Remote Sensing and GIS approach towards Groundwater Investigation in the Kairiku District of Central Province, PNG

Presenter: Jayson Inau, Professor Sailesh Samanta and Dr Cathy Koloa

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Introduction and Problem Statement

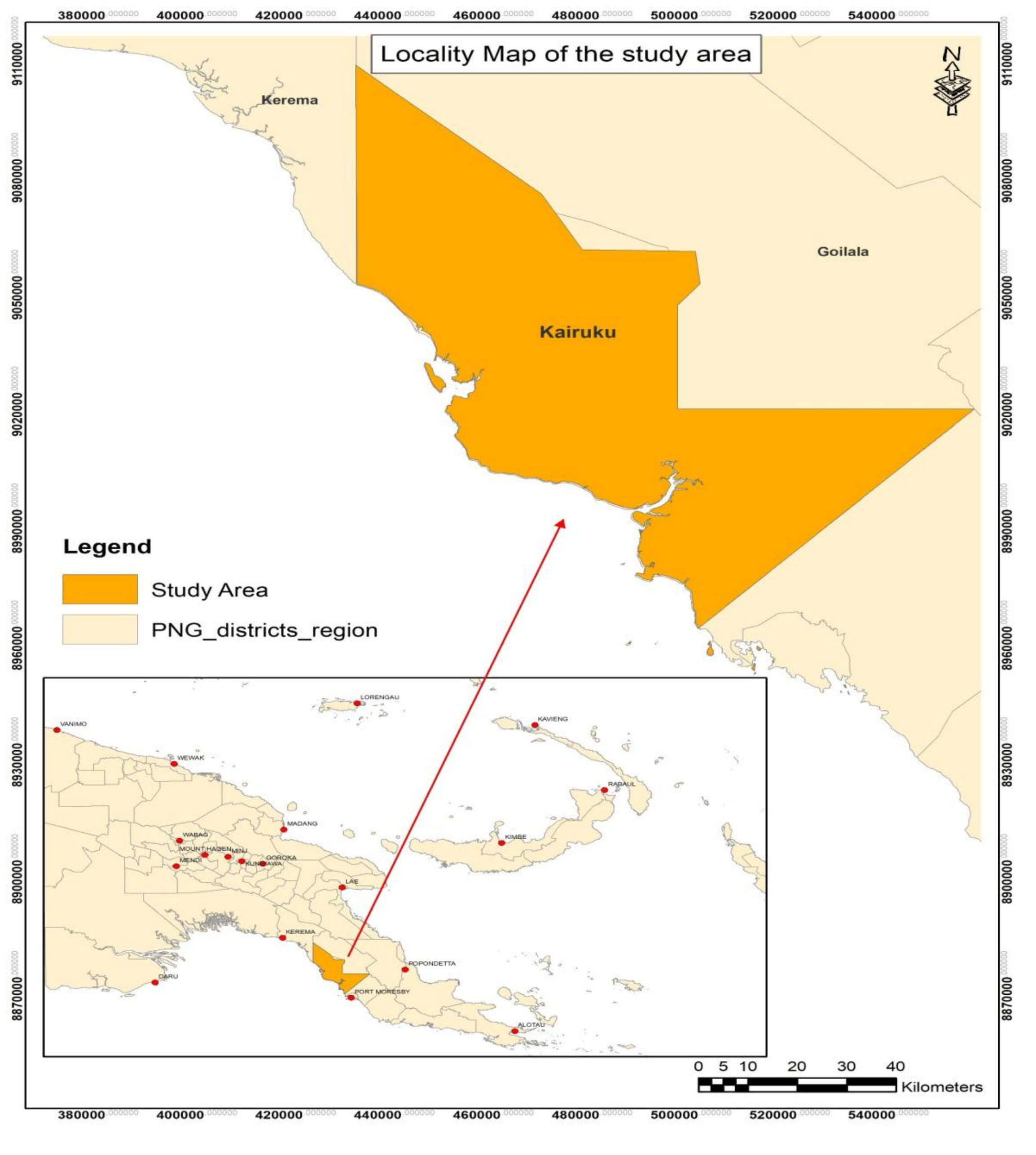
- **The Challenge:** Water is essential for life, yet fresh surface water is scarce in low-rainfall areas of Papua New Guinea.
- **The Need:** Groundwater is essential, but traditional Vertical Electrical Sounding (VES) surveys are costly and labor-intensive.
- **The Solution:** While VES surveys are accurate but costly, Remote Sensing and GIS offer a cheaper, less labour-intensive alternative for groundwater mapping.

Study Area

- ❖**Location**:Kairiku District is located at 8°50′38.4″S, 146°40′48″E.

Geography:Coastal areas have low-density forest, grassland, and shrubland; inland areas have dense forest and higher elevation.

- ❖**Environment**:Annual rainfall ranges from 1000–4500mm, contain major rivers likeAngabanga and Tauri.
- ❖ **Population**: 77,035 (2024 census).
- ❖Connected to Port Moresby via Hiritano National HighwaGroundwater is essential, but traditional Vertical Electrical Sounding (VES) surveys are costly and labor-intensive. Groundwater is essential, but traditional Vertical Electrical Sounding (VES) surveys are costly and labor-intensive.y.



Research Aim & Objectives

Primary Aim: To investigate and map Groundwater Potential Zones(GWPZ) using GIS and Remote Sensing

Key Objectives:

- ❖ Identify and analyze thematic layers (lithology,geomorphology,slope,soil,elevation,drainage density,NDVI,landuse landcover and inundation).
- ❖ Model GWPZ using Multi-Criteria Decision Analysis (MCDA) and the Analytical Hierarchy Process (AHP).
- ❖ Validate the model against existing Mineral Resources Authority (MRA) resistivity data

Methodology Overview

Flowchart illustrating the steps in generating a groundwater potential map

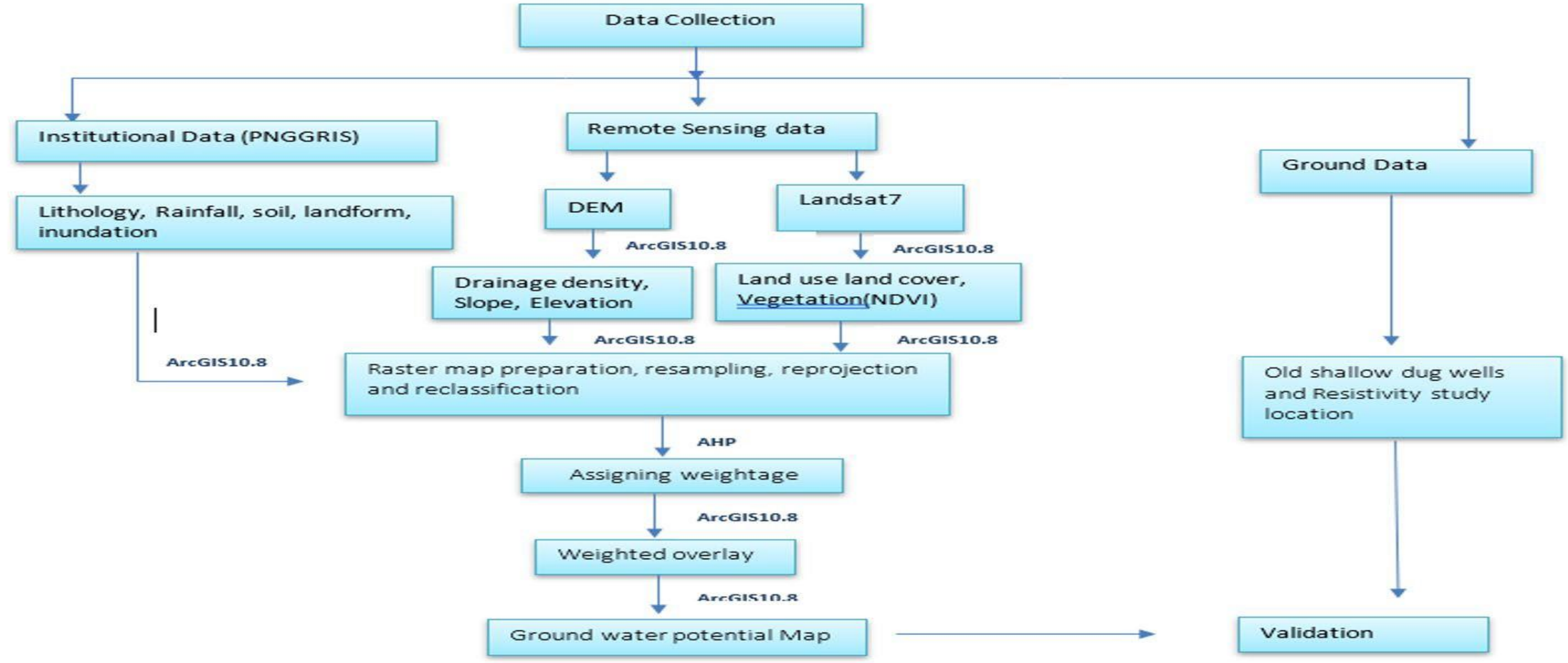


Fig.2. Flow chart showing the adapted methodology for this study

Table showing the data and their source for groundwater delineation.

Data Layers	Description	Scale/Resolution	Year	Source
Geomorphology/Landform	PNGRIS	1:500 000	1995	PNGRIS
4.Vegetation health	Landsat 7	30m	2025	USGS
Soil type	PNGRIS	1:500 000	1995	PNGRIS
Rainfall data	PNGRIS	1:500 000	1995	PNGRIS
Land use and Landcover	Landsat 7	30m	2025	USGS
Digital Relief (elevation)	*DEM*	90*m*	2025	PNG Lands & Survey Department
Slope	*DEM*	90*m*	2025	PNG Lands & Survey Department
Drainage Density	*DEM*	90*m*	2025	PNG Lands & Survey Department
Inundation	*PNGRIS*	*1:500 000*	*1995*	*PNGRIS*
lithology	*PNGRIS*	*1:500 000*	*1995*	*PNGRIS*

Multi-Criteria Analysis

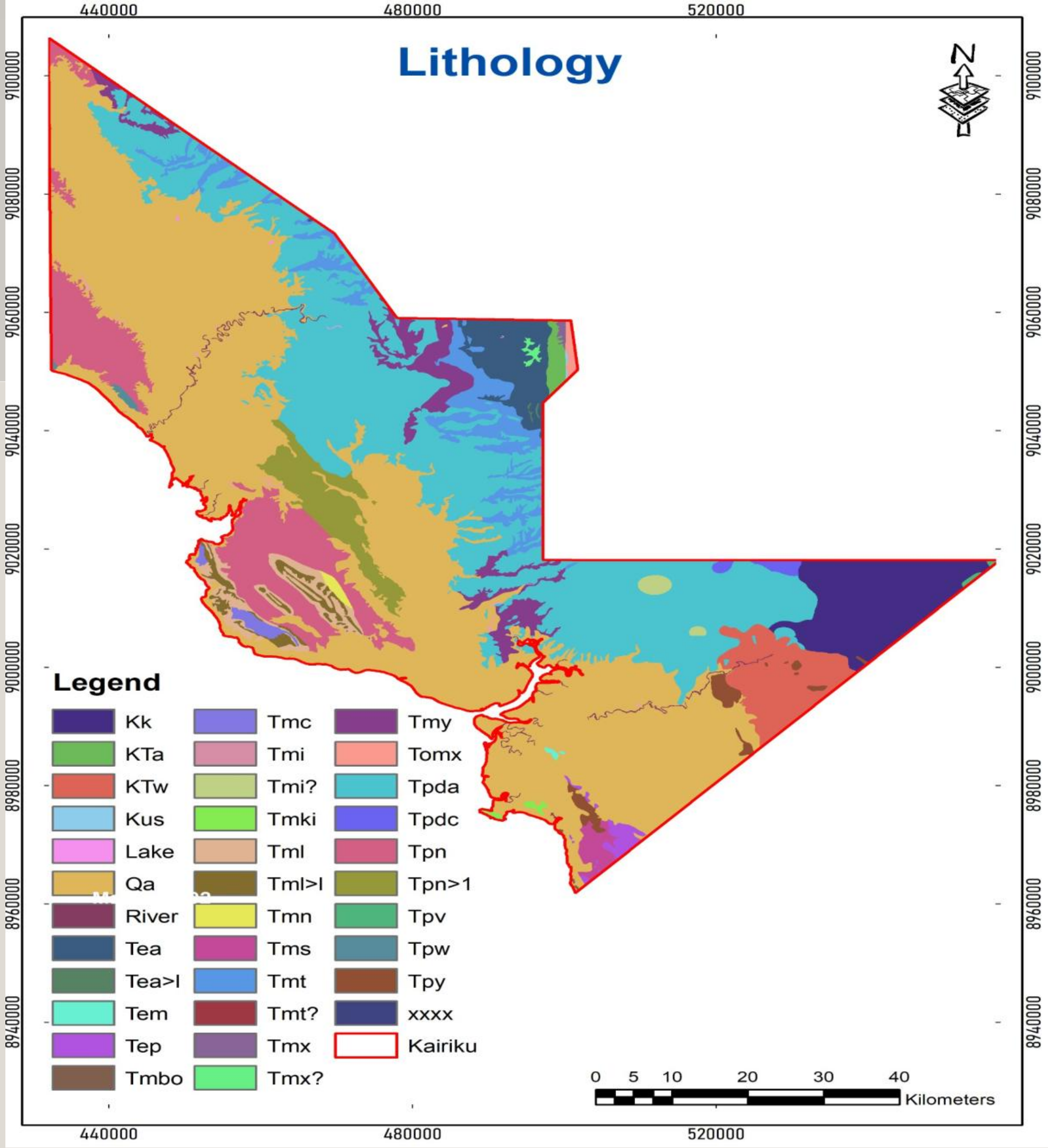
- Multicriteria Analytical hierarchy Process
- Pairwise Matrix table was used in calculating weightage for each parameters

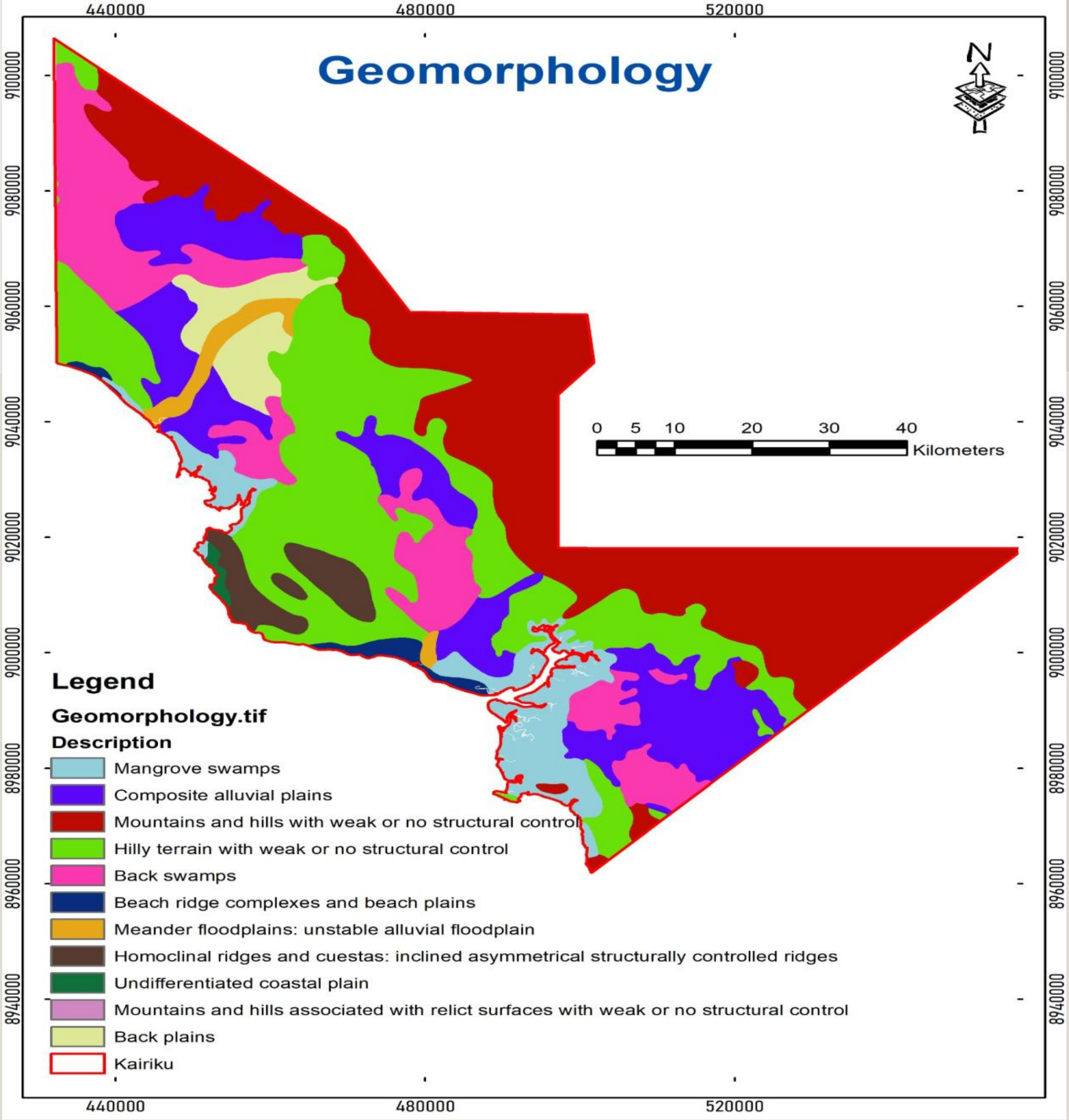
- **Factor Weighting:** Ten parameters were ranked, with **Lithology (0.138)** and **Rainfall (0.121)** receiving the highest weights.
- **Consistency:** The analysis achieved a Consistency Ratio (CR) of 0, indicating a perfectly consistent pairwise matrix (using Saaty's Random Index of 1.49 for n=10).
- **Formula:** GWP=∑(Wi·Xi).

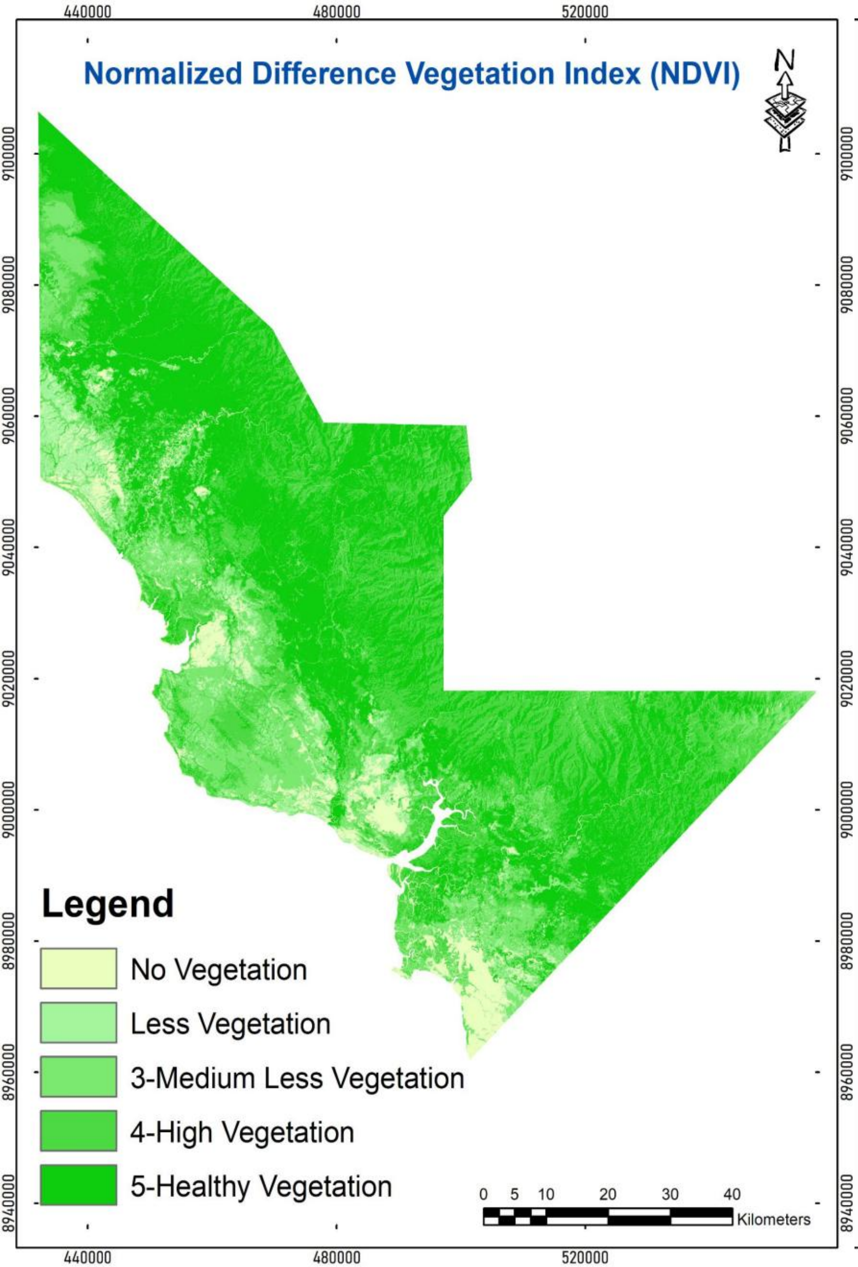
Pairwise Matrix

Factors	*Assigned weight*	*Lithology*	*Rainfall*	*Soil*	*Slope*	*Drainage Density*	*Vegetation (NDVI)*	*LULC*	*Elevation*	*landform*	*Inundation*	*Normalized Weight*
Lithology	8	8/8	7/8	8/5	8/5	8/7	8/5	8/6	8/4	8/7	8/4	0.137931034
Rainfall	7	7/8	7/7	7/5	7/5	7/7	7/5	7/6	7/4	7/7	7/4	0.120689655
Soil	5	5/8	5/7	5/5	5/5	5/7	5/5	5/6	5/4	5/7	5/4	0.086206897
Slope	5	5/8	5/7	5/5	5/5	5/7	4/5	5/6	5/4	5/7	5/4	0.086206897
Drainage Density	7	7/8	7/7	7/5	7/5	7/7	7/5	7/6	7/4	7/7	7/4	0.120689655
Vegetation (NDVI)	5	5/8	5/7	5/5	5/5	5/7	5/5	5/6	5/4	5/7	5/4	0.086206897
LULC	6	6/8	6/7	6/5	6/5	6/7	6/5	6/6	6/4	6/7	6/4	0.103448276
Elevation	4	4/8	4/7	4/5	4/5	4/7	4/5	4/6	4/4	4/7	4/4	0.068965517
landform	7	7/8	7/7	7/5	7/5	7/7	7/5	7/6	7/4	7/7	7/4	0.120689655
Inundation	4	4/8	4/7	4/5	4/5	4/7	4/5	4/6	4/4	4/7	4/4	0.068965517
Total		**7.25**	**8.286**	**11.6**	**11.6**	**8.286**	**11.6**	**9.667**	**14.5**	**8.286**	**14.5**	**1**

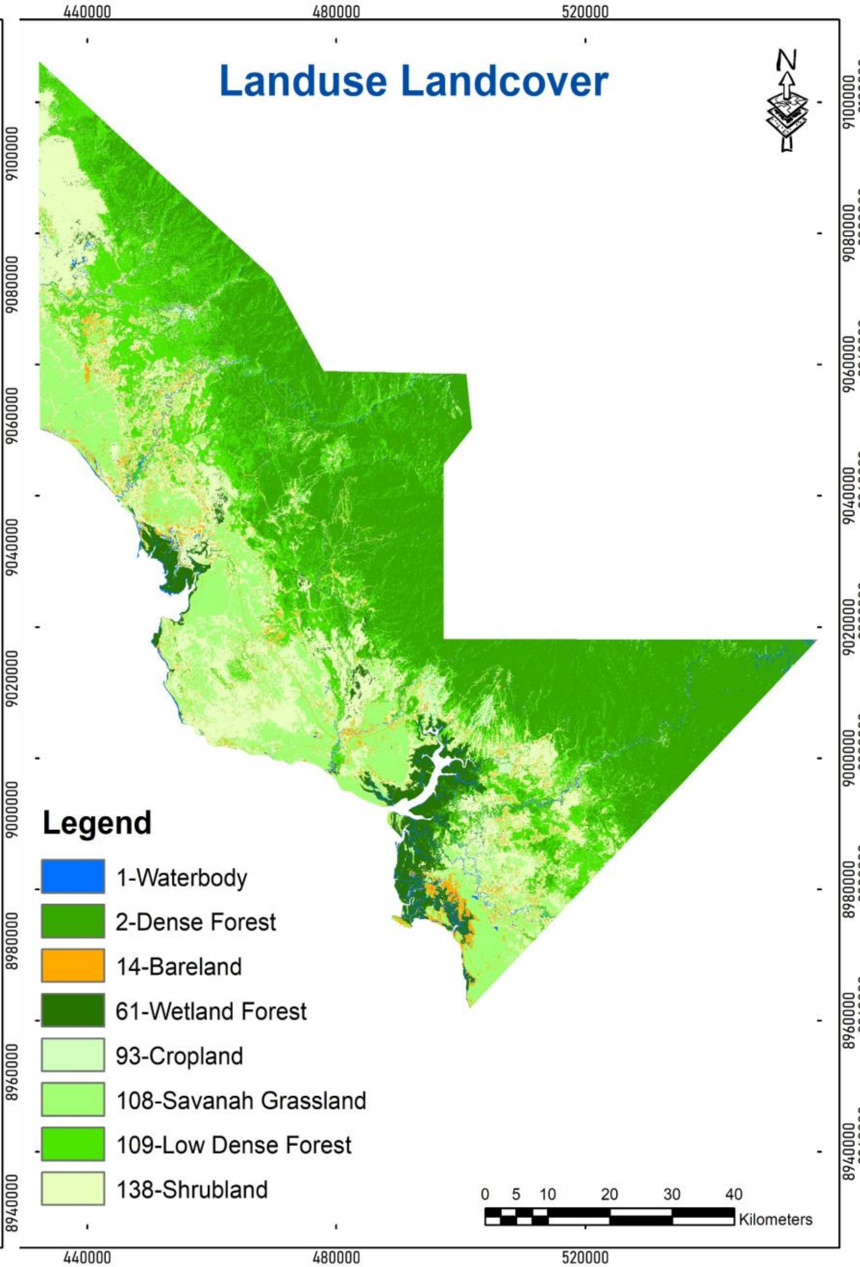
Rank	Parameter	Weightage	Reason for rank
8	**Lithology**	0.138	Governs permeability and storativity of water(colluvium and cast carbonate highest while shale lowest. Types of rock and soil determine how easily water can move and stored
7	**Rainfall**	0.121	Primary driver of recharge of groundwater
7	**Landform**	0.121	Alluvial plains, flood plains,beaches,ridge plains often host productive aquifer-Hills and mountains favour run off
7	**Drainage Density**	0.121	Low drainage density often correlate with infiltration and potential recharge-high drainage density suggest fast run off and less recharge
6	**Land use landcover**	0.103	Urban areas block water infiltration forest areas allows recharge
5	**Soil**	0.086	Control infiltration-sandy/loamy soil let water soak, clay and salty soil block water
5	**Vegetation**	0.086	Plants helps protect soil but use up water
5	**Slope**	0.086	Steeper slope increase runoff and reduce infiltration, gentle slope favours recharge
4	**Elevation**	0.121	Higher elevation affects water flow
4	**Inundation**	0.121	Brief inundation supports recharge,-permanent/tidal flooding brings salts and stop infiltration


Lithology
N
Legend
Kk
KTa
KTw
Kus
Lake
Qa
River
Tea
Tea>l
Tem
Tep
Tmbo
Tmc
Tmi
Tmi?
Tmki
Tml
Tml>l
Tmn
Tms
Tmt
Tmt?
Tmx
Tmx?
Tmy
Tomx
Tpda
Tpdc
Tpn
Tpn>1
Tpv
Tpw
Tpy
xxxx
Kairiku
0 5 10 20 30 40
Kilometers
440000
480000
520000
9100000
9080000
9060000
9040000
9020000
9000000
8980000
8960000
8940000

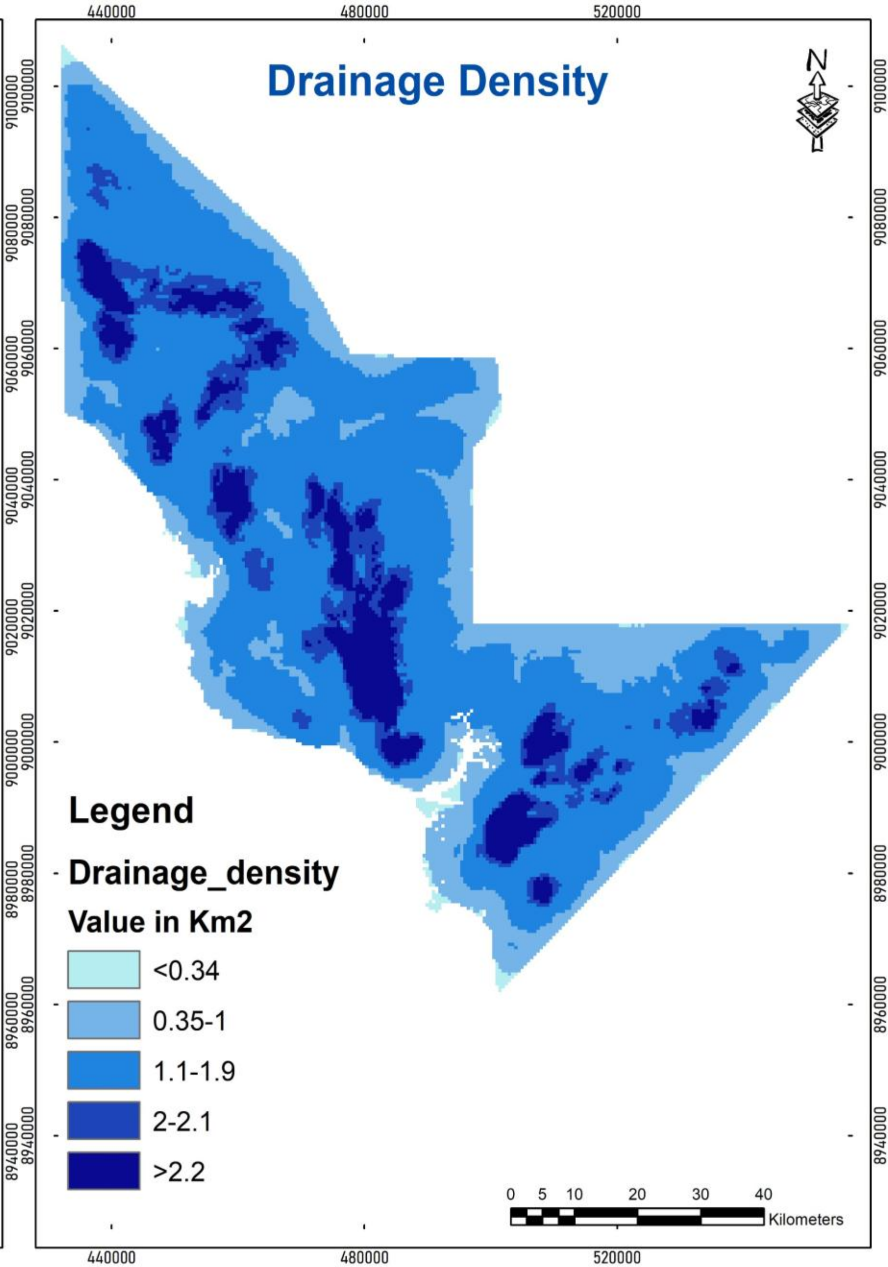

Geomorphology
N
0 5 10 20 30 40
Kilometers
Legend
Geomorphology.tif
Description
Mangrove swamps
Composite alluvial plains
Mountains and hills with weak or no structural control
Hilly terrain with weak or no structural control
Back swamps
Beach ridge complexes and beach plains
Meander floodplains: unstable alluvial floodplain
Homoclinal ridges and cuestas: inclined asymmetrical structurally controlled ridges
Undifferentiated coastal plain
Mountains and hills associated with relict surfaces with weak or no structural control
Back plains
Kairiku
440000
480000
520000
9100000
9080000
9060000
9040000
9020000
9000000
8980000
8960000
8940000



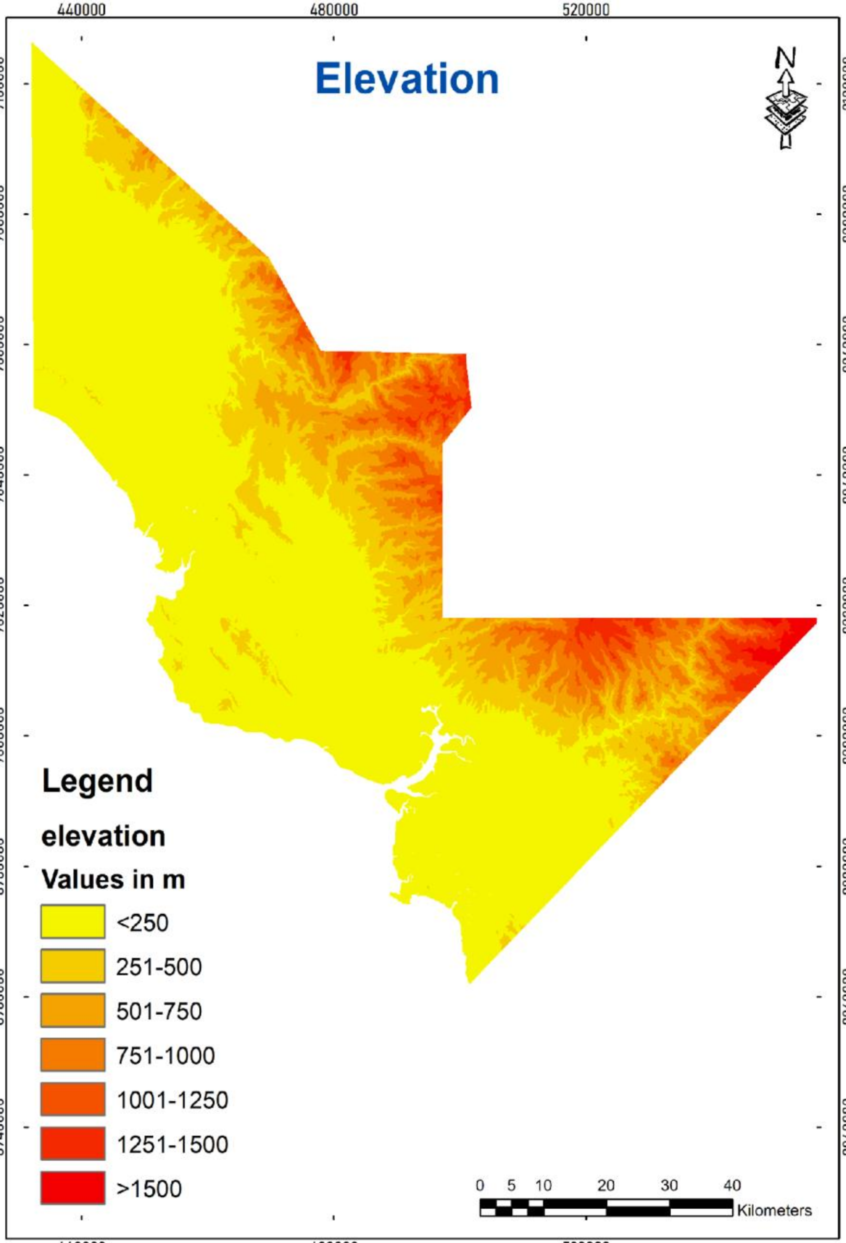
Normalized Difference Vegetation Index (NDVI)
Legend
No Vegetation
Less Vegetation
3-Medium Less Vegetation
4-High Vegetation
5-Healthy Vegetation
0 5 10 20 30 40 Kilometers



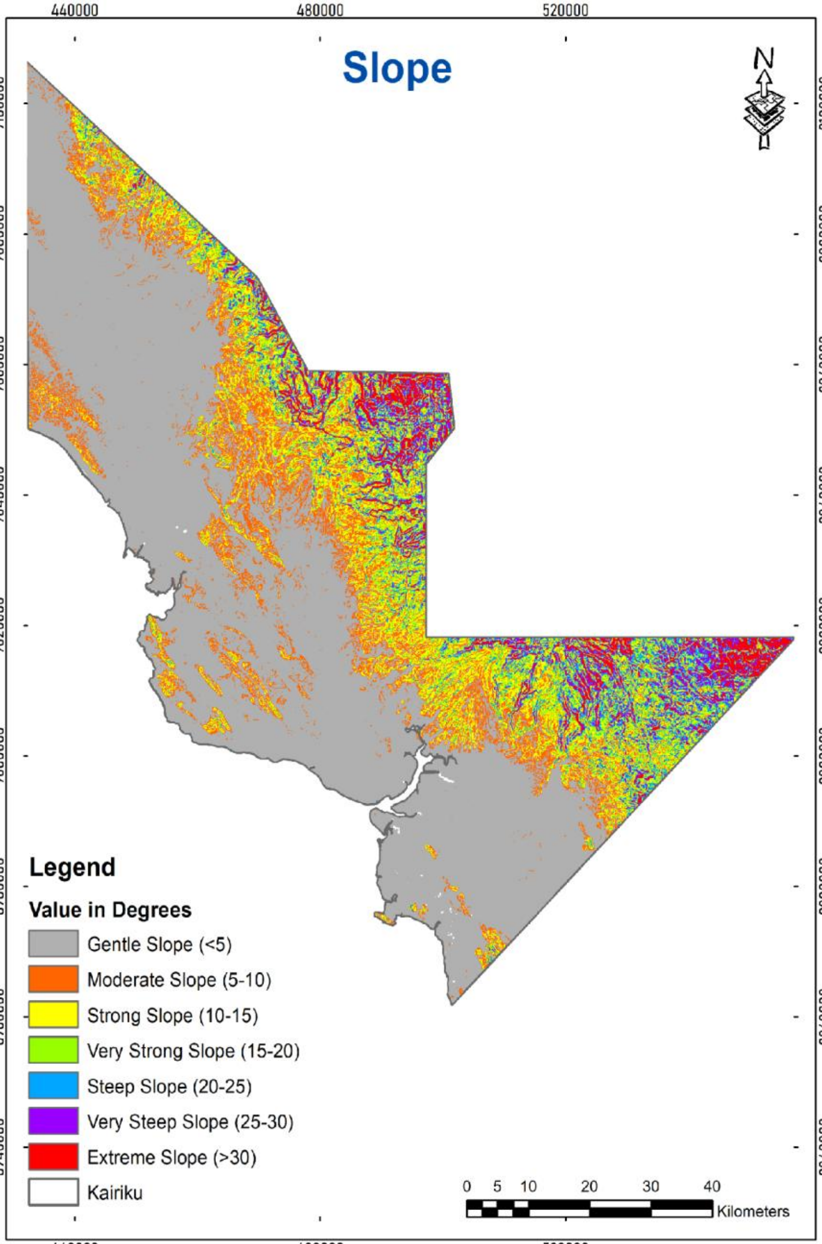
Landuse Landcover
Legend
1-Waterbody
2-Dense Forest
14-Bareland
61-Wetland Forest
93-Cropland
108-Savanah Grassland
109-Low Dense Forest
138-Shrubland
0 5 10 20 30 40 Kilometers



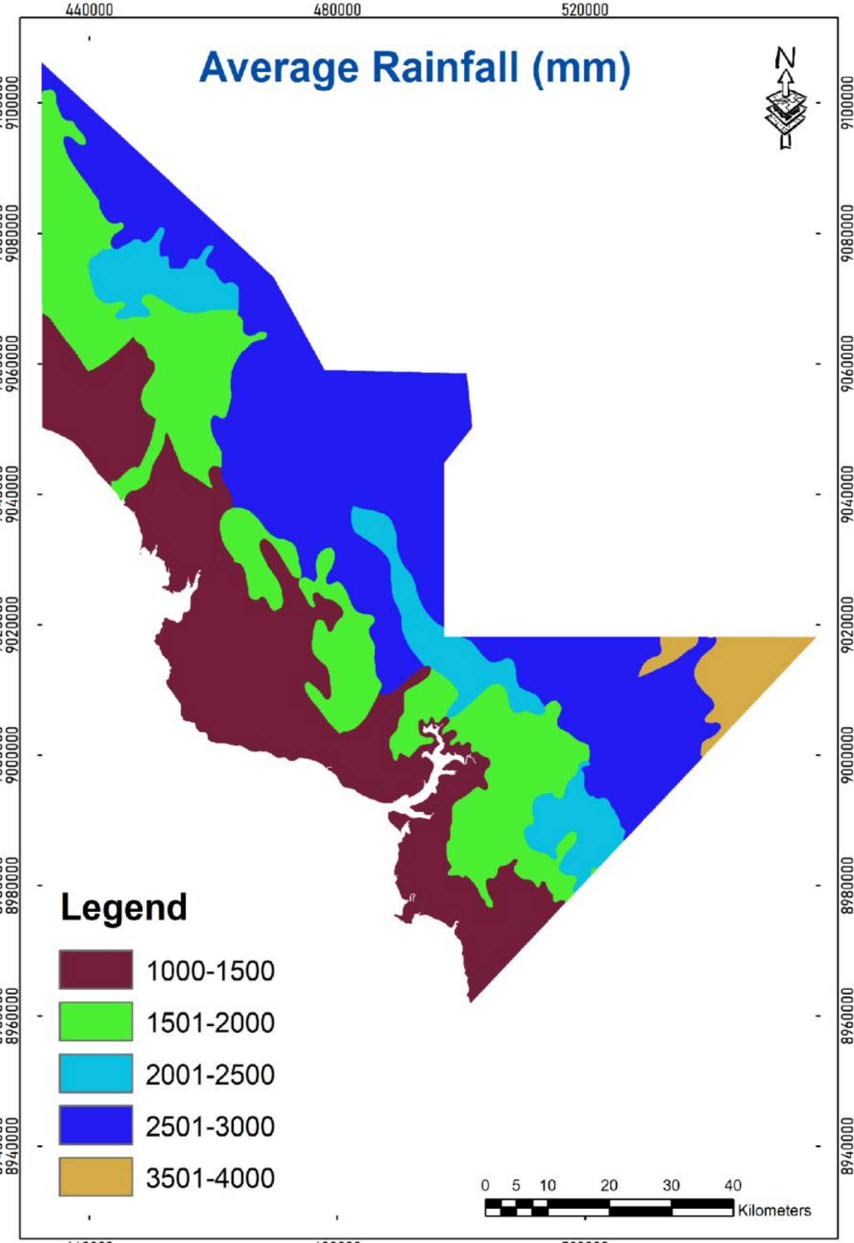
Drainage Density
Legend
Drainage_density
Value in Km2
<0.34
0.35-1
1.1-1.9
2-2.1
>2.2
0 5 10 20 30 40 Kilometers



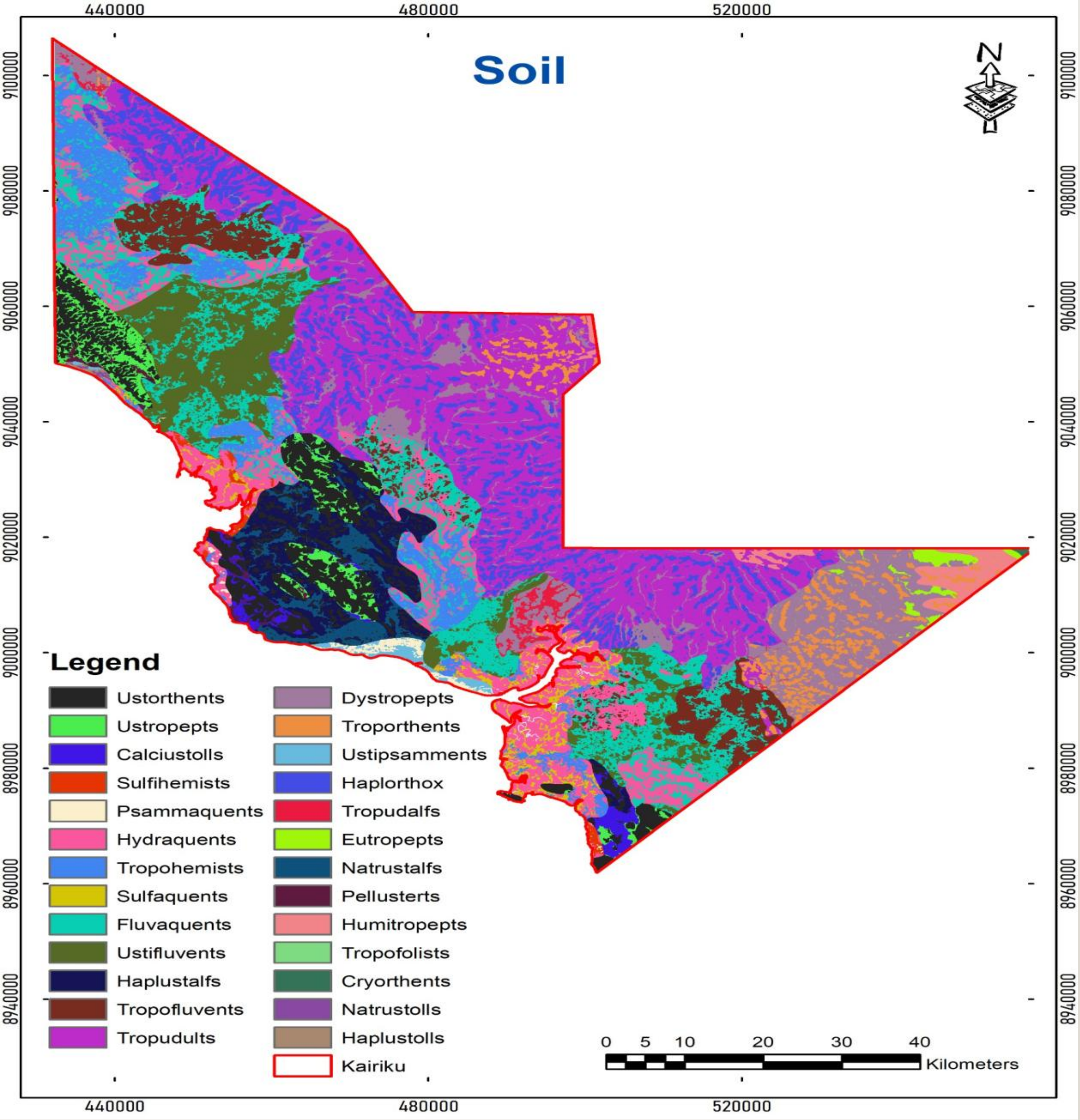
Elevation
N
Legend
elevation
Values in m
<250
251-500
501-750
751-1000
1001-1250
1251-1500
>1500
0 5 10 20 30 40
Kilometers
440000
480000
520000

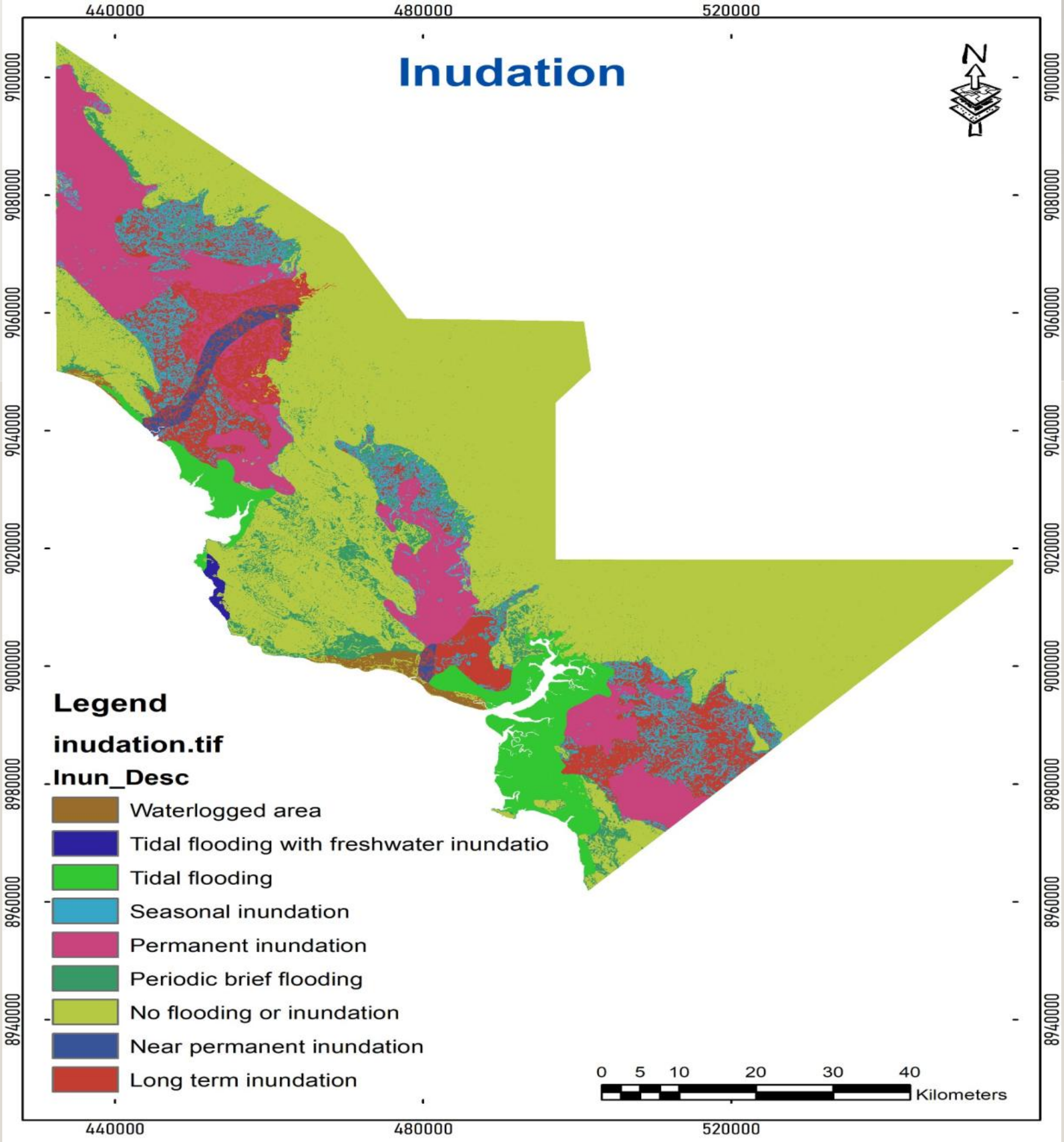


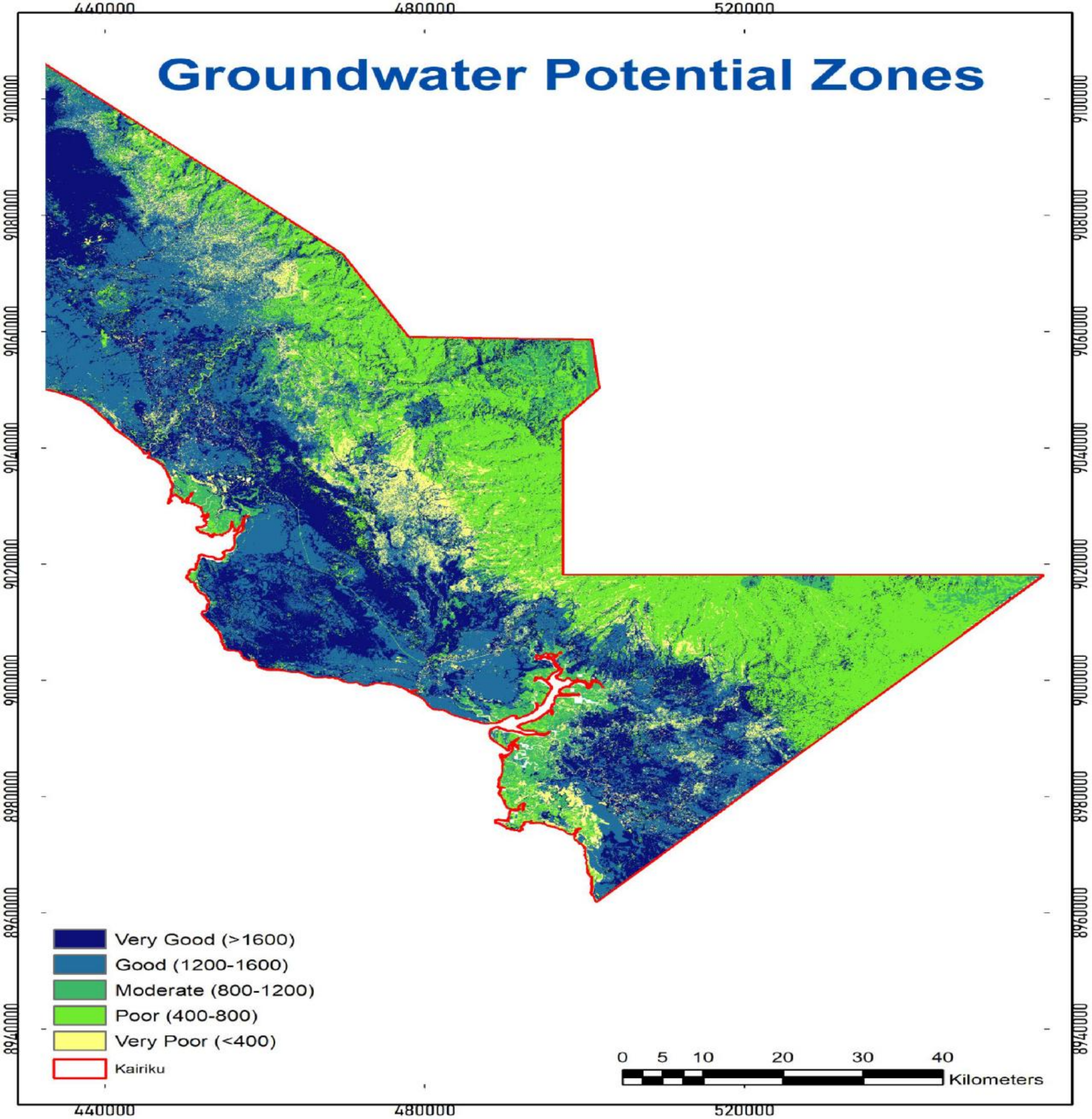
Slope
N
Legend
Value in Degrees
Gentle Slope (<5)
Moderate Slope (5-10)
Strong Slope (10-15)
Very Strong Slope (15-20)
Steep Slope (20-25)
Very Steep Slope (25-30)
Extreme Slope (>30)
Kairiku
0 5 10 20 30 40
Kilometers
440000
480000
520000

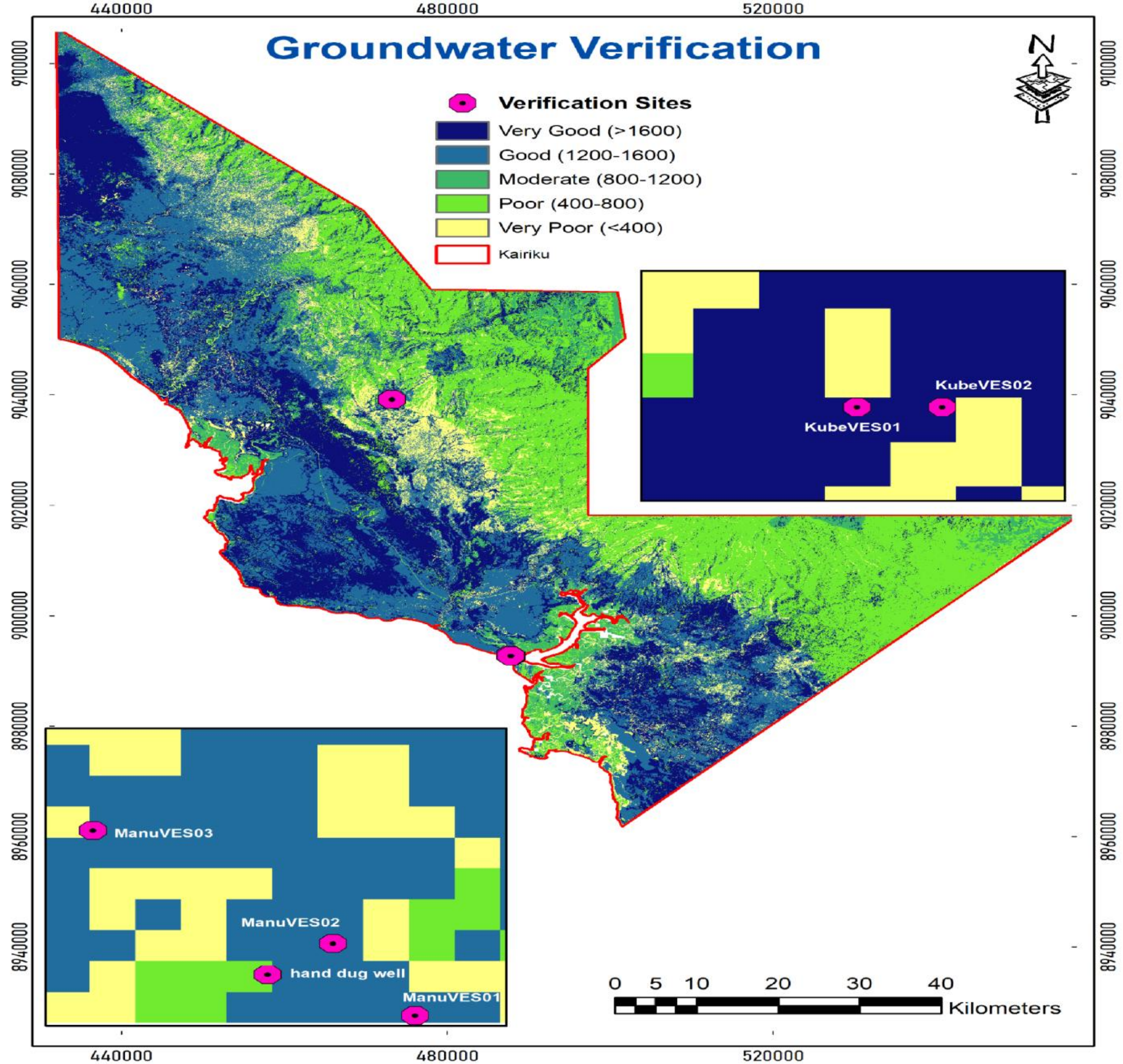


Average Rainfall (mm)
N
Legend
1000-1500
1501-2000
2001-2500
2501-3000
3501-4000
0 5 10 20 30 40
Kilometers
440000
480000
520000


Soil
Legend
Ustorthents
Ustropepts
Calciustolls
Sulfihemists
Psammaquents
Hydraquents
Tropohemists
Sulfaquents
Fluvaquents
Ustifluvents
Haplustalfs
Tropofluvents
Tropudults
Dystropepts
Troporthents
Ustipsamments
Haplorthox
Tropudalfs
Eutropepts
Natrustalfs
Pellusterts
Humitropepts
Tropofolists
Cryorthents
Natrustolls
Haplustolls
Kairiku
0 5 10 20 30 40 Kilometers
440000 480000 520000
9100000 9080000 9060000 9040000 9020000 9000000 8980000 8960000 8940000


Inudation
Legend
inudation.tif
Inun_Desc
Waterlogged area
Tidal flooding with freshwater inundatio
Tidal flooding
Seasonal inundation
Permanent inundation
Periodic brief flooding
No flooding or inundation
Near permanent inundation
Long term inundation
0 5 10 20 30 40 Kilometers
440000 480000 520000
9100000 9080000 9060000 9040000 9020000 9000000 8980000 8960000 8940000


Groundwater Potential Zones
Very Good (>1600)
Good (1200-1600)
Moderate (800-1200)
Poor (400-800)
Very Poor (<400)
Kairiku
0 5 10 20 30 40 Kilometers
440000
480000
520000
9100000
9080000
9060000
9040000
9020000
9000000
8980000
8960000
8940000


Groundwater Verification
N
Verification Sites
Very Good (>1600)
Good (1200-1600)
Moderate (800-1200)
Poor (400-800)
Very Poor (<400)
Kairiku
KubeVES02
KubeVES01
ManuVES03
ManuVES02
hand dug well
ManuVES01
0 5 10 20 30 40 Kilometers
440000
480000
520000
9100000
9080000
9060000
9040000
9020000
9000000
8980000
8960000
8940000

Validation and Field Findings

- **Kubuna Station:** VES01 (aquifer at 6.67–40.96m) and VES02 matched a "Very Good" zone
- **Manumanu Village:** ManuVES01,ManuVES02 and ManuVES03 matched Good Zone
- Detected brackish groundwater at shallow depths (1.3–3.1m); these sites generally fell within "Moderate" to "Poor" zones.
- **Verification:** Comparing the map with resistivity data provides confidence in the GIS model's accuracy.

Kubuna Station VES survey result

Sounding	layer	Resistivity (Ωm)	Thickness (m)	Depth (m)	Elevation (m)	Interpretation
VES01	1	100.37	1.66	0 – 1.66	60 – 58.35	Wet top soil
	2	173.46	1.61	1.66 – 3.27	58.35 – 56.73	Dry soil, sand
	3	71.06	3.40	3.27 – 6.67	56.73 – 53.33	Wet sand, silt, gravel
	4	15.68	34.29	6.67 – 40.96	53.33 – 19.04	Possible aquifer
	5	20.32	??	40.96 - ??	19.04 - ???	Continuation of possible aquifer

Sounding	Layer	Resistivity (Ωm)	Thickness (m)	Depth (m)	Elevation (m)	Interpretation
VES02	1	61.49	1.29	0.00 – 1.29	60.00 – 58.35	Dry top soil
	2	20.21	1.27	1.29 – 2.55	58.35 – 56.73	Wet soil, silt, sand
	3	71.06	3.90	2.55 – 6.46	56.73 – 53.33	Wet sand, gravel
	4	12.75	32.69	6.46 – 39.14	53.33 – 19.04	Possible aquifer
	5	20.59	??	39.14 - ??	19.04 - ??	Continuation of possible aquifer

Manumanu VES survey result

Sounding	Layer	Resistivity (Ωm)	Thick-ness (m)	Depth (m)	Elevation (m)	Interpretation
VES01	1	18.1	1.1	0.00 – 1.10	7.00 – 5.90	Dry top soil / sand
	2	2.0	2.0	1.10 – 3.10	5.90 – 3.90	Wet soil, sand
	3	0.6	??	3.10 - ??	3.90 - ??	Brackish water

Table 3: Modelled results and interpretation of ManuVES01.

7.2.2 Resistivity Sounding_ManuVES02

ManuVES02 was conducted in front of the main entrance of the Manu Manu Primary School at an approximate location of 487834 mE and 8992737 mN and elevation of 8 m above sea level. It was oriented in the E-W direction (or bearing of 89 ^{0}) and had a maximum current electrode spacing of 200 m (or AB/2 = 100 m).

Sounding	Layer	Resistivity (Ωm)	Thick-ness (m)	Depth (m)	Elevation (m)	Interpretation
VES01	1	959.40	1.1	0.00 – 1.10	8.00 – 6.90	Dry top soil / sand
	2	17.2	0.4	1.10 – 1.50	6.90 – 6.50	Wet soil, sand
	3	3.2	??	1.50 - ??	6.50 - ??	Brackish water

Table 4: Modelled results and interpretation of ManuVES02.

7.2.3 Resistivity Sounding_ManuVES03

ManuVES03 was conducted along the main road toward the Manu Manu Village and Primary School at an approximate location of 487834 mE and 8992737 mN and elevation of 5 m above sea level. It was oriented in the E-W direction (or bearing of 93 ^{0}) and had a maximum current electrode spacing of 200 m (or AB/2 = 100 m).

Sounding	Layer	Resistivity (Ωm)	Thick-ness (m)	Depth (m)	Elevation (m)	Interpretation
VES01	1	3.7	1.10	0.00 – 1.10	5.00 – 3.90	Wet top soil / sand
	2	7.7	0.20	1.10 – 1.30	3.90 – 3.70	Dry road sand, gravel
	3	0.5	??	1.30 - ??	3.70 - ??	Brackish water

Table 5: Modelled results and interpretation of ManuVES03.

Pictures of the shallow hand-dug wells

Kubuna

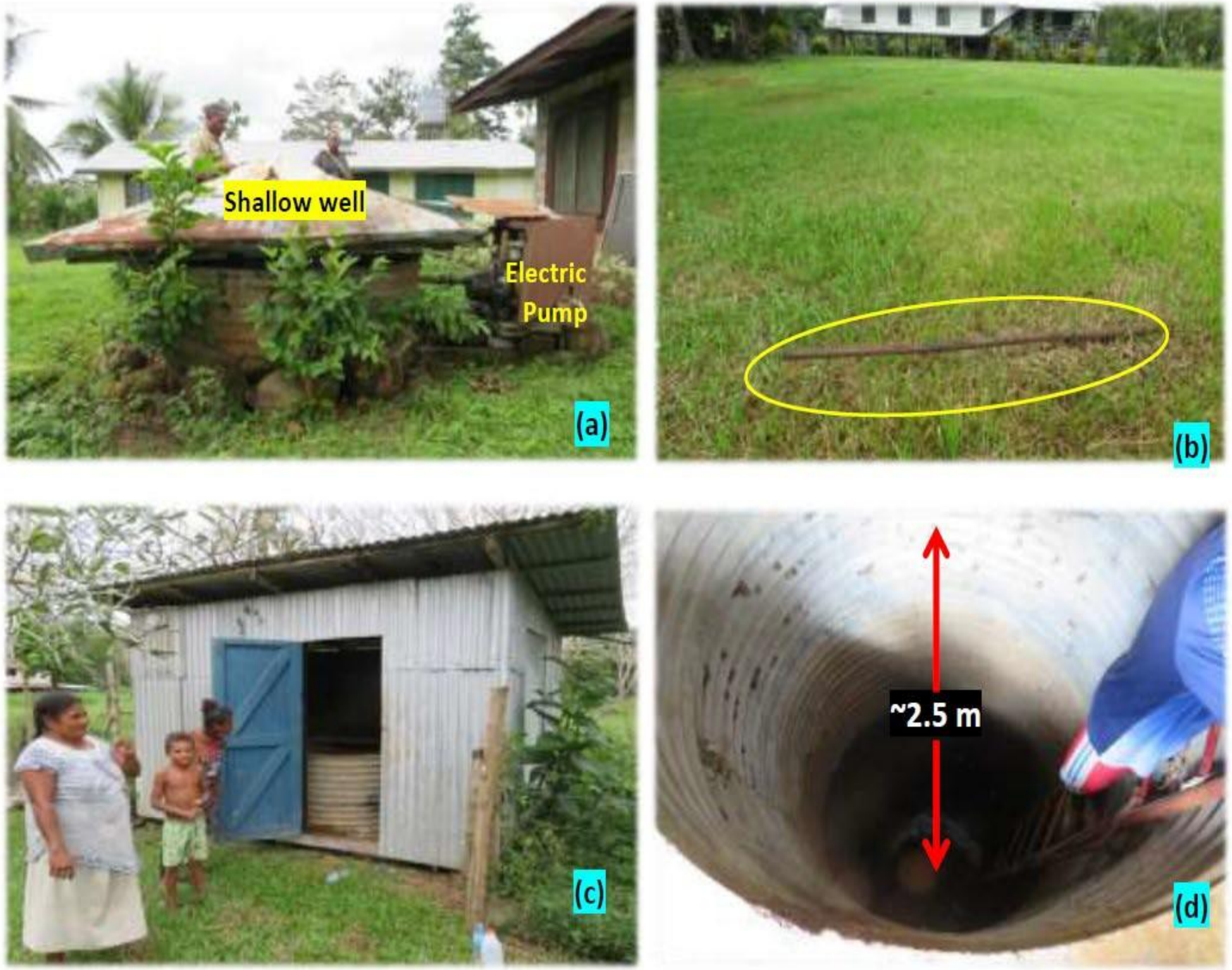


Figure 3: Water supply system at Kubuna. (a) Shallow well near priest's residence. (b) Remains of 20 mm water supply pipe (yellow circle) from the spring located 500 m west. (c & d) Shallow well near the Pastoral Centre building.

Manumanu

Figure 4: Current Manu Manu Village Water Supply System: *(a) Shallow well at Manu Manu School. (b) Shallow well at the councillor's house at the village. (c) Abandoned shallow well at Kubuna School. (d) Staff house at Manu Manu School with a 2000 L tuffa tank for collecting rainwater.*

Conclusion & Significance

- **Impact:** The study provides a practical guide for hydrogeologists to plan detailed investigations and identifies sites for community water pumps.
- **Community Benefit:** Supports agriculture and strengthens resilience against water scarcity.
- **Future Work:** Recommendation to further validate the map with future borehole data

END OF PRESENTATION