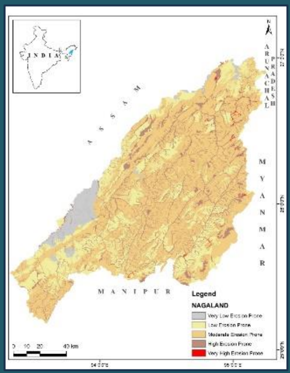
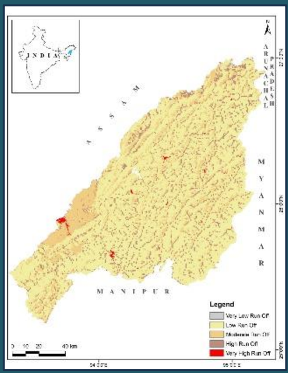
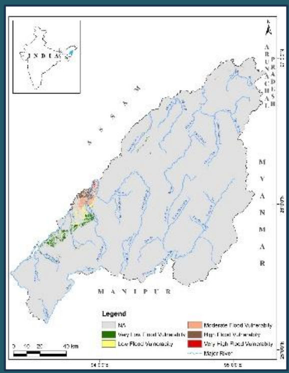
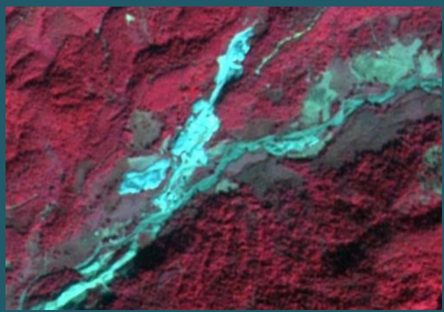
Multi-criteria Geo-spatial Analysis for identification of Flood Vulnerable areas using Surface Runoff and Erosion dynamics in Nagaland









NGISRSC

NGIS&RSC Research & Development Program Series- NGISRSC/RD/Evnhz/2024

Document Control Sheet

Document Control No.	***NGIS&RSC Research & Development Program Series-NGISRSC/RD/Evnhz/2024***
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Authors	*Nagaland GIS & Remote Sensing Centre(NGISRSC), Kohima*
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Originating Unit	*Nagaland GIS & Remote Sensing Centre(NGISRSC), Kohima*
Sponsored By	*NA*
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Abstracts	*Flood vulnerability study is crucial for effective disaster management and mitigation strategies, particularly in regions, characterized by diverse topography and extreme weather events. This study focuses on applying Multicriteria Analysis (MCA) to evaluate the impact of surface runoff and erosion on flood vulnerability in Nagaland. By integrating spatial data on Curve Number (CN), land use, rainfall, slope, desertification, lithology, geomorphology, landslide incidences, soil and digital elevation model (DEM), a comprehensive model was established to assess areas at high risk of flooding. The MCA methodology was employed to prioritize and weigh the significance of various factors contributing to flood vulnerability, allowing for a nuanced understanding of spatial patterns and risk hotspots. The results highlight regions where surface runoff and erosion combined exacerbate flood risks, providing valuable insights for local authorities to develop targeted flood management strategies.*
Keywords	*Remote sensing; multicriteria analysis; spatial data; curve number; erosion; flood vulnerability; potential flash flood; micro watershed*

Multi-criteria Geo-spatial Analysis for identification of Flood Vulnerable areas using Surface Runoff and Erosion dynamics in Nagaland

A study undertaken by Nagaland GIS & Remote Sensing Centre, Planning & Transformation Department, Kohima

Abstract: Flood vulnerability study is crucial for effective disaster management and mitigation strategies, particularly in regions, characterized by diverse topography and extreme weather events. This study focuses on applying Multicriteria Analysis (MCA) to evaluate the impact of surface runoff and erosion on flood vulnerability in Nagaland. By integrating spatial data on Curve Number (CN), land use, rainfall, slope, desertification, lithology, geomorphology, landslide incidences, soil and digital elevation model (DEM), a comprehensive model was established to assess areas at high risk of flooding. The MCA methodology was employed to prioritize and weigh the significance of various factors contributing to flood vulnerability, allowing for a nuanced understanding of spatial patterns and risk hotspots. The results highlight regions where surface runoff and erosion combined exacerbate flood risks, providing valuable insights for local authorities to develop targeted flood management strategies. This approach emphasizes the importance of using multicriteria methods for environmental hazard assessment, offering a robust framework for disaster preparedness and land use planning in flood-prone regions.

Keywords: Remote sensing; multicriteria analysis; spatial data; curve number; erosion prone; flood vulnerability; potential flash flood; micro watershed.

Introduction

Soil erosion has serious repercussions, often manifesting in the form of landslides, flash floods, and flooding. Erosion poses a major environmental challenge in Nagaland, a state in northeastern India. Due to its hilly terrain and heavy monsoon rainfall, the region is particularly prone to soil erosion caused by extensive surface runoff, resulting in considerable consequences for both the environment and local communities. The combination of deforestation, unsustainable farming practices, and natural factors such as steep slopes and intense rainfall exacerbates the problem. Erosion destabilizes the land, increasing the risk of landslides and floods. Landslides are one of the most visible and devastating consequences of soil erosion. Soil and vegetation depletion due to deforestation and shifting cultivation weakens slopes, increasing their susceptibility to landslides, particularly during heavy monsoons. Flash floods are sudden, localized floods that occur quickly, typically due to heavy rainfall. They are common in areas affected by erosion, where increased water runoff, reduced vegetation cover, and steep slopes contribute to their occurrence. Steep slopes intensify the impact of heavy rainfall, causing water to flow rapidly downhill, gaining momentum and triggering flash floods in valleys or low-lying areas. Erosion and heavy runoff contribute to flooding in low-lying areas by removing the protective layer of soil and vegetation, which typically absorbs rainfall. As the land becomes more degraded, it loses its ability to absorb water, causing rainwater to flow rapidly across the surface. This increased runoff accumulates in lower-lying regions, overwhelming drainage systems and leading to localized flooding, damaging property, disrupting communities, and harming the environment.

This independent study, initiated by the Nagaland GIS & Remote Sensing Centre (appendix-1), highlights the significance of erosion, surface runoff and flood, with its findings intended for use by relevant agencies.

Study area and data used

The study area encompasses the entire state, situated in the far northeastern part of the Indian subcontinent bordering the states of Arunachal Pradesh in the north, Manipur in the south, Assam in the northwest and Myanmar in the east. It lies between 93°19′39.52″ & 95°12′47.44″ east longitudes and 25°10'53.17″ & 27°3′20″ north latitudes (fig.1). Thematic layers such as rainfall, slope, desertification, lithology, geomorphology, landslide incidences, soil, global curve number datasets, flat and valley geomorphon and DEM (Fig. 2a - 2k) were incorporated in this work.

Objective

The objective of the study is to develop an inventory database on flood vulnerability using a multi-faceted approach.

1. To analyse the relationship between rainfall, slope, desertification, lithology, geomorphology and landslide incidences in determining erosion prone in the state.

2. To analyse erosion-prone density and curve number index for the generation of flood-vulnerable areas.
3. Determination of possible flash flood area, at micro-watershed level using Composite analysis of erosion vulnerability vs surface runoff (CN).

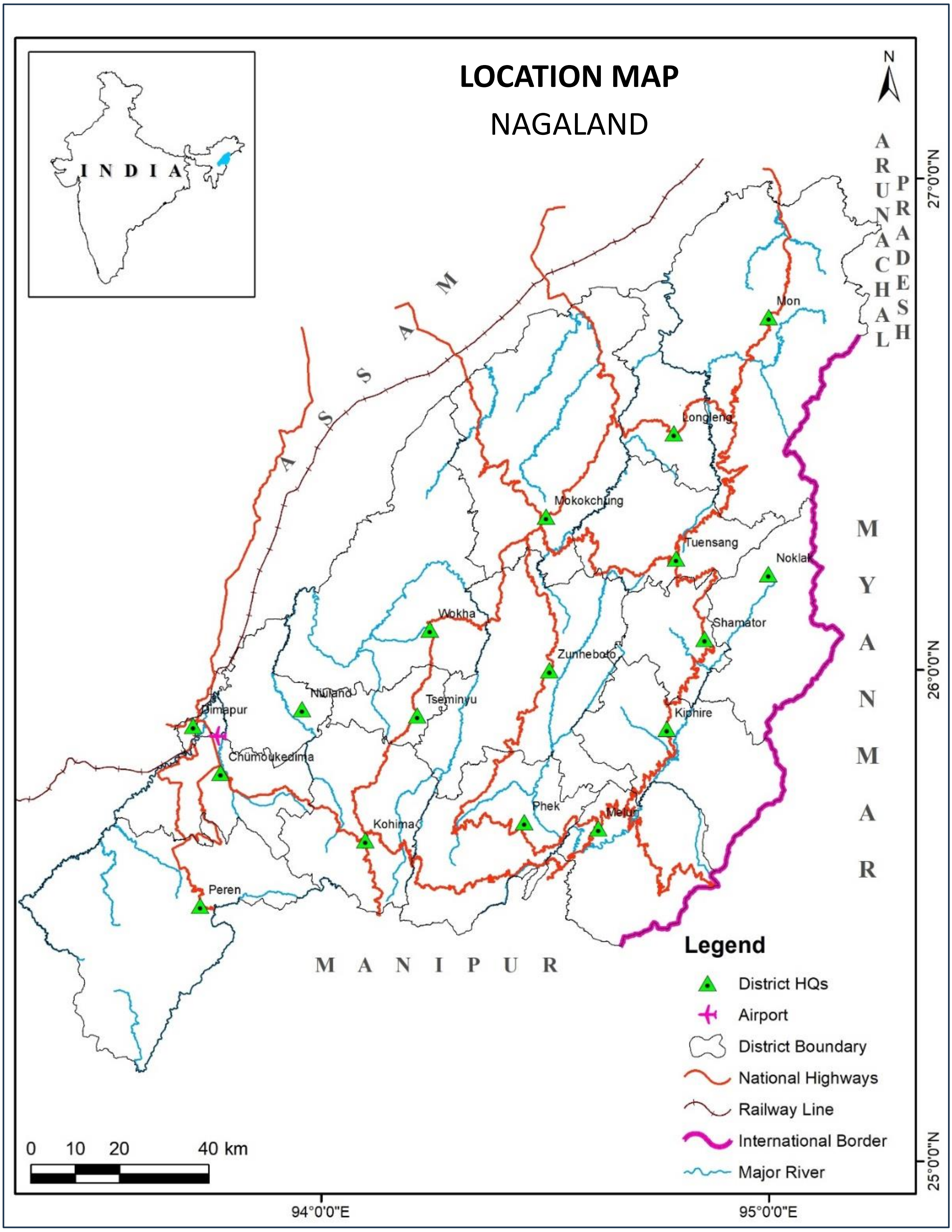

Fig. 1.

Methodology

The workflow for multicriteria analysis to identify flood-vulnerable regions requires the integration of various environmental and geographic factors (chart 1). This approach was employed to prioritize and weigh the significance of various factors contributing to flood vulnerability.

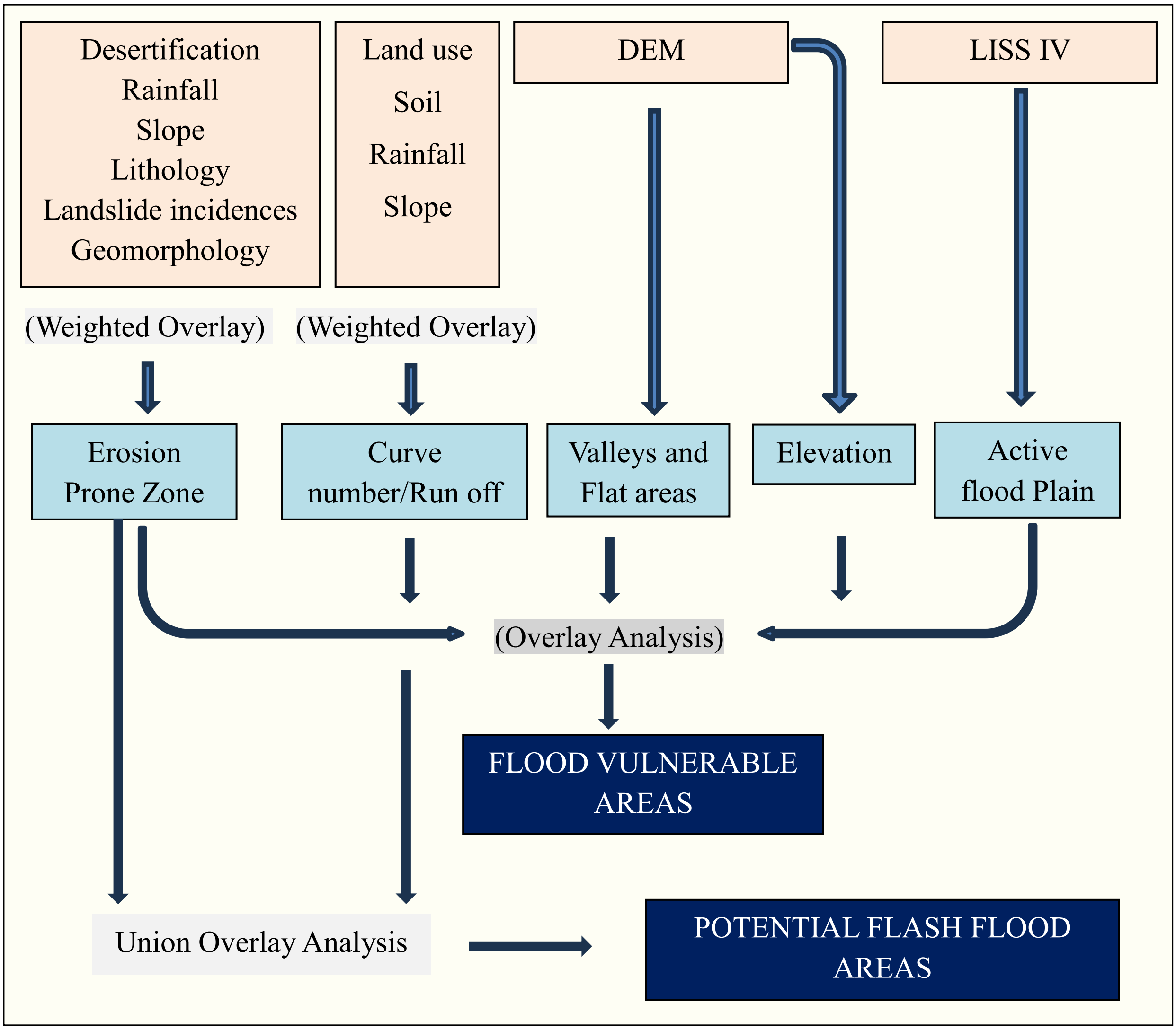

Chart 1. Workflow for multicriteria analysis

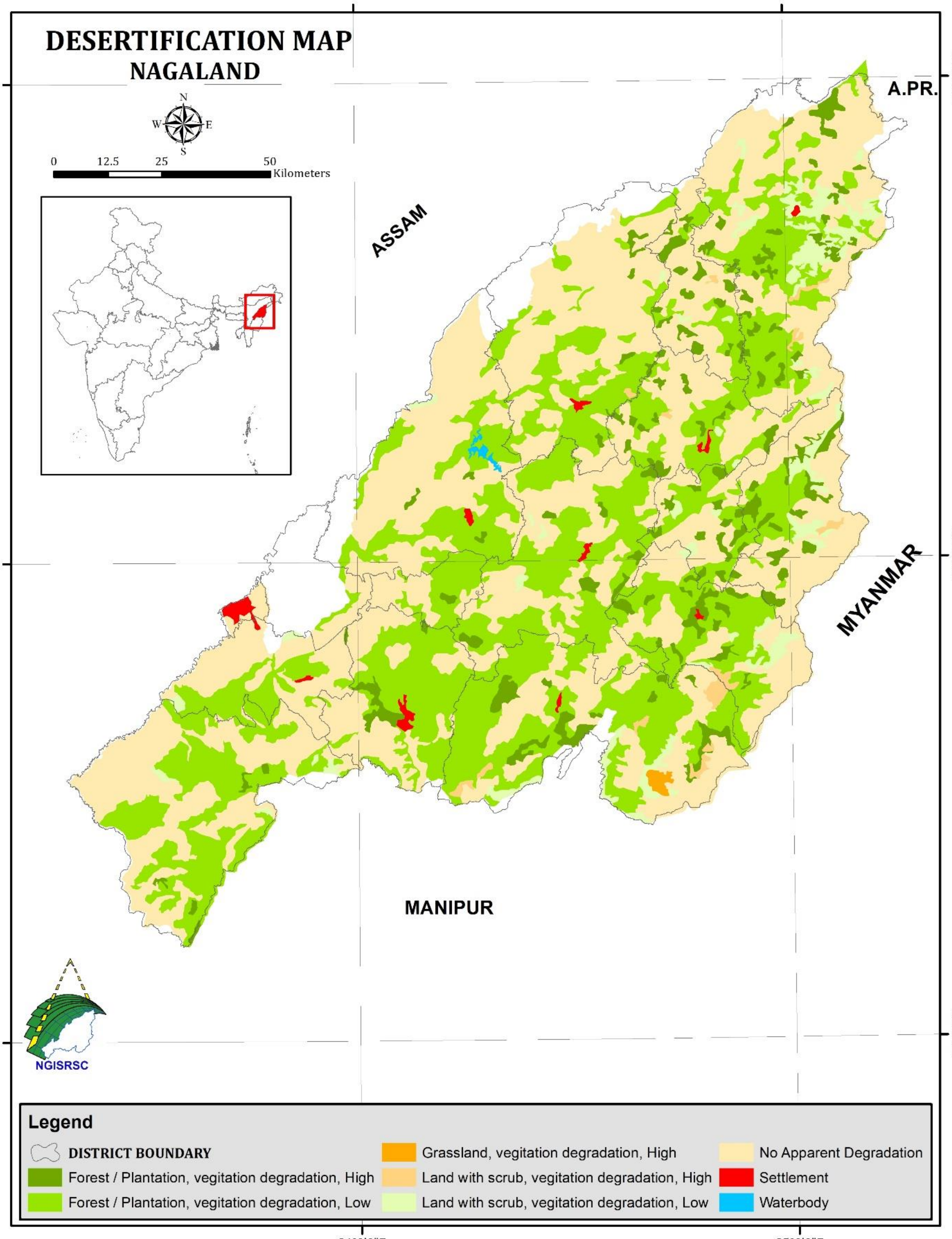
DESERTIFICATION MAP
NAGALAND
N
W
E
S
0
12.5
25
50
Kilometers
ASSAM
A.PR.
MYANMAR
MANIPUR
27°0'0"N
26°0'0"N
25°0'0"N
94°0'0"E
95°0'0"E
NGISRSC
Legend
DISTRICT BOUNDARY
Forest / Plantation, vegitation degradation, High
Forest / Plantation, vegitation degradation, Low
Grassland, vegitation degradation, High
Land with scrub, vegitation degradation, High
Land with scrub, vegitation degradation, Low
No Apparent Degradation
Settlement
Waterbody

Fig. 2a

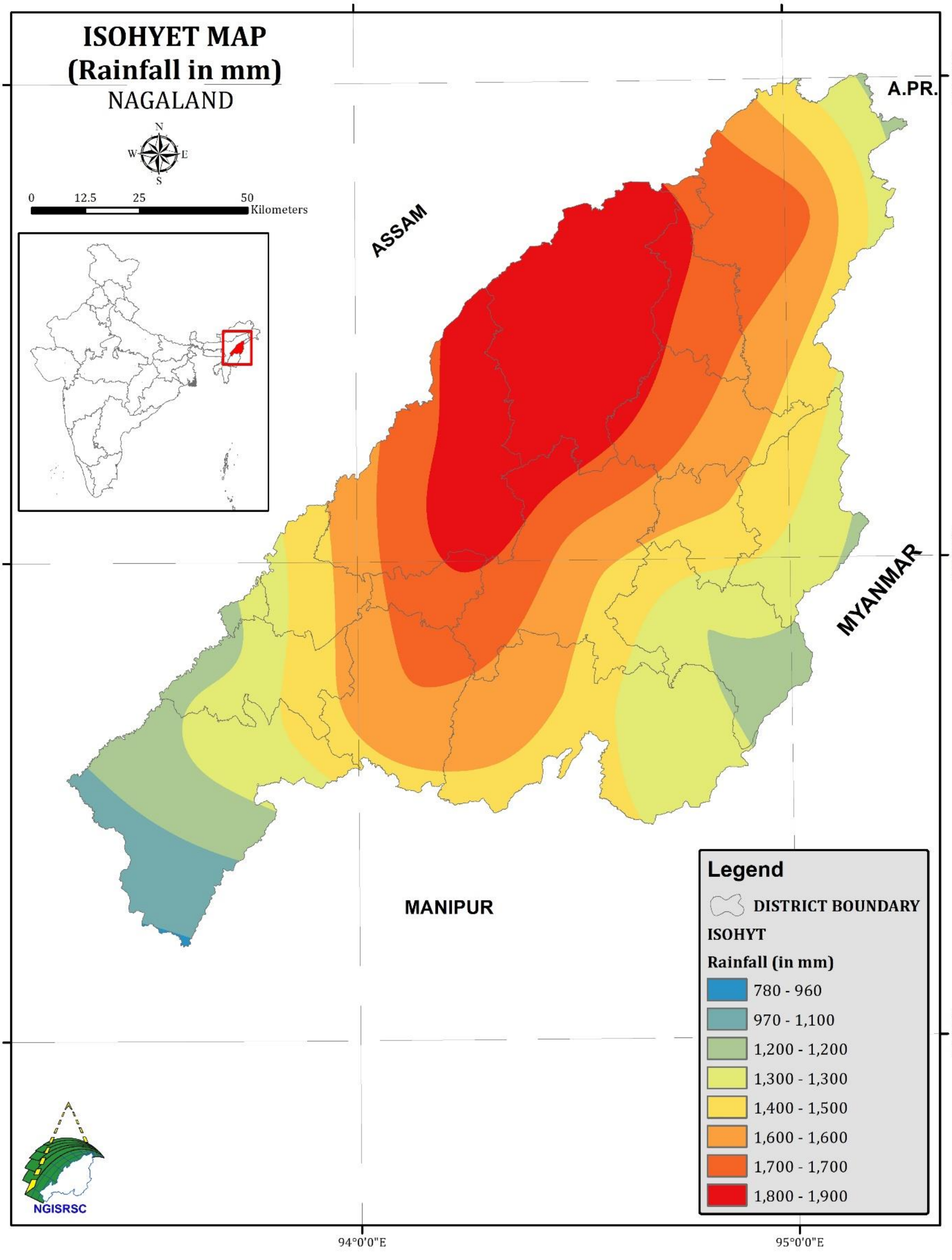
ISOHYET MAP
(Rainfall in mm)
NAGALAND
N
W
E
S
0
12.5
25
50
Kilometers
ASSAM
A.PR.
MYANMAR
MANIPUR
27°0'0"N
26°0'0"N
25°0'0"N
94°0'0"E
95°0'0"E
Legend
DISTRICT BOUNDARY
ISOHYT
Rainfall (in mm)
780 - 960
970 - 1,100
1,200 - 1,200
1,300 - 1,300
1,400 - 1,500
1,600 - 1,600
1,700 - 1,700
1,800 - 1,900
NGISRSC

Fig. 2b

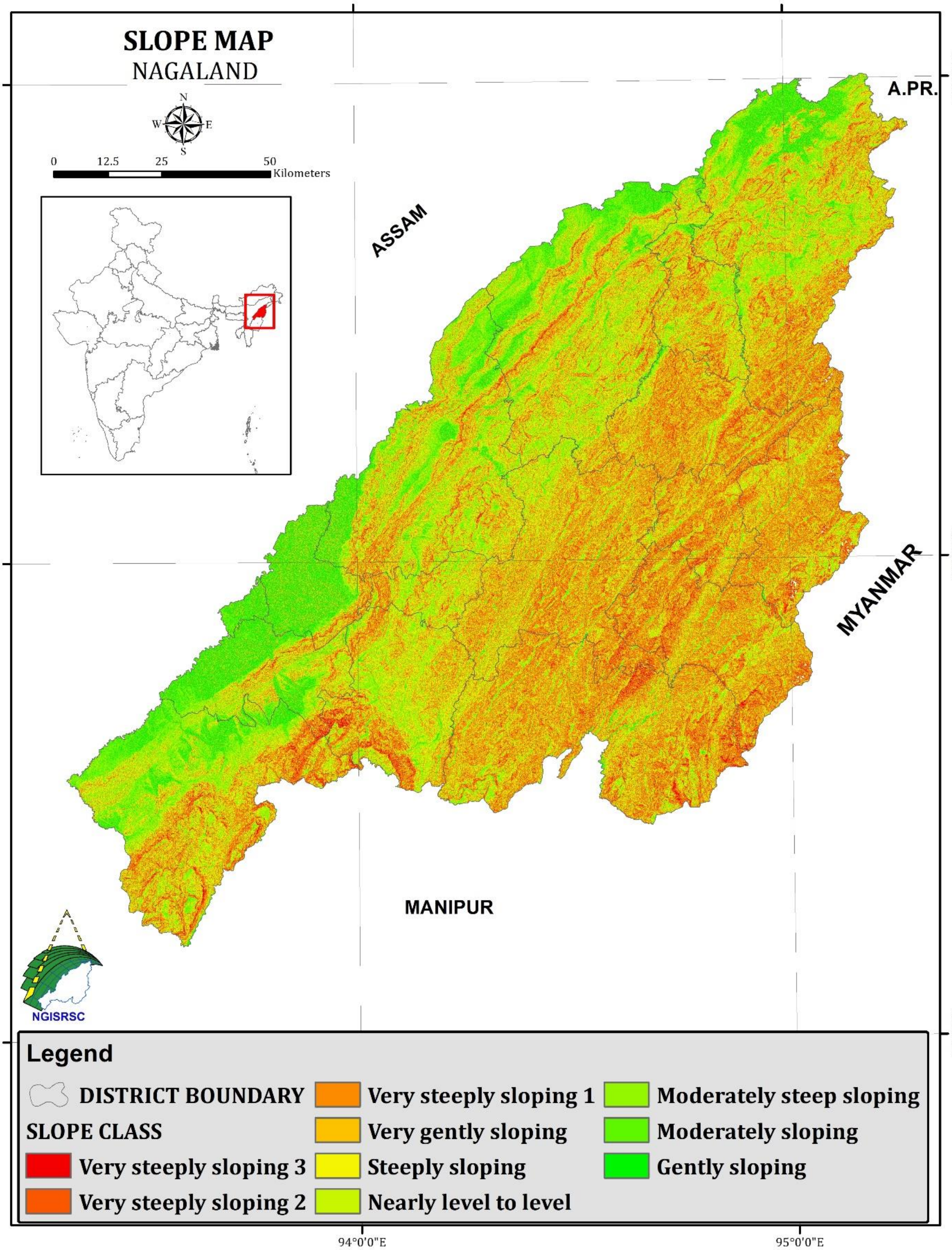
SLOPE MAP
NAGALAND
N
W
E
S
0
12.5
25
50
Kilometers
ASSAM
A.PR.
MYANMAR
MANIPUR
NGISRSC
27°0'0"N
26°0'0"N
25°0'0"N
94°0'0"E
95°0'0"E
Legend
DISTRICT BOUNDARY
SLOPE CLASS
Very steeply sloping 3
Very steeply sloping 2
Very steeply sloping 1
Very gently sloping
Steeply sloping
Nearly level to level
Moderately steep sloping
Moderately sloping
Gently sloping

Fig. 2c

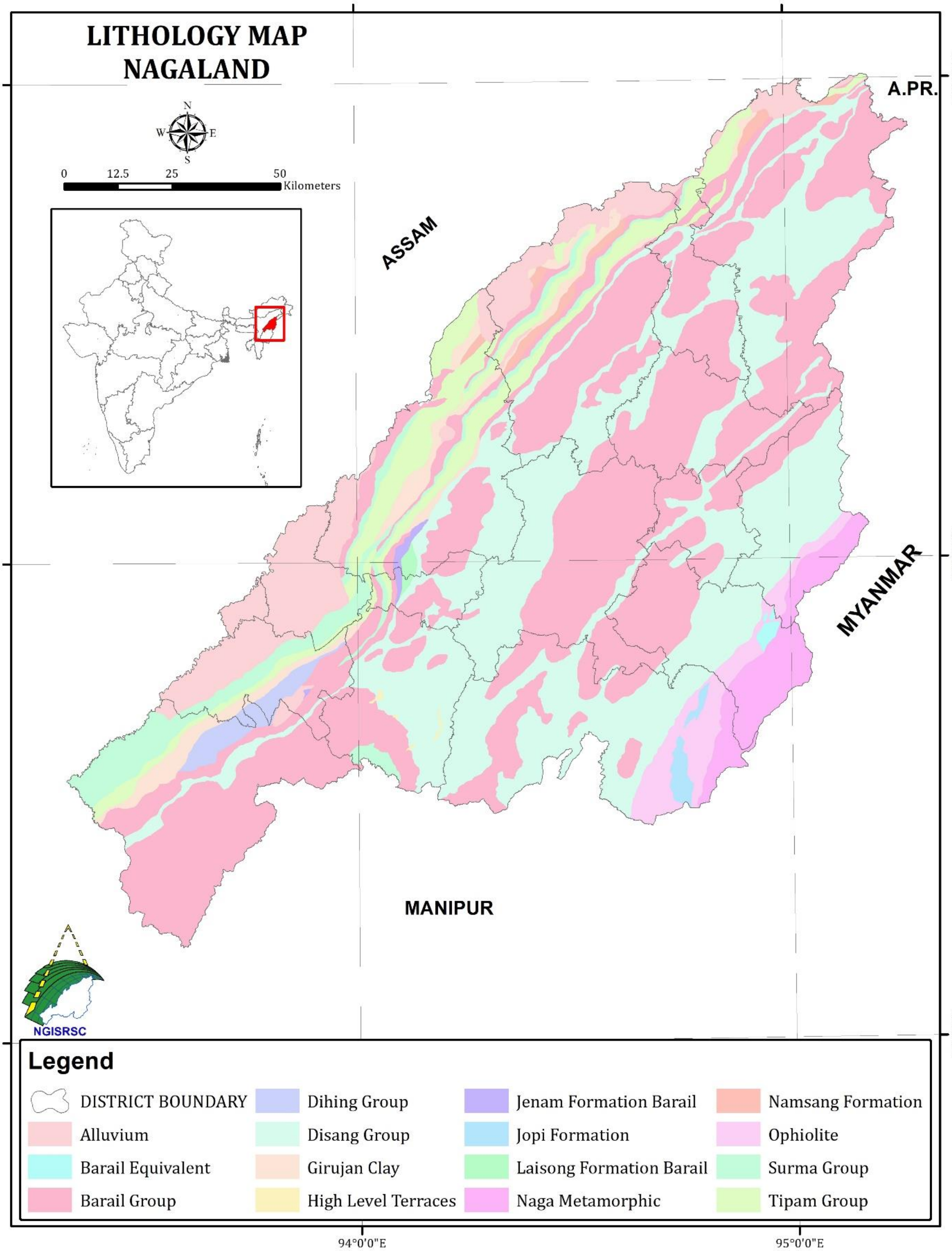
LITHOLOGY MAP
NAGALAND
N
W
E
S
0
12.5
25
50
Kilometers
ASSAM
A.PR.
MYANMAR
MANIPUR
27°0'0"N
26°0'0"N
25°0'0"N
94°0'0"E
95°0'0"E
NGISRSC
Legend
DISTRICT BOUNDARY
Alluvium
Barail Equivalent
Barail Group
Dihing Group
Disang Group
Girujan Clay
High Level Terraces
Jenam Formation Barail
Jopi Formation
Laisong Formation Barail
Naga Metamorphic
Namsang Formation
Ophiolite
Surma Group
Tipam Group

Fig. 2d

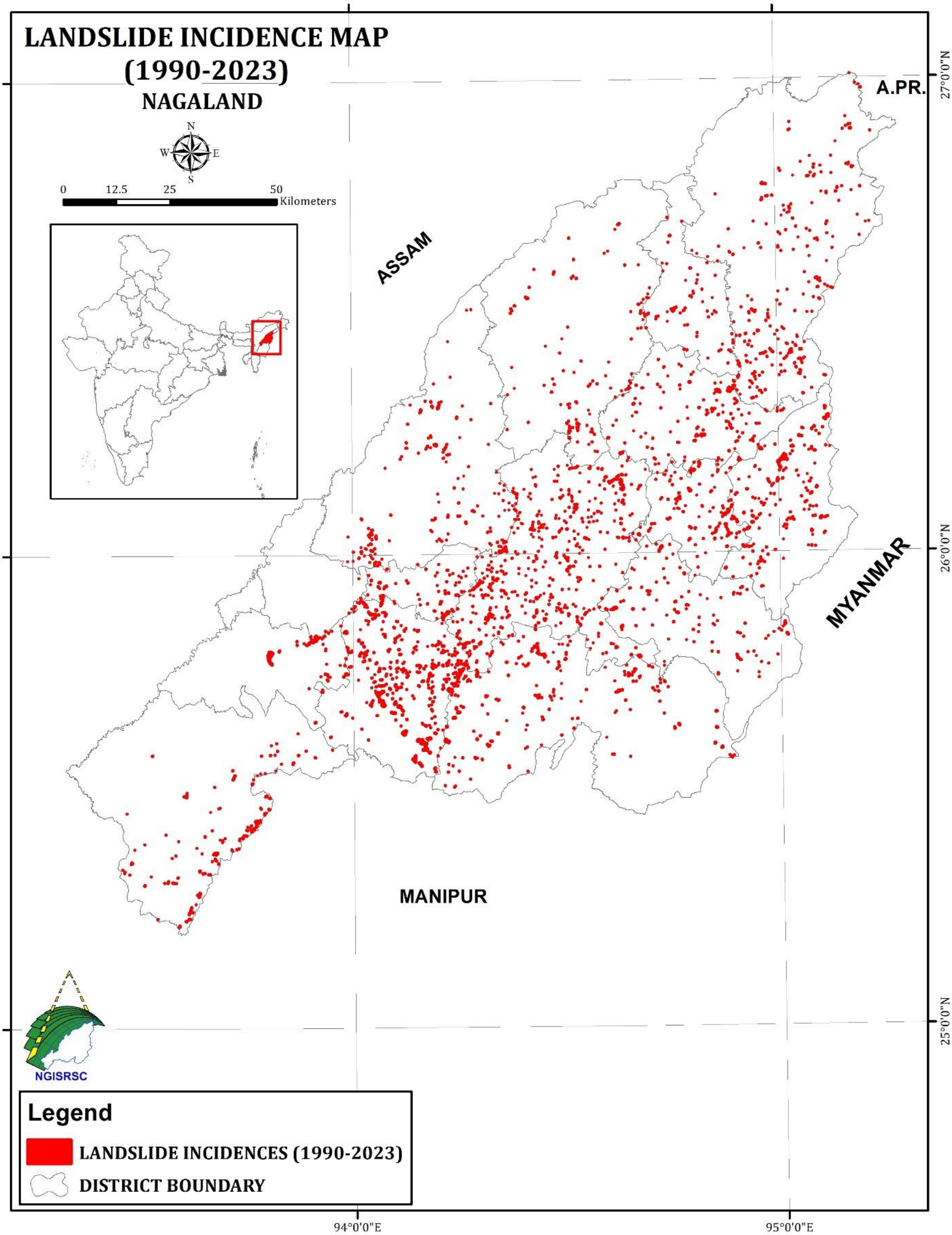
LANDSLIDE INCIDENCE MAP
(1990-2023)
NAGALAND
N
W
E
S
0
12.5
25
50
Kilometers
ASSAM
A.PR.
MYANMAR
MANIPUR
27°0'0"N
26°0'0"N
25°0'0"N
94°0'0"E
95°0'0"E
NGISRSC
Legend
LANDSLIDE INCIDENCES (1990-2023)
DISTRICT BOUNDARY

Fig. 2e

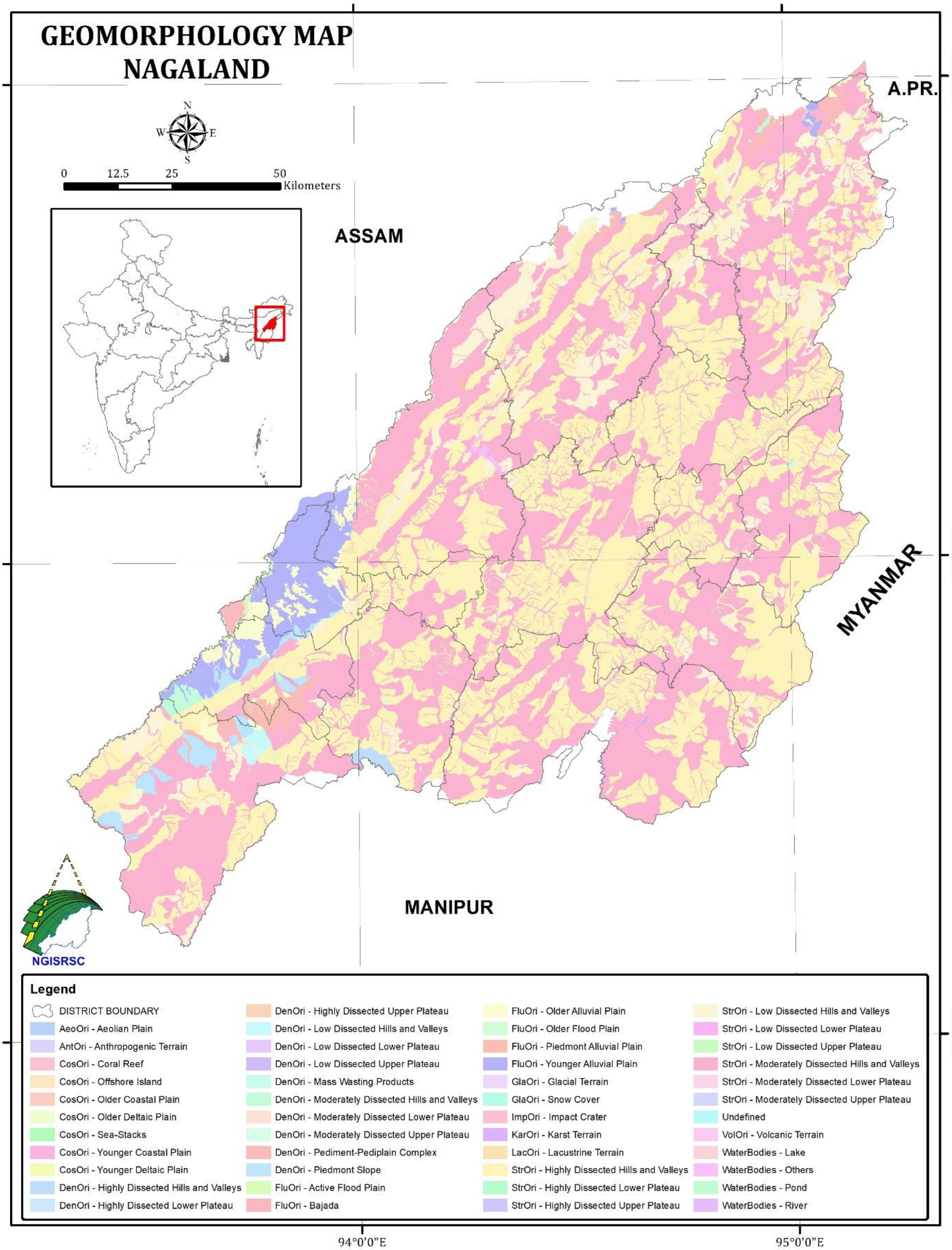
GEOMORPHOLOGY MAP
NAGALAND
N
W
E
S
0
12.5
25
50
Kilometers
ASSAM
A.PR.
MYANMAR
MANIPUR
NGISRSC
27°0'0"N
26°0'0"N
25°0'0"N
94°0'0"E
95°0'0"E
Legend
DISTRICT BOUNDARY
AeoOri - Aeolian Plain
AntOri - Anthropogenic Terrain
CosOri - Coral Reef
CosOri - Offshore Island
CosOri - Older Coastal Plain
CosOri - Older Deltaic Plain
CosOri - Sea-Stacks
CosOri - Younger Coastal Plain
CosOri - Younger Deltaic Plain
DenOri - Highly Dissected Hills and Valleys
DenOri - Highly Dissected Lower Plateau
DenOri - Highly Dissected Upper Plateau
DenOri - Low Dissected Hills and Valleys
DenOri - Low Dissected Lower Plateau
DenOri - Low Dissected Upper Plateau
DenOri - Mass Wasting Products
DenOri - Moderately Dissected Hills and Valleys
DenOri - Moderately Dissected Lower Plateau
DenOri - Moderately Dissected Upper Plateau
DenOri - Pediment-Pediplain Complex
DenOri - Piedmont Slope
FluOri - Active Flood Plain
FluOri - Bajada
FluOri - Older Alluvial Plain
FluOri - Older Flood Plain
FluOri - Piedmont Alluvial Plain
FluOri - Younger Alluvial Plain
GlaOri - Glacial Terrain
GlaOri - Snow Cover
ImpOri - Impact Crater
KarOri - Karst Terrain
LacOri - Lacustrine Terrain
StrOri - Highly Dissected Hills and Valleys
StrOri - Highly Dissected Lower Plateau
StrOri - Highly Dissected Upper Plateau
StrOri - Low Dissected Hills and Valleys
StrOri - Low Dissected Lower Plateau
StrOri - Low Dissected Upper Plateau
StrOri - Moderately Dissected Hills and Valleys
StrOri - Moderately Dissected Lower Plateau
StrOri - Moderately Dissected Upper Plateau
Undefined
VolOri - Volcanic Terrain
WaterBodies - Lake
WaterBodies - Others
WaterBodies - Pond
WaterBodies - River

Fig. 2f

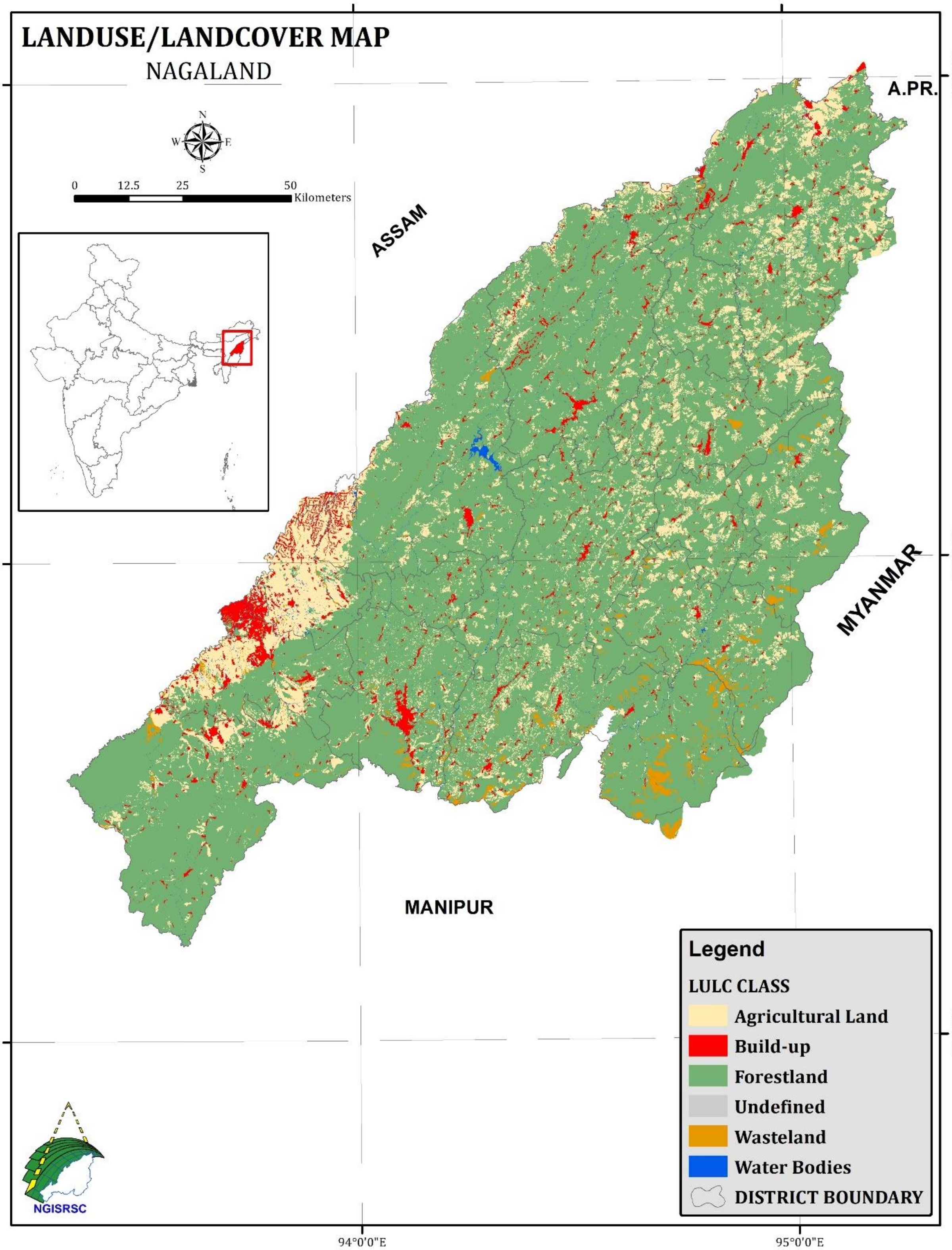
LANDUSE/LANDCOVER MAP
NAGALAND
N
S
E
W
0
12.5
25
50
Kilometers
ASSAM
A.PR.
MYANMAR
MANIPUR
27°0'0"N
26°0'0"N
25°0'0"N
94°0'0"E
95°0'0"E
Legend
LULC CLASS
Agricultural Land
Build-up
Forestland
Undefined
Wasteland
Water Bodies
DISTRICT BOUNDARY
NGISRSC

Fig. 2g

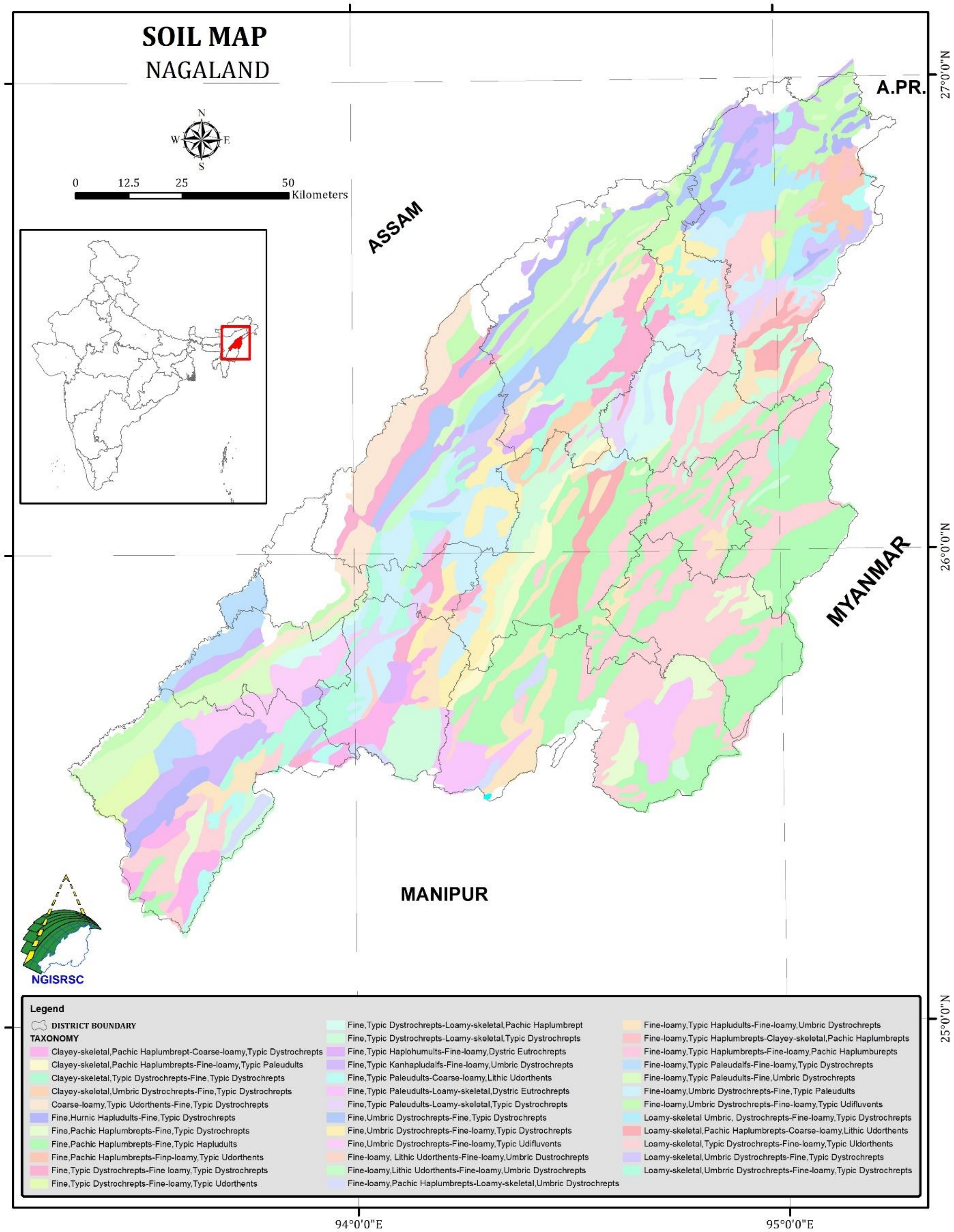
SOIL MAP
NAGALAND
N
S
E
W
0
12.5
25
50
Kilometers
ASSAM
A.PR.
MYANMAR
MANIPUR
27°0'0"N
26°0'0"N
25°0'0"N
94°0'0"E
95°0'0"E
NGISRSC
Legend
DISTRICT BOUNDARY
TAXONOMY
Clayey-skeletal,Pachic Haplumbrept-Coarse-loamy,Typic Dystrochrepts
Clayey-skeletal,Pachic Haplumbrepts-Fine-loamy,Typic Paleudults
Clayey-skeletal,Typic Dystrochrepts-Fine,Typic Dystrochrepts
Clayey-skeletal,Umbric Dystrochrepts-Fine,Typic Dystrochrepts
Coarse-loamy,Typic Udorthents-Fine,Typic Dystrochrepts
Fine,Hurnic Hapludults-Fine,Typic Dystrochrepts
Fine,Pachic Haplumbrepts-Fine,Typic Dystrochrepts
Fine,Pachic Haplumbrepts-Fine,Typic Hapludults
Fine,Pachic Haplumbrepts-Finp-loamy,Typic Udorthents
Fine,Typic Dystrochrepts-Fine loamy,Typic Dystrochrepts
Fine,Typic Dystrochrepts-Fine-loamy,Typic Udorthents
Fine,Typic Dystrochrepts-Loamy-skeletal,Pachic Haplumbrept
Fine,Typic Dystrochrepts-Loamy-skeletal,Typic Dystrochrepts
Fine,Typic Haplohumults-Fine-loamy,Dystric Eutrochrepts
Fine,Typic Kanhapludalfs-Fine-loamy,Umbric Dystrochrepts
Fine,Typic Paleudults-Coarse-loamy,Lithic Udorthents
Fine,Typic Paleudults-Loamy-skeletal,Dystric Eutrochrepts
Fine,Typic Paleudults-Loamy-skeletal,Typic Dystrochrepts
Fine,Umbric Dystrochrepts-Fine,Typic Dystrochrepts
Fine,Umbric Dystrochrepts-Fine-loamy,Typic Dystrochrepts
Fine,Umbric Dystrochrepts-Fine-loamy,Typic Udifluvents
Fine-loamy, Lithic Udorthents-Fine-loamy,Umbric Dustrochrepts
Fine-loamy,Lithic Udorthents-Fine-loamy,Umbric Dystrochrepts
Fine-loamy,Pachic Haplumbrepts-Loamy-skeletal,Umbric Dystrochrepts
Fine-loamy,Typic Hapludults-Fine-loamy,Umbric Dystrochrepts
Fine-loamy,Typic Haplumbrepts-Clayey-skeletal,Pachic Haplumbrepts
Fine-loamy,Typic Haplumbrepts-Fine-loamy,Pachic Haplumburepts
Fine-loamy,Typic Paleudalfs-Fine-loamy,Typic Dystrochrepts
Fine-loamy,Typic Paleudults-Fine,Umbric Dystrochrepts
Fine-loamy,Umbric Dystrochrepts-Fine,Typic Paleudults
Fine-loamy,Umbric Dystrochrepts-Fine-loamy,Typic Udifluvents
Loamy-skeletal Umbric, Dystrochrepts-Fine-loamy,Typic Dystrochrepts
Loamy-skeletal,Pachic Haplumbrepts-Coarse-loamy,Lithic Udorthents
Loamy-skeletal,Typic Dystrochrepts-Fine-loamy,Typic Uldorthents
Loamy-skeletal,Umbric Dystrochrepts-Fine,Typic Dystrochrepts
Loamy-skeletal,Umbrric Dystrochrepts-Fine-loamy,Typic Dystrochrepts

Fig. 2h

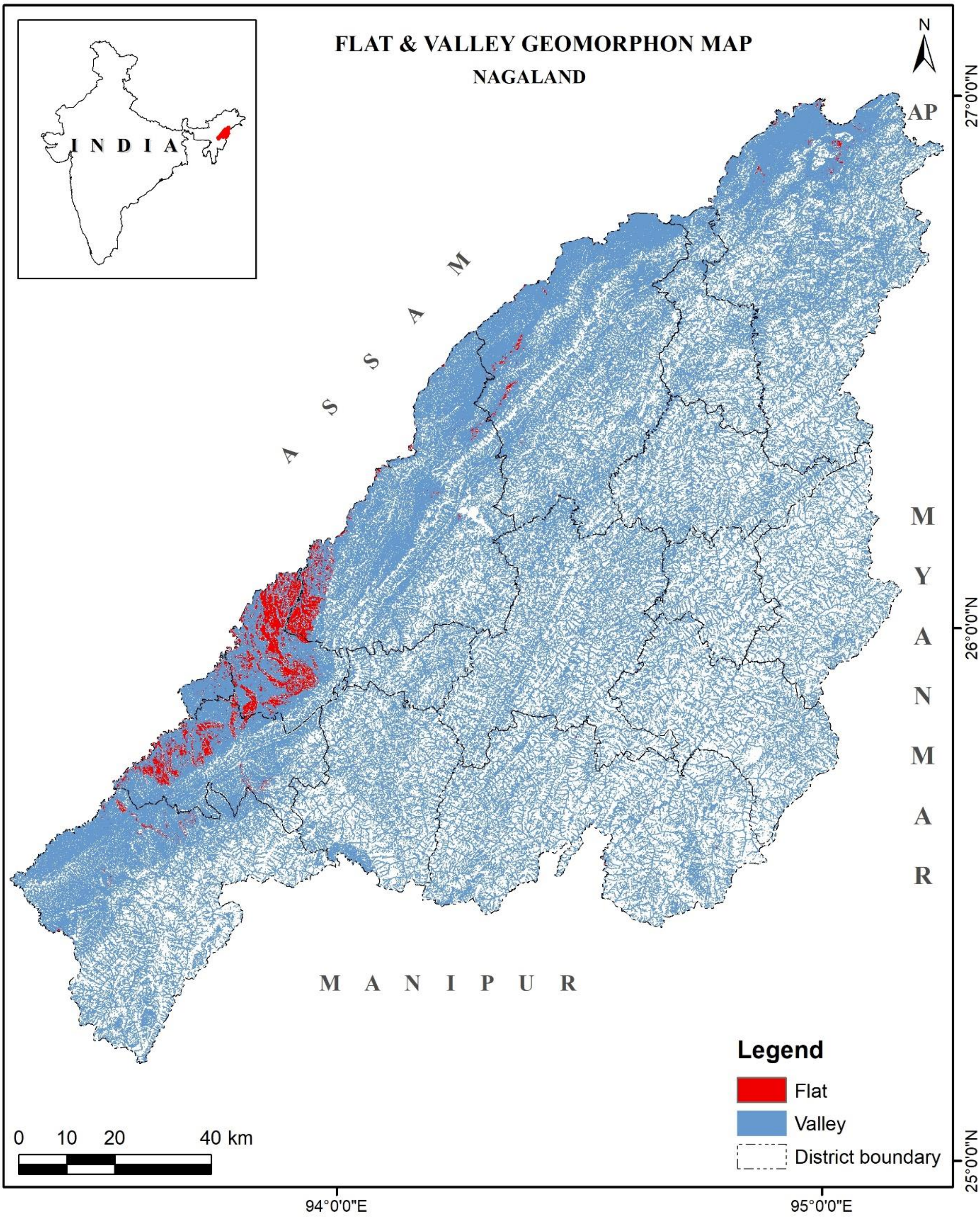
FLAT & VALLEY GEOMORPHON MAP
NAGALAND
INDIA
ASSAM
AP
MYANMAR
MANIPUR
N
27°0'0"N
26°0'0"N
25°0'0"N
94°0'0"E
95°0'0"E
Legend
Flat
Valley
District boundary
0 10 20 40 km

Fig. 2i

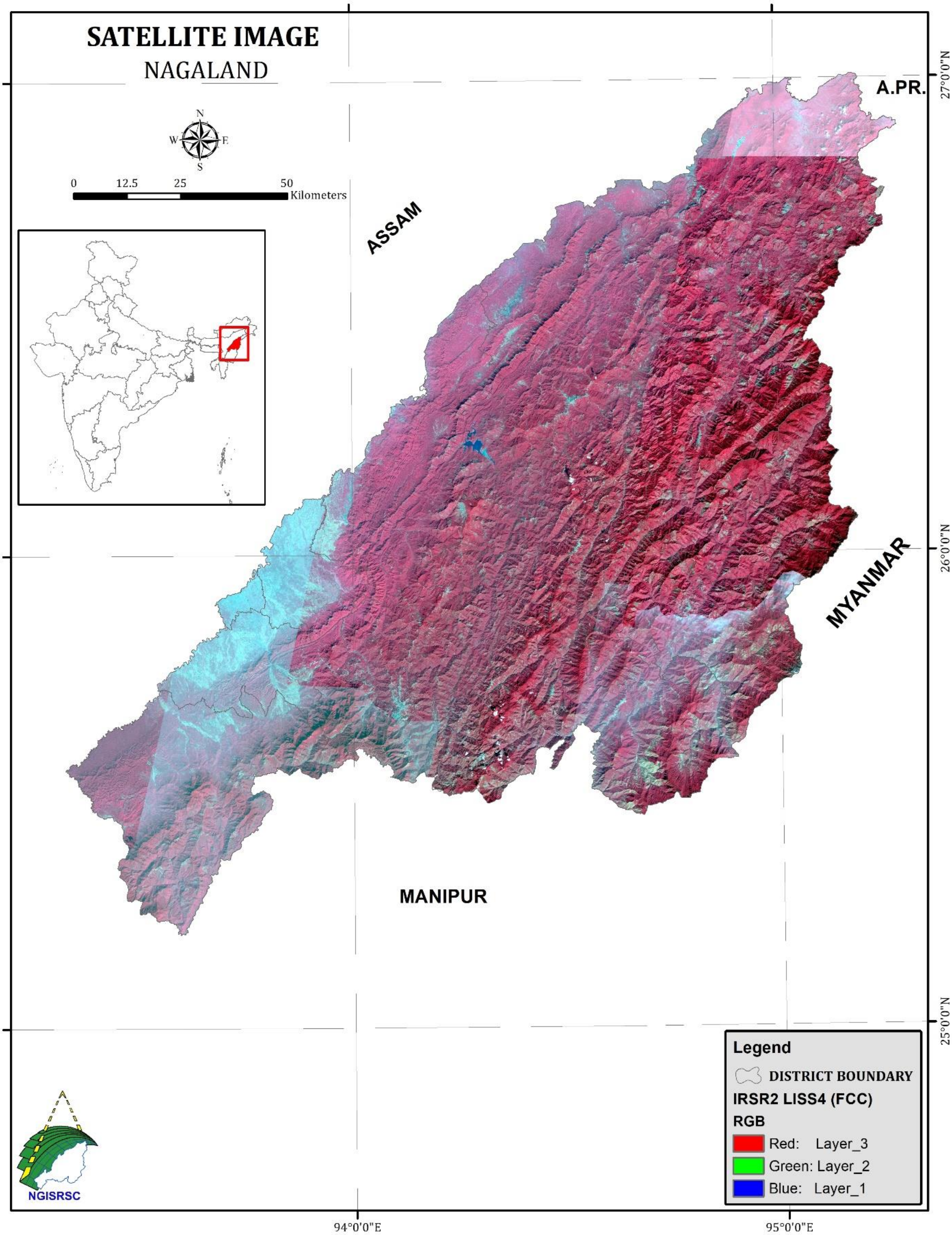
SATELLITE IMAGE
NAGALAND
N
S
W
E
0
12.5
25
50
Kilometers
ASSAM
A.PR.
MYANMAR
MANIPUR
27°0'0"N
26°0'0"N
25°0'0"N
94°0'0"E
95°0'0"E
Legend
DISTRICT BOUNDARY
IRSR2 LISS4 (FCC)
RGB
Red: Layer_3
Green: Layer_2
Blue: Layer_1
NGISRSC

Fig. 2j

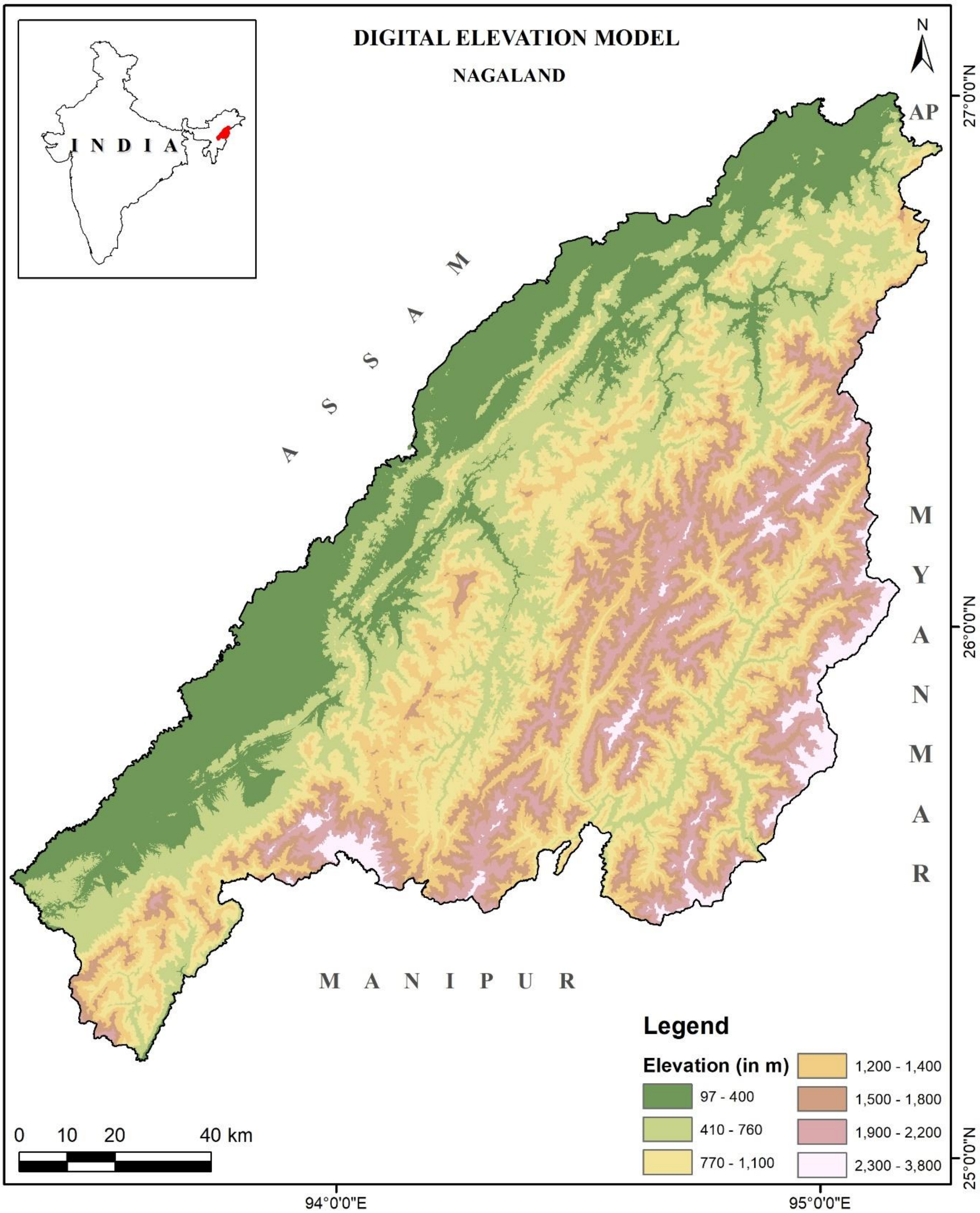
DIGITAL ELEVATION MODEL
NAGALAND
INDIA
N
AP
ASSAM
MYANMAR
MANIPUR
27°0'0"N
26°0'0"N
25°0'0"N
94°0'0"E
95°0'0"E
Legend
Elevation (in m)
97 - 400
410 - 760
770 - 1,100
1,200 - 1,400
1,500 - 1,800
1,900 - 2,200
2,300 - 3,800
0 10 20 40 km

Fig. 2k

1. Weighted overlay analysis for erosion-prone area (EPA)

   This method is employed to assess and map erosion-prone areas by considering various influencing factors, each assigned a specific weight based on its significance in driving erosion processes. Key factors in the analysis include rainfall, slope, and landslide occurrences, which have the most substantial effect on identifying areas vulnerable to erosion. These are followed by secondary factors such as lithology, geomorphology, and desertification.

Raster	**Influence %**
Desertification	10
Rainfall	20
Slope	20
Lithology	15
Geomorphology	15
Landslide incidences	20

2. Analysis of curve number

   The curve number (CN) is a dimensionless value ranging from 0 to 100 that represents the potential for a specific land use, soil type, and antecedent moisture condition to generate runoff. It is a key parameter used in hydrology to estimate surface runoff from a rainfall event. It is part of the SCS Curve Number Method, developed by the Soil Conservation Service (SCS), now known as the Natural Resources Conservation Service (NRCS). The method is widely used in engineering, water resource management, and environmental modeling. The CN is determined based on: Land Use and Land Cover: Such as forest, agriculture, or urban development. Soil Type: Classified into four Hydrologic Soil Groups (HSGs) based on infiltration rates:

   A: High infiltration (sandy or gravelly soils).

   B: Moderate infiltration (loamy soils).

   C: Low infiltration (clay loam soils).

   D: Very low infiltration (clay soils or shallow soils over a hardpan).

   Antecedent Moisture Conditions (AMC): Reflect the soil's moisture content before the rainfall event:

   AMC I: Dry conditions.

   AMC II: Average conditions (commonly used).

AMC III: Wet conditions.

The curve number method uses the following formula to calculate runoff depth (Q):

$Q = \frac{(P-0.2S)^2}{P+0.8S}$, P > 0.25

Where:

Q: Runoff depth (in inches or mm).

P: Rainfall depth (in inches or mm).

S: Potential maximum retention after runoff begins, calculated as:

$$S = \frac{1000}{CN} - 10$$

For P≤0.2S, Q=0 (no runoff).

3. Overlay analysis parameters for flood vulnerable area
    a. Elevation data extracted from DEM
    b. DEM derived valley and flat area using geomorphon approach (Grass GIS)
    c. EPA raster generated by weighted overlay analysis
    d. CN (Runoff) raster
    e. Active flood plain derived from LISS IV image

   The flood vulnerability analysis is conducted by overlaying various parameters, focusing on areas where high curve number values intersect with high erosion-prone areas and overlap with valleys/ flat regions and active flood plains.

4. Determination of possible flash flood area, at micro-watershed level using Composite analysis of erosion vulnerability vs surface runoff (CN).
    a. The resultant Surface Run-off i.e. Curve Number (CN) and the Flood vulnerability were overlaid on the delineated micro-watershed (3324 Nos) map of Nagaland and subsequently each micro-watershed was assigned a weightage based on its predominant (area) weightage category that falls within the micro-watershed (fig. 6 & 7).
    b. The two variables were then combined into a single composite map using union matrix technique to derive a possible micro-watershed level flash-flood vulnerability area map.

c. Based on the ensuing composite analysis results, the entire study area (Sub-watersheds) was categorized into Very Low, Low, Medium, High and Very High. (table 3a).
d. Identification and listing of the areas (Micro-watershed) falling within the high and very high flash flood vulnerability category (180 Micro-watersheds) was done and attempt has been made to list down the names of the generic River names falling within the grouping.

Results

The results of the weighted overlay analysis generate a scale that helps categorize areas based on their relative susceptibility to erosion (table 1a &1b). A low value suggests that the area is less prone to erosion, indicating favorable conditions such as stable terrain, healthy vegetation cover, and soil properties that help resist soil loss (fig. 3 & fig. 3a - 3p). In contrast, a high value corresponds to areas with greater vulnerability to erosion, where factors like steep slopes, frequent landslides, and other contributing elements combine to increase the risk of rapid soil erosion. This method helps prioritize areas for intervention and conservation by clearly identifying the most vulnerable zones based on a combination of environmental factors.

The results of the surface runoff analysis show that low CN values (e.g., 30 - 50) indicate high infiltration rates and low runoff potential, typically found in areas with permeable soils, dense vegetation, or minimal urbanization. Conversely, high CN values (e.g., 70 - 90) suggest low infiltration rates and high runoff potential, commonly associated with impervious surfaces, compacted soils, or regions with sparse vegetation (table 2a & 2b). The results of the flood vulnerability analysis reveal that areas with high Curve Number values overlapping erosion-prone zones, especially in low-lying regions, are more prone to flooding (fig. 4 & fig. 4a - 4p). This overlap is particularly noticeable in valleys and flat areas, where CN and EPA values are elevated, highlighting regions with increased flood susceptibility (fig. 5).

Flash floods are characterized by their rapid onset, often occurring within just a few hours due to intense rainfall or sudden cloud bursts. These events are highly dynamic, with the risk of flooding changing quickly based on factors like rainfall intensity, geography, and soil conditions. Flash floods are typically associated with monsoon seasons, so the analysis is particularly focused on weather events driven by monsoon rains, which bring heavy and concentrated rainfall that increases the risk of flooding. It's important to note that areas where

CN and EPA values intersect are most likely to experience flash floods during a cloud burst. Potential flash flood area was derived from two variables i.e Curve Number (Surface Run-off) and the Flood vulnerability zone using overlay analysis at micro-watershed level. Micro-watersheds falling within the high and very high flash flood vulnerability category and subsequent affected rivers were identified (fig. 8; table 3b)

Table 1a. Erosion prone area-wise percentage

Erosion Prone Category	Area (sq.m)	Area (%)
Very Low Erosion Prone	873511699.3	4.97%
Low Erosion Prone	4403853707	25.07%
Moderate Erosion Prone	10056210324	57.24%
High Erosion Prone	2202617443	12.54%
Very High Erosion Prone	32251073.56	0.18%

Table 1b. District-wise erosion prone area in percentage

District	Area (sq.m)	Very Low Erosion Prone	Low Erosion Prone	Moderate Erosion Prone	High Erosion Prone	Very High Erosion Prone
Chümoukedima	698310251.3	28.95%	37.07%	26.73%	7.26%	0.00%
Dimapur	68029213.1	44.90%	37.25%	1.05%	16.80%	0.00%
Kiphire	1021357240	0.00%	27.97%	58.10%	13.80%	0.13%
Kohima	1001241192	0.07%	34.65%	53.95%	11.34%	0.00%
Longleng	584217293.7	1.89%	11.29%	72.47%	14.27%	0.08%
Mokokchung	1902484612	1.01%	24.07%	61.08%	13.83%	0.01%
Mon	2278917169	2.64%	20.83%	63.28%	12.37%	0.89%
Niuland	481440594.1	74.35%	5.82%	16.26%	3.57%	0.00%
Noklak	912203919.2	0.00%	12.93%	71.30%	15.46%	0.31%
Peren	1811690346	2.83%	41.45%	46.32%	9.40%	0.00%
Phek	1963214673	0.05%	35.25%	50.37%	13.99%	0.33%
Shamator	468761467.3	0.00%	14.61%	68.47%	16.92%	0.0017%
Tseminyu	289819323.7	0.00%	28.07%	61.08%	10.85%	0.00%
Tuensang	801707784.3	0.00%	3.45%	83.76%	12.75%	0.04%
Wokha	1736069003	8.04%	31.36%	48.17%	12.43%	0.00%
Zunheboto	1548528491	0.0001%	11.44%	73.95%	14.58%	0.03%

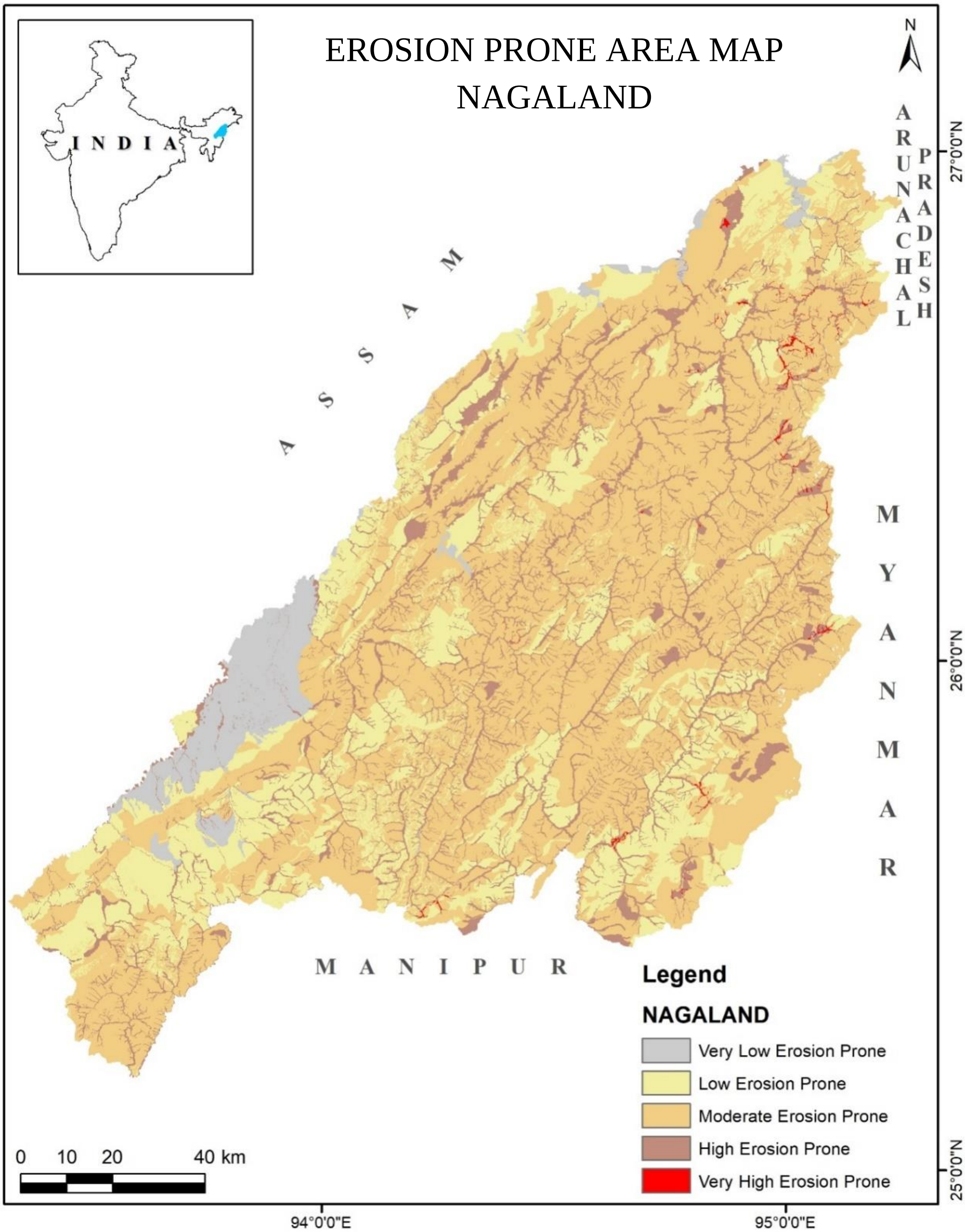

Fig. 3. Erosion Prone Area Map of Nagaland

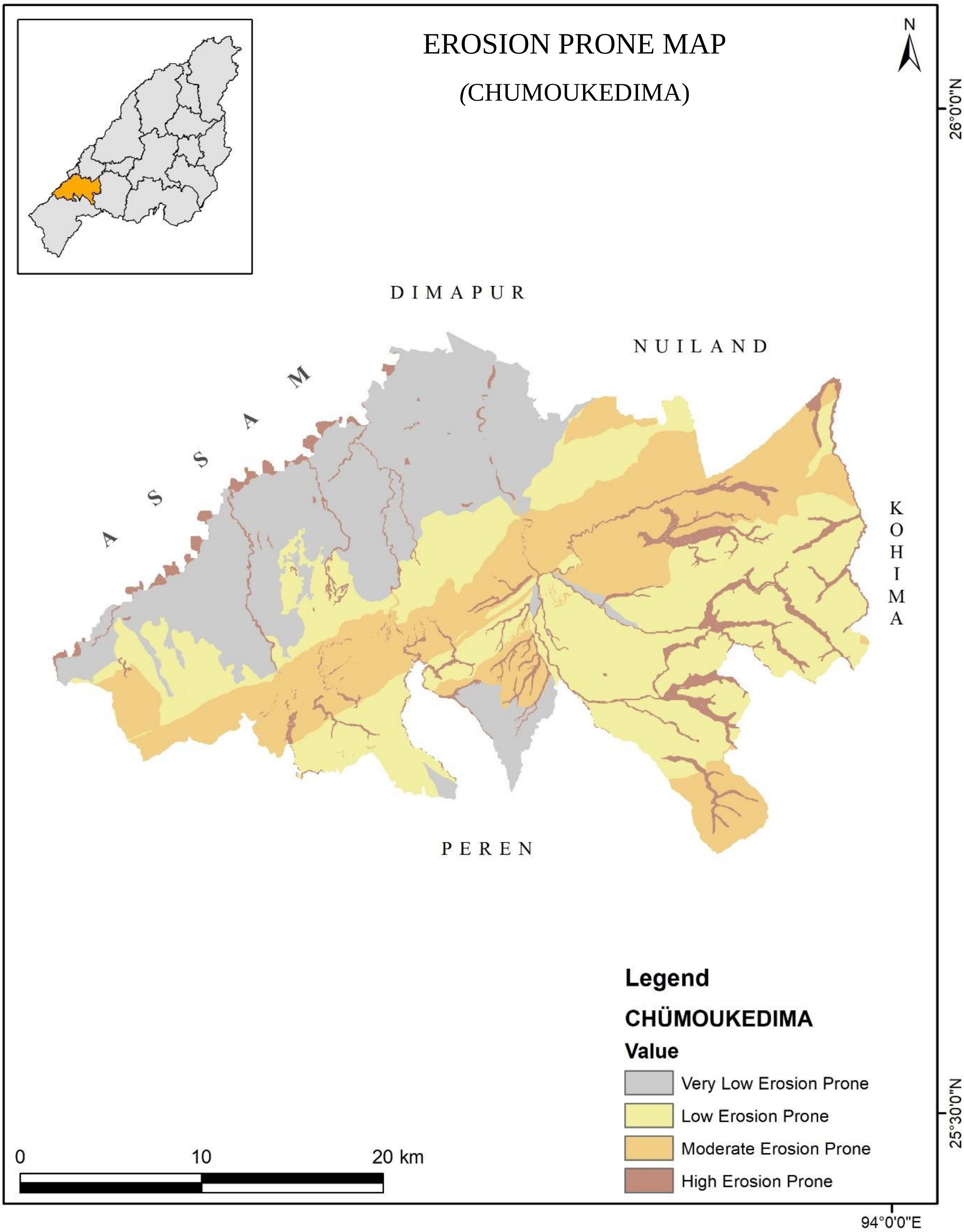
EROSION PRONE MAP
(CHUMOUKEDIMA)
N
26°0'0"N
25°30'0"N
94°0'0"E
DIMAPUR
NUILAND
ASSAM
KOHIMA
PEREN
Legend
CHÜMOUKEDIMA
Value
Very Low Erosion Prone
Low Erosion Prone
Moderate Erosion Prone
High Erosion Prone
0
10
20 km

Fig. 3a.

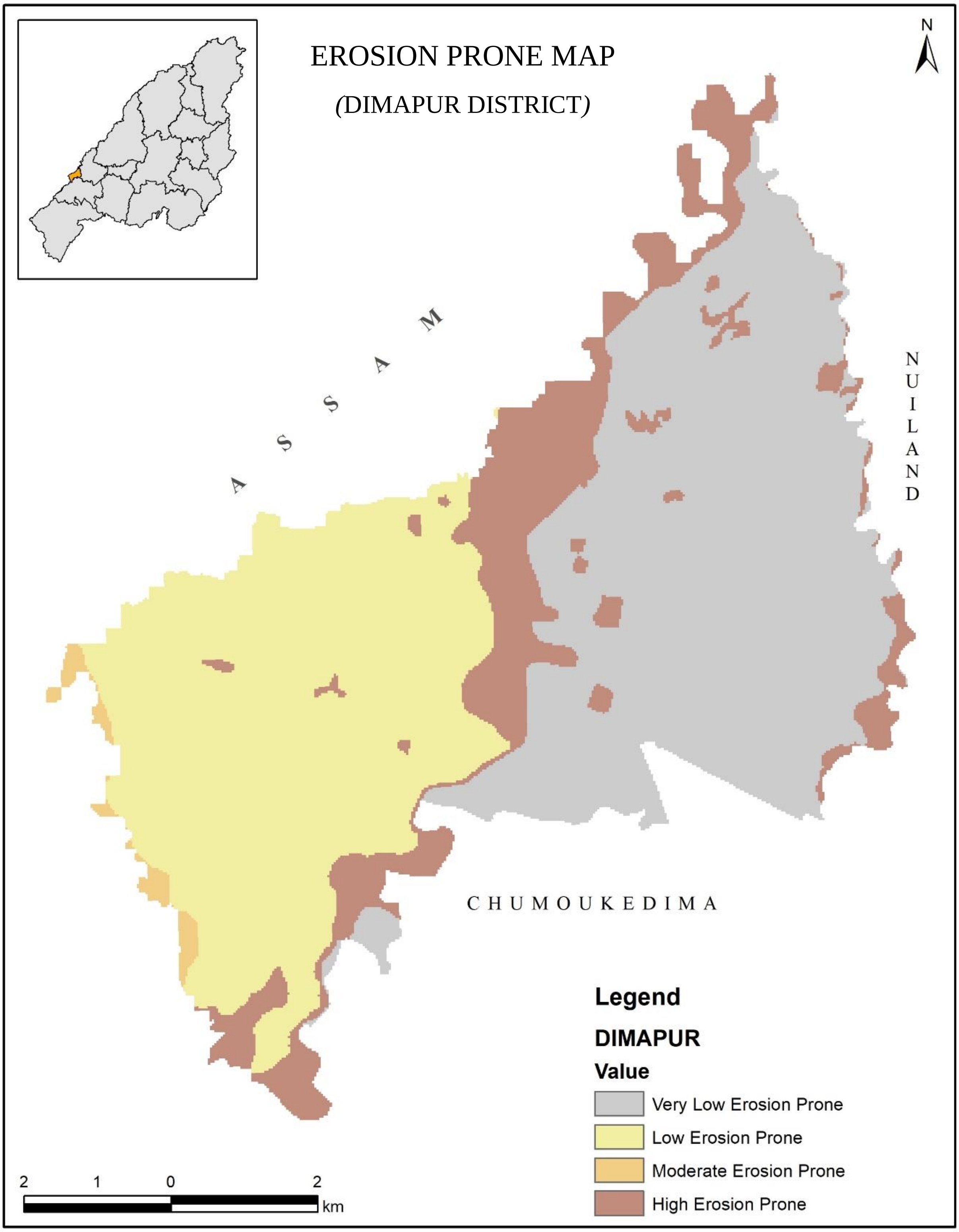
EROSION PRONE MAP
(DIMAPUR DISTRICT)
N
A S S A M
N U I L A N D
C H U M O U K E D I M A
Legend
DIMAPUR
Value
Very Low Erosion Prone
Low Erosion Prone
Moderate Erosion Prone
High Erosion Prone
2 1 0 2
km

Fig. 3b.

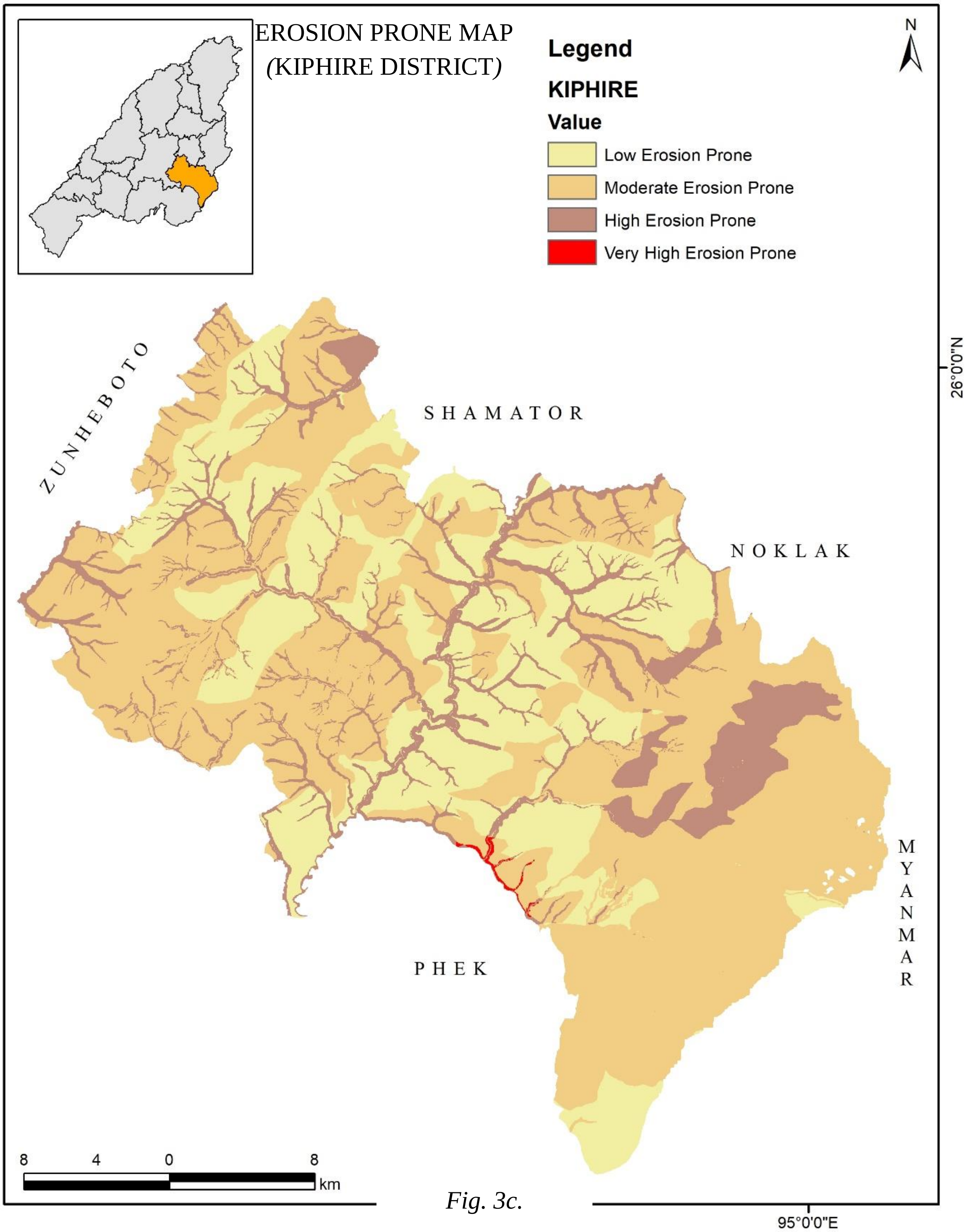
EROSION PRONE MAP
(KIPHIRE DISTRICT)
Legend
KIPHIRE
Value
Low Erosion Prone
Moderate Erosion Prone
High Erosion Prone
Very High Erosion Prone
N
ZUNHEBOTO
SHAMATOR
NOKLAK
MYANMAR
PHEK
26°0'0"N
95°0'0"E
8 4 0 8
km

Fig. 3c.

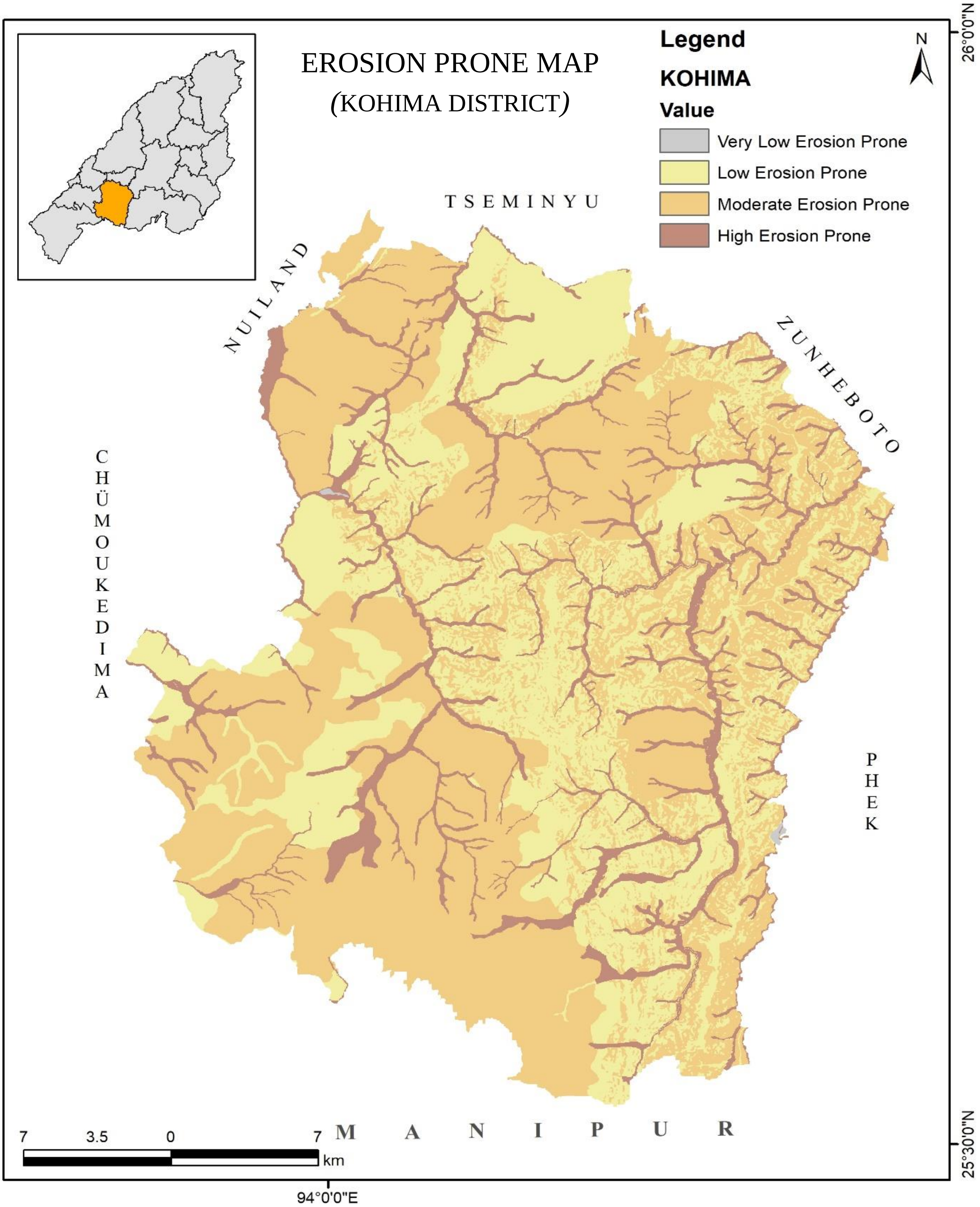
EROSION PRONE MAP
(KOHIMA DISTRICT)
Legend
KOHIMA
Value
Very Low Erosion Prone
Low Erosion Prone
Moderate Erosion Prone
High Erosion Prone
N
26°0'0"N
25°30'0"N
94°0'0"E
TSEMINYU
NUILAND
ZUNHEBOTO
CHÜMOUKEDIMA
PHEK
MANIPUR
7
3.5
0
7
km

Fig. 3d.

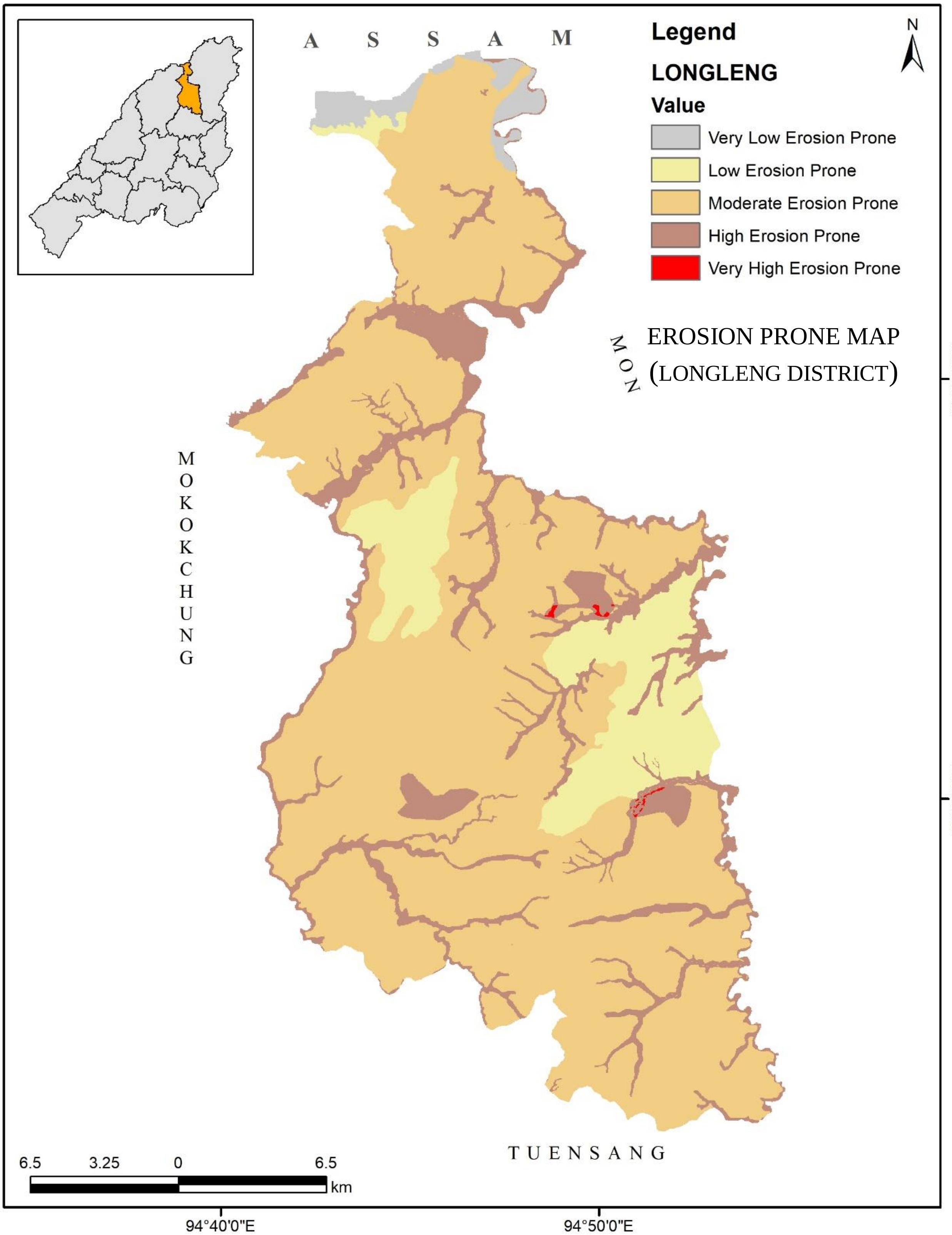
A S S A M
Legend
LONGLENG
Value
Very Low Erosion Prone
Low Erosion Prone
Moderate Erosion Prone
High Erosion Prone
Very High Erosion Prone
N
EROSION PRONE MAP
(LONGLENG DISTRICT)
MON
MOKOKCHUNG
TUENSANG
6.5 3.25 0 6.5
km
26°40'0"N
26°30'0"N
94°40'0"E
94°50'0"E

Fig. 3e.

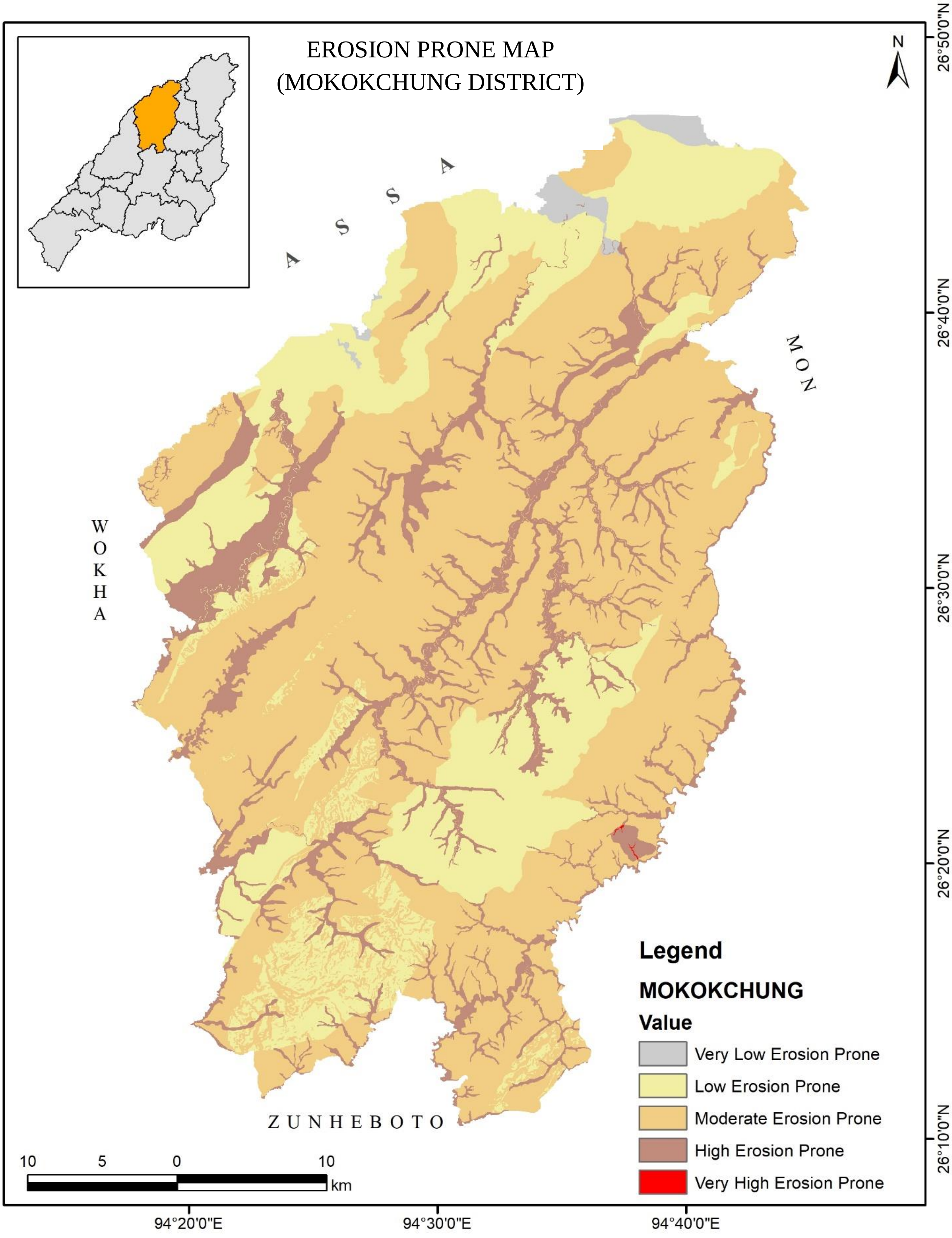
EROSION PRONE MAP
(MOKOKCHUNG DISTRICT)
N
A S S A
M O N
W O K H A
Z U N H E B O T O
Legend
MOKOKCHUNG
Value
Very Low Erosion Prone
Low Erosion Prone
Moderate Erosion Prone
High Erosion Prone
Very High Erosion Prone
10 5 0 10
km
26°50'0"N
26°40'0"N
26°30'0"N
26°20'0"N
26°10'0"N
94°20'0"E
94°30'0"E
94°40'0"E

Fig. 3f.

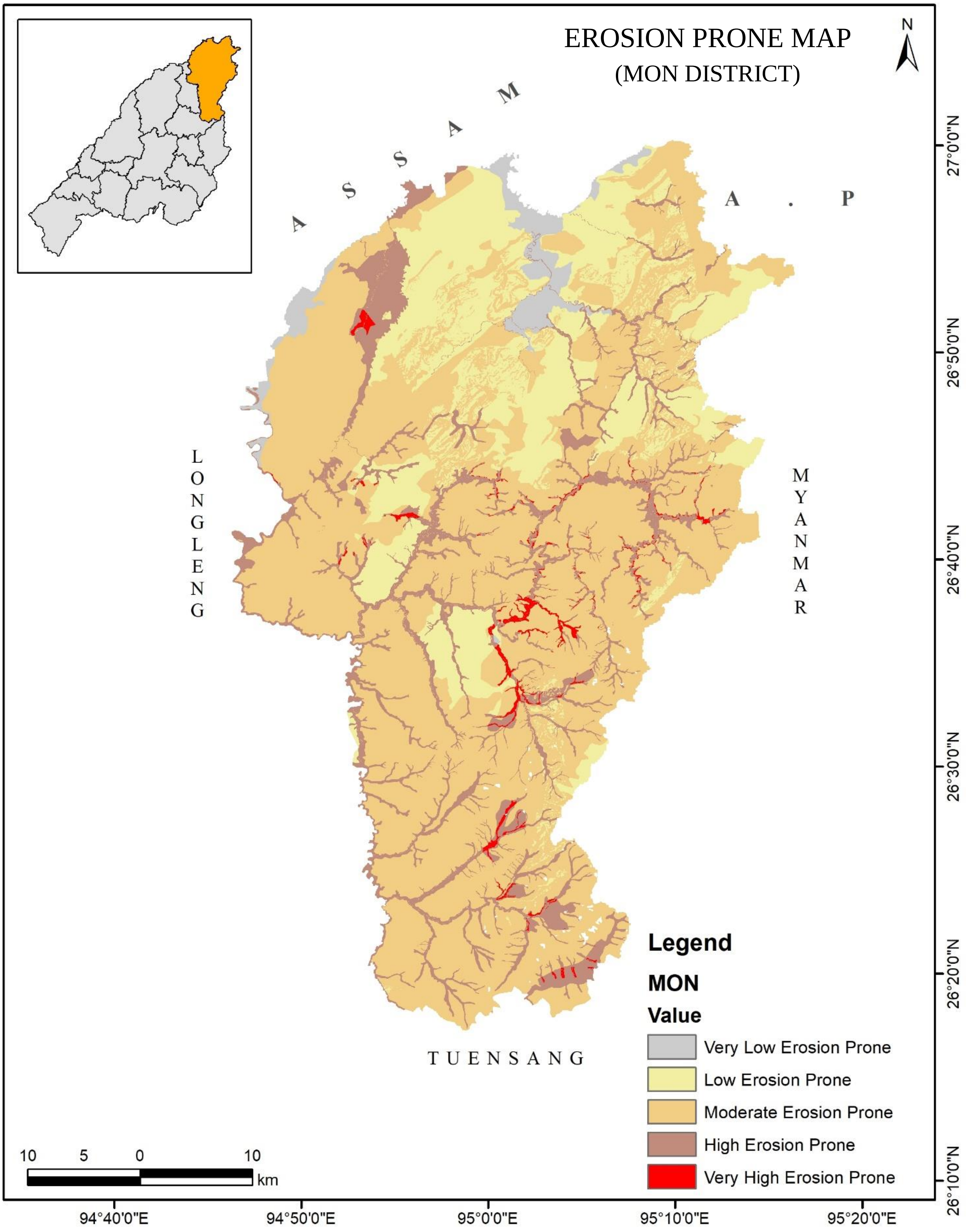
EROSION PRONE MAP
(MON DISTRICT)
N
A S S A M
A . P
L O N G L E N G
M Y A N M A R
T U E N S A N G
Legend
MON
Value
Very Low Erosion Prone
Low Erosion Prone
Moderate Erosion Prone
High Erosion Prone
Very High Erosion Prone
10 5 0 10
km
94°40'0"E
94°50'0"E
95°0'0"E
95°10'0"E
95°20'0"E
27°0'0"N
26°50'0"N
26°40'0"N
26°30'0"N
26°20'0"N
26°10'0"N

Fig. 3g.

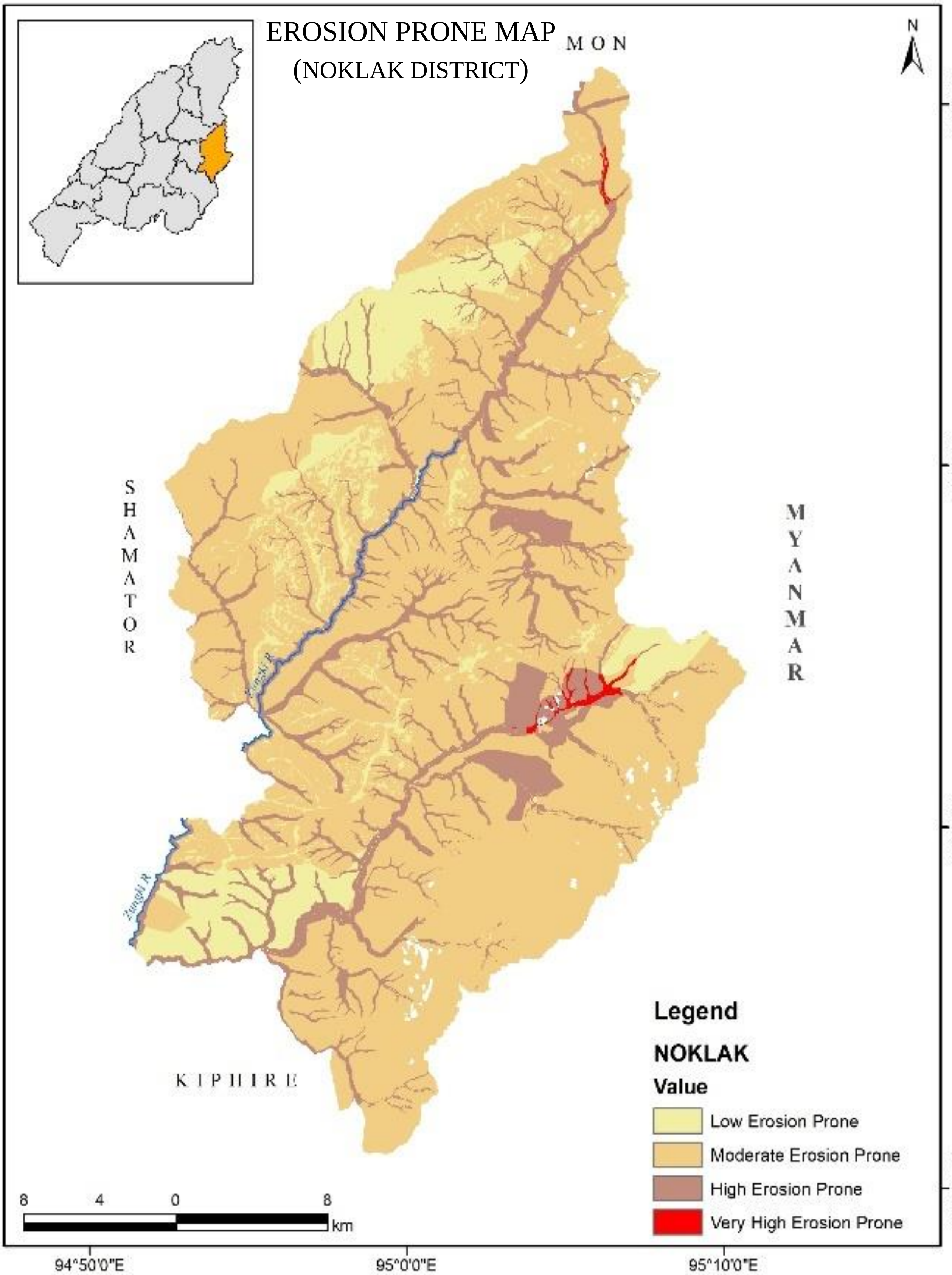
EROSION PRONE MAP
(NOKLAK DISTRICT)
MON
SHAMATOR
MYANMAR
KIPHIRE
Zungki R
Legend
NOKLAK
Value
Low Erosion Prone
Moderate Erosion Prone
High Erosion Prone
Very High Erosion Prone
8 4 0 8
km
94°50'0"E
95°0'0"E
95°10'0"E
26°20'0"N
26°10'0"N
26°0'0"N
25°50'0"N
N

Fig. 3h.

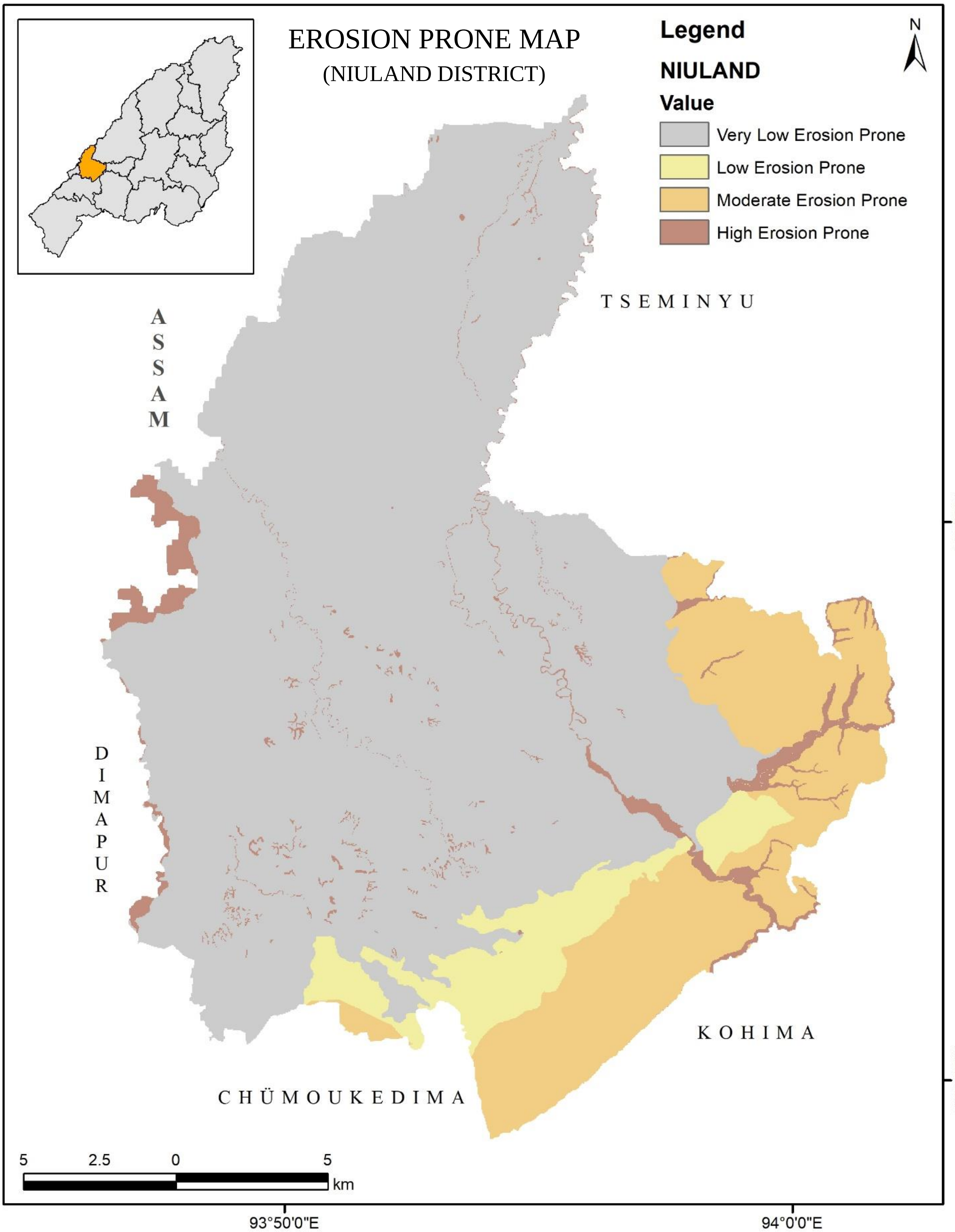
EROSION PRONE MAP
(NIULAND DISTRICT)
Legend
NIULAND
Value
Very Low Erosion Prone
Low Erosion Prone
Moderate Erosion Prone
High Erosion Prone
N
TSEMINYU
ASSAM
DIMAPUR
KOHIMA
CHÜMOUKEDIMA
26°0'0"N
25°50'0"N
93°50'0"E
94°0'0"E
5
2.5
0
5
km

Fig. 3i

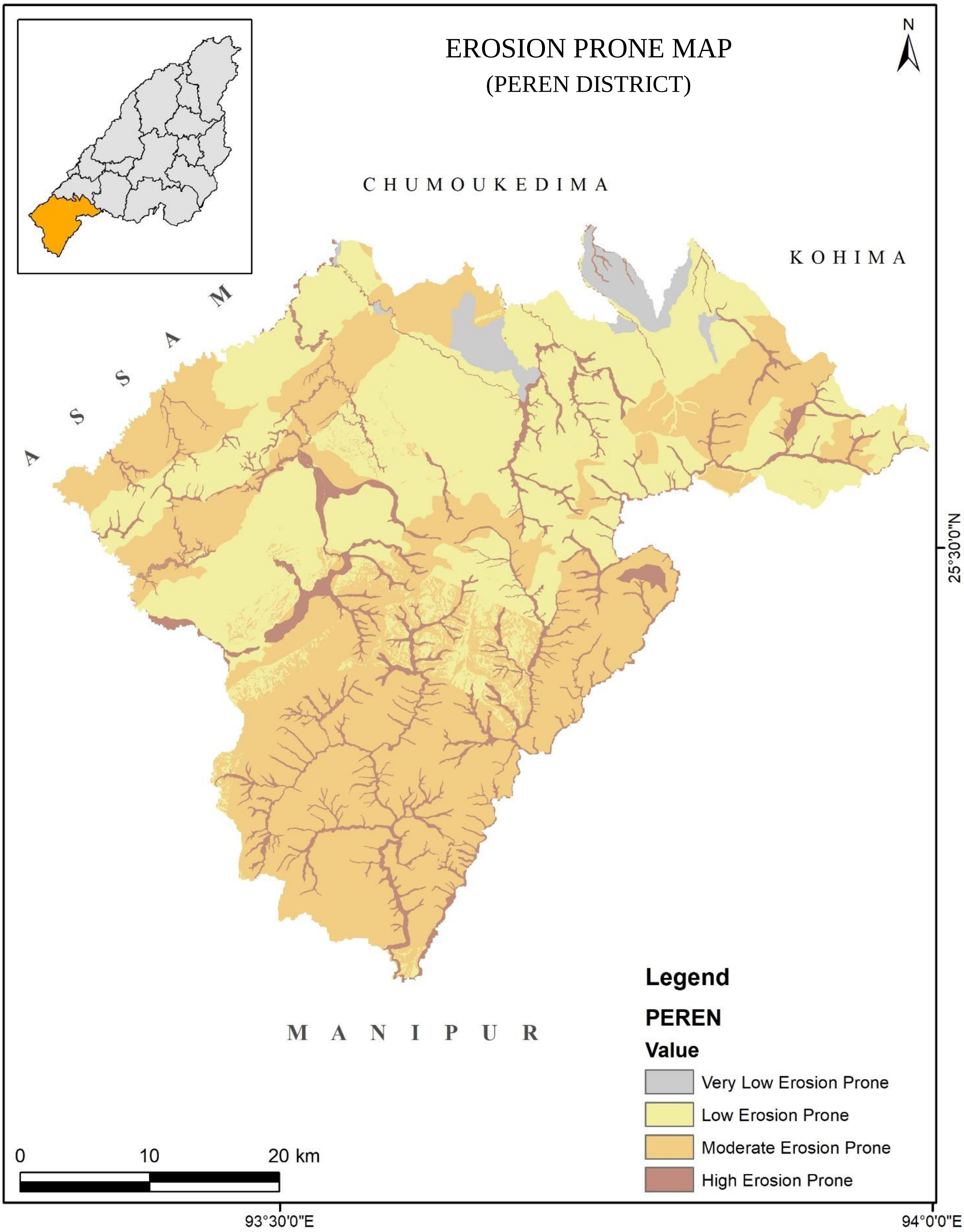
EROSION PRONE MAP
(PEREN DISTRICT)
N
CHUMOUKEDIMA
KOHIMA
ASSAM
MANIPUR
25°30'0"N
93°30'0"E
94°0'0"E
0
10
20 km
Legend
PEREN
Value
Very Low Erosion Prone
Low Erosion Prone
Moderate Erosion Prone
High Erosion Prone

Fig. 3j.

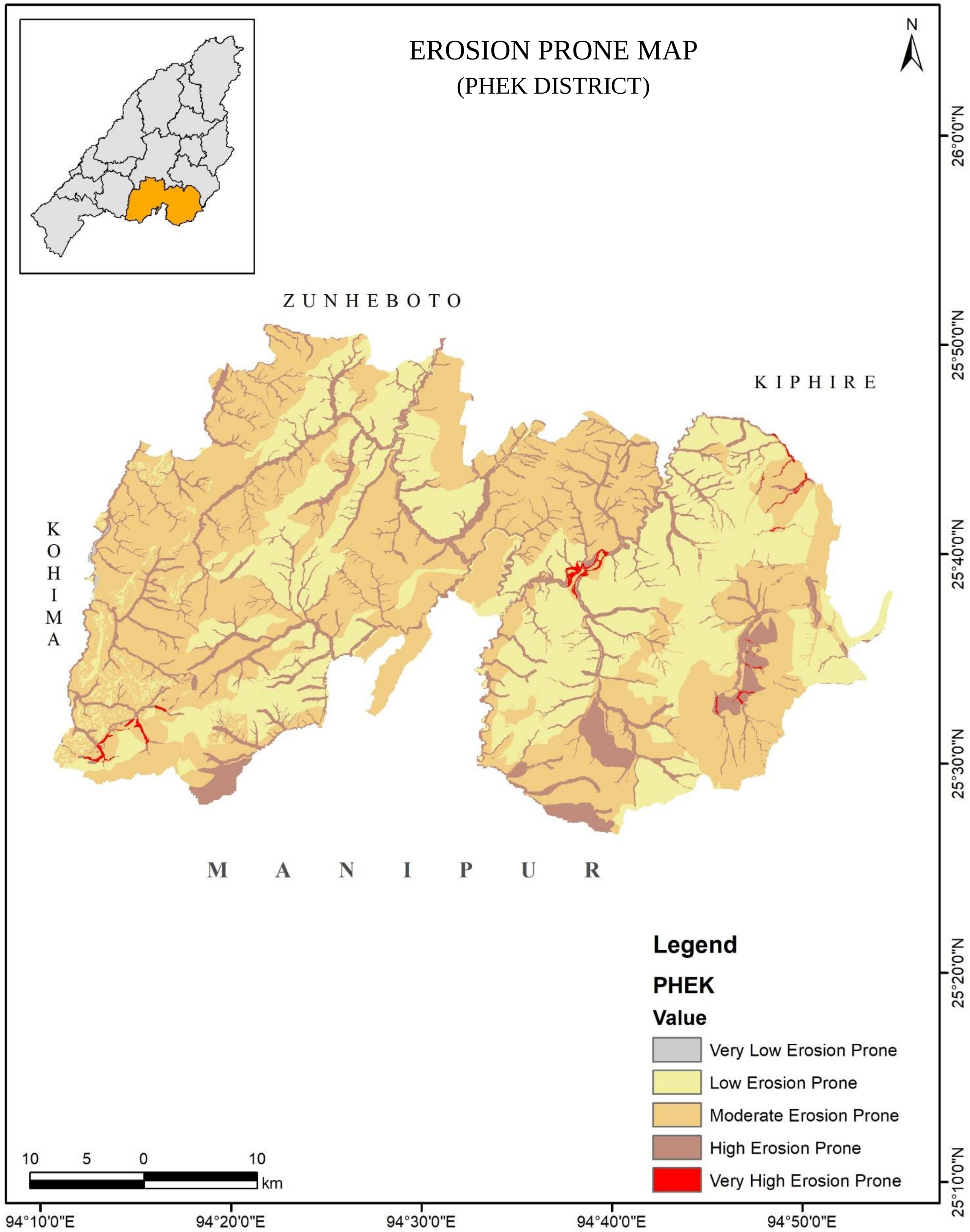
EROSION PRONE MAP
(PHEK DISTRICT)
N
ZUNHEBOTO
KIPHIRE
KOHIMA
MANIPUR
Legend
PHEK
Value
Very Low Erosion Prone
Low Erosion Prone
Moderate Erosion Prone
High Erosion Prone
Very High Erosion Prone
10 5 0 10
km
94°10'0"E
94°20'0"E
94°30'0"E
94°40'0"E
94°50'0"E
26°0'0"N
25°50'0"N
25°40'0"N
25°30'0"N
25°20'0"N
25°10'0"N

Fig. 3k.

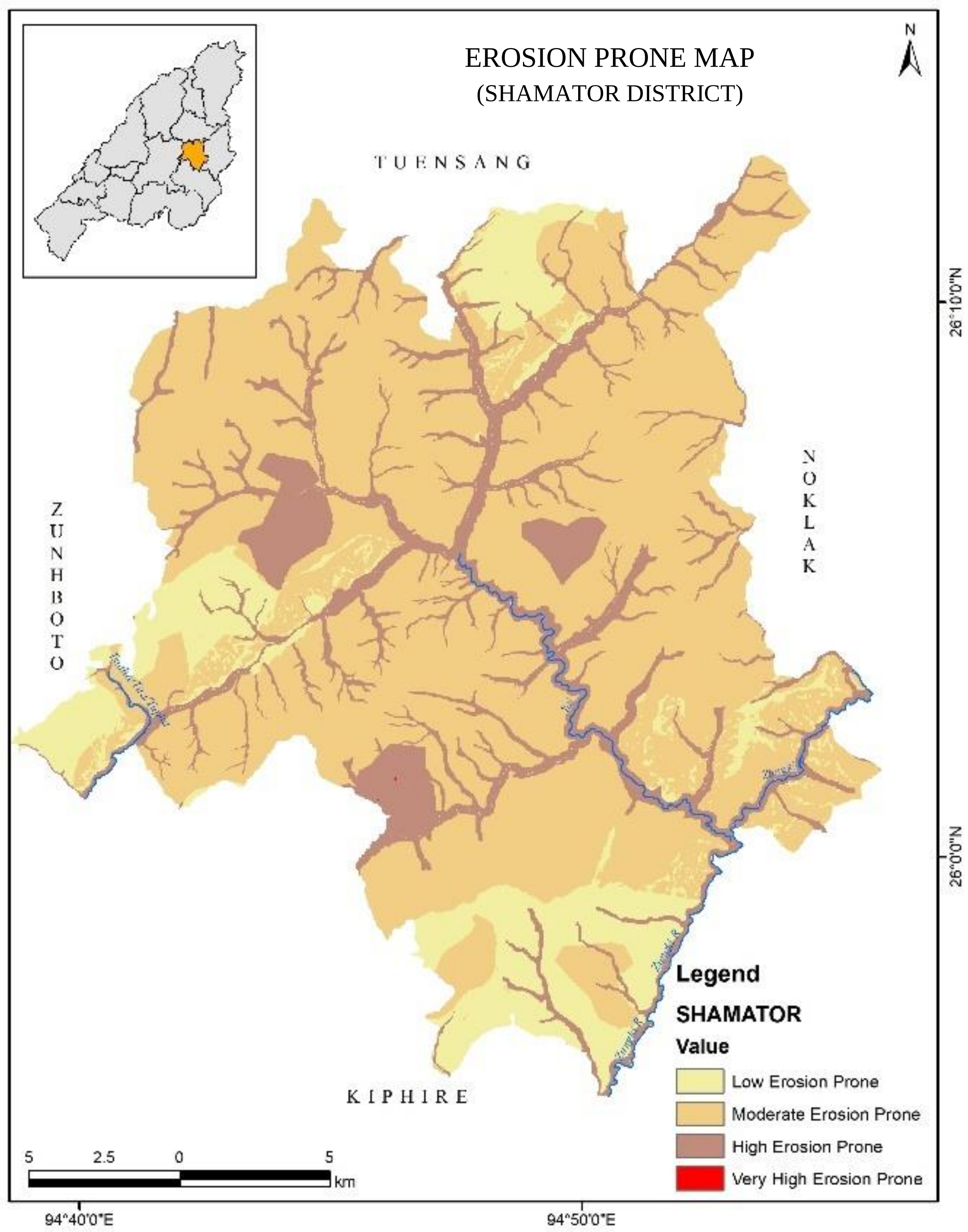
EROSION PRONE MAP
(SHAMATOR DISTRICT)
TUENSANG
NOKLAK
ZUNHBOTO
KIPHIRE
26°10'0"N
26°0'0"N
94°40'0"E
94°50'0"E
Legend
SHAMATOR
Value
Low Erosion Prone
Moderate Erosion Prone
High Erosion Prone
Very High Erosion Prone
5 2.5 0 5
km
N

Fig. 3l.

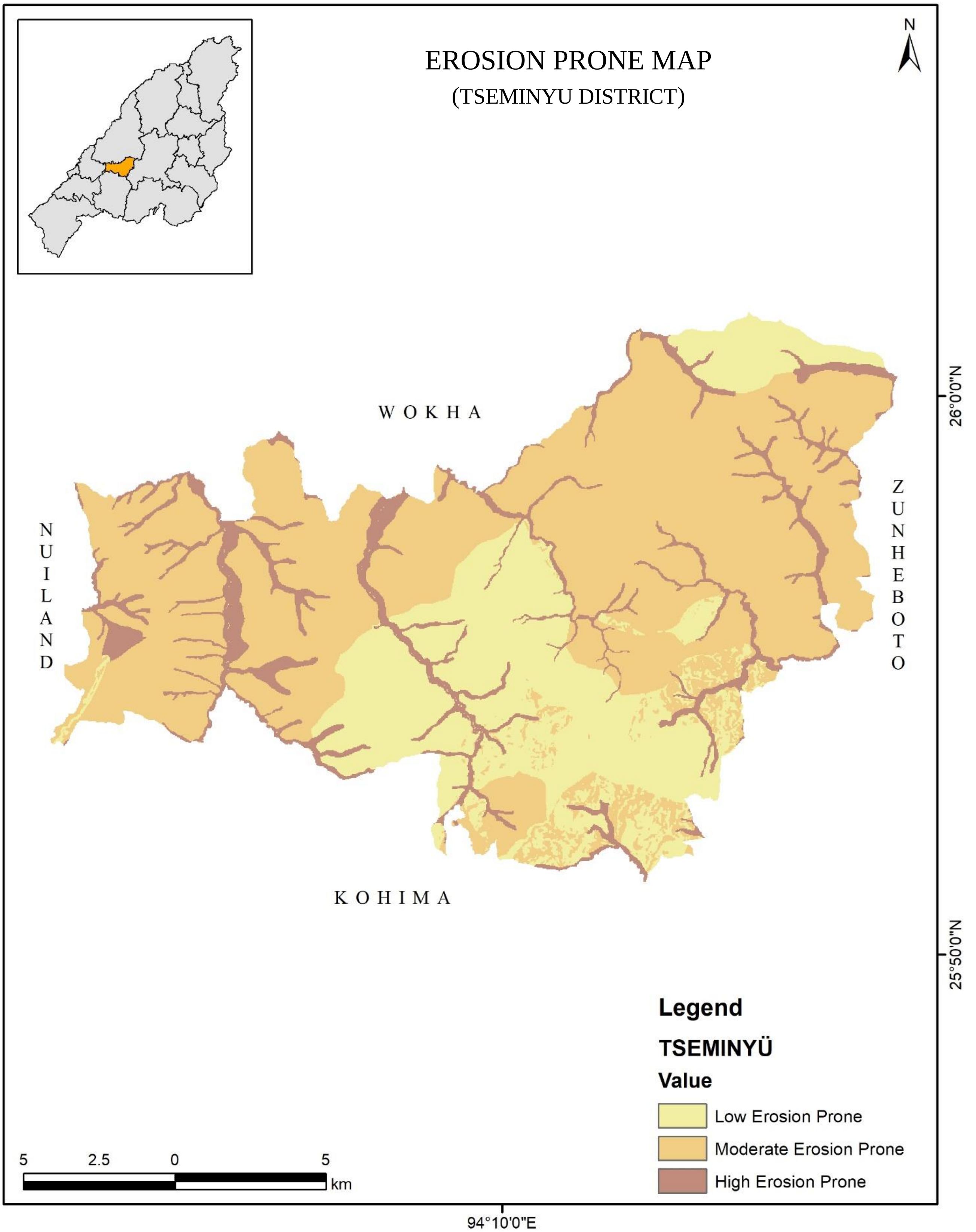
EROSION PRONE MAP
(TSEMINYU DISTRICT)
N
WOKHA
NUILAND
ZUNHEBOTO
KOHIMA
26°0'0"N
25°50'0"N
94°10'0"E
Legend
TSEMINYÜ
Value
Low Erosion Prone
Moderate Erosion Prone
High Erosion Prone
5
2.5
0
5
km

Fig. 3m.

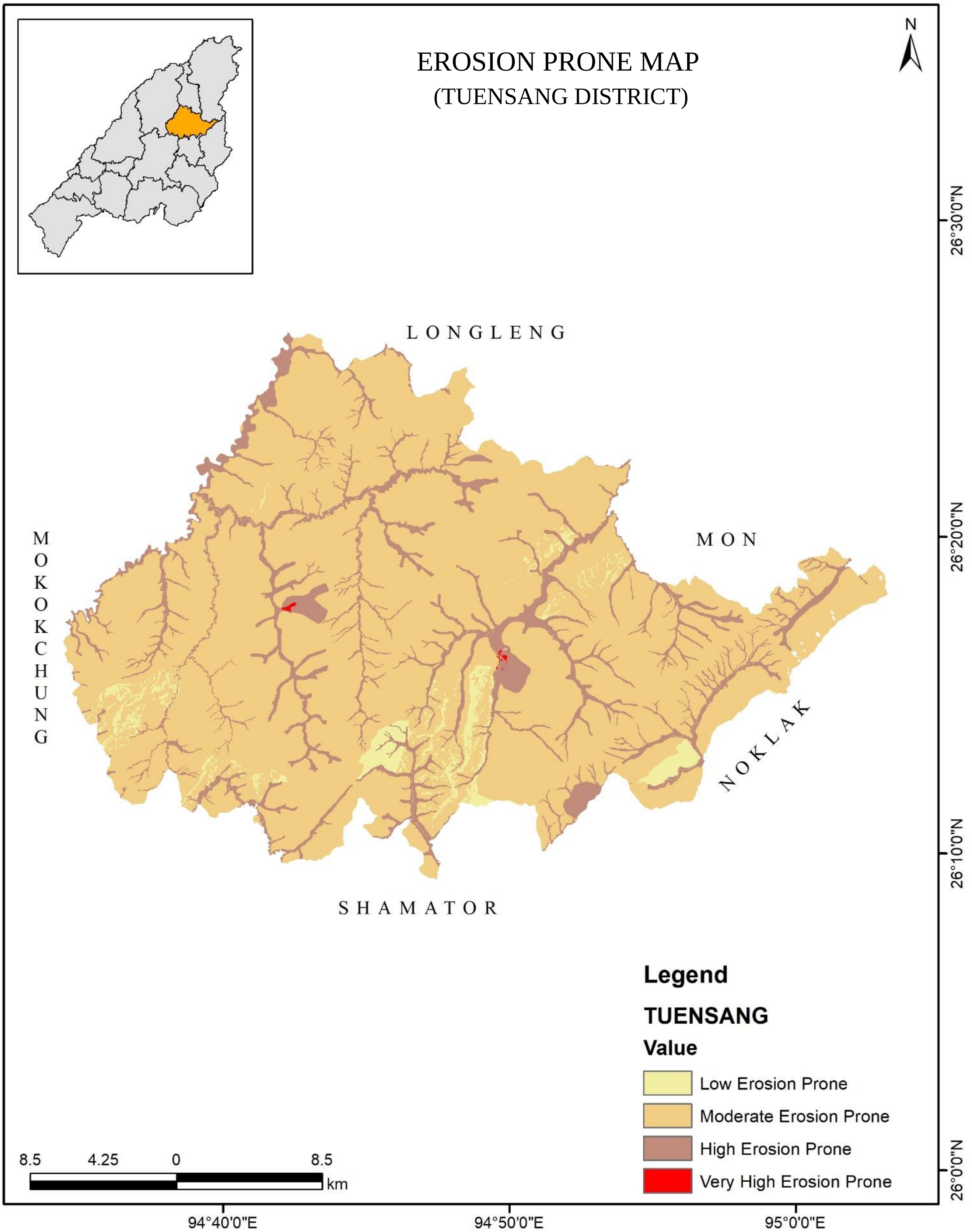
EROSION PRONE MAP
(TUENSANG DISTRICT)
N
LONGLENG
MOKOKCHUNG
MON
NOKLAK
SHAMATOR
Legend
TUENSANG
Value
Low Erosion Prone
Moderate Erosion Prone
High Erosion Prone
Very High Erosion Prone
8.5 4.25 0 8.5
km
26°30'0"N
26°20'0"N
26°10'0"N
26°0'0"N
94°40'0"E
94°50'0"E
95°0'0"E

Fig. 3n.

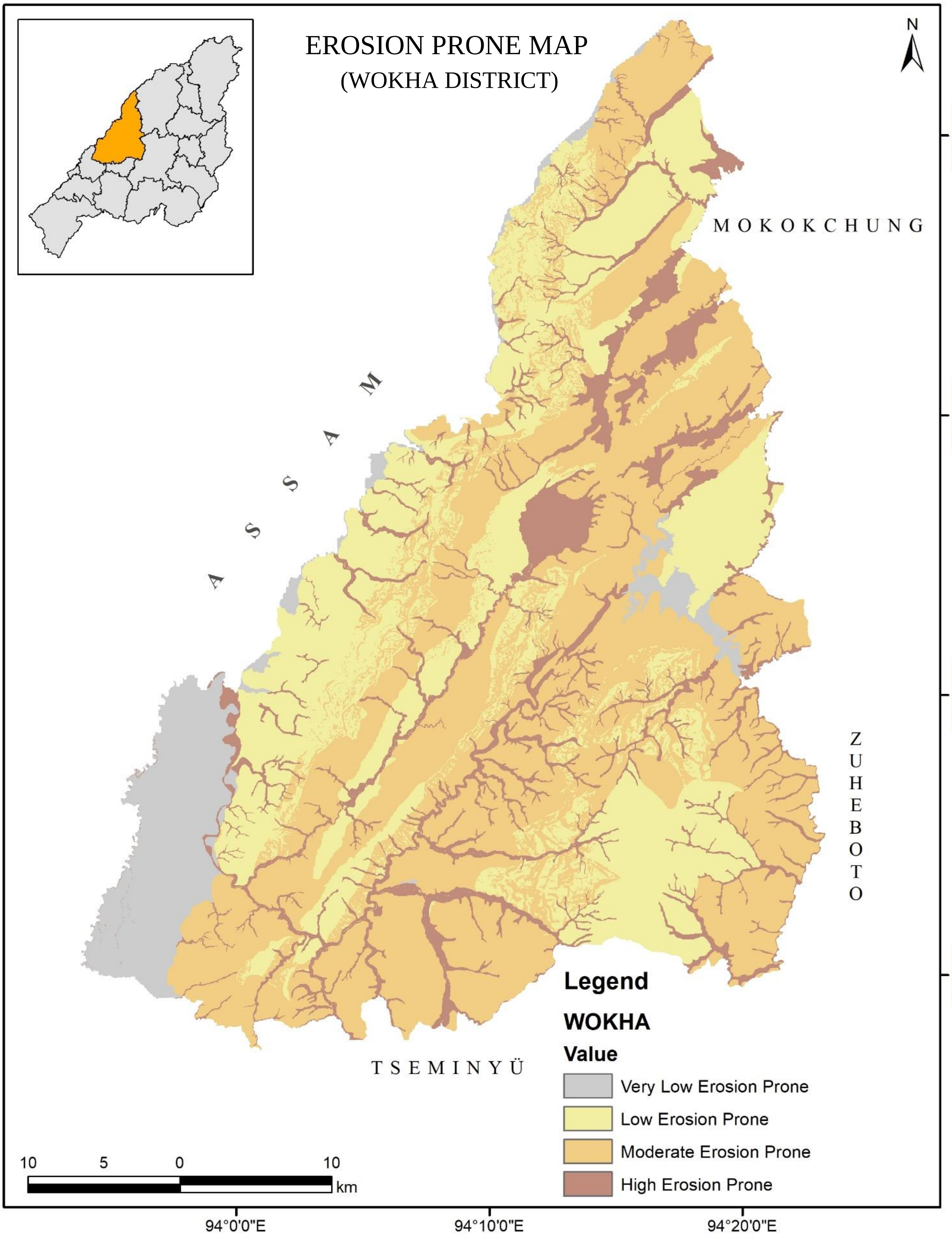
EROSION PRONE MAP
(WOKHA DISTRICT)
N
MOKOKCHUNG
ASSAM
ZUHEBOTO
TSEMINYÜ
Legend
WOKHA
Value
Very Low Erosion Prone
Low Erosion Prone
Moderate Erosion Prone
High Erosion Prone
10 5 0 10
km
26°30'0"N
26°20'0"N
26°10'0"N
26°0'0"N
94°0'0"E
94°10'0"E
94°20'0"E

Fig. 3o.

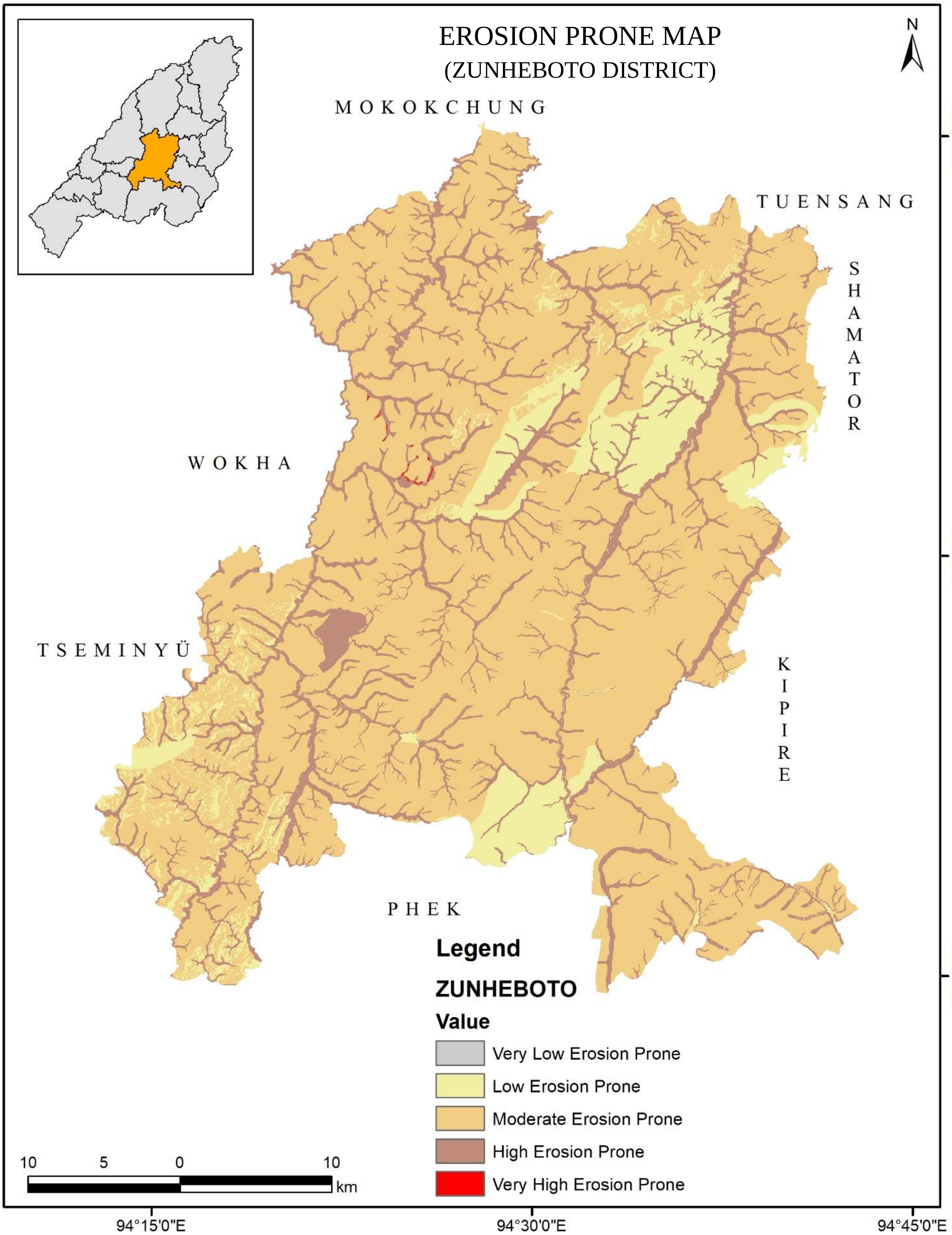
EROSION PRONE MAP
(ZUNHEBOTO DISTRICT)
N
MOKOKCHUNG
TUENSANG
SHAMATOR
WOKHA
TSEMINYÜ
KIPIRE
PHEK
26°15'0"N
26°0'0"N
25°45'0"N
94°15'0"E
94°30'0"E
94°45'0"E
Legend
ZUNHEBOTO
Value
Very Low Erosion Prone
Low Erosion Prone
Moderate Erosion Prone
High Erosion Prone
Very High Erosion Prone
10 5 0 10
km

Fig. 3p.

Table 2a. Curve number area-wise percentage

Curve Number Category	Area (sq.m)	Area (%)
Very Low Run-off	6806499.122	0.04%
Low Run-off	12328649529	70.09%
Moderate Run-off	3549598012	20.18%
High Run-off	1631774893	9.28%
Very High Run-off	73081361.89	0.42%

Table 2b. District-wise curve number in percentage

District	Area (sq.m)	Very Low Run-off	Low Run-off	Moderate Run-off	High Run-off	Very High Run-off
Chümoukedima	698310251.3	0.00%	46.31%	45.70%	7.04%	0.96%
Dimapur	68029213.1	0.00%	8.37%	48.74%	15.65%	27.24%
Kiphire	1021357240	0.00%	78.71%	11.50%	9.60%	0.20%
Kohima	1001241192	0.00%	82.53%	5.96%	10.09%	1.41%
Longleng	584217293.7	0.00%	65.75%	24.16%	9.87%	0.23%
Mokokchung	1902484612	0.00%	68.79%	21.83%	8.88%	0.50%
Mon	2278917169	0.30%	69.17%	17.81%	12.62%	0.11%
Niuland	481440594.1	0.00%	17.91%	75.88%	6.21%	0.00%
Noklak	912203919.2	0.00%	76.03%	14.83%	9.02%	0.11%
Peren	1811690346	0.00%	70.00%	22.12%	7.83%	0.04%
Phek	1963214673	0.00%	82.72%	7.67%	9.40%	0.21%
Shamator	468761467.3	0.00%	64.45%	25.16%	10.27%	0.11%
Tseminyu	289819323.7	0.00%	78.34%	13.45%	7.80%	0.40%
Tuensang	801707784.3	0.00%	71.70%	17.29%	10.57%	0.43%
Wokha	1736069003	0.00%	66.45%	26.25%	7.06%	0.24%
Zunheboto	1548528491	0.00%	74.93%	16.03%	8.83%	0.20%

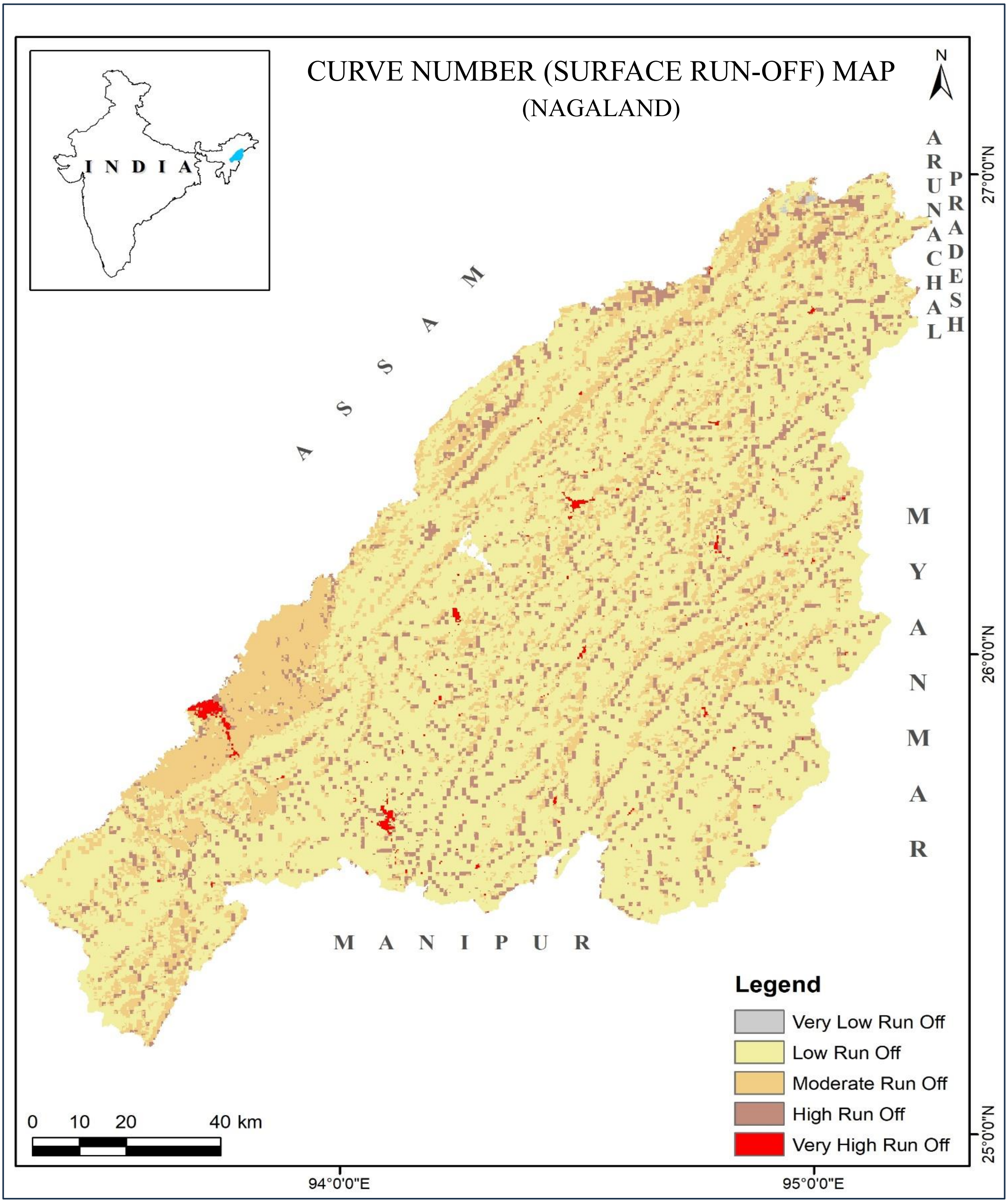
CURVE NUMBER (SURFACE RUN-OFF) MAP
(NAGALAND)
N
INDIA
ASSAM
ARUNACHAL PRADESH
MYANMAR
MANIPUR
27°0'0"N
26°0'0"N
25°0'0"N
94°0'0"E
95°0'0"E
0 10 20 40 km
Legend
Very Low Run Off
Low Run Off
Moderate Run Off
High Run Off
Very High Run Off

Fig. 4.

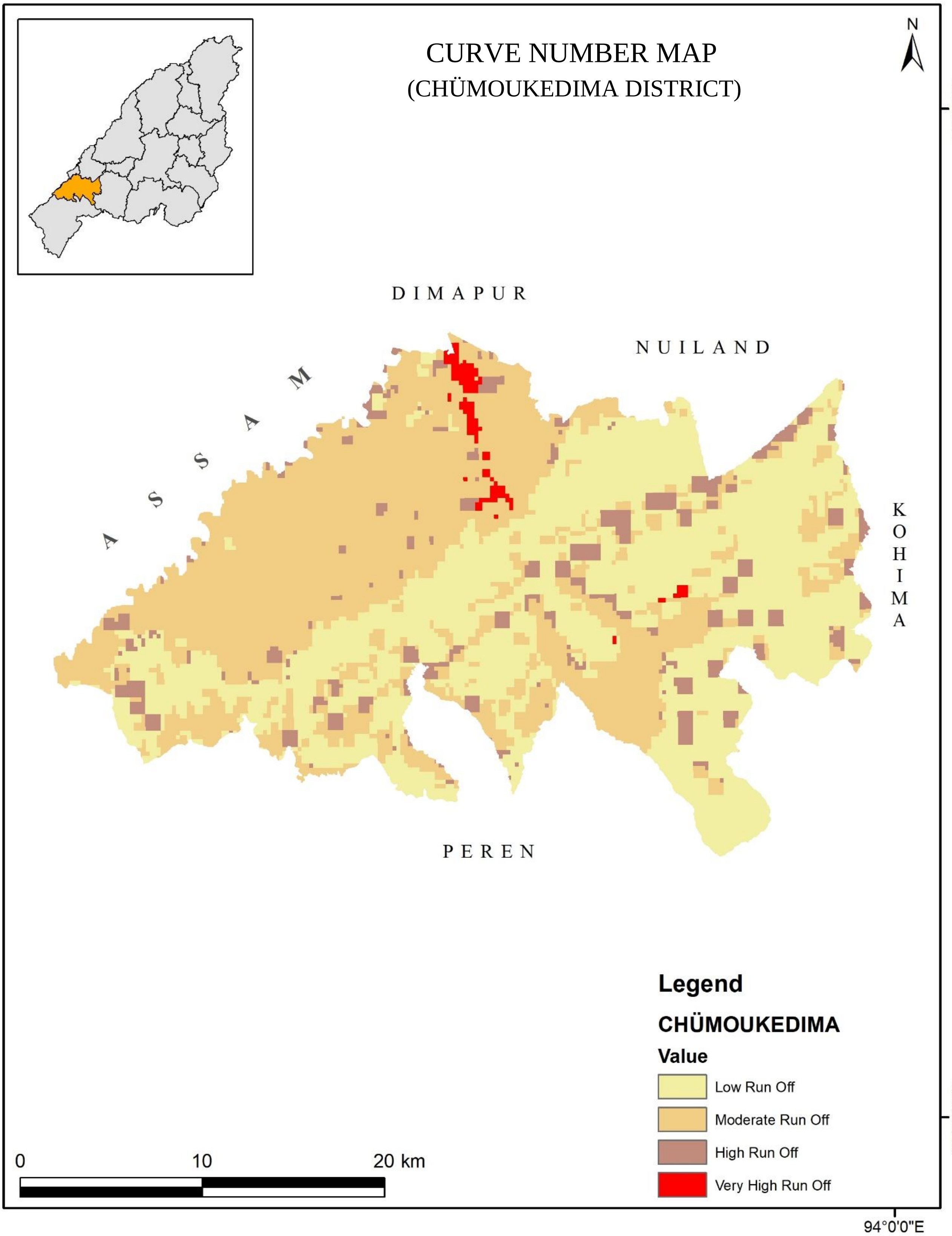
CURVE NUMBER MAP
(CHÜMOUKEDIMA DISTRICT)
N
26°0'0"N
DIMAPUR
NUILAND
ASSAM
KOHIMA
PEREN
Legend
CHÜMOUKEDIMA
Value
Low Run Off
Moderate Run Off
High Run Off
Very High Run Off
0
10
20 km
25°30'0"N
94°0'0"E

Fig. 4a.

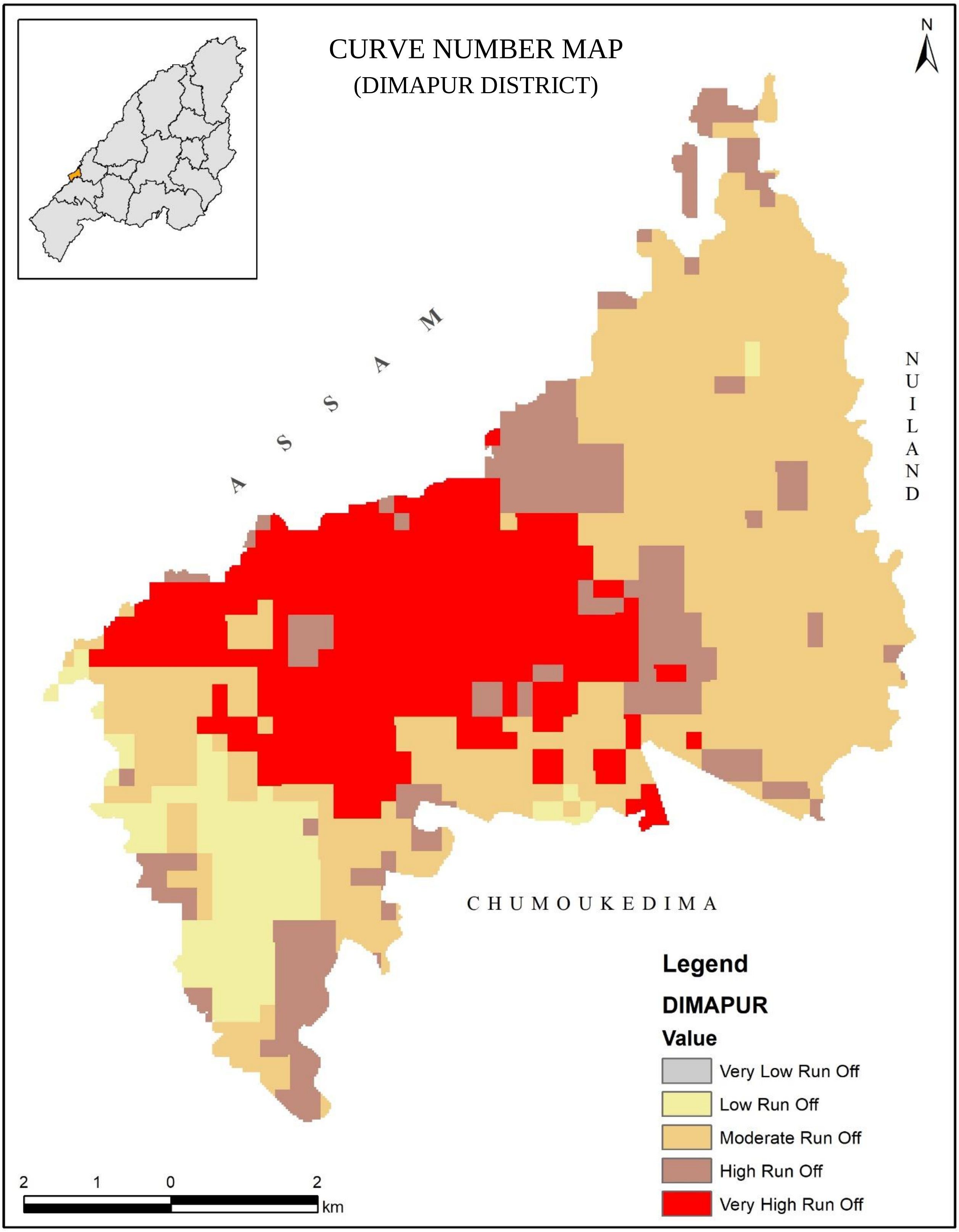
CURVE NUMBER MAP
(DIMAPUR DISTRICT)
N
ASSAM
NUILAND
CHUMOUKEDIMA
Legend
DIMAPUR
Value
Very Low Run Off
Low Run Off
Moderate Run Off
High Run Off
Very High Run Off
2 1 0 2
km

Fig. 4b.

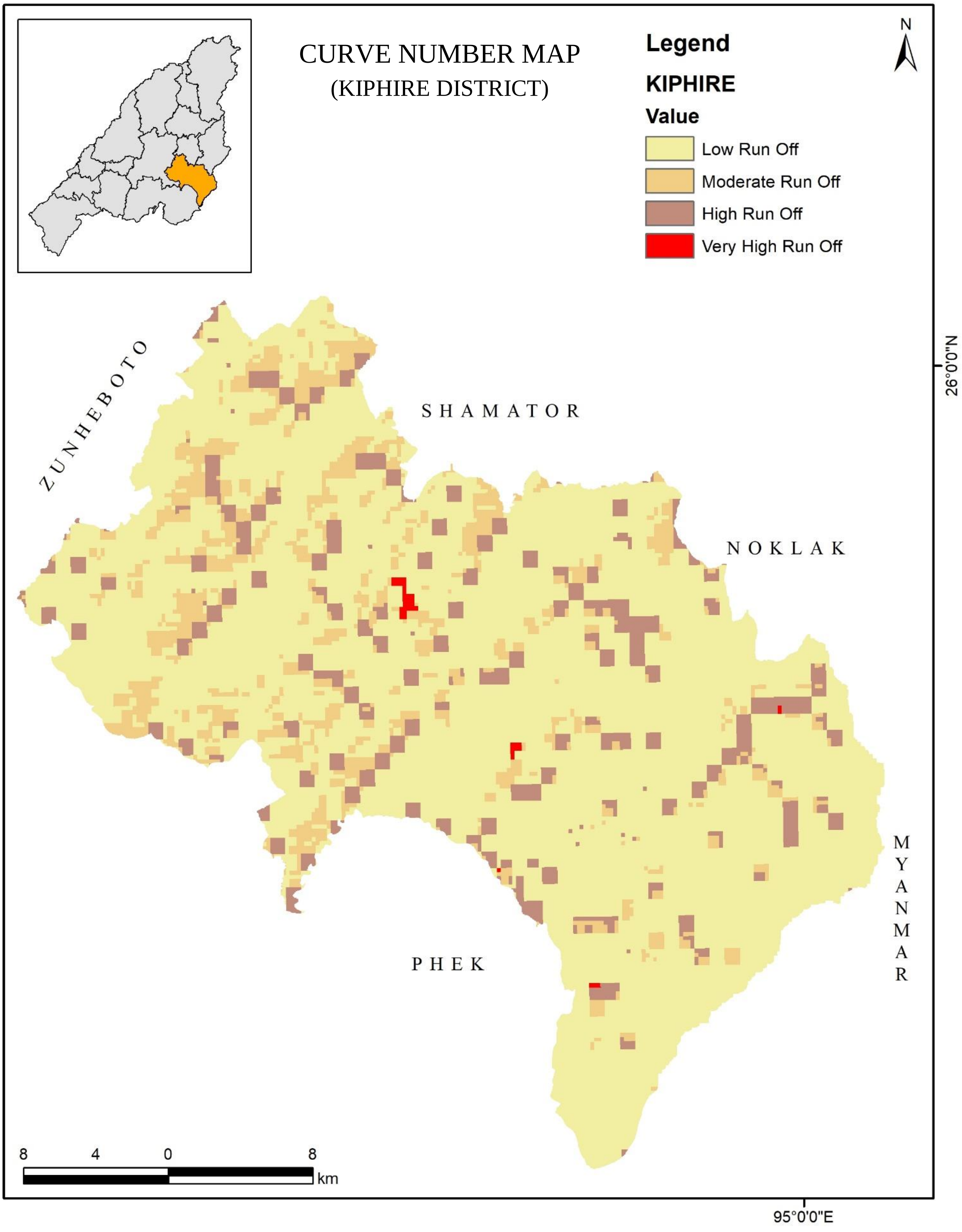
CURVE NUMBER MAP
(KIPHIRE DISTRICT)
Legend
KIPHIRE
Value
Low Run Off
Moderate Run Off
High Run Off
Very High Run Off
N
ZUNHEBOTO
SHAMATOR
NOKLAK
PHEK
MYANMAR
26°0'0"N
8 4 0 8
km
95°0'0"E

Fig. 4c.

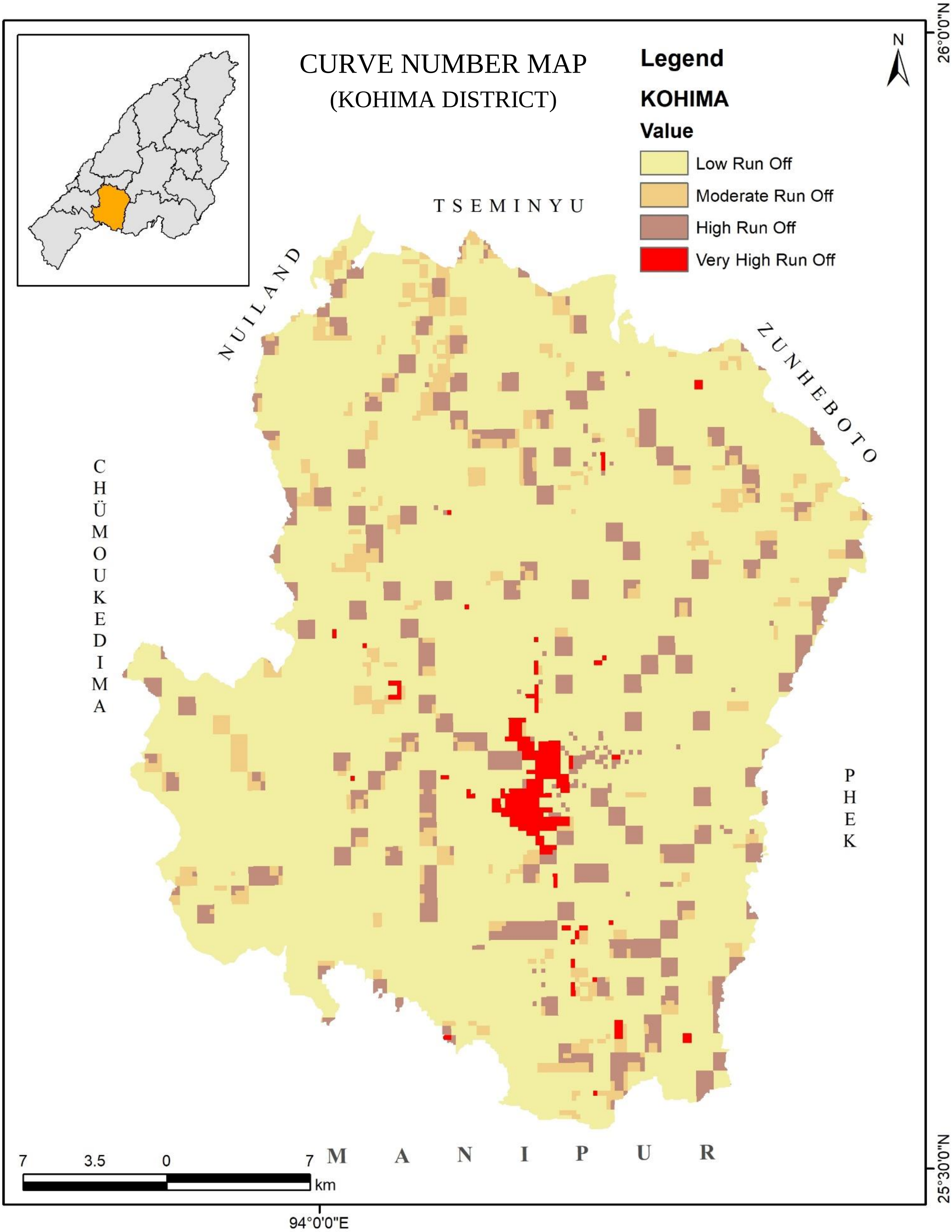
CURVE NUMBER MAP
(KOHIMA DISTRICT)
Legend
KOHIMA
Value
Low Run Off
Moderate Run Off
High Run Off
Very High Run Off
N
26°0'0"N
25°30'0"N
94°0'0"E
TSEMINYU
NUILAND
ZUNHEBOTO
CHÜMOUKEDIMA
PHEK
MANIPUR
7
3.5
0
7
km

Fig. 4d.

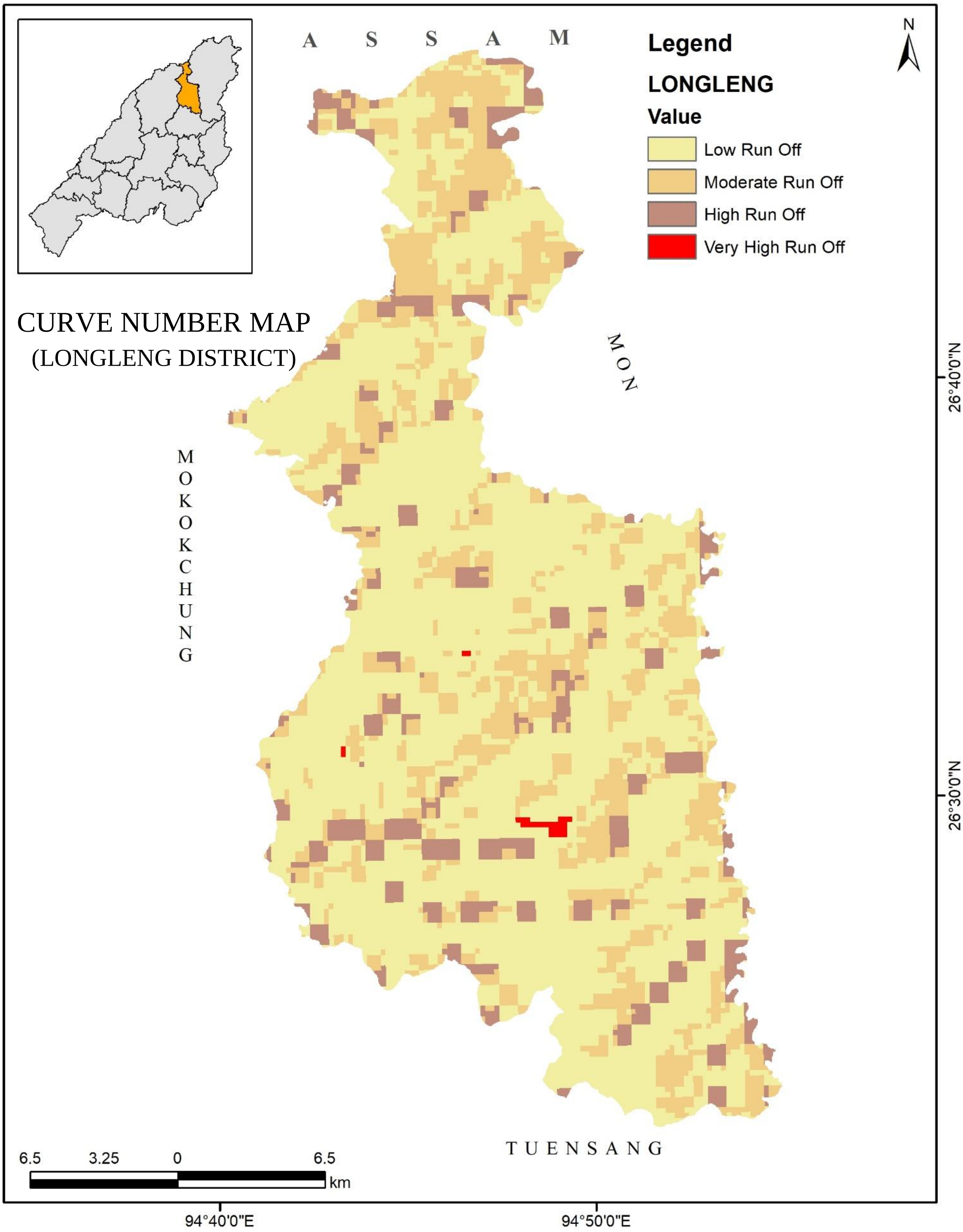
CURVE NUMBER MAP
(LONGLENG DISTRICT)
Legend
LONGLENG
Value
Low Run Off
Moderate Run Off
High Run Off
Very High Run Off
N
A S S A M
MON
MOKOKCHUNG
TUENSANG
6.5 3.25 0 6.5
km
94°40'0"E
94°50'0"E
26°40'0"N
26°30'0"N

Fig. 4e.

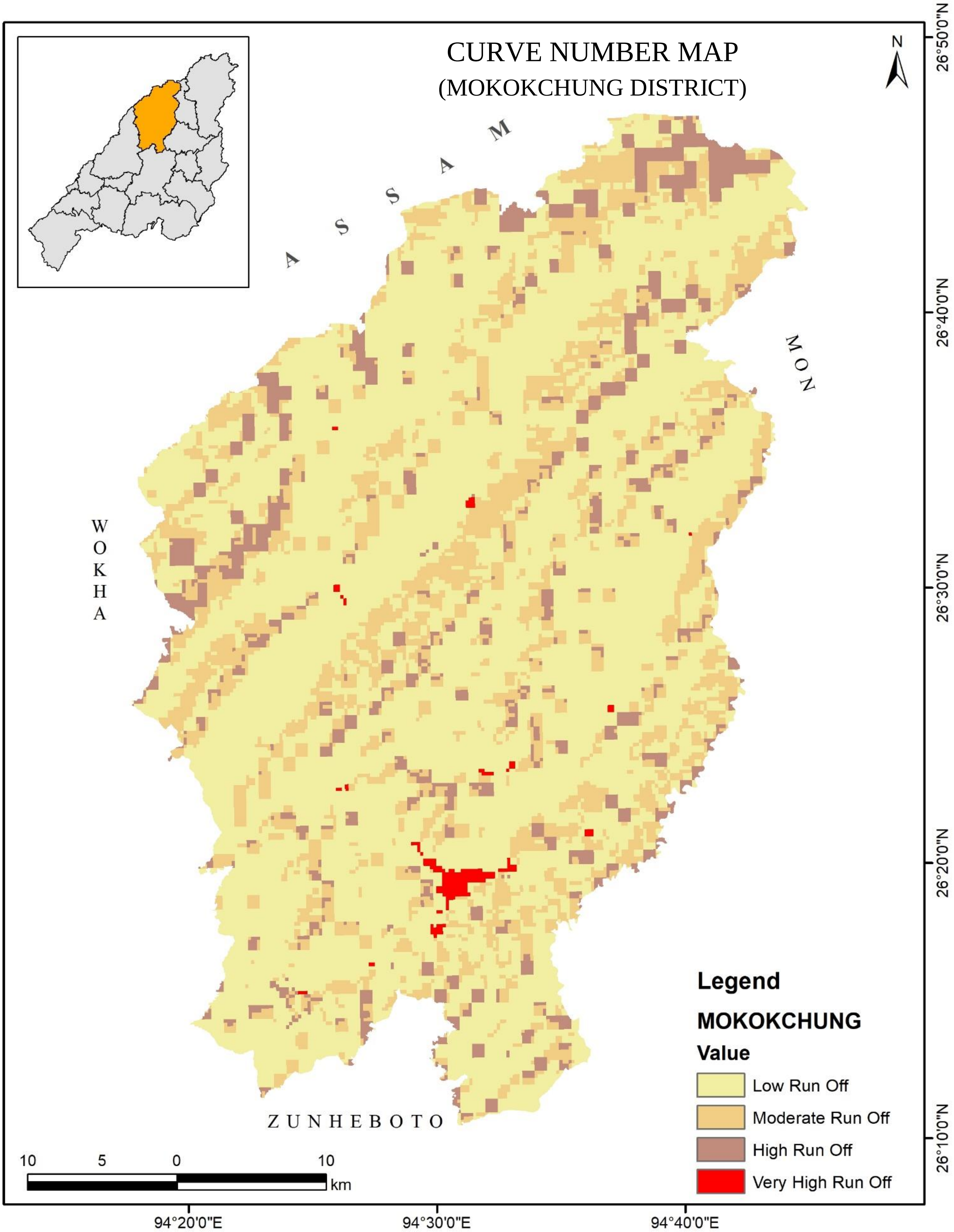
CURVE NUMBER MAP
(MOKOKCHUNG DISTRICT)
N
A S S A M
MON
WOKHA
ZUNHEBOTO
Legend
MOKOKCHUNG
Value
Low Run Off
Moderate Run Off
High Run Off
Very High Run Off
10 5 0 10
km
94°20'0"E
94°30'0"E
94°40'0"E
26°50'0"N
26°40'0"N
26°30'0"N
26°20'0"N
26°10'0"N

Fig. 4f.

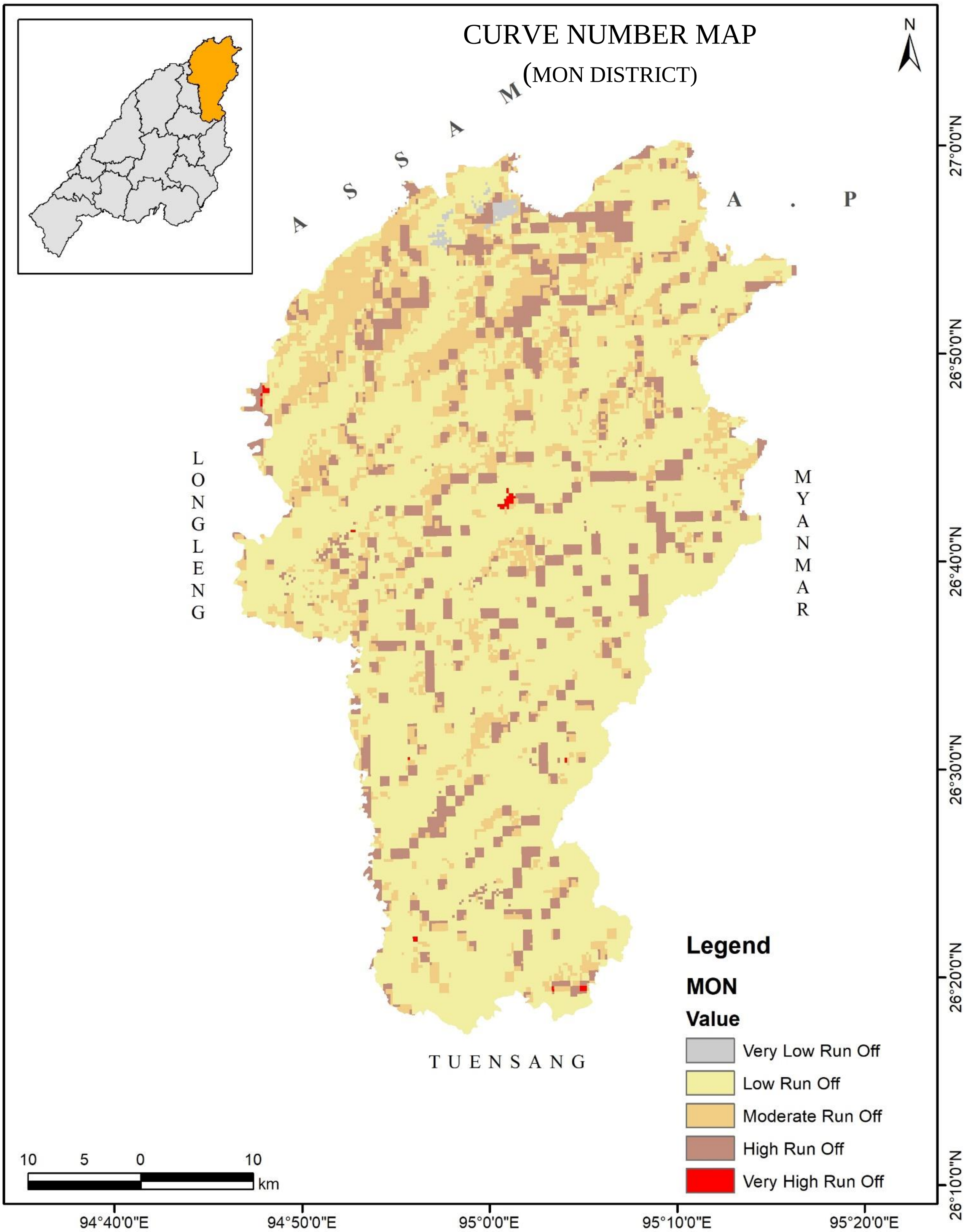
CURVE NUMBER MAP
(MON DISTRICT)
N
A S S A M
A . P
LONGLENG
MYANMAR
TUENSANG
Legend
MON
Value
Very Low Run Off
Low Run Off
Moderate Run Off
High Run Off
Very High Run Off
10 5 0 10
km
27°0'0"N
26°50'0"N
26°40'0"N
26°30'0"N
26°20'0"N
26°10'0"N
94°40'0"E
94°50'0"E
95°0'0"E
95°10'0"E
95°20'0"E

Fig. 4g.

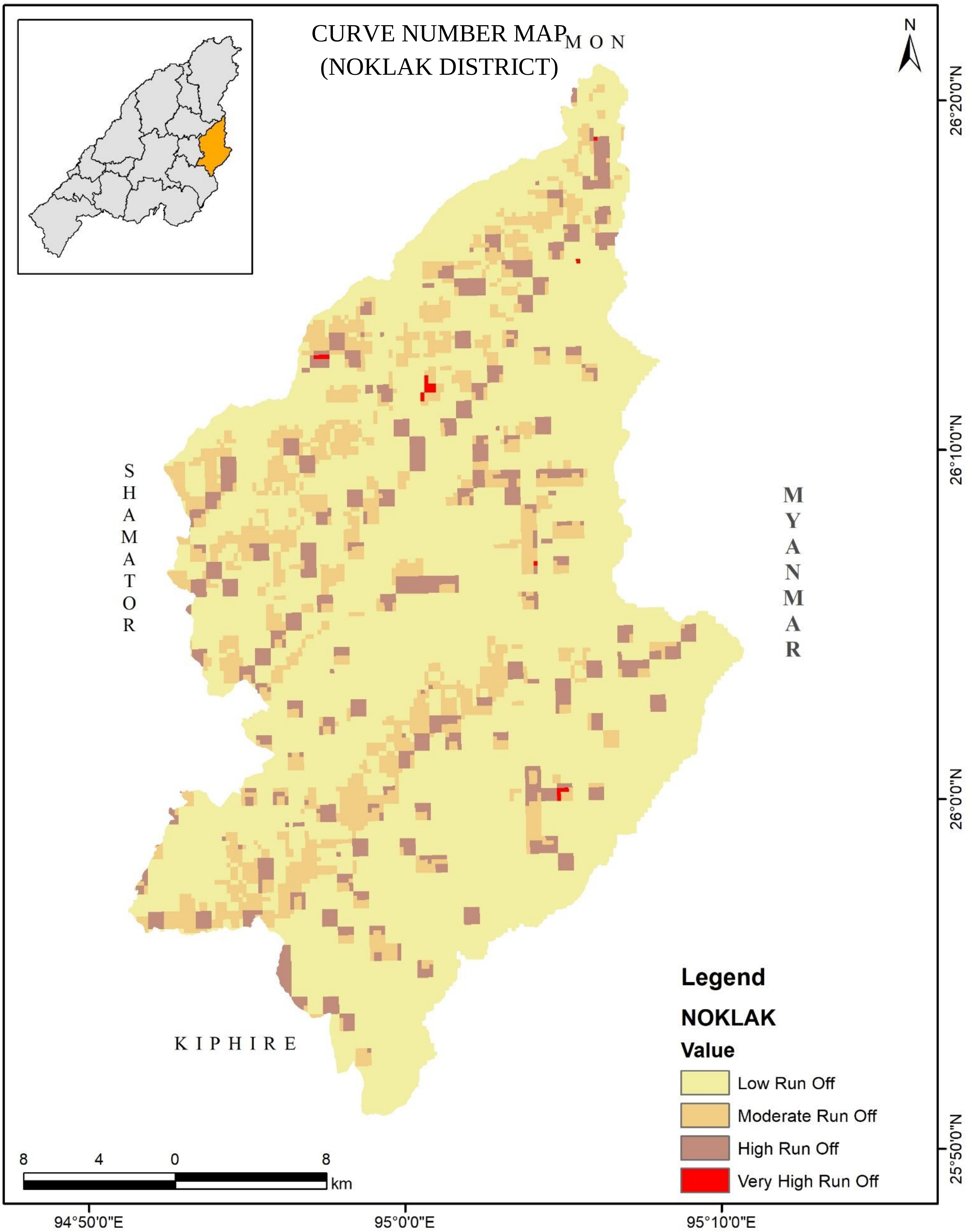
CURVE NUMBER MAP
(NOKLAK DISTRICT)
MON
SHAMATOR
MYANMAR
KIPHIRE
N
26°20'0"N
26°10'0"N
26°0'0"N
25°50'0"N
94°50'0"E
95°0'0"E
95°10'0"E
8 4 0 8
km
Legend
NOKLAK
Value
Low Run Off
Moderate Run Off
High Run Off
Very High Run Off

Fig. 4h.

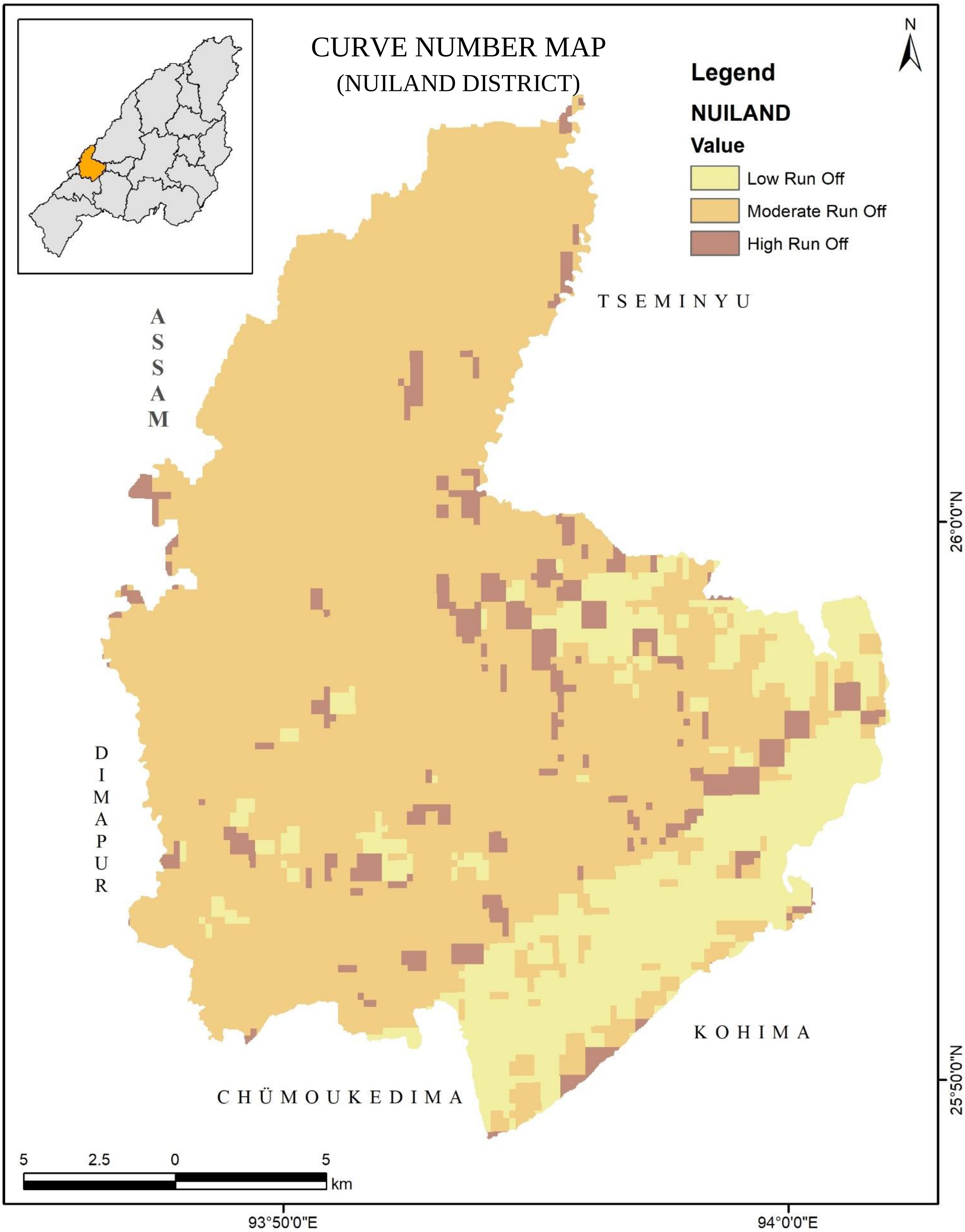
CURVE NUMBER MAP
(NUILAND DISTRICT)
Legend
NUILAND
Value
Low Run Off
Moderate Run Off
High Run Off
N
TSEMINYU
ASSAM
DIMAPUR
KOHIMA
CHÜMOUKEDIMA
26°0'0"N
25°50'0"N
5 2.5 0 5
km
93°50'0"E
94°0'0"E

Fig. 4i.

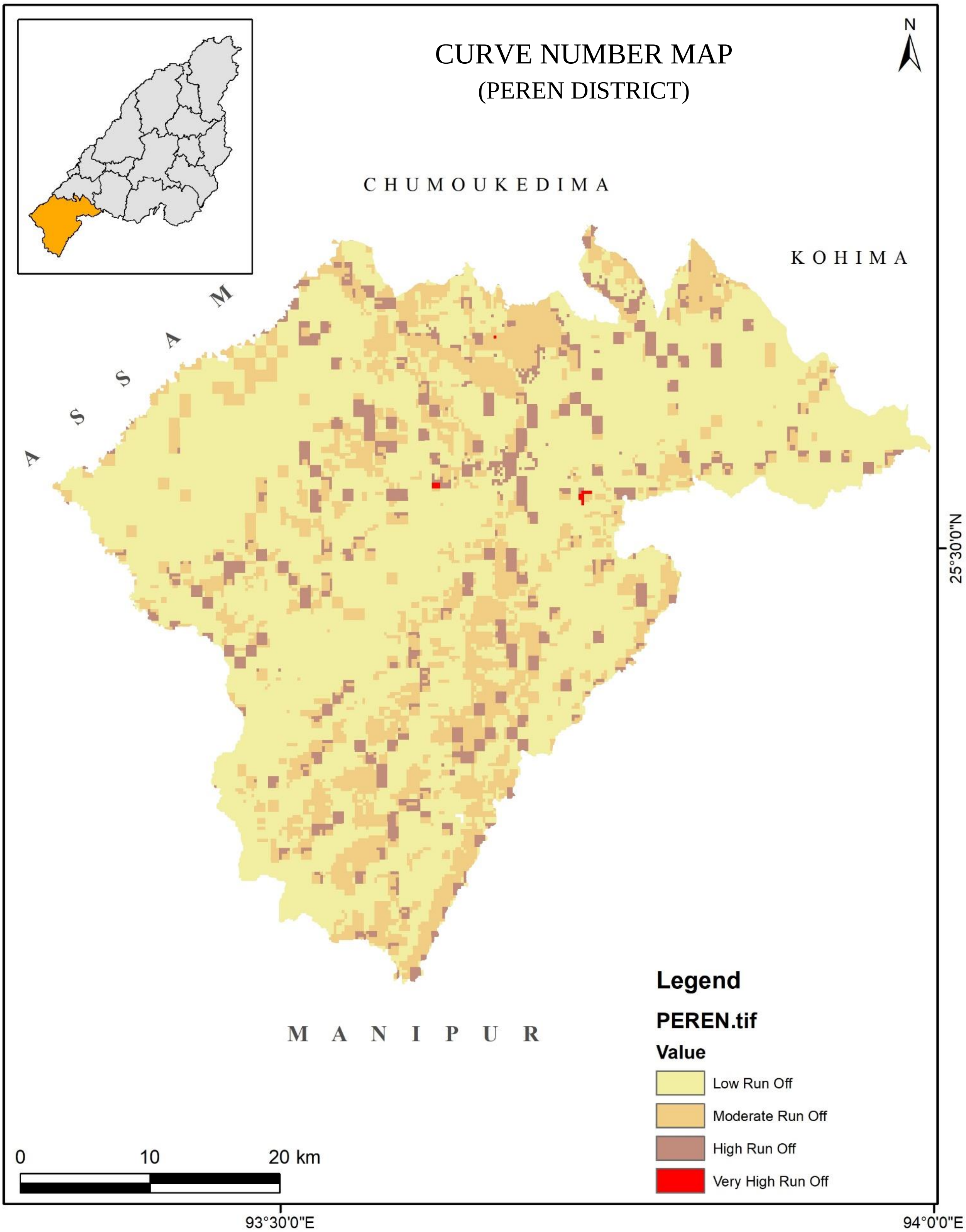
CURVE NUMBER MAP
(PEREN DISTRICT)
N
CHUMOUKEDIMA
KOHIMA
ASSAM
MANIPUR
25°30'0"N
93°30'0"E
94°0'0"E
0
10
20 km
Legend
PEREN.tif
Value
Low Run Off
Moderate Run Off
High Run Off
Very High Run Off

Fig. 4j.

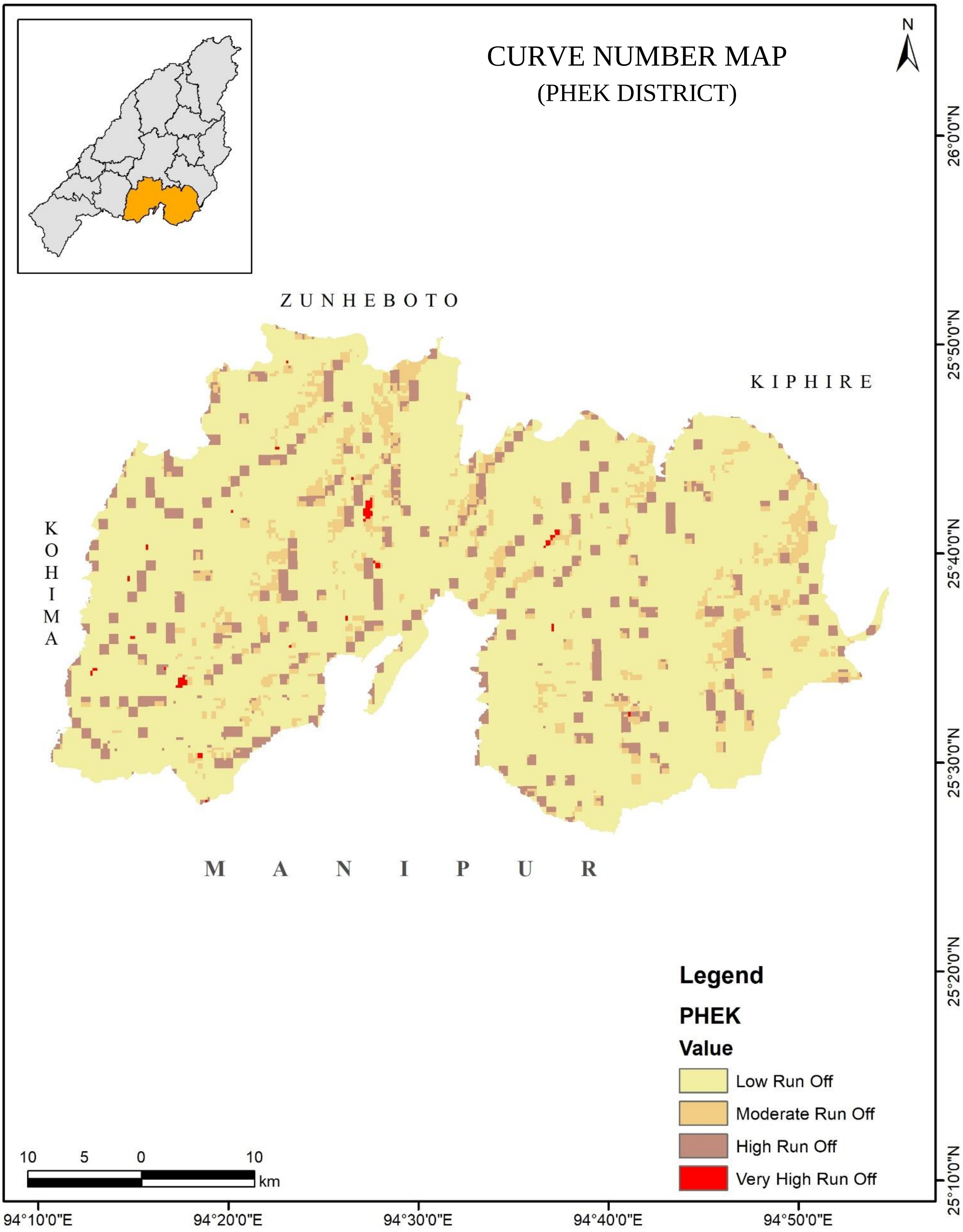
CURVE NUMBER MAP
(PHEK DISTRICT)
N
ZUNHEBOTO
KIPHIRE
KOHIMA
MANIPUR
Legend
PHEK
Value
Low Run Off
Moderate Run Off
High Run Off
Very High Run Off
10 5 0 10
km
94°10'0"E
94°20'0"E
94°30'0"E
94°40'0"E
94°50'0"E
26°0'0"N
25°50'0"N
25°40'0"N
25°30'0"N
25°20'0"N
25°10'0"N

Fig. 4k.

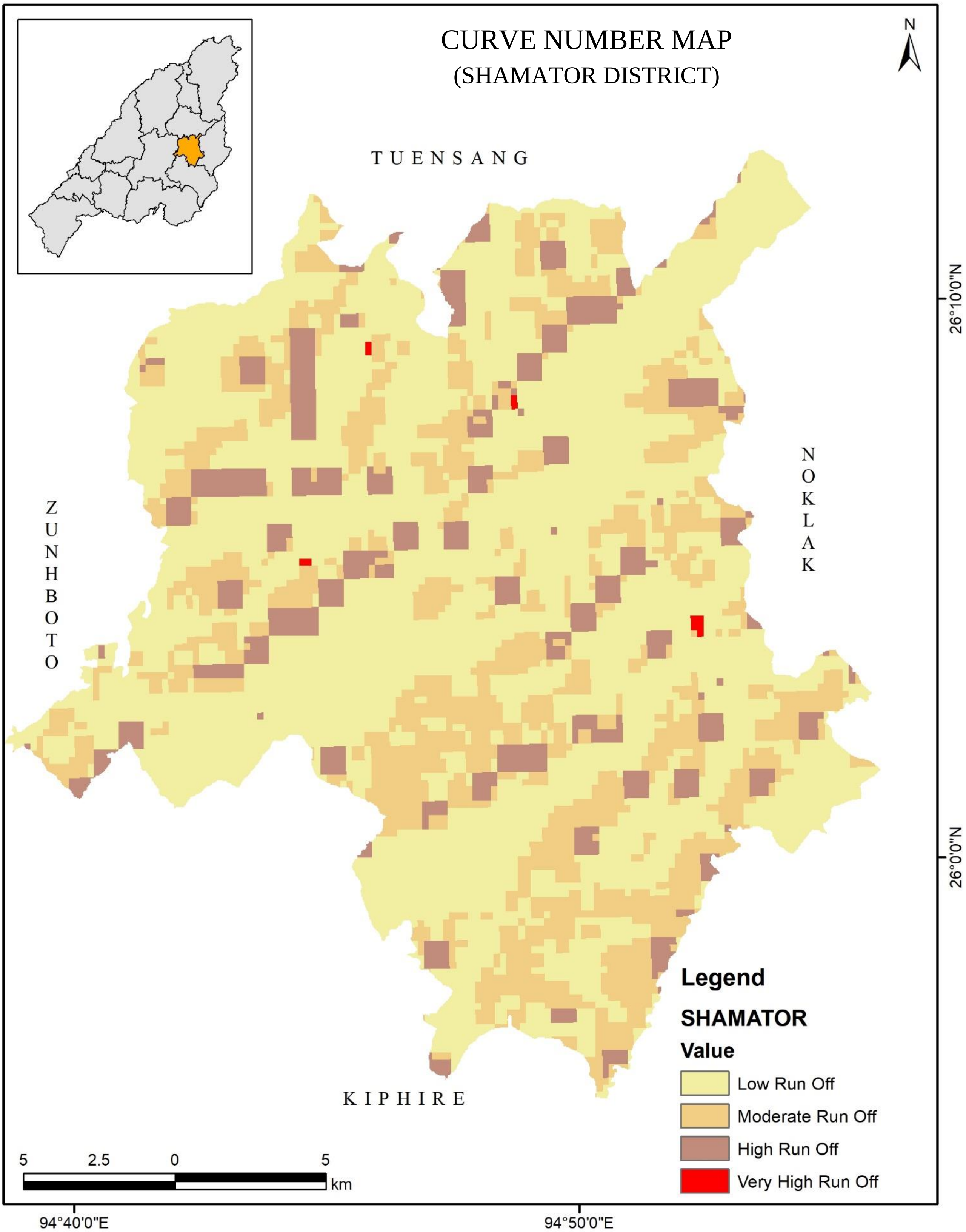
CURVE NUMBER MAP
(SHAMATOR DISTRICT)
N
TUENSANG
ZUNHBOTO
NOKLAK
KIPHIRE
26°10'0"N
26°0'0"N
94°40'0"E
94°50'0"E
5 2.5 0 5
km
Legend
SHAMATOR
Value
Low Run Off
Moderate Run Off
High Run Off
Very High Run Off

Fig. 4l.

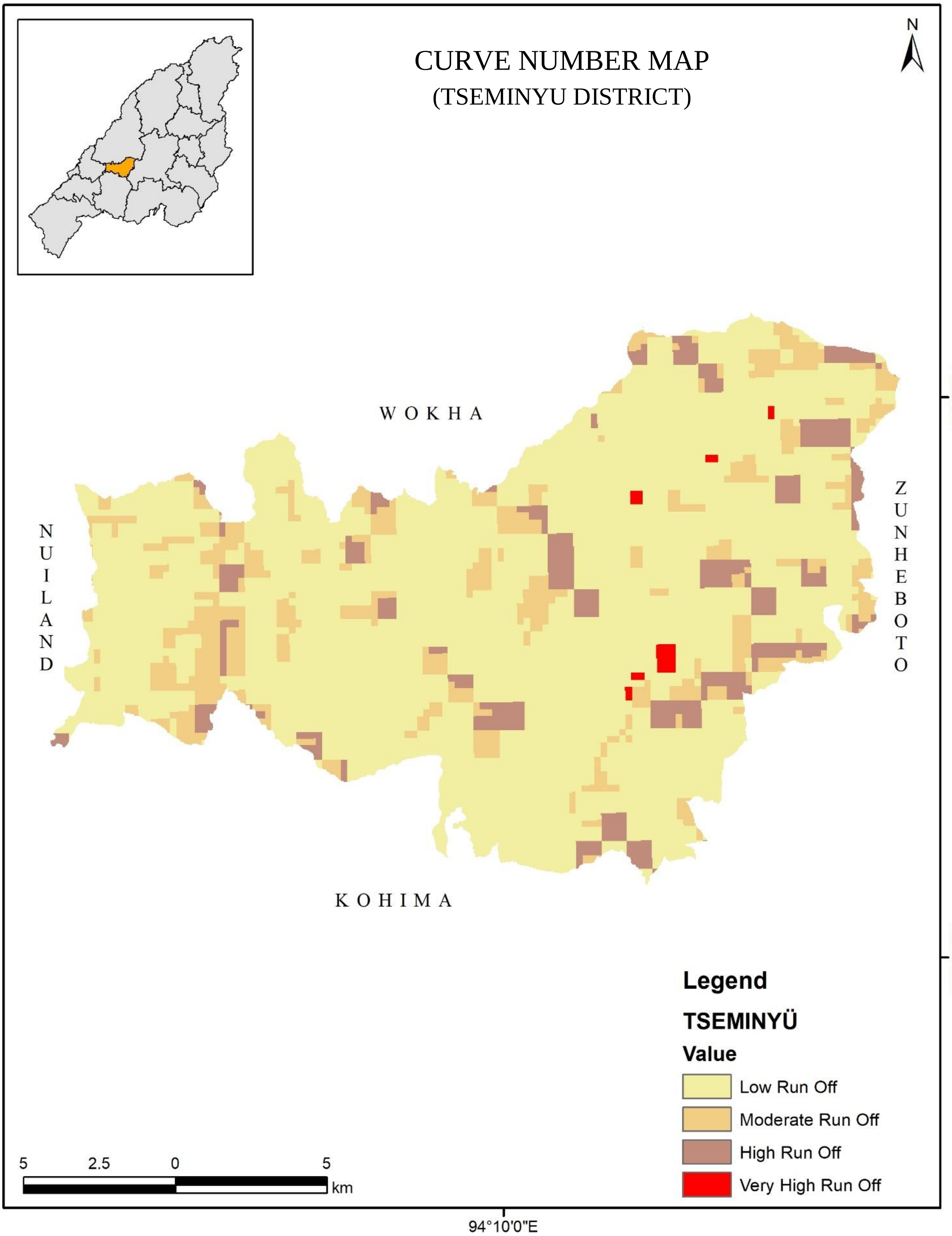
CURVE NUMBER MAP
(TSEMINYU DISTRICT)
N
WOKHA
NUILAND
ZUNHEBOTO
KOHIMA
26°0'0"N
25°50'0"N
94°10'0"E
Legend
TSEMINYÜ
Value
Low Run Off
Moderate Run Off
High Run Off
Very High Run Off
5 2.5 0 5
km

Fig. 4m.

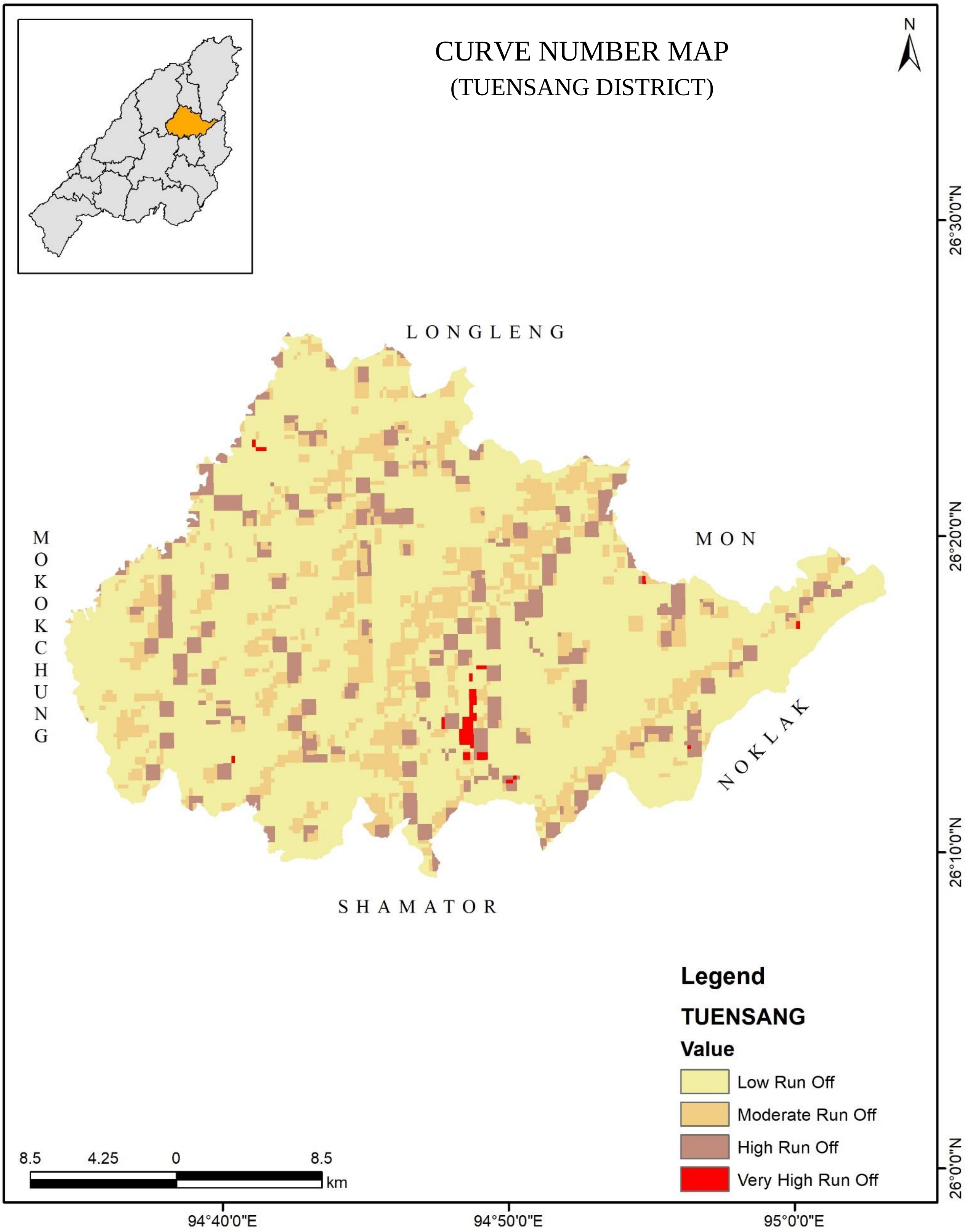
CURVE NUMBER MAP
(TUENSANG DISTRICT)
N
LONGLENG
MOKOKCHUNG
MON
NOKLAK
SHAMATOR
26°30'0"N
26°20'0"N
26°10'0"N
26°0'0"N
94°40'0"E
94°50'0"E
95°0'0"E
8.5
4.25
0
8.5
km
Legend
TUENSANG
Value
Low Run Off
Moderate Run Off
High Run Off
Very High Run Off

Fig. 4n.

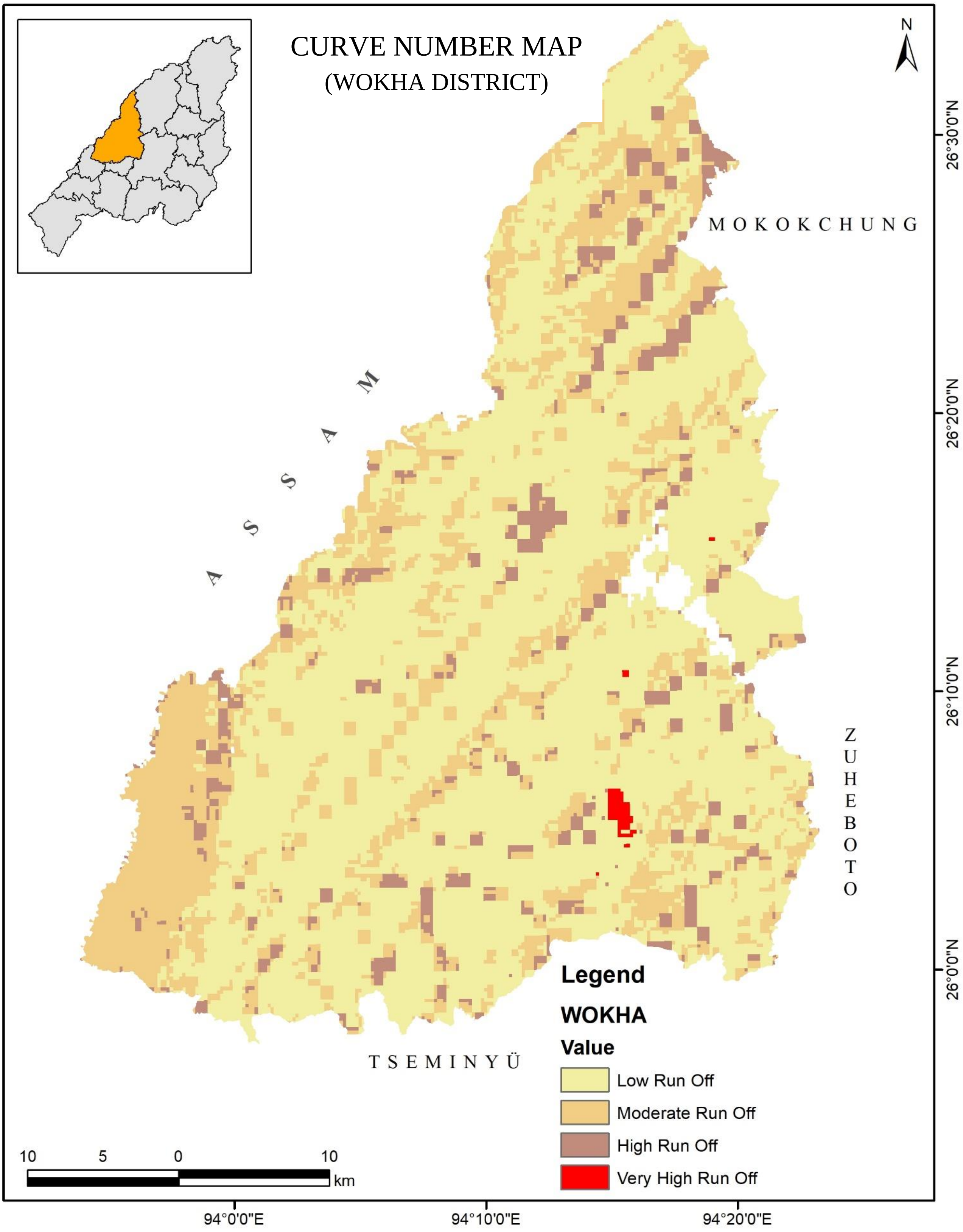
CURVE NUMBER MAP
(WOKHA DISTRICT)
N
MOKOKCHUNG
ASSAM
ZUHEBOTO
TSEMINYÜ
Legend
WOKHA
Value
Low Run Off
Moderate Run Off
High Run Off
Very High Run Off
10 5 0 10
km
26°30'0"N
26°20'0"N
26°10'0"N
26°0'0"N
94°0'0"E
94°10'0"E
94°20'0"E

Fig. 4o.

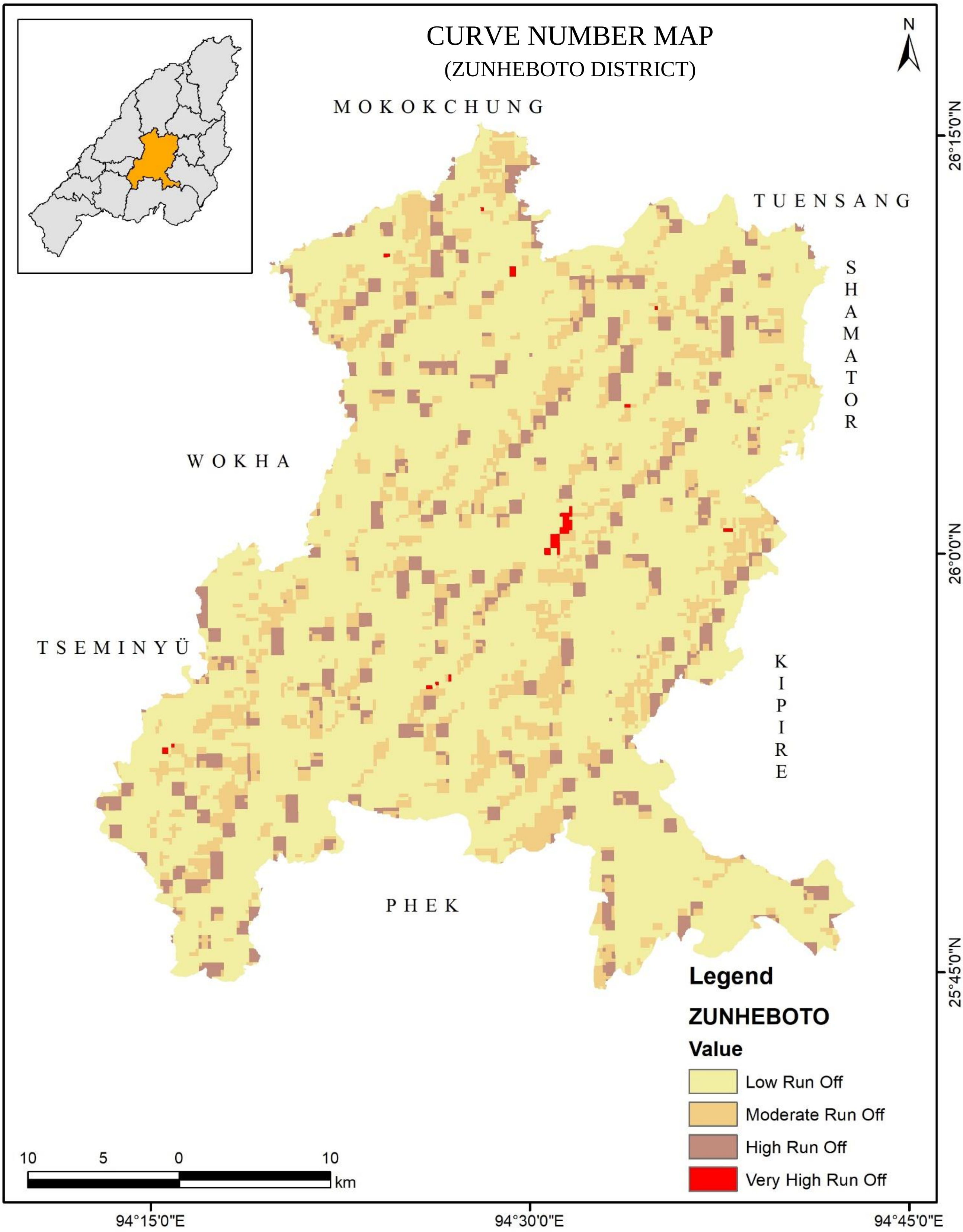
CURVE NUMBER MAP
(ZUNHEBOTO DISTRICT)
N
MOKOKCHUNG
TUENSANG
SHAMATOR
WOKHA
TSEMINYÜ
KIPIRE
PHEK
26°15'0"N
26°0'0"N
25°45'0"N
94°15'0"E
94°30'0"E
94°45'0"E
10 5 0 10
km
Legend
ZUNHEBOTO
Value
Low Run Off
Moderate Run Off
High Run Off
Very High Run Off

Fig. 4p.

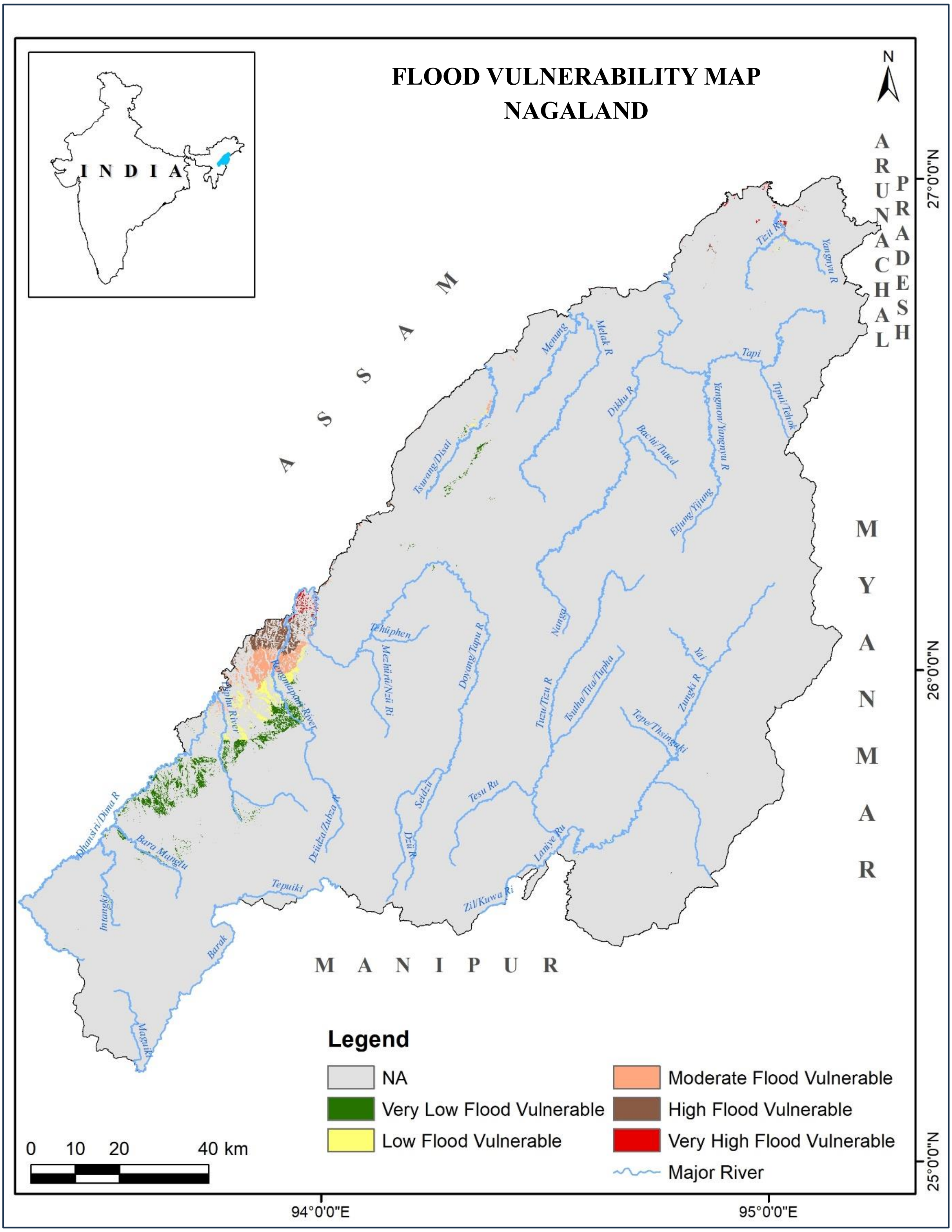

Fig. 5. Flood vulnerable map of Nagaland

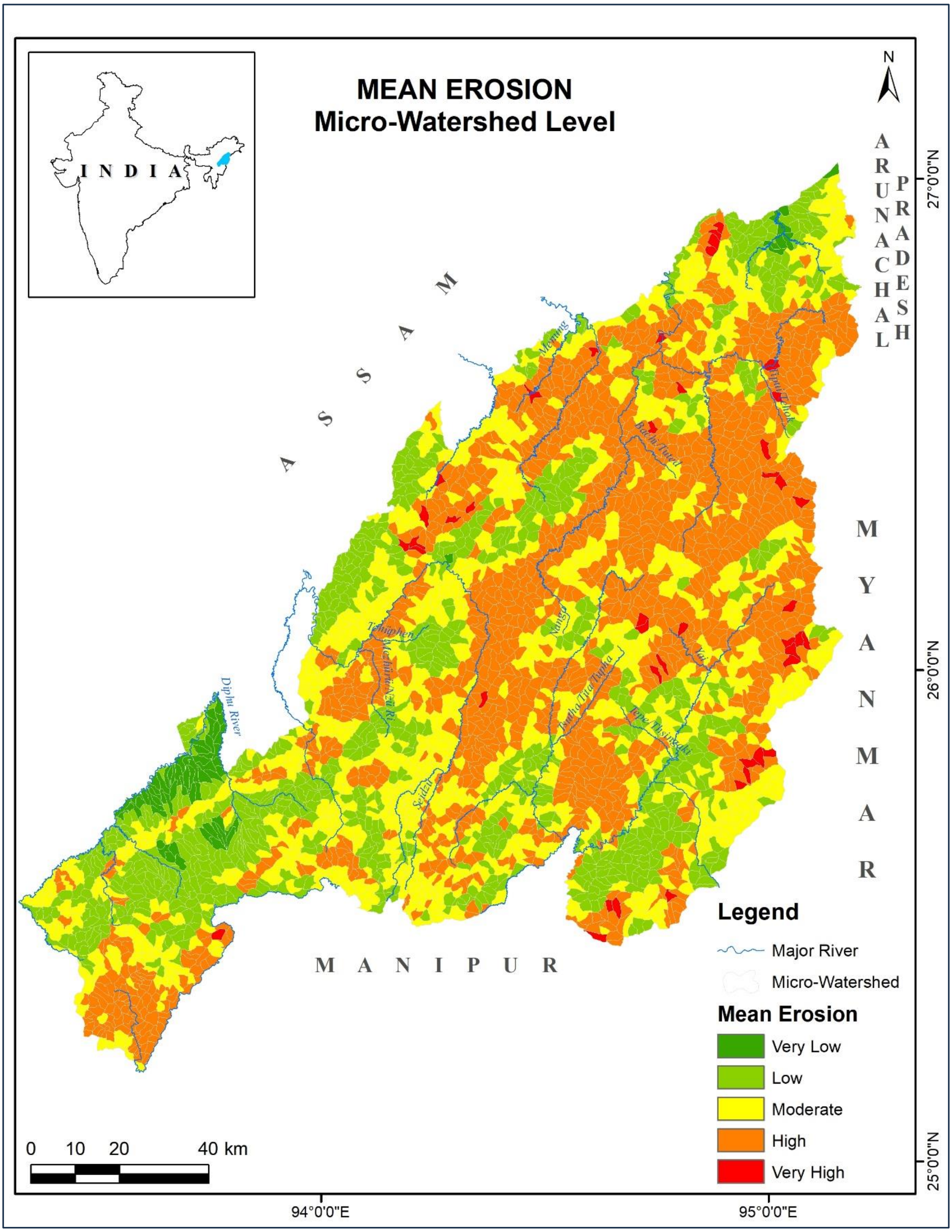

Fig. 6. Mean erosion map, Nagaland- micro-watershed level

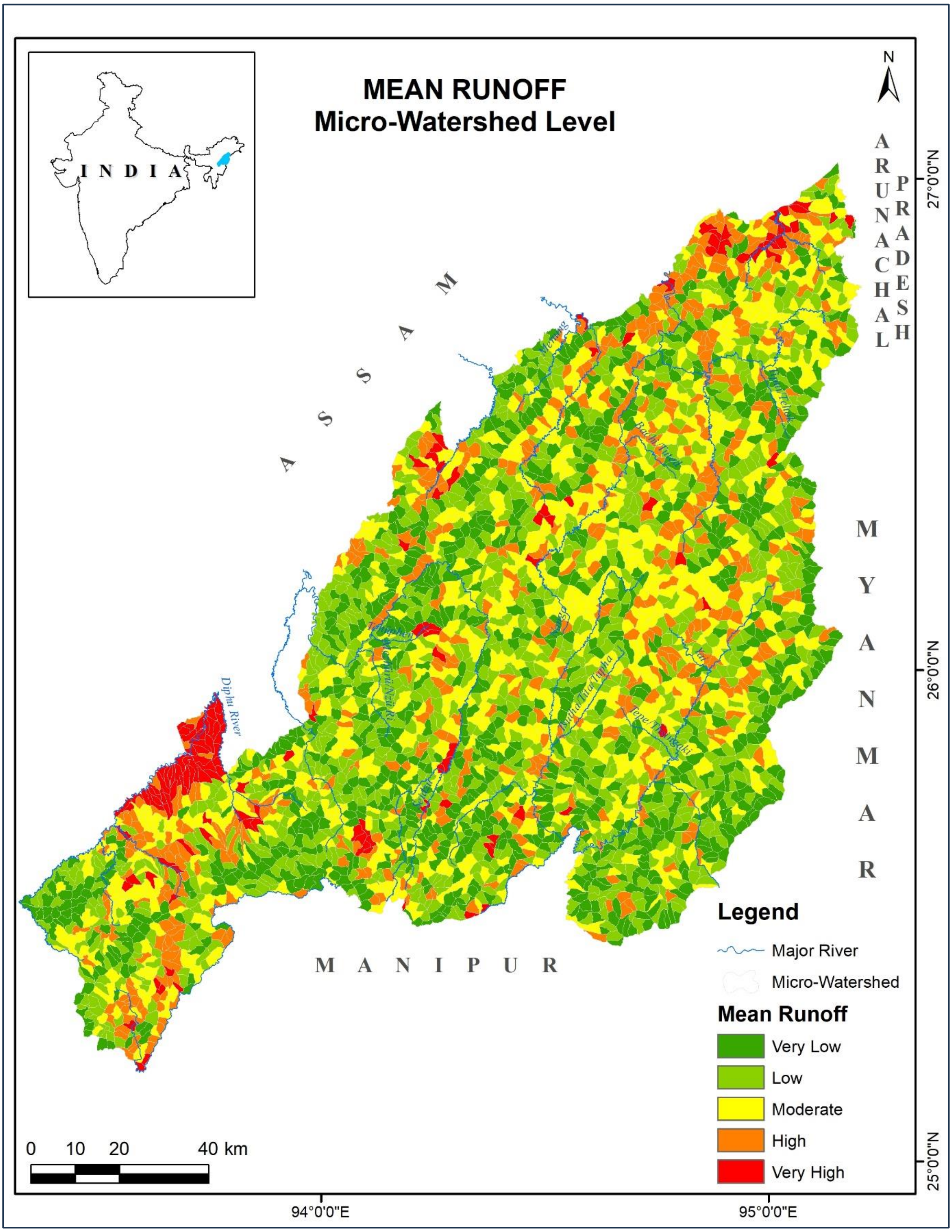

Fig. 7. Mean runoff map, Nagaland - micro-watershed level

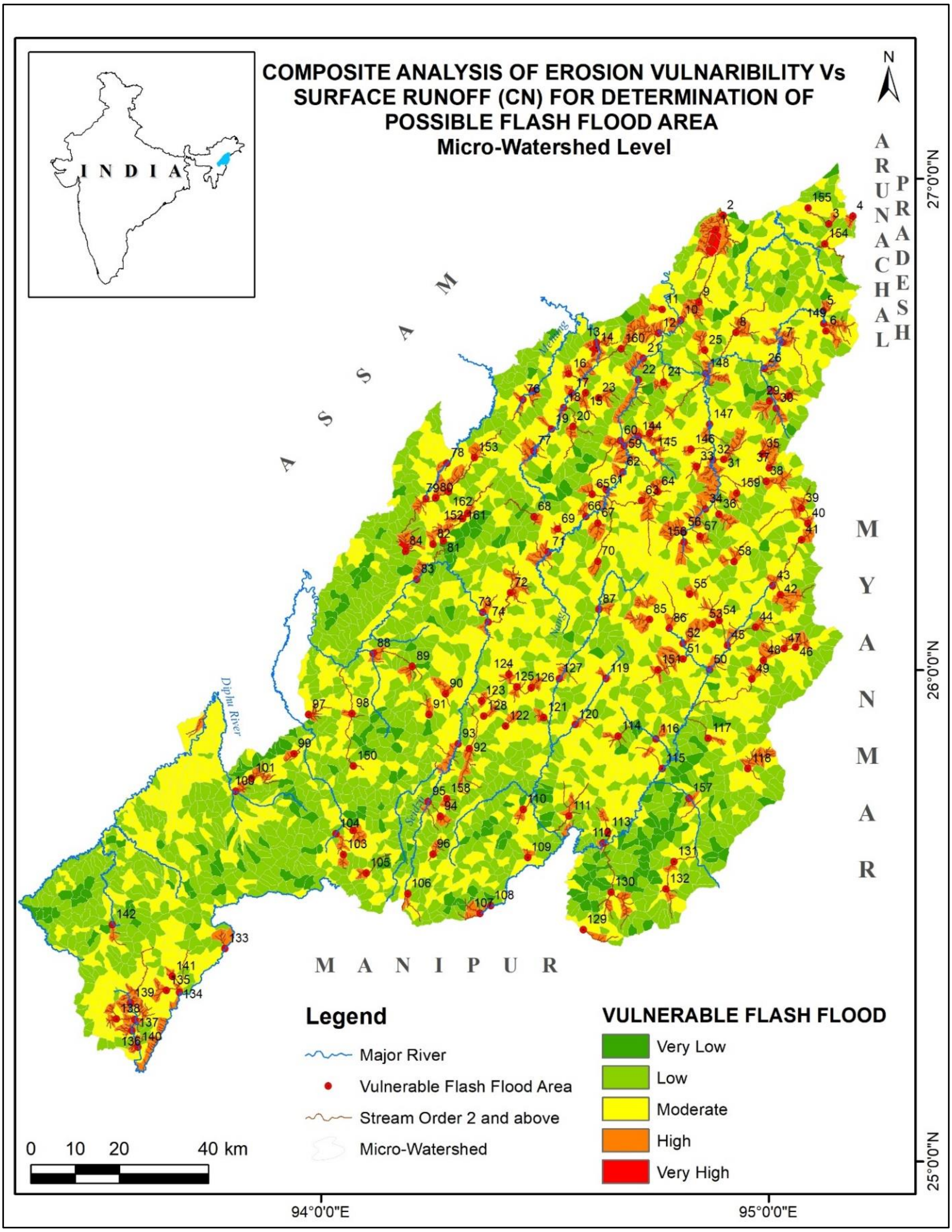

Fig. 8. Composite analysis of erosion vulnerability vs surface runoff (CN) for determination of possible flash flood area, micro-watershed level

Table 3a. Total area of Micro Watershed Falling within different level of combined Erosion and Runoff

Intensity	Category/Remark	Area Sq. m	Area Hà	Percentage
1	Very Low	1019080000	101908	6.1%
2	Low	6966310000	696631	42.0%
3	Medium	7153800000	715380	43.2%
4	High	1410290000	141029	8.5%
5	Very High	21433600	2143.36	0.1%
	Total	16570913600	1657091.36	100.0%

Table-3b. Identification of river names falling within the high and very high flash flood vulnerability category.

Sl.no	Intensity of erosion & runoff	Intensity of erosion & runoff at the upstream area	Drainage/ River	District
1	4	1,2,3 & 4	Dzumha/Tomma confluence with Kukhipani at Jharnapani	Chumoukedima
2	4	1,2,3 & 4	Kukhipani N	Chumoukedima
3	4	4	Amyi Ghoki/Balu Nodi	Chumoukedima
4	4	3 & 4	Tsungaki N	Kiphire
5	4	3 & 4	Teslote/Ahezhikikhi confluence with Zungki	Kiphire
6	4	1,2,3 & 4	Nguki confluence with Tepe N	Kiphire
7	4	2,3 & 4	Pake confluence of Makhute N with Wumoktai N	Kiphire
8	4	3 & 4	Ramongto Thatero Confluence of Likim Ro and Ramwongto N	Kiphire
9	4	2,3 & 4	Aki Ghoki confluence with Tsutha or Tita River	Kiphire
10	4	2,3 & 4	Kekhip confluence with Horungki N	Kiphire
11	4	1,2,3 & 4	Tuzu or Tizu R	Kiphire
12	4	3 & 4	Khokhuka N confluence with Dzutre Rü	Kohima
13	4	2 & 4	Lo rü confluence with Dzüna Rü	Kohima
14	4	1,2,3 & 4	Dzüna Rü confluence with Dzüdza or Zubza R	Kohima
15	4	3 & 4	Mezei Rü	Kohima
16	3	2 & 3	Tho Rü/Vitho Rü confluence with Sina Rü/Rorü/N	Kohima

17	4	2,3 & 4	Tsudzo Rü confluence with Sedzü or jeti	Kohima
18	4	4	Shiyong Yungyen	Longleng
19	4	4	Maishau confluence with Dikhu /Laiyen	Longleng
20	4	4	Alipayen confluence with Sipi N	Longleng
21	4	3 & 4	Supai N and Thangshu Shukha confluence	Longleng
22	4	3 & 4	Owengchong confluence with Lengjan	Longleng
23	4	3 & 4	Smadai Ho confluence with Tsubu nala	Longleng
24	4	2,3 & 4	Shangsha yong confluence with Bachi River	Longleng
25	4	3 & 4	Chini N/shinye	Longleng
26	4	2,3 & 4	Shotishung confluence with Tzusangra Yong/Shingha	Longleng
27	4	4	Manhen confluence with Yangmon or Yangnyu R	Longleng
28	4	4	Shunyei Yen confluence with Yangmon or Yangnyu R	Longleng
29	4	4	Nanga Ghoki	Longleng
30	4	3 & 4	Supai N/Shephei confluence with Yangmon or Yangnyu R	Longleng
31	4	3 & 4	Tuted ayong confluence with Nanga Ghoki/Tzula (Dikhu R)	Longleng
32	4	3 & 4	Nanung Nala confluence with Nanga Ghoki/Tzula (Dikhu R)	Longleng
33	4	1,2,3 & 4	Yangnyu R confluence with Yangmon or Yangnyu R	Longleng
34	5	4 & 5	Tuliyong confluence with Menung	Mokokchung
35	5	5	Tzutelang confluence with Menung/Melak	Mokokchung
36	4	4	Tzunungyong confluence with Tziimok Ayong	Mokokchung
37	4	4	Aktsuba yong confluence with Tzupen Yong/Tziipen Yong	Mokokchung
38	4	4	Moluchem Yong confluence with Menung	Mokokchung
39	4	4	Menung and Melak confluence	Mokokchung
40	4	4	Tongdentsu N confluence with Milak	Mokokchung
41	4	4	Menung	Mokokchung
42	4	4	Yong Tzhmok N	Mokokchung
43	4	3 & 4	Longkong confluence with Naong	Mokokchung
44	4	4	Tzuza Yong	Mokokchung
45	4	3 & 4	Tzusa Yong confluence with Tsungi Ayong	Mokokchung
46	4	3 & 4	Tzutep confluence with Dikhu	Mokokchung
47	4	3 & 4	Pangpang Tsu confluence with Tsurong	Mokokchung
48	4	3 & 4	Tsurong	Mokokchung

49	4	3 & 4	Aonglangpa Nala/Tsiichuyong confluence with Melak	Mokokchung
50	4	2,3 & 4	Lampi Nala confluence with Achaklangba Ayong	Mokokchung
51	4	4	Nanga Ghoki/Tzula (Dikhu R)	Mokokchung
52	4	3 & 4	Tuted ayong confluence with Nanga Ghoki/Tzula (Dikhu R)	Mokokchung
53	4	3 & 4	Nanung Nala confluence with Nanga Ghoki/Tzula (Dikhu R)	Mokokchung
54	4	3 & 4	Changchang Yong confluence with Nanga Ghoki/Tzula (Dikhu R)	Mokokchung
55	4	3 & 4	Tzuchi Tzu confluence with Dikhu	Mokokchung
56	4	1,2,3 & 4	Juyik confluence with Chubi Zukhu	Mokokchung
57	5	5	Shihu R	Mon
58	5	4 & 5	Shihu R	Mon
59	4	4	Yunam and Namsa confluence	Mon
60	4	4	Tapi R	Mon
61	4	4	Tikha	Mon
62	4	4	Tapi and Thomchik confluence	Mon
63	4	4	Tejang N and Chi N confluence	Mon
64	4	4	Ayan N	Mon
65	4	3 & 4	Shukhoh confluence with Shushem	Mon
66	4	4	Yangnyu R and Phoyo Nadi confluence	Mon
67	4	3 & 4	confluence with Wamnyu Sho	Mon
68	4	3 & 4	Tipui R and Wamnyu Sho confluence	Mon
69	4	4	Tipui R and Tisam or Yayam R confluence	Mon
70	4	4	Tipui R	Mon
71	4	4	Mukaha N	Mon
72	4	4	Sakhat N and Sakhat N confluence	Mon
73	4	4	Khuwangsa	Mon
74	4	3 & 4	Chenyu Sao	Mon
75	4	2,3 & 4	Chija Ho confluence with Yangmon or Yangnyu R	Mon
76	4	2,3 & 4	Tapi R	Mon
77	3	3	Titho N and Tachim N confluence	Mon
78	3	2 & 3	Tipaja and Lanam N Confluence	Mon
79	4	2,3 & 4	Kaimong N	Mon
80	4	4	Yangmon or Yangnyu R	Mon
81	4	4	Yangmon or Yangnyu R	Mon
82	4	3 & 4	Longkai confluence with Yangmon or Yangnyu R	Mon

83	4	4	Tangni or ephu Mong confluence with Makao R	Mon
84	4	1,2,3 & 4	Yangnyu R confluence with Yangmon or Yangnyu R	Mon
85	4	1,2,3 & 4	Tikdiri/Nyetsonji Rü	Niuland
86	4	4	Amyi Ghoki/Balu Nodi	Niuland
87	4	3 & 4	Haiyap confluence with Makao R	Noklak
88	4	3 & 4	Makao R	Noklak
89	4	4	Mouth of Liuhiu Mong	Noklak
90	4	3 & 4	Zungki R	Noklak
91	4	3 & 4	below Lomu N and Sangliahninyu N confluence	Noklak
92	4	3 & 4	Lomu N and Zungki R confluence	Noklak
93	4	3 & 4	Chokla R	Noklak
94	4	3 & 4	Chokla R	Noklak
95	4	3 & 4	Chokla R	Noklak
96	4	3 & 4	Ongoh/Longpang/Ohnyoh and Jüliutai /Taivuh/Joklo confluence	Noklak
97	4	3 & 4	Tsohyemung N Tributory	Noklak
98	4	3 & 4	Tsohyemung N	Noklak
99	4	4	Tangni or ephu Mong confluence with Makao R	Noklak
100	4	3 & 4	Zungki R	Noklak
101	4	3 & 4	Barak	Peren
102	4	2,3 & 4	Tesang Ki confluence with Barak	Peren
103	4	3 & 4	Duilin Ki and Baduiki confluence	Peren
104	4	2,3 & 4	Maguiki	Peren
105	4	2,3 & 4	Maguiki	Peren
106	4	3 & 4	Keliengeu Ki and Tepun Ki/Nga Ki confluence	Peren
107	4	2,3 & 4	Maguiki	Peren
108	4	2,3 & 4	Maguiki	Peren
109	4	4	Kerangreiki	Peren
110	4	2,3 & 4	Intangki	Peren
111	4	2 & 4	Tsudzo Rü	Phek
112	4	2,3 & 4	Khuzha Rü	Phek
113	4	2,3 & 4	Ziri N	Phek
114	4	1,2,3 & 4	Zil or Kuwa Ri or Razaru or Nobari N	Phek
115	4	1,2,3 & 4	Zil or Kuwa Ri or Razaru or Nobari N	Phek
116	4	2,3 & 4	Lozache Ri	Phek
117	4	1,2,3 & 4	Michu Ru	Phek

118	4	2,3 & 4	Tuza Ru	Phek
119	4	1,2,3 & 4	Tuzu or Tizu R	Phek
120	4	2,3 & 4	Anapo Rugu	Phek
121	4	2,3 & 4	Sising and Shukha Küpo confluence	Phek
122	4	2,3 & 4	Thongseh dung confluence with Arachu Nadi	Phek
123	4	1,2,3 & 4	Layo Ti	Phek
124	4	2,3 & 4	Layo Ti	Phek
125	4	2,3 & 4	Tsudzo Rü confluence with Sedzü or jeti	Phek
126	4	1,2,3 & 4	Tuzu or Tizu R	Phek
127	4	2 & 4	Thebokhu Rü	Phek
128	4	3 & 4	Horungki N	Shamator
129	4	3 & 4	Mangko confluence with Zungki or Yai	Shamator
130	4	3 & 4	Shetche N	Shamator
131	4	3 & 4	Below confluence of Hutangke N and Hutangke N	Shamator
132	4	3 & 4	Hukiyang N	Shamator
133	4	3 & 4	Zungki R	Shamator
134	4	2,3 & 4	Horungki N	Shamator
135	4	1,2,3 & 4	Achen Ru confluence with Tsuyi Rü	Tseminyu
136	4	1,2,3 & 4	Sarii confluence with Sina rü/Rorü/Nra/Nro	Tseminyu
137	4	2,3 & 4	Mitho N confluence with Etjung or Yijung	Tuensang
138	4	4	Moyung	Tuensang
139	4	3 & 4	Shamyung confluence with Etjung or Yijung	Tuensang
140	4	3 & 4	Konyahayou N	Tuensang
141	4	3 & 4	Confluence of Tiekyung N n Wokyung N at Langnyu R	Tuensang
142	4	3 & 4	Chisangyong Nala confluence with Nanga Ghoki	Tuensang
143	4	3 & 4	Phamji R	Tuensang
144	4	3 & 4	Phamji R	Tuensang
145	4	3 & 4	Jengho Nala	Tuensang
146	4	4	Chimenzu Yonki or Chimei River	Tuensang
147	4	2,3 & 4	Etjung or Yijung	Tuensang
148	4	3 & 4	Changchang Yong confluence with Nanga Ghoki	Tuensang
149	4	3 & 4	Tsushitsu R confluence with Nanga Ghoki	Tuensang
150	4	3 & 4	Sajak confluence with Tzurang	Wokha
151	4	3 & 4	Tchupvu confluence with Tchupvu Zhukhu at Tzurang	Wokha

152	4	3 & 4	Tsentsu	Wokha
153	4	3 & 4	Chusung Nala confluence with Chubi Zukhu	Wokha
154	4	3 & 4	Ngalan Zhukhu confluence with Etsungchu at Ngalang	Wokha
155	4	2,3 & 4	Diyung or Tapu R	Wokha
156	5	2,3,4 & 5	Zaktchu confluence with Baghty River	Wokha
157	4	3 & 4	Chuche N/Tchutho confluence with Nzhu	Wokha
158	4	1,2,3 & 4	Haney Aghako confluence with Chuche N/Tchutho	Wokha
159	4	2,3 & 4	Nangu Nala confluence with Chubi Zukhu	Wokha
160	4	2,3 & 4	Nafusa ghoki confluence with Juying	Wokha
161	4	3 & 4	Tishi Nala confluence with Diyung or Tapu R	Wokha
162	4	1,2,3 & 4	Juyik confluence with Chubi Zukhu	Wokha
163	4	3 & 4	Tishi Nala	Zunheboto
164	4	3 & 4	Diyung or Tapu R	Zunheboto
165	4	2,3 & 4	Kokshi Ghoki confluence with Zungki R	Zunheboto
166	4	4	Chisholimi Rü	Zunheboto
167	4	2,3 & 4	Tsuyi Rü	Zunheboto
168	4	2,3 & 4	Diyung or Tapu R	Zunheboto
169	4	2,3 & 4	Sumkhu N confluence with Tsutha or Tita River	Zunheboto
170	4	2 & 4	Azukikhipa and Kutu confluence	Zunheboto
171	4	2,3 & 4	Igho Ki	Zunheboto
172	4	3 & 4	Khamla Ru confluence with Mezi Ki	Zunheboto
173	4	2,3 & 4	Lang Ki	Zunheboto
174	4	2,3 & 4	Lang Ki	Zunheboto
175	4	4	Lang Ki	Zunheboto
176	4	1,2,3 & 4	Muzaki Ghoki confluence with Tuzu R	Zunheboto
177	4	2,3 & 4	Kulughu and Yejemo confluence	Zunheboto
178	4	3 & 4	Tishi Nala confluence with Diyung or Tapu R	Zunheboto
179	4	2,3 & 4	Aki Ghoki confluence with Tsutha or Tita River	Zunheboto
180	4	2 & 4	Thebokhu Rü	Zunheboto

Conclusion

The study utilizes GIS and remote sensing to efficiently assess and map erosion-prone regions. These technologies enable fast and cost-effective analysis of large datasets, helping identify patterns, analyze topography, and track environmental factors critical to understanding erosion and flood risks. The focus of the study is on examining various factors that contribute to erosion-prone areas within the state. These factors include terrain features, soil properties, vegetation cover, slope lithology, landslide incidences and rainfall patterns, all of which play a significant role in determining the susceptibility of land to erosion. It also highlights the link between erosion-prone areas and surface runoff, a key factor in both erosion and flood vulnerability. Erosion-prone regions are typically more vulnerable to increased runoff, which can lead to the loss of soil and erosion rates often experience greater flood vulnerability, as runoff can quickly lead to flooding when soil is unable to absorb and retain water effectively. By analyzing these interconnected factors, the study offers a comprehensive approach to understanding the spatial distribution of erosion and its impact on flood vulnerability. This method provides valuable insights for land management and flood risk mitigation strategies, enabling more informed decision-making in areas prone to both erosion and flooding. Results can be further refined with field data to enhance future erosion-related flood studies in targeted areas.

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Meteorological data: Rainfall: Source-Department of Soil and water Conservation, Government of Nagaland

Soil data: Department of Agriculture, Government of Nagaland & ICAR

Appendix 1

NAGALAND GIS & REMOTE SENSING CENTRE

Space technology, remote sensing, and Geographic Information System (GIS) applications have emerged as transformative tools for addressing challenges in sustainable economic growth and development. These technologies have evolved beyond traditional topographic and terrain mapping to redefine how geospatial data is utilized globally. In this context, the Nagaland GIS & Remote Sensing Centre (NGISRSC) has played a pivotal role in harnessing these advancements for the State of Nagaland.

Recognizing the significance of GIS as early as 2000, the Nagaland Government established the NGISRSC in 2006. The Centre has since become an important institution for geospatial technology in the State. It serves as a repository of spatial data and leverages cutting-edge technologies such as remote sensing, GIS, and drone technology. NGISRSC is also a hub for training, capacity building, innovation, and research and development, contributing to the State's decision support system.

The Nagaland GIS & Remote Sensing Centre (NGISRSC) has built a strong geospatial foundation that powers governance, planning, and decision-making in the state. Its robust geospatial data infrastructure enables the creation of thematic maps, applications, and services, making resource identification and development more efficient and systematic.

Through integrated geospatial platforms, NGISRSC has played role in implementing national schemes such as Jal Shakti Abhiyan, Jal Jeevan Mission, Digital Agriculture Mission, and Pradhan Mantri Gati Shakti. These platforms provide accurate, real-time data for better planning and monitoring, ensuring the successful execution of these initiatives.

The Centre’s innovative village-level resource mapping has its impact by optimizing resource utilization and conservation. Projects supported by international organizations such as IFAD, JICA, and the World Bank have benefited from this initiative, showcasing how localized expertise can contribute to global sustainability goals.

NGISRSC’s integration of advanced drone technology has improved operations in surveying, mapping, and disaster response. By conducting studies on landslides, rockfalls, and other natural hazards, the Centre has significantly enhanced disaster preparedness and response capabilities working in collaboration with the line departments. Moreover, the Centre has leveraged drone imagery for urban planning, producing detailed 3D models.

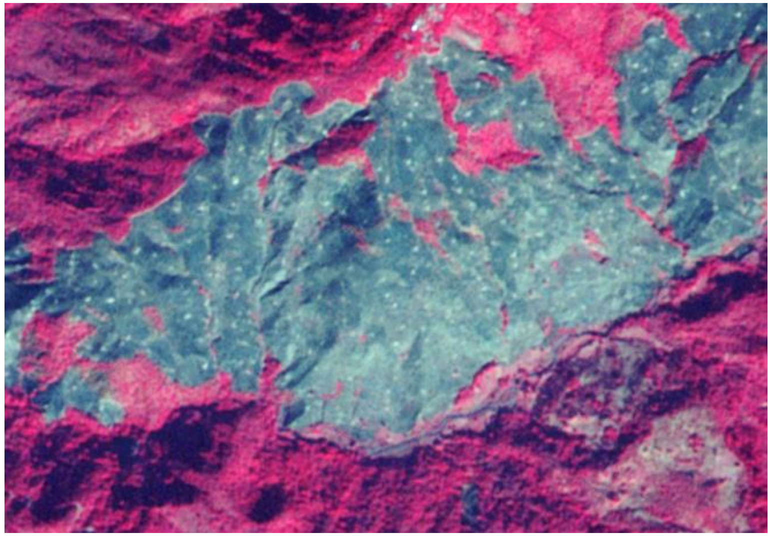
In its commitment to sustainability, NGISRSC actively monitors deforestation, land use changes, and river pollution, reinforcing its dedication to environmental conservation. Under its strategic plan (2021-2025), the Centre has initiated several transformative projects, including post-monsoon landslide inventory mapping and its contribution to the PM Gati Shakti Master Plan.

Nationally recognized for its pioneering work, NGISRSC’s expertise was spotlighted during a 2023 presentation to the Economic Advisory Council to the Prime Minister. Showcasing innovations like drone and 3D Twin Technology, the Centre earned accolades for its role in advancing geospatial technology.

Looking ahead, NGISRSC remains committed to pushing the boundaries of GIS, remote sensing, and drone technology. Through its initiatives, the Centre continues to drive sustainable development, resilience, and progress across Nagaland and beyond.

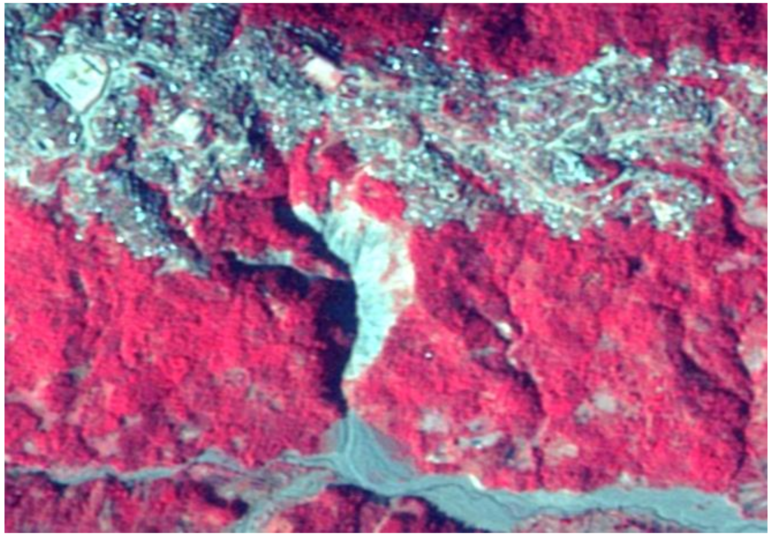
Plate

Erosion due to extensive jhumming, Kiphire district

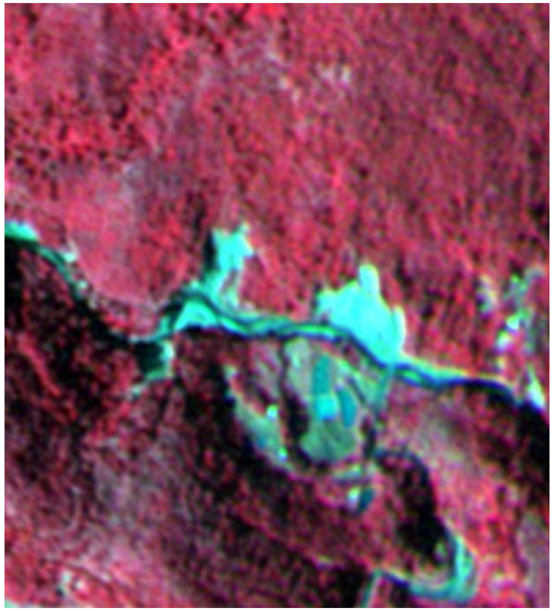


Erosion due to extensive jhumming, Tuensang district

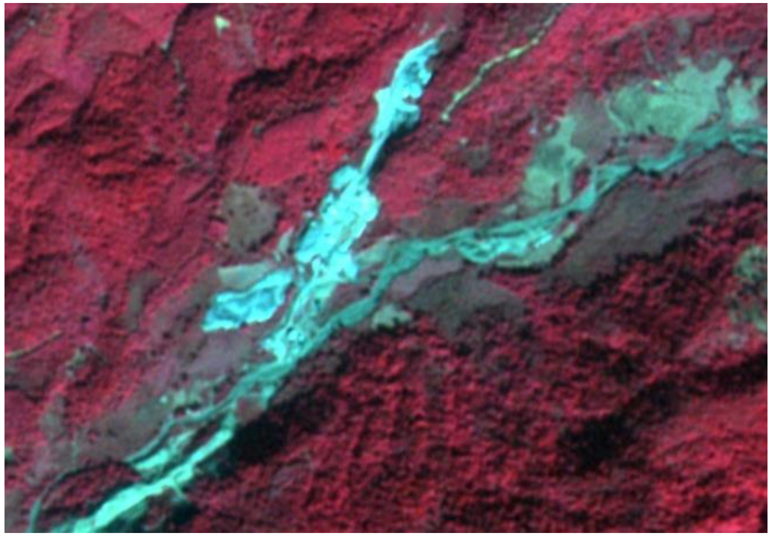
Landslide due to toe erosion, Chathi river

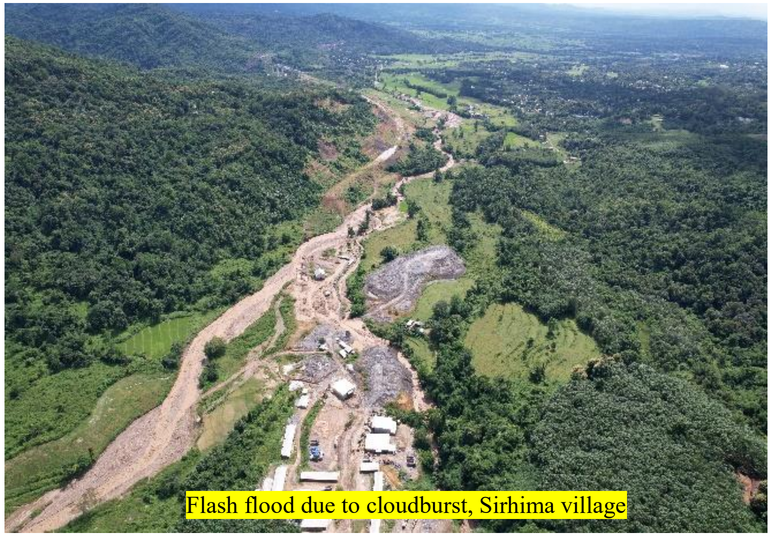


Landslide due to toe erosion, Tuensang town

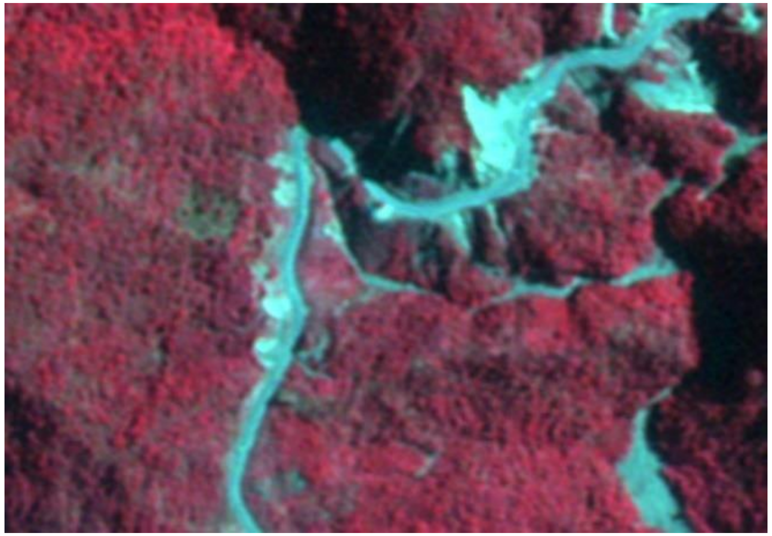


Landslide due to toe erosion, Etjung river, tuensang

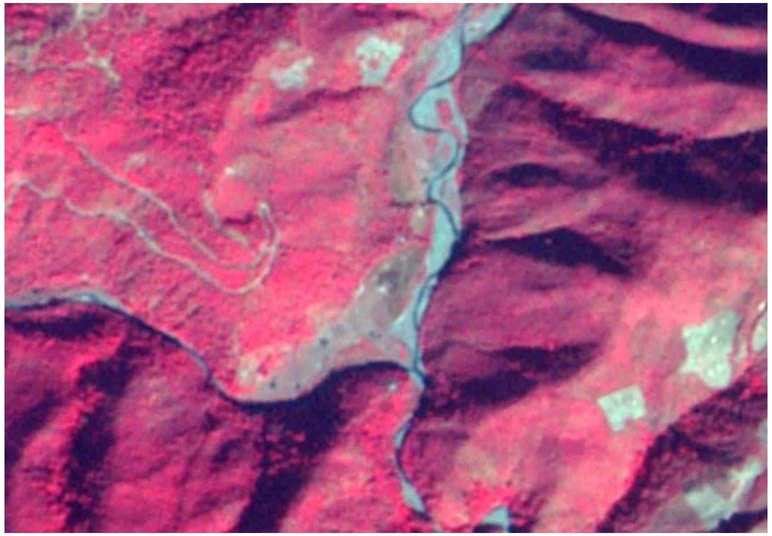




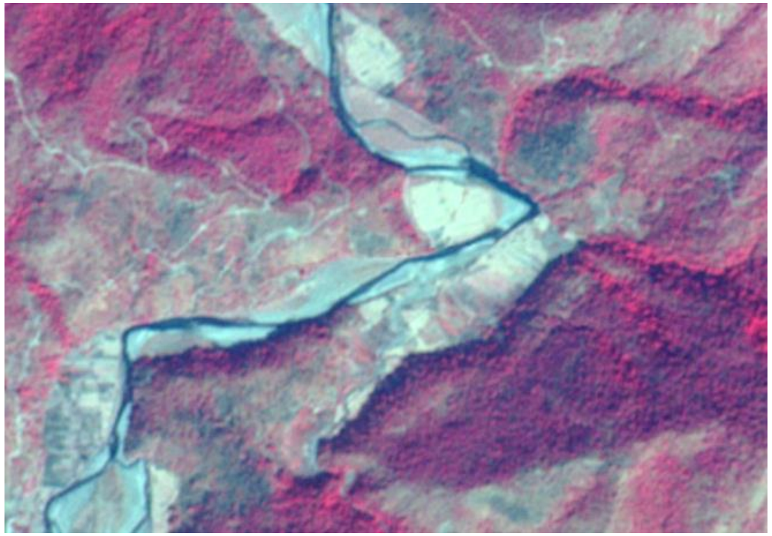
Flash flood due to cloudburst, Sirhima village



Flash flood due to cloudburst, Pherima village

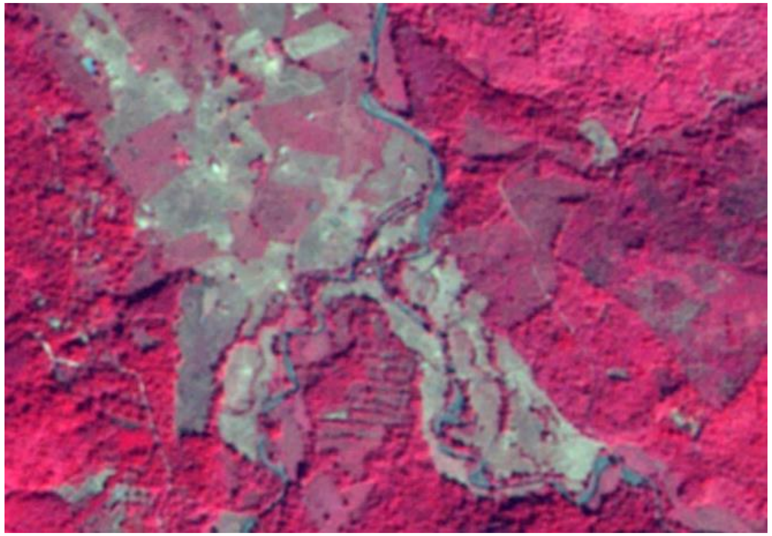


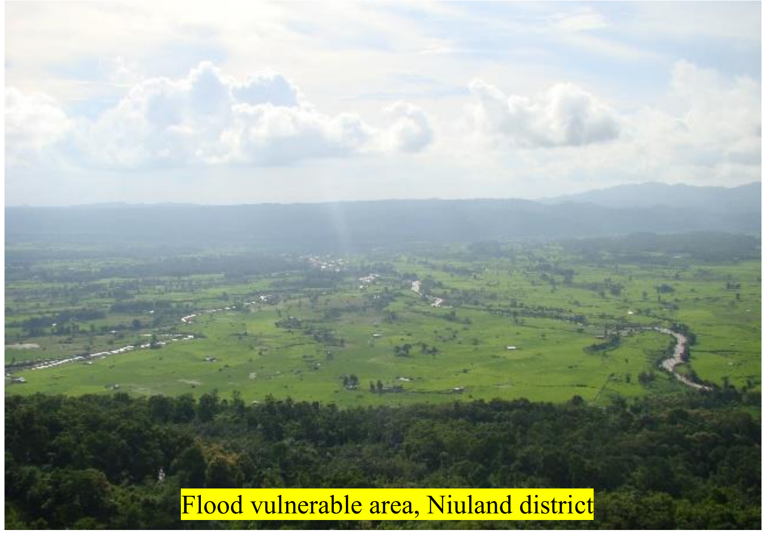
Active flood-plain, Shamator district



Active flood-plain, Phek district

Active flood-plain, Naganimora, Mon district





Flood vulnerable area, Niuland district

Satellite Image: IRSResourcesat2, LISS IV (2023-24)

A study undertaken by
Nagaland GIS & Remote Sensing Centre
Planning & Transformation Department, Kohima
2024-25

NGISRSC

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