Presentation given the TransLinks workshop:

Modeling and Managing Watersheds

September 13-16, 2011

Kigali, Rwanda
Umubano Hotel, Boulevard de l'umuganda

This workshop was hosted by the Wildlife Conservation Society, the United States Forest Service (USFS) and the United States Agency for International Development (USAID)

This workshop was generously supported by the American people through the United States Department of Agriculture (USDA) Forest Service and the United States Agency for International Development (USAID), under the terms of the TransLinks Cooperative Agreement No.EPP-A-00-06-00014-00 to the Wildlife Conservation Society (WCS). TransLinks is a partnership of WCS, The Earth Institute, Enterprise Works/VITA, Forest Trends and the Land Tenure Center. The contents are the responsibility of the authors and do not necessarily reflect the views of USAID or the United States government.

Modeling and Managing Watersheds Workshop: Results and Recommendations Tanzania

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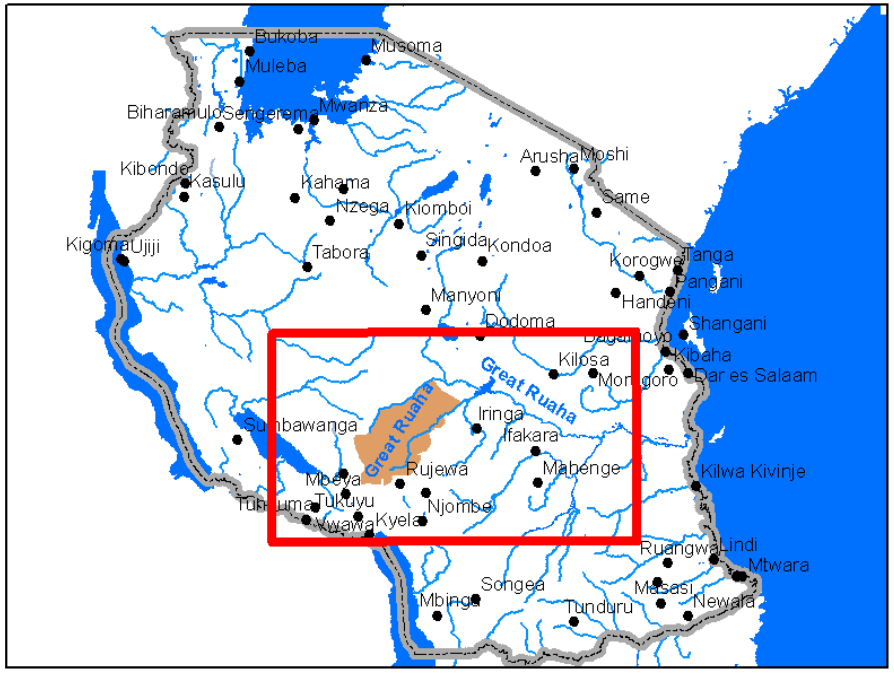
Eastern Forest Environmental Threat Assessment Center
Southern Research Station
USDA Forest Service, Raleigh NC

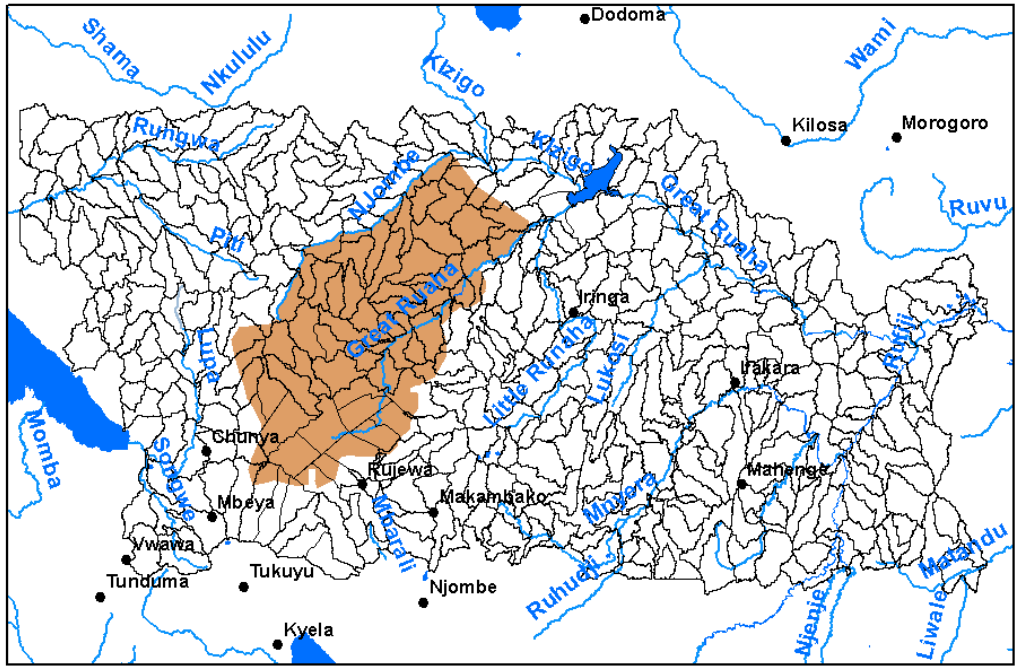
September 14, 2011; Kigali, Rwanda

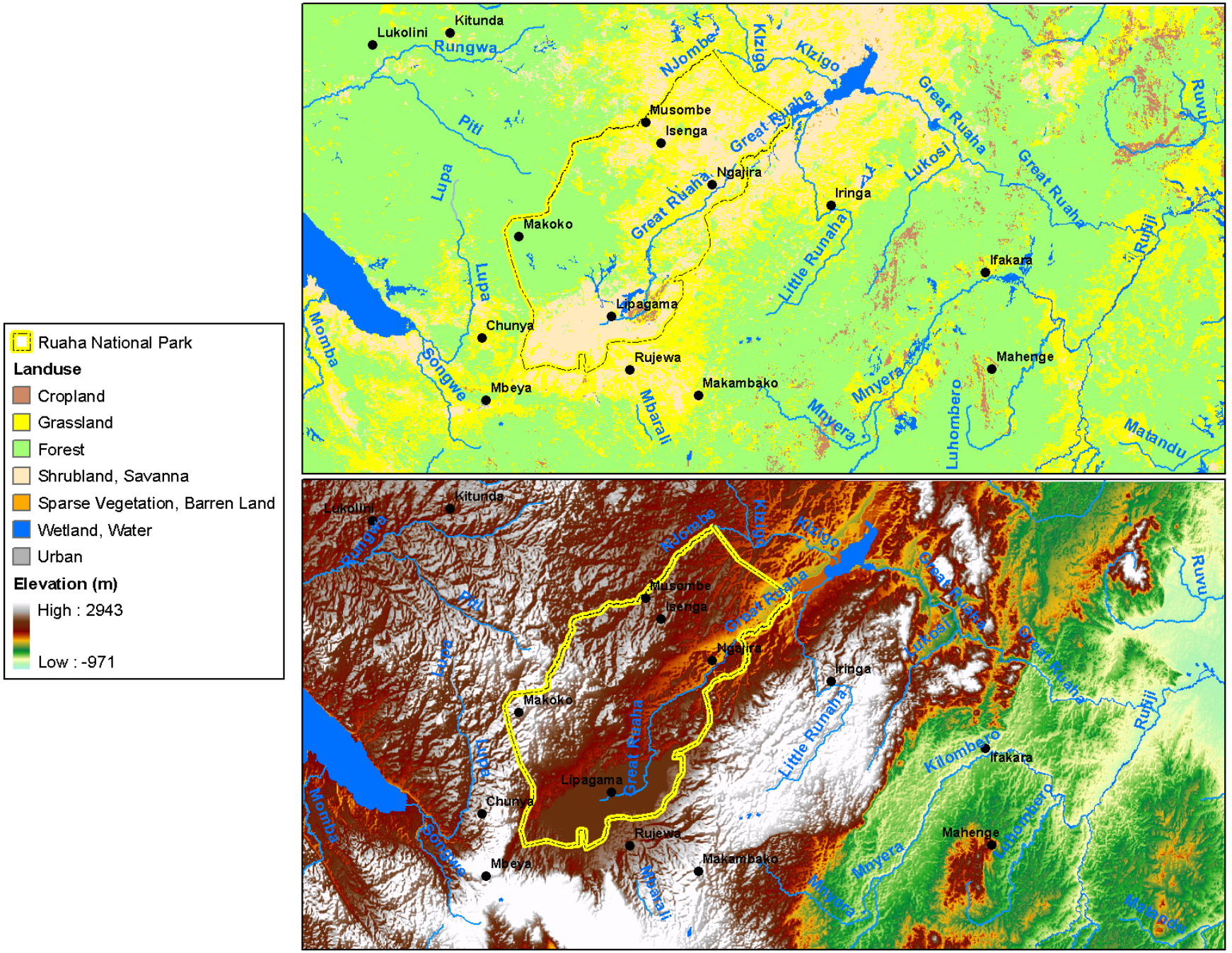
Outline

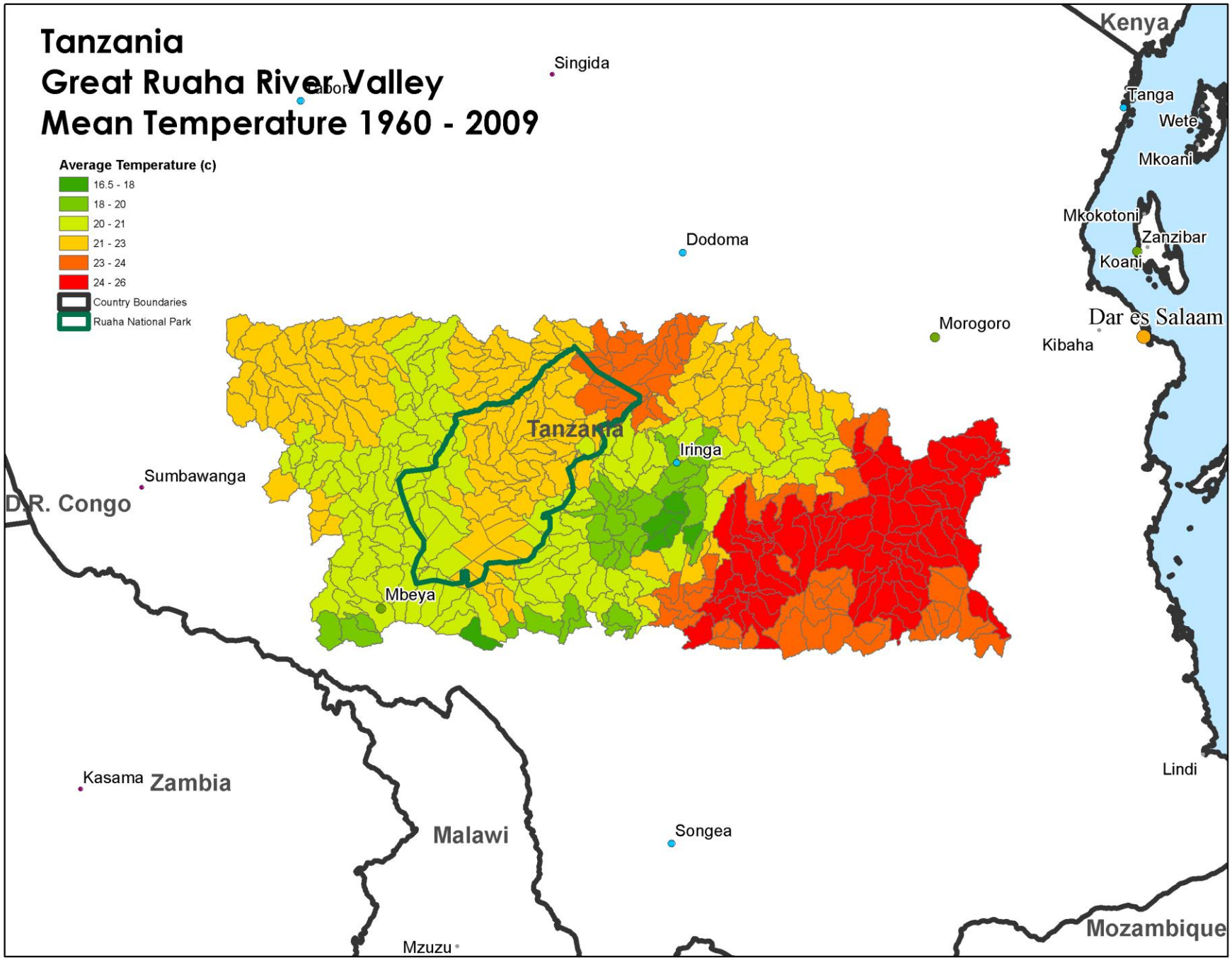
- Study Location
- Physical Characteristics
- Environmental Issues
- Goal
- Results
- Summary and Recommendation

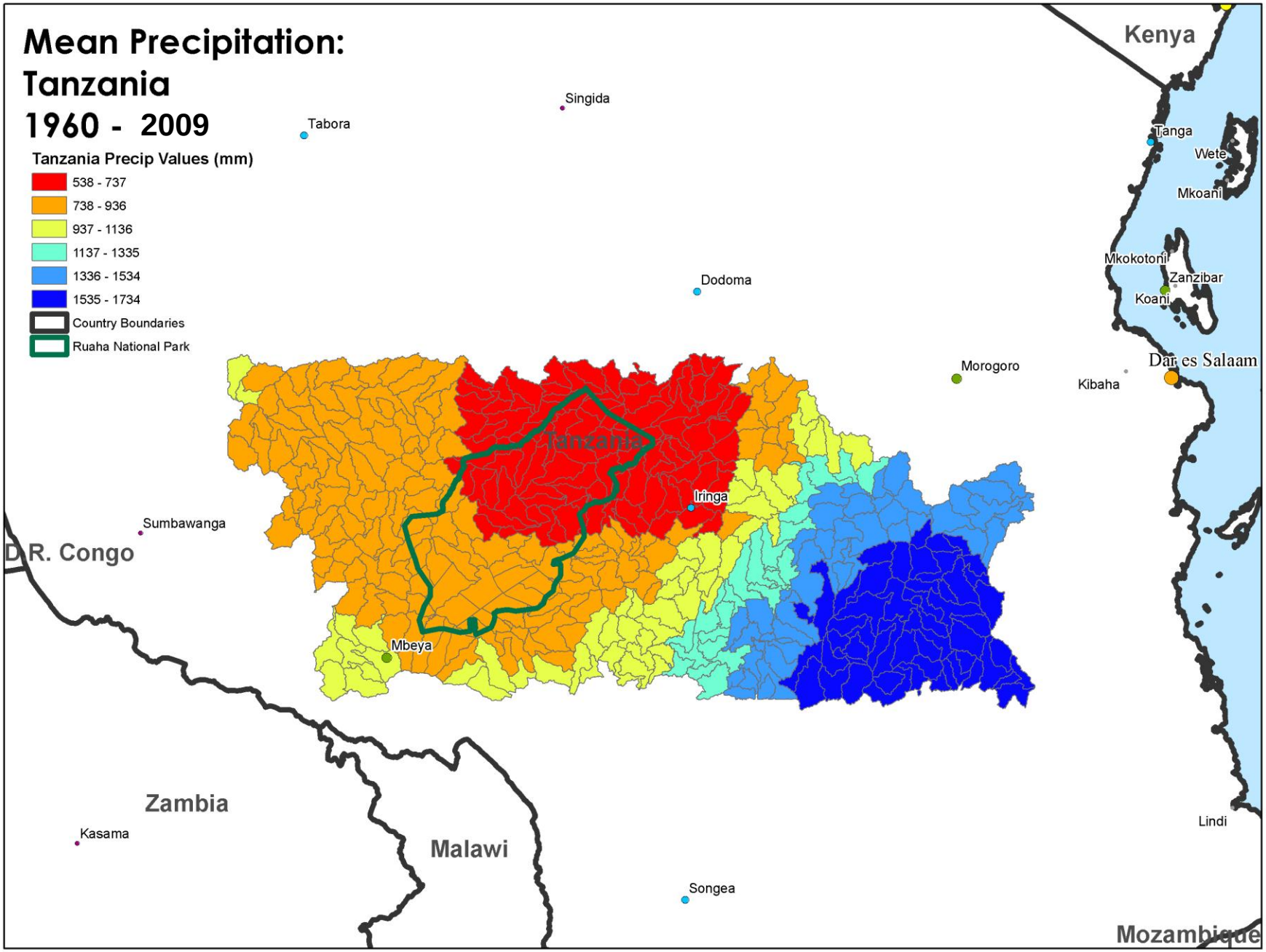
Study Location





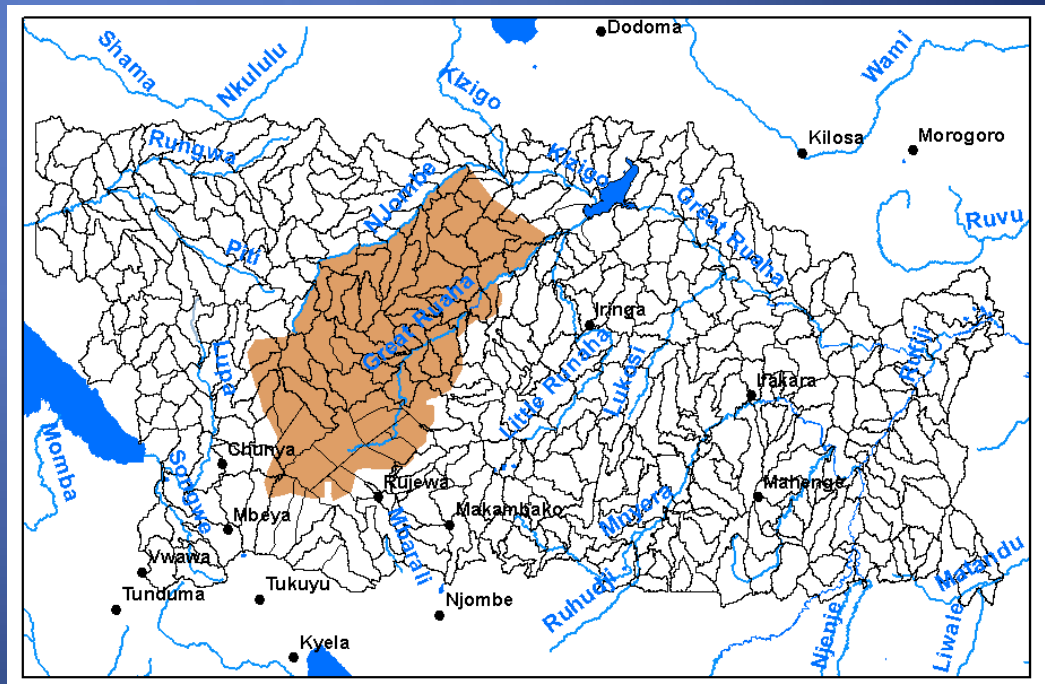

Ruaha National Park
Landuse
Cropland
Grassland
Forest
Shrubland, Savanna
Sparse Vegetation, Barren Land
Wetland, Water
Urban
Elevation (m)
High : 2943
Low : -971
Lukolini
Kitunda
Rungwa
Njombe
Kizigo
Musombe
Isenga
Great Ruaha
Ngajira
Iringa
Lukosi
Ruvu
Ruhuji
Piti
Lupa
Makoko
Little Ruaha
Ifakara
Lipagama
Chunya
Momba
Songwe
Rujewa
Mahenge
Mbeya
Makambako
Mbarali
Mnyera
Luhombero
Matandu


Tanzania
Great Ruaha River Valley
Mean Temperature 1960 - 2009
Average Temperature (c)
16.5 - 18
18 - 20
20 - 21
21 - 23
23 - 24
24 - 26
Country Boundaries
Ruaha National Park
Kenya
Singida
Tanga
Wete
Mkoani
Mkokotoni
Zanzibar
Koani
Dodoma
Morogoro
Dar es Salaam
Kibaha
Tanzania
Iringa
Sumbawanga
D.R. Congo
Mbeya
Kasama
Zambia
Malawi
Songea
Lindi
Mozambique
Mzuzu


Mean Precipitation:
Tanzania
1960 - 2009
Tanzania Precip Values (mm)
538 - 737
738 - 936
937 - 1136
1137 - 1335
1336 - 1534
1535 - 1734
Country Boundaries
Ruaha National Park
Kenya
Singida
Tabora
Tanga
Wete
Mkoani
Mkokotoni
Zanzibar
Koani
Dodoma
Morogoro
Dar es Salaam
Kibaha
Tanzania
Iringa
Sumbawanga
D.R. Congo
Mbeya
Zambia
Kasama
Malawi
Songea
Lindi
Mozambique

Environmental Issues

- Inconsistency in Seasonal flow
  - 1993 to present
  - Portions of the Great Ruaha River and its tributaries have weeks of no flow in the dry season
- Excessive Erosion and Storm Flow/Flooding
- Possible reasons
  - Water diversion for rice farming
  - Overgrazing
  - Little to no vegetative cover



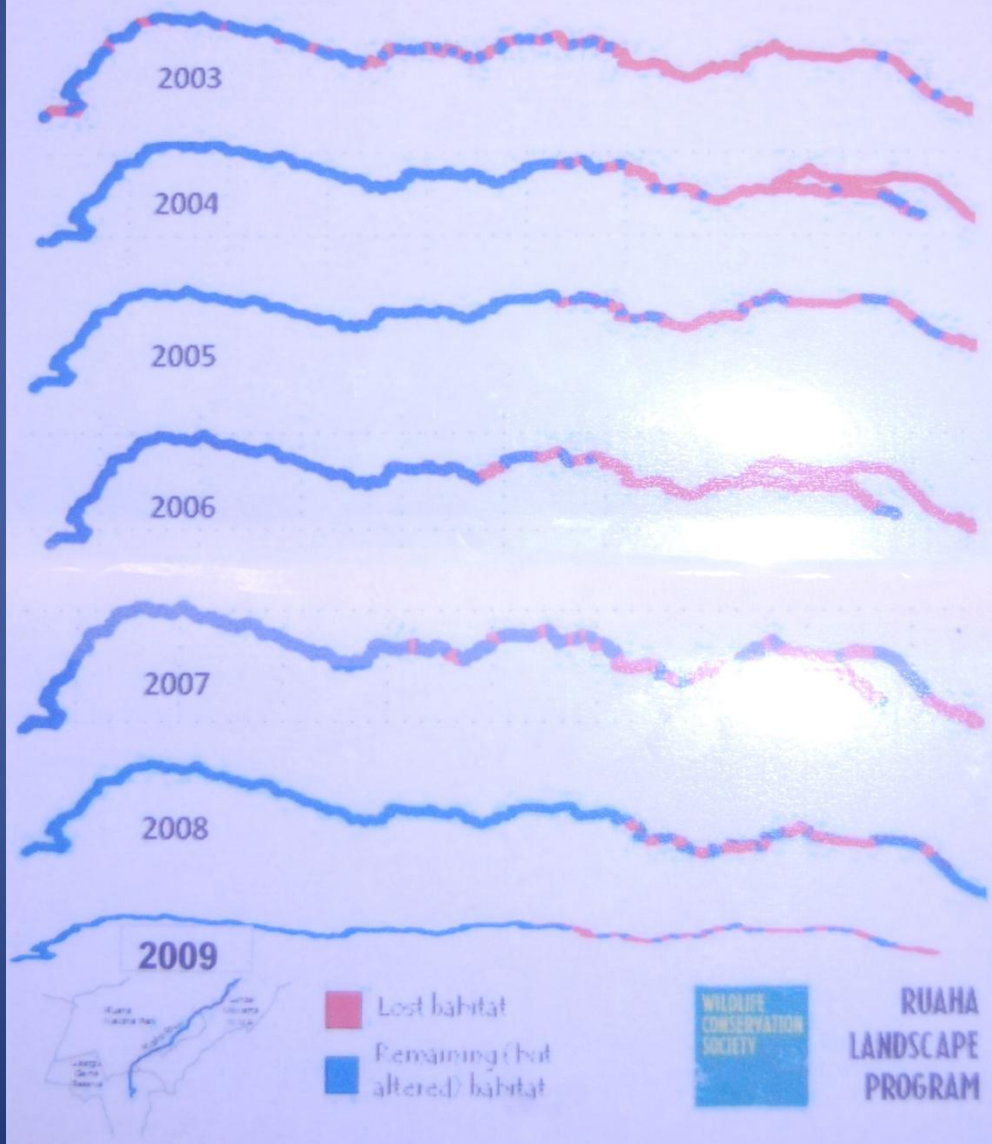
Tributary of The Great Ruaha River

The Great Ruaha River

Rice Farming

DRY SEASON HABITAT OF THE GREAT RUAHA RIVER 2003 TO 2009

AREAS <1KM FROM SURFACE WATER



The Great Ruaha River
Inside
the Ruaha National Park

Storm Flow and Flooding

Excessive Erosion

Goal

- Model water quantity and sedimentation within the Ruaha River Landscape with current landcover conditions

- To simulate landuse and/or climate change within the modeling framework and quantify its impact on water quantity and sedimentation

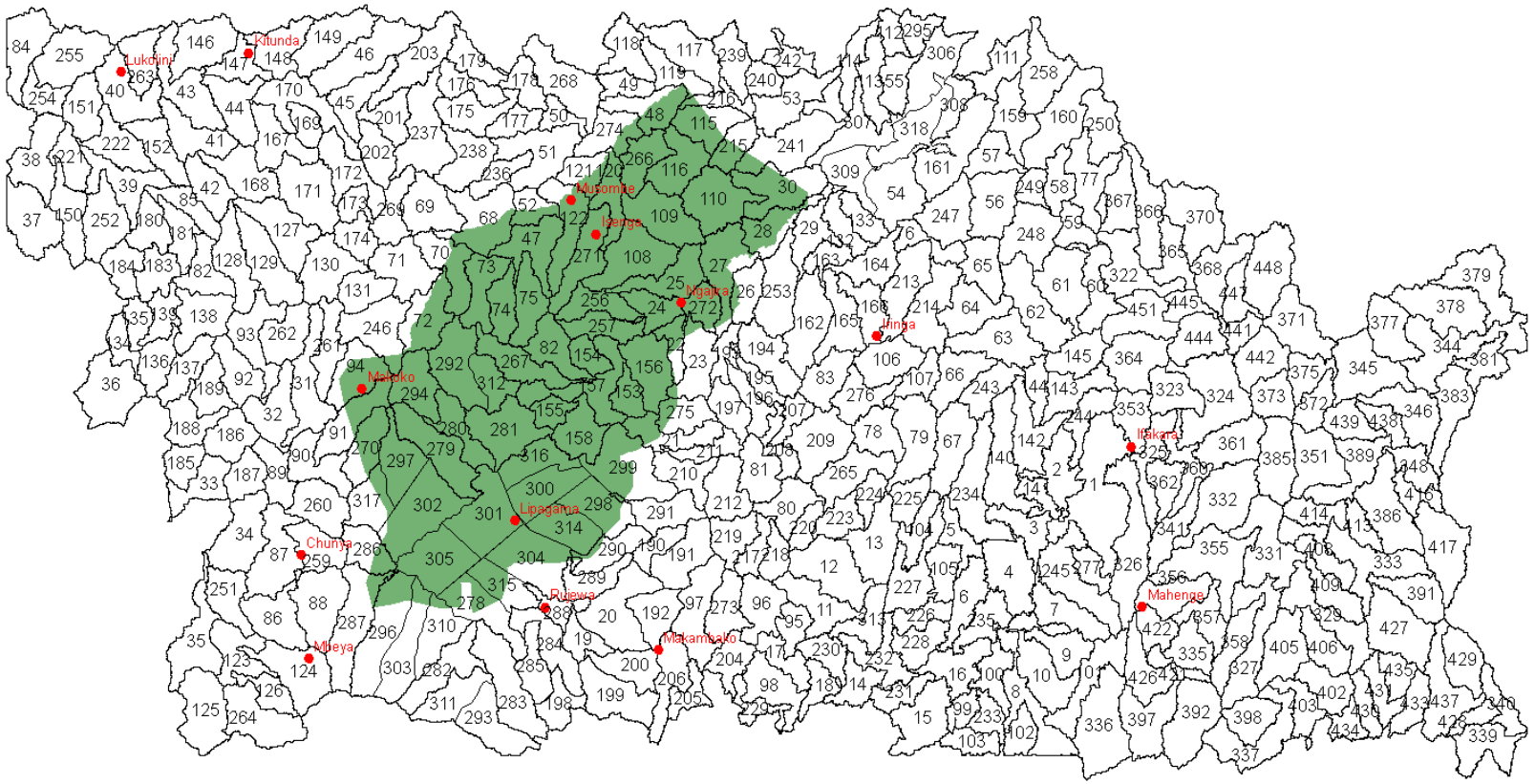
Result Scenario: Water Quantity

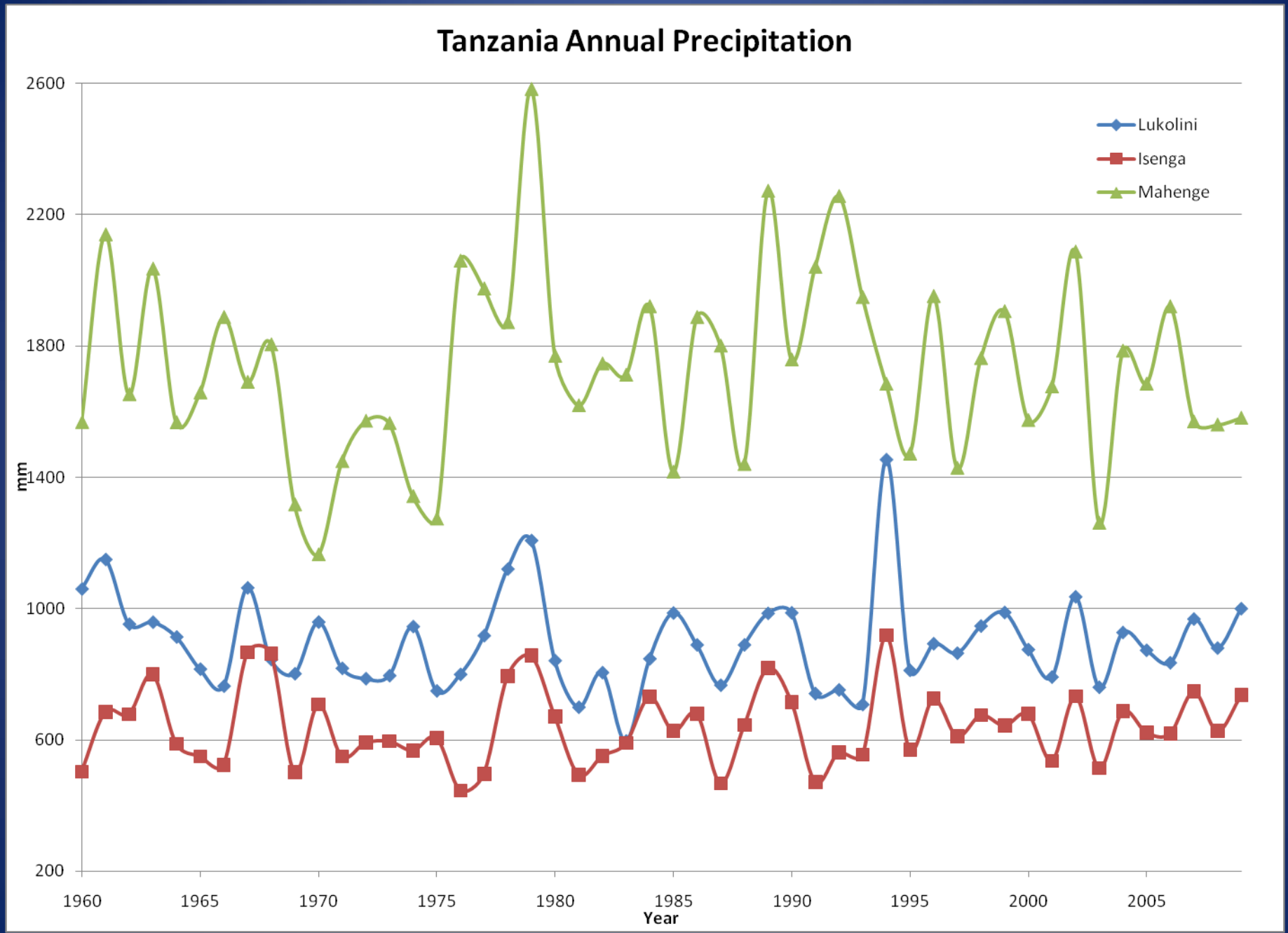
- Scenarios (4)
  - Baseline
    - 2009 landcover
    - Monthly precipitation and temperature from 1960-2009
  - Converting 20% of forest to cropland
  - 1 Degree temperature increase
  - 1 Degree temperature increase + 10% reduction in precipitation

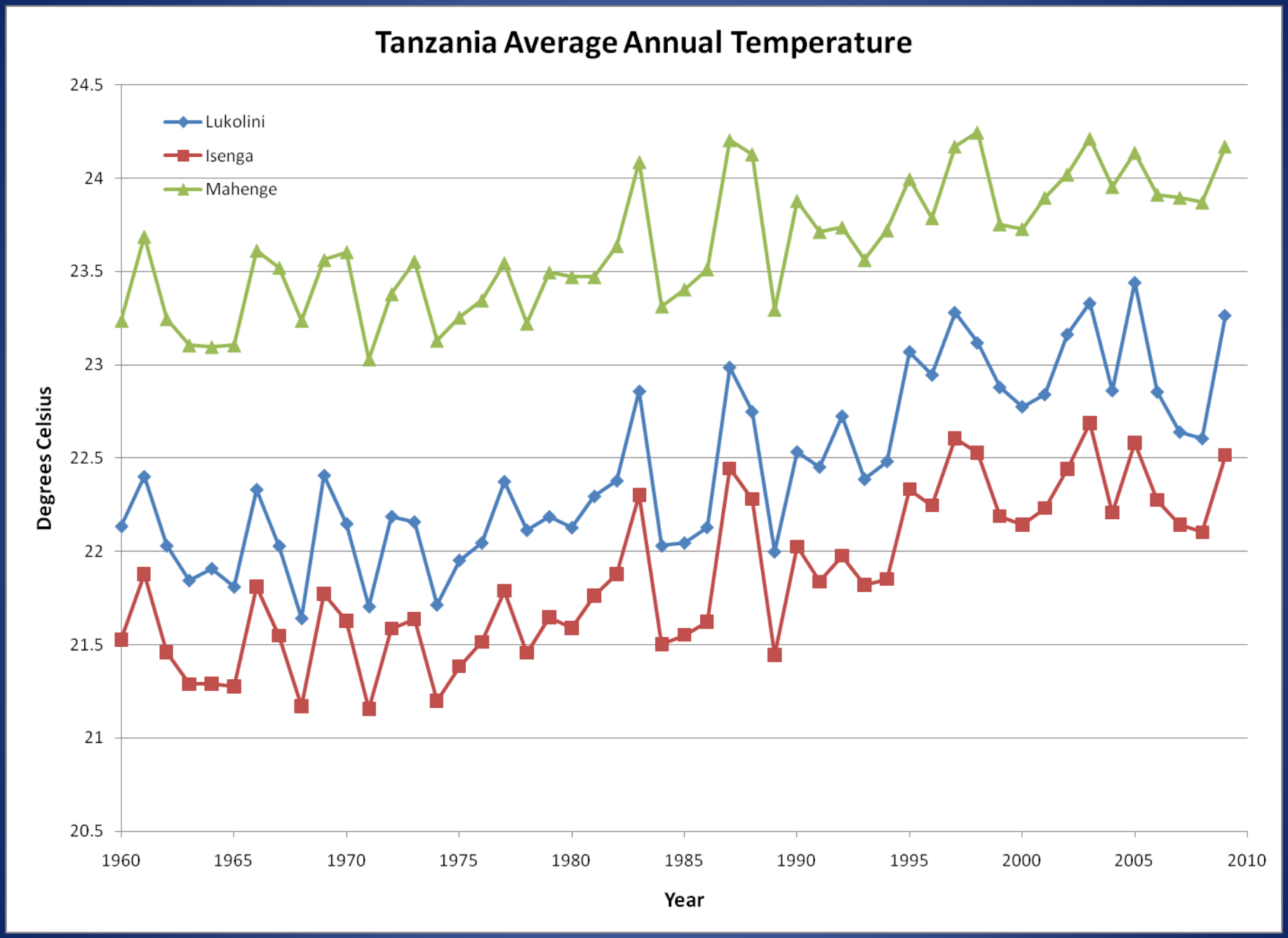
Input Databases

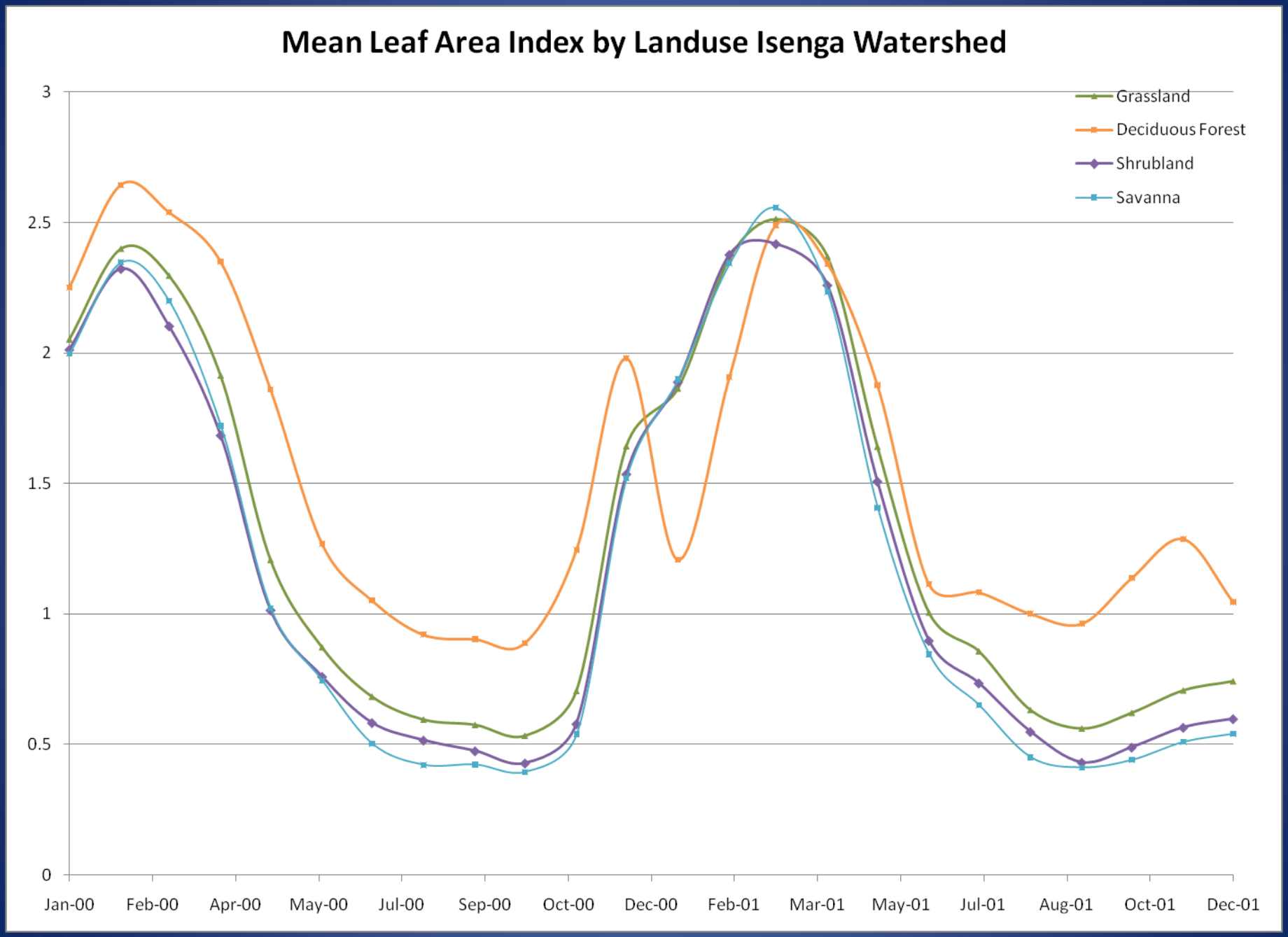
Data	Spatial Resolution	Temporal Resolution	Time Step	Source
Temperature and Precipitation	0.5° x 0.5°	1960-2009	Monthly	Climate Research Unit (CRU) Time-Series (TS) Dataset 3.1; The University of East Anglia
Leaf Area Index	1km x 1km	2000-2006	Monthly	Zhao et al.,2005; Numerical Terradynamic Simulation Group (NTSG) at the University of Montana Missoula MODIS Imagery, MOD15(FPAR/LAI),
Landcover	300m x 300m	2009	static	Globcover, European Space Agency (ESA), MERIS instrument

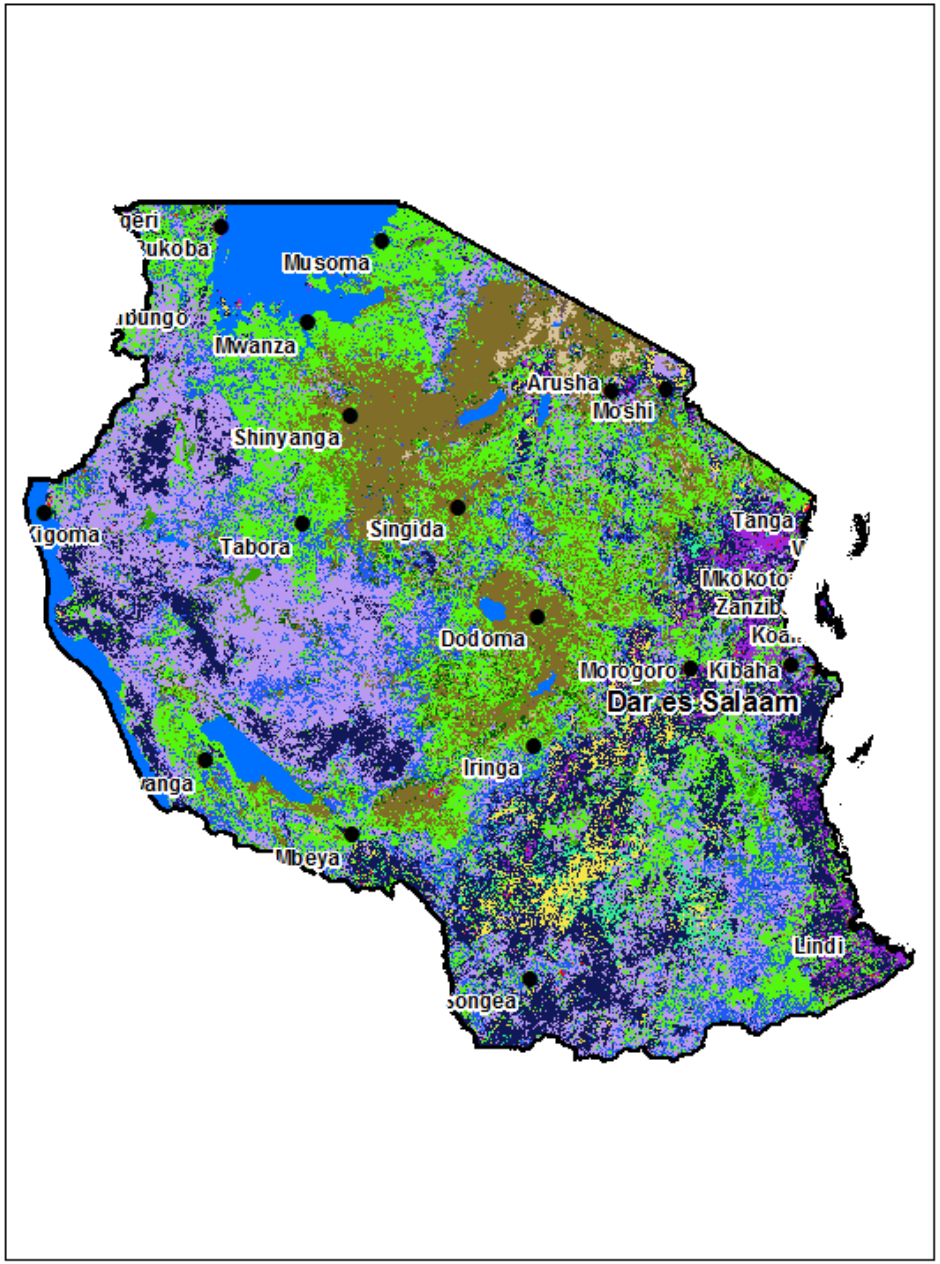
The Great Ruaha River and Ruaha National Park Watersheds Delineated from ASTER DEM




Tanzania Annual Precipitation
2600
2200
1800
1400
1000
600
200
mm
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
Year
Lukolini
Isenga
Mahenge


Tanzania Average Annual Temperature
Lukolini
Isenga
Mahenge
Degrees Celsius
24.5
24
23.5
23
22.5
22
21.5
21
20.5
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
Year


Mean Leaf Area Index by Landuse Isenga Watershed
3
2.5
2
1.5
1
0.5
0
Jan-00
Feb-00
Apr-00
May-00
Jul-00
Sep-00
Oct-00
Dec-00
Feb-01
Mar-01
May-01
Jul-01
Aug-01
Oct-01
Dec-01
Grassland
Deciduous Forest
Shrubland
Savanna



Tanzania

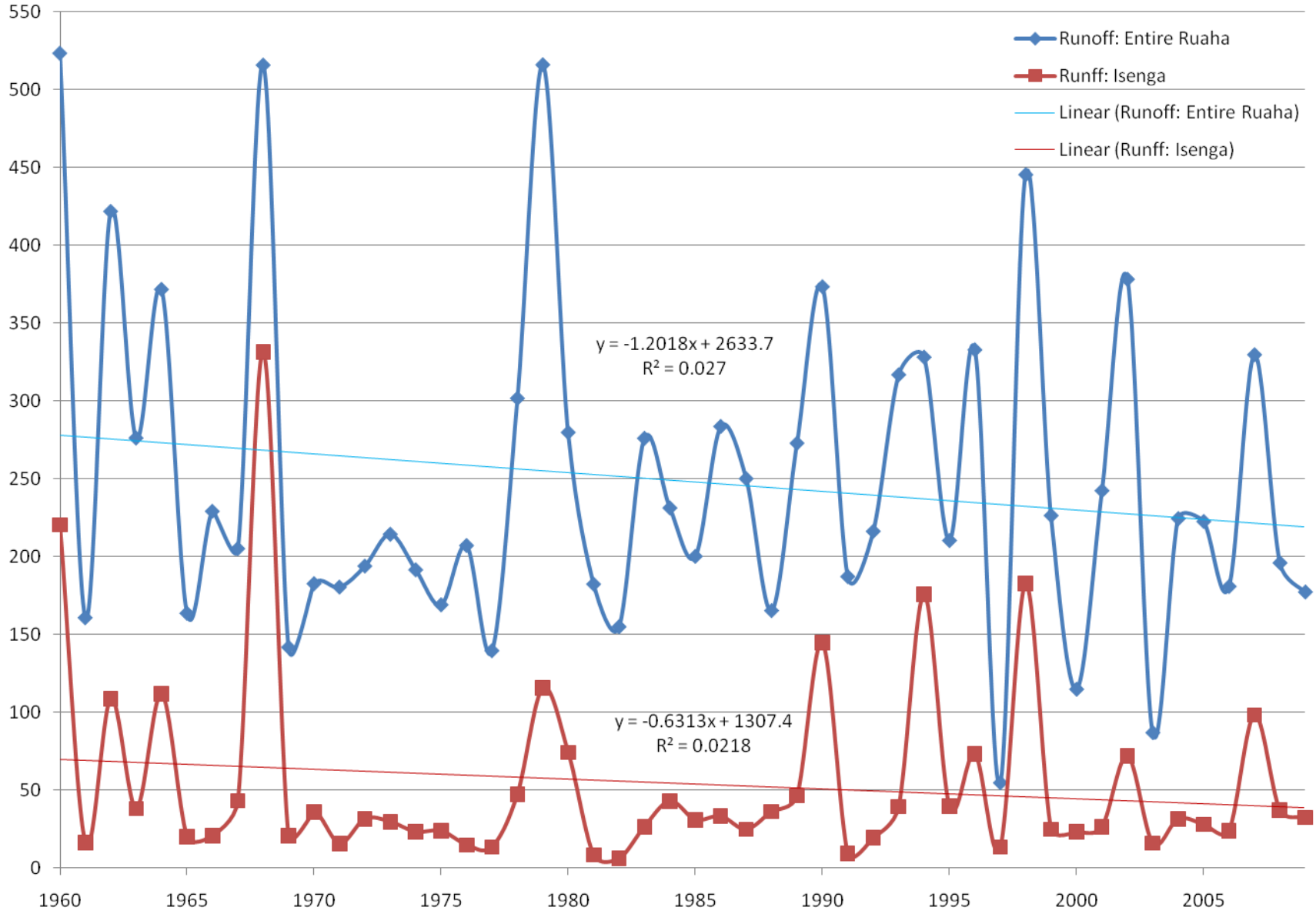
300 meter resolution
Land Cover
Globcover Dataset 2009

Land Cover Types

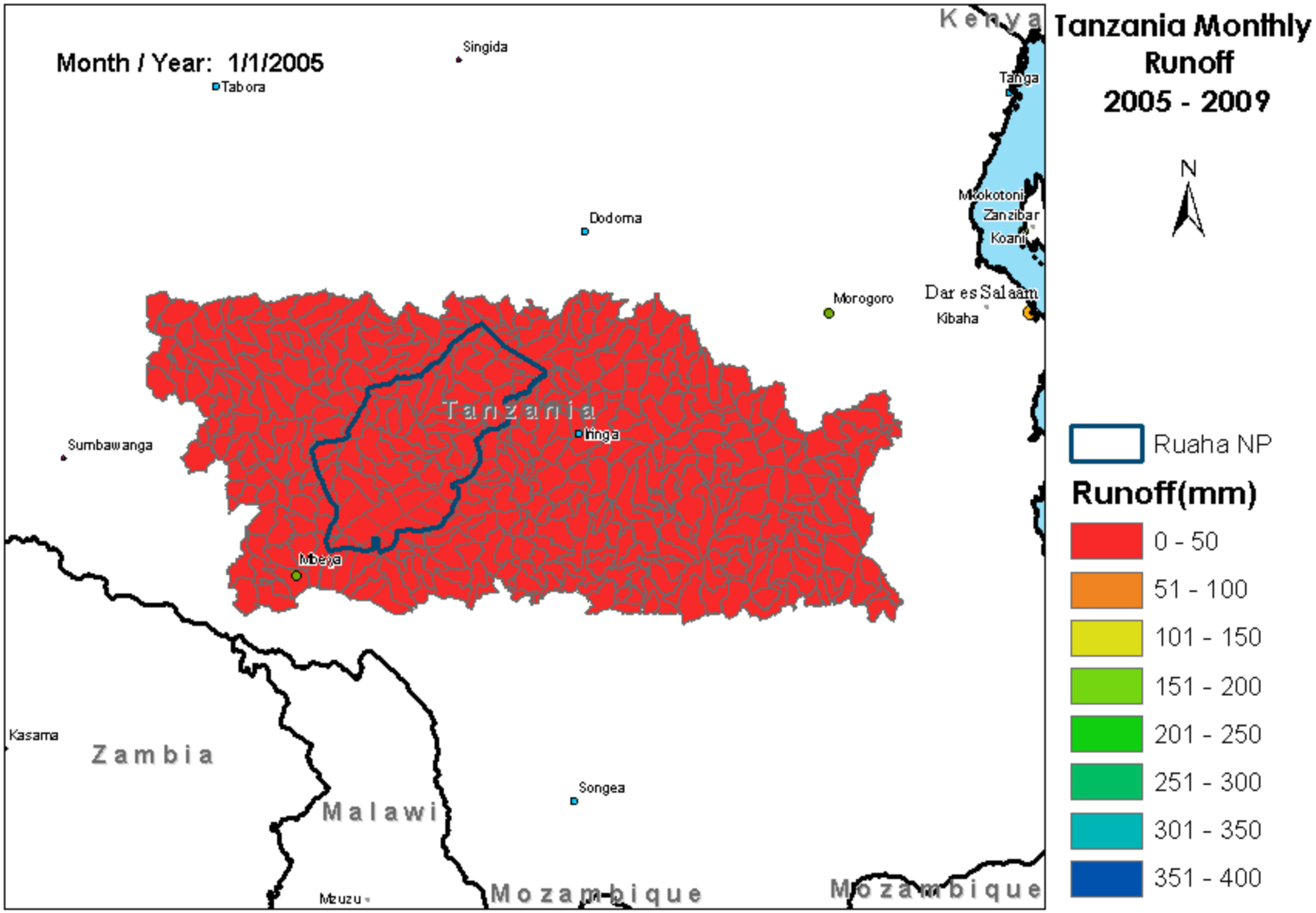
- Post-flooding or irrigated croplands
- Rainfed croplands
- Mosaic cropland (50-70%)
- Mosaic vegetation
- Closed to open (> 15%) broadleaved deciduous forest
- Closed (>40%) broadleaved deciduous forest
- Open (15 - 40 %) broadleaved deciduous forest
- Closed needleleaved evergreen forest
- Open needleleaved deciduous or evergreen forest
- Closed to open mixed broadleaved and needleleaved forest
- Mosaic forest or shrubland
- Mosaic grasland
- Closed to open shrubland
- Closed to open herbaceous vegetation
- Sparse Vegetation
- Closed to open flooded broadleaved forest
- Closed broadleaved forest permanently flooded
- Closed to open grassland or woody vegetation on waterlogged soil
- Artificial Surfaces and associated areas (Urban > 50%)
- Bare Areas
- Water bodies
- Permanent Snow

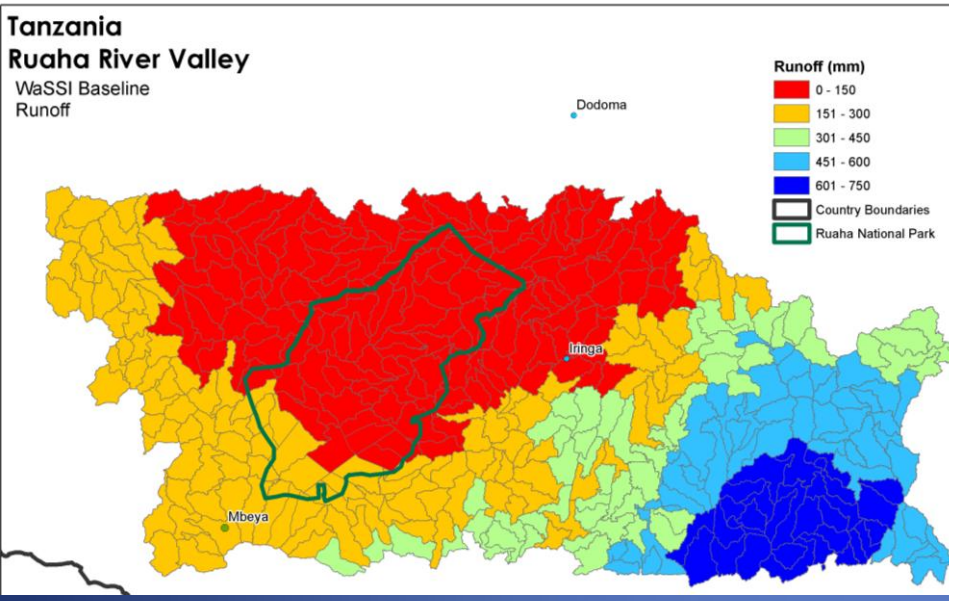
Model Output

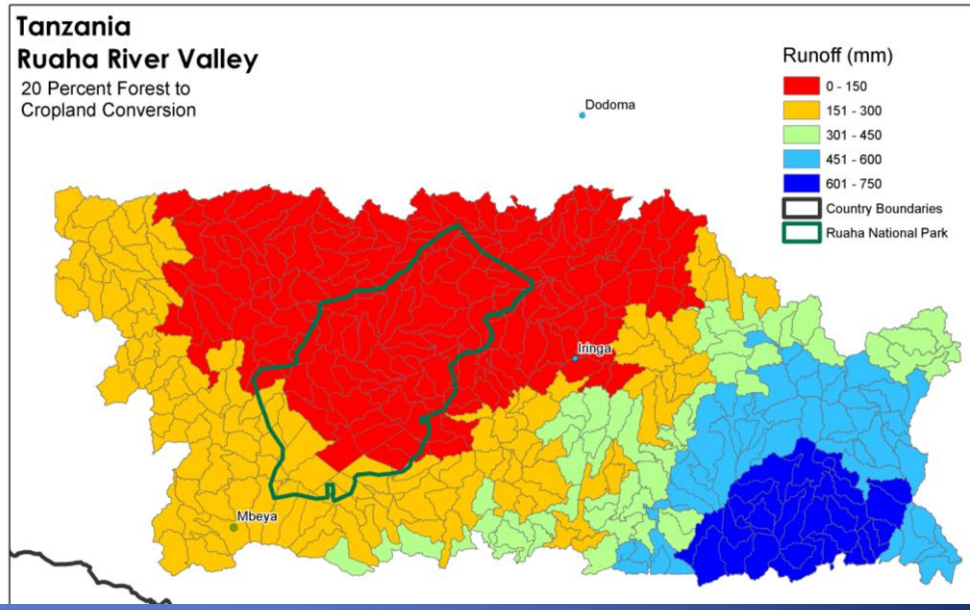
Modeled Runoff, Mean Entire Ruaha and Isenga Watershed

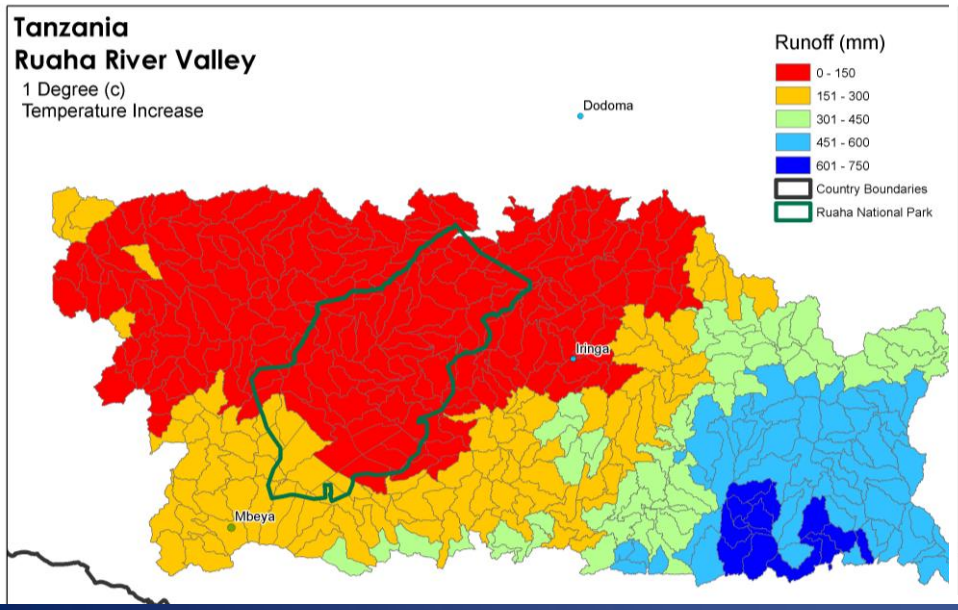


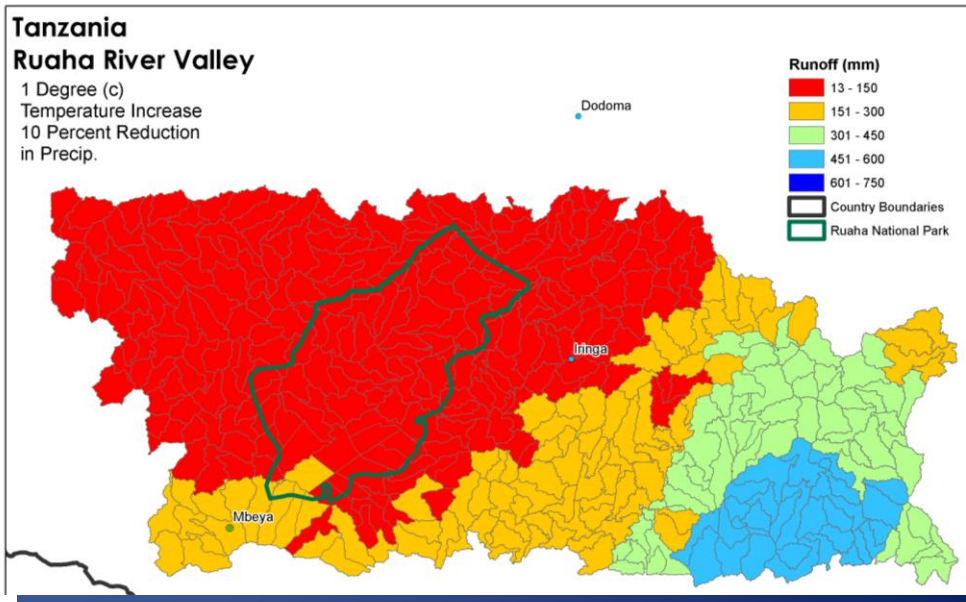
Baseline Monthly Runoff Animation

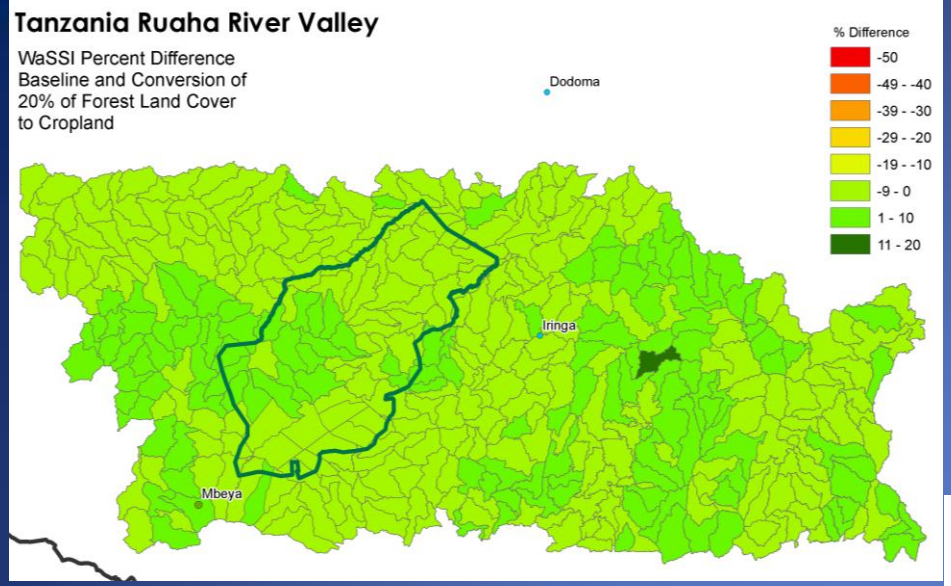

Month / Year: 1/1/2005
Tanzania Monthly Runoff 2005 - 2009
N
Kenya
Singida
Tabora
Tanga
Mkokotoni
Zanzibar
Koani
Dodoma
Morogoro
Dar es Salaam
Kibaha
Tanzania
Iringa
Sumbawanga
Mbeya
Kasama
Zambia
Malawi
Songea
Mzuzu
Mozambique
Mozambique
Ruaha NP
Runoff(mm)
0 - 50
51 - 100
101 - 150
151 - 200
201 - 250
251 - 300
301 - 350
351 - 400

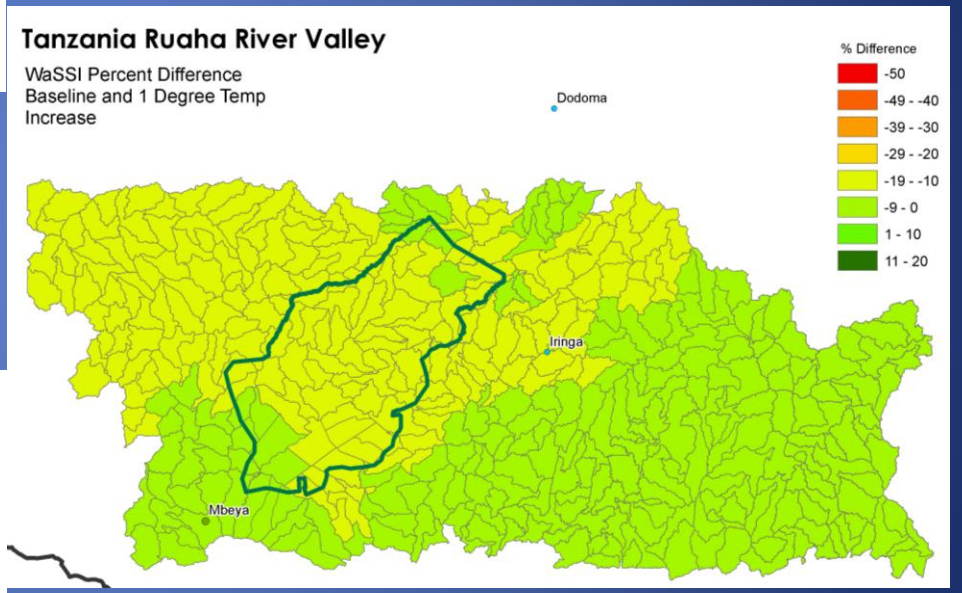

Tanzania
Ruaha River Valley
WaSSI Baseline
Runoff
Dodoma
Iringa
Mbeya
Runoff (mm)
0 - 150
151 - 300
301 - 450
451 - 600
601 - 750
Country Boundaries
Ruaha National Park

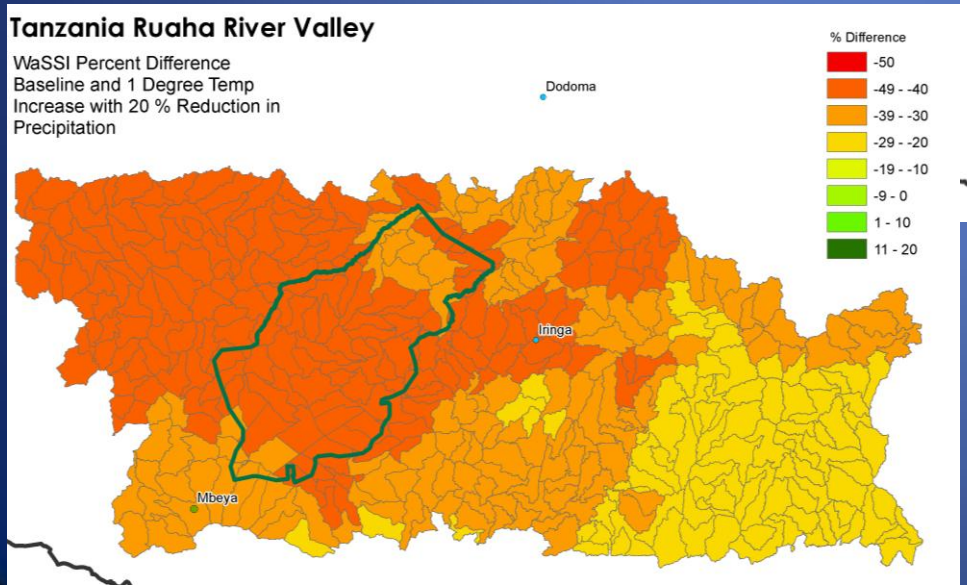

Tanzania
Ruaha River Valley
20 Percent Forest to
Cropland Conversion
Dodoma
Iringa
Mbeya
Runoff (mm)
0 - 150
151 - 300
301 - 450
451 - 600
601 - 750
Country Boundaries
Ruaha National Park


Tanzania
Ruaha River Valley
1 Degree (c)
Temperature Increase
Dodoma
Iringa
Mbeya
Runoff (mm)
0 - 150
151 - 300
301 - 450
451 - 600
601 - 750
Country Boundaries
Ruaha National Park


Tanzania
Ruaha River Valley
1 Degree (c)
Temperature Increase
10 Percent Reduction
in Precip.
Dodoma
Iringa
Mbeya
Runoff (mm)
13 - 150
151 - 300
301 - 450
451 - 600
601 - 750
Country Boundaries
Ruaha National Park


Tanzania Ruaha River Valley
WaSSI Percent Difference
Baseline and Conversion of
20% of Forest Land Cover
to Cropland
Dodoma
Iringa
Mbeya
% Difference
-50
-49 - -40
-39 - -30
-29 - -20
-19 - -10
-9 - 0
1 - 10
11 - 20


Tanzania Ruaha River Valley
WaSSI Percent Difference
Baseline and 1 Degree Temp
Increase
Dodoma
Iringa
Mbeya
% Difference
-50
-49 - -40
-39 - -30
-29 - -20
-19 - -10
-9 - 0
1 - 10
11 - 20


Tanzania Ruaha River Valley
WaSSI Percent Difference
Baseline and 1 Degree Temp
Increase with 20 % Reduction in
Precipitation
Dodoma
Iringa
Mbeya
% Difference
-50
-49 - -40
-39 - -30
-29 - -20
-19 - -10
-9 - 0
1 - 10
11 - 20

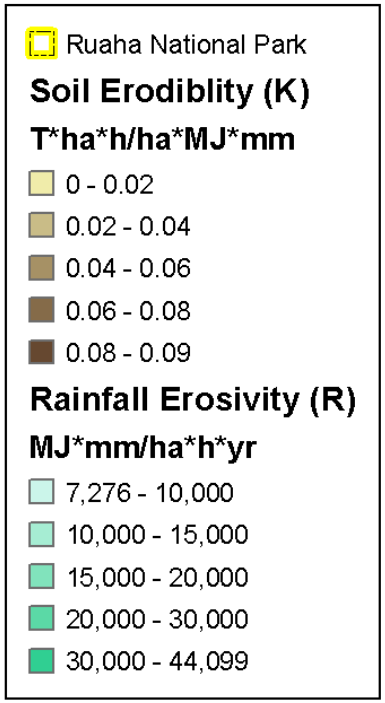
Result Scenario: Sedimentation

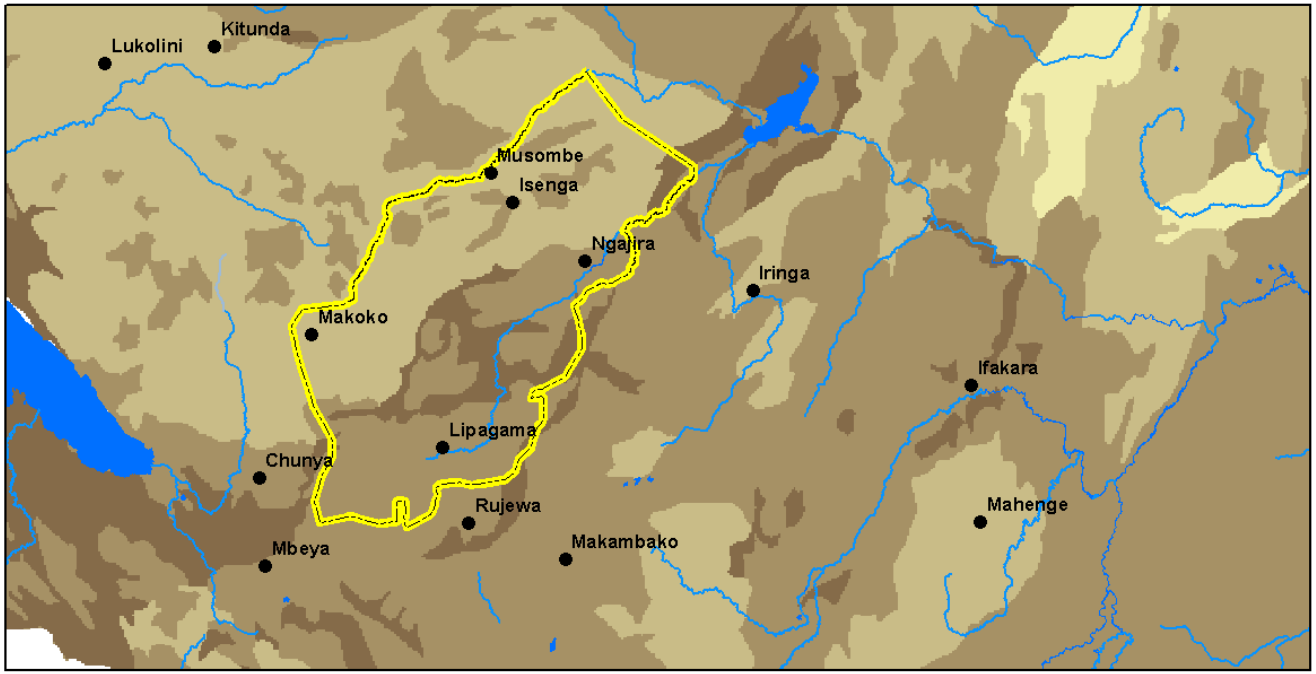
- Scenarios (2)
  - Baseline
    - 2009 landcover
    - Monthly precipitation and temperature from 1960-2009
  - Deforestation
    - Simulate converting one forest landcover class to crop
      - Open(15-40%) broadleaved deciduous forest/woodland (>5m)

Universal Soil Loss Equation

$$A = R * K * LS * C * P$$

A: Average annual soil loss (Tons/ha*yr)
R : Rainfall and runoff erosivity
K: Soil erodibility
LS: Slope length-gradient factor
C: Crop and management Factor
P: Support practice factor


Ruaha National Park
Soil Erodiblity (K)
T*ha*h/ha*MJ*mm
0 - 0.02
0.02 - 0.04
0.04 - 0.06
0.06 - 0.08
0.08 - 0.09
Rainfall Erosivity (R)
MJ*mm/ha*h*yr
7,276 - 10,000
10,000 - 15,000
15,000 - 20,000
20,000 - 30,000
30,000 - 44,099


Lukolini
Kitunda
Musombe
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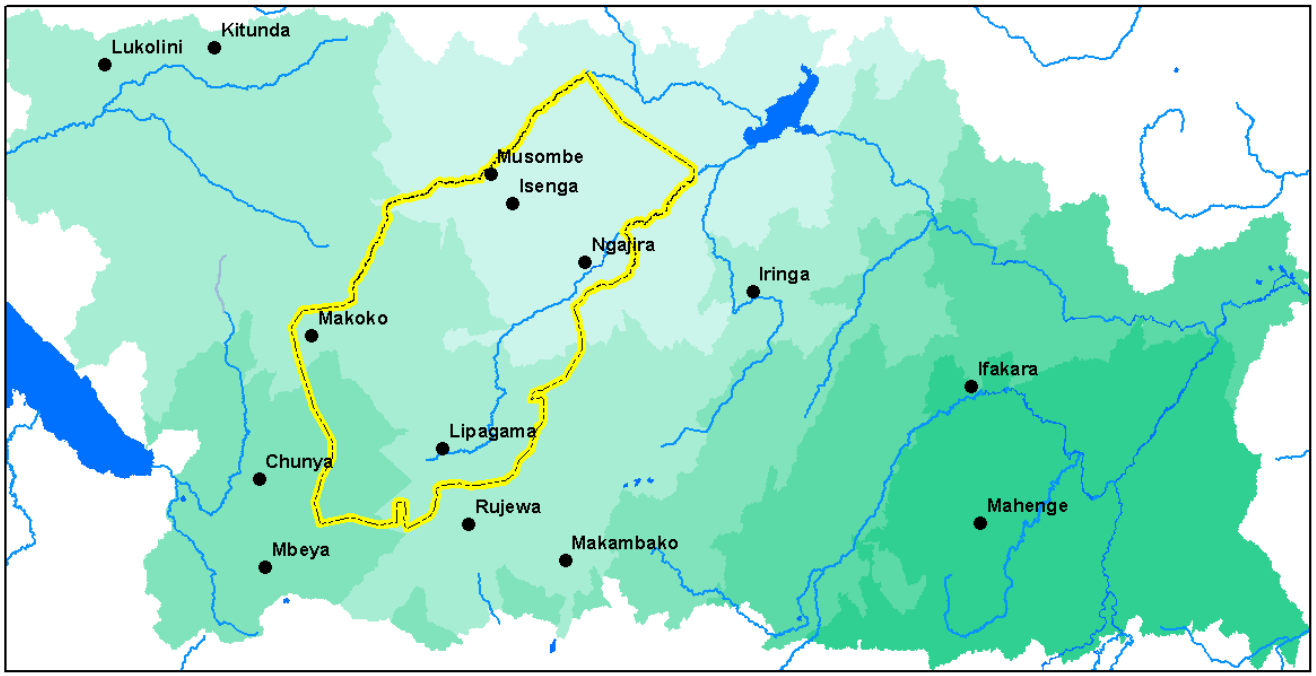
Lukolini
Kitunda
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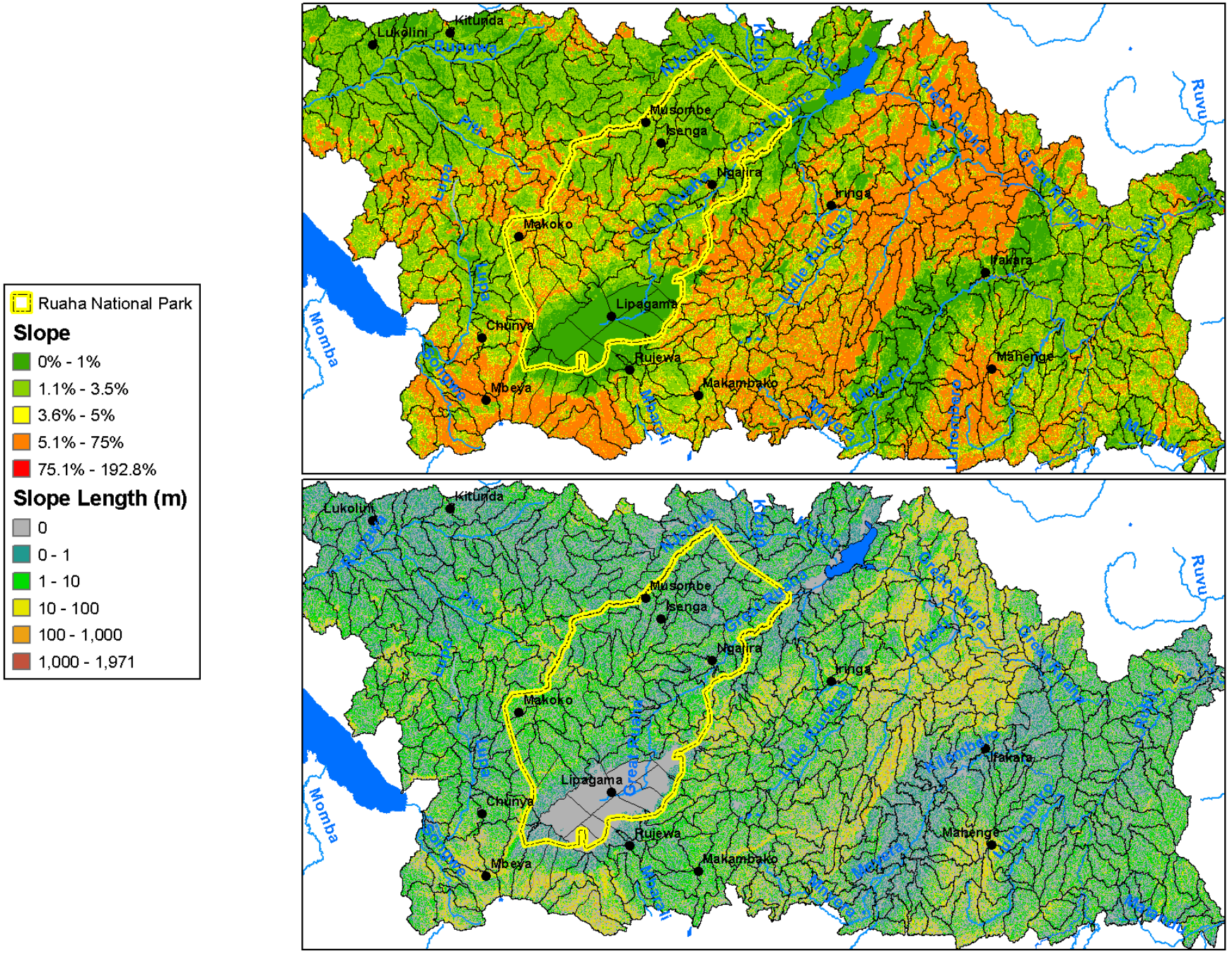
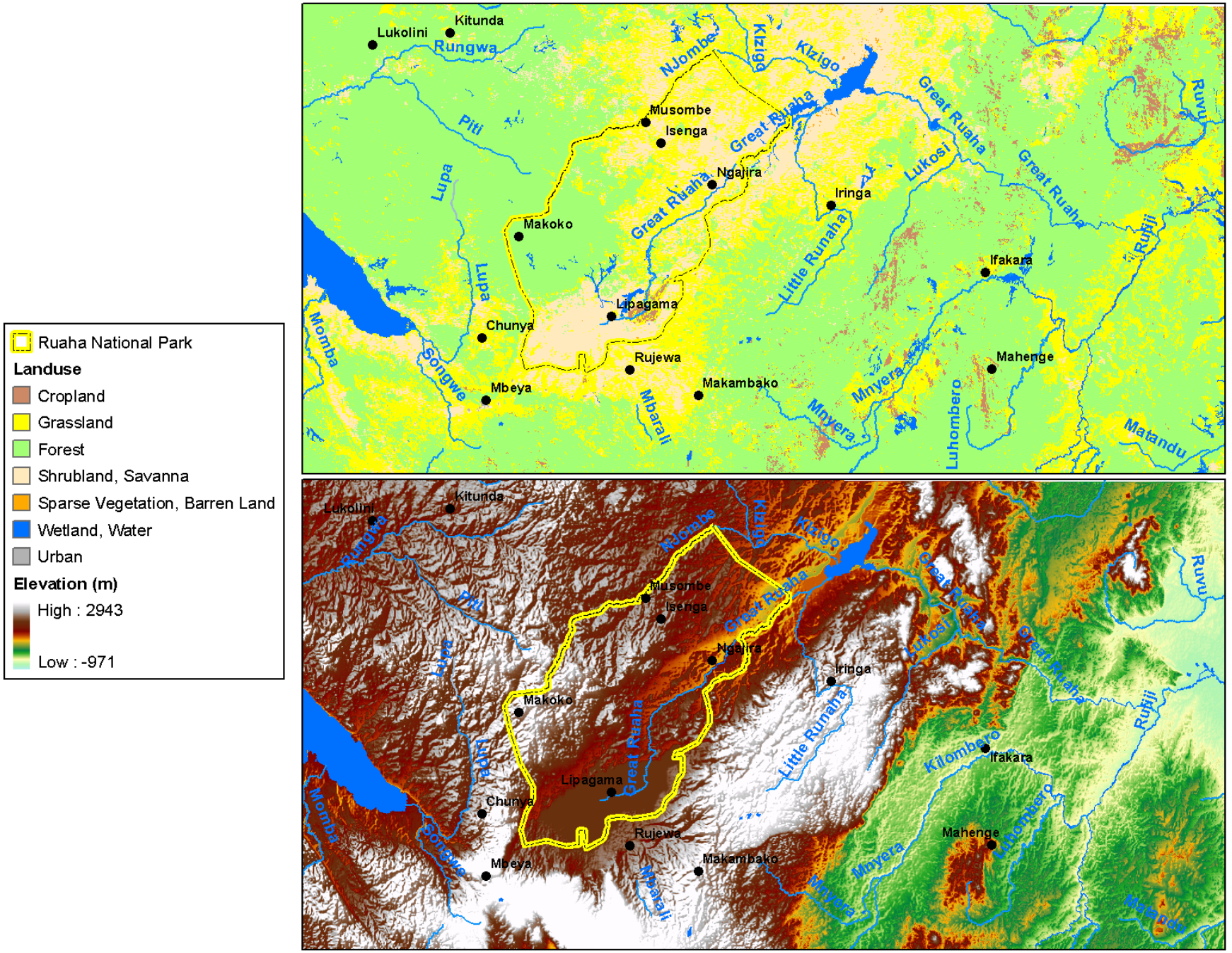
Makambako


Ruaha National Park
Slope
0% - 1%
1.1% - 3.5%
3.6% - 5%
5.1% - 75%
75.1% - 192.8%
Slope Length (m)
0
0 - 1
1 - 10
10 - 100
100 - 1,000
1,000 - 1,971
Kitunda
Lukolini
Musombe
Isenga
Ngaiira
Iringa
Makoko
Ifakara
Lipagama
Chunya
Rujewa
Mahenge
Mbeya
Makambako
Mtera
Ruvu
Momba
Great Ruaha
Little Ruaha
Kilombero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Landuse
Cropland
Grassland
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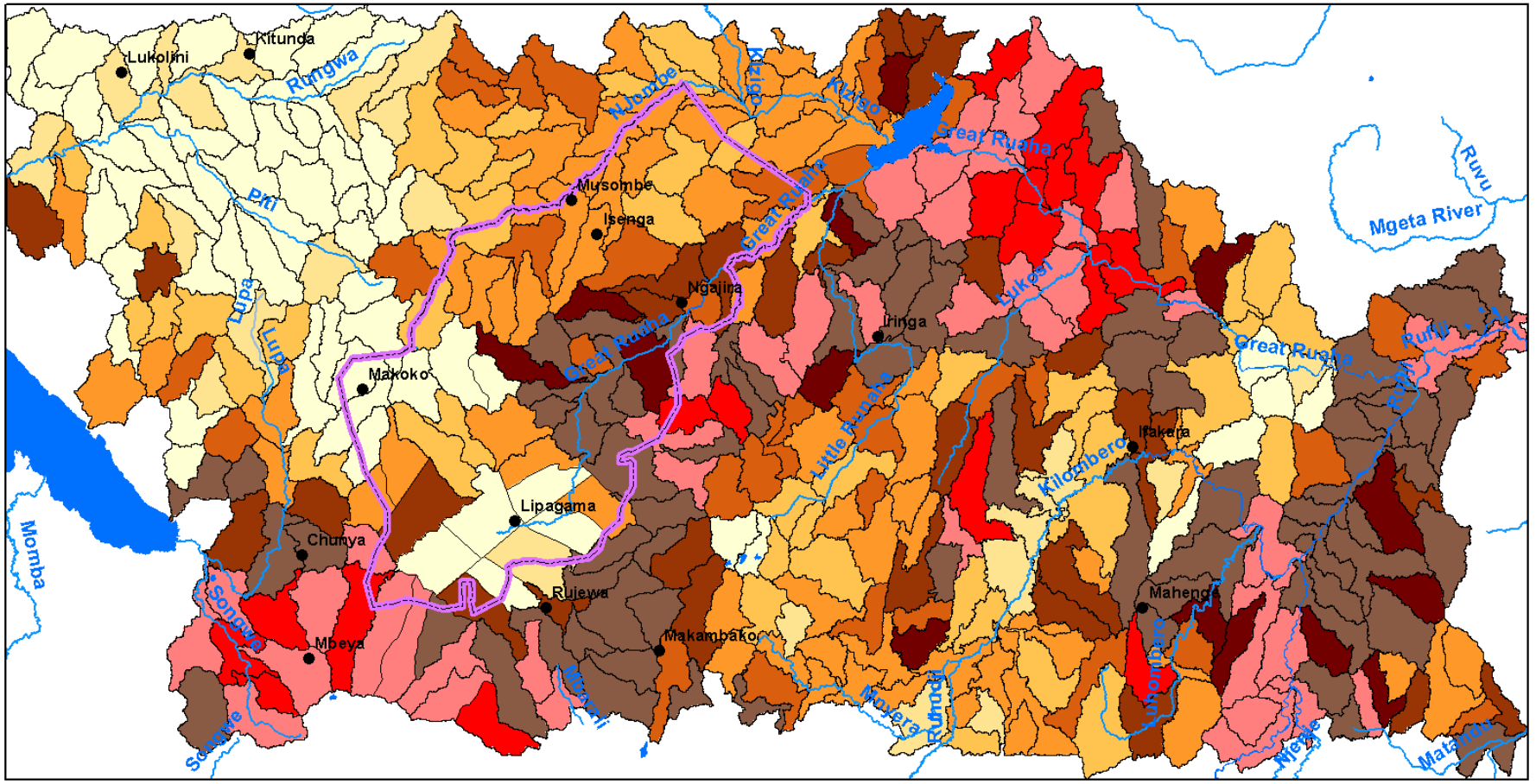
Ifakara
Lipagama
Chunya
Momba
Songwe
Rujewa
Mahenge
Mbeya
Makambako
Mbarali
Mnyera
Luhombero
Matandu

Cover and Management Factor(C) and Practice Factor (P)

lucode	LULC_desc	usle_c	usle_p
14	Rainfed croplands	0.07	0.5
20	Mosaic cropland (50-70%) / vegetation (grassland/shrubland/forest) (20-50%)	0.07	0.5
30	Mosaic vegetation (grassland/shrubland/forest) (50-70%) / cropland (20-50%)	0.1	1
40	Closed to open (>15%) broadleaved evergreen or semi-deciduous forest (>5m)	0.001	1
50	Closed (>40%) broadleaved deciduous forest (>5m)	0.001	1
60	Open (15-40%) broadleaved deciduous forest/woodland (>5m)	0.001	1
70	Closed (>40%) needleleaved evergreen forest (>5m)	0.001	1
90	Open (15-40%) needleleaved deciduous or evergreen forest (>5m)	0.001	1
100	Closed to open (>15%) mixed broadleaved and needleleaved forest (>5m)	0.001	1
110	Mosaic forest or shrubland (50-70%) / grassland (20-50%)	0.1	1
120	Mosaic grassland (50-70%) / forest or shrubland (20-50%)	0.1	1
130	Closed to open (>15%) (broadleaved or needleleaved, evergreen or deciduous) shrubland (<5m)	0.001	1
140	Closed to open (>15%) herbaceous vegetation (grassland, savannas or lichens/mosses)	0.1	1
150	Sparse (<15%) vegetation	0	1
160	Closed to open (>15%) broadleaved forest regularly flooded (semi-permanently or temporarily) - Fresh or brackish water	0	1
170	Closed (>40%) broadleaved forest or shrubland permanently flooded - Saline or brackish water	0	1
180	Closed to open (>15%) grassland or woody vegetation on regularly flooded or waterlogged soil - Fresh, brackish or saline water	0	1
190	Artificial surfaces and associated areas (Urban areas >50%)	0	1
200	Bare areas	0	1
210	Water bodies	0	1

- Georgia Soil Water and Conservation Commission, 2000, Manuel for Erosion and Sediment Control in Georgia
- USLE Fact Sheet, Ontario Ministry of Agriculture Food and Rural Affairs

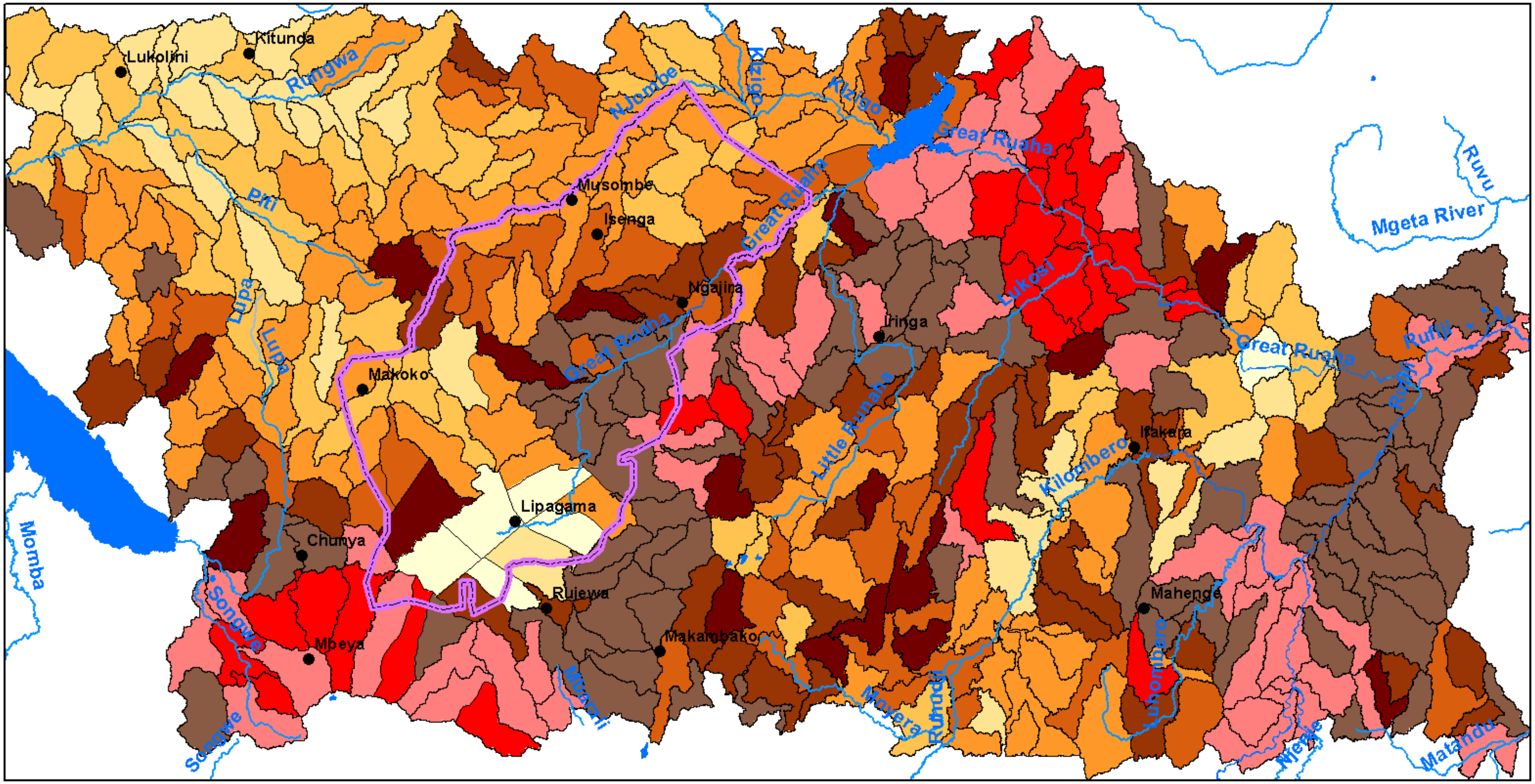


Universal Soil Loss Equation
Mean Potential Soil Loss
by
Watershed: Baseline

- Towns
- Ruaha National Park

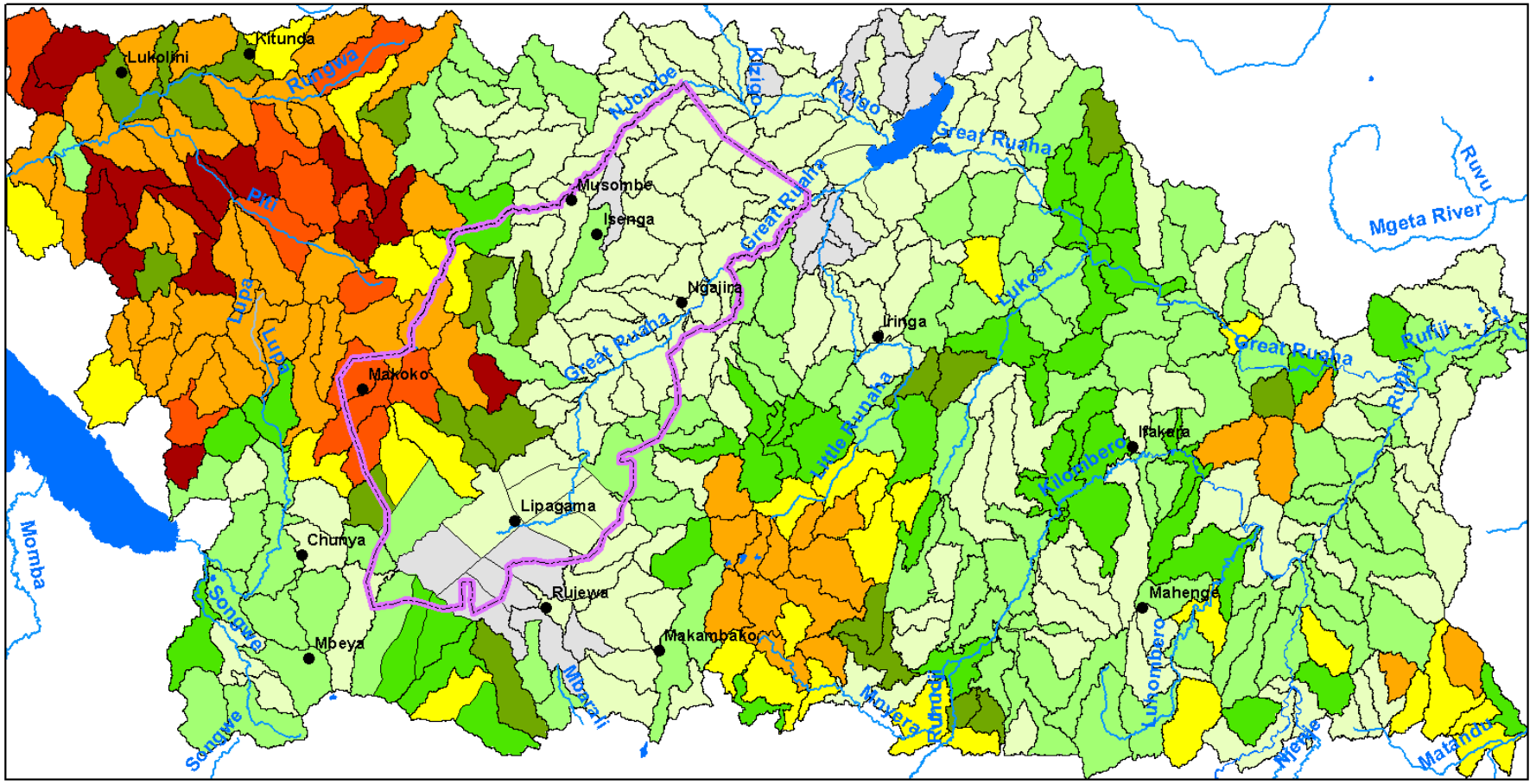
Tons/ha

- 0.2 - 5
- 5 - 10
- 10 - 20
- 20 - 40
- 40 - 60
- 60 - 80
- 80 - 100
- 100 - 200
- 200 - 400
- 400 - 1,014



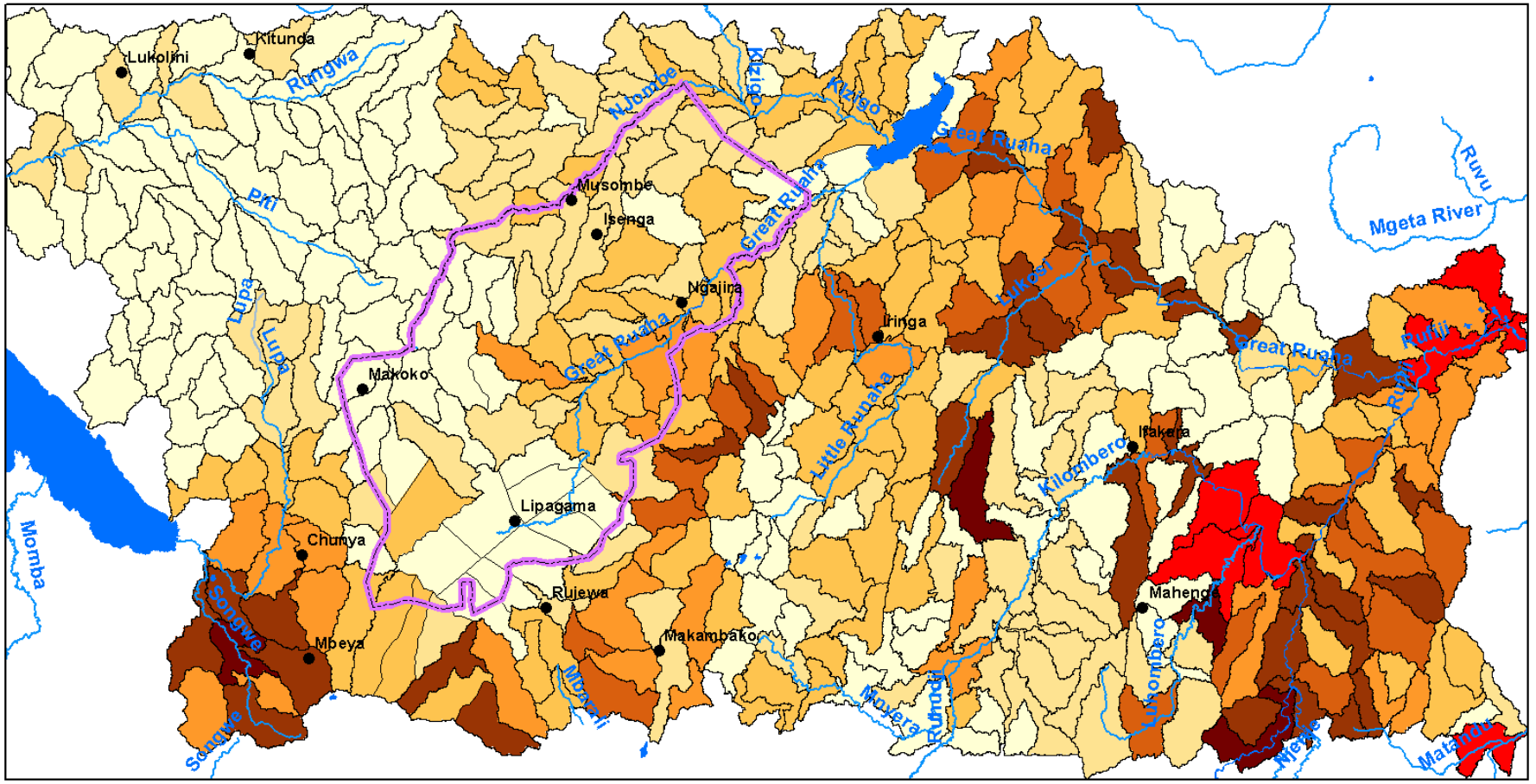
• Towns		10 - 20	100 - 200
Ruaha National Park		20 - 40	200 - 400
Tons/ha		40 - 60	400 - 1,126
0.2 - 5		60 - 80	
5 - 10		80 - 100	

Universal Soil Loss Equation
Mean Potential Soil Loss
by
Watershed: Deforestation



Universal Soil Loss Equation Potential Soil Loss by Watershed: Percent Difference

- Towns
- Ruaha National Park
- 0%
- 0% - 10%
- 10% - 30%
- 30% - 50%
- 50% - 70%
- 70% - 100%
- 100% - 500%
- 500% - 1000%
- 1000% - 2393%

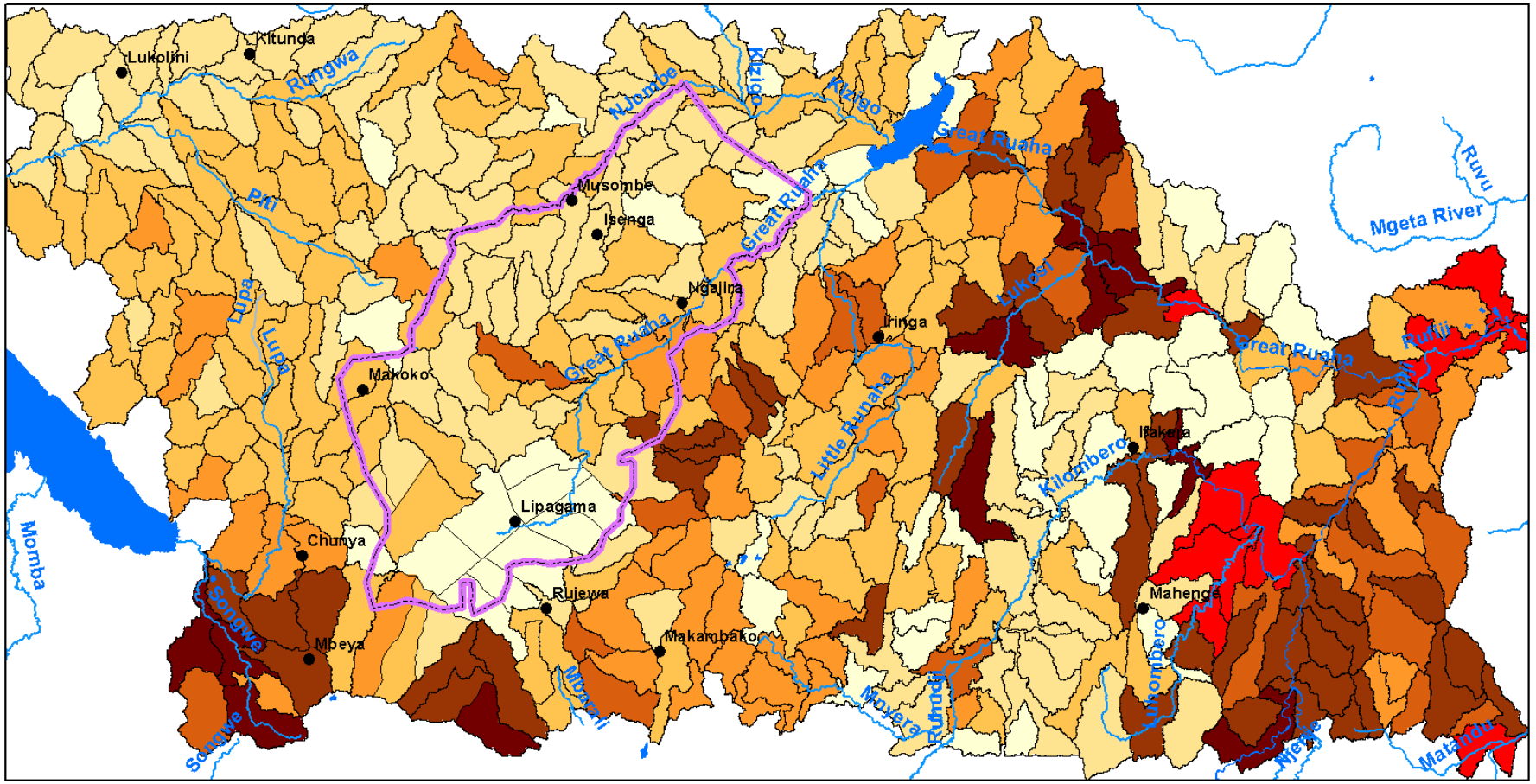


Mean Sediment Exported
by
Watershed: Baseline

- Towns
- Ruaha National Park

Tons/ha

- 0 - 0.5
- 0.5 - 1.5
- 1.5 - 4.5
- 4.5 - 7.5
- 7.5 - 10.5
- 10.5 - 30.5
- 30.5 - 50.5
- 50.5 - 122.6

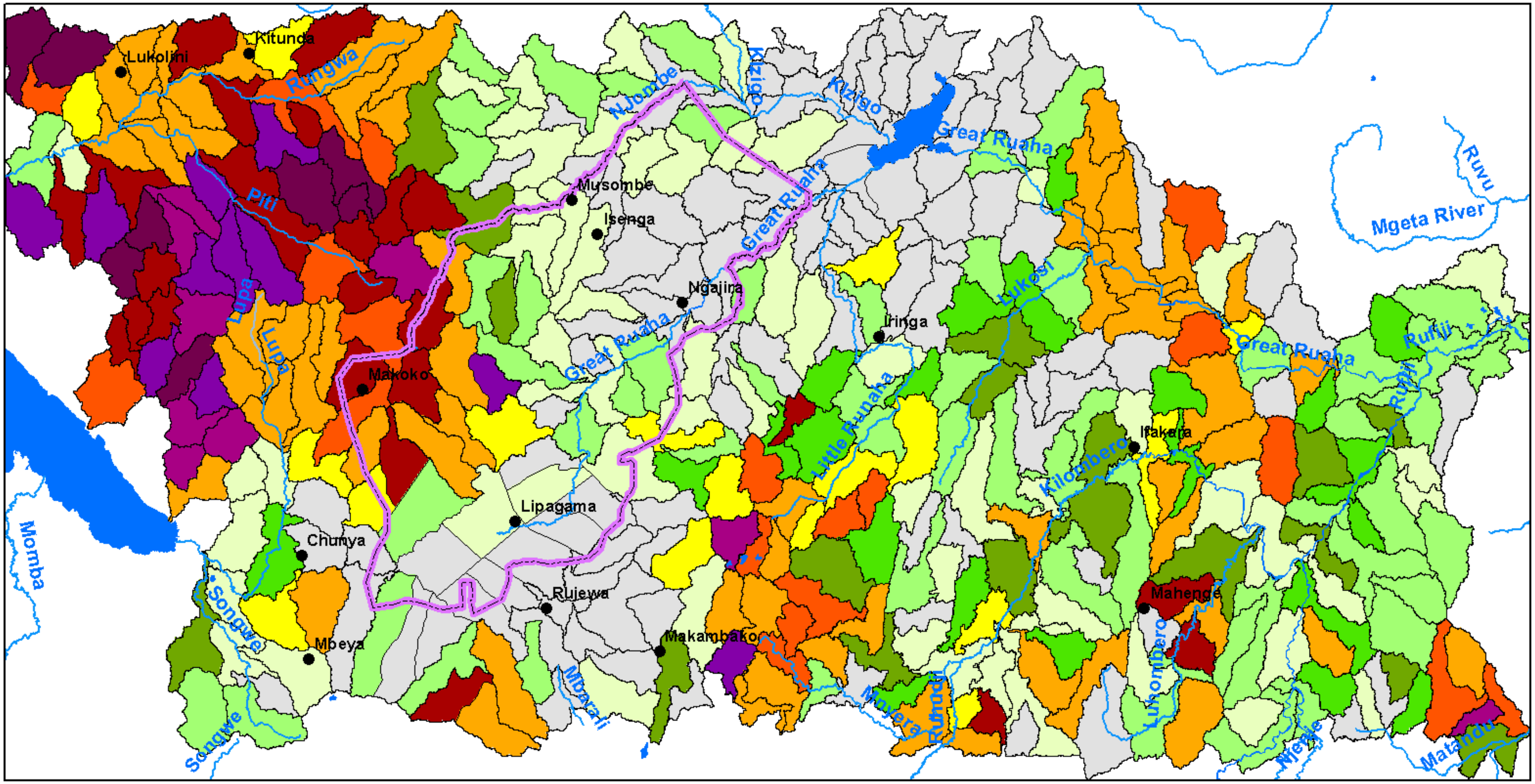


Mean Sediment Exported
by
Watershed: Deforestation

- Towns
- Ruaha National Park

Tons/ha

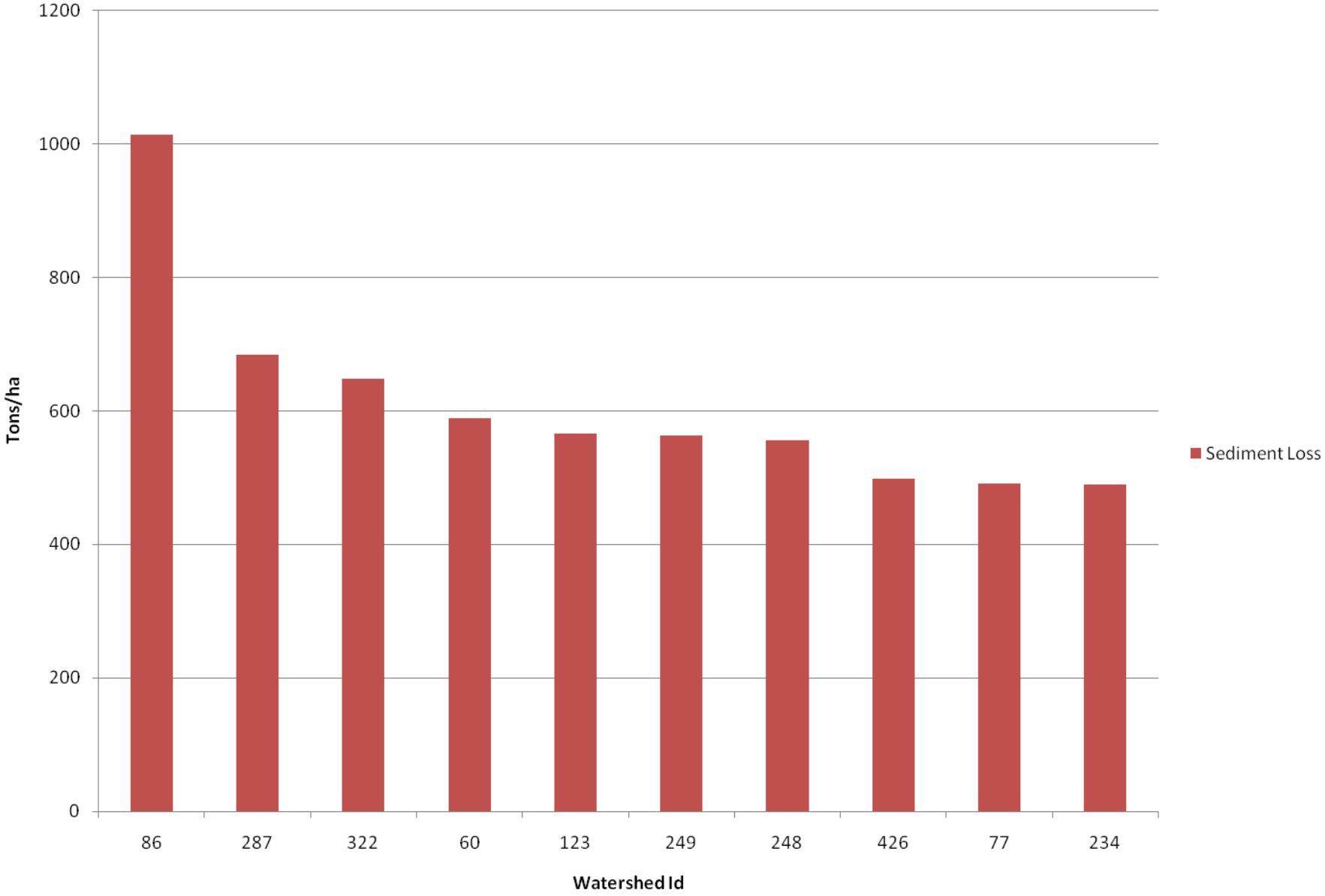
- 0 - 0.5
- 0.5 - 1.5
- 1.5 - 4.5
- 4.5 - 7.5
- 7.5 - 10.5
- 10.5 - 30.5
- 30.5 - 50.5
- 50.5 - 172.7

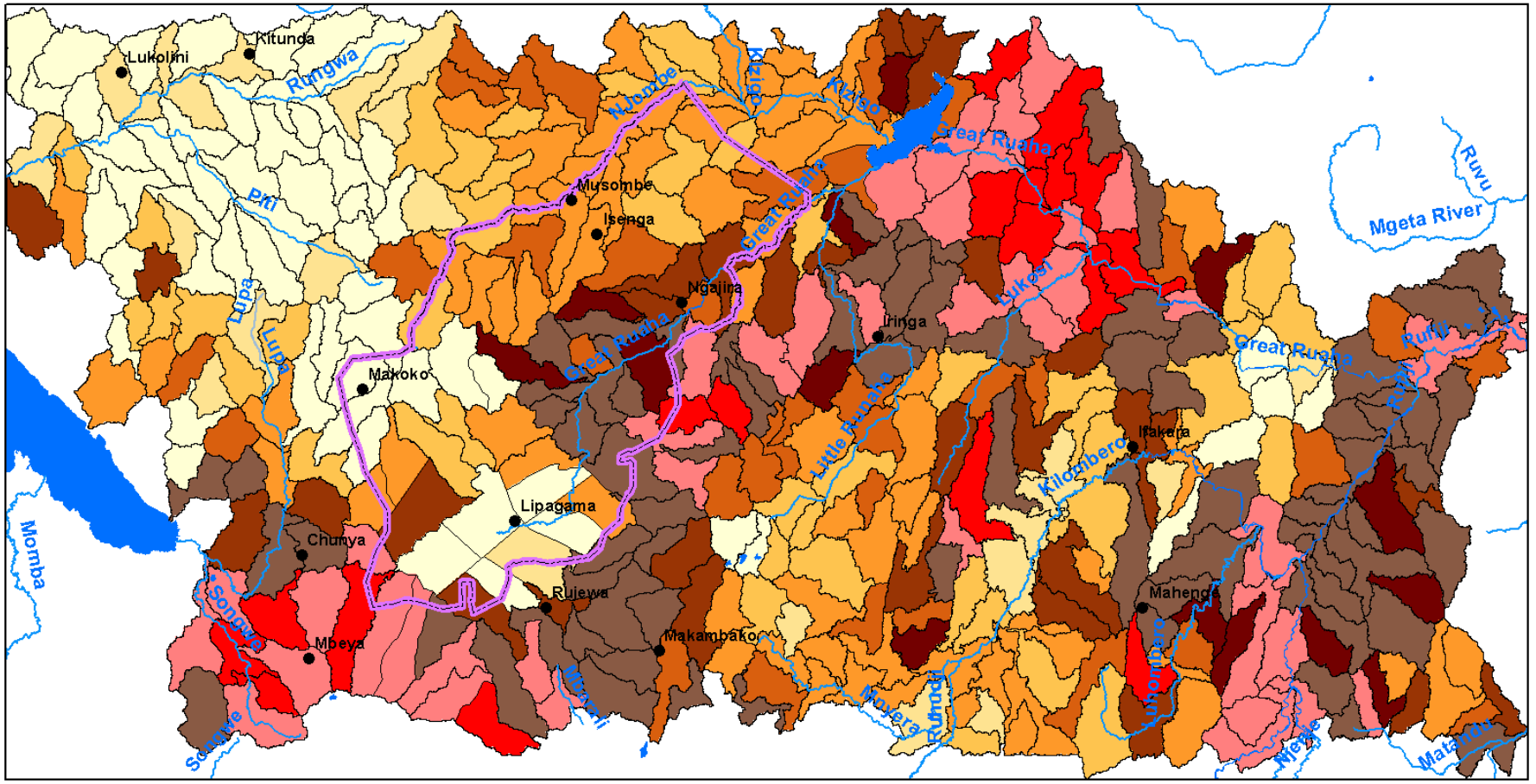


Sediment Exported by Watershed: Percent Difference

• Towns	30% - 50%	1000% - 3000%
Ruaha National Park	50% - 70%	3000% - 5000%
0%	70% - 100%	5000% - 7000%
0% - 10%	100% - 500%	7000% - 11802%
10% - 30%	500% - 1000%	

Mean Potential Soil Loss by Watershed Top 10: Baseline



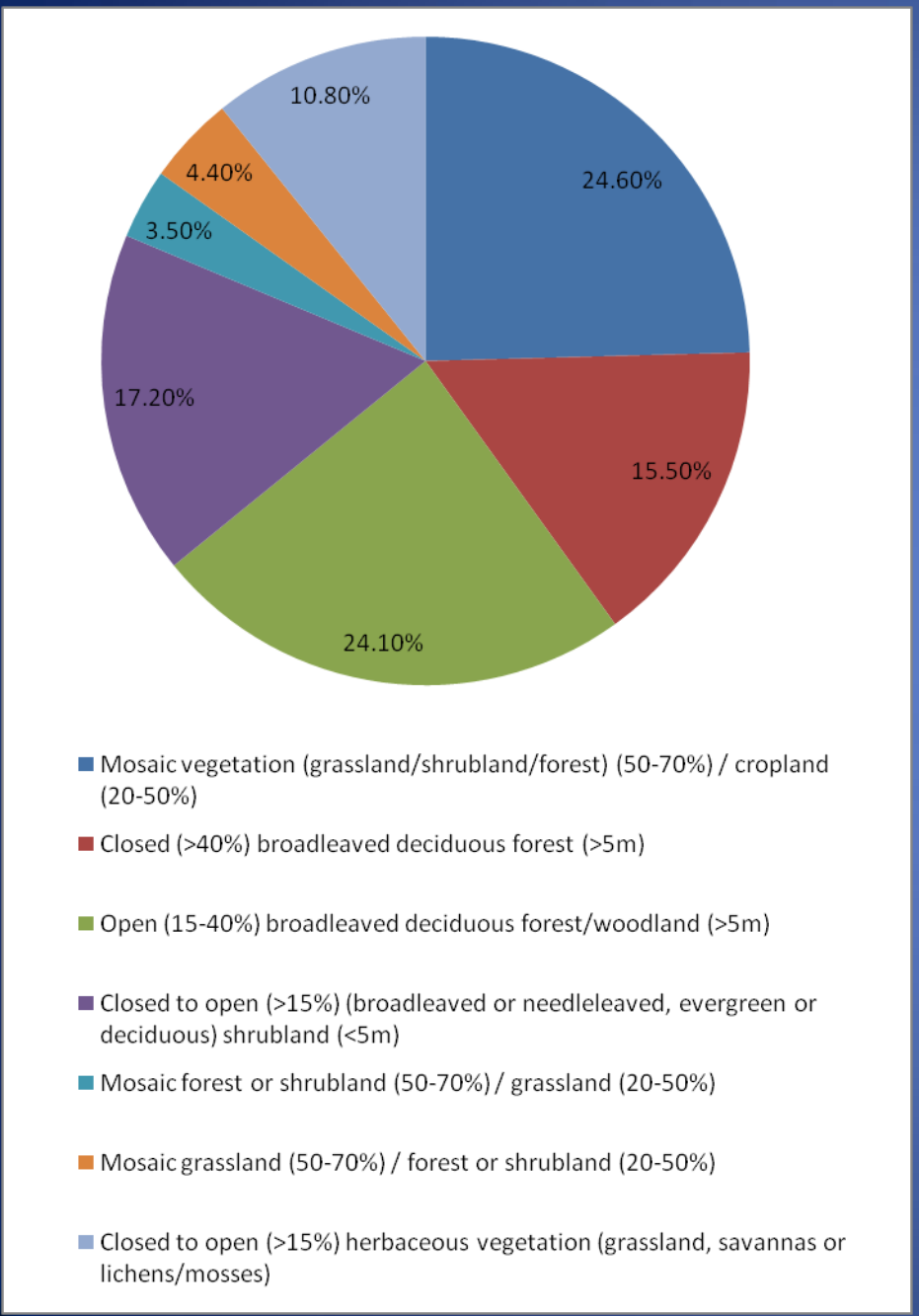


Universal Soil Loss Equation
Mean Potential Soil Loss
by
Watershed: Baseline

- Towns
- Ruaha National Park

Tons/ha

- 0.2 - 5
- 5 - 10
- 10 - 20
- 20 - 40
- 40 - 60
- 60 - 80
- 80 - 100
- 100 - 200
- 200 - 400
- 400 - 1,014



Deforestation Scenario

	Baseline	Deforestation	Percent Difference
Watershed Id	267	267	
Mean Sediment Exported (Tons/ha)	6.63	7.98	20.36%
Mean Potential Soil Loss (Tons/ha)	83.5	94.19	12.80%
Mean Slope (%)	4.33	4.33	
Mean Slope Length (m)	3.11	3.11	
Mean Soil Erodibility (MJ*mm)/ (ha*h*yr)	0.053	0.053	
Mean Rainfall Erosivity (T* ha*h) / (ha*MJ*mm)	10378	10378	
C Factor (deciduous forest)	0.001	0.07	
P Factor (deciduous forest)	1	0.5	

Summary and Recommendation

- Water Quantity
  - In general possible future climate dynamic such as increased temperature and reduced precipitation could potentially have a significant impact on runoff in the Great Ruaha River region.
  - This impact would be significant reductions in runoff.
  - In general conversion of forest land to crop land could potentially reduce runoff in some areas and increase runoff in other, but any increase in runoff will not sustain over time.

Summary and Recommendation

- Sedimentation
  - In general a conversion of forest land to agriculture land will increase the amount of sedimentation
  - As landuse activities are managed inside the Ruaha National Park the area of focus for any changes or policies in relation to land management should be in the watersheds outside of the park.
  - Specifically the watersheds whose sediment flow into the park or adjacent to the river. Within these watersheds , those with the highest potential for soil loss should have land management restrictions .

Summary and Recommendation

- Models can be useful tools in simulating ecosystem processes, but you need good data resources to run them and to validate them.
- When addressing environmental issues in a large area, models can help you identify subareas to focus project resources for more focuses studies.
- Validation is a very important part of using any model as it is an indicator as to how well the model performed.
- Validation was not performed on the case study presented here, but it should be considered as the next step in any future work.