Baseline Assessment: Vulnerability Assessment of Northern Sierra Madre Natural Park

Philippines Biodiversity and Watersheds Improved for Stronger Economy and Ecosystem Resilience (B+WISER) Program

22 June 2015

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- Fauna and Flora International (FFI)
- Haribon Foundation
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Philippines Biodiversity and Watersheds Improved for Stronger Economy and Ecosystem Resilience (B+WISER) Program

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ACRONYMS

	B	
B+WISER	Biodiversity and Watersheds Improved for Stronger Economy and Ecosystem Resilience	
BSWM	Bureau of Soils and Water Management	
	C	
CNCM3/ CNRM-CM3	Centre National de Recherches Météorologiques	
	D	
DEM	Digital Elevation Model	
DENR	Department of Environment and Natural Resources	
	E	
EDC	Energy Development Corporation	
	F	
FAO	Food and Agriculture Organization	
FMB	Forest Management Bureau	
FS	Flood Susceptibility	
	G	
GIS	Geographic Information System	
	L	
LCC	Land Capability Class	
LCCS	Land Capability Classification System	
LGU	Local Government Unit	
	M	
MDG	Millennium Development Goals	
	N	
NAMRIA	National Mapping and Resource Information Authority	
NDVI	Normalized Difference Vegetative index	
NOAH	Nationwide Operational Assessment of Hazards	
NSMNP	Northern Sierra Madre Natural Park	
NSO	National Statics Office	
	P	
PAGASA	Philippine Atmospheric, Geophysical and Astronomical Services Administration	
PHIVOLCS	Philippine Institute of Volcanology and Seismology	
	S	

SAFDZ	Strategic Agriculture and Fisheries Development Zone
SEI	Soil Erosion Index
SEP	Soil Erosion Potential
SPI	Standardized Precipitation Index
	U
USAID	United States Agency for International Development
USLE	Universal Soil Loss Equation
	V
VA	Vulnerability Assessment

RATIONALE

Ecosystem vulnerability assessment is an approach used in determining the degree to which a system is susceptible to the adverse effects of climate related hazards such as soil erosion, flooding, drought, landslides, etc. It is regarded as a planning tool as it serves as basis in making decisions that will help minimize the vulnerability of the watersheds to environmental and climate related disasters. Natural events such as typhoons and heavy rains can be hazardous and can pose a major threat both to the ecosystems and human beings.

Watersheds play significant role in pursuing sustainable development (Lasco et al. 2006). More than 70% of the country's total land area lies within watersheds. Around 20 to 24 million people – about one fourth of the country's total population – inhabit the watersheds and are dependent on them for survival (Cruz et al., 2005). Thus, assessing watersheds vulnerabilities to soil erosion, landslides, drought and flooding is of utmost importance. This will help minimize further destruction and degradation of watersheds due to climate related extreme events. The results of the assessment will provide basis in crafting mitigation and adaptation measures that have to be integrated in the management plan of Northern Sierra Madre Natural Park and development plans of the LGUs covered by the NSMNP.

THE NORTHERN SIERRA MADRE NATURAL PARK

The Northern Sierra Madre Natural Park (NSMNP) is the largest protected area of the Philippines covering the northern range of the Sierra Madre Mountains of eastern Luzon. The park is located in the eastern part of the province of Isabela in Cagayan Valley consisting of a total area of 359,486 ha. It lies between geographical coordinates 16˚ 30' 0" to 17˚ 40' 0" north latitude and 122˚ 00' 0" to 122˚ 40' 0" east longitude (Figure 1). It was first declared a wilderness reserve encompassing an area within a 45 km radius of Palanan Point known as the Palanan Wilderness Area through Letter of Instructions No. 917-A signed by President Ferdinand Marcos on 7 September 1979. On 10 March 1997, the area was converted into a natural park with the signing of Proclamation No. 978 by President Fidel Ramos.

The NSMNP lies in the midsection of the Sierra Madre mountain range which stretches from the province of Aurora to Cagayan. It consists of 287,861 ha of land area and 71,652 ha of coastline water area along the Isabela municipalities of Palanan, Divilacan and Maconacon, as well as portions of San Mariano, Dinapigue, San Pablo, Cabagan, Tumauini and the Ilagan City. It is bounded on the north by the Dikatayan River, on the south by the Disabungan River, on the west by Cagayan Valley, and on the east by the Philippine Sea.

This protected area is covered by a total of 58 barangays (Table 1). The municipality of Palanan shares the biggest area with a total of of 86,736 ha which falls under the political jurisdiction of 17 barangays inside the protected area. This is followed by the municipality of Divilacan, which occupies 57,736.8 ha with 12 barangays. On the other hand, the smallest area belongs to Cabagan, which has only 1 barangay within the protected area.

Northern Sierra Madre is drained by 14 major river systems, 11 of which empty into the Philippine Sea and 3 flow into the Rio Grande de Cagayan as tributaries of the Ilagan River. Palanan River, with an area of 63,571 ha, is the most extensive, followed by Abuan River and Catalangan River.

Table 1. Number of barangays by municipality/city and their area coverage within the Northern Sierra Madre Natural Park

Municipality	No. of barangays covered by the watershed	Area of the municipality (ha)*	Area covered by the watershed (ha)*	Percent covered
1. Cabagan	1	31,898.8	3,947.6	12.4
2. Dinapigue	4	70,127.4	32,508.1	46.4
3. Divilacalan	12	57,736.8	57,736.8	100.0
4. Ilagan	5	81,074.0	27,415.1	33.8
5. Maconacon	10	41,185.5	37,552.4	91.2
6. Palanan	17	88,551.6	86,736.5	98.0
7. San Mariano	5	103,013.0	33,495.1	32.5
8. San Pablo	3	33,447.7	6,446.4	19.3
9. Tumauini	1	51,746.2	15,331.1	29.6
Total	*58*	*558,781.0*	*301,169.1*	*53.9*

*GIS generated land area

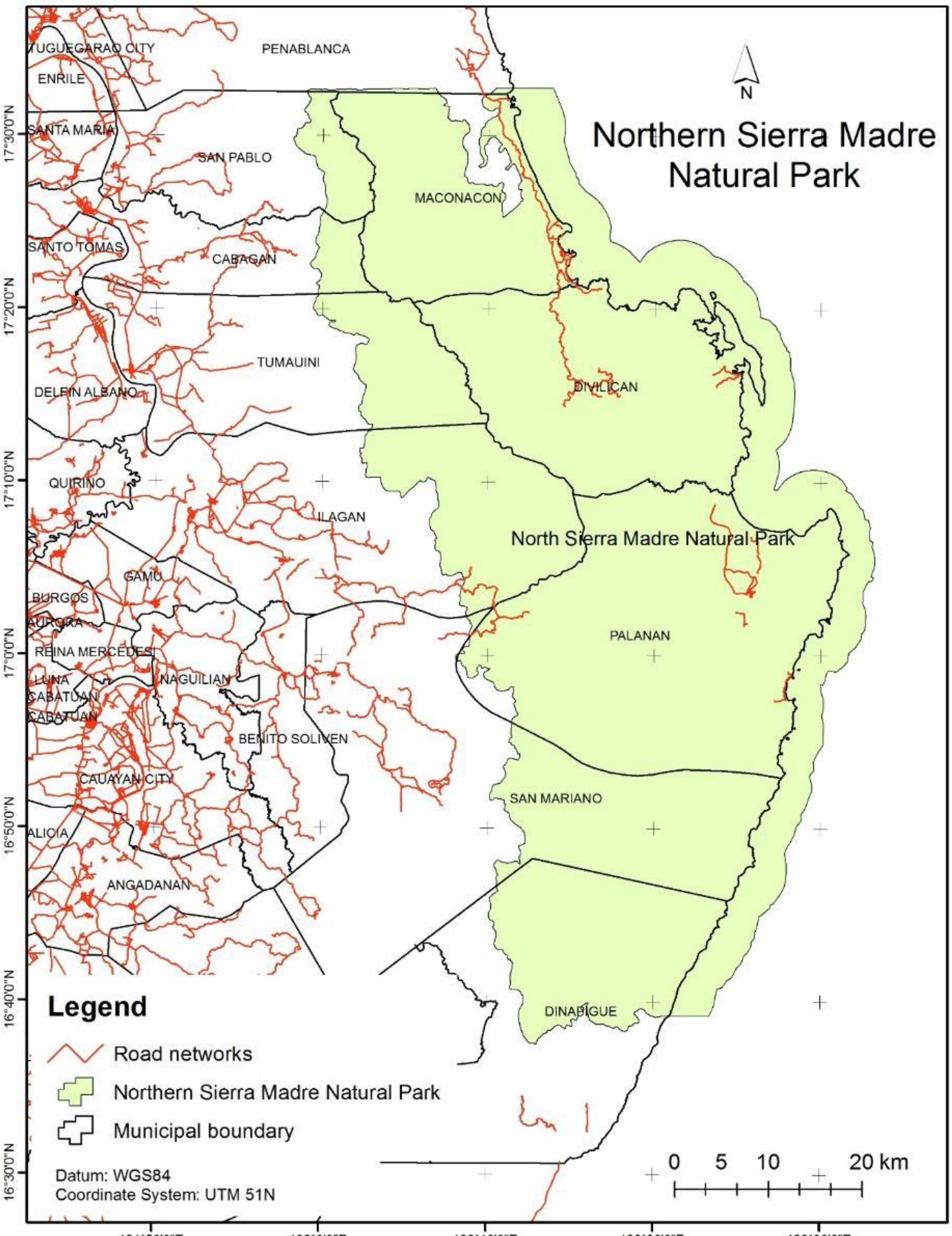

Figure 1. Location of the Northern Sierra Madre Natural Park

THE CLIMATE PROFILE

BASELINE CLIMATE

Based on Modified Corona's Classification System, the province of Isabela has two types of climate, namely: the type III and the type IV (Figure 2). The type III climate is characterized by two very distinct seasons (Agpaoa *et al.*, 1975). The dry season usually starts in November and ends in April while the wet season begins in May and peaks in July or August and ends in October or November. This type covers the central and western parts of the province.

The type IV of climate is characterized by no pronounced maximum rain period and no dry season. This means that rainfall is more or less evenly distributed throughout the year. This type covers the eastern part of the province, which comprises the towns of Maconacon, Divilacan, Palanan, San Mariano and Dinapigue. In the absence of weather data in this area, the use of data from Baler, Aurora weather station was considered for discussion.

The average annual rainfall in Baler was 3,082 mm. The rain period is from September to November with the latter month registering 1,151 mm. The months of March to May has the least rain with only 546 mm.

Temperature in the Philippines does not vary much from place to place except in places of relatively high altitudes. In Isabela, the hottest months are from June to August. The temperature in April is usually 28.7 °C. The approach of the cold months tones down the temperature to 24.1 °C, which is the average for January. The effects of typhoon upon the weather in the Philippines are of great significance. One important aspect is the amount of rainfall a typhoon brings as with the quick succession of typhoons, disastrous floods may follow.

Isabela is located in an area which is very frequently traversed by strong typhoons. Reports describe that a total of 13 typhoons pass through Isabela annually. This high frequency of occurrence is attributed to the geographical location of the province. One characteristic of typhoon in the Philippines is that they originate from the Pacific Ocean and move westward towards the Philippines usually swerving northward as they reach the eastern coasts of the Islands. In this northerly direction of the paths of typhoon, provinces in Northern Luzon are the ones generally affected (BANR, 1969).

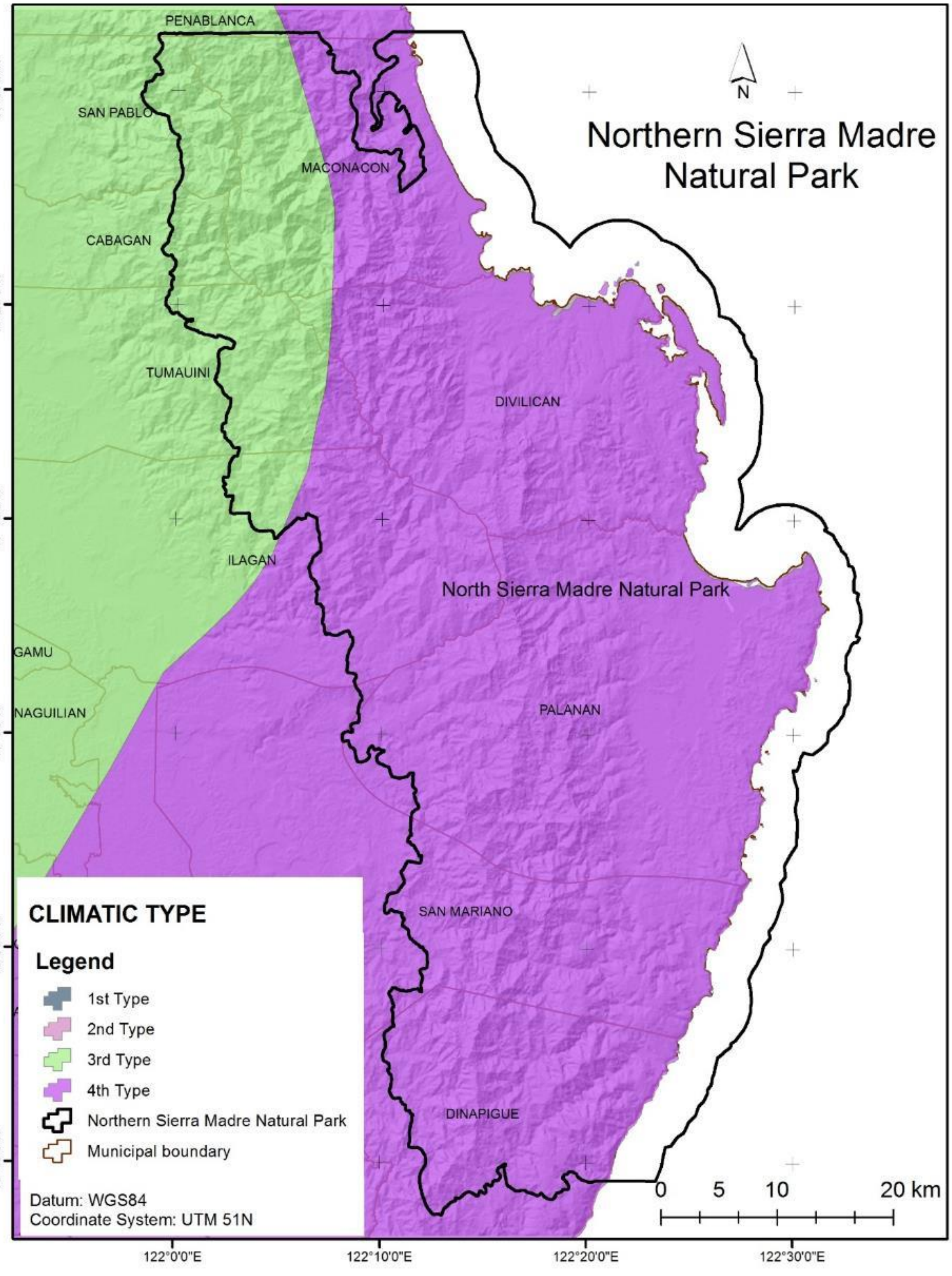

Figure 2. Climatic type of the Northern Sierra Madre Natural Park in Isabela Province

CLIMATE SCENARIO FOR ISABELA IN 2020 AND 2050

In order to assess future vulnerabilities to flooding, drought and landslide, projections of future changes in rainfall in 2020 and 2050 were prepared by the PAGASA using the CNRM-CM3 model (also known as CNCM3 model) with two scenarios. CNRM-CM3 coupled generation circulation model is the sum of the updated version of the different model components already present in CNRM-CM2 (Salas-Melia *et al.*, 2005).

In this assessment, the model outputs under the two scenarios were within a planning horizon of up to 2050. Outputs of the model under the A1B and A2 scenarios will only diverge after 2050 due to the long lifetimes of the greenhouse gases. The outputs of the model run for the observed monthly data, and changes in the monthly rainfall both in 2020 and 2050 were used in the vulnerability assessments.

The simulated monthly rainfall ranges from 29 mm to 652 mm. Mean monthly rainfalls of two scenarios (A1B and A2) were significantly different from each period. The driest month, April, still sees on average, over 62 mm of precipitation per year. The wettest months are August and December with a monthly mean of more than 300 mm (Figure 3 and Table 2).

In particular, the monthly precipitation fluctuated each month for two periods. However, the most distinct changes were predicted to be in the 2050s period in both scenarios. Rainfall amounts will most likely increase from November to April under A2 scenario while a decrease in A1B scenario. However, the A2 scenario predicts a drastic decrease in rainfall amounts during the supposed rainy season. On the other hand, the A1B scenario foresees a significant increase in rainfall from the months of June to September. Other periods closely followed the trends and patterns. Overall, an increase of annual rainfall was predicted in each scenario for two periods (Table 3).

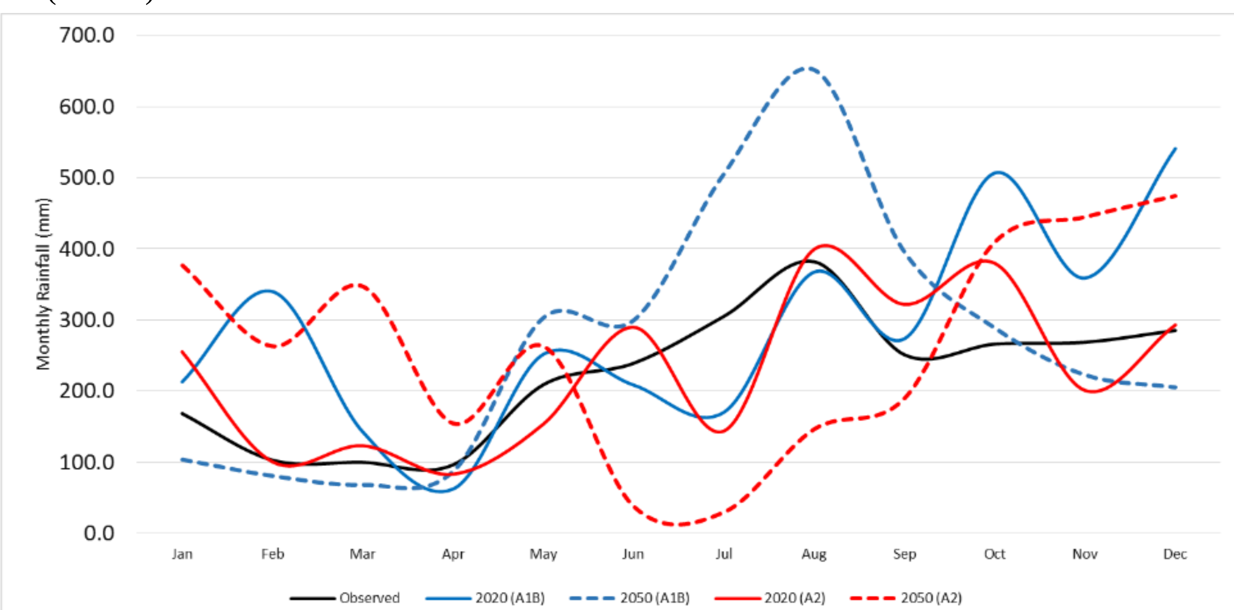

Figure 3. Observed and projected monthly rainfall for Isabela Province

Table 2. Projected rainfall based on CNCM3 model with two scenarios

Month	Observed	A1B		A2	
		2020	2050	2020	2050
Jan	168.6	213.0	103.4	255.3	376.3
Feb	103.1	340.0	80.4	100.8	262.7
Mar	100.0	142.8	67.9	123.3	346.6
Apr	96.5	62.4	86.8	83.4	154.3
May	209.0	251.7	302.9	153.7	262.7
Jun	239.2	208.6	299.4	289.8	37.6
Jul	305.1	170.4	505.3	144.0	29.6
Aug	382.0	367.4	651.5	399.4	146.3
Sep	251.2	273.7	395.3	321.9	189.5
Oct	266.2	506.6	288.6	379.6	408.9
Nov	268.8	358.9	222.5	201.1	444.2
Dec	285.4	540.9	205.0	293.0	473.8
Total	*2674.9*	*3436.5*	*3209.0*	*2745.3*	*3132.3*
Min	*96.5*	*62.4*	*67.9*	*83.4*	*29.6*
Max	*382.0*	*540.9*	*651.5*	*399.4*	*473.8*
SD	*90.25*	*143.02*	*181.77*	*109.27*	*152.10*
Ave	*222.9*	*286.4*	*267.4*	*228.8*	*261.0*

Table 3. Estimated changes in average monthly rainfall by 2020 and 2050

Month	A1		A2	
	2020	2050	2020	2050
Jan	26.3	-38.7	51.4	123.2
Feb	229.8	-22.0	-2.2	154.8
Mar	42.8	-32.1	23.3	246.6
Apr	-35.3	-10.1	-13.6	59.9
May	20.4	44.9	-26.5	25.7
Jun	-12.8	25.2	21.2	-84.3
Jul	-44.1	65.6	-52.8	-90.3
Aug	-3.8	70.5	4.6	-61.7
Sep	9.0	57.4	28.1	-24.6
Oct	90.3	8.4	42.6	53.6
Nov	33.5	-17.2	-25.2	65.3
Dec	89.5	-28.2	2.7	66.0
Total	28.5	20.0	2.6	17.1

ASSESSMENT FRAMEWORK AND METHODOLOGY

DATA COLLECTION

An exhaustive collection, examination and analysis of existing documents was conducted. The GIS geodatabase used in the overlay analysis was derived from the information contained in the sources and satellite data (Table 4).

Table 4. Available datasets for the assessment

Layer	Description	Source
Northern Sierra Madre Natural Park boundary	Extent of assessment	Interpolated from DEM NAMRIA; DENR-FMB
Fault lines	Fault lines of the Philippine Islands	PHILVOCS
Geology	Soil morphology	FAO datasets; BSWM
Soil series/ Soil texture	Soil series map	BSWM (1965; 2005)
Barangay	Barangay map	NAMRIA; PPDO; PENRO Isabela
Town and city	Administrative boundaries based on town and city	NAMRIA; PPDO; PENRO Isabela
DEM	Digital Elevation Model of the Philippines	ASTER-GDEM
River	River networks within the area	NAMRIA-DENR; MPDO
Standardized Precipitation Index	Computed based on monthly average rainfall	Derived
Land cover	2010 Land Cover Map	NAMRIA-DENR
Vegetative Index	Derived from land satellite 8 imageries	www.earthexplorer.usgs.gov
Rainfall	Daily rainfall data	www.acuaweather.com
Population Density	Based on 2010 population distribution by barangay	National Statics Office
Watershed shape	Based on sub-watersheds shape	Interpolated from DEM

VULNERABILITY ASSESSMENT

A GIS-based assessment was conducted to determine the areas vulnerable to the climate hazards. The assessment was undertaken by determining inherently sensitive areas due to topography and their exposure. Vulnerability or hazard maps were prepared to show which areas in the Natural Park require immediate attention to minimize the adverse impacts of changing climate. The assessment made use of simulated hazard maps derived from overlay analyses associated with different variables based on the observed and projected climate scenarios. Of the many different types of hazards related to climate change, flood, drought, and landslides were selected for assessment in this project. The selection is founded on the understanding that the projected climatic changes in the area involve significant variations in the amount, and seasonal pattern of rainfall. With shorter/drier dry seasons and longer/wetter wet seasons expected to become more prevalent, more frequent flood and drought events are expected to affect the local community's activities.

Hazard assessment was conducted based on different factors and their relative weights. Vulnerability maps to climate hazards for two (2) climate scenarios based on future with time periods of 2020 (base year 2006-2035) and 2050 (base year 2036-2065) were developed following the processes as illustrated in Figure 4.

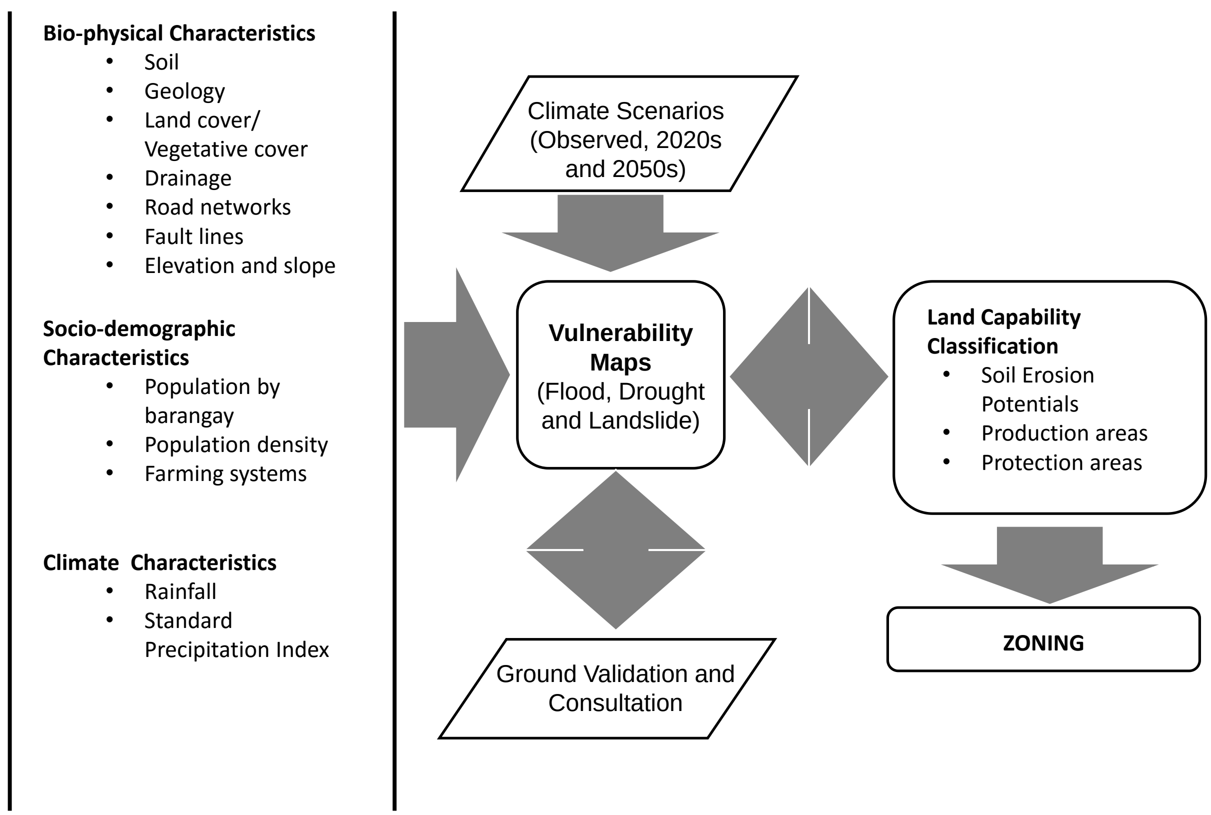

Figure 4. Framework of the vulnerability assessment

The assessment used the land capability evaluation tool in conducting adaptive capacity assessment. Land capability evaluation is a strategic planning tool in integrating climate change. The tool was used as part of vulnerability assessment under the MDG-F 1656 project for the purpose of developing an integrated watershed management plan. The tool was patterned after the VA framework by observing the process of problem identification, implementation and assessment following steps of Land Capability Classification Process.

Hazards Assessment

Flood Hazard Assessment

Flood hazard maps for 2020 and 2050 were generated by adjusting the existing flood hazard maps based on the projected mean annual frequency of days with rainfall of at least 100 mm. The susceptibility flood hazard map was generated based on different factors and their relative weights. The flood modeling is based on the overlay of six (6) contributing factors, namely slope, land cover/land use, soils, elevation, sub-watershed shape, and stream buffer (Table 5). Each factor is classified into five (5) categories ranging from low to very high classes. The different factors are described below:

a. Slope: The slope of the different sites was generated using a Digital Elevation Model (DEM) with a resolution of 30 m. A slope of >30% is considered to have very normal susceptibility and a slope range of 0-3% is classified to be highly susceptible to flood.

b. Land Cover: The 2010 land cover data was used for this factor. Water bodies and open areas are classified as highly susceptible to flood because they can generate high surface runoff while forested areas are considered to have normal susceptibility to flooding.

c. Soils: The different soil textural classes, commonly known as the soil series, describe the soil factors. These textural classes ranged from clay to sandy types. Water-holding capacity of soils at field capacity and wilting point of different soil textures are considered in the classification. Hence, clay types are deemed to be highly susceptible and sandy types are classified to have low susceptibility to flood.

d. Elevation: The elevation was generated from the DEM. Higher elevations are considered to be resistant to flooding and these are classified to have normal susceptibility while lower elevations are regarded as areas with very high susceptibility to flooding.

e. Watershed Shape: Shape of different sub-watersheds with the watershed was interpolated from the DEM. Almost elongated watershed is classified to be less susceptible while a watershed with nearly circular in shape is highly susceptible to flood.

f. Stream Buffer: Streams were generated from the 30 m DEM and then buffers were interpolated. Distance within 30 m from the stream is classified to be highly susceptible to flood while buffers with >1000 m distance from the stream is regarded to have low susceptibility.

Table 5. Summary of the classified ranges for the different layers/factors considered in the flood susceptibility

Layer/ Factor	Classes/ Ranges	Relative weights
Elevation **(ranges in m asl)**	>150	1
	80 - 150	2
	40 - 80	3
	20 - 40	4
	<20	5
Slope **(% ranges)**	>30	1
	18 - 30	2
	8 - 18	3
	3 - 8	4
	0 - 3	5
Stream buffer **(buffer ranges in m)**	<100	1
	100 – 200	2
	200 – 300	3
	300 – 500	4
	>500	5
Soil texture **(categories)**	Fine sand	1
	Sandy loam; Fine sandy loam	2
	Loam; Sandy clay loam; Sandy clay; Silty clay; Silt loam	3
	Silty clay loam; Clay loam	4
	Clay	5
Land cover **(categories)**	Closed forest	1
	Open forest; Plantation	2
	Shrubs; Natural grassland	3
	Agricultural/Cultivated; Pasture land; Built-up	4
	Bare; Water bodies; Inland water	5
Watershed shape **(ratio; descriptive)**	<0.25 (almost elongated)	5
	0.25 – 0.40	4
	0.40 – 0.60	3
	0.60 – 0.80	2
	>0.80 (almost circular)	1

The flood susceptibility (FS) map was generated using a map overlay analysis of the six (6) criteria or factors namely, slope, soils, stream buffer, elevation and land cover. The highest relative weight was given to elevation (38%). It was followed by slope factor (24%), stream buffer (17%), shape of the watershed (12%) and soil series (6%), while the lowest relative weight was calculated for the land cover factor (3%). Relative weights were applied to determine the flood susceptibility using the following equation:

$$FS = (Elevation \times 0.38) + (Slope \times 0.24) + (Stream\ buffer \times 0.17) + (Shape \times 0.12) + (Soil\ series \times 0.06) + (Land\ cover \times 0.03)$$

Based on the overlay analyses of these factors, the different flood susceptibility models were generated.

Drought Hazard Assessment

Vulnerability to drought is the relationship of susceptibility to physical factors, exposure to climatic factors and adaptability to anthropogenic factors. Basically, each factor was assigned a relative weight according to their influence. Each factor with the specific hazard values was prepared and analyzed for simulation. All factors followed the same scaling factor procedures to assess and map out vulnerable areas (Table 6). Overall, drought hazard maps for observed, 2020s and 2050s periods were produced based on different factors and their relative weights. Different factors are described below:

a. Standardized Precipitation Index: The Standardized Precipitation Index (SPI) is a tool developed primarily for defining and monitoring drought. It determines the rarity of a drought at a given time scale of interest for the given station. It can also be used to determine periods of anomalously wet events. It must be noted that the SPI is not a drought prediction tool. Mathematically, the SPI is based on the cumulative probability of a given rainfall event occurring in the station.

   The SPI was generated from the variation in a gamma distribution function. The function was a standard deviation and a mean, which depends on the rainfall characteristics of the area. The SPI can effectively represent the amount of rainfall over a given time scale, with the advantage that it provides not only information on the amount of rainfall, but also an indication of the relation of this amount to the normal. This information leads to the definition of whether a station is experiencing drought or not. In essence, the SPI value of greater than 0 is considered to be wet to extremely wet. Higher exposure values are greater than 2, which were classified as extremely dry.

b. Elevation: The elevation was generated using the digital elevation model. Higher elevations are classified as resistant to drought and have low susceptibility while low elevations are regarded as areas with severe susceptibility to drought.

c. Soils: The different soil textural classes, known as the soil series, describe the soil factors. These textural classes range from fine sand to clay types. Water retention of several soil textures varies such as fine sand types are deemed to be highly susceptible and silt loam types are classified to have low susceptibility to drought.

d. Irrigation Canal and River: Streams and canals assessment is based on the available datasets and buffers that were interpolated. Distance within 500 m from the stream and canal is classified as not susceptible to drought while buffers with >2000 m distance from the stream is regarded to have low susceptibility.

e. Population Density: Population density was estimated based on the 2010 population and area per barangay. The barangays with more than 200 person/ha are classified to be severely susceptible to drought while barangays with less than 10 person/ha are assigned to have low susceptibility.

f. Vegetative Index: The latest land satellite imageries were used for this factor. The influence of water bodies is considered normal with values ranging from -1 to 0. Open and built up areas are classified as severely susceptible to drought because they can generate high soil and surface evaporation losses.

Table 6. Summary of the classified ranges for the different layers/factors considered in the drought susceptibility

Layer/ Factor	Classes/ Ranges	Relative weights
Standardized Precipitation Index	>0 wet to extremely wet	1
	0 – -1 (near normal)	2
	-1 to -1.5 (moderately dry)	3
	-1.5 to -2.0 (severely dry)	4
	>-2 (extremely dry)	5
Elevation **(m asl)**	>1000	1
	500 - 1000	2
	200 - 5000	3
	100 - 200	4
	0 – 100	5
Distance of existing irrigation canal and river **(buffer ranges in m)**	0-250	1
	250-500	2
	500-1000	3
	2000-3000	4
	>3000	5
Soil texture **(categories)**	Silt loam	1
	Clay loam; Loam	2
	Fine sandy loam	3
	Sandy loam; Clay; Sandy loam	4
	Fine sand	5
Vegetative index **(NDVI range index)**	-1.0 - 0	1
	0.5 – 1.0	2
	0.30 – 0.50	3
	0.15 – 0.30	4
	0 - 0.15	5
Population Density **(person/ha) by barangays**	<10	1
	10 -50	2
	50 - 100	3
	100 - 500	4
	>500	5

Landslide Hazard Assessment

It is essential for landslide susceptibility assessment to involve the detailed knowledge of slope processes that lead to landslides. Such information includes geology, geomorphology and hydrogeology. Sufficient geotechnical information about the slopes also improves slope failure modeling. A number of important data are at present, not yet available with the Province of Isabela, such as soil thickness and rainfall-landslide thresholds. Hence, additional constraints were incorporated in the landslide susceptibility modeling to improve its reliability. In order to define the landslide susceptibility, the matrix method in a GIS environment was applied (e.g., Irigaray *et al.*, 2007; Jimenez-Peralvarez, 2009).

The vulnerability to landslide is a function of different physical factors, and the different thematic maps (slope, soil, geology (geo-hazard), land cover and climate). Essentially, each factor was assigned a relative weight according to their influence in landslide occurrence. Each factor with the specific hazard values was prepared and analyzed for simulation (Table 7). All physical factors followed the same scaling factor procedures. Degrees within each factor were given relative weights (from low to high) depending on the degree by which they could influence landslide susceptibility. The geomorphologic and heuristics analyses were utilized to assess and map out areas vulnerable to landslide.

Table 7. Summary of the classified ranges for the different layers/factors considered in the landslide susceptibility modeling

Layer/ Factor	Classes/ Ranges	Relative weights
Elevation **(ranges in m asl)**	<200	1
	200 - 400	2
	400 - 600	3
	600 - 800	4
	>800	5
Slope **(% ranges)**	<8	1
	8 - 18	2
	18 - 30	3
	30 - 50	4
	>50	5
Rainfall **(buffer ranges in mm)**	<100	1
	100 – 200	2
	200 – 300	3
	300 – 500	4
	>500 mm	5
Soil Morphology **(categories)**	Tropaquepts w/ Entropepts; Udorthents & Tropepts	1
	Tropopsamments w/ Troporthents; Eutrandepts w/ Eutropepts	2
	Tropudalfs w/ Tropepts	3
	Entropepts w/ Dystropepts	4
	Tropudults w/ Tropudalfs; Mountain soils w/ Entisols, Inecptisols, Ultisols and Alfisols	5
Land cover **(categories)**	Closed forest	1
	Open forest; Plantation	2
	Shrubs; Natural grassland	3
	Agricultural/Cultivated; Pasture land; Built-up	4
	Bare	5
Fault lines **(buffer ranges in meters)**	<500	5
	500 - 2000	4
	2000 - 5000	3
	5000 - 8000	2
	>8000	1
Road Network **(buffer ranges in meters)**	<150	5
	150 - 300	4
	300 - 500	3
	500 - 1000	2
	>1000	1

LAND CAPABILITY CLASSIFICATION

Land capability is the capability of the land to sustain the forest ecosystem. Rainfall, soil and topography are the factors considered for determining the survival of a forest ecosystem. These factors are assessed for land capability assessment for sustaining forests and (other) ecosystems. Before, land capability assessment is being conducted without the consideration of climate change. Today, climate change has been incorporated with land capability, since climate change will have an impact on forest ecosystems over time.

Land capability evaluation process looks at the characteristics of each factor and how it affects the capability of the land to sustain the forest ecosystem. This process was applied as a product of land capability classification, which was undertaken using the potential soil erosion of an area as basis.

Figure 5 shows the framework derived from the erosion-based land capability classification system (LCCS) developed by Warren *et al*. (1989) in the United States and applied by Cruz (1990) in Ibulao Watershed, by De Asis (1998) in UP Land Grant, Quezon-Laguna, and by Cruz *et al*. (2010) in Pantabangan and Ambuklao-Binga Watersheds, Philippines by EDC (2012) in five (5) geothermal project sites, and by DENR-R4 (2013) in San Juan River Watershed.

Soil erosion is a suitable indicator of land capability because of common key determinants (*i.e*., rainfall, soil and topography). Soil erosion is also a good measure of the sustainability of land productivity, which is the primary success indicator of land capability. The premise of an erosion-based LCCS is that any use that is compatible with a specific land capability class (LCC) or zone will not cause significant soil erosion that will lead to the deterioration of land productivity and soil and water resources. Furthermore, the planned use should not bring about adverse offsite impacts. Climate change related hazards, such as floods, rain-induced landslides and other natural hazards, impose limitations on the potential uses of LCC.

Following the procedure described by Warren *et al.* (1989) and with the aid of GIS analytical techniques, the erosion index was developed and used for land capability classification.

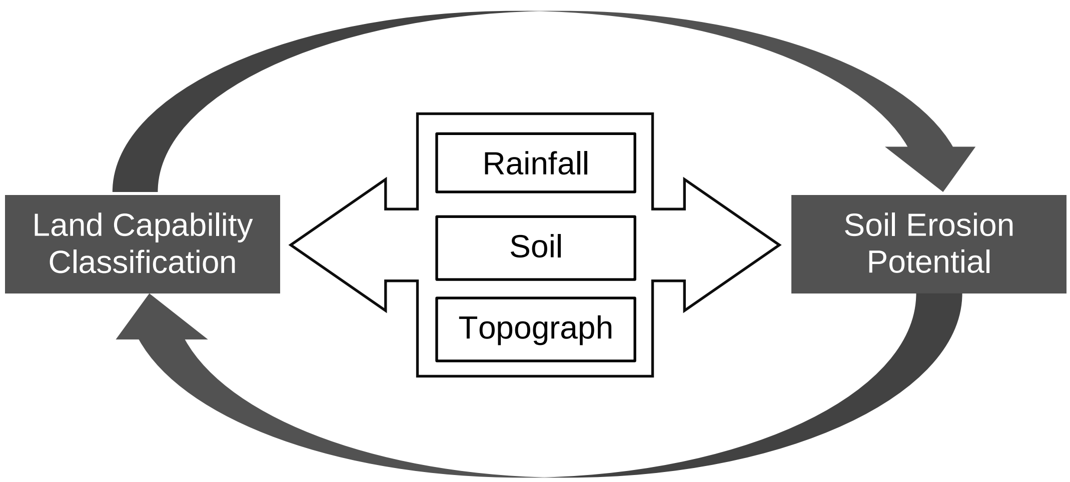

Figure 5. Framework for erosion-based land capability classification system

Generation of Soil Erosion Potential

Soil erosion potential (SEP) was estimated using the principle of the Universal Soil Loss Equation (USLE) developed by Wischmeier and Smith (1978). Originally, the equation includes the rainfall erosivity factor (R), soil erodibility factor (K), topographic factors (slope, S and length, L), plant cover and farming techniques (C), and erosion control practices (P). However, SEP was computed the same except for C factor. The C was excluded because it can easily be altered by the activities of man. In particular, the equation is as follows:

$$SEP = R \times K \times LS \times P$$

Rainfall Factor (R)

In 1987, David and Collado adopted an equation to estimate the value of *R* given the limited rainfall data in Northern and Central Luzon, Philippines. The equation is shown as follows:

$$R_j = A\sum P_i^{\ m}$$

where:
R_j = number of erosion index units on a given year *j*;
P_i = daily precipitation total for a given day *i* in any year *j*;
m = an exponent; and
A = an empirical constant designed to relate the precipitation amount P with raindrop erosive energy.

In the application of the above equation, only rainfall totals, P_i exceeding the threshold value of 25 mm is used, while values of *m* and *A* are 2.0 and 0.002, respectively.

In this assessment, the computation of *R* was based on the above equation. According to David (1988), the use of an *A* value of 0.002 renders the *R* estimates compatible with those of the USLE. The *R* factor is computed from the daily rainfall records exceeding or equal to 25 mm, which is commonly considered as erosion producing rainfall events. These records were obtained from *acuaweather* data portal.

Soil Erodibility Factor (K)

Owing to the lack of a detailed soil map, the *K*-values were estimated using the Wischmeier and Mannering (1969) equation as modified by David (1987) and used by Cruz (1990), Pudasaini (1992), Singh (1993), Bantayan (1996), De Asis (1998), and Combalicer (2000). This equation was estimated on the basis of particle size distribution, organic matter content, and pH. It was also simplified and adjusted for Philippine conditions. The equation is as follows:

$$K = \left[(0.043)(pH) + \frac{0.621}{OM} + 0.0082(Sa) - 0.0062(C) \right] S$$

where:

K = erodibility factor
OM = organic matter content in percent
Sa = percent sand
$C = \text{clay ratio} = \dfrac{\%\text{clay}}{\%\,\text{sand} + \%\,\text{silt}}$
$\text{S} = \dfrac{\%\,\text{silt}}{100}$

The *K* values for the different soil series identified are shown in Table 8.

Table 8. K-values for the Northern Sierra Madre Natural Park

Soil series	*K*-value
Alaminos clay loam	0.220
Bago sandy loam	0.265
Beach sand	0.300
Bigaa clay	0.150
Cauayan clay	0.150
Cauayan sandy loam	0.300
Hydrosol	0.150
Ilagan loam	0.280
Ilagan sandy loam (eroded phase)	0.265
Mountain soil (undifferentiated)	0.200
Quingua sandy loam	0.230
Rugao clay	0.150
Rugao clay loam	0.250
Rugao sandy clay loam	0.250
San Manuel loam	0.280
San Manuel sandy loam	0.265

Slope Length and Slope Gradient Factor (LS)

The topographic factor is the combined effects of slope length (*L*) and slope steepness (*S*) on soil erosion. Slope length is the horizontal distance downslope from the point where overland flow begins up to where runoff enters a waterway or where deposition starts. Slope gradient is the field or segment slope, usually expressed as a percentage.

Slope length and slope gradient have significant roles in the erosion process. Since they are related, the effects of both factors were evaluated as a single topographic factor. Using combination equations of Smith and Wischmeier (1957) and Williams and Berndt (1972) as adopted by Cruz (1990), Sing (1993), Pudasaini (1993), Oszaer (1994), and Combalicer (2000). *LS* can be computed as follows:

$$LS = 4.705 \left(\frac{L}{22.13} \right)^m \left(0.0076 + 0.0053\, S + 0.00076\, S^2 \right)$$

where:

LS = topographic factor (unitless)
L = slope length factor
S = average slope in %
m = an exponent
m = 0.5 if $S>5$
m = 0.4 if $5>S>3$
m = 0.3 if $3>S>1$
m = 0.2 if $S<1$

Creation of Soil Loss Tolerance

Soil loss tolerance limit of a watershed is a common expression of the SEP estimates. The T value is an expression of the maximum soil loss that an area can sustain without regressing in productivity permanently or temporarily. It is a function of the rate of soil accumulation in an area that is dependent on the slope of an area. Hence, the slope was reclassified according to its soil loss tolerable limits (Table 9).

Table 9. Prescribed soil loss tolerance in the watershed

Slope	Soil Loss Tolerance (ton/ha)
0 - 3	20
3 - 8	15
8 - 18	12
18 - 30	10
30 – 50	7
>50	5

Determination of Soil Erosion Index

The computation of soil erosion index (SEI) is essential to standardize the SEP estimates. As it is, the SEP per se, when directly used as indicator of sensitivity or susceptibility of an area to soil erosion, does not capture the full weight of slope as a determinant of soil erosion in an area. Hence, the equation is as follows:

$$SEI = \frac{SEP}{SLT}$$

Generation of Land Capability Classification

Land use zones were delineated based on land capability as indicated by the *Soil Erosion Index* and other criteria as shown in Table 10. Two (2) major zones, namely protection and production, were identified. Each major zone was further classified into subzones. It is noted here that the output zonation and the indicative land uses in the area are intended to provide a scientific basis for allocating the lands in the municipalities to various uses.

Zoning is not meant to be prescriptive in any absolute sense. The land capability zoning map is an ideal physical framework for allocating the lands within the watershed. The primary goal is to sustain the long-term productivity of the land and promote the sustainability of biodiversity, soil and water resources and the delivery of key services of ecosystems in and out of the area. The decision on how the lands are ultimately used still rests with the managers, farmers, and other stakeholders.

Table 10. Land capability classification criteria

Class	Land Classification	SEI	Management Prescriptions
I	**PROTECTION AREAS**		
IA	***Strict Protection Zone*** All remaining natural forests, all areas with high erosion potential and slope >50%, all key biodiversity areas, all areas categorized as SAFDZ, all other areas with SEI > 5	>5	Strict protection, limited collection of ornamental plants, herbs, vines, fruits and other non-timber products may be allowed
IB	***Protection Buffer Zone*** All areas within 40 m of stream banks, all areas within 50 m of major watershed divides;		Permanent crops (fruit trees, bamboo), harvesting of fruits and bamboo shoots and culms will be allowed but no harvesting of trees will be allowed
IC	***Key Biodiversity Area***		For biodiversity conservation
II	**PRODUCTION AREAS**	0 - 5	
IIA	***Unlimited Production Zone*** Grasslands and brushlands; built up and cultivated areas	0 - 1	Timber and fruit tree plantations, agriculture and agroforestry can be allowed with suitable soil and water conservation measures, settlement can be allowed
IIB	***Multiple Use Zone*** Grasslands and brushlands; built up and cultivated areas	1 - 3	Multi-story timber and fruit tree plantations, agroforestry can be allowed with suitable soil and water conservation measures
IIC	***Limited Production Zone***	3 - 5	Multi-story timber and fruit tree plantations

VALIDATION

Results of simulation based on physical, demographic, vegetative and climatic data were validated on site. Different stakeholders from municipalities within the watershed were considered as key informants in the area. Key informants are primarily the municipal planning and development officer and the disaster risk reduction risk and management officer (Plate No. 1). Each informant was asked of his/her observation on the degree of hazard susceptibility of every barangay. High susceptible barangays are considered to have previous experience of landslide, drought and flood.

Site visits followed the interviews and document gathering in the entire watershed. The location of sites visited is shown in Figure 6.

Plate 1. Participants during the vulnerability assessment validation workshop, (January 21, 2015)

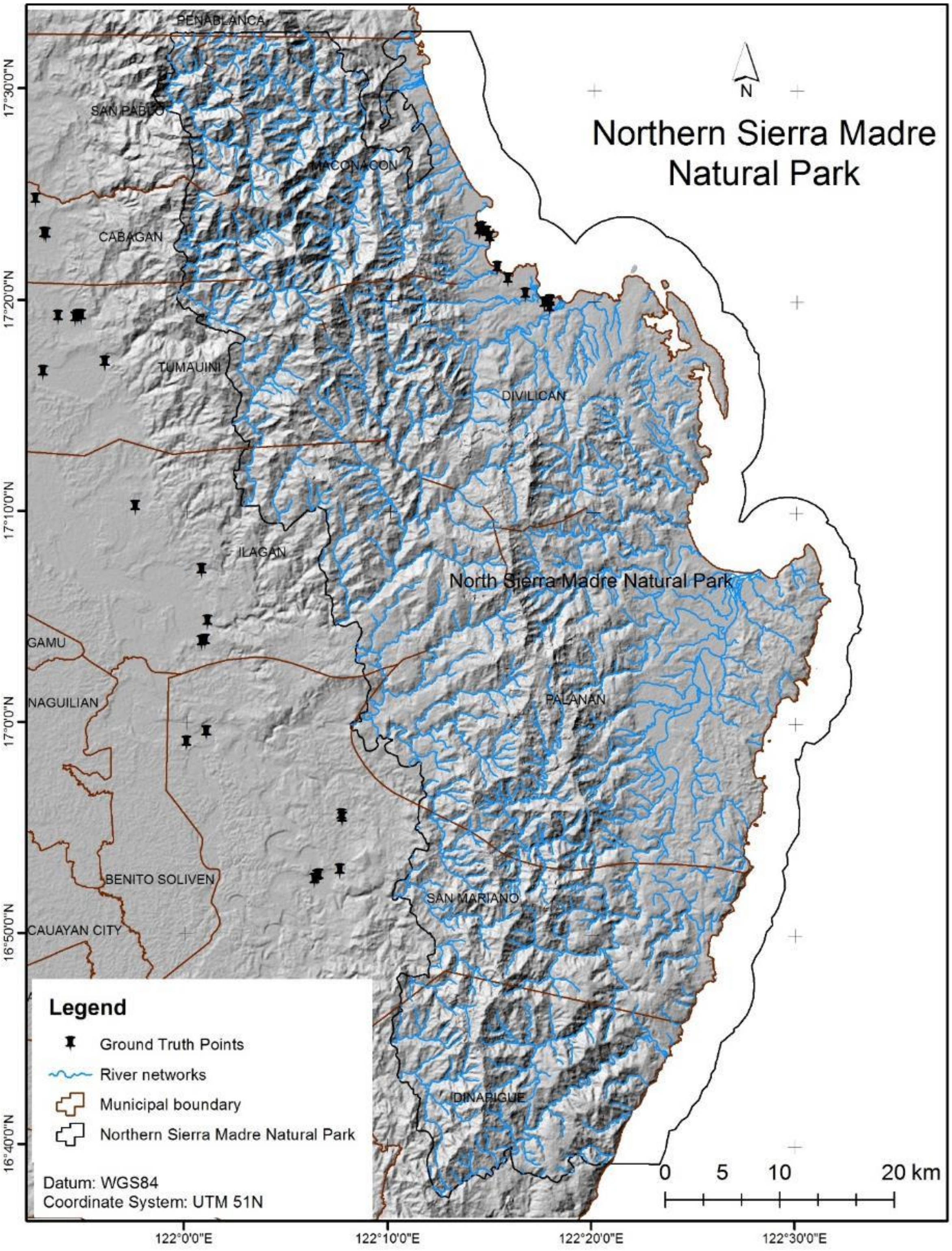

Figure 6. Sites visited during the validation

FINDINGS

HAZARDS ASSESSMENT

Flood Hazard Assessment

Flood is commonly defined as an overflow of water onto normally dry land. It is also described as the inundation of a normally dry land caused by rising water in an existing river networks and stream channels. In this assessment, flood scenarios were generated given physical factors, vegetative conditions and rainfall amounts based on CNCM3 model with two scenarios during the 2020s and 2050s periods.

Table 11 shows the summary of vulnerability ratings and area coverage in the Northern Sierra Madre Natural Park. Highly vulnerable areas ranges from 8,000 to 13,500 ha given the observed and projected scenarios for 2020s and 2050s periods. Results show that in Northern Sierra Madre mountain ranges, there will likely be a very low indication of flooding. The park is characterized by high mountains with very steep slopes in the central portion of the range and relatively low hills with dominantly moderate steep slopes towards the coast. The assessment predicts the spatial influences of flooding will likely be increasing under A1B scenario in the 2050 period. However, there would be no significant changes in other periods and scenarios even with an increase of annual rainfalls due to fluctuating patterns and a decline of monthly rainfalls and long dry spells.

As shown in Figures 7 to 11, the assigned colors represent specific categories and are translated into susceptibilities. It is the possibility of flooding that is covered by each colored representation. However, susceptibility to flooding cannot be equated with floodwaters. In particular, the blue color suggests that the areas covered are highly susceptible to flooding at any given event. Although it was categorized in one single category, this does not mean that the entire area will be under flooding all at the same time. Rather, flooding will depend on the magnitude of rainfall and influence of associated factors. In any given tropical storms and extreme rainfall events, the northern parts of the influence watershed will be highly affected, others moderately affected, and some low at all.

Table 12 describes the barangay vulnerability ratings to floods given the observed and predicted scenarios. Areas highly affected by flood risk were found in more or less 20 barangays: one (1) in Dinapigue (Dimalauade), three (3) in Divilacan (Dicambangan, Dicatian, and Dimapula), one (1) in Ilagan (Villa Imelda), four (4) in Maconacon (Diana, Eleonor, Lita, Minanga), nine (9) in Palanan (Dialaoyao, Dicabisagan East, Dicabisagan West, Dimalicu-licu, Dimatican, Maligaya, Marikit, Santa Jacinta, and Villa Robles), and two (2) in San Pablo (Caddangan/Limbauan, and San Vicente). The remaining barangays were rated low or moderate in terms of flooding. As a result, spatial flood risk assessment described that a low lying portion in the eastern coast sides appears highly susceptible to flooding. Flood prone areas are evident in portions of Palanan, Divilican, and Maconacon, Isabela (Plate No. 2). It must be noted that other municipalities and their barangays in the western sides would also be classified as highly vulnerable to flooding. However, these areas are adjacent to and outside the declared protected areas (Plate No. 3).

Plate 2. Flood prone areas in the eastern side located in Maconacon, Isabela (January 23, 2015)

Plate 3. Flood prone areas in the western side of the NSMNP located in San Mariano, Isabela (January 23, 2015)

Northern Sierra Madre is drained by 14 major river systems, 11 of which empty into the Philippine Sea and three (3) flow into the Rio Grande de Cagayan as tributaries of the Ilagan River. Palanan River, with a watershed area of 63,571 ha or 29% of the park's total area, is the most extensive, followed by Abuan River and Catalangan River.

In the case of Palanan Watershed, the rivers are seasonally flooded. Accordingly, flood water reaches more than 5 - 10 m in depth especially during torrential and/or extreme rainfall events. River floods were intensified by factors associated with the drainage networks and stream channels from the Northern Sierra Madre mountain ranges. Most of the channels operate to speed up the movement of water within the watershed located in the southern part. Another contributing factor of flooding is the sea level rise especially in terms of river mouth flood risks. The coastal areas of Palanan River near the mouth are potentially significant geo-hazard areas due to fluvial flooding. Occasionally, high tide coincides with heavy rainfall events.

Overall, flooding in low-lying areas and stream channels could also be considered as a leading concern in the park. Historically, the eastern side was flooded in 1970 due to typhoon influences. Again, after fifty (50) years return period, the NSMNP have experienced flooding events that affected residents in terms of lives lost and damage to properties and crops in 2010. Antecedent rainfalls brought by tropical storm and *typhoon Juan* caused the incidents of flooding as well as flash flooding over the Palanan River in Palanan, and Sangay and Diana rivers in Maconacon. These catastrophes were perceived due to the municipal government that tolerate illegal logging in the protected area (Ploeg *et al*., 2012). Flood carrying logs and plenty of mud are indications that the water came from the mountains and is also the reason behind the very fast occurrence of flooding. Moreover, flooding is being triggered by heavy continuous rainfalls that is aggravated by reduced soil absorptive capacity in the upstream and the watershed itself. Again, it must be noted that the larger the watershed, the larger is the flood produced from a watershed-wide rainfall event.

Table 11. Susceptibility to flooding and its area coverage based on CNCM3 model

Susceptibility	Observed	A1B		A2	
		2020	2050	2020	2050
Low	266,795	266,795	256,020	266,795	266,795
Moderate	15,098	15,098	21,060	15,098	15,098
High	8,594	8,594	13,407	8,594	8,594
Total	290,488	290,488	290,488	290,488	290,488

Table 12. Susceptibility index to flooding by barangay based on CNCM3 scenarios

Barangay/ Municipality	Observed	Validated	A1B		A2	
			2020	2050	2020	2050
CABAGAN						
Union	low	low	low	Low	low	low
DINAPIGUE						
Ayod	low	Low	low	Low	low	low
Bucal Norte	low	Low	low	Low	low	low
Bucal Sur	low	low	low	Low	low	low
Dimaluade	low	high	low	Low	low	low
DIVILACAN						
Bicobian	moderate	low	moderate	moderate	moderate	moderate
Dibulos	low	moderate	low	Low	low	low
Dicambangan	moderate	high	moderate	High	moderate	moderate
Dicaroyan	low	low	low	Low	low	low
Dicatian	high	high	high	High	high	high
Dilakit	moderate	low	moderate	moderate	moderate	moderate
Dimapnat	low	moderate	low	moderate	low	low
Dimapula	high	low	high	high	high	high
Dimasalansan	moderate	low	moderate	high	moderate	moderate
Dipudo	moderate	low	moderate	high	moderate	moderate
Ditarum	low	moderate	low	low	low	low
Sapinit	low	low	low	low	low	low
ILAGAN						
Cabeseria 25	low	low	low	high	low	low
Pasa	low	low	low	low	low	low
Sindon Bayabo	low	low	low	high	low	low
Sindon Maride	low	low	low	high	low	low
Villa Imelda	high	high	high	high	high	high
MACONACON						
Aplaya	low	moderate	low	low	low	low
Canadam	low	low	low	high	low	low
Diana	high	high	high	moderate	high	high
Eleonor	high	moderate	high	low	high	high
Fely	moderate	moderate	moderate	low	moderate	moderate
Lita	high	low	high	high	high	high
Malasin	low	moderate	low	moderate	low	low
Minanga	high	high	high	high	high	high
Reina Mercedes	low	moderate	low	low	low	low
Santa Marina	low	moderate	low	low	low	low

Barangay/ Municipality	Observed	Validated	A1B		A2	
			2020	2050	2020	2050
PALANAN						
Alomanay	low		low	low	low	low
Bisag	low		low	moderate	low	low
Culasi	moderate		moderate	high	moderate	moderate
Dialaoyao	high		high	high	high	high
Dicabisagan East	high		high	high	high	high
Dicabisagan West	high		high	high	high	high
Dicadyuan	moderate		moderate	moderate	moderate	moderate
Diddadungan	moderate		moderate	moderate	moderate	moderate
Didiyan	low		low	moderate	low	low
Dimalicu-Licu	high		high	high	high	high
Dimasari	moderate		moderate	low	moderate	moderate
Dimatican	high		high	high	high	high
Maligaya	high		high	high	high	high
Marikit	high		high	high	high	high
San Isidro	low		low	moderate	low	low
Santa Jacinta	high		high	moderate	high	high
Villa Robles	high		high	high	high	high
SAN MARIANO						
Casala	moderate	low	moderate	low	moderate	moderate
Dibuluan	low	low	low	low	low	low
Disulap	low	low	low	low	low	low
Del Pillar	low	moderate	moderate	low	low	low
San Jose	low	low	low	low	low	low
SAN PABLO						
Caddangan/ Limbauan	high	high	high	high	high	high
Libertad	low	low	low	low	low	low
San Vicente	high	high	high	high	high	high
TUMAUINI						
Cumabao	low	low	low	low	low	low

Note: No validation was made in Palanan due to inaccessibility during the site visit

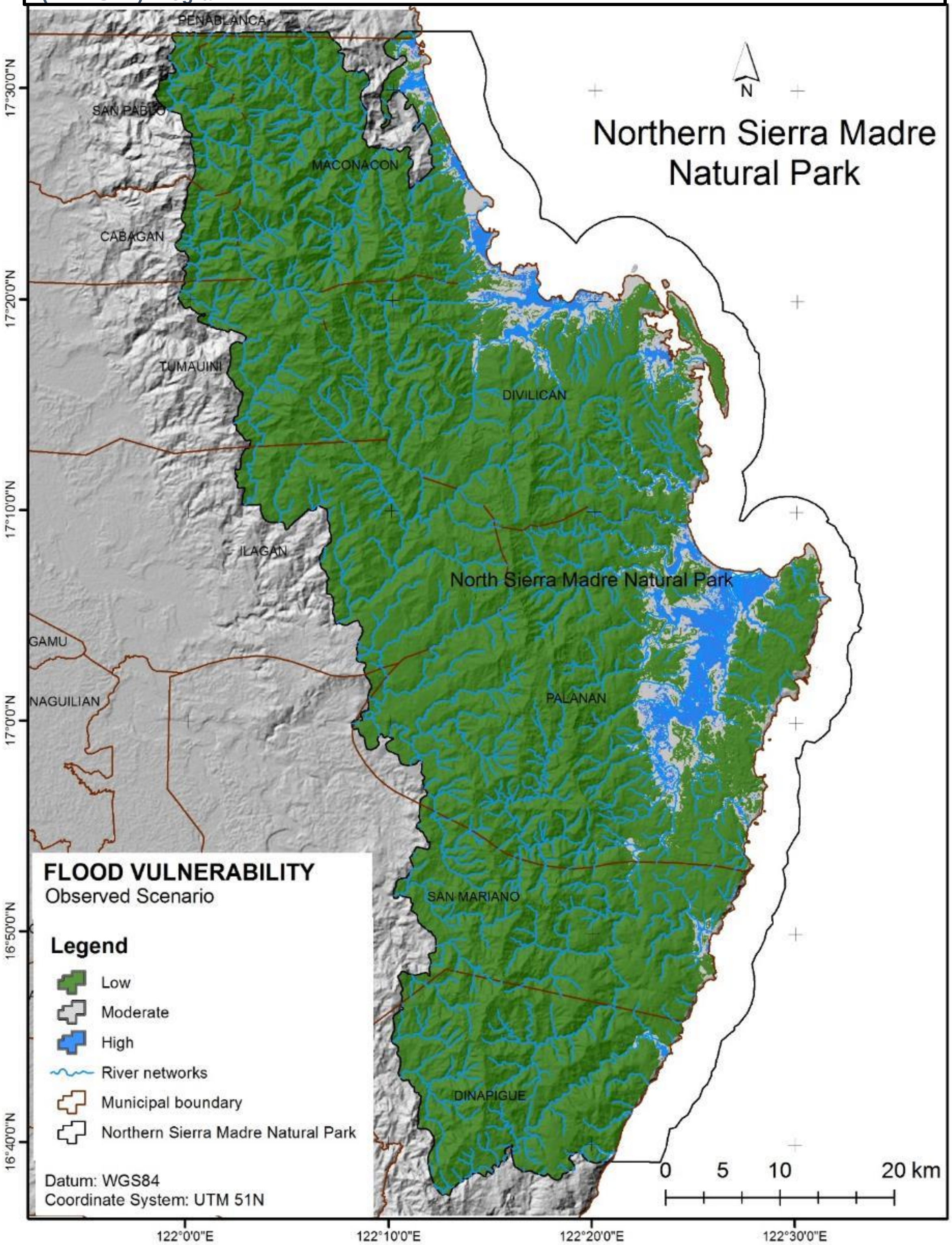

Figure 7. Flood susceptibility based on CNCM3 model observed scenario in the Northern Sierra Madre Natural Park

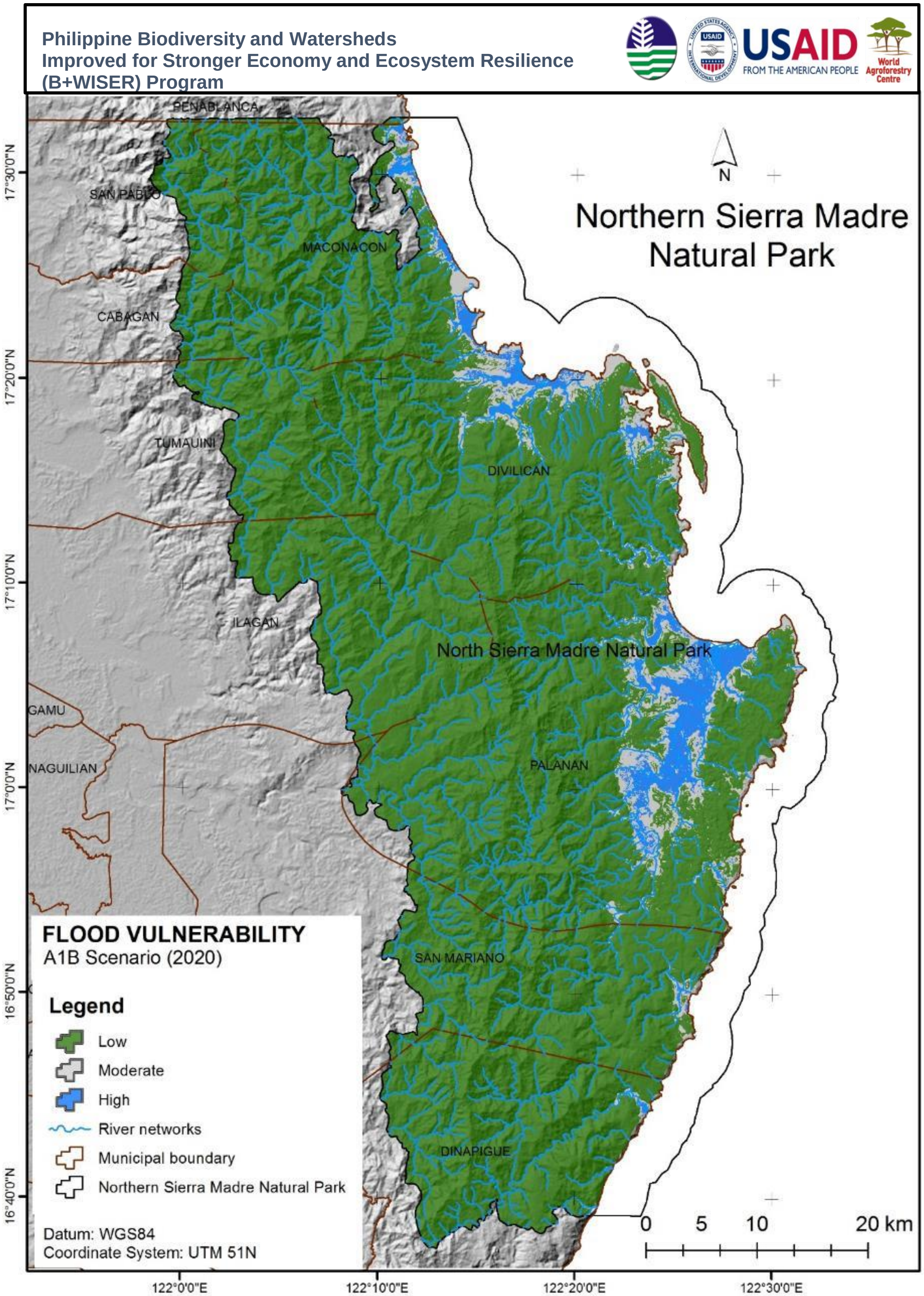

Figure 8. Flood susceptibility based on CNCM3 A1B scenario (2020s period) in the Northern Sierra Madre Natural Park

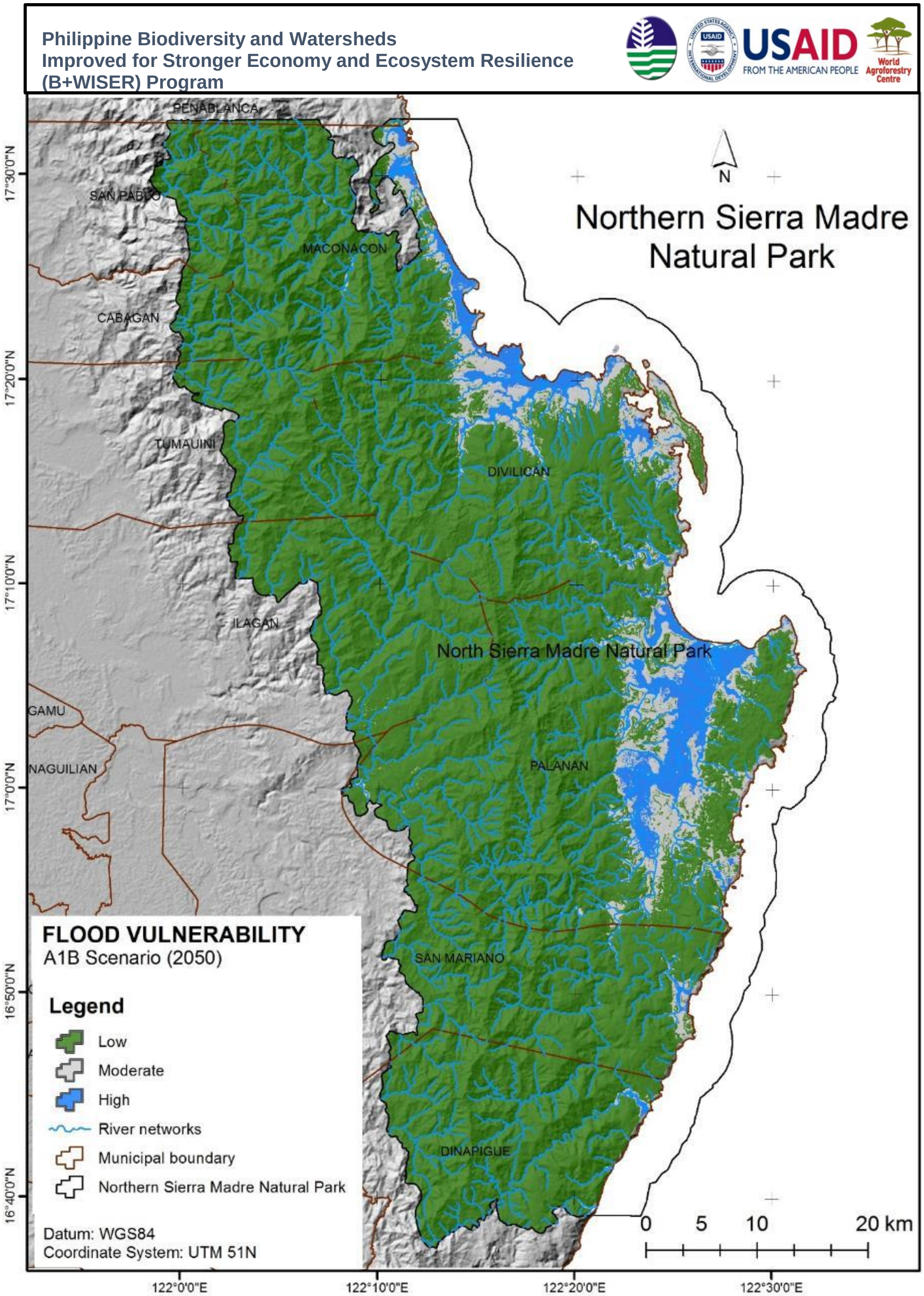

Figure 9 Flood susceptibility based on CNCM3 A1B scenario (2050s period) in the Northern Sierra Madre Natural Park

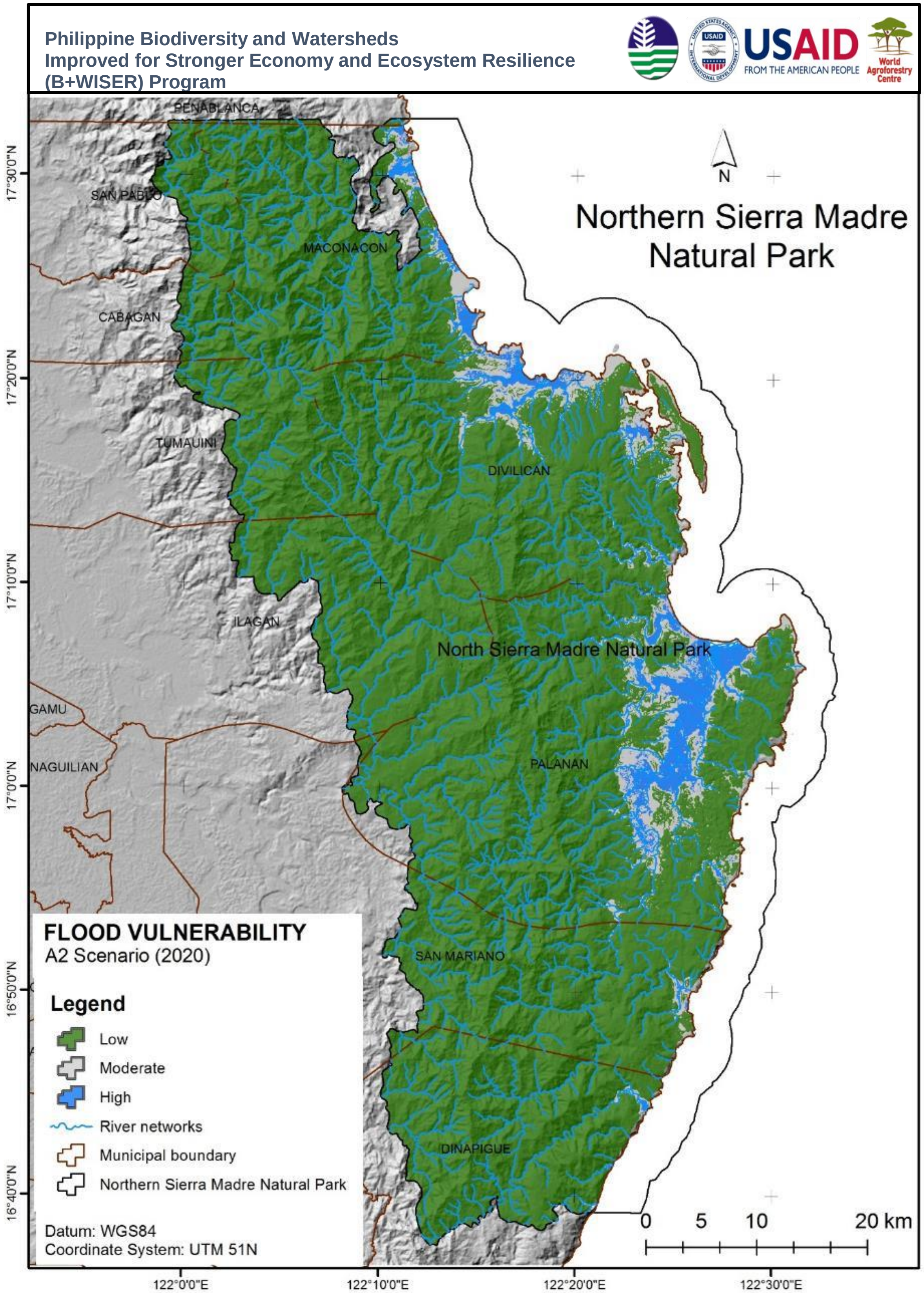

Figure 10. Flood susceptibility based on CNCM3 A2 scenario (2020s period) in the Northern Sierra Madre Natural Park

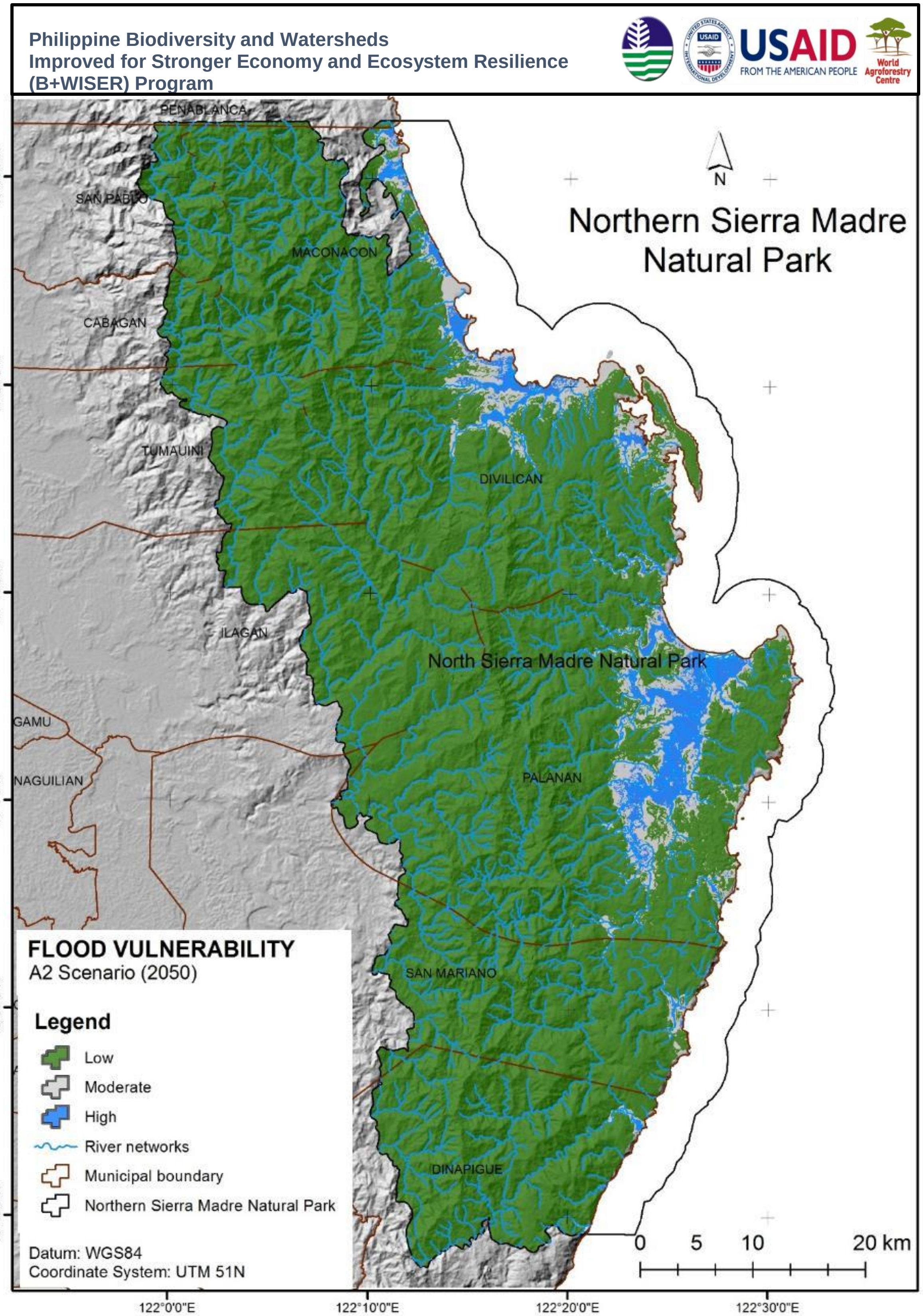

Figure 11. Flood susceptibility based on CNCM3 A2 scenario (2050s period) in the Northern Sierra Madre Natural Park

Drought Hazard Assessment

Drought is described as the unavailability of water due to extreme weather conditions such as a long period of abnormally low rainfall. It is also a condition of moisture deficit sufficient to have an effect on vegetation, animals, and man over a sizeable area. Basically, a drought-related hazard is an event in which a significant reduction of water brings about severe economic, social and environmental hardships to the population.

The vulnerability to drought was assessed primarily based on precipitation exposure, influence and distribution. In the Northern Sierra Madre Natural Park, the occurrence of drought will take place from February to May with a possibility to extend up to July under the observed and 2020s periods and scenarios. However, the dry season will likely occur from April to September according to A2 scenario in 2050s period. Months of February to May under observed scenario, 2020s (A2 scenario) and 2050s periods (A1B scenario) are registered as moderately dry (-1.0 to -1.5). The 2020s A1B scenario and 2050s A2 scenario are simulated as an extremely dry during the months of April and July, respectively. Remaining months are likely predicted to have wet conditions (Figures 12 to 13).

Table 13 presents the distribution of vulnerability rating from the Northern Sierra Madre Natural Park. Results show that there are only about 6,000 ha that would be highly susceptible to drought given the projected scenarios. A large portion of the influence watersheds appears highly susceptible to drought under the A1B scenario in 2020s period. The SPI in these periods was both registered to be extremely dry.

The climate-related drought risk maps were generated and labeled as high (yellow), moderate (gray), and low (green) as shown in Figures 14 to 18. The attribute table was then generated to determine the towns and barangays exposed to drought. The spatial assessment indicates that a total of 5 barangays are vulnerable to drought, namely barangays Bicobian, Dicaroyan, Dicatian and Dipudo in Dinapigue, and the barangay Villa Imelda in Ilagan. Other details are presented in Table 14.

Generally, drought has been considered a recurring catastrophe particularly in the agricultural sectors. Five (5) municipalities in the western side of the park are considered for being agro-industrial towns, which are very susceptible to long dry spells. It would bring adverse loss and damage to crops, which significantly affects the productivity of the sector, translated to income or opportunity loss. For instance, the recurring long dry spells (January to June) have greatly affected the present plantations of corn, rice, cassava, banana, mango, and other high value crops in the area.

Based on key informant interviews and direct observations during the validation workshop, there were evidences of drought, which affect cropping season in the areas. Insufficient water supply, irrigation systems, and water impoundment are also contributing factors that describe the adverse effects of drought particularly along the foothills of the Mt. Sierra Madre mountain ranges (Plate No. 4). However, the effects of drought in the protected areas did not significantly vary as mainly influenced by its good and intact vegetative covers. This can be attributed to the influence of its topography and water availability during a summer season. Forest areas appear unaffected because of the presence of perennial streams in the area.

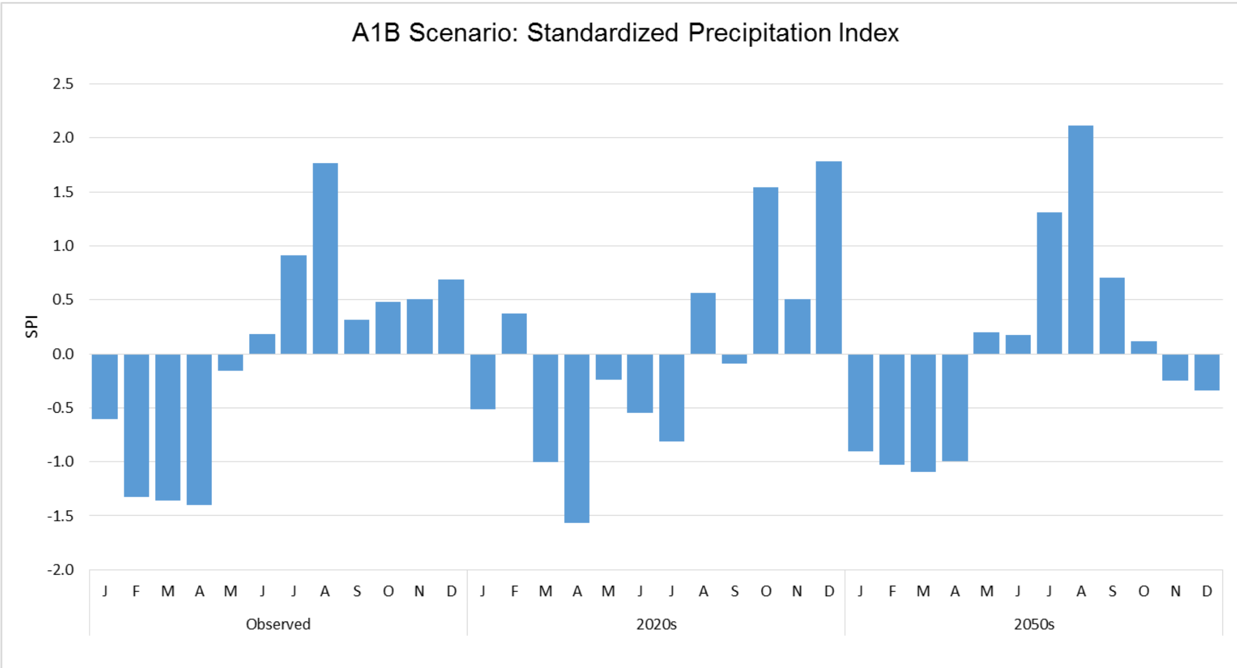

Figure 12. Standardized precipitation index based on A1B scenario in Isabela Province

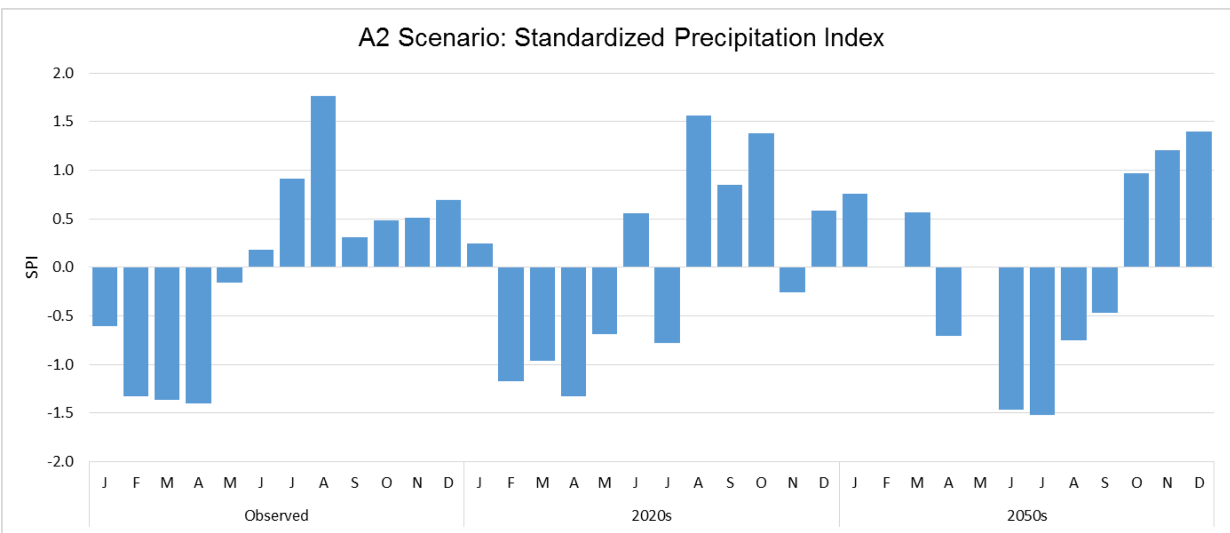

Figure 13. Standardized precipitation index based on A2 scenario in Isabela Province

Table 13. Drought vulnerability and its area coverage based on CNCM3 model in the Northern Sierra Madre Natural Park

Susceptibility	Observed	A1B		A2	
		2020	2050	2020	2050
Low	230,028	202,308	230,028	230,028	202,308
Moderate	57,735	79,679	57,735	57,735	79,679
High	33	5,810	33	33	5,810
Total	287,796	287,796	287,796	287,796	287,796

Table 14. Drought vulnerability ratings by barangays in Northern Sierra Madre Natural Park

Barangay/ Municipality	Observed	Validated	A1B		A2	
			2020	2050	2020	2050
CABAGAN						
Union	low		low	low	low	low
DINAPIGUE						
Ayod	low	Low	low	low	low	low
Bucal Norte	moderate	Low	low	moderate	moderate	low
Bucal Sur	low	Low	low	low	low	low
Dimaluade	low	Low	moderate	low	low	moderate
Bicobian	low	High	moderate	low	low	moderate
Dibulos	low	Low	moderate	low	low	moderate
Dicambangan	low	Low	moderate	low	low	moderate
Dicaroyan	moderate	High	moderate	moderate	moderate	moderate
Dicatian	low	High	moderate	low	low	moderate
Dilakit	low	Low	moderate	low	low	moderate
Dimapnat	low	Low	moderate	low	low	moderate
Dimapula	low	Low	moderate	low	low	moderate
Dimasalansan	low	Low	moderate	low	low	moderate
Dipudo	low	High	moderate	low	low	moderate
Ditarum	moderate	Low	moderate	moderate	moderate	moderate
Sapinit	moderate	low	low	moderate	moderate	low
ILAGAN						
Cabeseria 25	low	moderate	moderate	low	low	moderate
Pasa	low	low	low	low	low	low
Sindon Bayabo	low	moderate	moderate	low	low	moderate
Sindon Maride	low	moderate	moderate	low	low	moderate
Villa Imelda	moderate	high	high	moderate	moderate	high
MACONACON						
Aplaya	low	moderate	moderate	low	low	moderate
Canadam	low	moderate	moderate	low	low	moderate
Diana	moderate	moderate	moderate	moderate	moderate	moderate

Barangay/ Municipality	Observed	Validated	A1B		A2	
			2020	2050	2020	2050
Eleonor	low	moderate	moderate	low	low	moderate
Fely	low	moderate	moderate	low	low	moderate
Lita	low	moderate	moderate	low	low	moderate
Malasin	low	moderate	moderate	low	low	moderate
Minanga	low	moderate	moderate	low	low	moderate
Reina Mercedes	low	low	moderate	low	low	moderate
Santa Marina	low	low	moderate	low	low	moderate
PALANAN						
Alomanay	low		low	low	low	low
Bisag	low		moderate	low	low	moderate
Culasi	low		moderate	low	low	moderate
Dialaoyao	moderate		moderate	moderate	moderate	moderate
Dicabisagan East	low		moderate	low	low	moderate
Dicabisagan West	moderate		moderate	moderate	moderate	moderate
Dicadyuan	moderate		high	moderate	moderate	high
Diddadungan	low		moderate	low	low	moderate
Didiyan	low		low	low	low	low
Dimalicu-Licu	moderate		moderate	moderate	moderate	moderate
Dimasari	low		low	low	low	low
Dimatican	low		high	low	low	high
Maligaya	moderate		moderate	moderate	moderate	moderate
Marikit	moderate		moderate	moderate	moderate	moderate
San Isidro	moderate		moderate	moderate	moderate	moderate
Santa Jacinta	low		moderate	low	low	moderate
Villa Robles	moderate		low	moderate	moderate	low
SAN MARIANO						
Casala	low	Moderate	low	low	low	low
Dibuluan	low	Moderate	low	low	low	low
Disulap	low	Low	moderate	low	low	moderate
Del Pillar	low	moderate	low	low	low	low
Libertad	low	low	low	low	low	low
San Jose	low	low	moderate	low	low	moderate
SAN PABLO						
Caddangan/ Limbauan	moderate	moderate	low	moderate	moderate	low
San Vicente	moderate	moderate	low	moderate	moderate	low
TUMAUINI						
Cumabao	low	low	low	low	low	low

Note: No validation was made in Palanan due to inaccessibility during the site visit

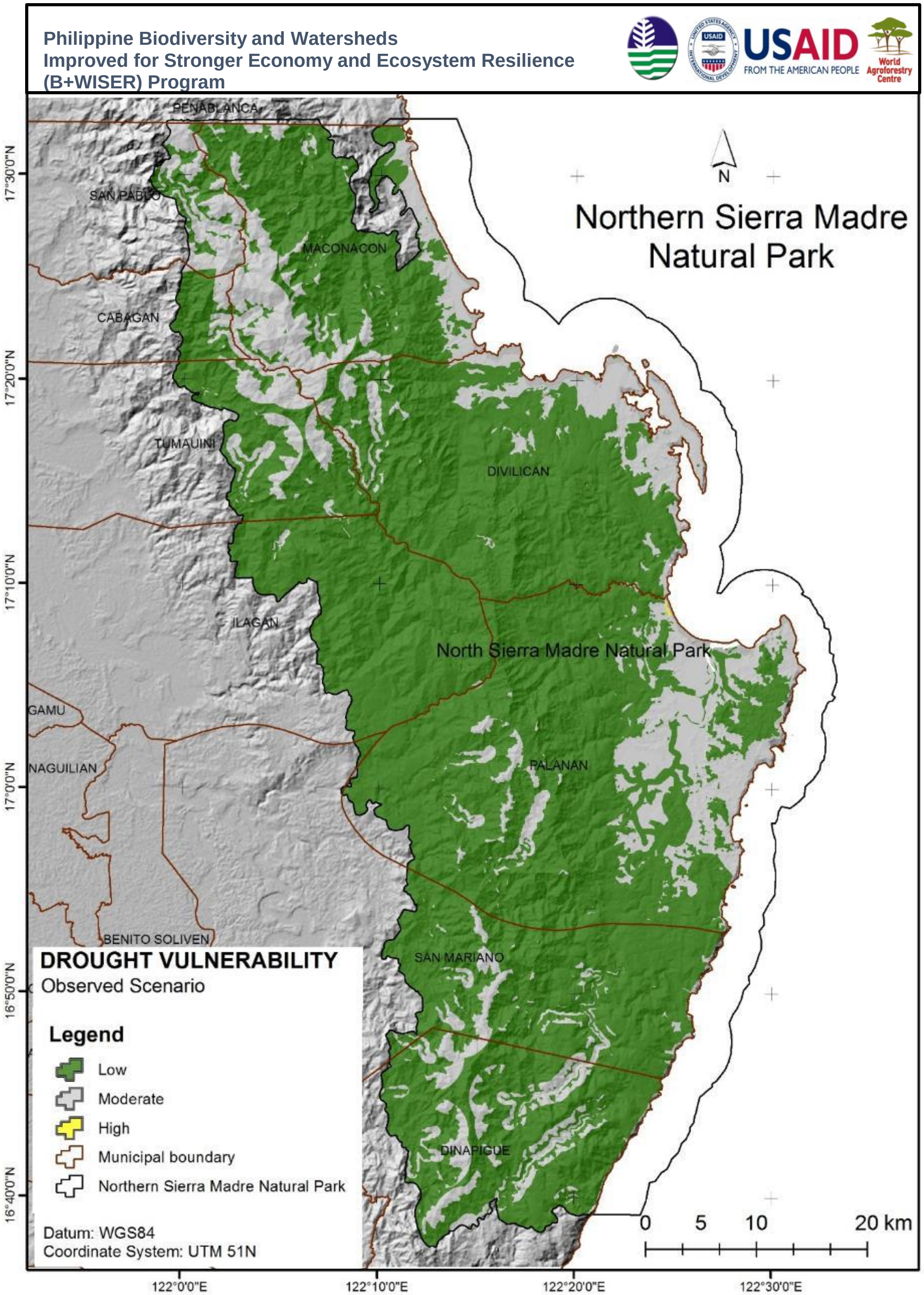

Figure 14. Drought vulnerability based on CNCM3 model observed scenario in the Northern Sierra Madre Natural Park

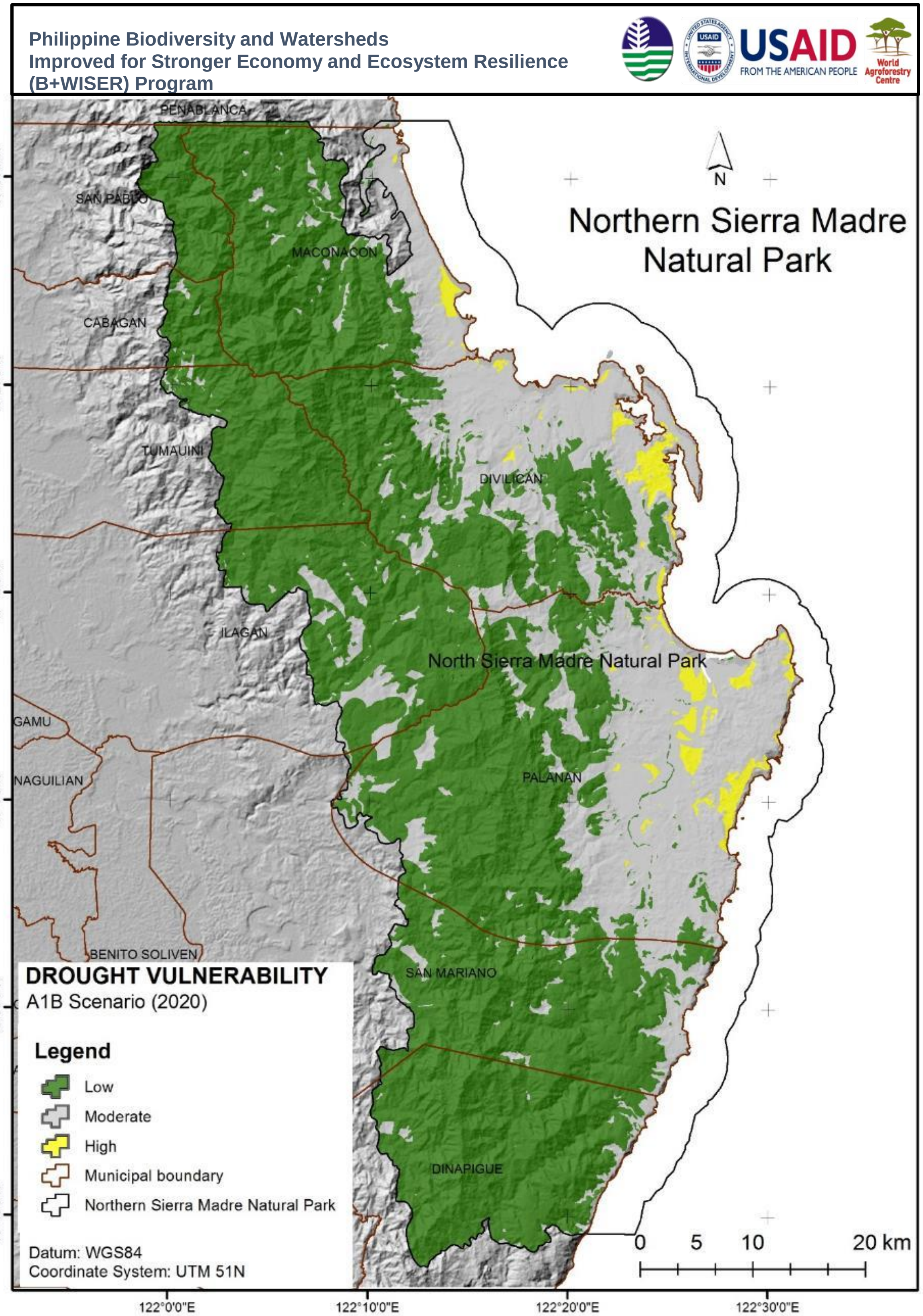

Figure 15. Drought vulnerability in 2020s period based on CNCM3 A1B scenario in the Northern Sierra Madre Natural Park

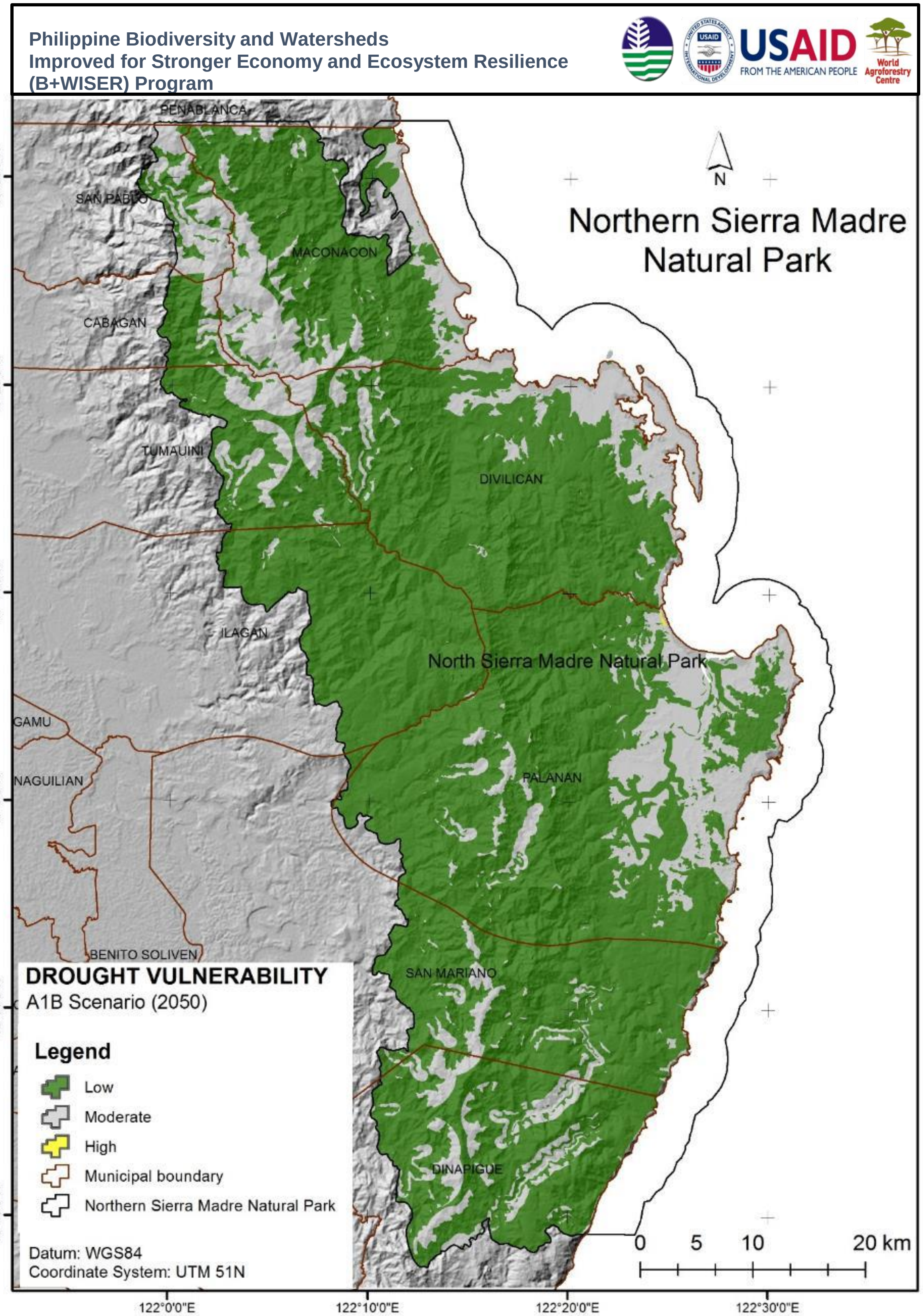

Figure 16. Drought vulnerability in 2050s period based on CNCM3 A1B scenario in the Northern Sierra Madre Natural Park

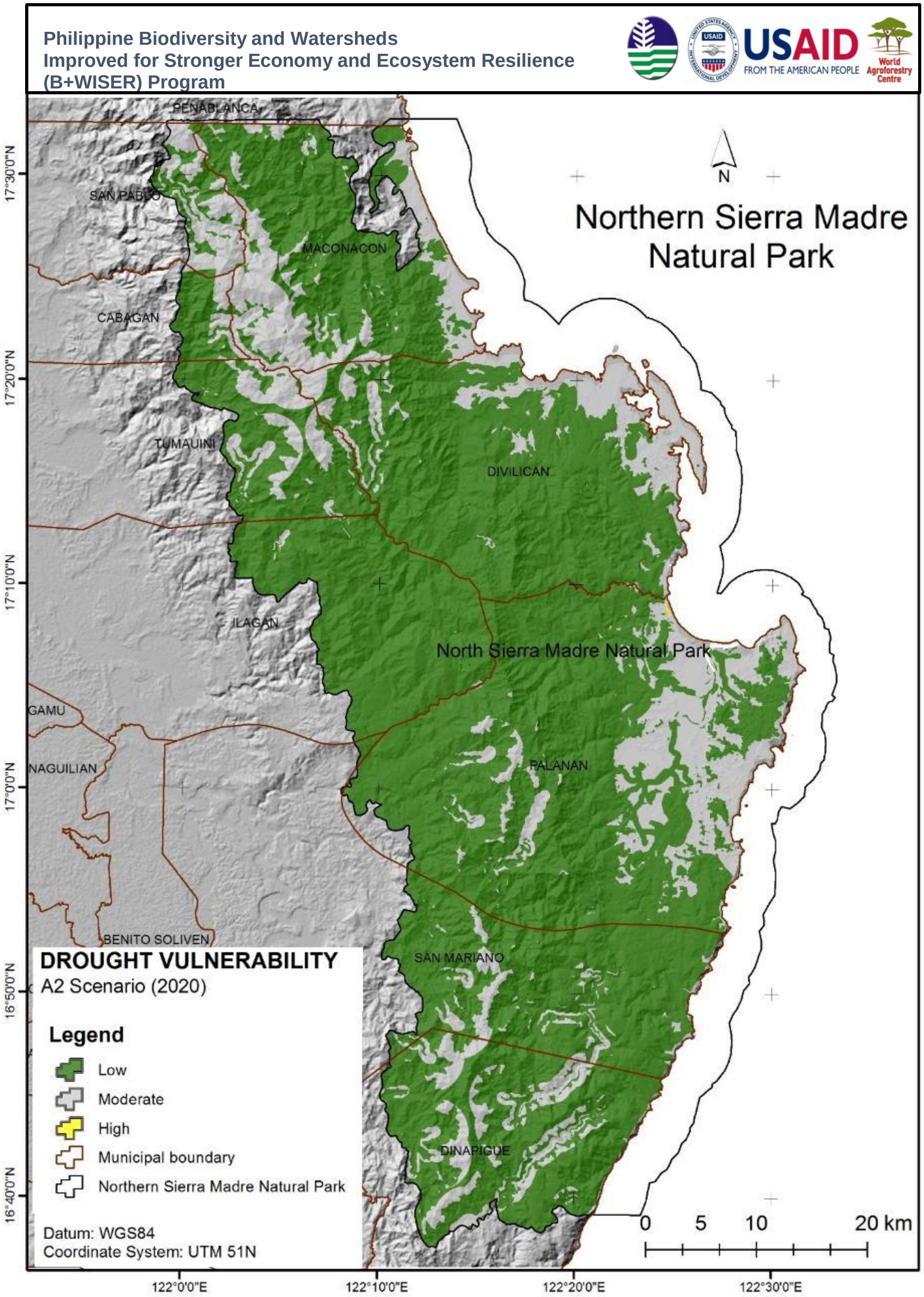

Figure 17. Drought vulnerability in 2020s period based on CNCM3 A2 scenario in the Northern Sierra Madre Natural Park

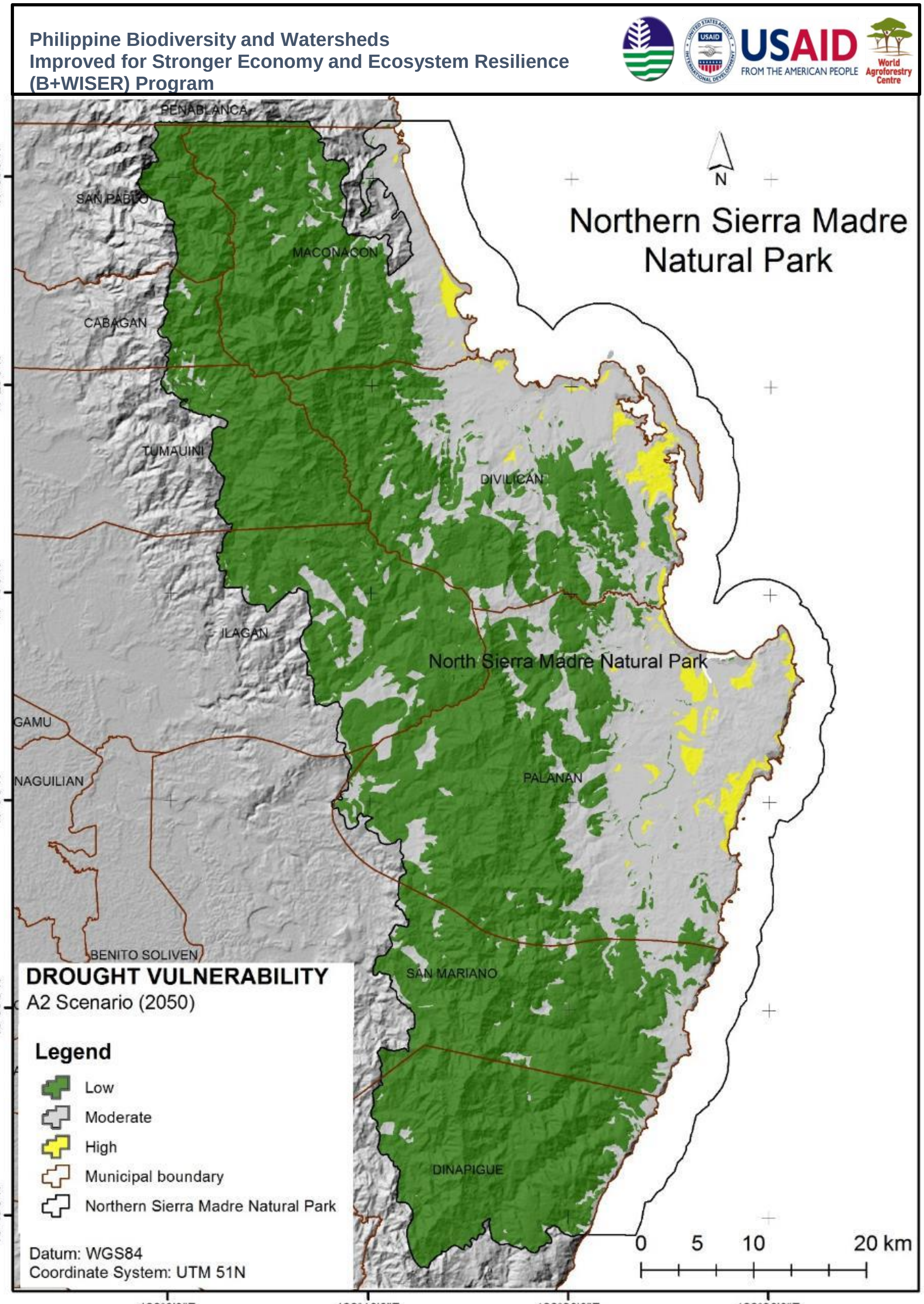

Figure 18. Drought vulnerability in 2050s period based on CNCM3 A2 scenario in the Northern Sierra Madre Natural Park

Plate 4. Vulnerable areas around the Northern Sierra Madre Natural Park (Cabagan, Isabela, January 22, 2015)

Landslide Hazard Assessment

Landslide is essentially described as the downward movement of a relatively dry mass of earth and rock. It is a process where soil particles detached, transported and deposited from one place to another and is usually triggered by excessive rainfall or the occurrence of an earthquake strong enough to cause instability in the underlying rock layer. The rain-induced landslide hazard maps for the Northern Sierra Madre Natural Park were assessed and generated based on the physical conditions, vegetated factors, and climate change influences given the CNCM3 model and scenarios.

Table 15 shows the distribution of rain-induced landslide affected areas in different periods. It was estimated that high vulnerable landslide areas range from 14,000 to 50,000 ha. Changes of highly vulnerable areas appeared significant to the forest landscape under 2020s A1B scenario (Figures 19 - 23). This can primarily be associated with the drastic increase in monthly rainfalls during the months of July to September.

About twenty (20) barangays were found highly exposed to rain-induced landslides. Most of these areas are apparent in the southern and western part of the protected area. Highly exposed barangays are composed of four (4) barangays in Dinapigue (Ayod, Bucal Norte, Bucal Sur, and Dimaluade), three (3) in Divilacan (Dicaroyan, Ditarum, and Sapinit), four (4) barangays in Ilagan (Cabeseria 25, Sindon Bayado, Sindon Maride, and Villa Imelda), two (2) in Maconacon

(Reina Mercedes and Santa Marina), five (5) in Palanan (Alomanay, Bisag, Didiyan, Dimasari, and Villa Robles), and three (3) in San Mariano (Casala, Del Pillar, and Libertad). It must be noted that the assessment only covered barangays within the protected area. Other details are presented in Table 16.

As shown in the landslide hazard maps (Figures 20 to 24), the susceptibility was described in three categories of low, medium and high. Areas that are assessed prone to geologic hazard have high exposure to impact of extreme climate variability. In general, the protected area is considered an evergreen rainforest, which is estimated to have more or less 49,000 ha closed forest and 225,000 ha open forest conditions. The park also serves as a habitat to many endemic species of plants including various species of tall, straight and slender trees of the family Dipterocarpaceae such as Shorea spp. and Hopea spp., various orchids and the leguminous plants. Nonetheless, large areas are still highly erodible particularly those with steep slopes and high elevations. This can be seen in mountain ranges of Mt. Cresta on Sierra Madre's western flank and Mt. Divilacan on its eastern border.

Table 15. Landslide susceptibility and its area coverage of the Northern Sierra Madre Natural Park

Susceptibility	Observed	A1B		A2	
		2020	2050	2020	2050
Low	105,750	105,750	85,630	105,750	105,750
Moderate	170,984	170,984	156,606	170,984	170,984
High	14,948	14,948	49,445	14,948	14,948
Total	291,681	291,681	291,681	291,681	291,681

Table 16. Landslide susceptibility by barangay in Northern Sierra Madre Natural Park

Barangay/ Municipality	Observed	Validated	A1B		A2	
			2020s	2050s	2020s	2050s
CABAGAN						
Union	moderate	moderate	moderate	moderate	moderate	moderate
DINAPIGUE						
Ayod	high	high	high	high	high	high
Bucal Norte	high	high	high	high	high	high
Bucal Sur	high	high	high	moderate	moderate	moderate
Dimaluade	high	high	high	high	high	high
DIVILACAN						
Bicobian	low	moderate	low	moderate	moderate	moderate
Dibulos	low	moderate	low	low	low	low
Dicambangan	moderate	moderate	moderate	low	low	low
Dicaroyan	high	moderate	high	high	high	high
Dicatian	moderate	low	moderate	low	low	low
Dilakit	low	moderate	low	low	low	low
Dimapnat	moderate	moderate	moderate	moderate	moderate	moderate

Barangay/ Municipality	Observed	Validated	A1B		A2	
			2020s	2050s	2020s	2050s
Dimapula	low	low	low	low	low	low
Dimasalansan	low	moderate	low	low	low	low
Dipudo	low	low	low	low	low	low
Ditarum	high	high	high	high	high	high
Sapinit	high	high	high	moderate	moderate	moderate
ILAGAN						
Cabeseria 25	high	high	high	high	high	high
Pasa	low	low	low	low	low	low
Sindon Bayabo	high	high	high	moderate	moderate	moderate
Sindon Maride	high	high	high	moderate	moderate	moderate
Villa Imelda	high	high	high	high	high	high
MACONACON						
Aplaya	moderate	moderate	moderate	moderate	moderate	moderate
Canadam	moderate	moderate	moderate	moderate	moderate	moderate
Diana	moderate	moderate	moderate	high	high	high
Eleonor	low	low	low	low	low	low
Fely	low	low	low	low	low	low
Lita	moderate	low	moderate	moderate	moderate	moderate
Malasin	moderate	moderate	moderate	moderate	moderate	moderate
Minanga	moderate	low	moderate	moderate	moderate	moderate
Reina Mercedes	moderate	high	moderate	moderate	moderate	moderate
Santa Marina	low	high	low	low	low	low
PALANAN						
Alomanay	high		high	moderate	moderate	moderate
Bisag	high		high	moderate	moderate	moderate
Culasi	low		low	low	low	low
Dialaoyao	low		low	low	low	low
Dicabisagan East	low		low	low	low	low
Dicabisagan West	moderate		moderate	moderate	moderate	moderate
Dicadyuan	low		low	low	low	low
Diddadungan	low		low	low	low	low
Didiyan	high		high	moderate	moderate	moderate
Dimalicu-Licu	low		low	low	low	low
Dimasari	high		high	high	high	high
Dimatican	low		low	low	low	low
Maligaya	low		low	low	low	low
Marikit	low		low	low	low	low
San Isidro	low		low	low	low	low
Santa Jacinta	low		low	low	low	low

Barangay/ Municipality	Observed	Validated	A1B		A2	
			2020s	2050s	2020s	2050s
Villa Robles	high		high	high	high	high
SAN MARIANO						
Casala	high	moderate	high	high	high	high
Dibuluan	moderate	moderate	moderate	moderate	moderate	moderate
Disulap	low	low	low	low	low	low
Del Pillar	high	moderate	high	high	high	high
Libertad	high	high	high	high	high	high
San Jose	moderate	moderate	moderate	low	low	low
SAN PABLO						
Caddangan/Limbauan	moderate	moderate	moderate	high	high	high
San Vicente	moderate	moderate	moderate	high	high	high
TUMAUINI						
Cumabao	low	low	low	low	low	low

Note: No validation was made in Palanan due to inaccessibility during the site visit

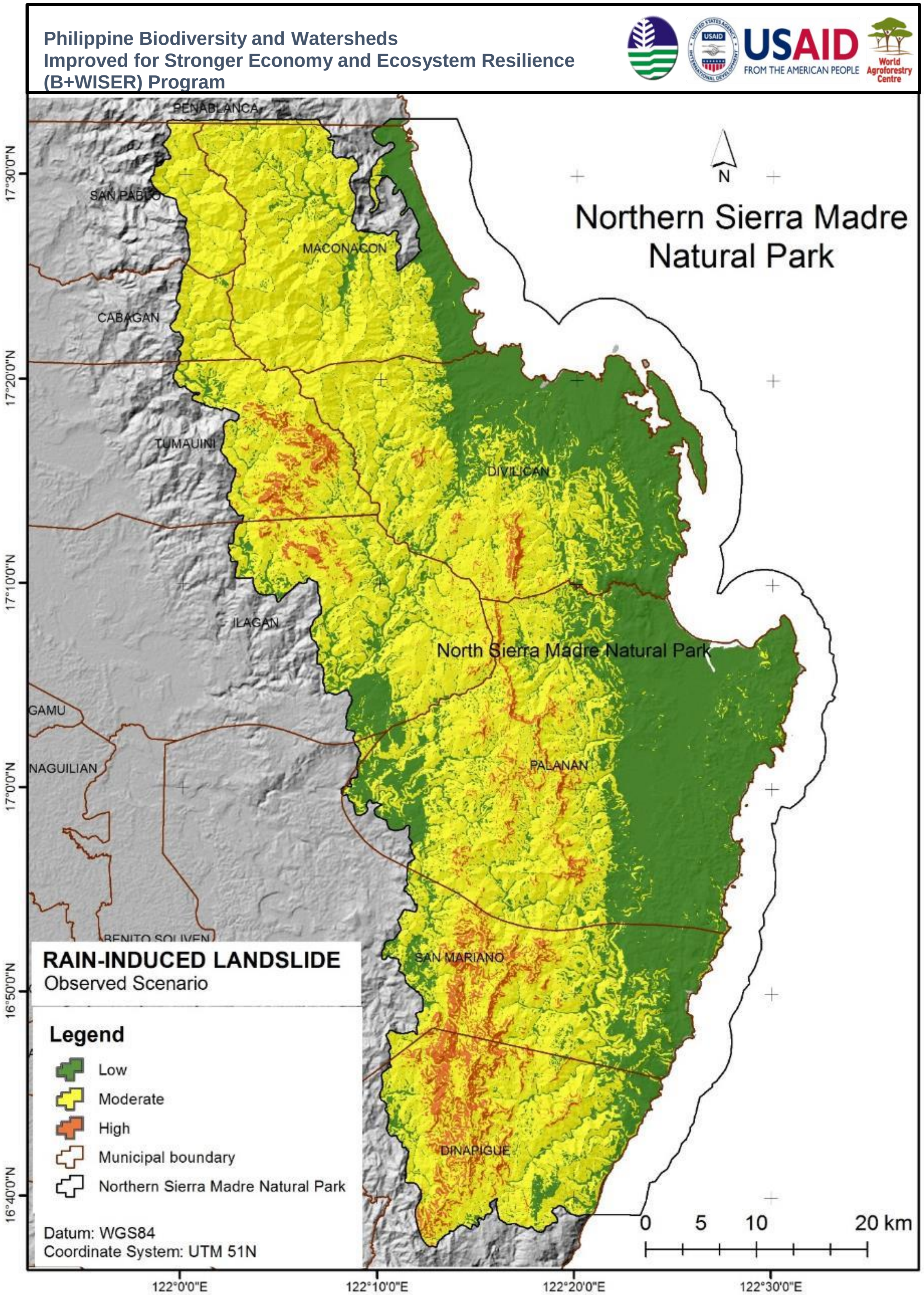

Figure 19. Rain-Induced landslide susceptibility based on CNCM3 model observed scenario in the Northern Sierra Madre Natural Park

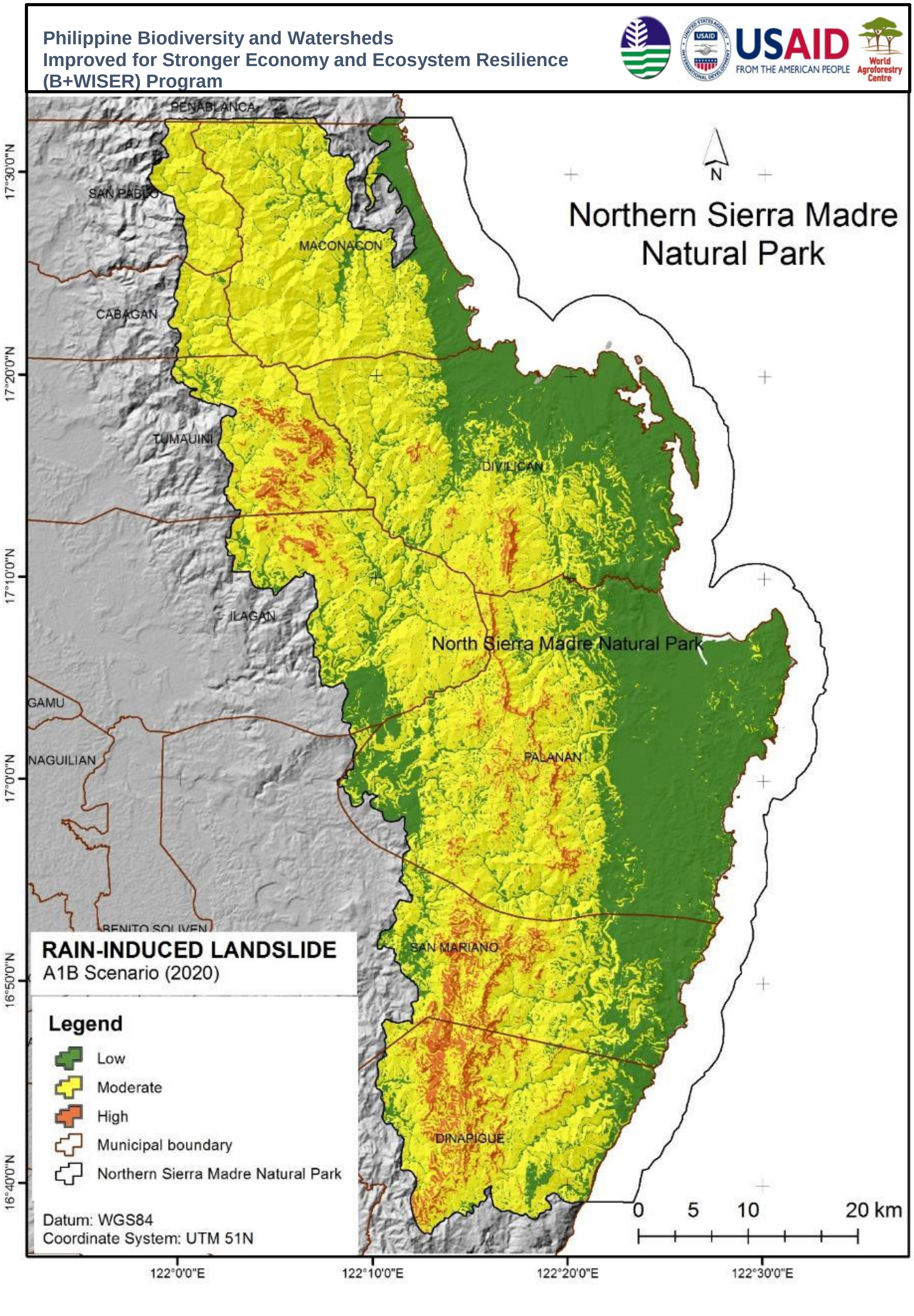

Figure 20. Rain-Induced landslide susceptibility based on CNCM3 A1B scenario (2020s period) in the Northern Sierra Madre Natural Park

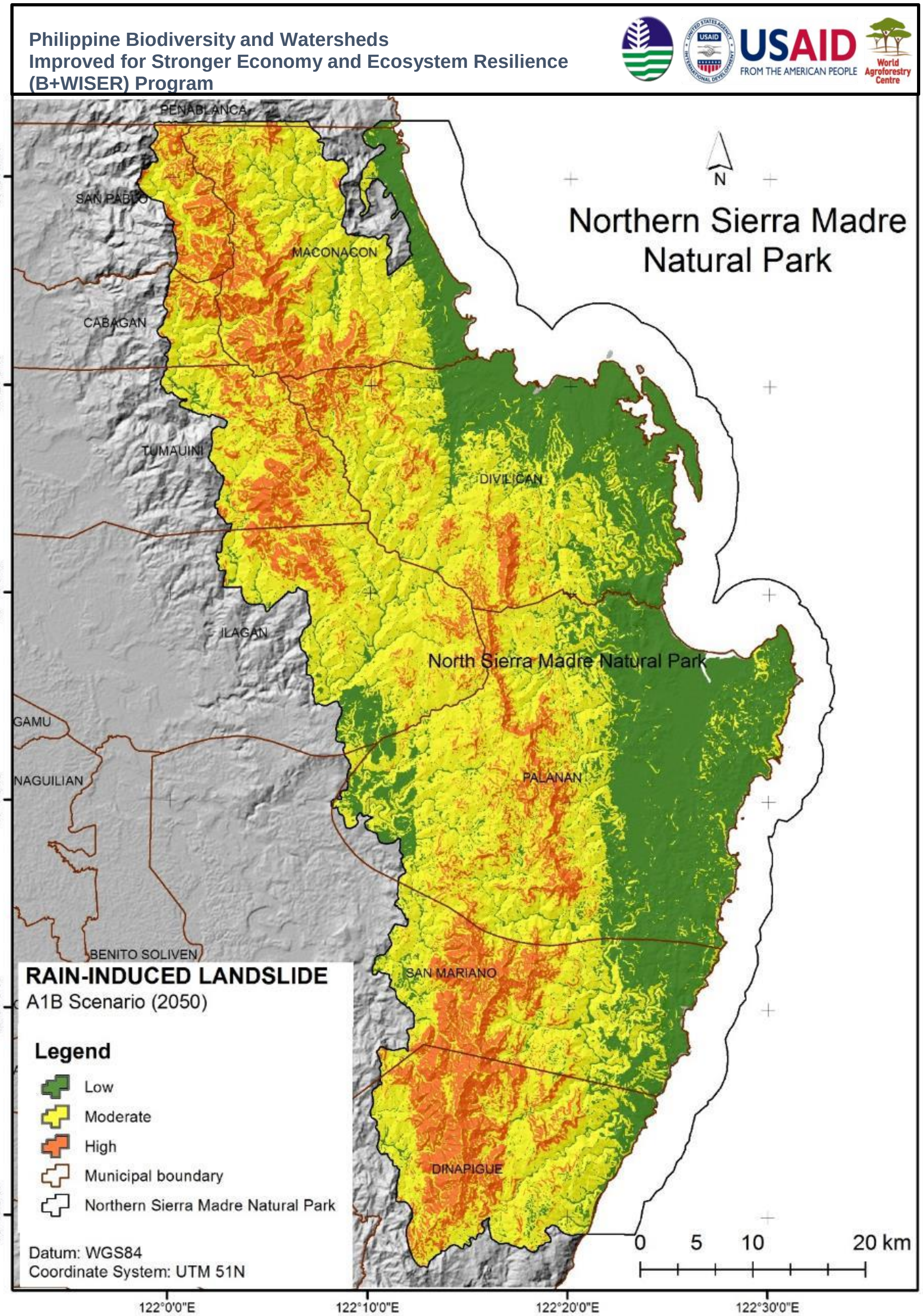

Figure 21. Rain-Induced landslide susceptibility based on CNCM3 A1B scenario (2050s period) in the Northern Sierra Madre Natural Park

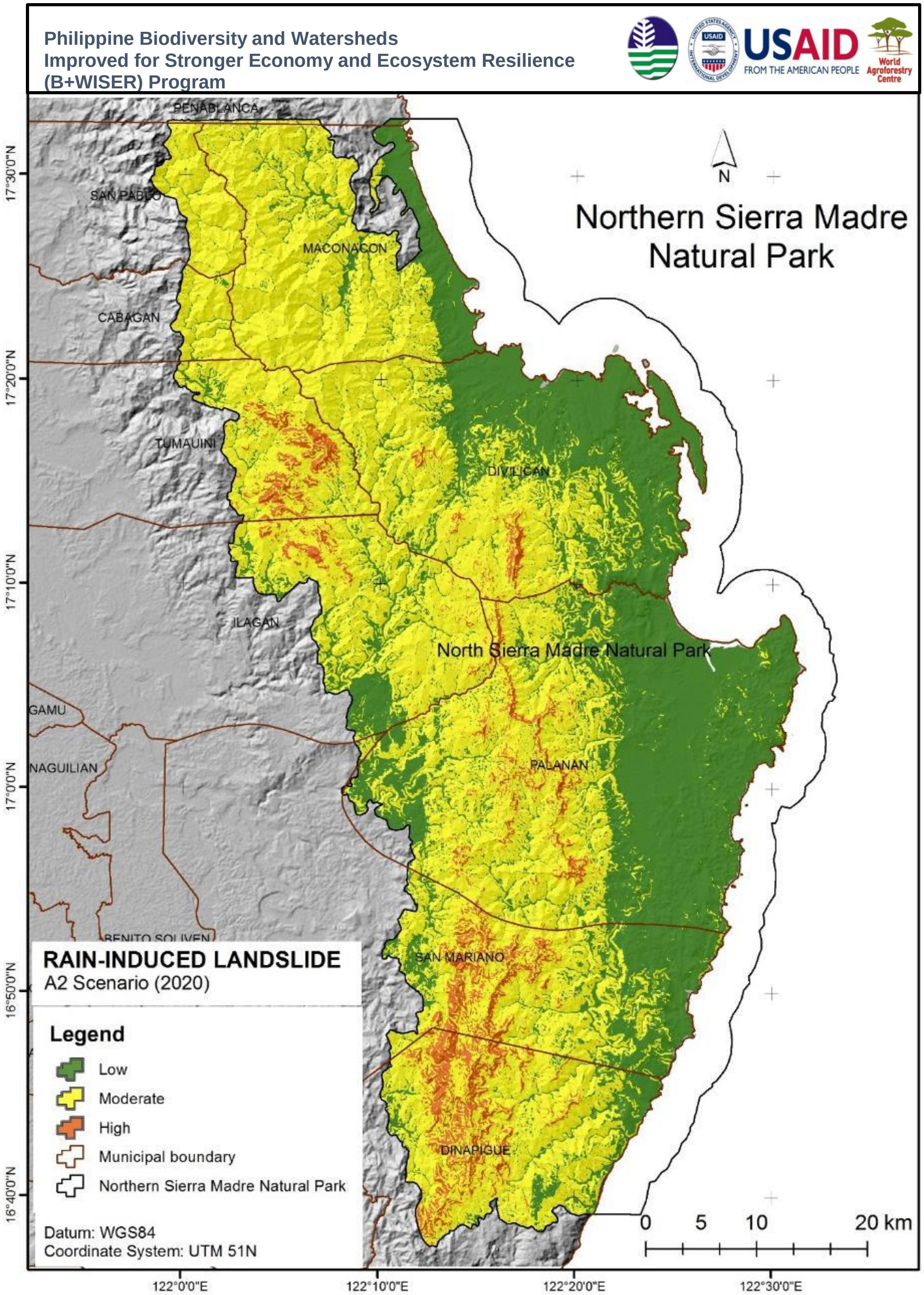

Figure 22. Rain-Induced landslide susceptibility based on CNCM3 A2 scenario (2020s period) in the Northern Sierra Madre Natural Park

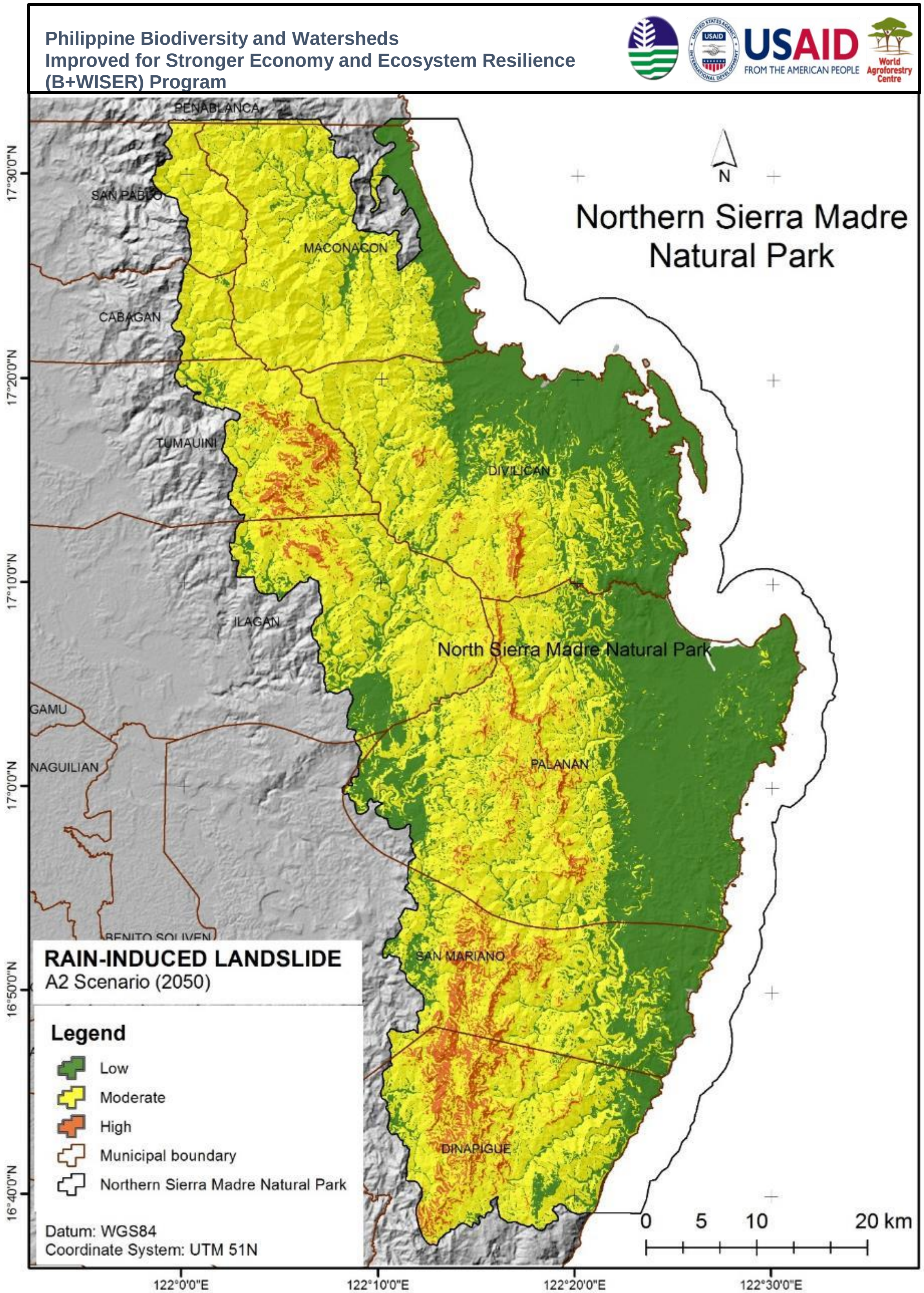

Figure 23. Rain-Induced landslide susceptibility based on CNCM3 A2 scenario (2050s period) in the Northern Sierra Madre Natural Park

Land Capability Classification

Land capability classification is derived from soil erosion index and other criteria. Five (5) major zones were identified for the area. The classification and management prescriptions are intended to provide a scientific basis for allocating the lands to various uses.

Zoning is not meant to be prescriptive in any absolute sense. Basically, the land capability zoning is an ideal physical framework for allocating the land resources. The primary goal is to sustain the long-term productivity of the land and promote the sustainability of biodiversity, soil and water resources, and the delivery of key services of ecosystems in and out of the area. The decision on how the lands are ultimately used still rests with the managers, decision makers, and other stakeholders.

Protection Areas

Protection areas are designated mainly for the conservation of biodiversity; conservation of soil and water; protection of unique habitats, vegetation, geologic formation and landscape, and areas of sociocultural values; and minimization of climate-related and other natural risks and hazards associated with soil erosion, landslides and floods.

Table 17 presents the land capability classification, management prescriptions, area coverage, and its existing hazards. About 275,000 ha are classified as protection areas (Figure 24). As shown in Table 18, a large portion of this area belongs to closed forest (47,366 ha), and open forest (219,629 ha). The land cover with closed and open forests is seen in the overwhelming landscape of the Northern Sierra Madre mountain ranges.

Key Biodiversity Areas

The remaining natural forests in the protected area are by law and logic, areas that need to be protected at all costs (Plate No. 5). About 357,000 ha of the Northern Sierra Madre mountain range are declared as a protected area including its coastline area. The only sensible option is to make sure that these forests and coastal areas are protected ecologically or environmentally and socio-culturally. However, the land areas are identified as vulnerable to landslide.

Plate 5. A remaining natural or closed forests as key biodiversity areas (January 23, 2015)

Stream Buffer Areas

The banks of rivers and streams and the shores of the seas throughout their entire length and within a zone of 3 m in urban areas, 20 m in agricultural areas and 40 m in forest areas, along their margins, are subject to easement of public use in the interest of recreation, navigation, float age, fishing and salvage. This provision is mandated by law (PD 705, Section 17) and pursuant to the provisions of the Water Code. These areas are essential buffers for the rivers that serve as filters to incoming sediments and other pollutants. These buffers that are supposed to be covered with vegetation are also excellent protection of the streamflow against excessive solar exposure to keep water temperature at ideal level. Stream buffer areas that are currently covered with open forest (4,021 ha), annual crop (686 ha), and closed forest (660 ha) or otherwise have inadequate vegetation must be targeted for re-vegetation using perennial forest species (Plate No. 7). Planting of bamboo and ferns is also potentially beneficial in these areas as these plants are known to be good soil cover and at the same time can provide income without the need to clear the area.

Plate 6. Stream buffer areas within the Abuan Watershed in Ilagan, Isabela (January 21, 2015)

Production Areas

A production zone is made up of lands that are suited for intensive land uses such as farming, multiple use forestry and other uses requiring disturbance of the soil and other resources found in the area. This zone also includes areas that are used for settlement and urbanization and other built-up purposes. Almost 208,031 ha (49%) of the influence watersheds is classified as production areas. About 89,295 ha of the production areas are classified for an unlimited production zone, 78,736 ha for the multiple use zone, and 40,000 ha for the limited production zone.

Multiple Use Zone

In general, the multiple use system that is envisioned for the area is the multi-story system. This will provide income generation opportunities for the farmers and at the same time enhance the ability of the area to remain ecologically stable. Potentially, the areas that can be devoted for multiple use development include areas that are currently under annual crop (2,132 ha), and open forest (1,246 ha).

Limited Production Zone

Limited production zones can be allocated as agricultural areas that are classified within alienable and disposable lands. About 4,755 ha can be allocated to multi-story timber and fruit tree plantations. However, these areas are fragmented within the protected areas. Currently, areas devoted for agriculture and plantation development include the annual crops (1,791 ha) and open forest (1,578 ha).

Recognizing that farming and animal raising are still a much preferred livelihood activity, this zone will not attempt to deliberately convert the use of areas into other uses. However, options can be presented to the farmers to convert their annual crop farms to other equally if not more rewarding land uses like agroforestry or multiple use system.

Plantation development for production purposes and for rehabilitation of degraded land has a great impact in the area. Forest rehabilitation refers to the re-establishment of the productivity of some, but not necessarily all, of the plant and animal species originally present in the area. For ecological or economic reasons, the multi-story system with a combination of various fruit trees may improve the structure, productivity and species diversity of the area.

Unlimited Production Zone

Almost 877 ha are found suitable areas for settlement purposes which consist mostly of areas that are currently used for the same purposes. As the community population continuously grows, the settlement and community areas may expand only to production areas immediately adjacent to the existing areas. By no means can the areas for settlement and community purposes be permitted to extend in multiple use or even in the protection areas as this will likely compromise the ecological and environmental integrity of the area.

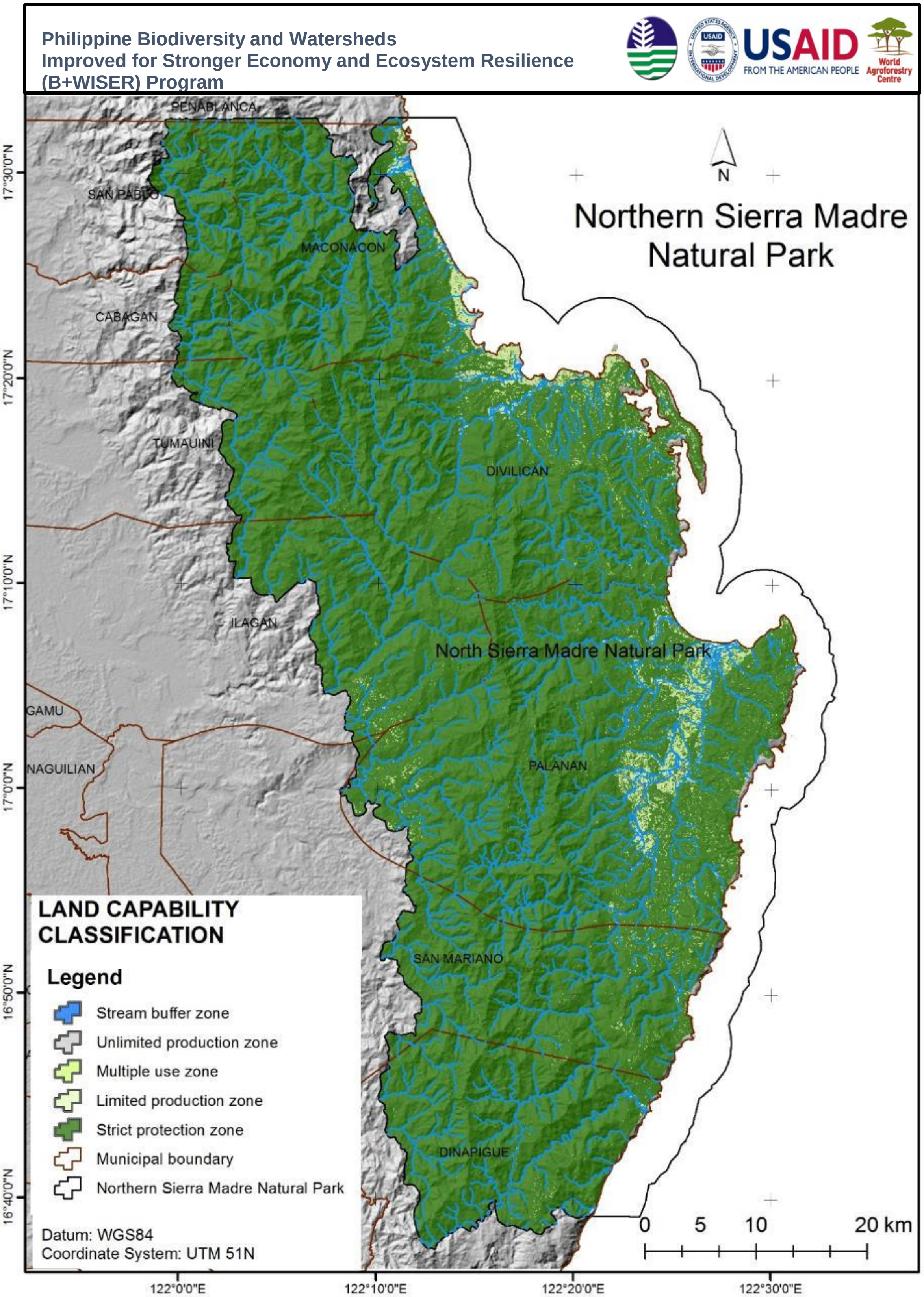

Figure 24. Prescribed land capability classification in the Northern Sierra Madre Natural Park

Table 17. Prescribed land capability classification of the Northern Sierra Madre Natural Park

Class	Land Classification	Management Prescriptions	Area (ha)	Hazard Considerations
1	**PROTECTION AREAS (288,746 ha) 97%**			
1A	**Strict protection zone**	Strict protection, limited collection of ornamental plants, herbs, vines, fruits and other non-timber products may be allowed; Planting of endemic species	274,976	Highly vulnerable to flooding (6,086 ha) Highly vulnerable to landslide (50,864 ha) Highly vulnerable to drought (4,649 ha)
1B	**Stream buffer zone**	Permanent crops (fruit trees, bamboo), harvesting of fruits and bamboo shoots and culms will be allowed but no harvesting of trees will be allowed	5,788	Highly vulnerable to flooding (1,150 ha)
1C	**KBA (**including terrestrial and coastal areas**)**	For biodiversity conservation	357,000	
2	**PRODUCTION AREAS (10,206 ha) 3%**			
2A	**Unlimited production zone** Grasslands and brushlands; built up and cultivated areas	Timber and fruit tree plantations, agriculture (corn, rice, banana, cassava, peanut, pineapple and other high value crops) and agroforestry can be allowed with suitable soil and water conservation measures, settlement can be allowed	871.47	Highly vulnerable to flooding (674 ha) Highly vulnerable to drought (124 ha)
2B	**Multiple use zone** Grasslands and brushlands; built up and cultivated areas	Multi-story timber and fruit tree plantations (i.e., mango, coconut), agroforestry can be allowed with suitable soil and water conservation measures; Pasture lands	4,494	Highly vulnerable to flooding (3,190 ha) Highly vulnerable to drought (635 ha)
2C	**Limited production zone** Grasslands and brushlands; built up and cultivated areas	Multi-story timber and fruit tree plantations; Gmelina plantation	4,669	Highly vulnerable to flooding (564 ha) Highly vulnerable to drought (564 ha)

Table 18. Area distribution of the land capability classification by land cover

Land Cover	Protection areas		Production areas			Total
	Protection zone	Stream Buffer Zone	Unlimited Production	Multiple Use Zone	Limited Production Zone	
Annual Crop	5,924	686	430	2,132	1,791	10,964
Built-up	7	-	0	2	2	11
Closed Forest	47,366	660	68	460	659	49,213
Fallow	92	-	0	2	3	97
Grassland	1,184	118	48	239	233	1,821
Inland Water	189	153	10	49	44	446
Mangrove Forest	257	22	34	130	93	536
Open Forest	219,625	4,021	227	1,246	1,578	226,696
Open/Barren	12	-	0	2	1	15
Shrubs	2,545	55	13	87	106	2,805
Wooded grassland	5,591	239	47	225	245	6,347
Total	*282,791*	*5,955*	*877*	*4,574*	*4,755*	*298,951*

CONCLUSION

- Flood hazard assessment showed that there will likely be a very low indication of flooding which primarily associated with topographic location. Even though the assessment predicted that the spatial influences will likely increase under A1B scenario in 2050 period, there would be no significant changes in other periods and scenarios. A portion of 20 barangays are found to be vulnerable to flooding especially during torrential and/or extreme rainfall events.

- Drought hazard assessment reveals that drought would take place from February to May and a possibility to extend up to July under the observed and 2020s periods and scenarios. A fluctuation of dry season will likely occur from April to September based on A2 scenario in 2050s period, months of February to May under observed scenario, A2 scenario in 2020s and A1B scenario in 2050s periods. A large portion (6,000 ha) of the influence watersheds appeared highly susceptible to drought under the A1B scenario in 2020s period which covered the five (5) barangays namely barangays Bicobian, Dicaroyan, Dicatian and Dipudo in Dinapigue, and the barangay Villa Imelda in Ilagan.

- The southern and western part of the protected area which cover about 20 barangys composed of four (4) barangays in Dinapigue (Ayod, Bucal Norte, Bucal Sur, and Dimaluade), three (3) in Divilacan (Dicaroyan, Ditarum, and Sapinit), four (4) barangays in Ilagan (Cabeseria 25, Sindon Bayado, Sindon Maride, and Villa Imelda), two (2) in Maconacon (Reina Mercedes and Santa Marina), five (5) in Palanan (Alomanay, Bisag, Didiyan, Dimasari, and Villa Robles), and three (3) in San Mariano (Casala, Del Pillar, and Libertad) are found highly exposed to rain-induced landslides. Spatial distributions and extents of rain-induced landslide are found significant to the forest landscape in 2020s and 2050s periods. For the worst-case scenario, the extreme rainfall events resulting to rain-induced landslide will affect the forest areas that are located in steep slopes.

- Based on land capability classification, about 97% of the protected area are estimated to be likely suitable as protection areas which include the classification of strict protection, stream buffer, and key biodiversity areas. More than 10,000 ha are classified suitable for production purposes.

As agreed upon by the different stakeholders and the B+WISER team, results of the assessment including shape files will be shared to them to ensure that results will be used by the targeted clientele.

RECOMMENDATION

Results of the vulnerability assessment will serve as inputs to the management plan of Northern Sierra Madre Natural Park as well as in the comprehensive land use plans of the different LGUs inside the watershed and PAs. Mainstreaming climate change considerations such as results of the vulnerability assessment will enable the managers and LGUs to design mitigation and adaptation strategies that will make the ecosystems and its components to become resilient to the adverse impacts of climate change. Vulnerability assessment is a critical part of any planning exercise since climate change cuts across a wide array of various sectors.

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ANNEX A. B+WISER DIRECTORY

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