EASTERN AFRICA CRUDE OIL PIPELINE (EACOP)

THE GIS ROUTING EXPERIENCE

ENERGY SECTOR GIS WORKING GROUP

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SKY HOTEL, KAMPALA
13th September 2018

PRESENTATION OUTLINE

EACOP Routing: The GIS Experience

- Introduction
- Overview of the oil and gas sector in Uganda
- Back ground: Pipeline in Uganda
- Criteria for Pipeline Routing
- Data collection and Analysis
- Results
- Conclusions

INTRODUCTION

THE PETROLEUM VALUE CHAIN

LICENSING
EXPLORATION
DEVELOPMENT
PRODUCTION

→ **UPSTREAM**

TRANSPORTATION
REFINING
GAS PROCESSING

→ **MIDSTREAM**

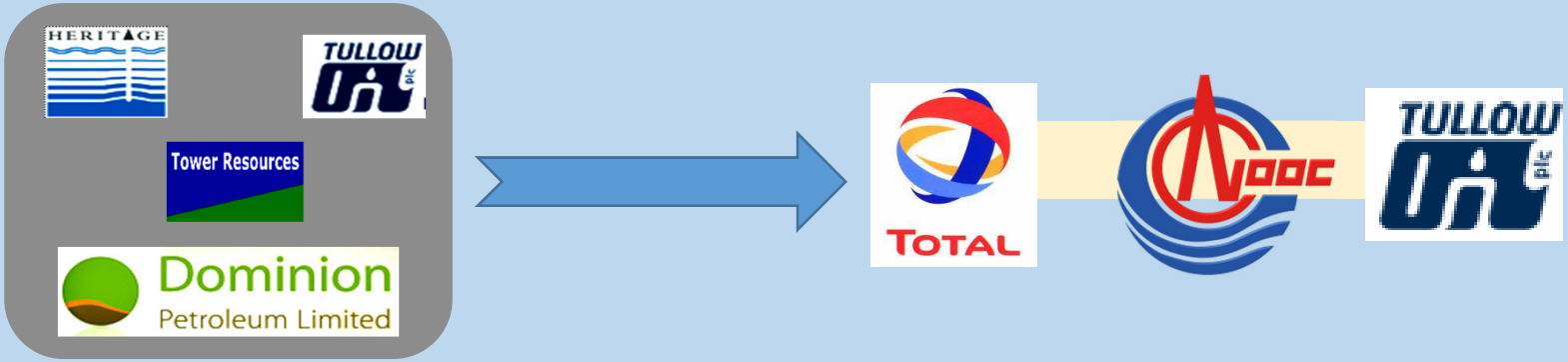
DISTRIBUTION
MARKETING
SALES

→ **DOWNSTREAM**

OVERVIEW OF THE OIL AND GAS SECTOR IN UGANDA

- Changed from small independent companies to large International oil companies after first commercial discovery

- 4 licenses with Three companies; CNOOC, Total and Tullow.



- New Licensees – Armour Energy, Oranto Petroleum

armour energy

4

OVERVIEW OF THE OIL AND GAS SECTOR IN UGANDA

2006 – Commercial Discovery

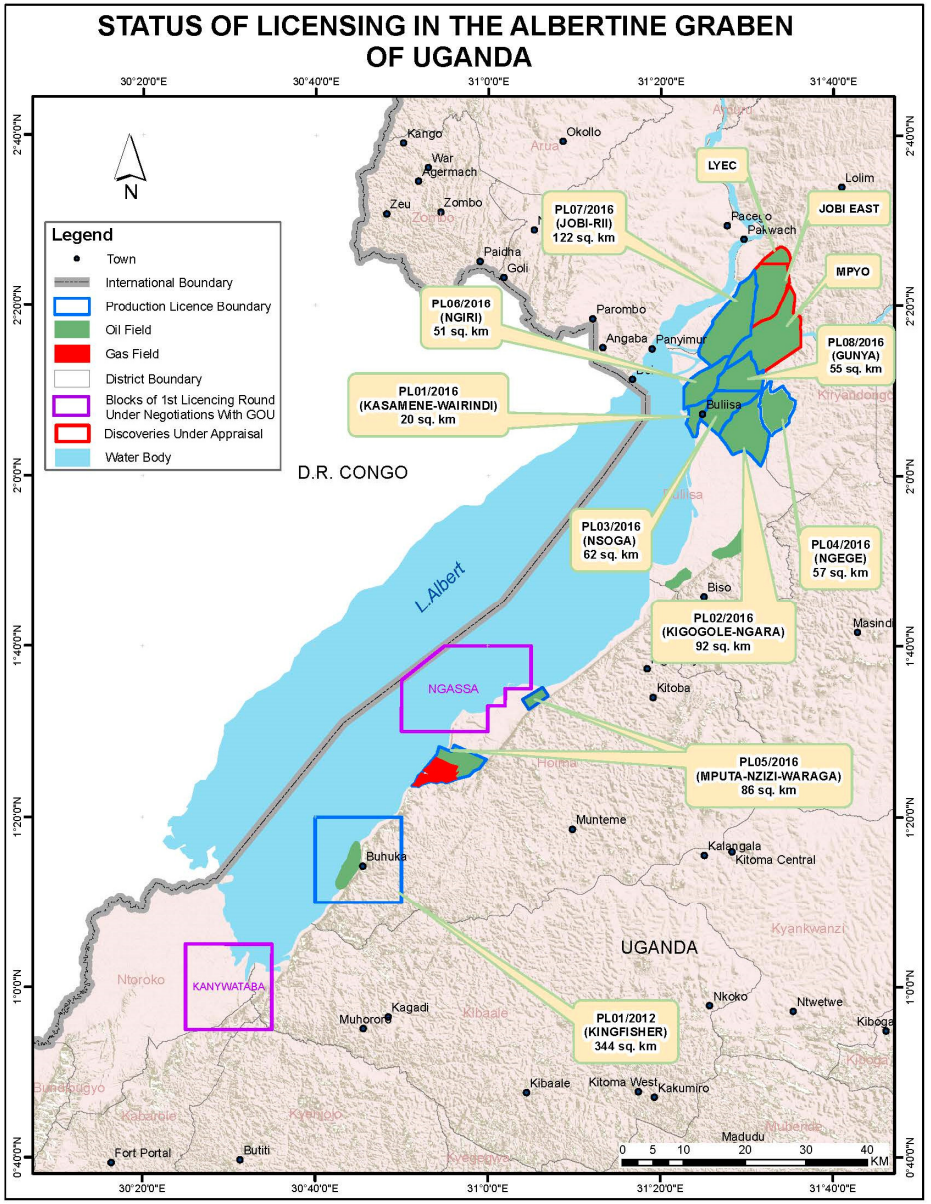
21 Discoveries; 88% drilling success rate

6.5 BBLS STOIIP; 1.4 billion reserves

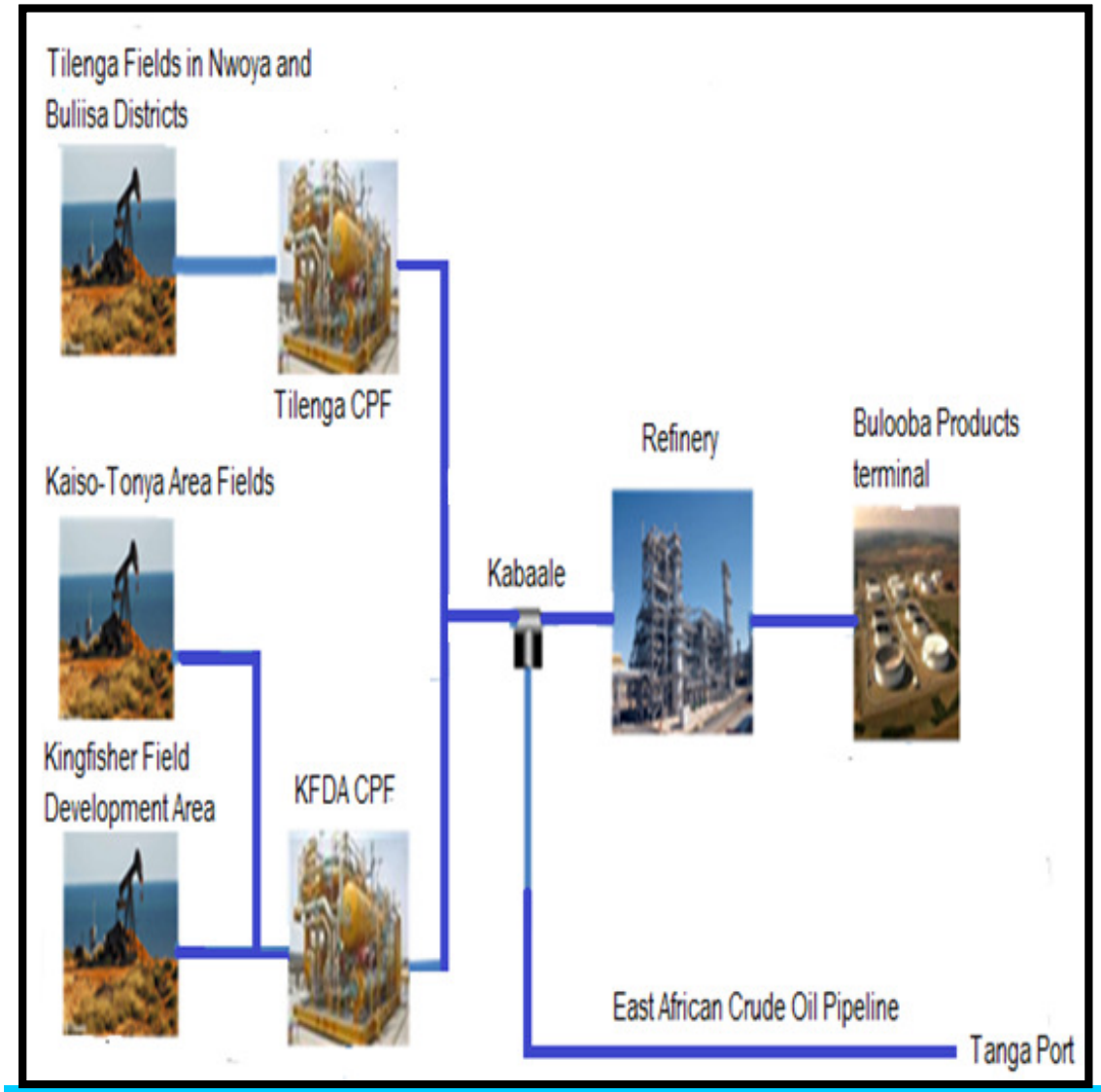
9 production licenses over 14 discoveries

10% of Albertine Graben Licensed

3 New exploration licenses issued in 2017



OVERVIEW OF THE PIPELINES



FACILITIES

Feeder Pipelines

- Northern 97km long from Tilenga CPF
- Southern 47km long from KFDA CPA

Refinery

- 60k barrels of oil refinery in Hoima

Product Pipelines

- 205km long Products pipelines

East African Crude Oil Pipeline

- 1445km long Hoima to Tanga Port pipeline (EACOP)

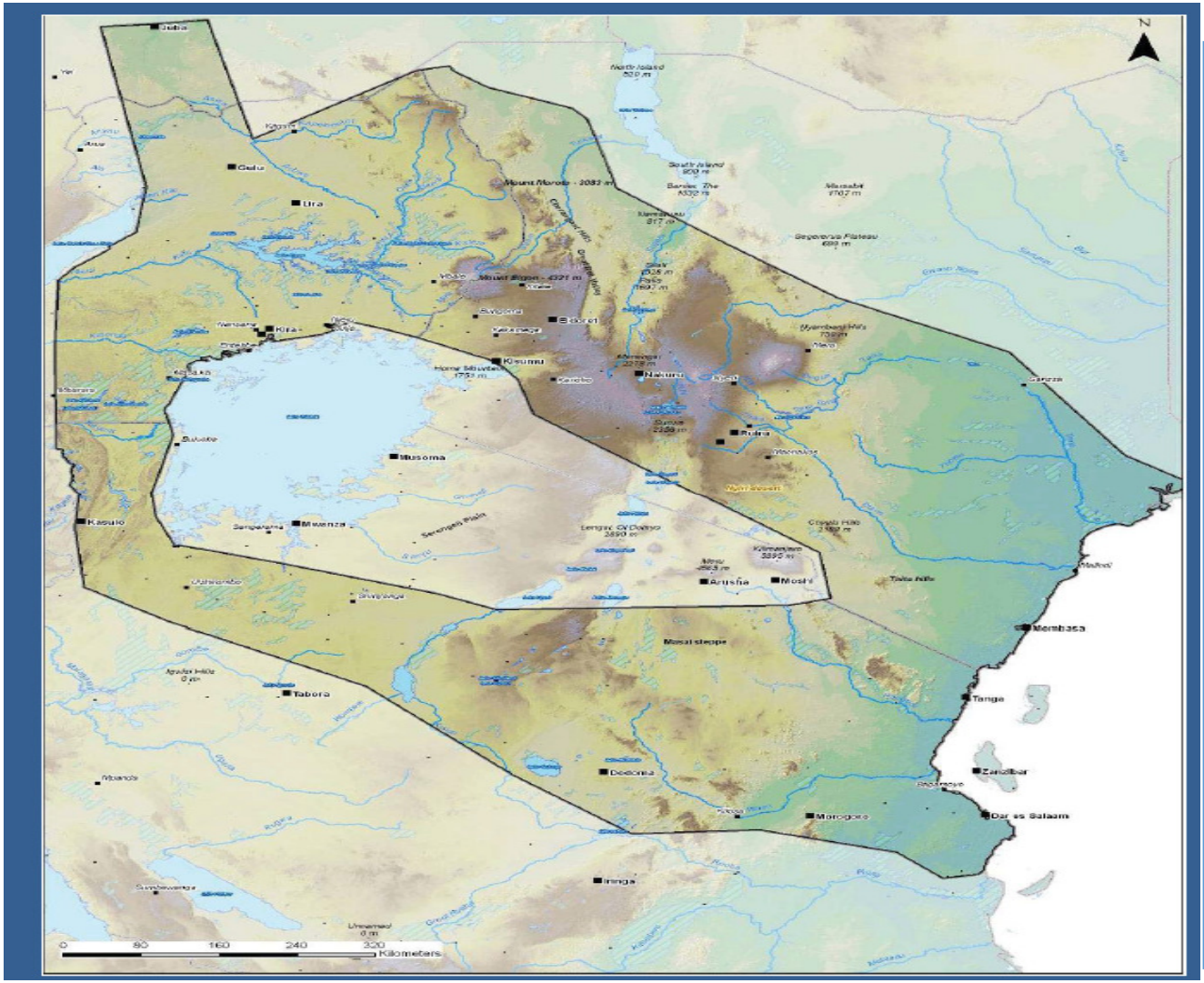
OIL EXPORT PEPELINE –GIS ROUTING STUDY

MAIN OBJECTIVE: Identify and select the preferred pipeline route and alternatives.

3 PHASES

- **PHASE 1:** GIS Risk Based Pipeline Routing Study (Scale 1:200,000)
- **PHASE 2 :** Manual Routing Improvement Using High Resolution Satellite Imagery (Scale 1:50000) and Lidar Data.
- **PHASE 3:** Ground Truthing / Field based investigations

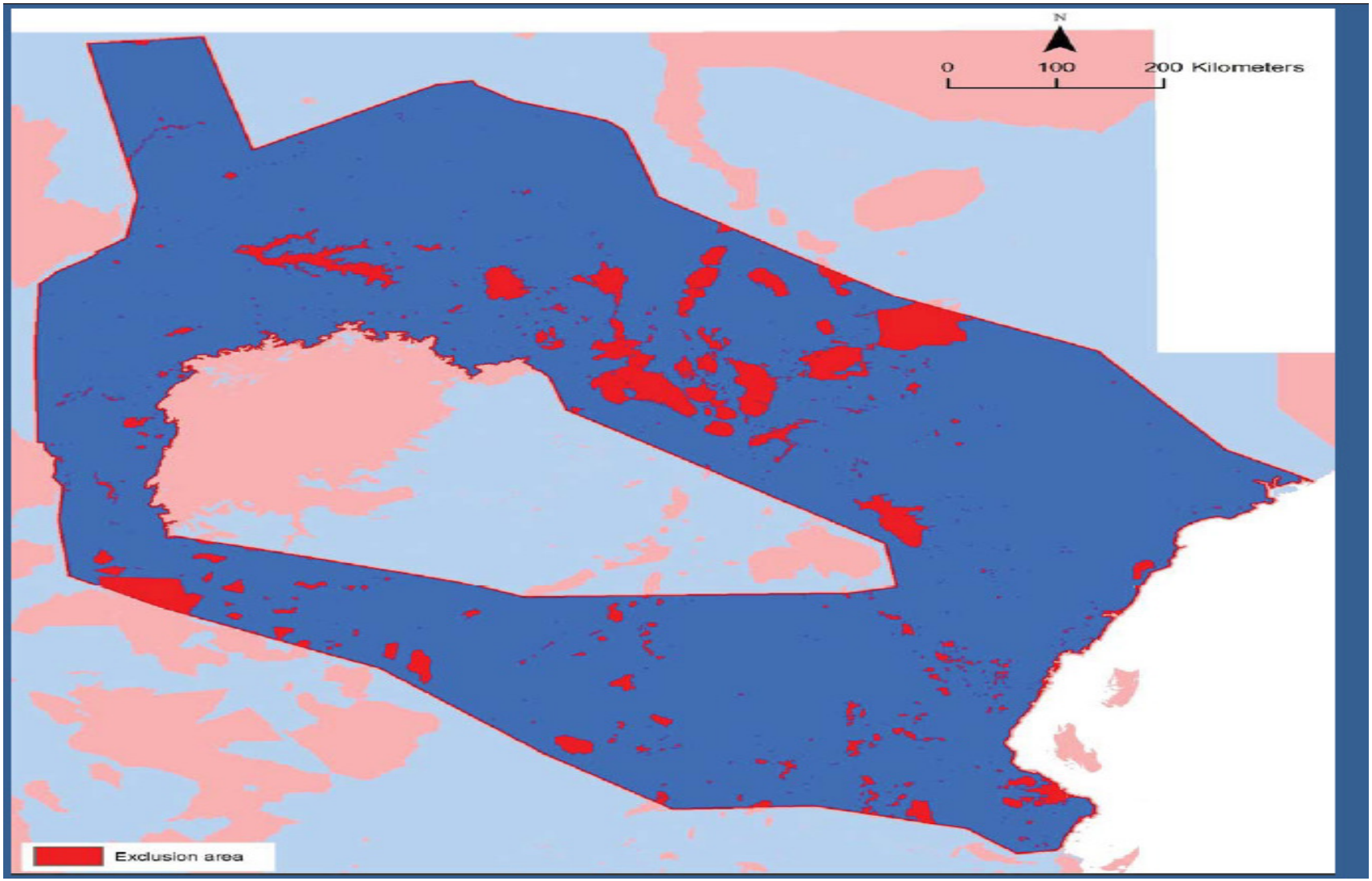
PHASE 1: GIS Risk Based Pipeline Routing Study



- ✓ Identification of area of interest (AOI)

From Hoima to the Indian ocean coastline excluding areas with slopes above 45 degrees, Main Cities, Lake crossing, Elevation above 2500m, Active Volcanoes, 1km from Archaeological & Tourist sites, and Protected areas.

AOI (Exclusion Area)



PHASE 1: GIS Risk Based Pipeline Routing Study

✓ Development of a GIS database at scale 1: 200000

Infrastructure, land use, environment, geo hazards (Volcanoes. Seismic, flooding, etc.), tourism, archeology and heritage, hydrology, population among others. Harmonizing data for Kenya, Uganda, Tanzania and Southern Sudan.

✓ Identification and prioritization risk factors and their impact on pipeline cost

Five thematic risks were considered

Construction, operational, socioeconomic, environmental and security

Construction	1	Building cost over high slopes
	2	Urban construction cost
	3	Crossing cost
	4	ROW distance from existing infrastructures
	5	Shallow or surface bedrock requiring blasting
	6	Lakes and wetlands crossing

PHASE 1: GIS Risk Based Pipeline Routing Study (thematic risks)

Operational	7	Seismic activity damage in Ag
	8	Active fault crossing and active rifting
	9	Landslide threat
	10	Extreme temperature in soil
	11	Limited access to pipeline
	12	High elevation
	13	Volcanic activity damage
	14	Flooding hazard damage
	15	Liquefaction susceptibility
Socio-Economic	16	Agriculture impact
	17	Pollution of populated areas
	18	Cultural & archaeological heritage
	19	Touristic degradation
Environmental	20	Wetlands and rivers geothermal fields/springs pollution
	21	Deforestation (of non protected forests)
	22	Sensitive and protected areas damage
Security	23	Area of conflict
	24	Sabotage damage

PHASE 1: GIS Risk Based Pipeline Routing Study

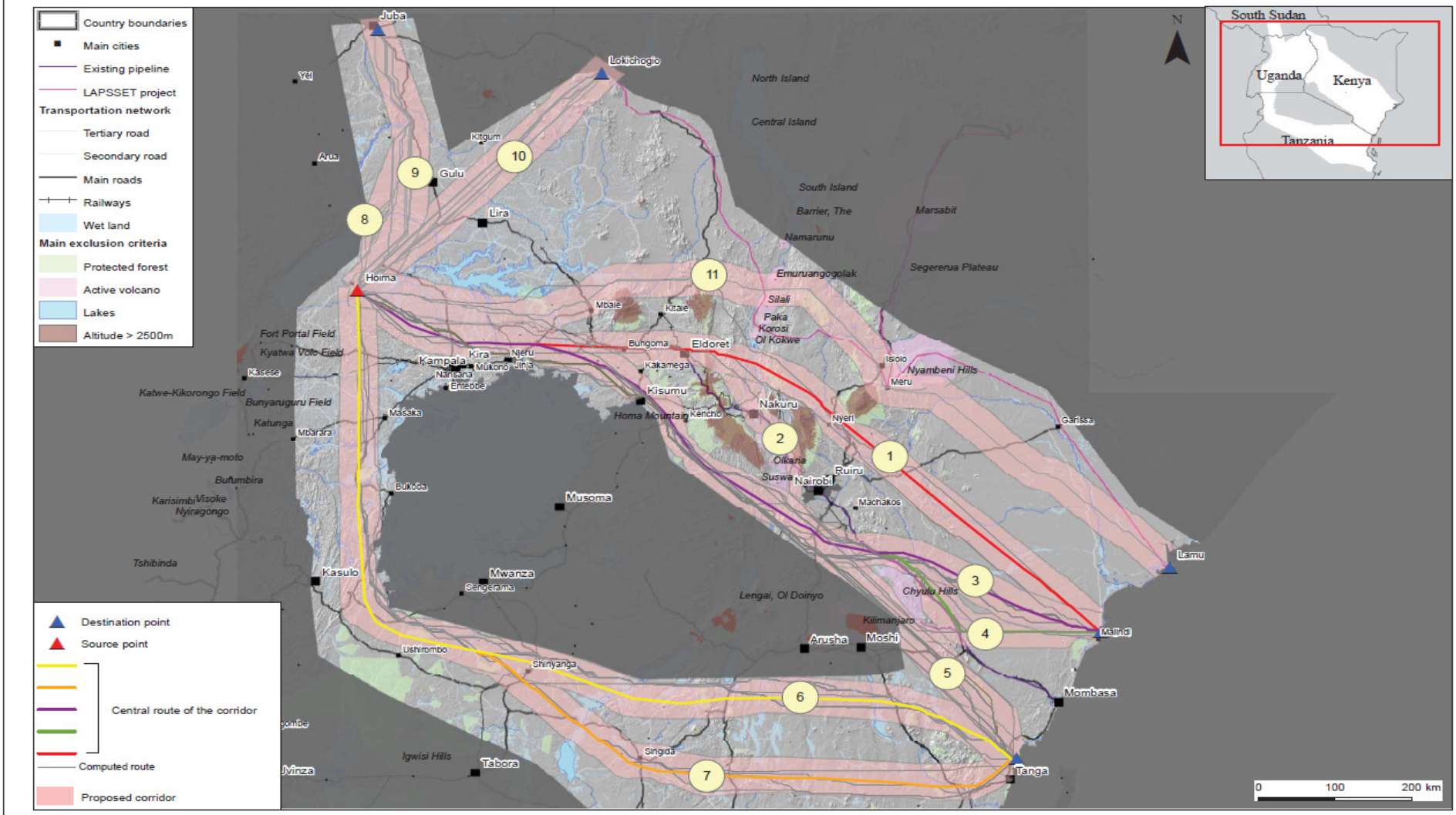
✓ Development of GIS tool to calculate least costly route using weighted index

Analytical hierarchy Process(AHP) method was chosen as it uses pairwise comparison and each factor is characterized by an index according to the relative importance of that factor.

- Agreed end points at the Indian Ocean.
- Malindi / Lamu at the Kenyan coast
- Tanga along the Tanzanian coast
- Juba in South Sudan
- Lokichogio in Kenya

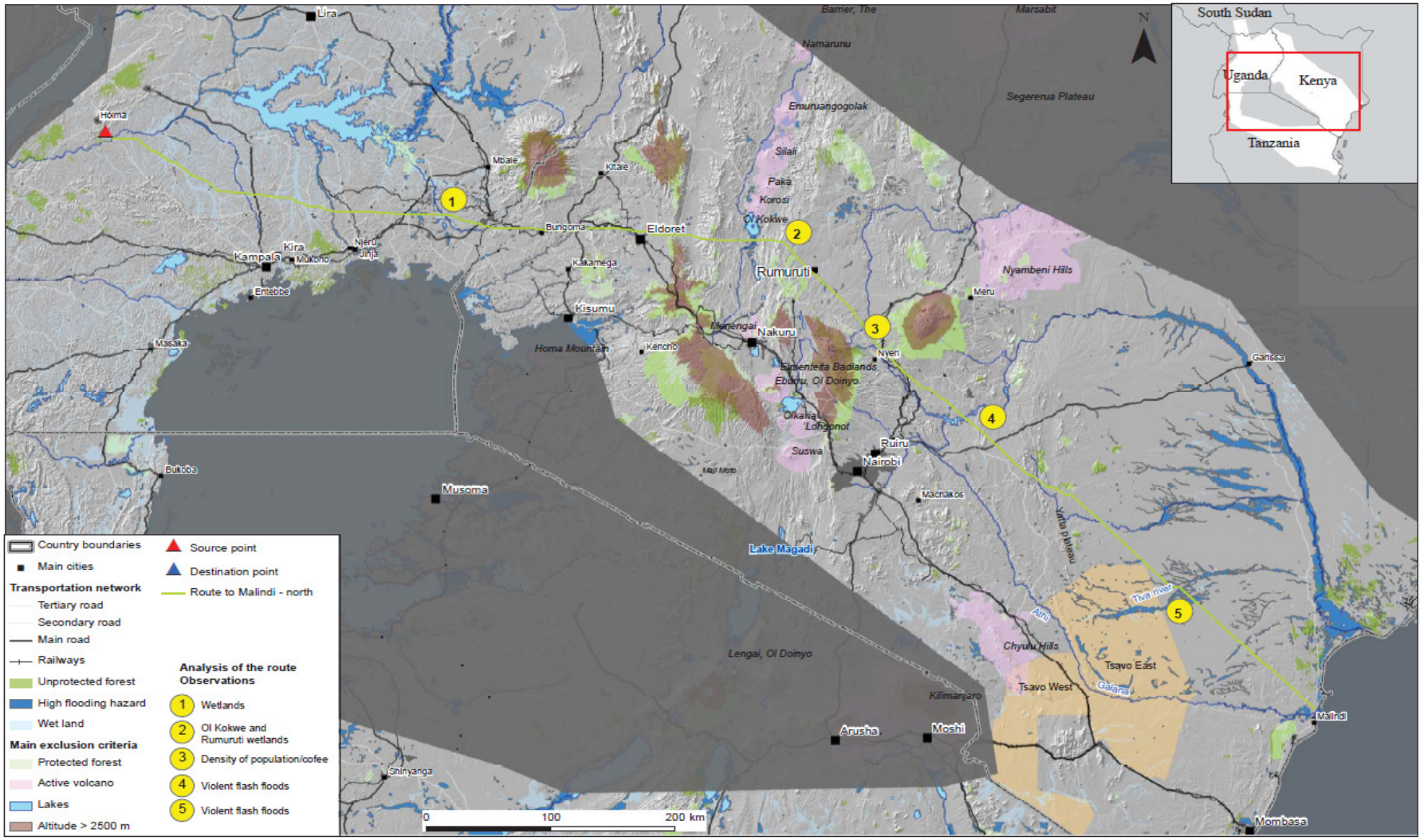
	GEOTER	TOTAL CNOOC	TULLOW CNOOC	Common agreement GEOTER/TOTAL TULLOW/CNOOC
1 - Building cost over high slopes	0.030	0.028	0.045	0.060
2 - Urban construction cost	0.060	0.060	0.033	0.024
3 - Crossing cost	0.119	0.060	0.103	0.121
4 - ROW distance from existing infrastructures	0.014	0.017	0.015	0.014
5 - Shallow or surface bedrock constructibility	0.119	0.060	0.103	0.060
6 - Wetlands crossing	0.060	0.060	0.057	0.060
9 - Seismic activity damage	0.014	0.017	0.010	0.012
10 - Active fault crossing and active rifting	0.119	0.114	0.103	0.121
11 - Landslide threat	0.036	0.114	0.057	0.060
12 - Extreme temperature in soil	0.014	0.017	0.013	0.013
13 - Limited access to pipeline	0.014	0.017	0.015	0.013
14 - Elevation	0.119	0.168	0.103	0.121
15 - Volcanic activity damage	0.014	0.017	0.010	0.013
16 - Flooding hazard damage	0.018	0.017	0.022	0.019
17 - Liquefaction susceptbility	0.024	0.028	0.033	0.018
18 - Agriculture impact	0.060	0.028	0.033	0.060
19 - Pollution of populated areas	0.014	0.017	0.033	0.012
20 - Cultural & archaeological heritage	0.014	0.017	0.013	0.013
21 - Touristic degradation	0.014	0.017	0.013	0.013
23 - Wet lands and rivers geothermal fields/springs	0.018	0.017	0.033	0.033
24 - Deforestation	0.014	0.017	0.015	0.015
25 - Sensitive and protected areas damage (RAMSAR)	0.060	0.060	0.103	0.103
27 - Area of conflict	0.015	0.017	0.017	0.017
28 - Sabotage damage	0.015	0.017	0.017	0.017

Identification of 50km wide corridors



Hoima to Malindi

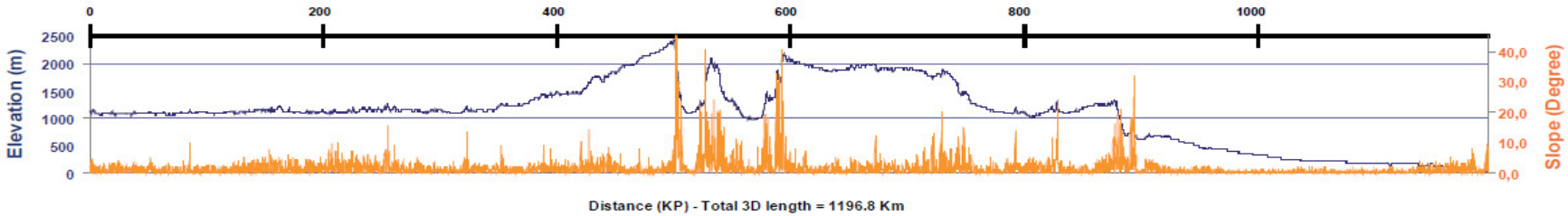
Hoima to Malindi – Corridor 1, North - Analysis of the socio-economic and environmental constraints | FIGURE: 12

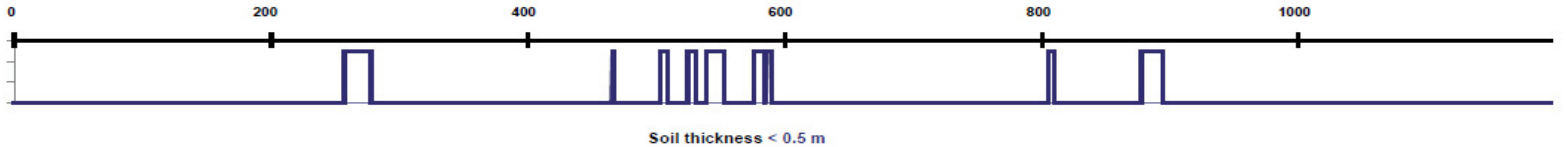


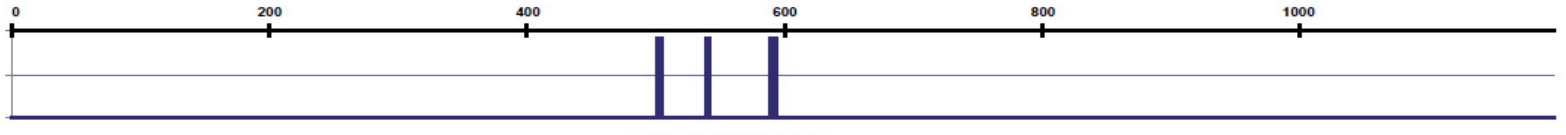
Hoima to Malindi

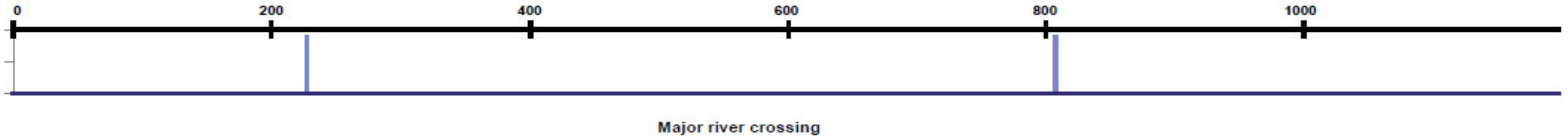
Hoima to Malindi – Corridor 1, North - Profile

FIGURE: 13





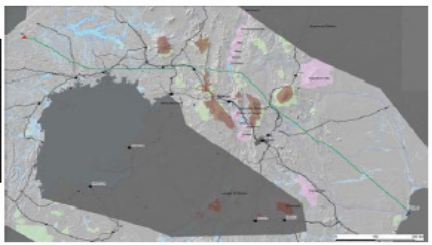




	> 1.5 m	0.5 - 1.5 m	< 0.5 m	< 0.5 m classe A
Soils conditions (length km)	583	534	80	0

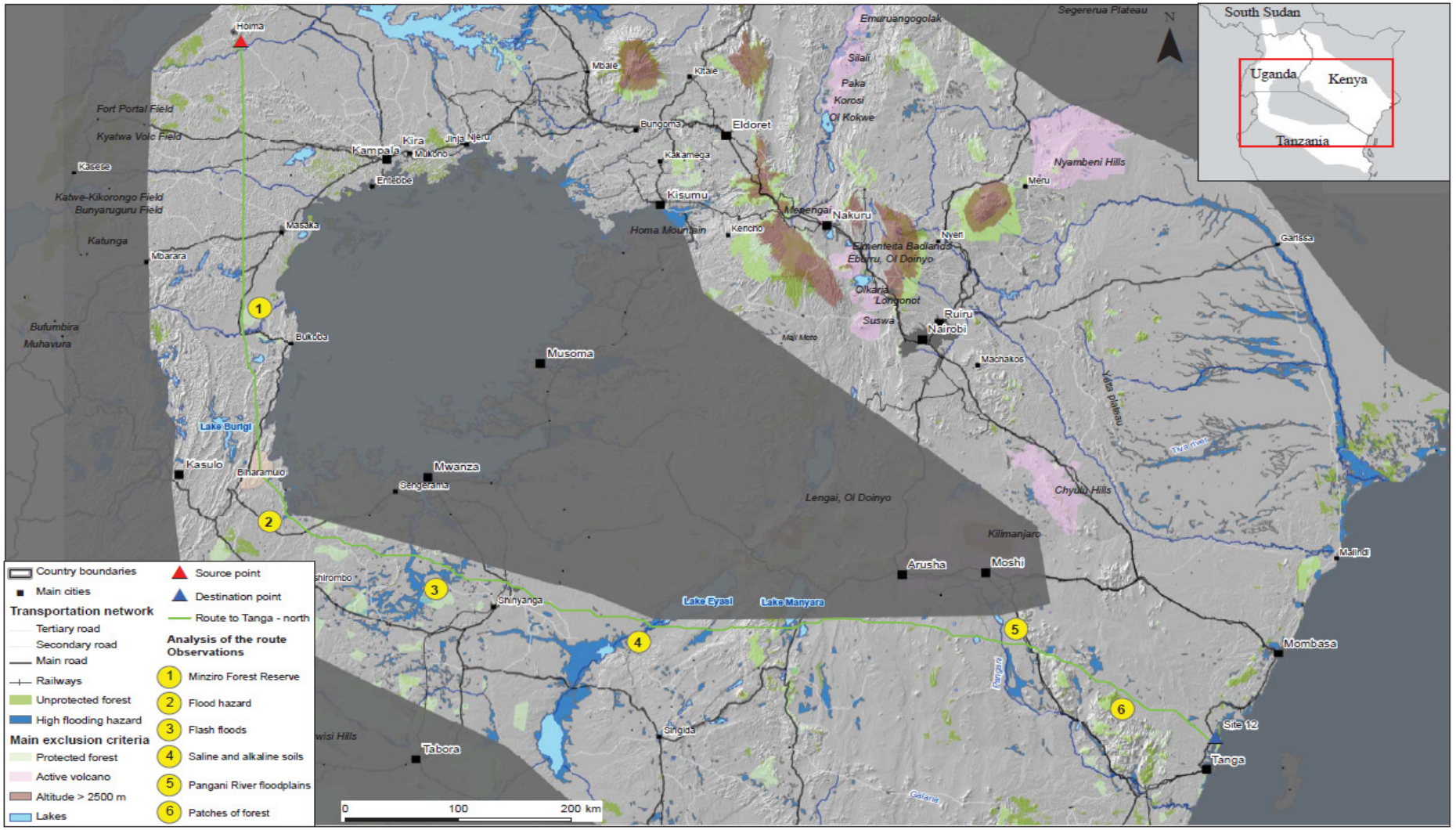
	<1500	1500-2000	2000-2500
Altitude (length km)	943	202	52

Route length (3D) = 1196.8 km
Max. elevation = 2432 m
Max. slope = 45°



Hoima to Tanga

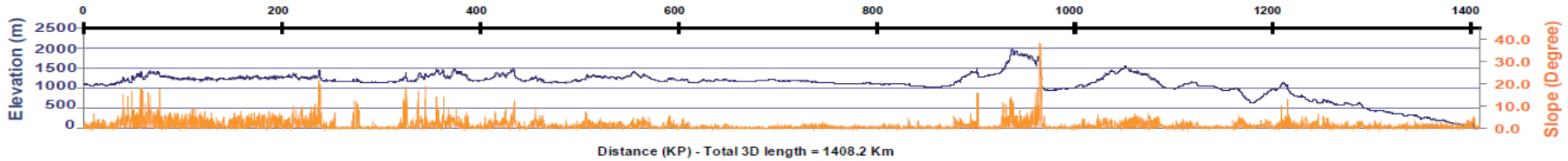
Hoima to Tanga – Corridor 6, North by Tanzania - Analysis of the socio-economic and environmental constraints | FIGURE: 17



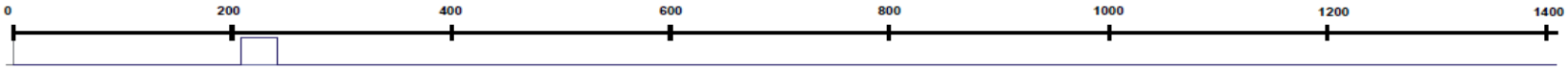
Hoima to Tanga

Hoima to Tanga – Corridor 6, North by Tanzania -- Profile

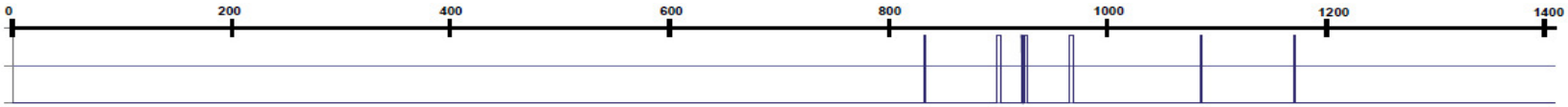
FIGURE: 18



Distance (KP) - Total 3D length = 1408.2 Km



Soil thickness < 0.5 m



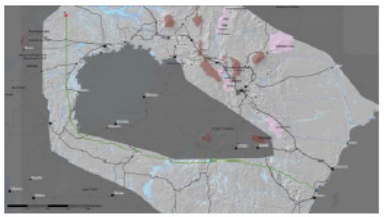
Major faults with scarps

No major river crossings

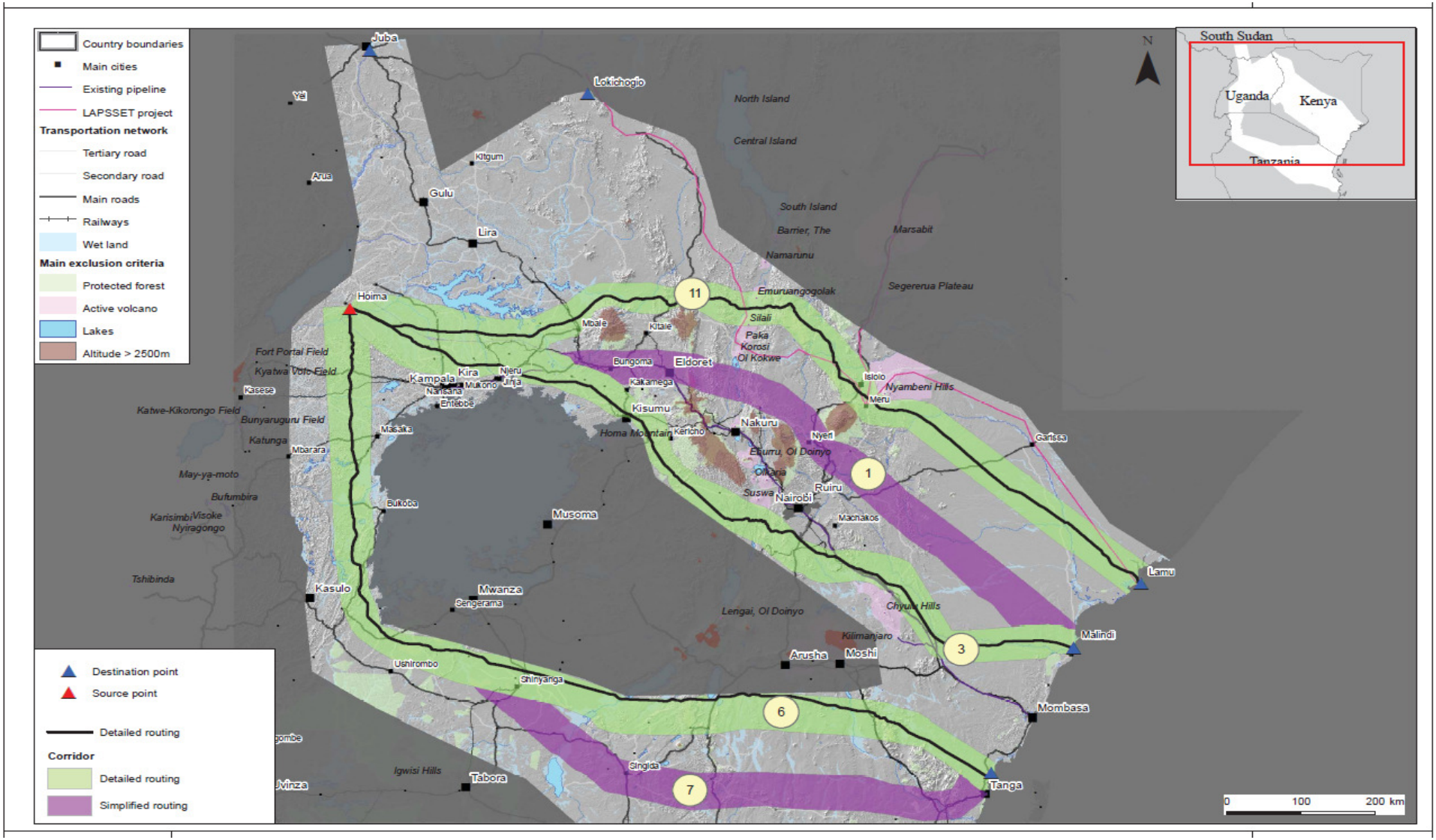
	> 1.5 m	0.5 - 1.5 m	< 0.5 m	< 0.5 m classe A
Soils conditions (length km)	722	654	32	0

	<1500	1500-2000	2000-2500
Altitude (length km)	1369	39	0

Route length (3D) = 1408.2 km
Max. elevation = 2004 m
Max. slope = 38.2°



Best routes considered for further evaluation



Risk Analysis

General Routing constraints

- High slopes
- Crossings –hydrology and transport
- Shallow surface bedrock
- Wetlands (opt for seasonal)

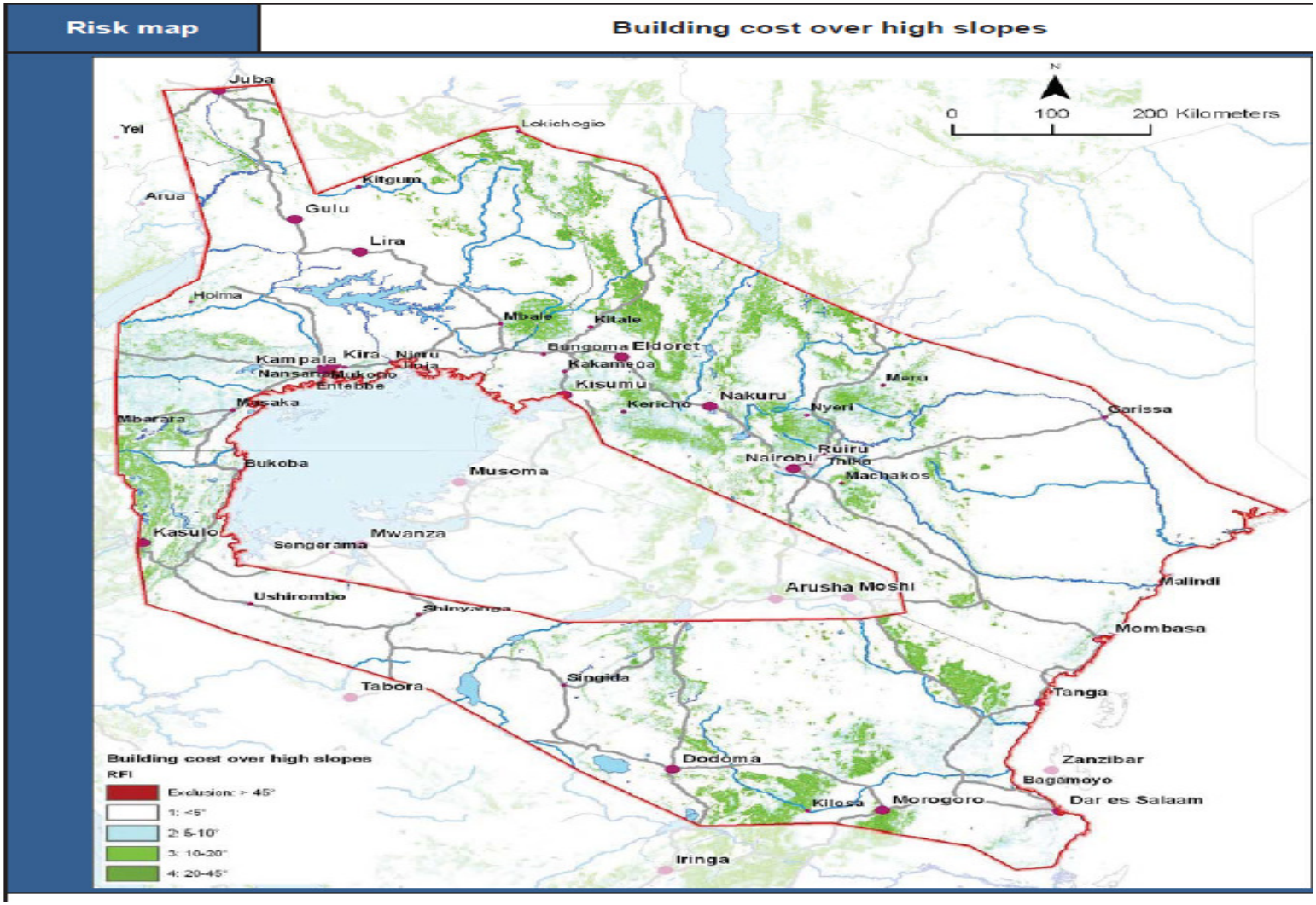
Operational constraints

- Active fault crossing and active rift
- Land slide threat
- Elevation

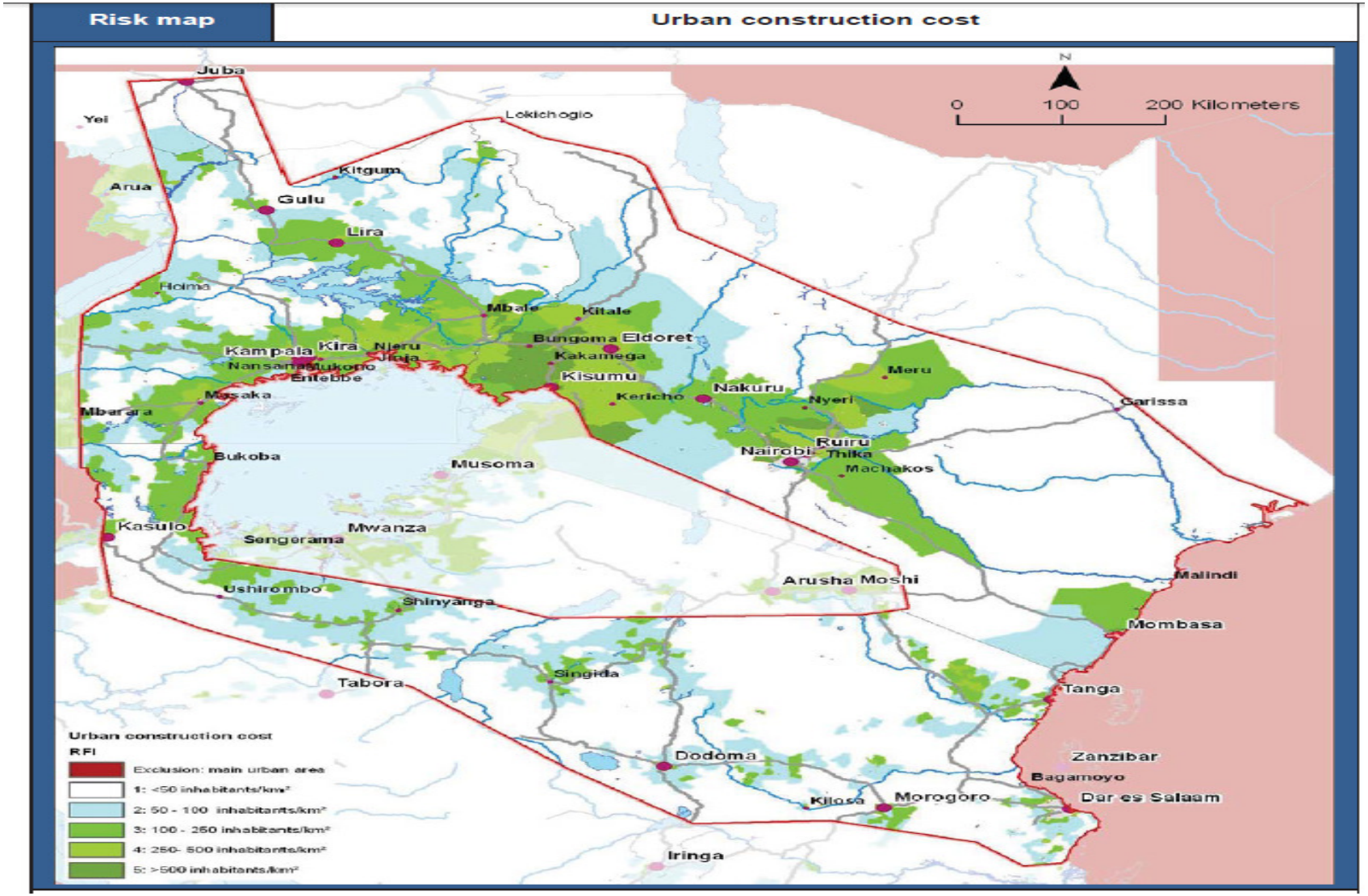
Social economic and Environmental Constraints

- Forests
- Farms Mainly Tea And Coffee

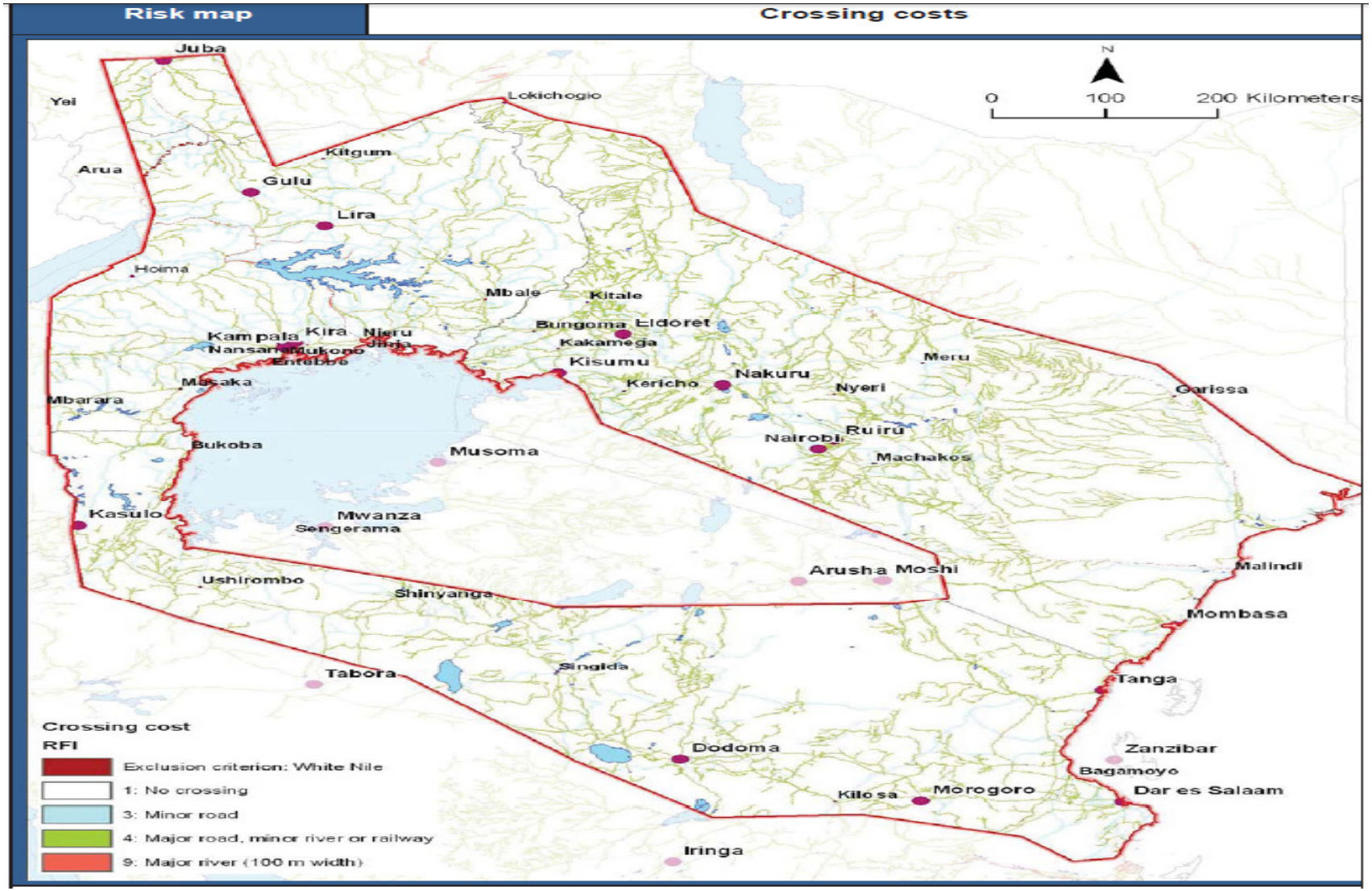
Risk Maps


Risk map
Building cost over high slopes
N
0
100
200 Kilometers
Juba
Yei
Arua
Gulu
Kitgum
Lokichogio
Lira
Hoima
Mbale
Kitale
Bungoma
Eldoret
Kakamega
Kampala
Kira
Nansana
Mukono
Entebbe
Kisumu
Kericho
Nakuru
Meru
Nyeri
Garissa
Masaka
Mbarara
Bukoba
Musoma
Nairobi
Ruiru
Thika
Machakos
Kasulo
Sengerama
Mwanza
Ushirombo
Arusha
Moshi
Malindi
Mombasa
Singida
Tabora
Tanga
Dodoma
Zanzibar
Bagamoyo
Kilosa
Morogoro
Dar es Salaam
Iringa
Building cost over high slopes
RFI
Exclusion: > 45°
1: <5°
2: 5-10°
3: 10-20°
4: 20-45°

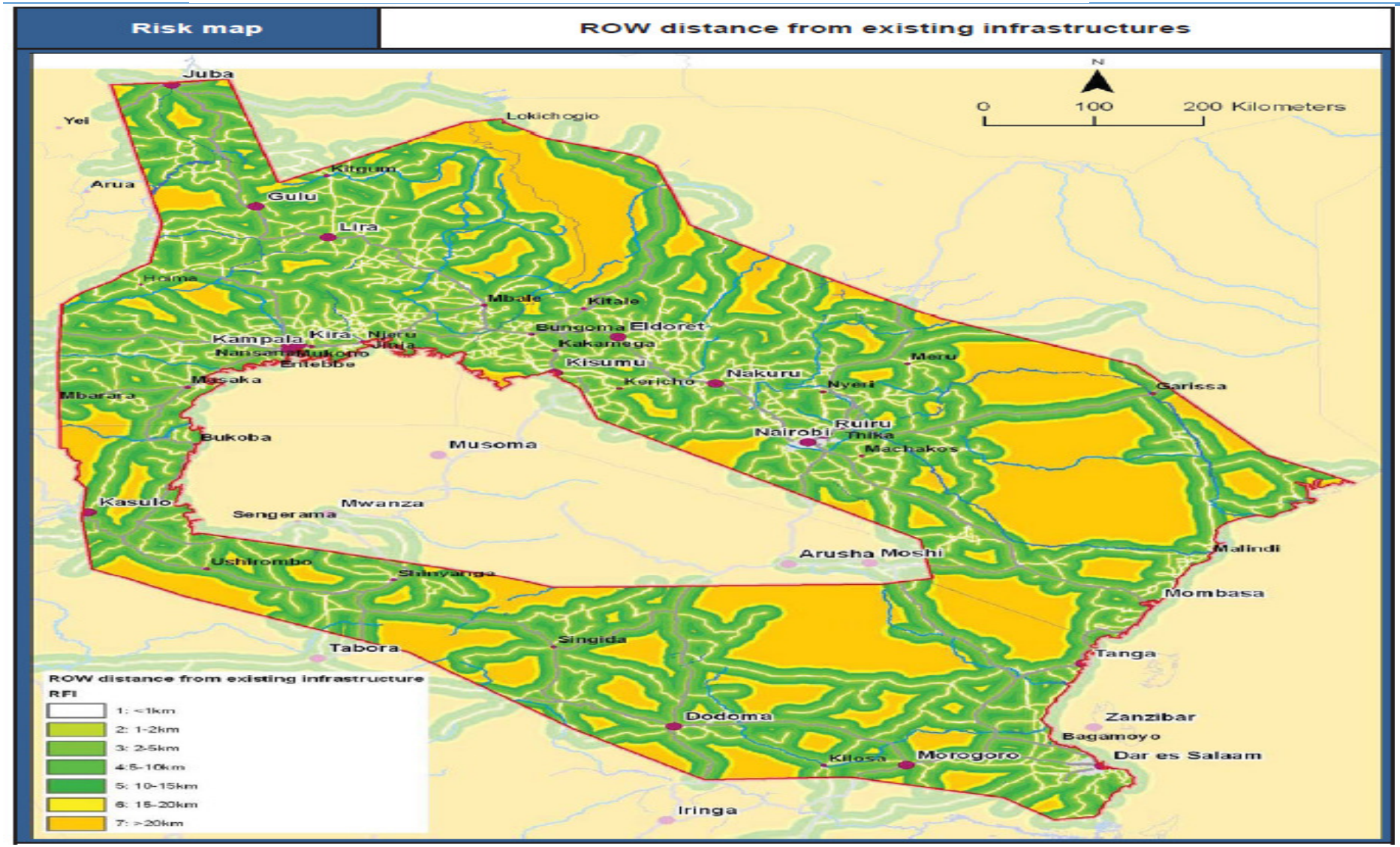
Risk Maps


Risk map
Urban construction cost
N
0
100
200 Kilometers
Juba
Yei
Lokichogio
Kitgum
Arua
Gulu
Lira
Hoima
Mbale
Kitale
Bungoma
Eldoret
Kampala
Kira
Nteru
Jinja
Kakamega
Nansana
Mukono
Entebbe
Kisumu
Meru
Masaka
Kericho
Nakuru
Nyeri
Garissa
Mbarara
Ruiru
Nairobi
Thika
Machakos
Bukoba
Musoma
Kasulo
Mwanza
Sengerema
Arusha
Moshi
Malindi
Ushirombo
Shinyanga
Mombasa
Singida
Tanga
Tabora
Zanzibar
Bagamoyo
Dodoma
Kilosa
Morogoro
Dar es Salaam
Iringa
Urban construction cost
RFI
Exclusion: main urban area
1: <50 inhabitants/km²
2: 50 - 100 inhabitants/km²
3: 100 - 250 inhabitants/km²
4: 250- 500 inhabitants/km²
5: >500 inhabitants/km²

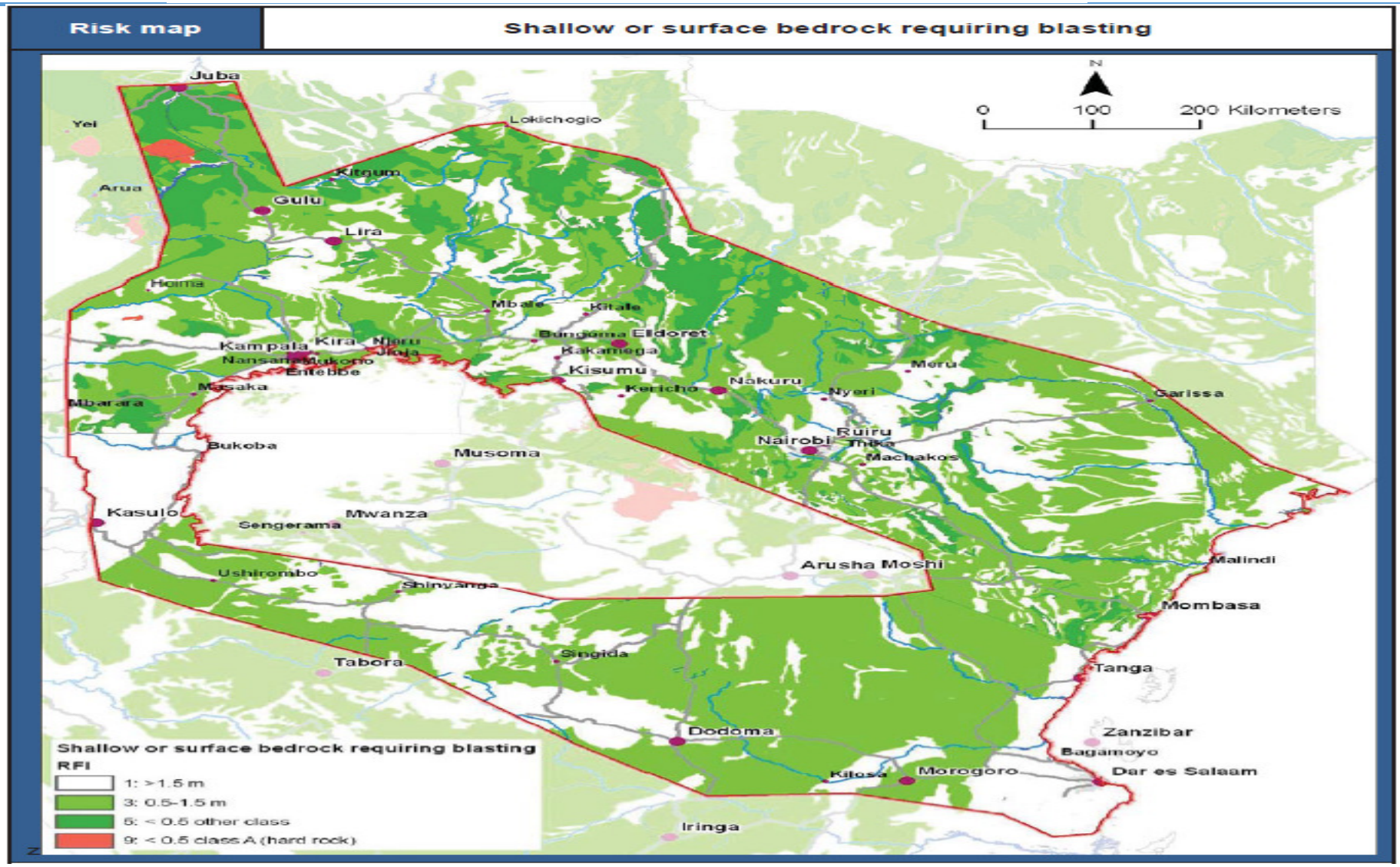
Risk Maps


Risk map
Crossing costs
N
0
100
200 Kilometers
Juba
Yei
Arua
Kitgum
Gulu
Lira
Lokichogio
Hoima
Mbale
Kitale
Bungoma
Eldoret
Kakamega
Kampala
Kira
Nieru
Jinja
Nansana
Mukono
Entebbe
Kisumu
Meru
Masaka
Kericho
Nakuru
Nyeri
Garissa
Mbarara
Nairobi
Ruiru
Bukoba
Musoma
Machakos
Kasulo
Mwanza
Sengerama
Arusha
Moshi
Malindi
Ushirombo
Shinyanga
Mombasa
Singida
Tanga
Tabora
Dodoma
Zanzibar
Bagamoyo
Kilosa
Morogoro
Dar es Salaam
Iringa
Crossing cost
RFI
Exclusion criterion: White Nile
1: No crossing
3: Minor road
4: Major road, minor river or railway
9: Major river (100 m width)

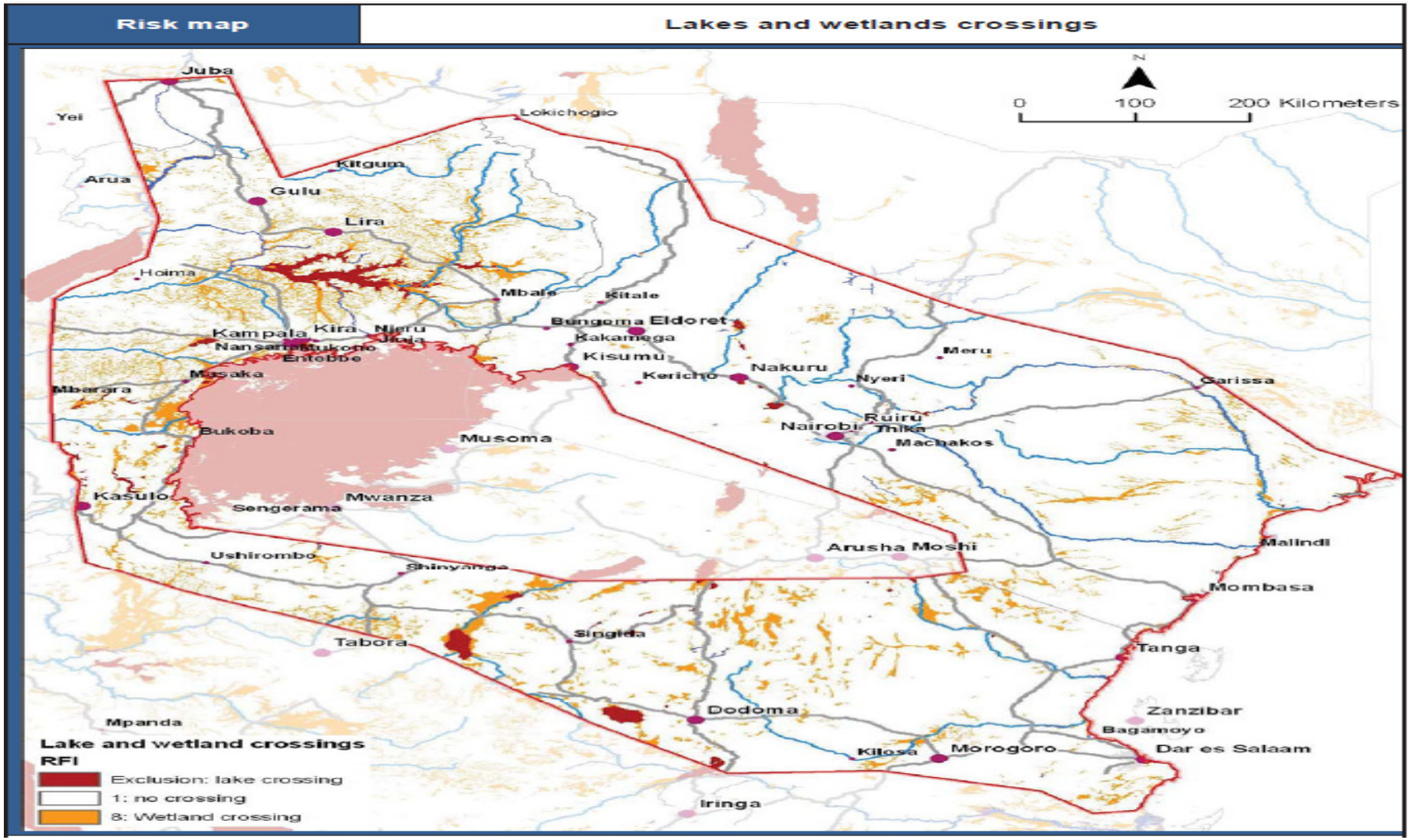
Risk Maps


Risk map
ROW distance from existing infrastructures
N
0
100
200 Kilometers
Juba
Yei
Arua
Kitgum
Gulu
Lira
Lokichogio
Hoima
Mbale
Kitale
Bungoma
Eldoret
Kampala
Kira
Njeru
Jinja
Nansana
Mukono
Entebbe
Kakamega
Kisumu
Masaka
Kericho
Nakuru
Nyeri
Meru
Garissa
Mbarara
Bukoba
Musoma
Nairobi
Ruiru
Thika
Machakos
Kasulo
Mwanza
Sengerama
Ushirombo
Shinyanga
Arusha
Moshi
Malindi
Mombasa
Tabora
Singida
Tanga
Dodoma
Zanzibar
Bagamoyo
Kilosa
Morogoro
Dar es Salaam
Iringa
ROW distance from existing infrastructure
RFI
1: <1km
2: 1-2km
3: 2-5km
4: 5-10km
5: 10-15km
6: 15-20km
7: >20km

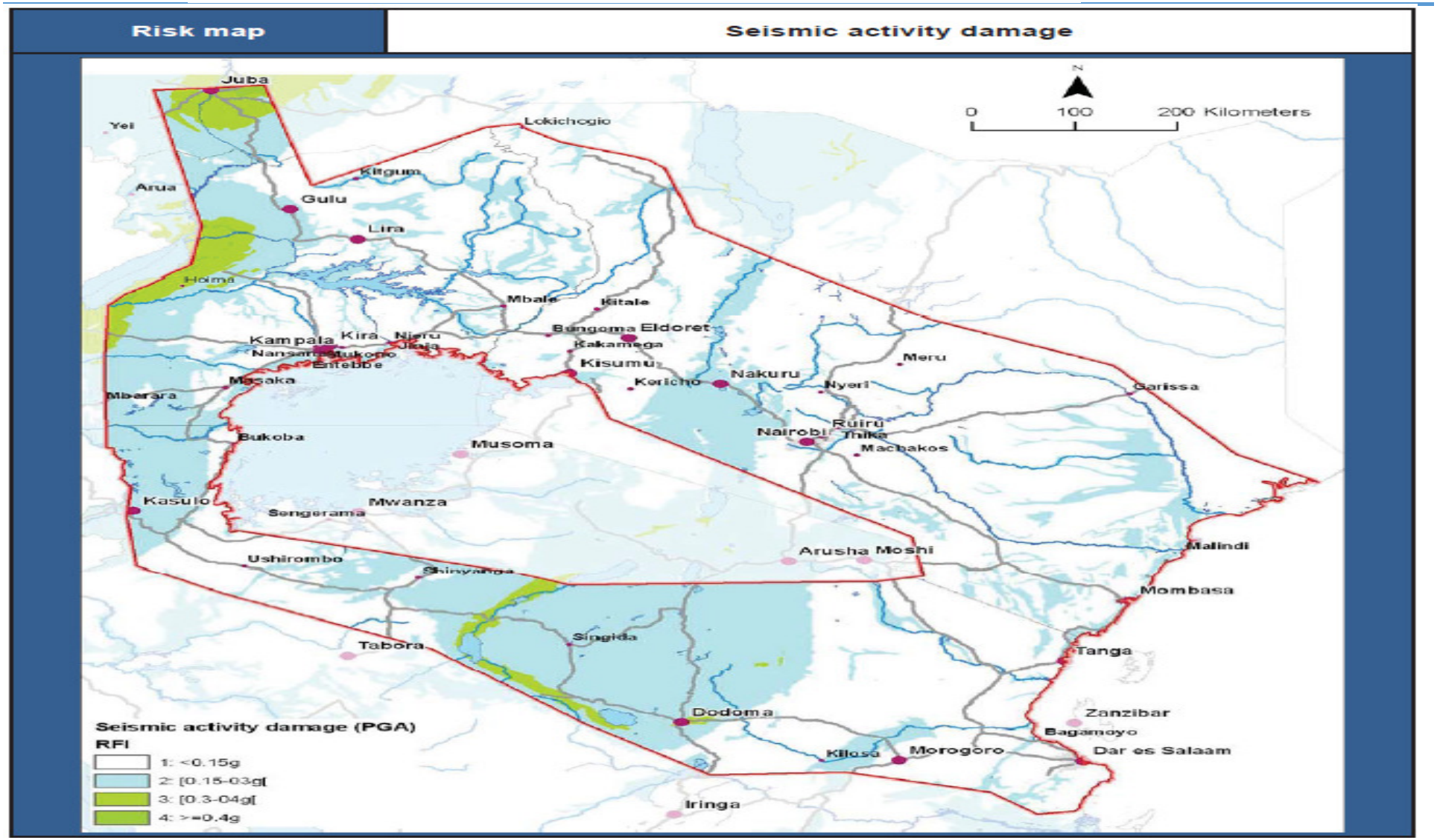
Risk Maps


Risk map
Shallow or surface bedrock requiring blasting
N
0
100
200 Kilometers
Juba
Yei
Lokichogio
Arua
Kitgum
Gulu
Lira
Hoima
Mbale
Kitale
Bungoma
Eldoret
Kampala
Kira
Nsangi
Kakamega
Entebbe
Kisumu
Meru
Masaka
Kericho
Nakuru
Nyeri
Garissa
Mbarara
Ruiru
Nairobi
Thika
Machakos
Bukoba
Musoma
Kasulo
Mwanza
Sengerama
Arusha
Moshi
Malindi
Ushirombo
Shinyanga
Mombasa
Singida
Tabora
Tanga
Dodoma
Zanzibar
Bagamoyo
Kilosa
Morogoro
Dar es Salaam
Iringa
Shallow or surface bedrock requiring blasting
RFI
1: >1.5 m
3: 0.5-1.5 m
5: < 0.5 other class
9: < 0.5 class A (hard rock)

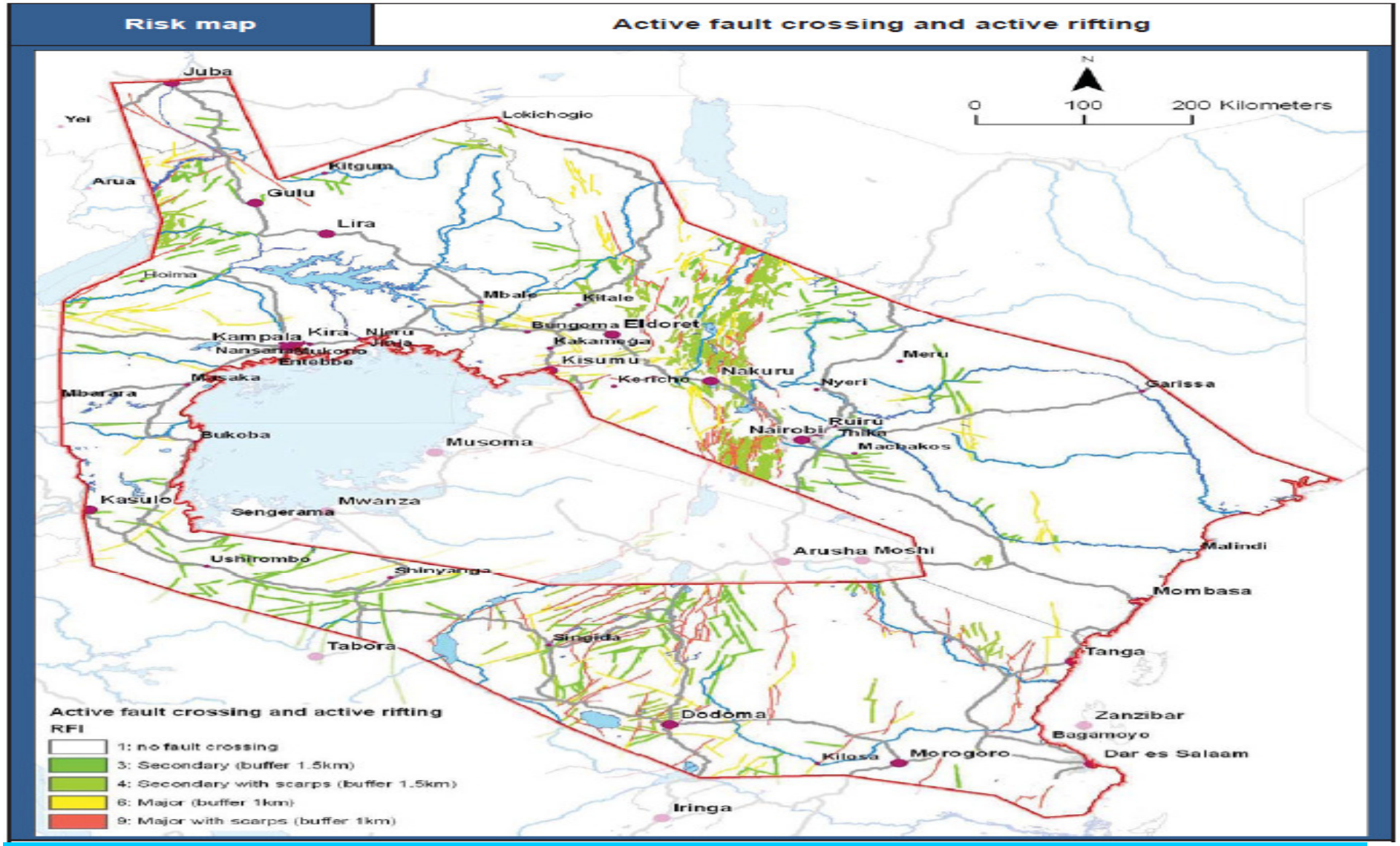
Risk Maps


Risk map
Lakes and wetlands crossings
N
0
100
200 Kilometers
Juba
Yei
Arua
Kitgum
Lokichogio
Gulu
Lira
Hoima
Mbale
Kitale
Bungoma
Eldoret
Kakamega
Kampala
Kira
Nansana
Entebbe
Kisumu
Kericho
Nakuru
Meru
Nyeri
Garissa
Masaka
Mbarara
Bukoba
Musoma
Nairobi
Ruiru
Thika
Machakos
Kasulo
Sengerama
Mwanza
Ushirombo
Shinyanga
Arusha
Moshi
Malindi
Mombasa
Tabora
Singida
Tanga
Dodoma
Zanzibar
Bagamoyo
Kilosa
Morogoro
Dar es Salaam
Mpanda
Iringa
Lake and wetland crossings
RFI
Exclusion: lake crossing
1: no crossing
8: Wetland crossing

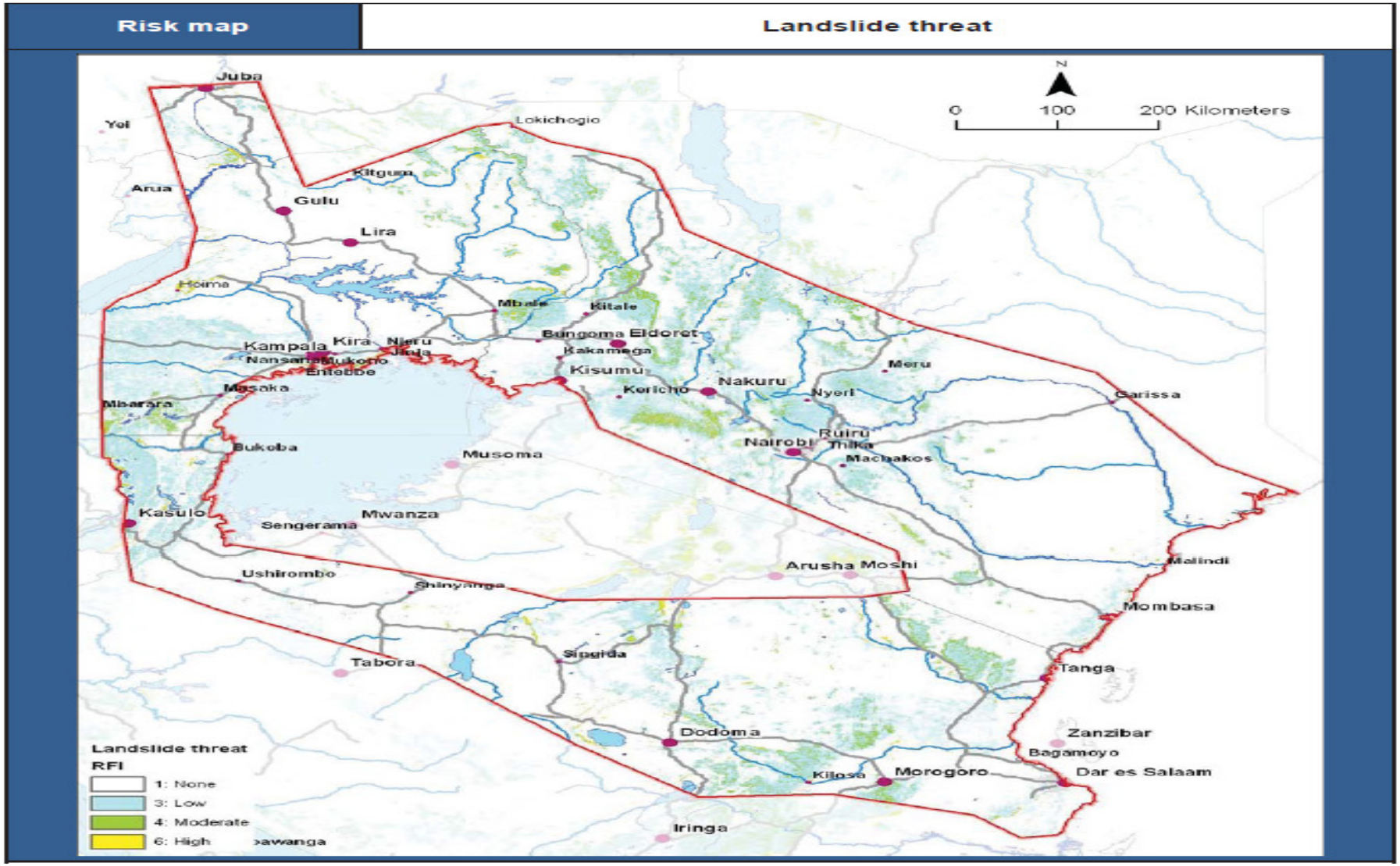
Risk Maps


Risk map
Seismic activity damage
N
0
100
200 Kilometers
Juba
Yei
Arua
Gulu
Kitgum
Lokichogio
Lira
Hoima
Mbale
Kitale
Bungoma
Eldoret
Kampala
Kira
Nansana
Mukono
Jinja
Entebbe
Kakamega
Kisumu
Masaka
Mbarara
Kericho
Nakuru
Meru
Nyeri
Garissa
Nairobi
Ruiru
Thika
Machakos
Bukoba
Musoma
Kasulo
Sengerema
Mwanza
Ushirombo
Shinyanga
Arusha
Moshi
Malindi
Mombasa
Singida
Tabora
Tanga
Dodoma
Zanzibar
Bagamoyo
Kilosa
Morogoro
Dar es Salaam
Iringa
Seismic activity damage (PGA)
RFI
1: <0.15g
2: [0.15-03g[
3: [0.3-04g[
4: >=0.4g

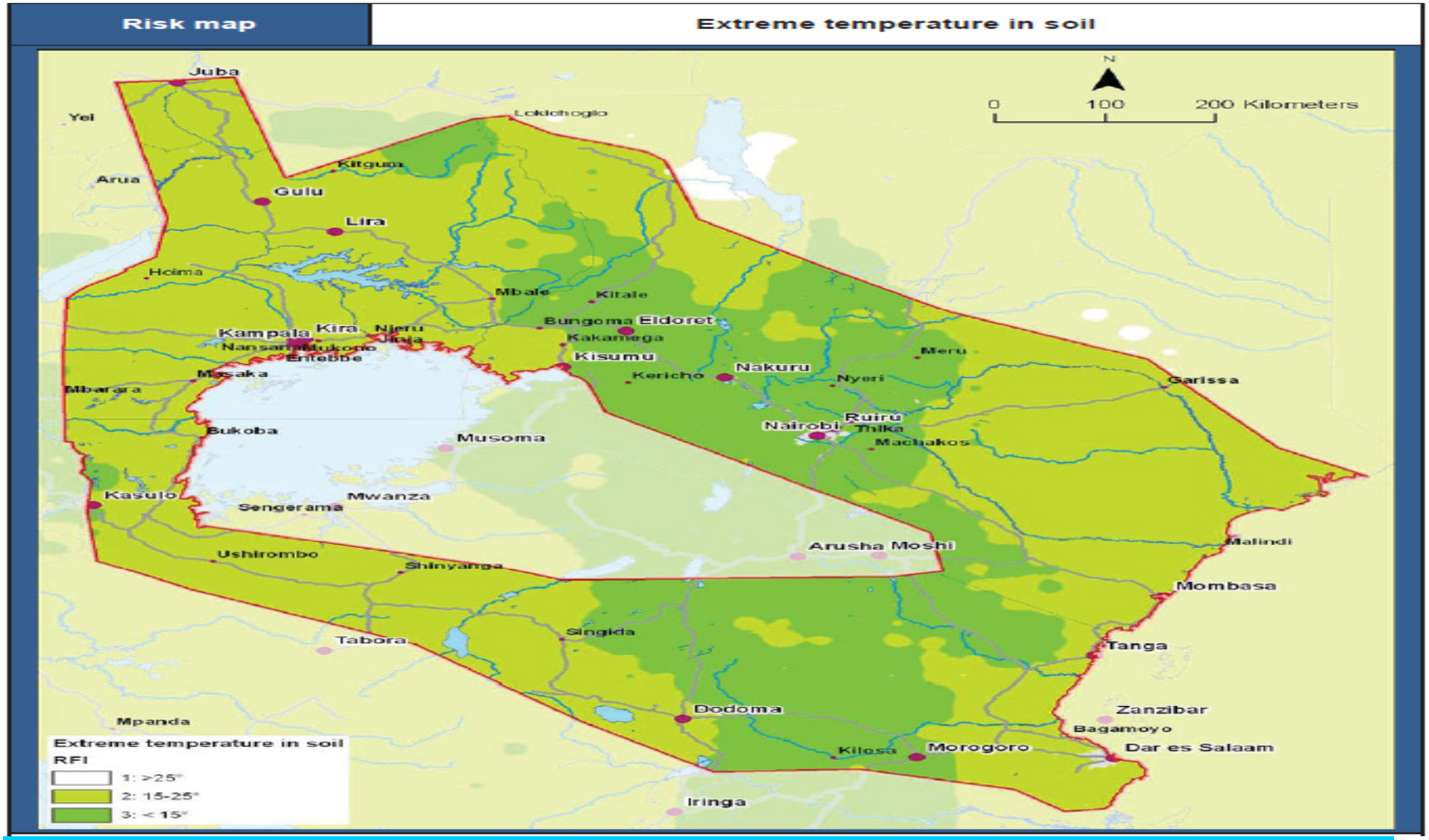
Risk Maps


Risk map
Active fault crossing and active rifting
N
0
100
200 Kilometers
Juba
Yei
Arua
Gulu
Kitgum
Lokichogio
Lira
Hoima
Mbale
Kitale
Bungoma
Eldoret
Kakamega
Kampala
Kira
Nansana
Mukono
Entebbe
Jinja
Kisumu
Kericho
Nakuru
Meru
Nyeri
Garissa
Masaka
Mbarara
Bukoba
Musoma
Nairobi
Ruiru
Thika
Machakos
Kasulo
Sengerama
Mwanza
Ushirombo
Shinyanga
Arusha
Moshi
Malindi
Mombasa
Singida
Tabora
Tanga
Dodoma
Zanzibar
Bagamoyo
Kilosa
Morogoro
Dar es Salaam
Iringa
Active fault crossing and active rifting
RFI
1: no fault crossing
3: Secondary (buffer 1.5km)
4: Secondary with scarps (buffer 1.5km)
6: Major (buffer 1km)
9: Major with scarps (buffer 1km)

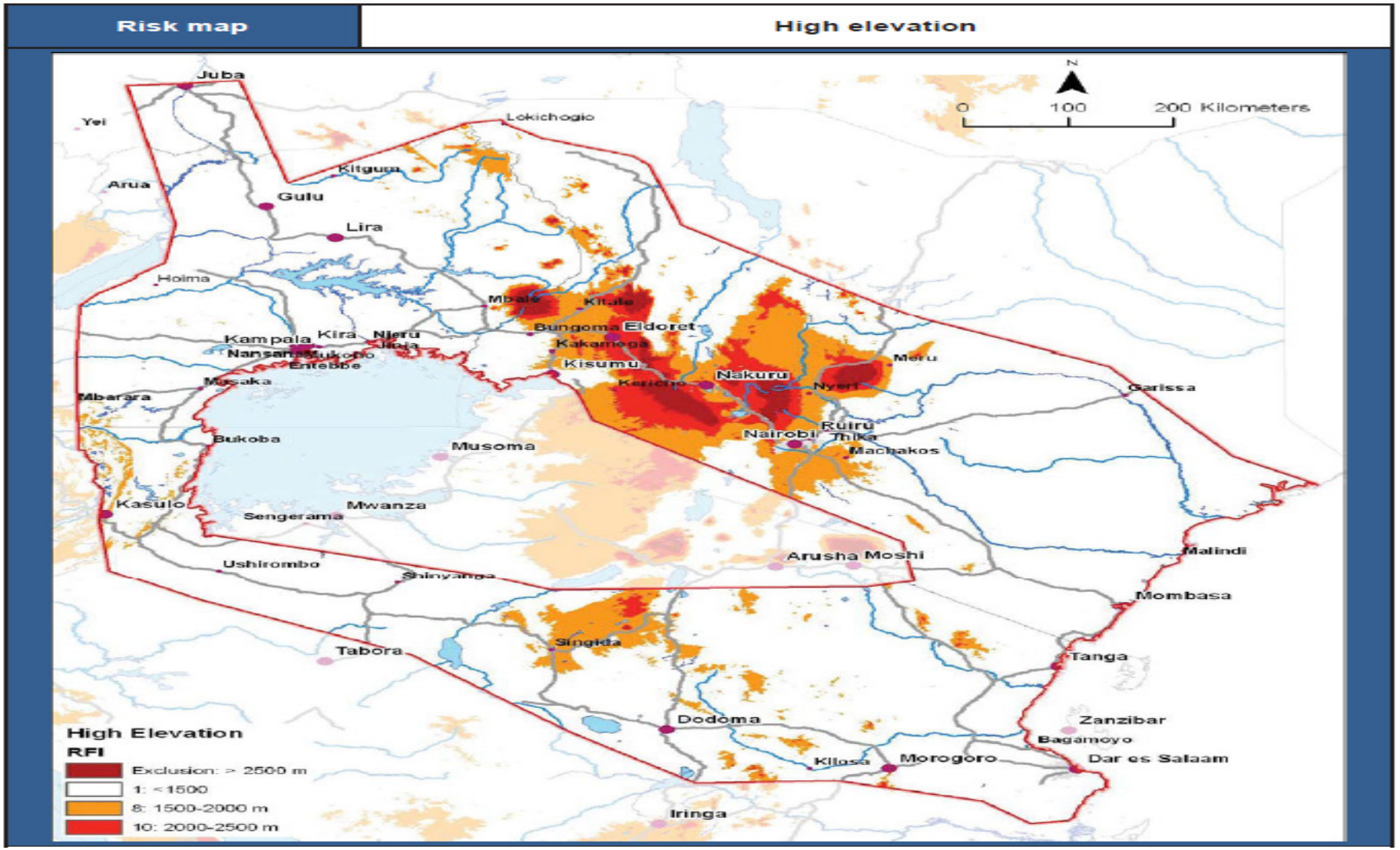
Risk Maps


Risk map
Landslide threat
N
0
100
200 Kilometers
Juba
Yei
Lokichogio
Kitgum
Arua
Gulu
Lira
Hoima
Mbale
Kitale
Bungoma
Eldoret
Kampala
Kira
Nansana
Mukono
Entebbe
Jinja
Kakamega
Kisumu
Kericho
Nakuru
Meru
Nyeri
Garissa
Masaka
Mbarara
Nairobi
Ruiru
Thika
Machakos
Bukoba
Musoma
Kasulo
Sengerema
Mwanza
Arusha
Moshi
Malindi
Mombasa
Ushirombo
Shinyanga
Singida
Tabora
Tanga
Dodoma
Zanzibar
Bagamoyo
Kilosa
Morogoro
Dar es Salaam
Iringa
Landslide threat
RFI
1: None
3: Low
4: Moderate
6: High

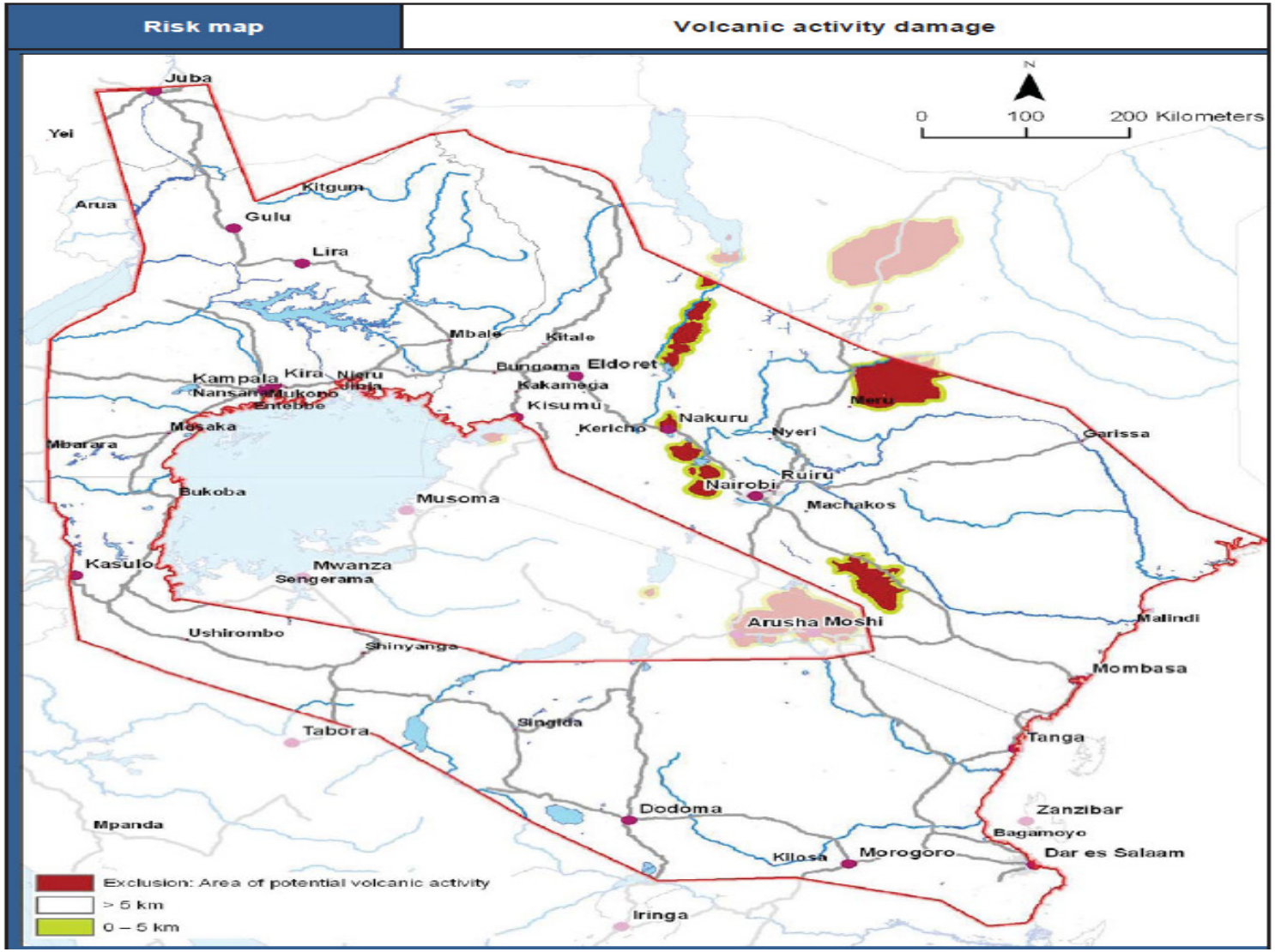
Risk Maps


Risk map
Extreme temperature in soil
N
0
100
200 Kilometers
Juba
Yei
Arua
Gulu
Kitgum
Lokichoglo
Lira
Hoima
Mbale
Kitale
Bungoma
Eldoret
Kakamega
Kampala
Kira
Nansana
Mukono
Jinja
Entebbe
Kisumu
Masaka
Kericho
Nakuru
Nyeri
Meru
Garissa
Mbarara
Bukoba
Musoma
Nairobi
Ruiru
Thika
Machakos
Kasulo
Sengerama
Mwanza
Arusha
Moshi
Malindi
Ushirombo
Shinyanga
Mombasa
Singida
Tabora
Tanga
Dodoma
Zanzibar
Bagamoyo
Kilosa
Morogoro
Dar es Salaam
Mpanda
Iringa
Extreme temperature in soil
RFI
1: >25°
2: 15-25°
3: < 15°

Risk Maps


Risk map
High elevation
N
0
100
200 Kilometers
Juba
Yei
Lokichogio
Kitgum
Arua
Gulu
Lira
Holma
Mbale
Kitale
Bungoma
Eldoret
Kampala
Kira
Nansana
Entebbe
Kakamega
Kisumu
Kericho
Nakuru
Nyeri
Meru
Garissa
Masaka
Mbarara
Bukoba
Musoma
Nairobi
Ruiru
Thika
Machakos
Kasulo
Sengerama
Mwanza
Ushirombo
Shinyanga
Arusha
Moshi
Malindi
Mombasa
Singida
Tabora
Tanga
Dodoma
Zanzibar
Bagamoyo
Kilosa
Morogoro
Dar es Salaam
Iringa
High Elevation
RFI
Exclusion: > 2500 m
1: <1500
8: 1500-2000 m
10: 2000-2500 m

Risk Maps


Risk map
Volcanic activity damage
N
0
100
200 Kilometers
Juba
Yei
Arua
Kitgum
Gulu
Lira
Mbale
Kitale
Bungoma
Eldoret
Kampala
Kira
Nansana
Mukono
Entebbe
Kakamega
Kisumu
Nakuru
Kericho
Nyeri
Meru
Garissa
Masaka
Mbarara
Bukoba
Musoma
Nairobi
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Mwanza
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Malindi
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Ushirombo
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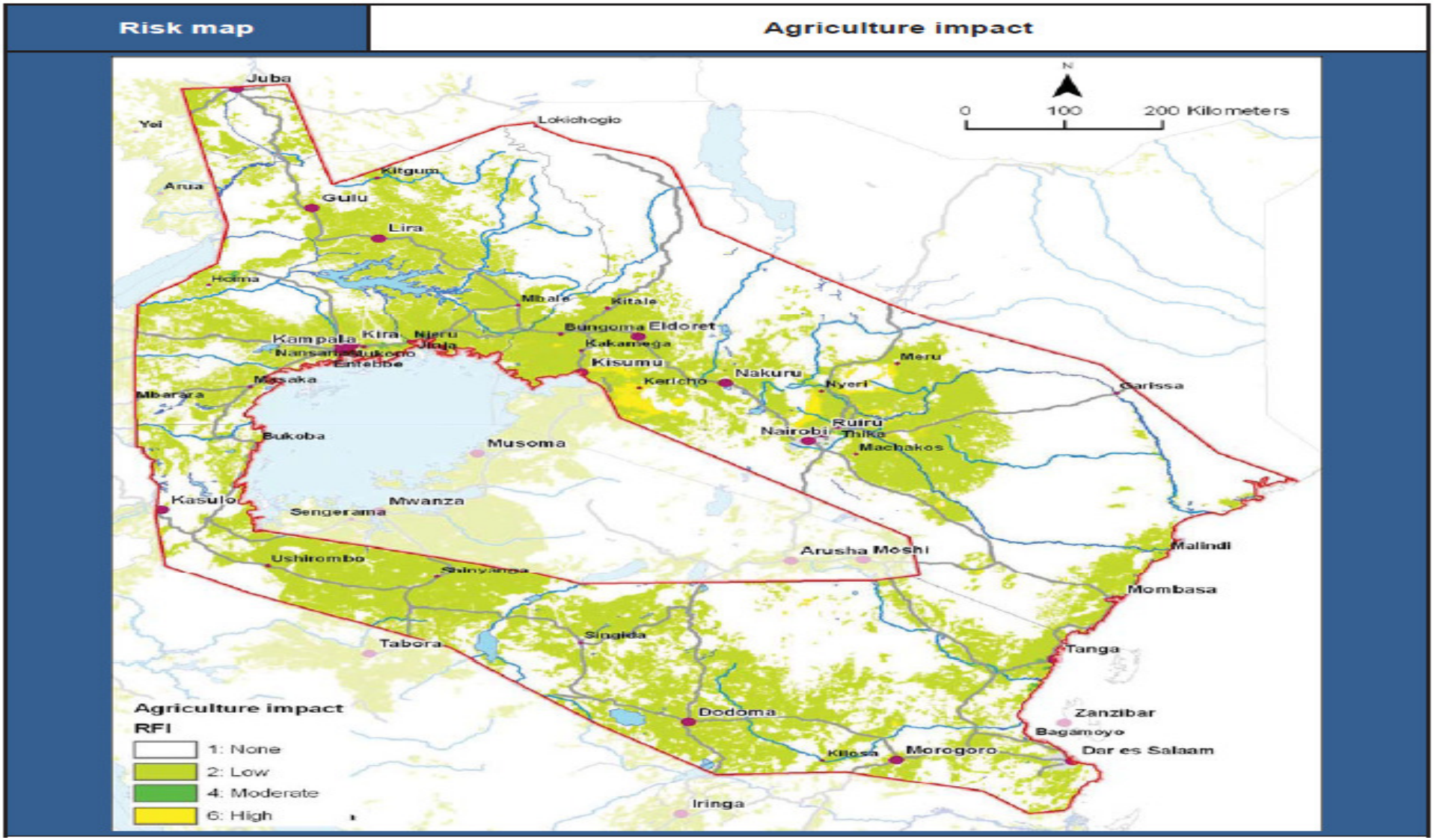
Singida
Tabora
Tanga
Dodoma
Zanzibar
Bagamoyo
Dar es Salaam
Morogoro
Kilosa
Mpanda
Iringa
Exclusion: Area of potential volcanic activity
> 5 km
0 – 5 km

Risk Maps


Risk map
Agriculture impact
N
0
100
200 Kilometers
Juba
Yei
Lokichogio
Kitgum
Arua
Gulu
Lira
Hoima
Mbale
Kitale
Bungoma
Eldoret
Kampala
Kira
Njeru
Jinja
Nansana
Mukono
Entebbe
Kakamega
Kisumu
Meru
Masaka
Kericho
Nakuru
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Garissa
Mbarara
Ruiru
Nairobi
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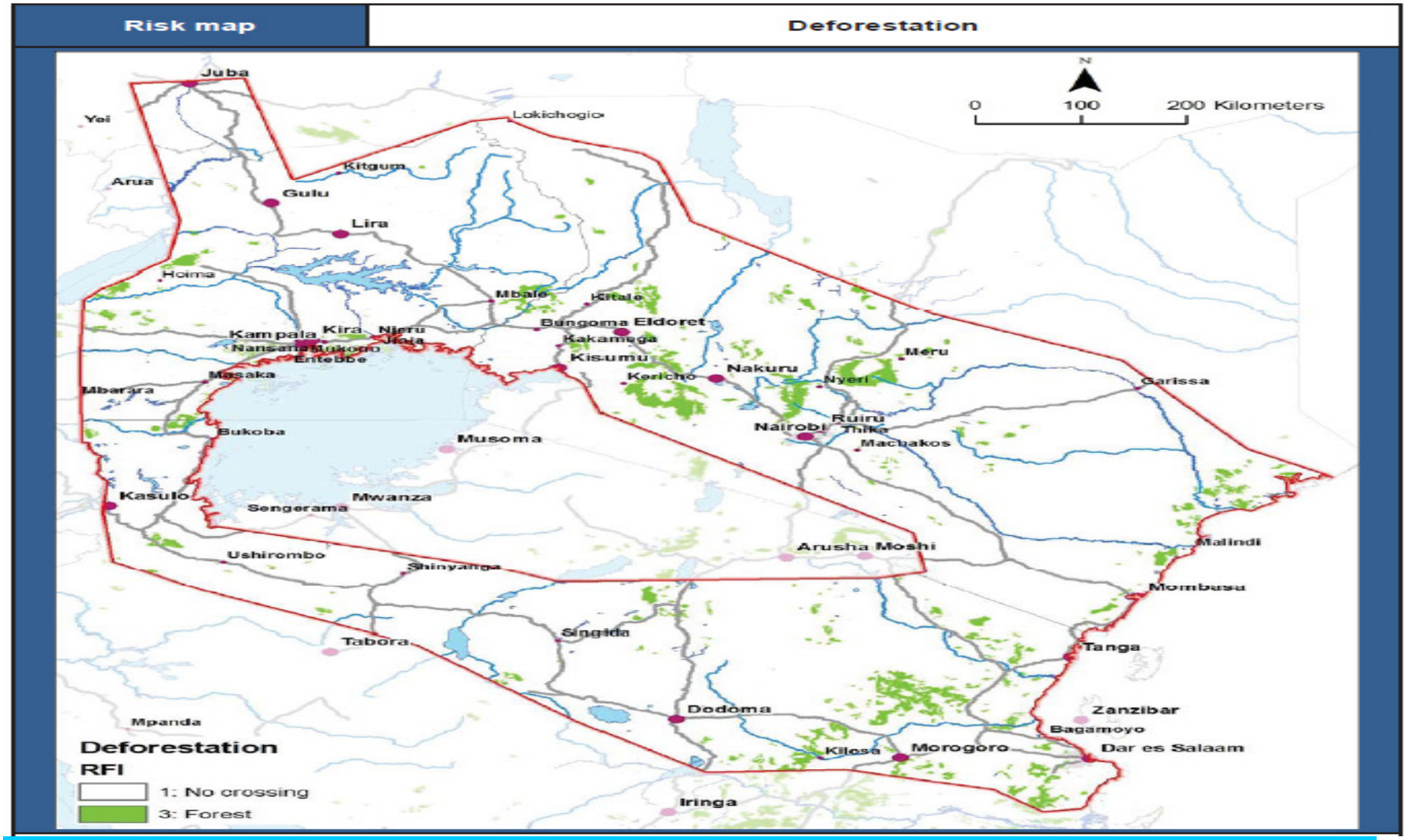
Machakos
Bukoba
Musoma
Kasulo
Sengerana
Mwanza
Arusha
Moshi
Malindi
Ushirombo
Shinyanga
Mombasa
Singida
Tabora
Tanga
Zanzibar
Bagamoyo
Dodoma
Kilosa
Morogoro
Dar es Salaam
Iringa
Agriculture impact
RFI
1: None
2: Low
4: Moderate
6: High

Risk Maps


Risk map
Deforestation
N
0
100
200 Kilometers
Juba
Yei
Arua
Kitgum
Lokichogio
Gulu
Lira
Hoima
Mbale
Kitale
Bungoma
Eldoret
Kakamega
Kampala
Kira
Nansana
Mukono
Entebbe
Jinja
Kisumu
Kericho
Nakuru
Nyeri
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Garissa
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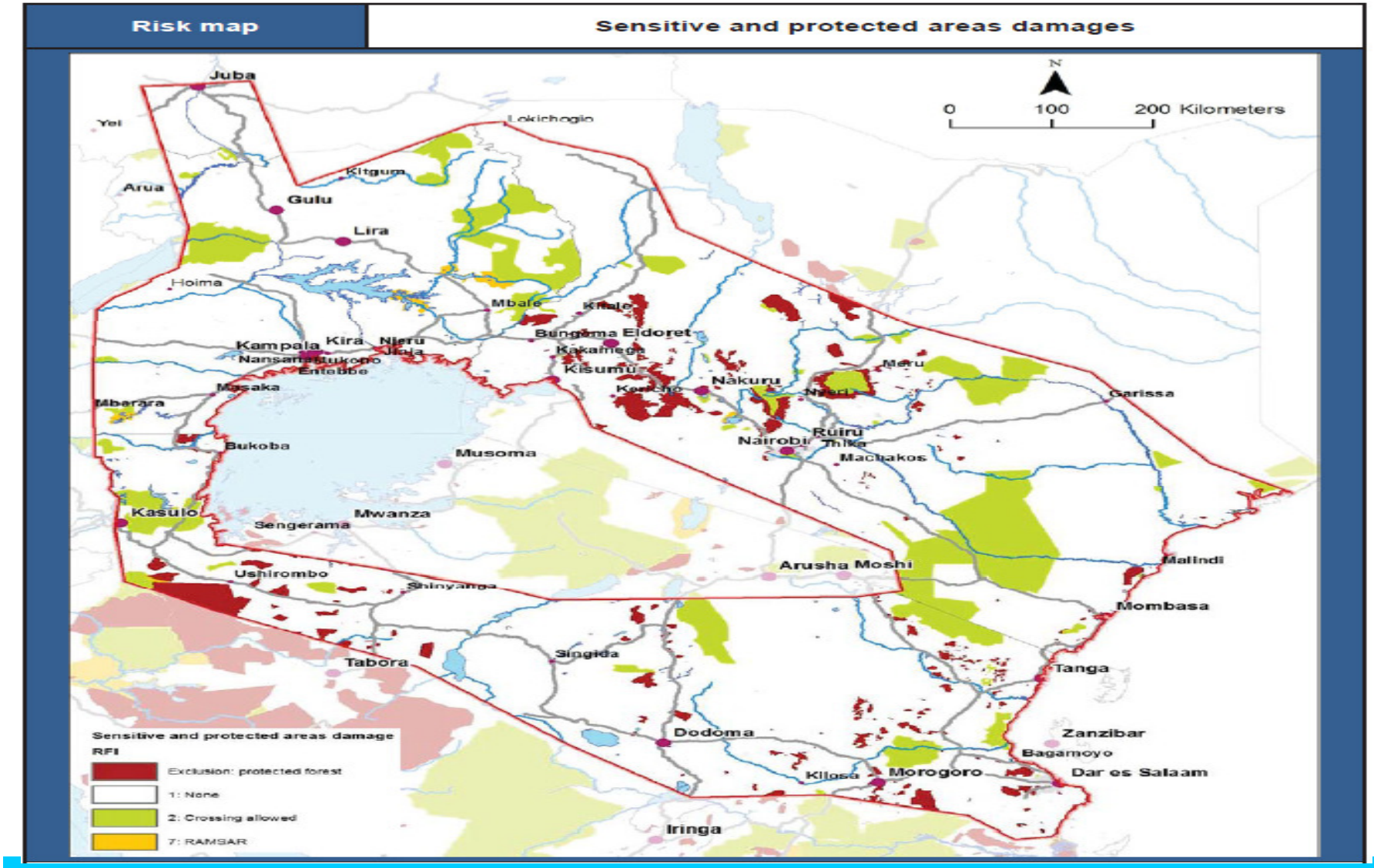
Ushirombo
Shinyanga
Singida
Tabora
Tanga
Dodoma
Zanzibar
Bagamoyo
Kilosa
Morogoro
Dar es Salaam
Mpanda
Iringa
Deforestation
RFI
1: No crossing
3: Forest

Risk Maps


Risk map
Sensitive and protected areas damages
N
0
100
200 Kilometers
Juba
Yei
Lokichogio
Kitgum
Arua
Gulu
Lira
Hoima
Mbale
Kitale
Bungoma
Eldoret
Kampala
Kira
Nansana
Entebbe
Kakamega
Kisumu
Meru
Nakuru
Nyeri
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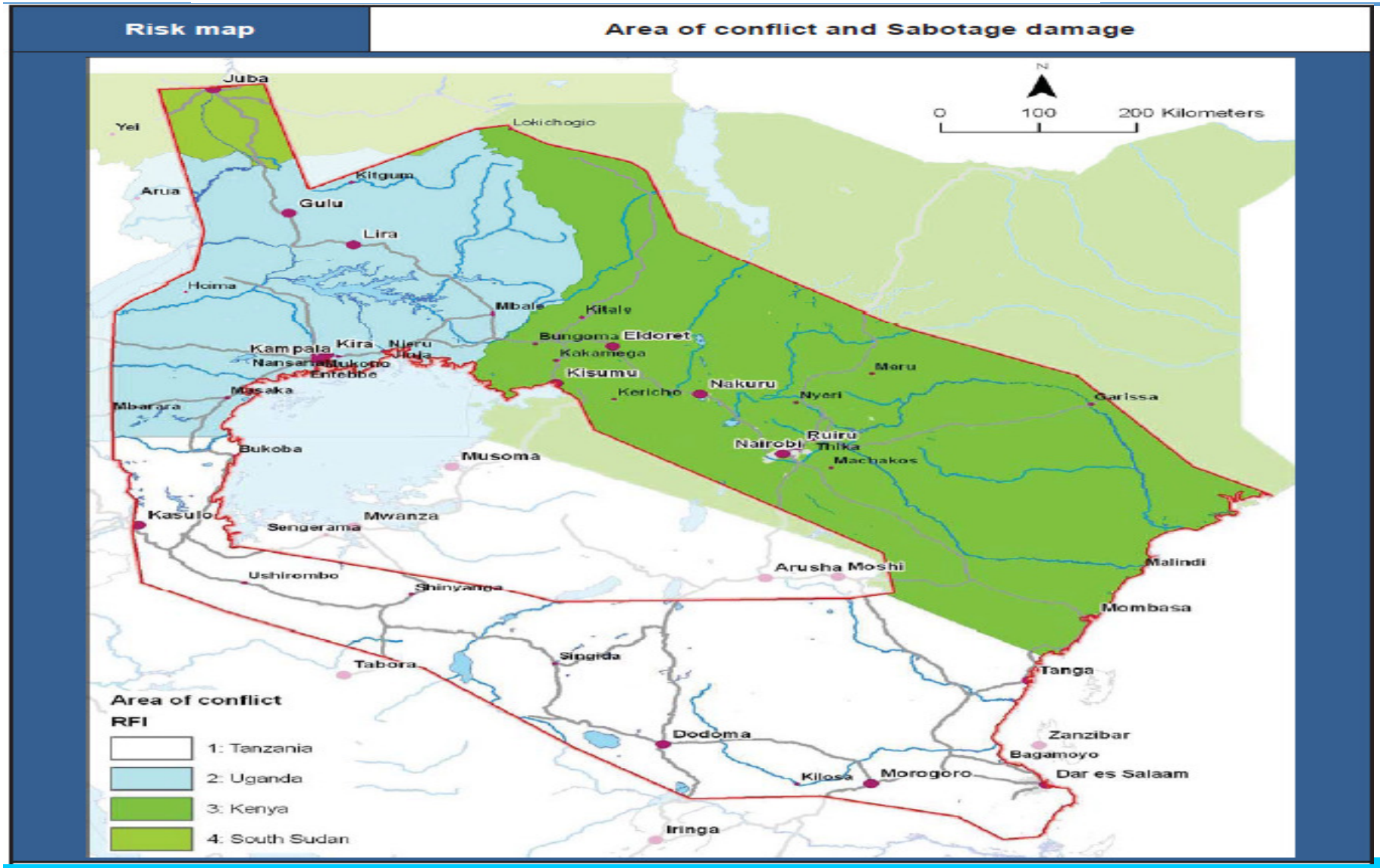
Nairobi
Ruiru
Thika
Machakos
Kasulo
Sengerama
Mwanza
Arusha
Moshi
Malindi
Mombasa
Ushirombo
Shinyanga
Singida
Tabora
Tanga
Dodoma
Zanzibar
Bagamoyo
Kilosa
Morogoro
Dar es Salaam
Iringa
Sensitive and protected areas damage
RFI
Exclusion: protected forest
1: None
2: Crossing allowed
7: RAMSAR

Risk Maps


Risk map
Area of conflict and Sabotage damage
N
0
100
200 Kilometers
Juba
Yei
Lokichogio
Kitgum
Arua
Gulu
Lira
Hoima
Mbale
Kitale
Bungoma
Eldoret
Kakamega
Kampala
Kira
Nsangi
Mukono
Entebbe
Jinja
Kisumu
Nakuru
Kericho
Nyeri
Meru
Garissa
Masaka
Mbarara
Bukoba
Musoma
Nairobi
Ruiru
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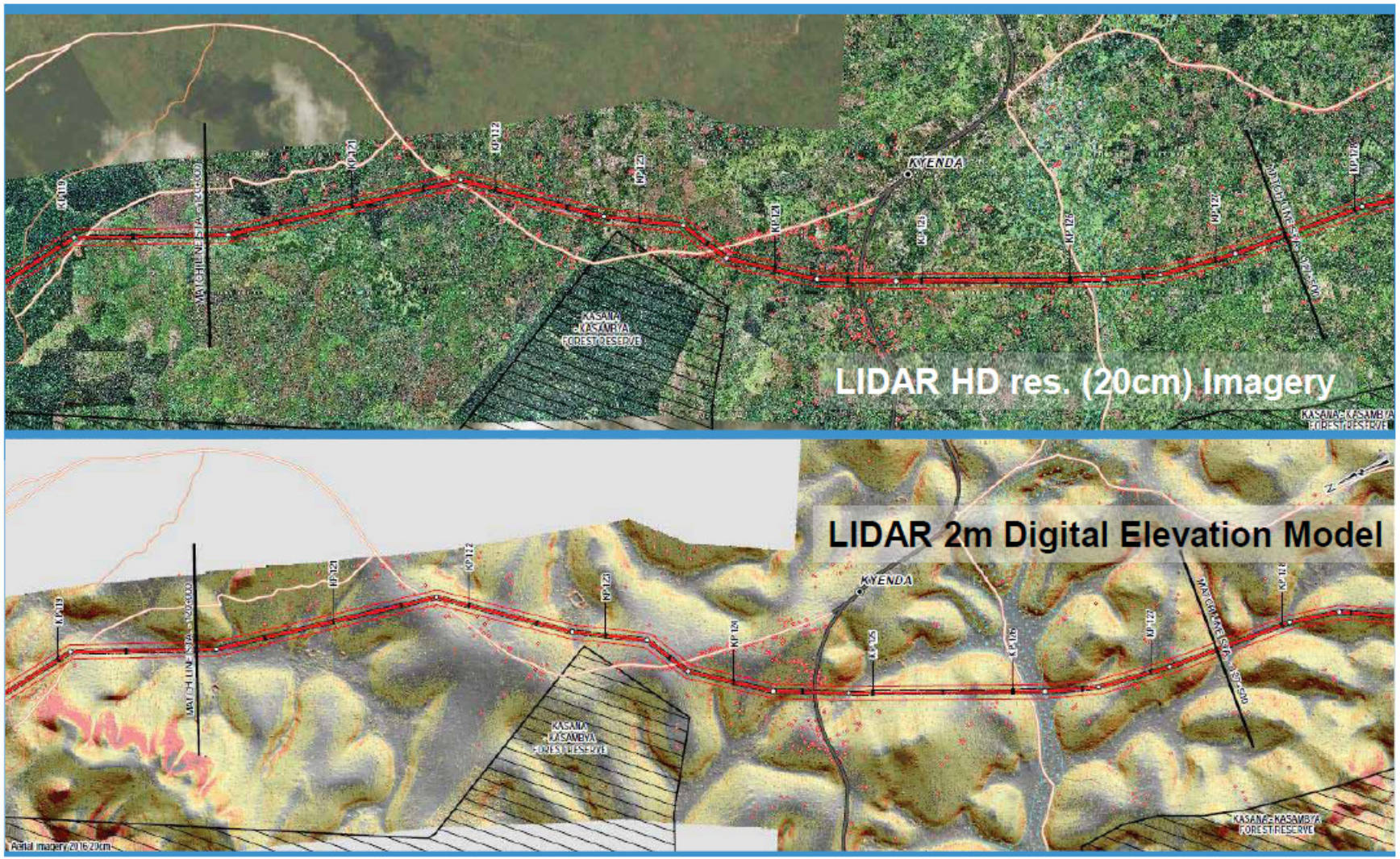
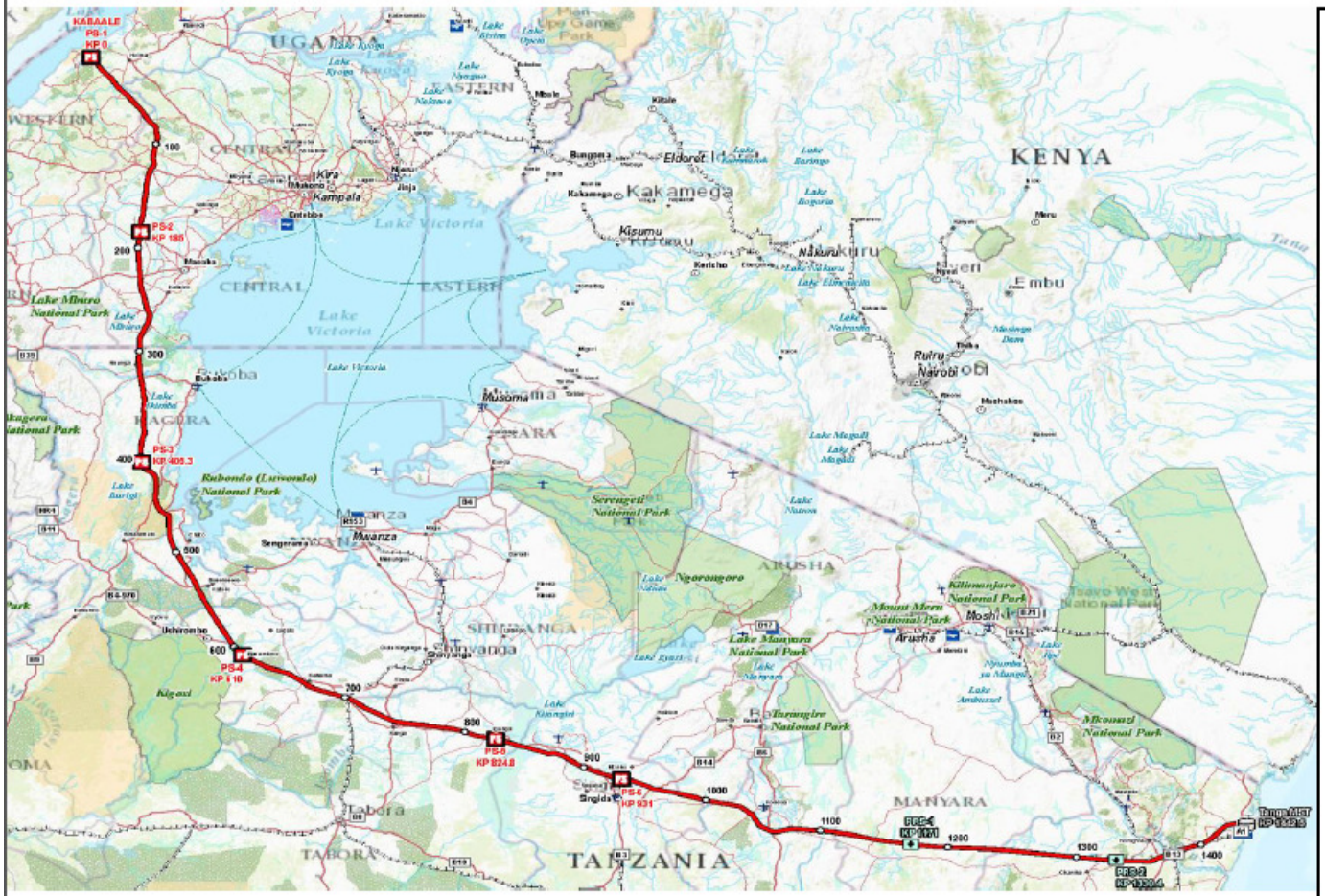
Kasulo
Sengerama
Mwanza
Ushirombo
Shinyanga
Arusha
Moshi
Malindi
Mombasa
Tanga
Singida
Tabora
Zanzibar
Bagamoyo
Dodoma
Kilosa
Morogoro
Dar es Salaam
Iringa
Area of conflict
RFI
1: Tanzania
2: Uganda
3: Kenya
4: South Sudan

Best route after optimization



Best route after optimization



1445km – one of longest crude oil pipelines

- **216 kbopd** design capacity
- Waxy Crude (up to 45°C PP) & Viscous Oil
- **Insulated** 24in pipeline
- Longest Trace Heated Pipeline in the World
- 6 Pumps Stations (PS)
- 2 Pressure Reduction Stations (PRS)
- Power Generation at PS 3 & 5 and Terminal
- Future Heating Facilities at PS
- Marine Storage and Export Terminal
- Interfacing Upstream (Tilenga/ Kingfisher) + Refinery
- **Approx. 430,000 t of material & equipment**

Conclusion

- Oil and gas facilities development needed for production
  - Tilenga project
  - KFDA project
  - Kabaale industrial park
- GIS used from project inception to decommission
- GIS for data management and decision making for the pipeline Routing
- Future prospects for GIS in facility management

THANK YOU

Questions/Comments ????

Contact: Directorate of Petroleum
Plot 21-29 Johnstone Road
Entebbe
Email: directorate@petroleum.go.ug
Web: http://www.petroleum.go.ug/