landslide

Division	District Name	Risk Level / Number of Pucca Structures			
		D1	D2	D3	D4
Chittagong	Bandarban	4	107	2,182	591
	Brahmanbaria	44,193	-	-	-
	Chandpur	36,975	1	-	-
	Chittagong	268,890	56,687	56,220	1,206
	Comilla	101,123	2,331	850	-
	Cox's Bazar	5,549	7,089	11,826	1,326
	Feni	46,020	55	16	-
	Khagrachhari	183	262	2,419	79
	Lakshmipur	27,766	-	-	-
	Noakhali	45,136	2	-	-
	Rangamati	51	1,116	4,626	374
Sylhet	Habiganj	18,604	1,328	1,306	-
	Maulvibazar	24,660	7,670	10,209	1,162
	Sunamganj	20,940	7,606	514	1
	Sylhet	16,108	94,822	13,986	4,435

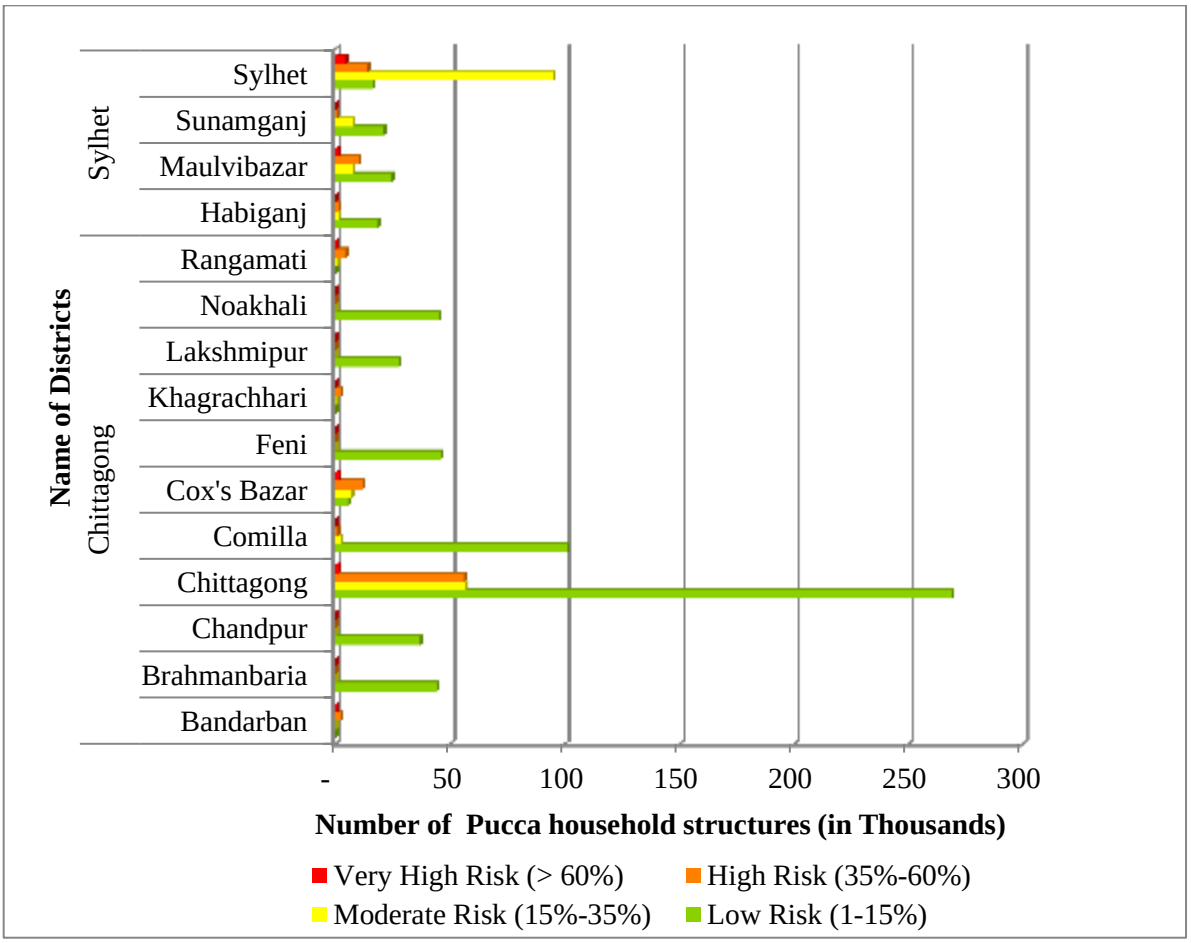


Figure 4.38: Pucca household structures at different risk levels due to landslide at district level

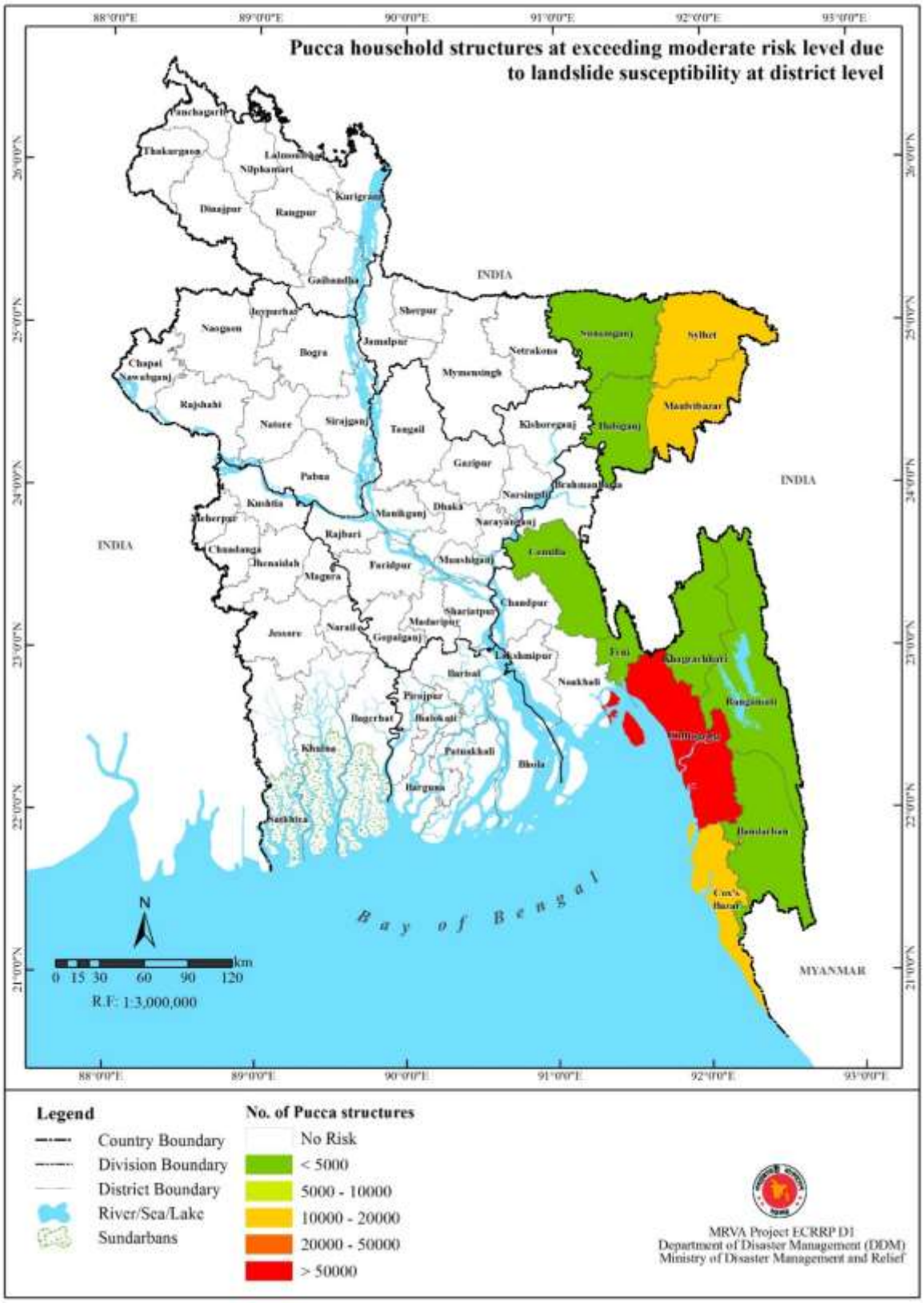


Figure 4.39: Pucca household structures at exceeding moderate risk level due to landslide at district level

Table 4.23: Semi-Pucca household structures at different risk levels due to landslide

Division	District Name	Risk Level / Number of Semi-Pucca Structures			
		D1	D2	D3	D4
Chittagong	Bandarban	7	-	160	4,159
	Brahmanbaria	73,834	-	-	-
	Chandpur	44,573	-	1	-
	Chittagong	221,566	-	46,710	47,319
	Comilla	160,366	-	3,696	1,349
	Cox's Bazar	10,382	-	13,263	24,607
	Feni	49,347	-	59	17
	Khagrachhari	583	-	833	7,948
	Lakshmipur	27,035	-	-	-
	Noakhali	45,136	-	2	-
	Rangamati	88	-	1,907	8,542
Sylhet	Habiganj	63,049	-	4,500	4,425
	Maulvibazar	59,512	-	18,510	27,442
	Sunamganj	37,121	-	13,484	914
	Sylhet	23,160	-	136,333	26,484

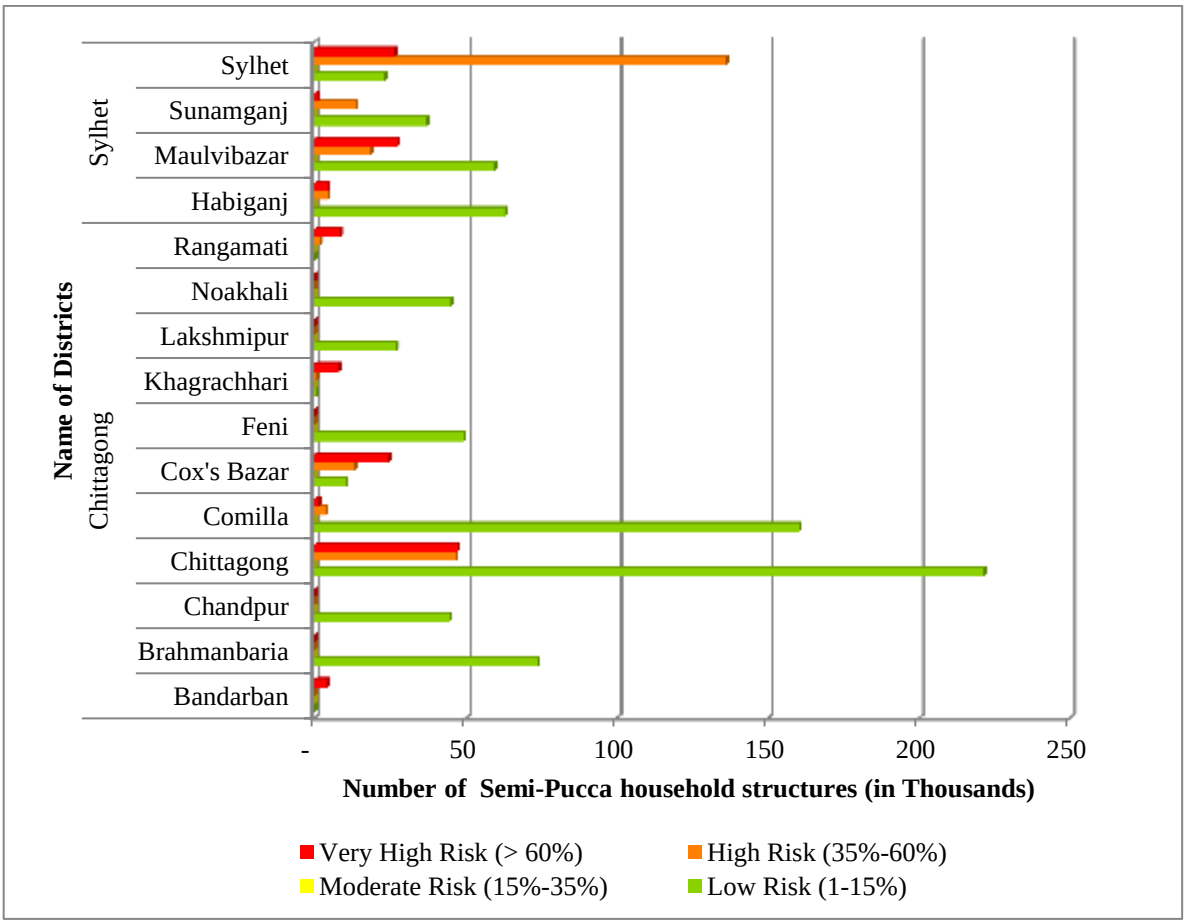


Figure 4.40: Semi-Pucca household structures at different risk levels due to landslide at district level

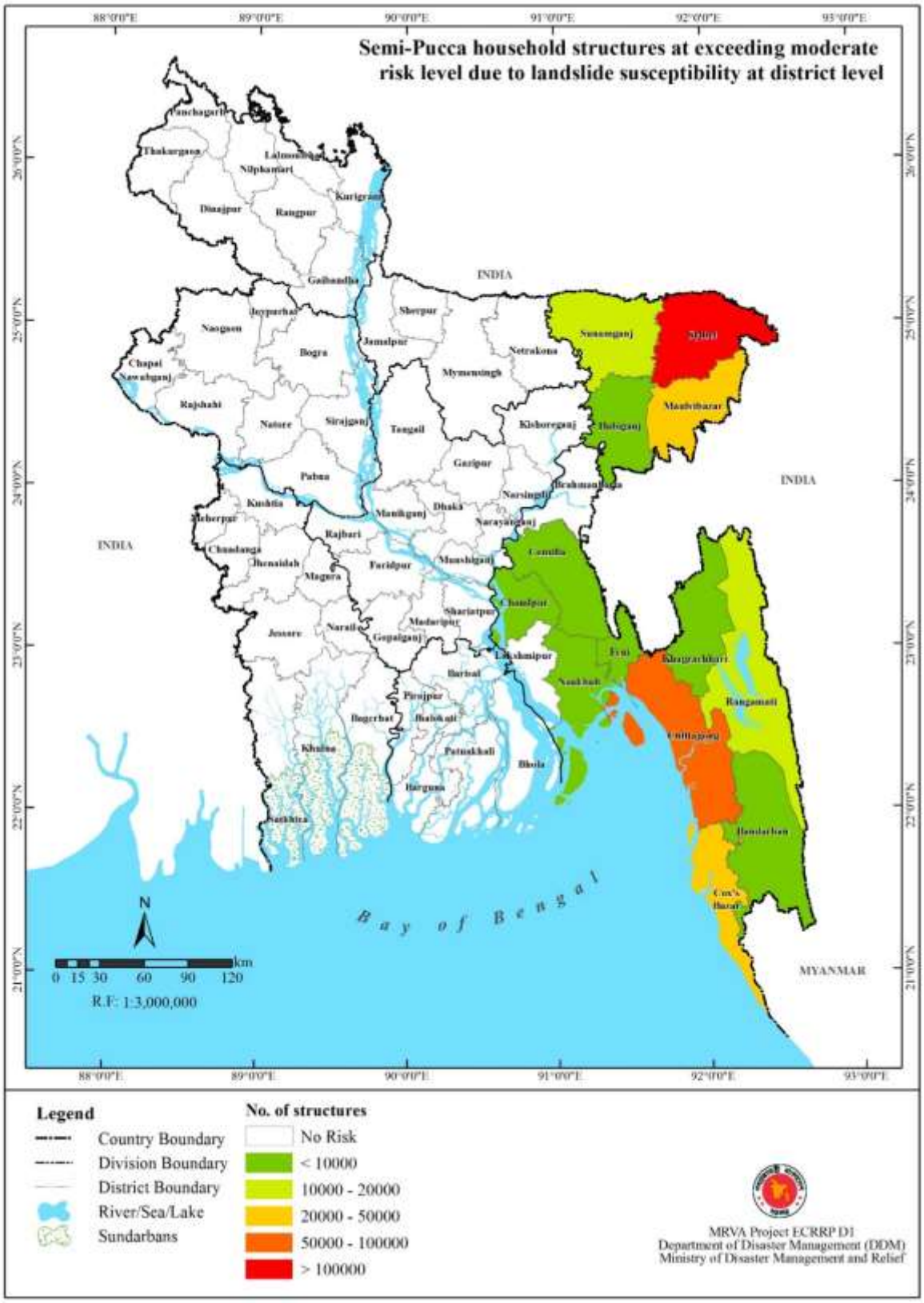


Figure 4.41: Semi-Pucca household structures at exceeding moderate risk level due to landslide at district level

Table 4.24: Kutcha household structures at different risk levels due to landslide

Division	District Name	Risk Level / Number of Kutcha Structures			
		D1	D2	D3	D4
Chittagong	Bandarban	-	105	-	68,062
	Brahmanbaria	-	414,981	-	-
	Chandpur	-	421,924	-	8
	Chittagong	-	519,496	-	220,467
	Comilla	-	746,672	-	23,489
	Cox's Bazar	-	61,664	-	224,928
	Feni	-	178,262	-	277
	Khagrachhari	-	7,242	-	109,023
	Lakshmipur	-	301,770	-	-
	Noakhali	-	478,681	-	17
	Rangamati	-	875	-	104,106
Sylhet	Habiganj	-	251,507	-	35,603
	Maulvibazar	-	114,539	-	88,442
	Sunamganj	-	245,886	-	95,371
	Sylhet	-	33,404	-	234,832

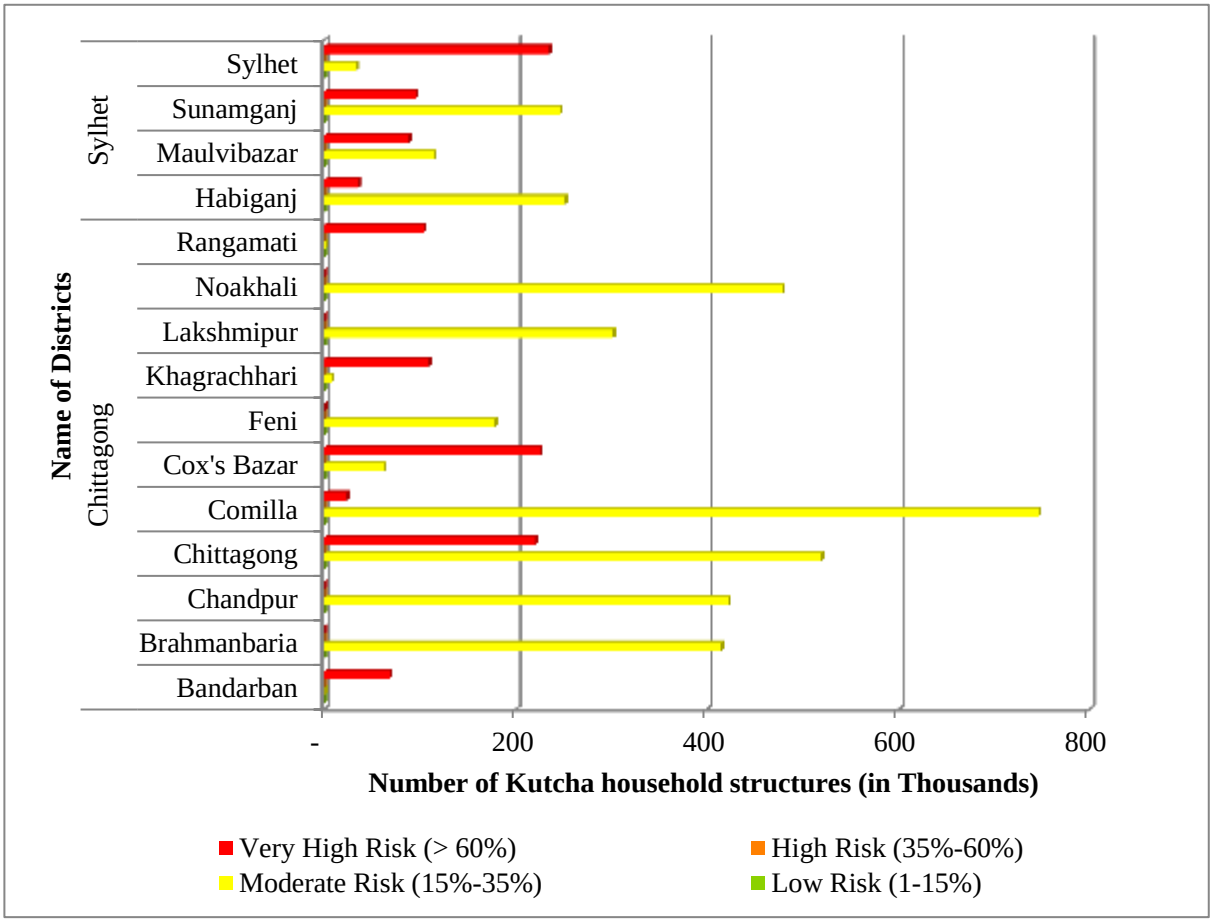


Figure 4.42: Kutcha household structures at different risk levels due to landslide at district level

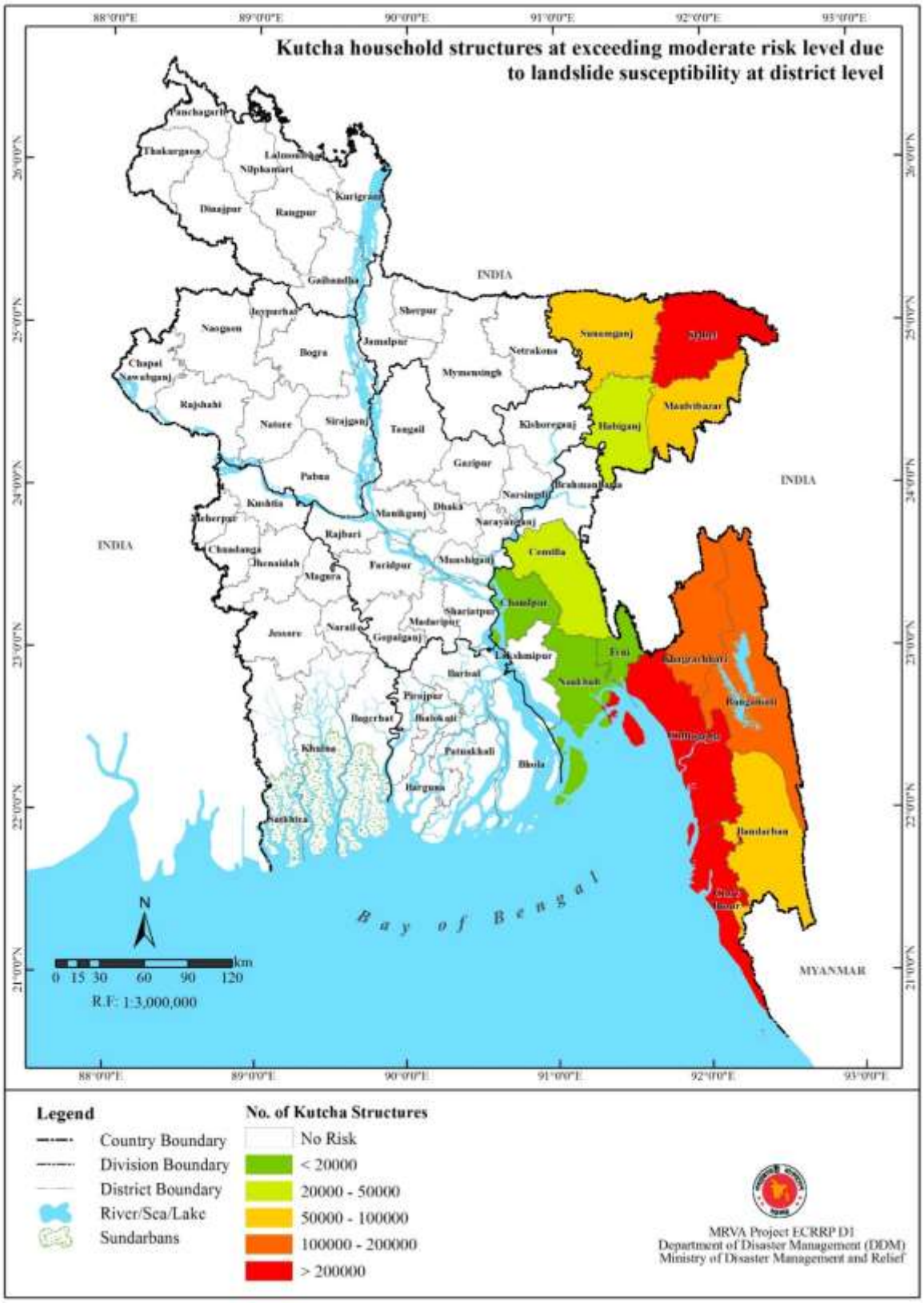


Figure 4.43: Kutcha household structures at exceeding moderate risk level due to landslide at district level

Table 4.25: Jhupri household structures at different risk levels due to landslide

Division	District Name	Risk Level / Number of Jhupri Structures			
		D1	D2	D3	D4
Chittagong	Bandarban	-	7	-	4,719
	Brahmanbaria	-	5,928	-	-
	Chandpur	-	3,039	-	0
	Chittagong	-	65,609	-	27,844
	Comilla	-	13,278	-	418
	Cox's Bazar	-	11,903	-	43,419
	Feni	-	3,604	-	6
	Khagrachhari	-	325	-	4,893
	Lakshmipur	-	8,768	-	-
	Noakhali	-	24,944	-	1
	Rangamati	-	57	-	6,753
Sylhet	Habiganj	-	11,370	-	1,609
	Maulvibazar	-	5,095	-	3,934
	Sunamganj	-	13,325	-	5,169
	Sylhet	-	1,559	-	10,959

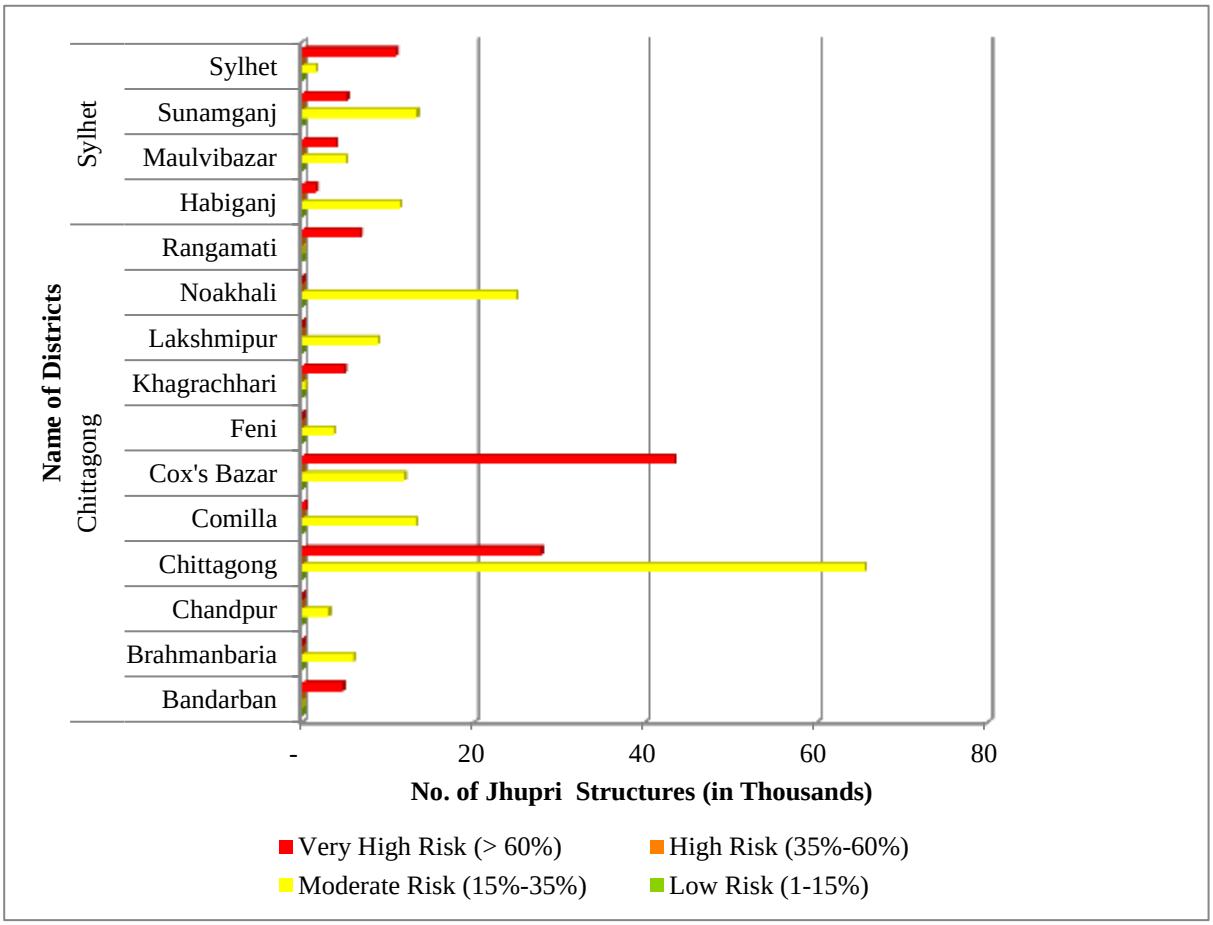


Figure 4.44: Jhupri household structures at different risk levels due to landslide at district level

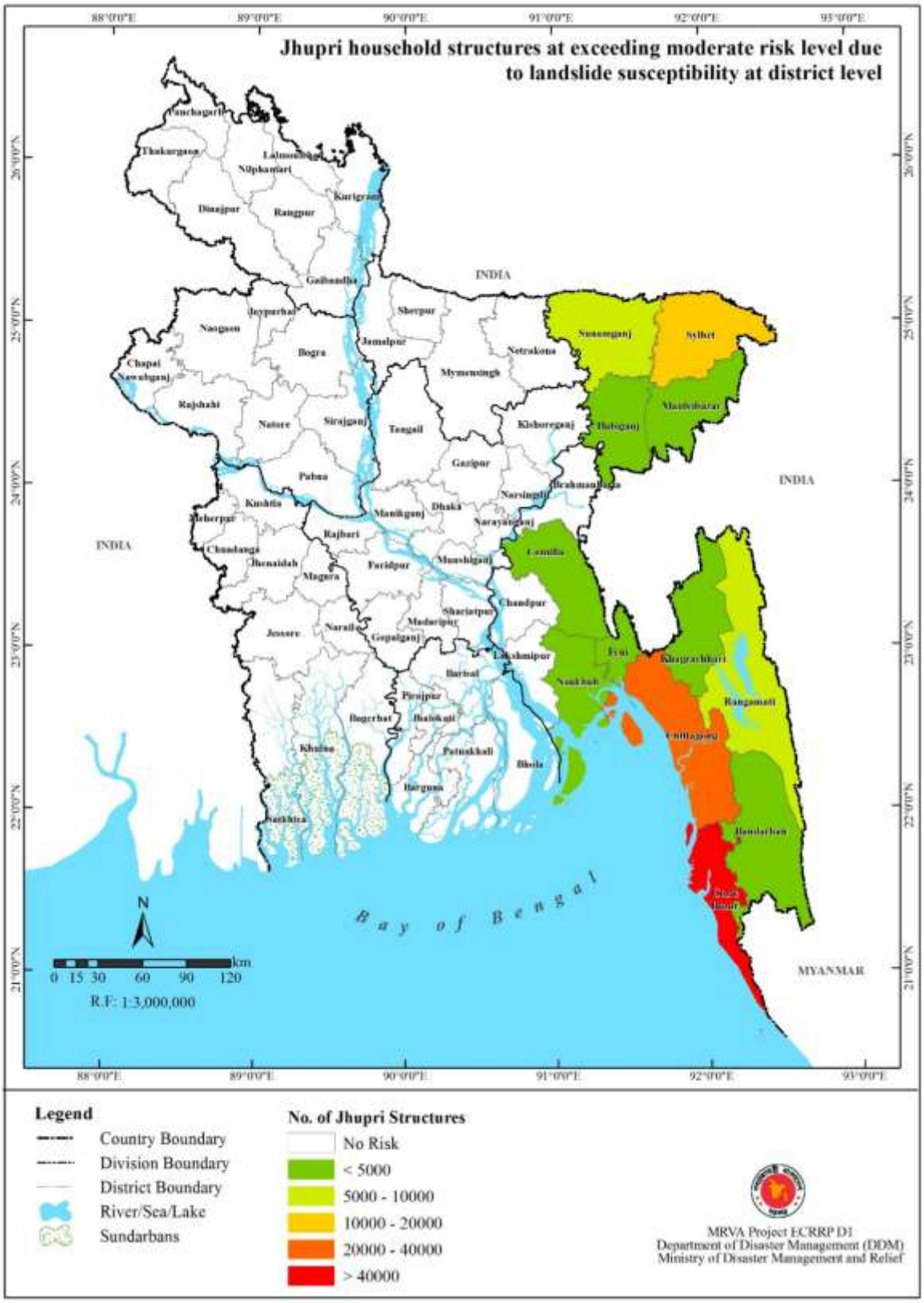


Figure 4.45: Jhupri household structures at exceeding moderate risk level due to landslide at district level

Chapter 5: Exposure, Vulnerability & Risk Assessment to Drought hazard

Drought hazard map consists of 4 drought hazard categories i.e. Near Normal, Moderate, Severe and Extreme.

5.1 Exposure Assessment

Drought hazard assessment is carried out for 10, 50 and 100 year return period droughts for climate seasons of pre-monsoon/pre-Kharif, monsoon, winter, cropping seasons of Kharif and Rabi. Among the elements at risk considered in this study, only population and livelihood (agriculture) are considered for exposure assessment during pre-monsoon/pre-Kharif drought. Because, slow nature of drought affects the population for their livelihood especially agriculture during highest crop growing season of pre-monsoon/pre-Kharif in Bangladesh.

5.1.1 Population

As explained in section 1.1 of Volume III of thus report, based on the area of exposure of the settlements in each union, number of population exposed is calculated. The population data considered for exposure assessment due to drought are, Gender (male, female), Age (0-14 years, 14 - 59 years and more than 59 years), and Employment (Agriculture) only. Pre-monsoon/pre-Kharif hazard map is combined with population maps for exposure assessment. Exposure assessment results of affected population at division / district / upazila level are given below.

5.1.1.1 Gender

During pre-monsoon/pre-Kharif season drought categories existing in Bangladesh are near normal and moderate. Population based on gender exposed to moderate and near-normal drought hazard category during pre-monsoon/pre-Kharif season in Rajshahi and Rangpur divisions is given in table 5.1 and at division level in figure 5.1. Population (male) exposed at district level is given in figure 5.2 and Population (female) exposed at district level in figure 5.3.

Table 5.1: Population (gender) exposed to pre-monsoon/pre-Kharif drought hazard categories at district level

Division	District	Population exposed to Pre-Monsoon Drought categories			
		Near Normal		Moderate	
		Male	Female	Male	Female
Rajshahi	Bogra	566,100	560,555	1,142,706	1,131,513
	Chapai Nawabganj	0	0	810,218	837,303
	Joypurhat	0	0	459,284	454,484
	Naogaon	10,041	10,039	1,290,186	1,289,891
	Natore	806,137	804,539	48,046	47,951

Division	District	Population exposed to Pre-Monsoon Drought categories			
		Near Normal		Moderate	
		Male	Female	Male	Female
	Pabna	1,262,934	1,260,245	0	0
	Rajshahi	688,437	675,517	621,453	609,790
	Sirajganj	1,551,368	1,546,121	0	0
Rangpur	Dinajpur	0	0	1,508,670	1,481,458
	Gaibandha	846,969	876,672	322,158	333,456
	Kurigram	1,010,442	1,058,831	0	0
	Lalmonirhat	553,368	552,049	75,431	75,251
	Nilphamari	91,110	89,955	831,854	821,312
	Panchagarh	0	0	496,725	490,919
	Rangpur	714,645	711,405	729,171	725,865
	Thakurgaon	0	0	701,281	688,761
	Total	63,072,614	62,945,948	9,037,182	8,987,953

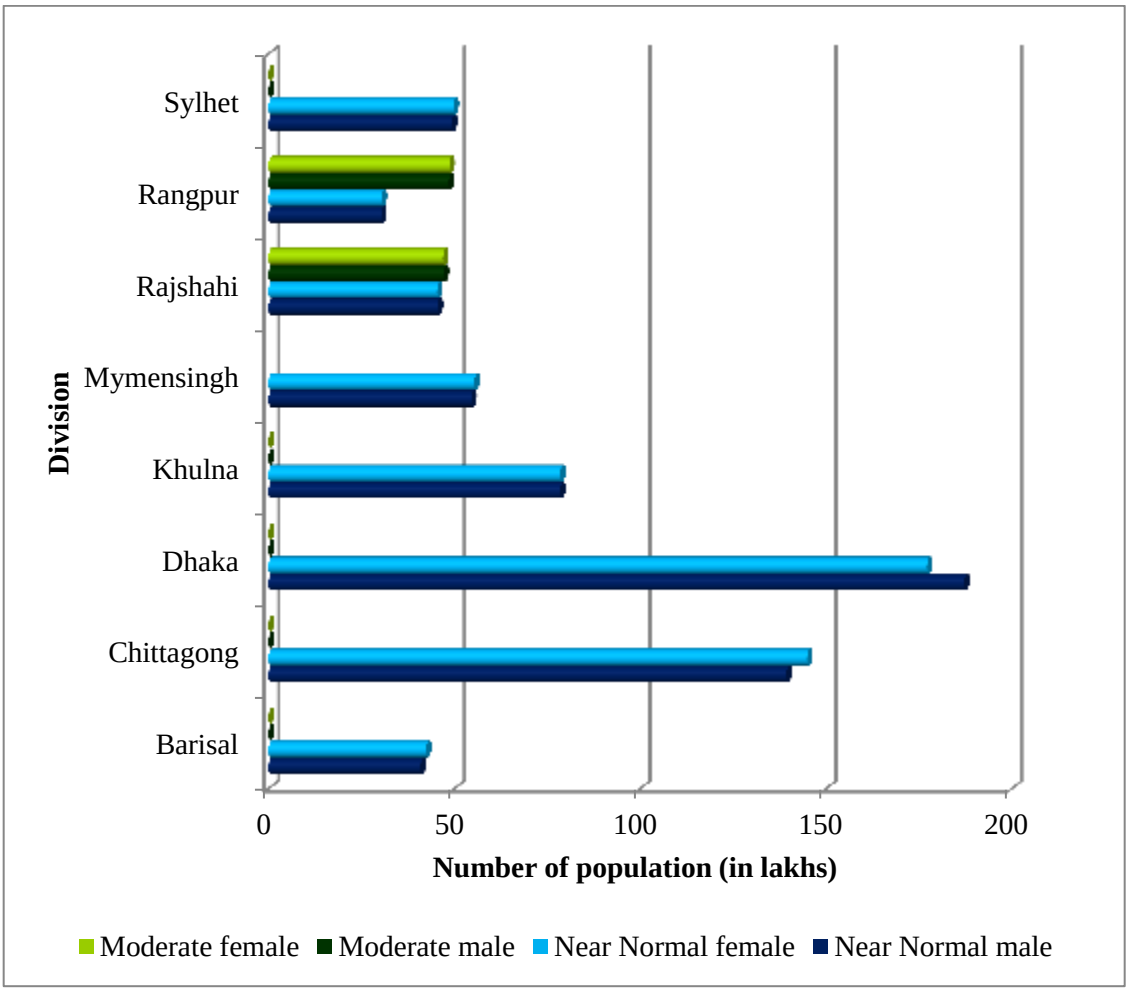


Figure 5.1: Population exposed to pre-monsoon/pre-Kharif drought hazard at division level

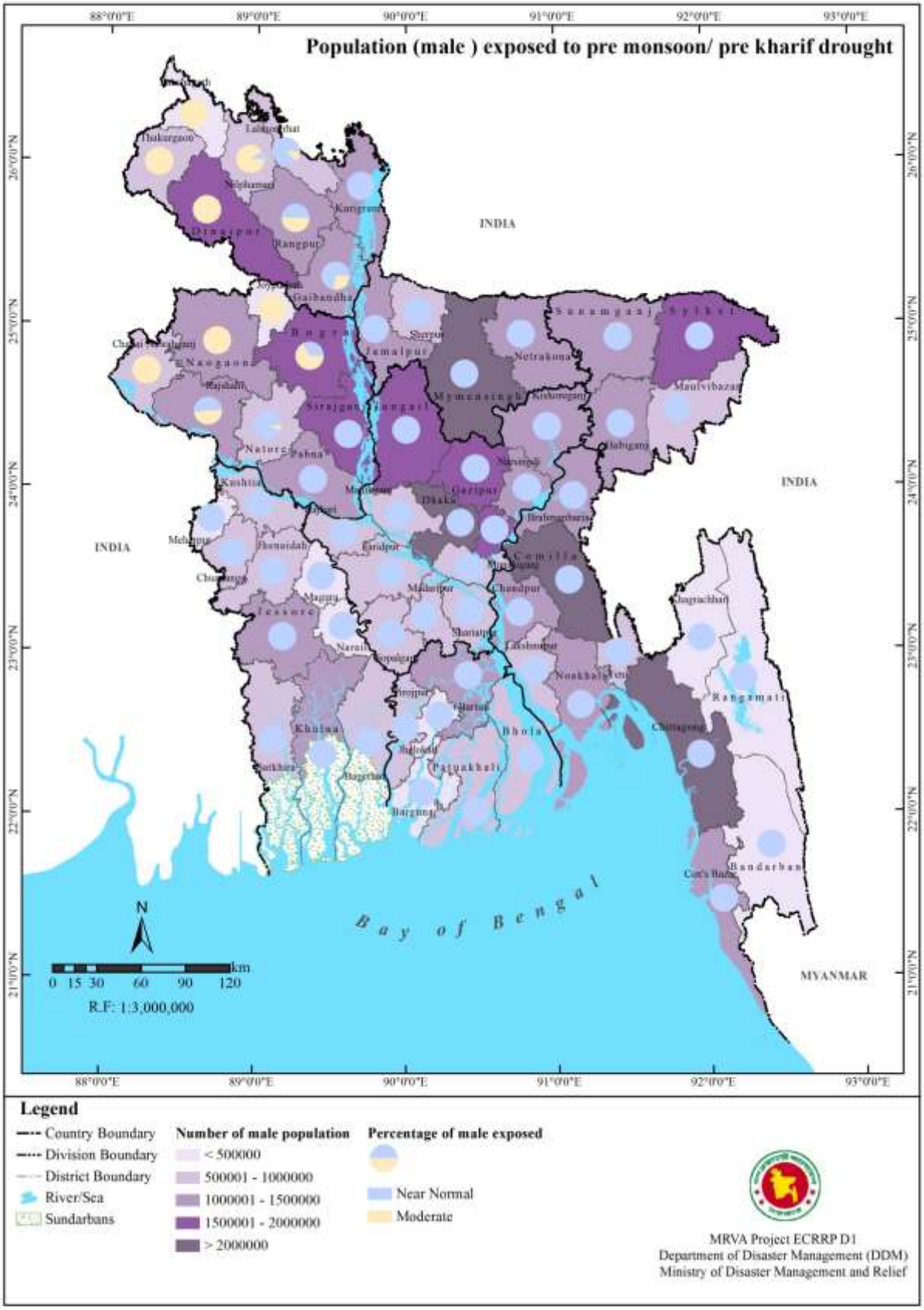


Figure 5.2: Population (male) exposed to pre-monsoon/pre-Kharif drought hazard at district level

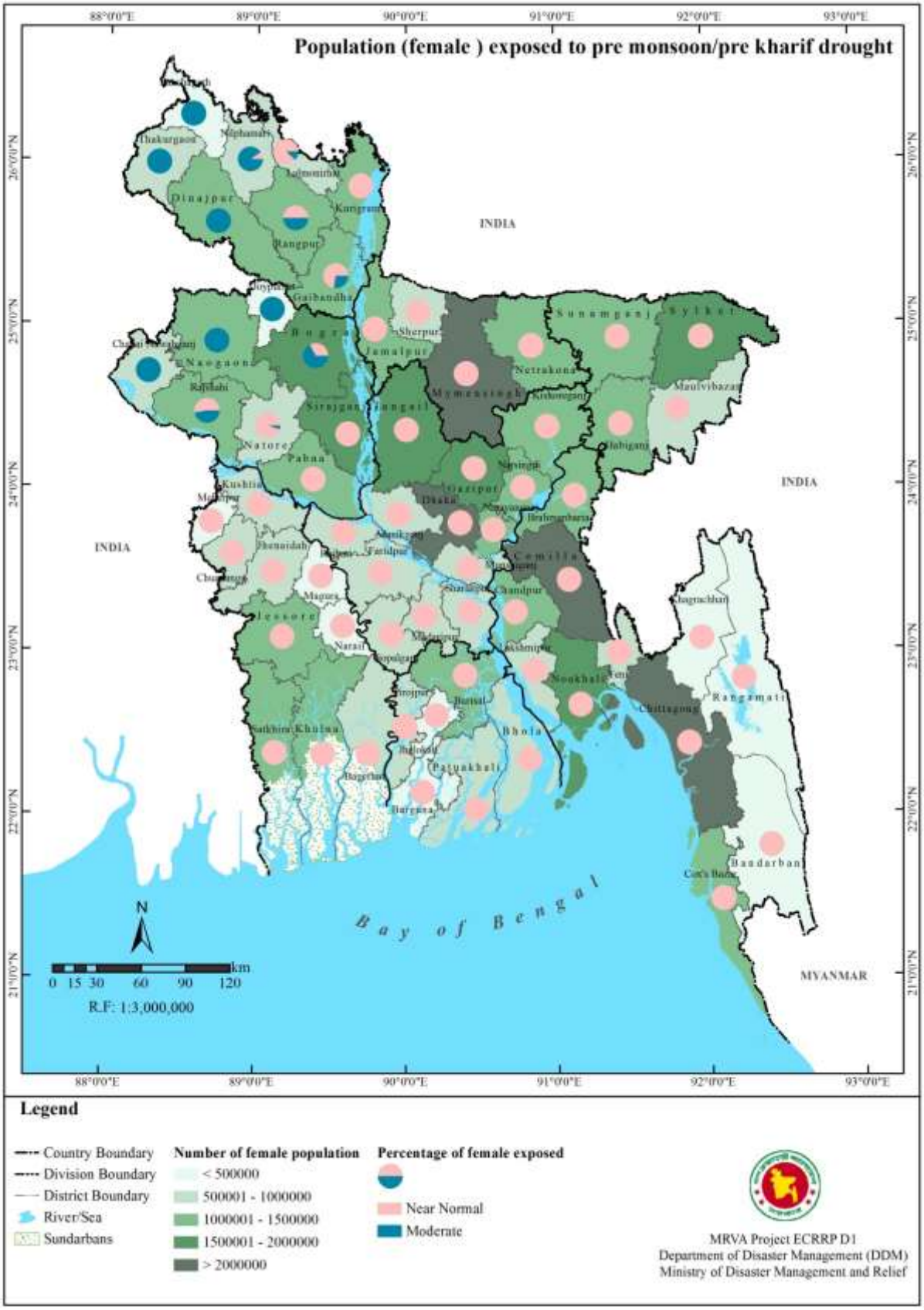


Figure 5.3: Population (female) exposed to pre-monsoon/pre-Kharif drought hazard at district level

5.1.1.2 Age

As explained in section 1.1.2 of volume III of this report, population by age is regrouped into 0-14 years, 14 - 59 years and more than 59 years. Population in the age group of 0-14 years, 14 - 59 years and more than 59 years exposed to moderate and near-normal drought hazard category during pre-monsoon/pre-Kharif drought hazard categories in Rajshahi and Rangpur divisions are given table 5.2 and at division level in figure 5.4. Distribution of population at district level based on age groups is shown in figure 5.5 for 0-14 years, figure 5.6 for 14 - 59 years and figure 5.7 for more than 59 years.

Table 5.2: Population (age) exposed to pre-monsoon/pre-Kharif drought hazard categories

Division	District	Number of Population (age) exposed to Pre Monsoon Drought					
		Near Normal			Moderate		
		0 - 14	14 - 59	> 59	0 - 14	14 - 59	> 59
Rajshahi	Bogra	347,010	692,893	86,752	700,459	1,398,645	175,115
	Chapai Nawabganj	0	0	0	579,927	955,562	112,031
	Joypurhat	0	0	0	261,338	576,588	75,843
	Naogaon	5,884	12,591	1,606	755,962	1,617,707	206,407
	Natore	491,256	990,566	128,854	29,279	59,038	7,680
	Pabna	850,311	1,473,537	199,331	0	0	0
	Rajshahi	401,003	864,747	98,205	361,985	780,608	88,649
	Sirajganj	1,111,999	1,756,276	229,214	0	0	0
Rangpur	Dinajpur	0	0	0	974,782	1,788,097	227,250
	Gaibandha	610,169	977,305	136,168	232,087	371,733	51,793
	Kurigram	740,800	1,162,931	165,542	0	0	0
	Lalmonirhat	402,372	622,350	80,695	54,848	84,834	11,000
	Nilphamari	66,451	102,302	12,312	606,712	934,039	112,416
	Panchagarh	0	0	0	349,626	573,821	64,197
	Rangpur	476,301	839,943	109,806	485,982	857,017	112,038
	Thakurgaon	0	0	0	487,905	807,614	94,523
	Total	44,008,595	72,575,293	9,434,668	5,880,894	10,805,303	1,338,941

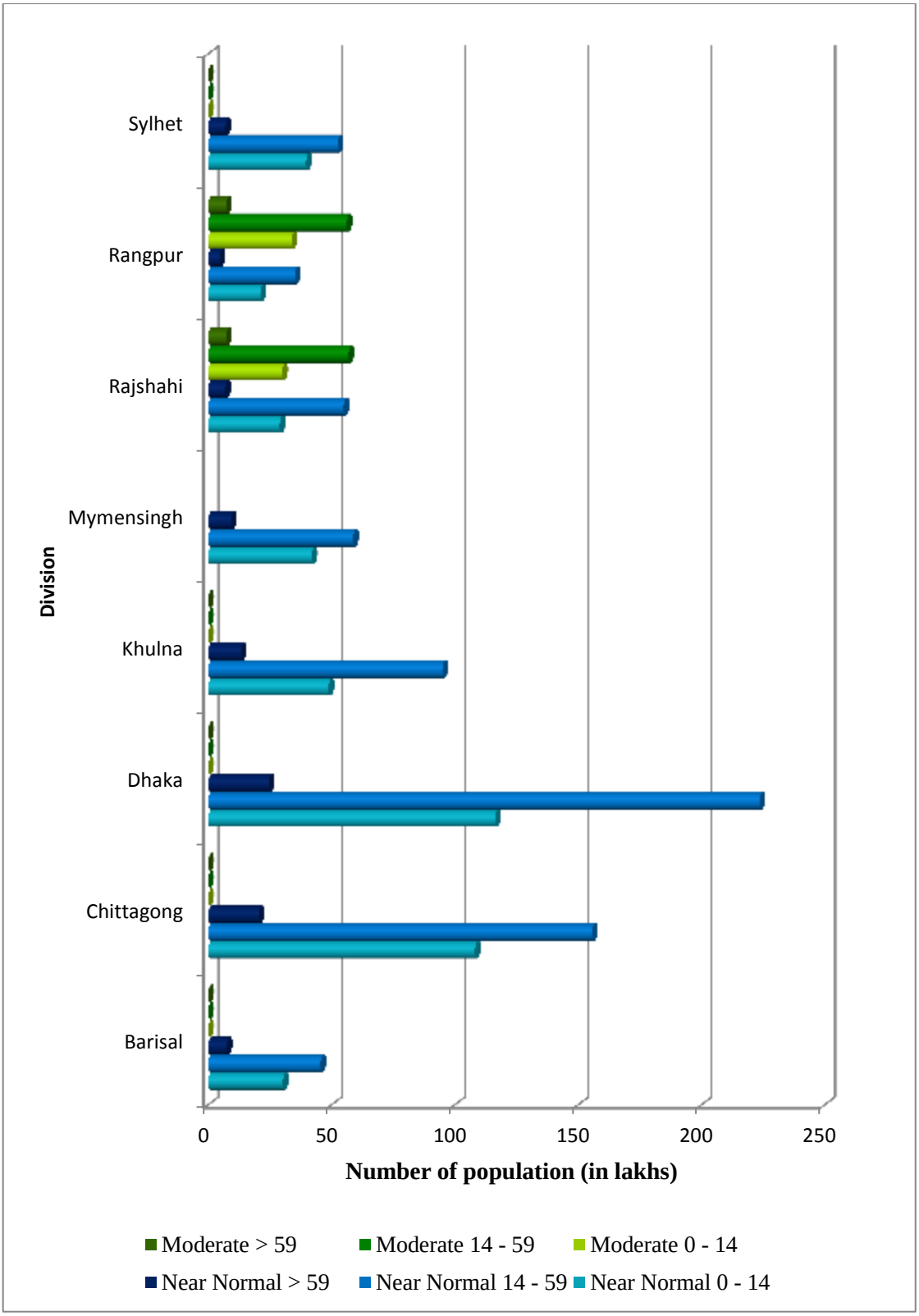


Figure 5.4: Population (all age group) exposed to pre-monsoon/pre-Kharif drought hazard categories at division level

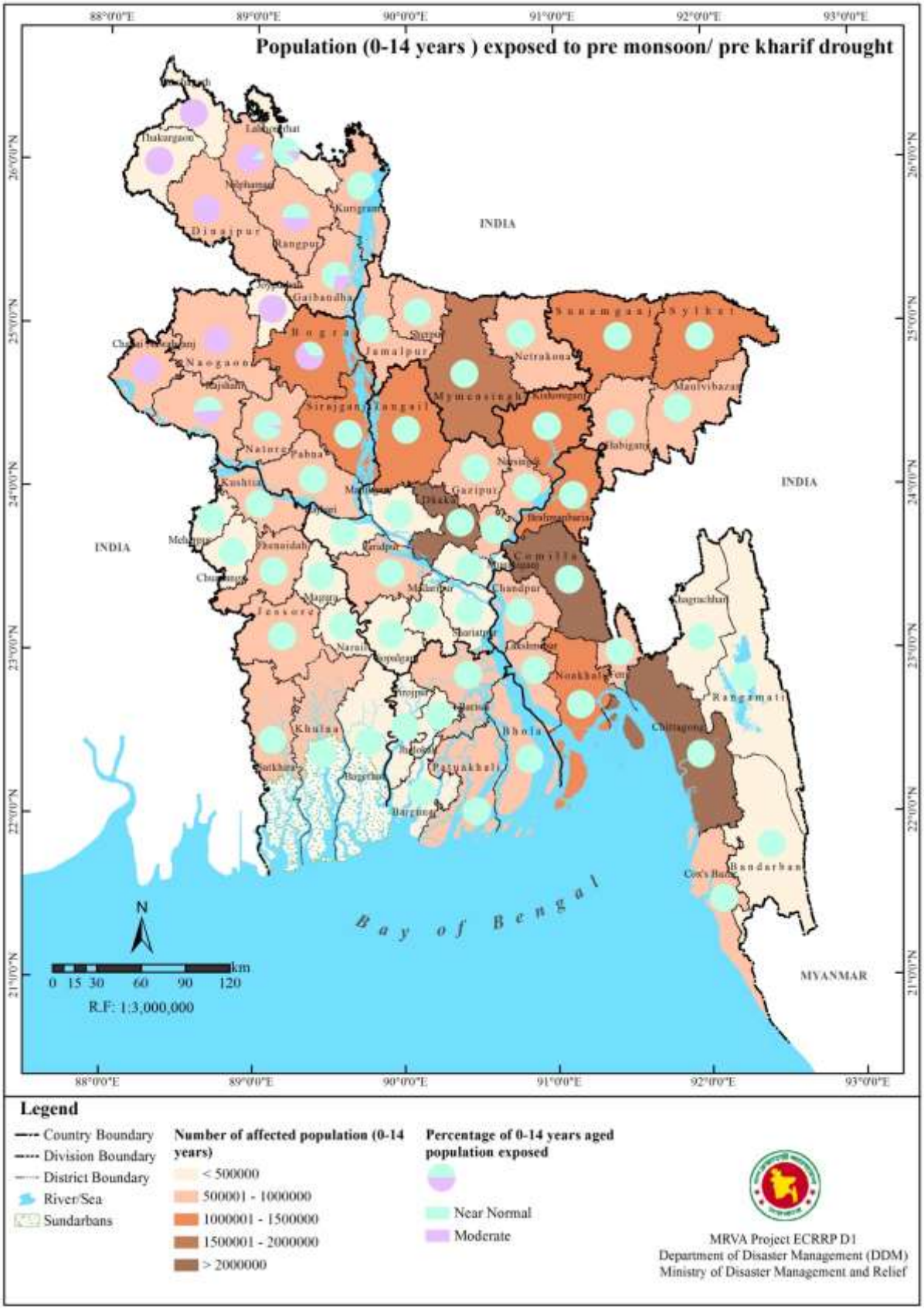


Figure 5.5: Population (0-14 years) exposed to pre-monsoon/pre-Kharif drought hazard at district level

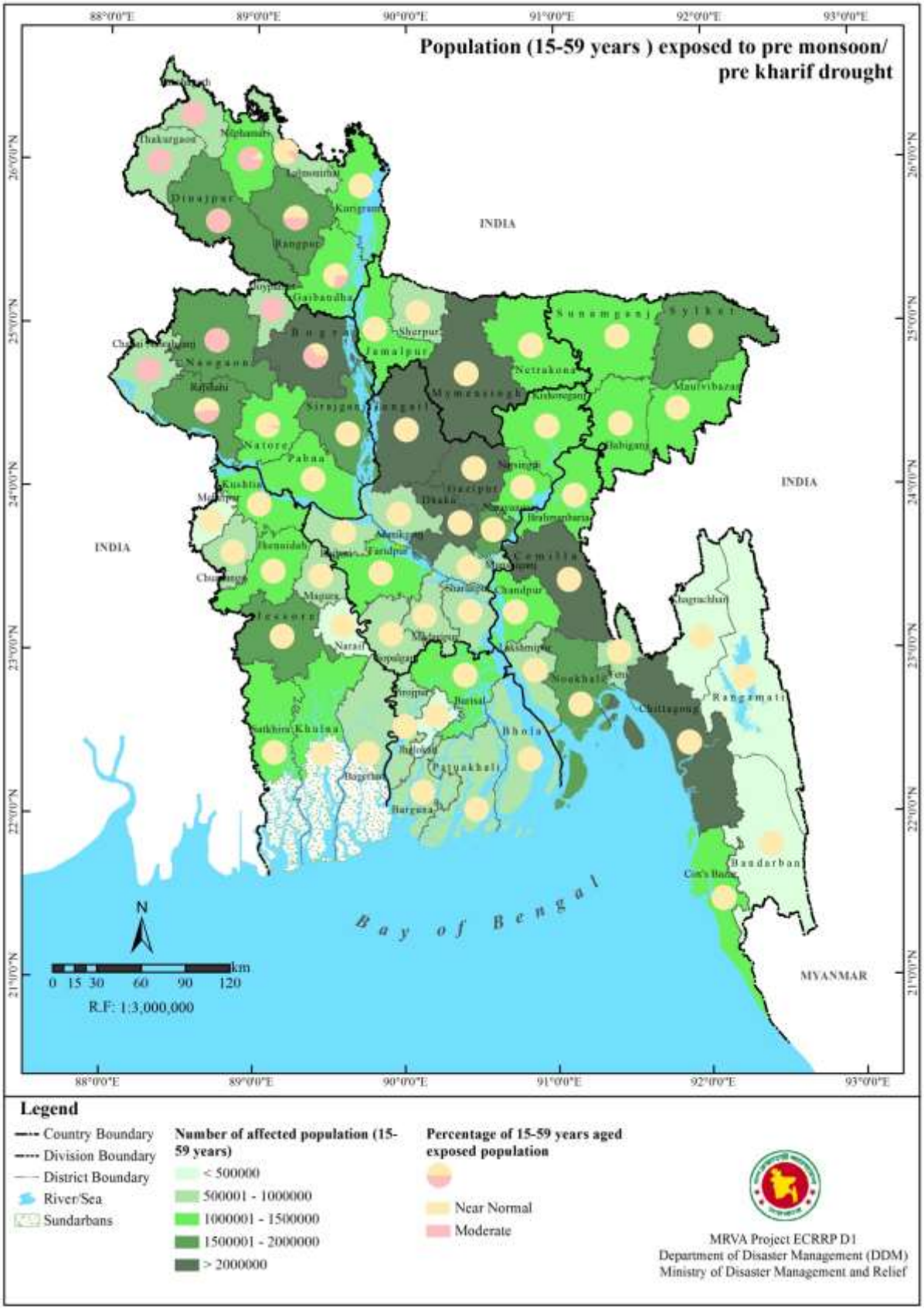


Figure 5.6: Population (15 – 59 years) exposed to pre-monsoon/pre-Kharif drought hazard at district level

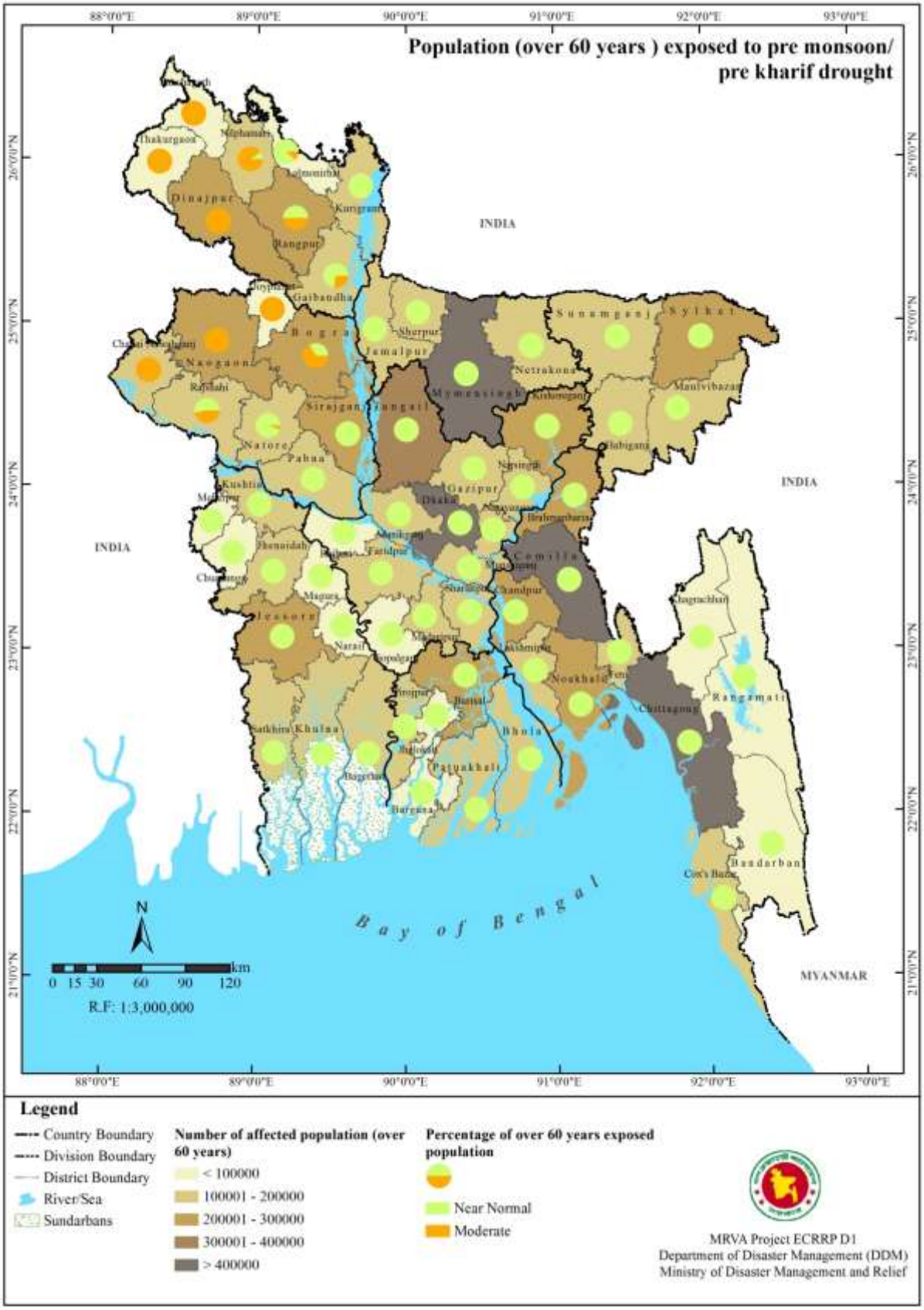


Figure 5.7: Population (over 60 years) exposed to pre-monsoon/pre-Kharif drought hazard at district level

5.1.1.3 Employment

As explained in section 1.1.4, employments of population considered are agriculture and industry. Population employed in Agriculture sector in Rajshahi and Rangpur divisions exposed to moderate and near-normal drought hazard category in pre-monsoon/pre-Kharif drought hazard is given table 5.3 and at division level in figure 5.8. Distribution of the employed population in agriculture exposed to moderate and near-normal drought hazard at district level is shown in figure 5.9.

Table 5.3: Population (employed in agriculture) exposed to pre-monsoon/pre-Kharif drought hazard

Division	District	Number of Population (employed in agricultural sector) exposed to pre-monsoon Drought			
		Near Normal		Moderate	
		Male	Female	Male	Female
Rajshahi	Bogra	106,306	2,552	214,586	5,152
	Chapai Nawabganj	0	0	176,291	3,732
	Joypurhat	0	0	79,054	2,925
	Naogaon	2,047	77	263,040	9,926
	Natore	181,187	4,961	10,799	296
	Pabna	264,018	6,004	0	0
	Rajshahi	118,064	4,331	106,577	3,909
	Sirajganj	290,870	6,582	0	0
Rangpur	Dinajpur	0	0	232,760	14,110
	Gaibandha	205,554	6,526	78,186	2,482
	Kurigram	249,358	10,345	0	0
	Lalmonirhat	111,996	6,589	15,267	898
	Nilphamari	19,479	813	177,844	7,427
	Panchagarh	0	0	77,610	5,476
	Rangpur	142,205	6,455	145,095	6,587
	Thakurgaon	0	0	115,580	7,317
	Total	8,460,996	352,663	1,692,688	70,236

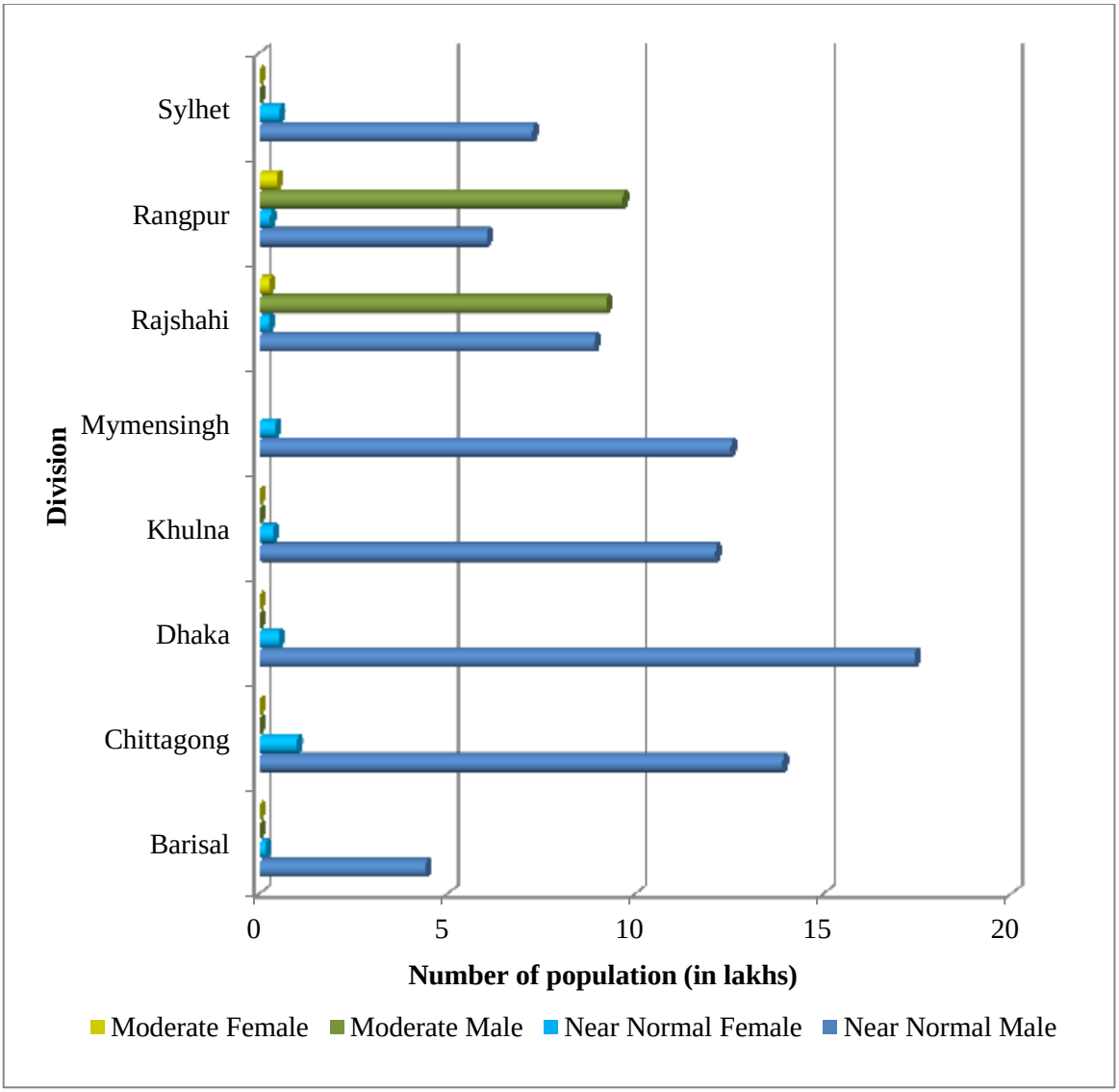


Figure 5.8: Employed population (agriculture) exposed to pre-monsoon/pre-Kharif drought hazard at division level

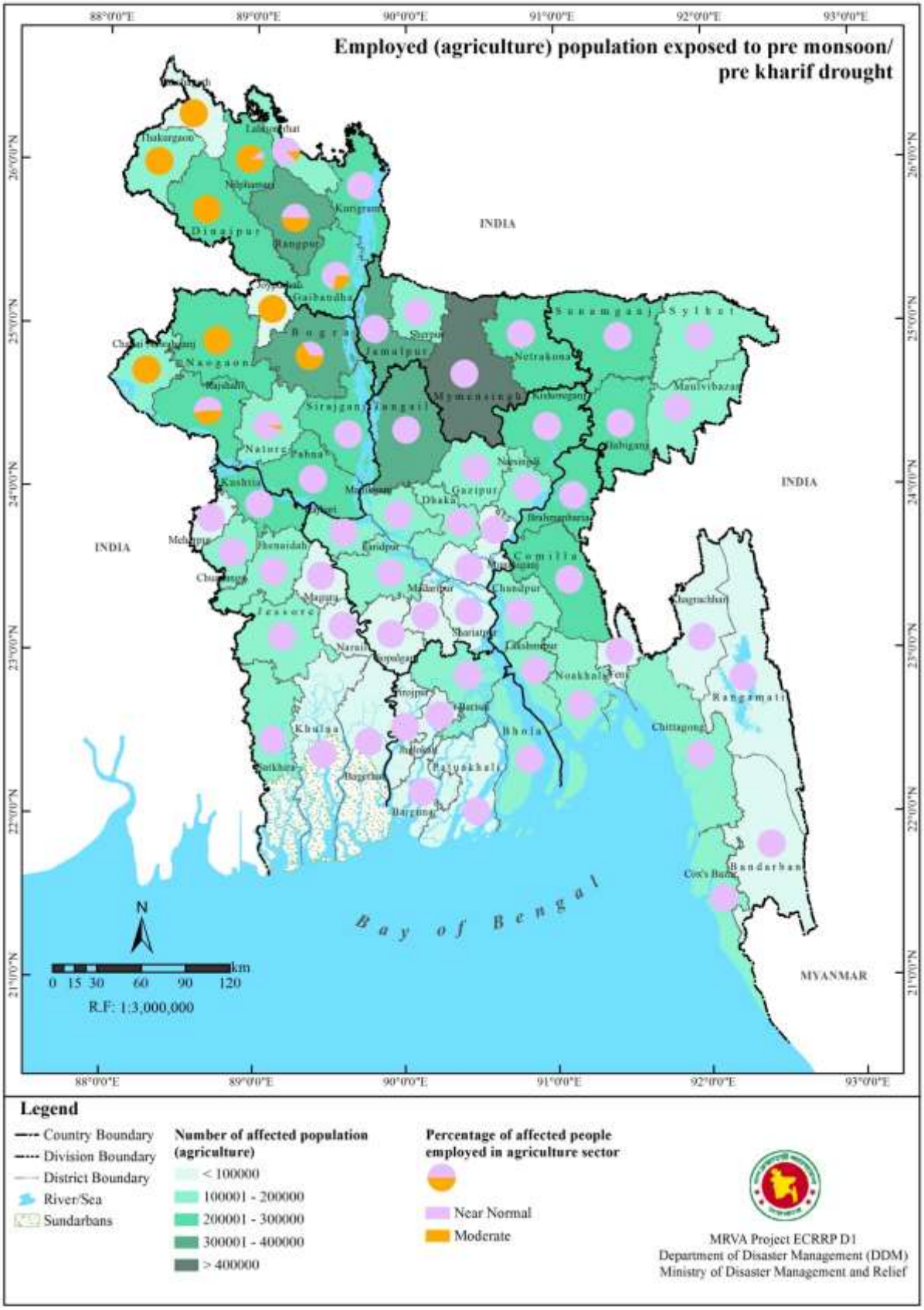


Figure 5.9: Employed (agriculture) population exposed to pre-monsoon/pre-Kharif drought hazard at district level

5.1.2 Livelihood

5.1.2.1 Agriculture

For livelihood sectors considered in this study are Agriculture (Transplanted Aman) and Industries. However, for exposure assessment due to drought only Agriculture (Transplanted Aman) is considered. Total transplanted aman crop area in Bangladesh, based on the land use and land cover provided by WARPO is 64113 km^2. The distribution among districts is given in table 5.4 and figure 5.10. Distribution of exposed transplanted aman crop in pre-monsoon/pre-kharif drought at district level is shown in figure 5.11.

Table 5.4: Exposure of livelihood (transplanted aman crop) to pre-monsoon/pre-kharif drought

Division	District	pre-monsoon/pre-Kharif Drought risk of agricultural area (sqkm) in each District in Bangladesh			
		Near Normal		Moderate	
		Area	Percentage	Area	Percentage
Barisal	Barguna	0	0	1227.7585	100
	Barisal	0	0	1883.7797	100
	Bhola	0	0	1722.8353	100
	Jhalokati	0	0	702.9306	100
	Patuakhali	0	0	2350.7431	100
	Pirojpur	0	0	1128.3933	100
Chittagong	Bandarban	0	0	4.3641	100
	Brahmanbaria	0	0	156.8751	100
	Chandpur	0	0	555.6461	100
	Chittagong	0	0	2382.6267	100
	Comilla	0	0	1482.6918	100
	Cox's Bazar	0	0	897.9825	100
	Feni	0	0	868.8444	100
	Lakshmipur	0	0	1082.8703	100
	Noakhali	0	0	1744.9381	100
	Rangamati	0	0	13.9251	100
Dhaka	Dhaka	0	0	7.9737	100
	Faridpur	0	0	45.6324	100
	Gazipur	0	0	371.5371	100
	Gopalganj	0	0	21.3319	100
	Kishoreganj	0	0	914.9042	100
	Madaripur	0	0	59.8822	100
	Manikganj	0	0	25.6637	100
	Narayanganj	0	0	21.6117	100
	Narsingdi	0	0	740.0422	100
	Shariatpur	0	0	9.1786	100
	Tangail	0	0	1056.1769	100
Khulna	Bagerhat	0	0	1596.2027	100
	Chuadanga	0	0	279.5	100

Division	District	pre-monsoon/pre-Kharif Drought risk of agricultural area (sqkm) in each District in Bangladesh			
		Near Normal		Moderate	
		Area	Percentage	Area	Percentage
	Jessore	0	0	1544.5	100
	Jhenaidah	0	0	1242.7	100
	Khulna	0	0	1532.1	100
	Kushtia	0	0	480.9	100
	Magura	0	0	611.7	100
	Meherpur	0	0	82.6	100
	Narail	0	0	247.4	100
	Satkhira	0	0	2238.8	100
Mymensingh	Jamalpur	0	0	1084.6	100
	Mymensingh	0	0	3102.2	100
	Netrakona	0	0	958.5	100
	Sherpur	0	0	1130.9	100
Rajshahi	Bogra	0	0	2358.	100
	Chapai Nawabganj	0	0	535.0	100
	Joypurhat	0	0	958.3	100
	Naogaon	0	0	2713.8	100
	Natore	0	0	731.1	100
	Pabna	0	0	840.0	100
	Rajshahi	0	0	825.3	100
	Sirajganj	0	0	864.3	100
Rangpur	Dinajpur	0	0	3174.6	100
	Gaibandha	0	0	1412.7	100
	Kurigram	0	0	1383.3	100
	Lalmonirhat	0	0	929.0	100
	Nilphamari	0	0	1122.8	100
	Panchagarh	0	0	1053.7	100
	Rangpur	0	0	1781.4	100
	Thakurgaon	0	0	1254.0	100
Sylhet	Habiganj	5.8	0.9	662.9	99.1
	Maulvibazar	1088.8	83.3	217.2	16.6
	Sunamganj	305.1	70.7	126.2205	29.2
	Sylhet	2310.9	100.0	0.0	0

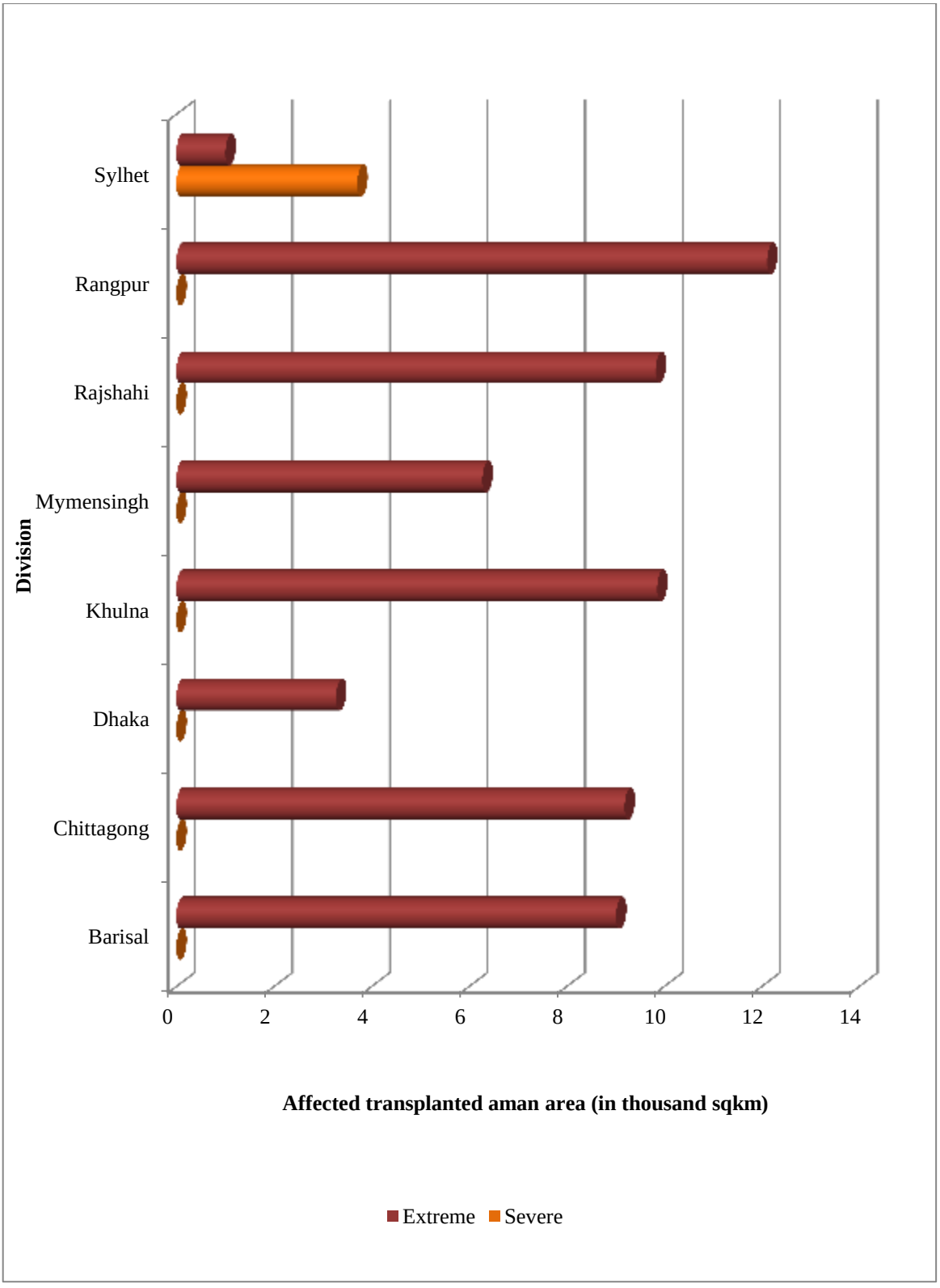


Figure 5.10: Transplanted aman area exposed to pre-monsoon/pre-Kharif drought hazard at division level

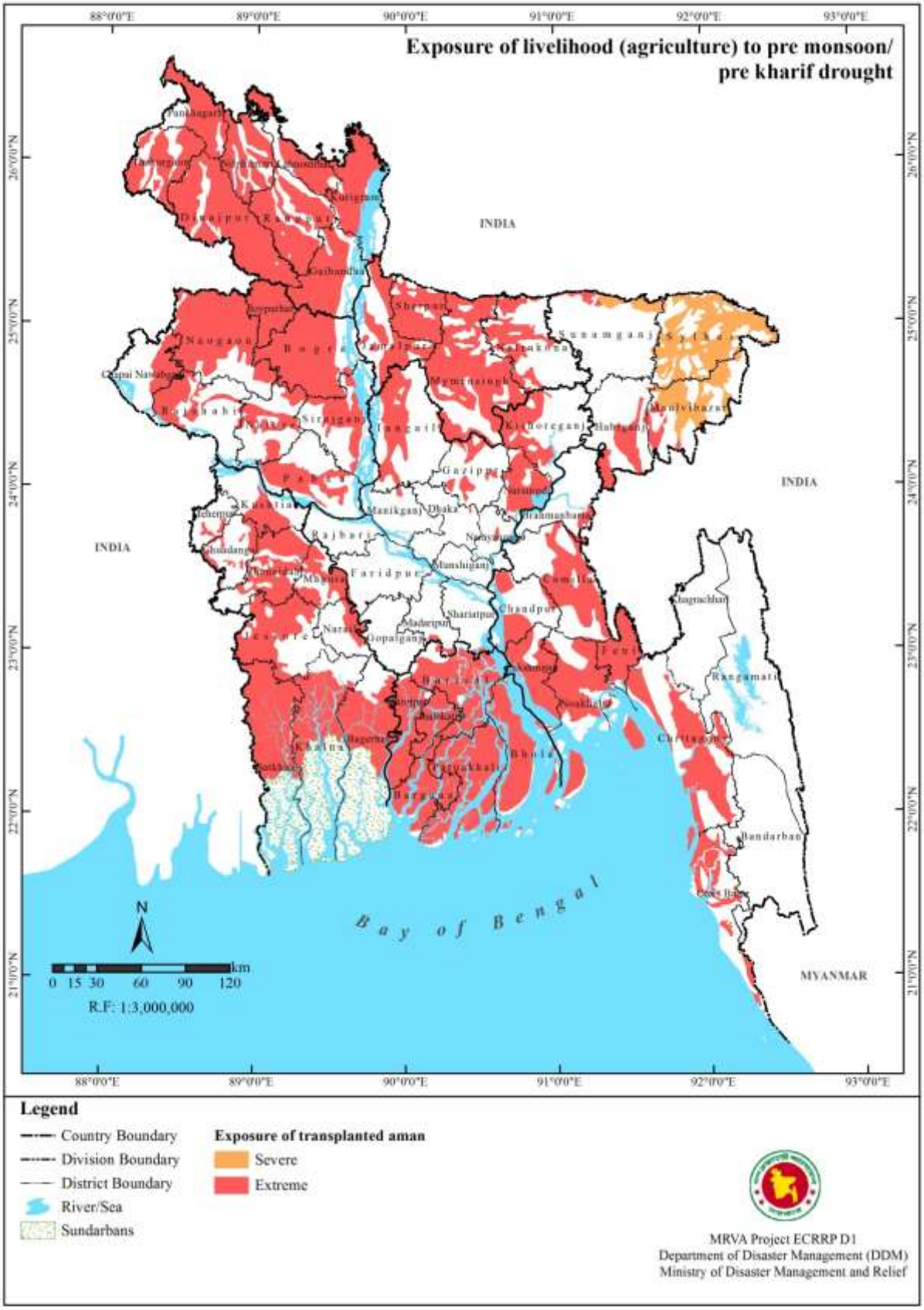


Figure 5.11: Exposure of livelihood (agriculture) exposed to pre-monsoon/pre-Kharif drought hazard at district level

5.2 Vulnerability / Damage Assessment

5.2.1 Livelihood (Agriculture)

The exposure map of livelihood (agriculture) i.e. transplanted Aman to drought hazard is used for risk assessment. Since crop duration of paddy is approximately 110 days, it is divided into 4 crop growth stages (seedling, vegetative stage, reproductive stage and mature). The number of days from the date of sowing is given in table 5.5, based on the literature and also discussion with Prof. Mirza, Share-e-Bangla Agriculture University, Dhaka.

Table 5.5: Crop growth stages of Transplanted Aman crop

Crop	Crop growth stages in days				Total days (90- 110)
	Seedling (7-10)	Vegetative state (45-50)	Reproductive stage (60-75)	Mature (90-110)	
Transplanted (Aman Rice)	9	47	68	100	110
Height of the crop (m)	0.15	0.7 (0.6 - 0.8)	1.05 (0.9 - 1.20)	1.05 (0.9 - 1.20)	
Period of season (Jul./ Aug. to Nov. /Dec.)	Jul / Aug	Aug / Sep	Sep / Oct	Nov / Dec	

Vulnerability / Damage curves of livelihood (Agriculture)

The risk levels of transplanted Aman to drought hazard depends upon the onset of drought and crop growth stage. Drought is expected due to decrease in rainfall during the monsoon season. The effect of decrease in rainfall during drought will affect the crops during August and September. Based on this, risk matrix indicating the risk levels of transplanted Aman due to drought in Augsut is given in table 5.6 and for September in table 5.7.

Table 5.6: Risk matrix of transplanted Aman crop to Drought hazard (in August)

Drought in August	Crop growth stages (cumulative days)			
	Seedling (7-10)	Vegetative state (45-50)	Reproductive stage (60-75)	Mature (90-110)
Planting date:	Jul / Aug	Aug / Sep	Sep / Oct	Nov / Dec
Height of the crop (m) / Drought hazard category	0.15	0.7 (0.6 - 0.8)	1.05 (0.9 - 1.20)	1.05 (0.9 - 1.20)
Moderate	D1	D2	D3	D3
Severe	D2	D3	D3	D3
Extreme	D3	D4	D4	D4

Table 5.7: Risk matrix of transplanted Aman crop to Drought hazard (in September)

Drought in September	Crop growth stages (cumulative days)			
	Seedling (7-10)	Vegetative state (45-50)	Reproductive stage (60-75)	Mature (90-110)
Planting date:	Jul / Aug	Aug / Sep	Sep / Oct	Nov / Dec
Height of the crop (m) / Drought hazard category	0.15	0.7 (0.6 - 0.8)	1.05 (0.9 - 1.20)	1.05 (0.9 - 1.20)
Moderate	D0	D1	D2	D3
Severe	D0	D2	D3	D3
Extreme	D0	D3	D4	D4

Using these risk matrices, risk levels of transplanted Aman is calculated and presented in table 5.8, figure 5.12 and figure 5.13.

Table 5.8: Transplanted Aman area (km^2) at different risk levels due to pre-monsoon/pre-kharif drought at division level

Name of Division	Risk level (%)				
	0	0-15	15-35	35-60	>60
Barisal	0	0	0	0	9016.4
Chittagong	0	0	0	0	9190.7
Dhaka	0	0	0	0	3273.9
Khulna	0	0	0	0	9856.9
Mymensingh	0	0	0	0	6276.2
Rajshahi	0	0	0	0	9826.2
Rangpur	0	0	0	0	12112.1
Sylhet	0	0	0	3710.7	1006.4
Total	0	0	0	3710.7	60559.1

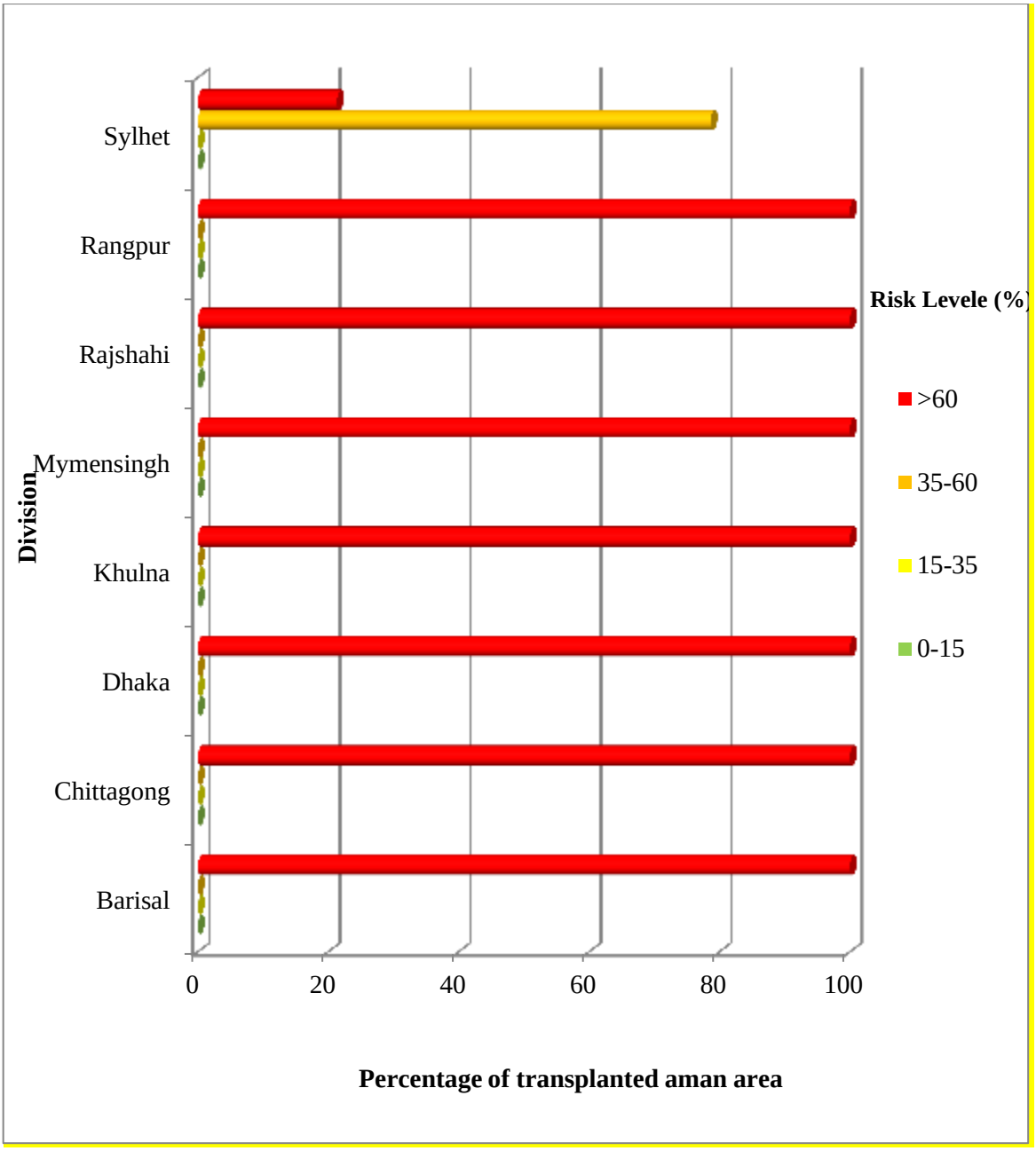


Figure 5.12: Percentage of transplanted aman area at different risk levels due to pre-monsoon/pre-kharif drought at division level

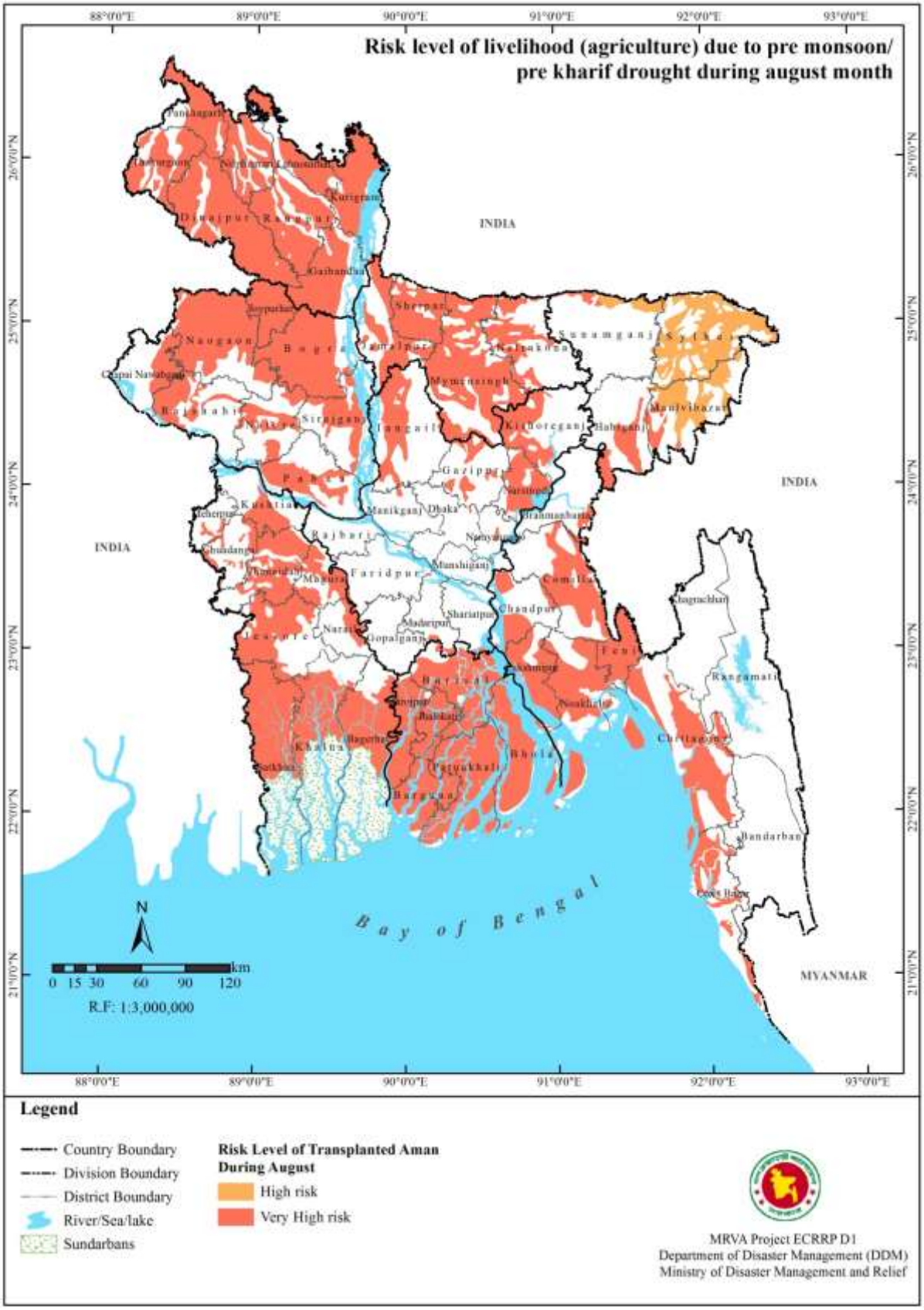


Figure 5.13: Risk level of livelihood (agriculture) to pre monsoon/ pre kharif drought during August at district level

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Annexure – I

Probabilistic Damage Functions_MRVAM_NGI_Report.pdf

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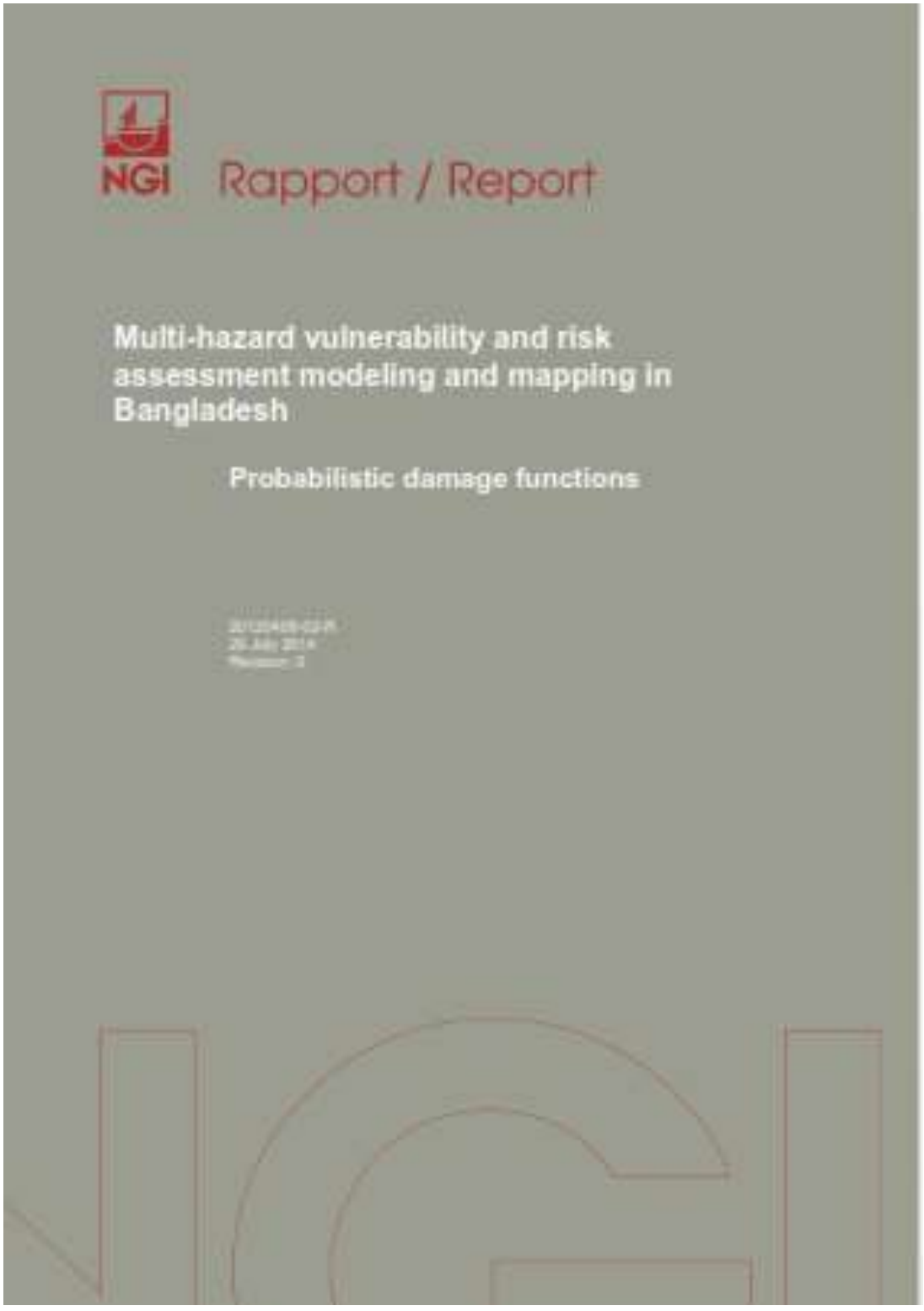

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