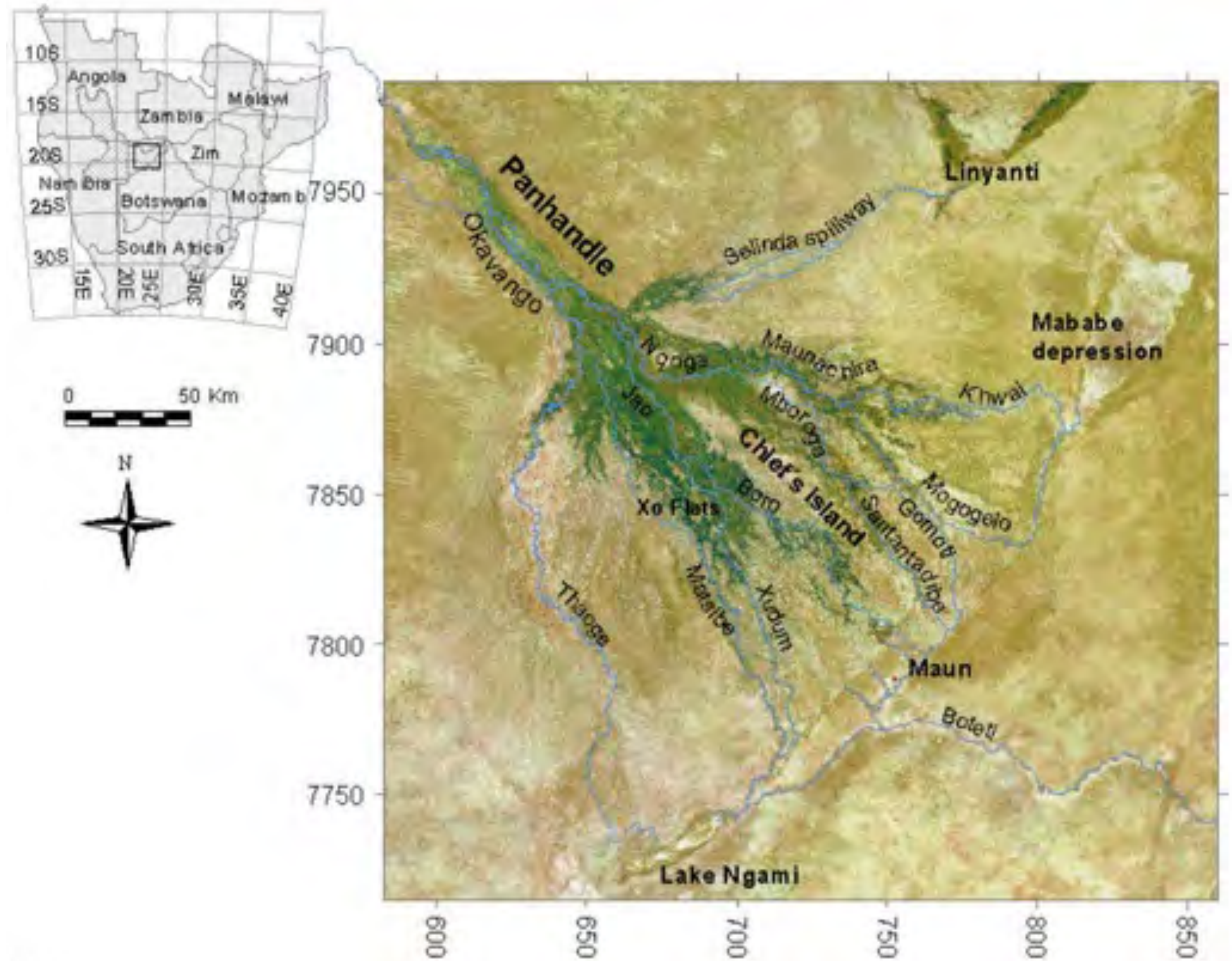
Remote sensing system perspective on the Okavango

Thomas Gumbricht

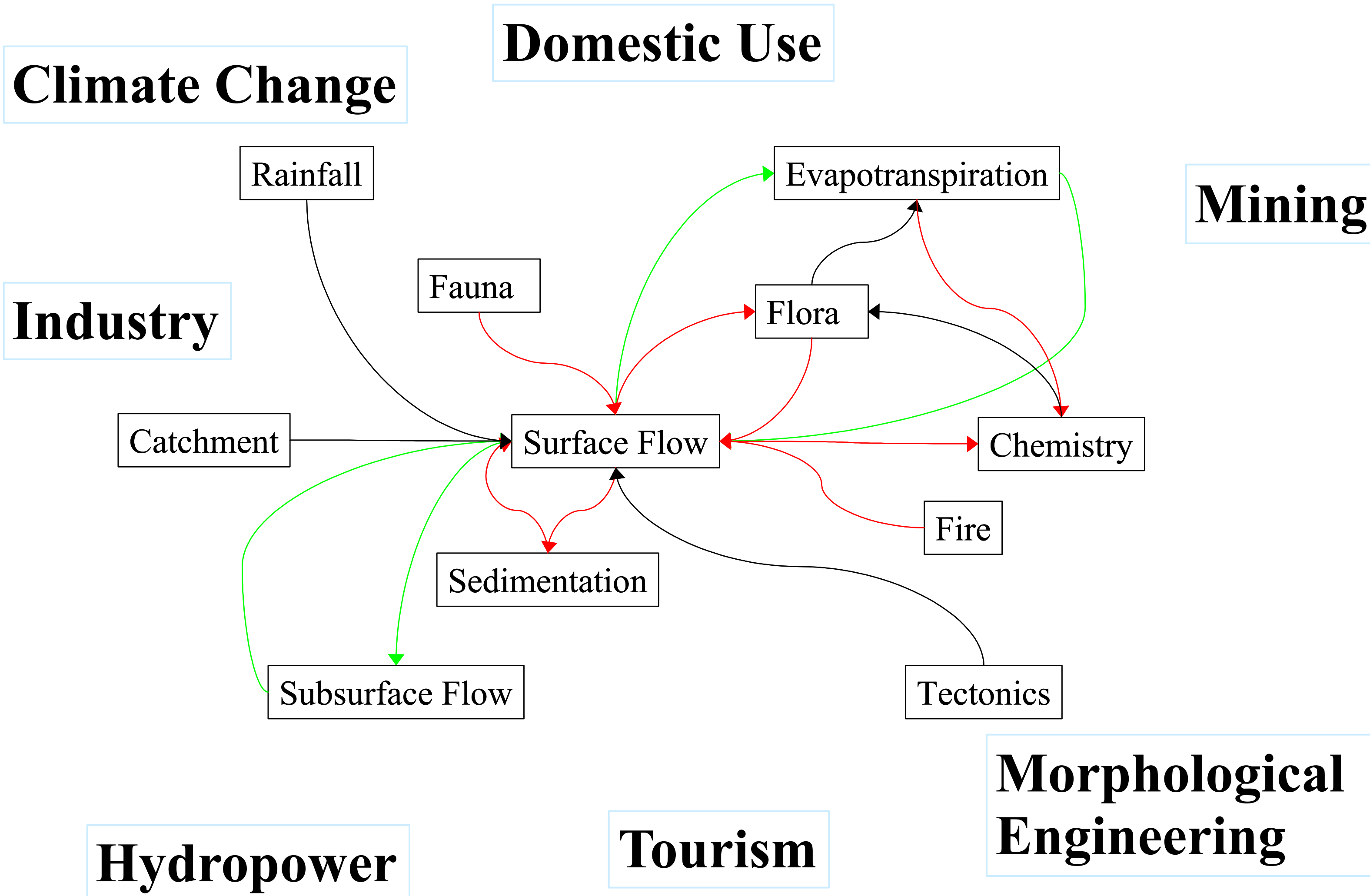
WERRD Mid term meeting, Heja Lodge, Windhoek

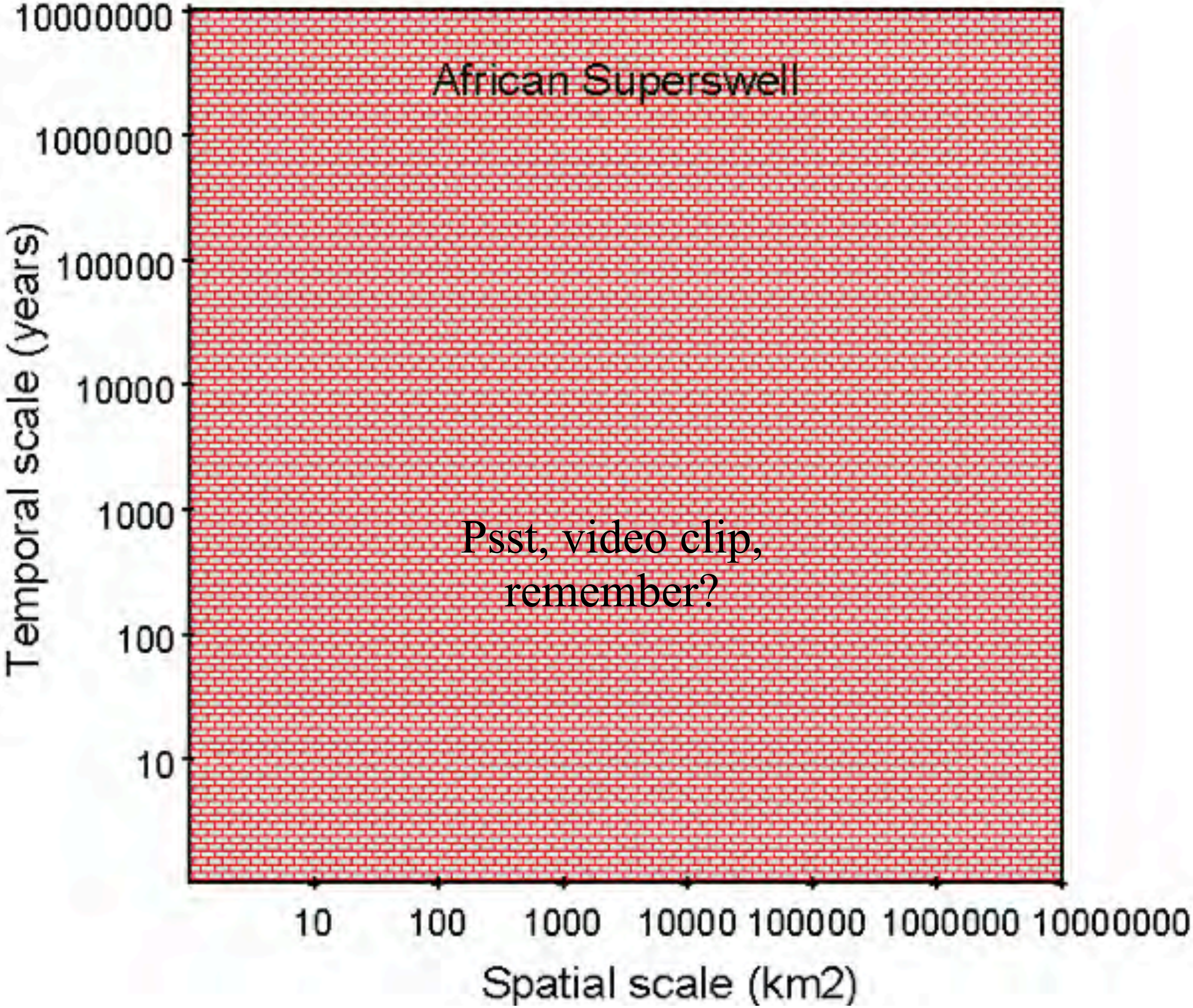
25-28 August 2003



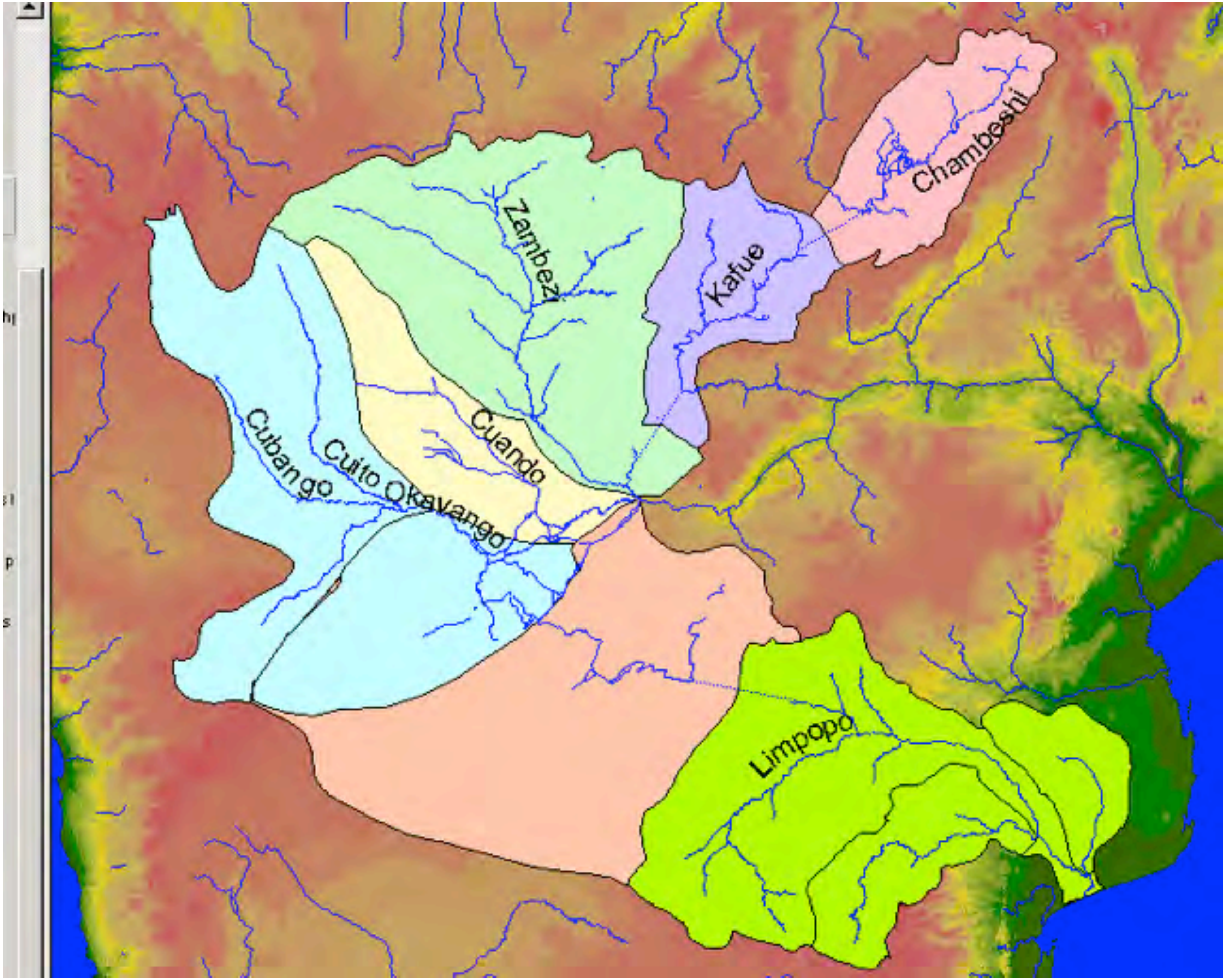
The integrated system perspective:

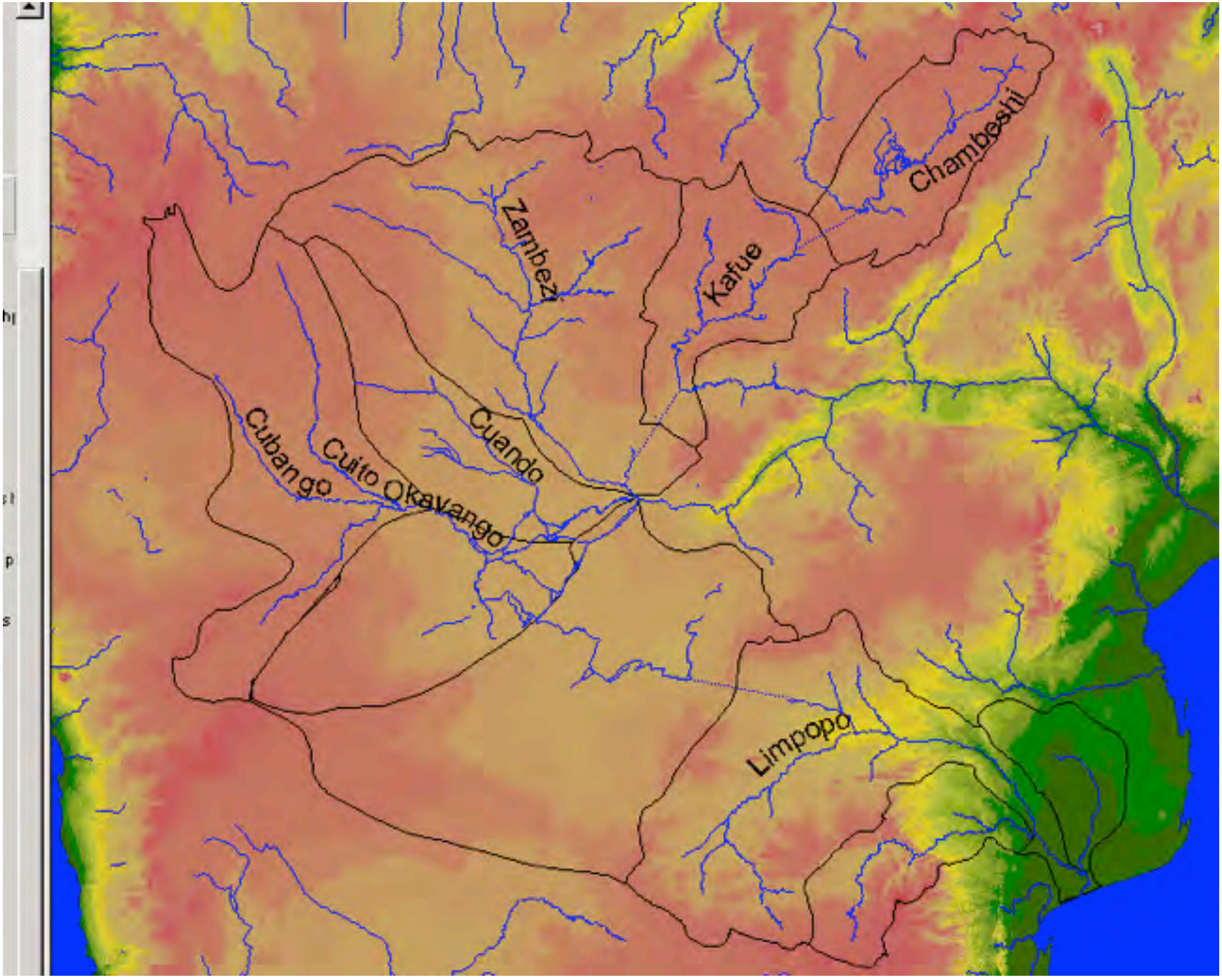
The Okavango Delta – Africa´s last eden



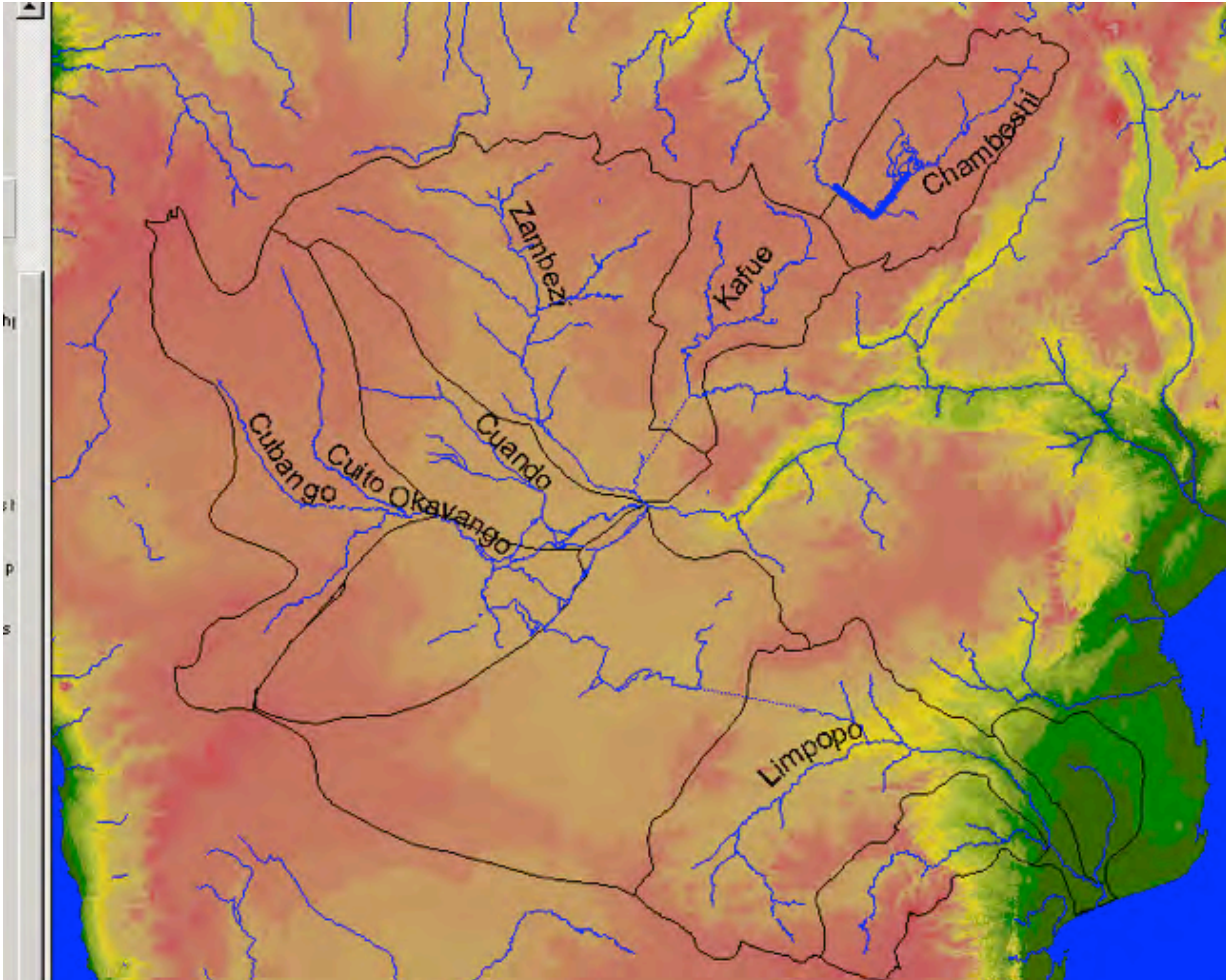


African Superswell
Psst, video clip, remember?
Temporal scale (years)
10000000
1000000
100000
10000
1000
100
10
Spatial scale (km2)
10
100
1000
10000
100000
1000000
10000000

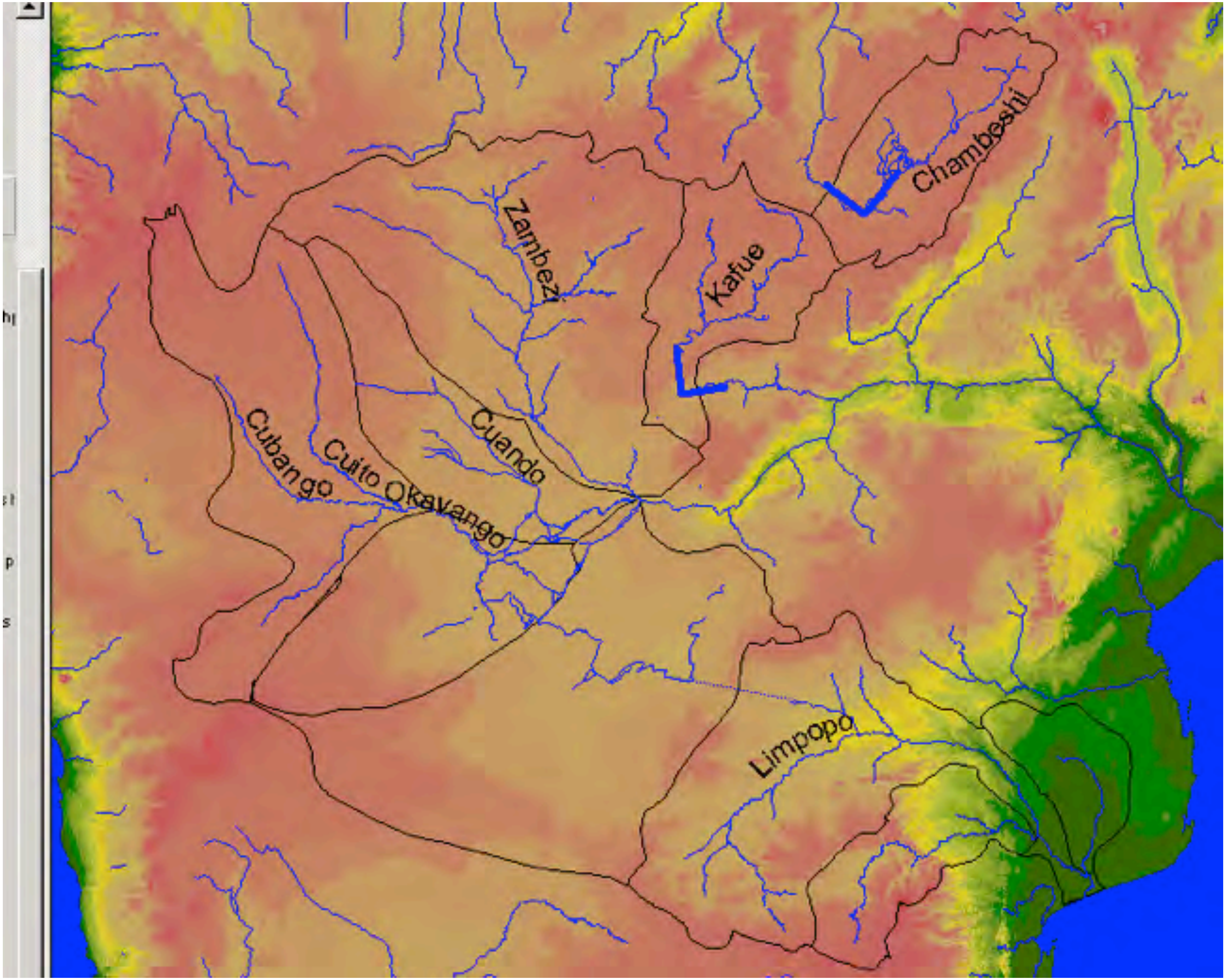

Chambeshi
Zambezi
Kafue
Cuando
Cubango
Cuito
Okavango
Limpopo



Chambeshi
Zambezi
Kafue
Cuando
Cubango
Cuito
Okavango
Limpopo



Chambeshi
Zambezi
Kafue
Cuando
Cubango
Cuito
Okavango
Limpopo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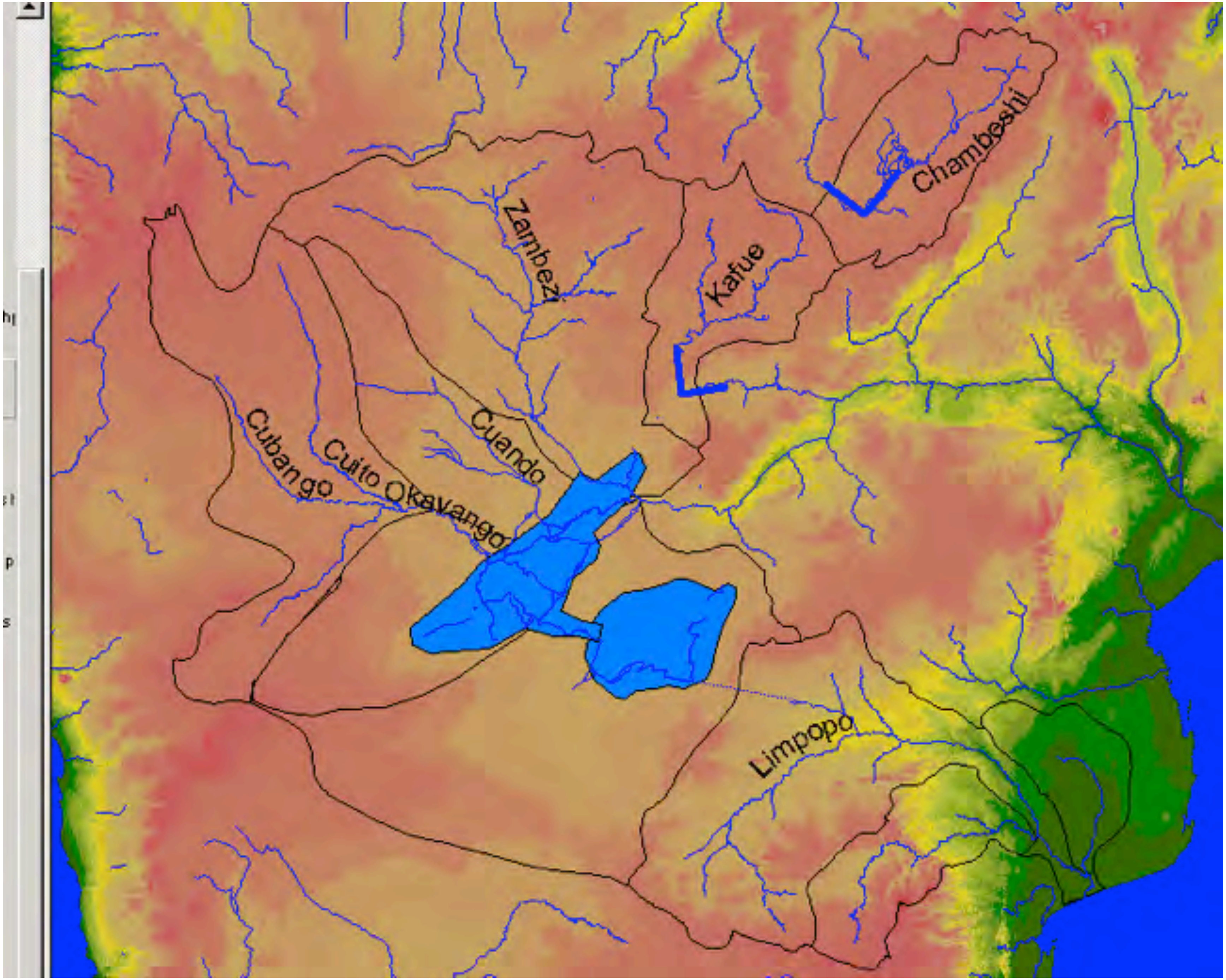
Zambezi
Kafue
Cuando
Cubango
Cuito
Okavango
Limpopo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Zambezi
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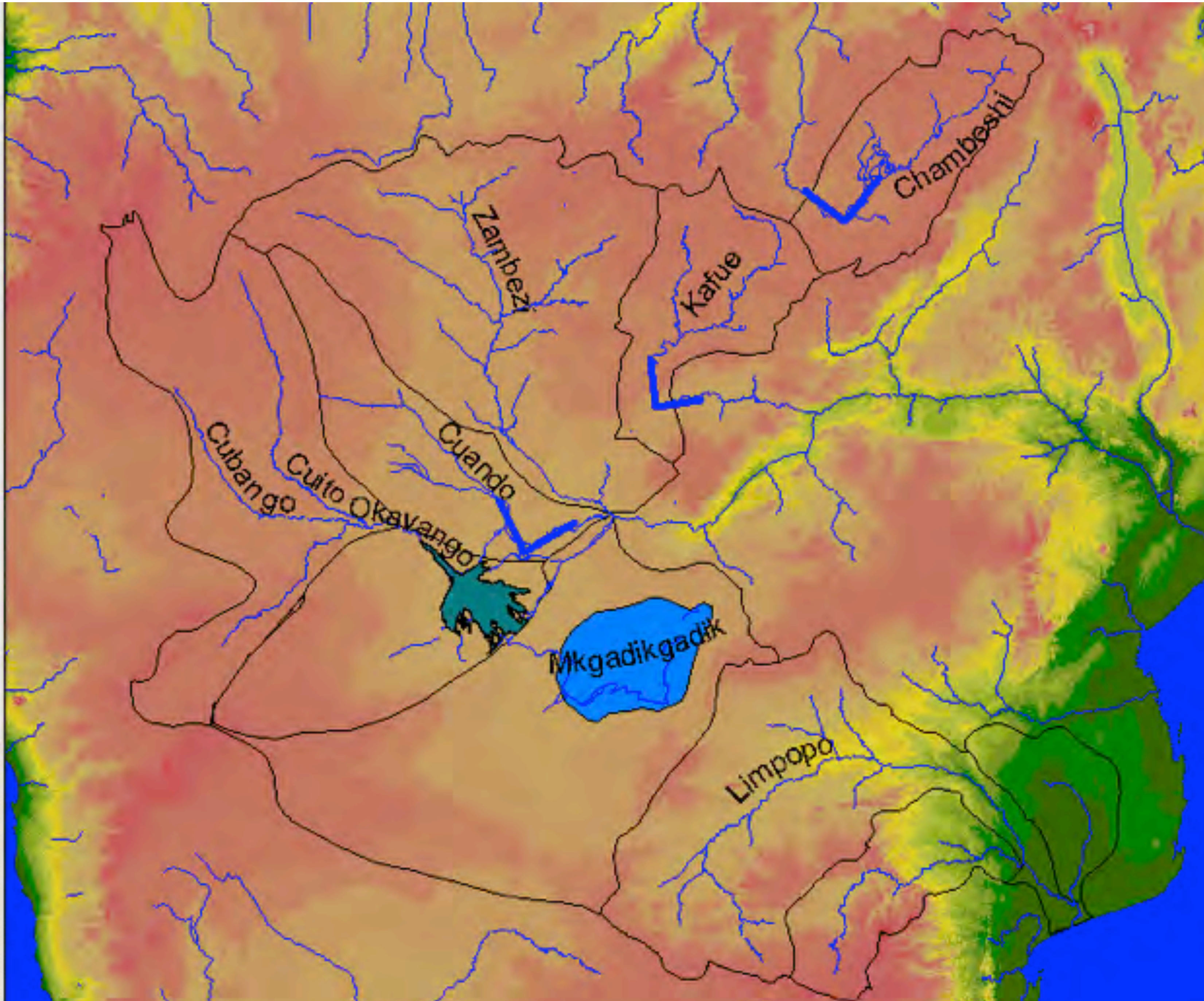
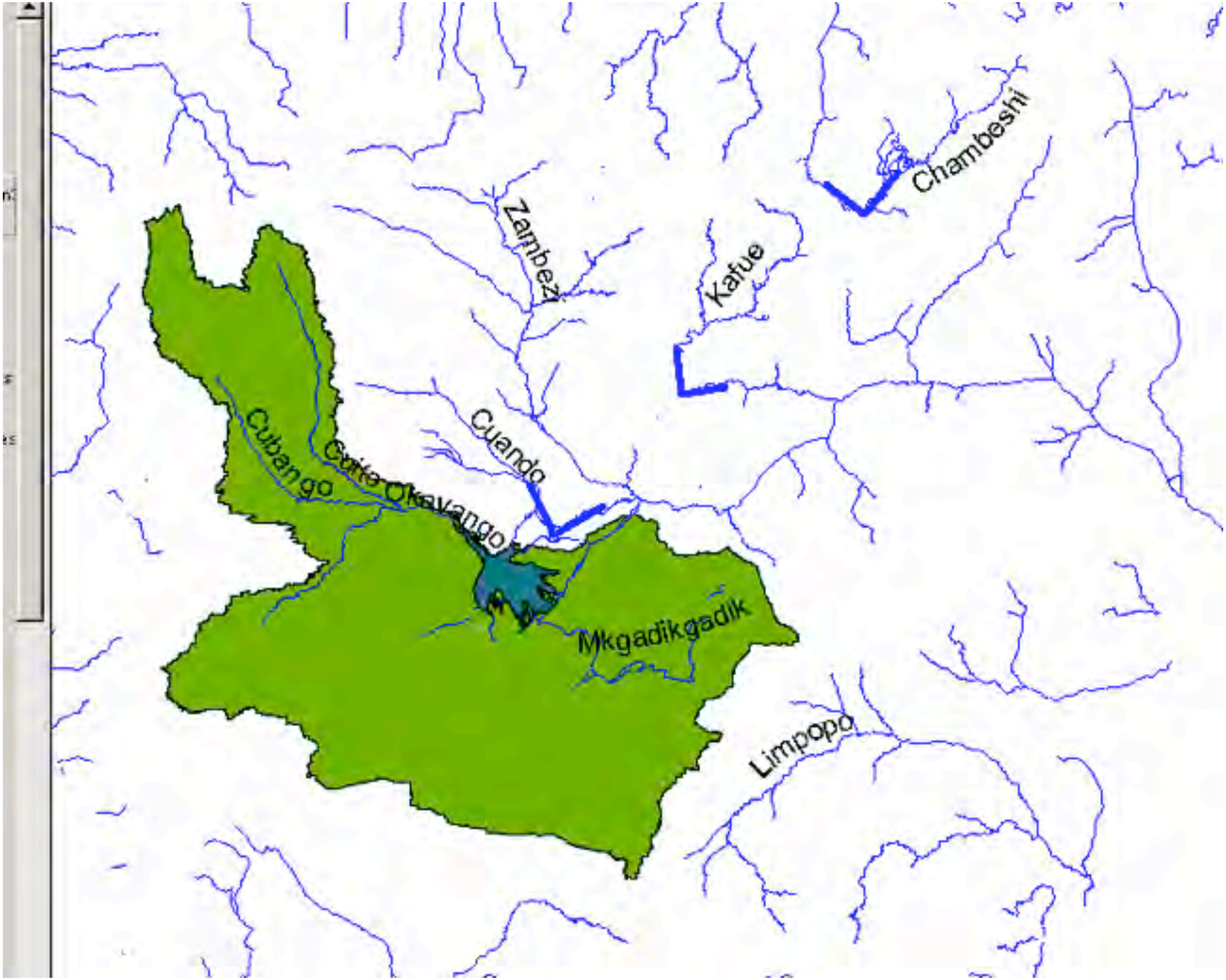
Okavango
Limpopo


Chambeshi
Zambezi
Kafue
Cubango
Cuito
Cuando
Okavango
Mkgadikgadik
Limpopo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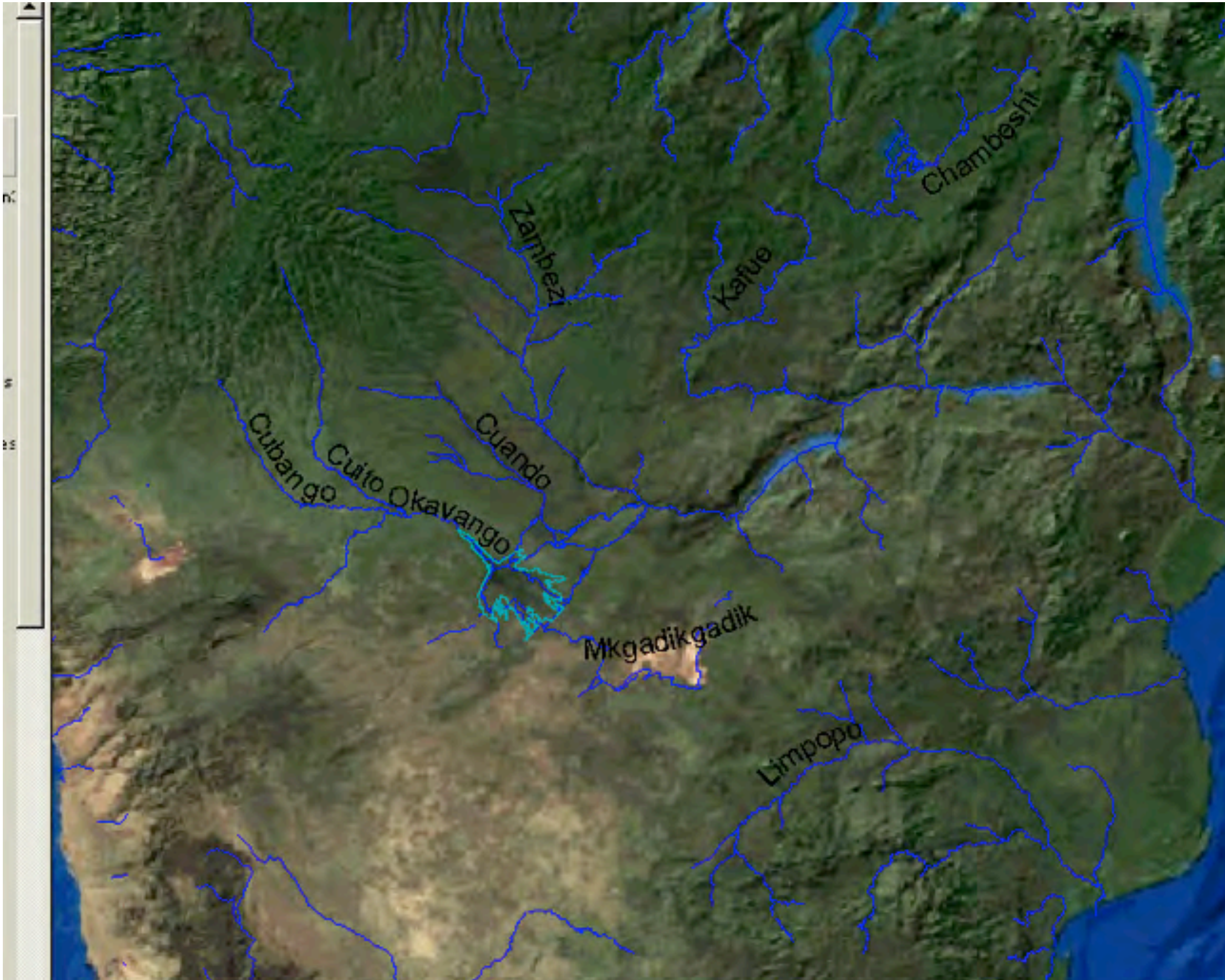
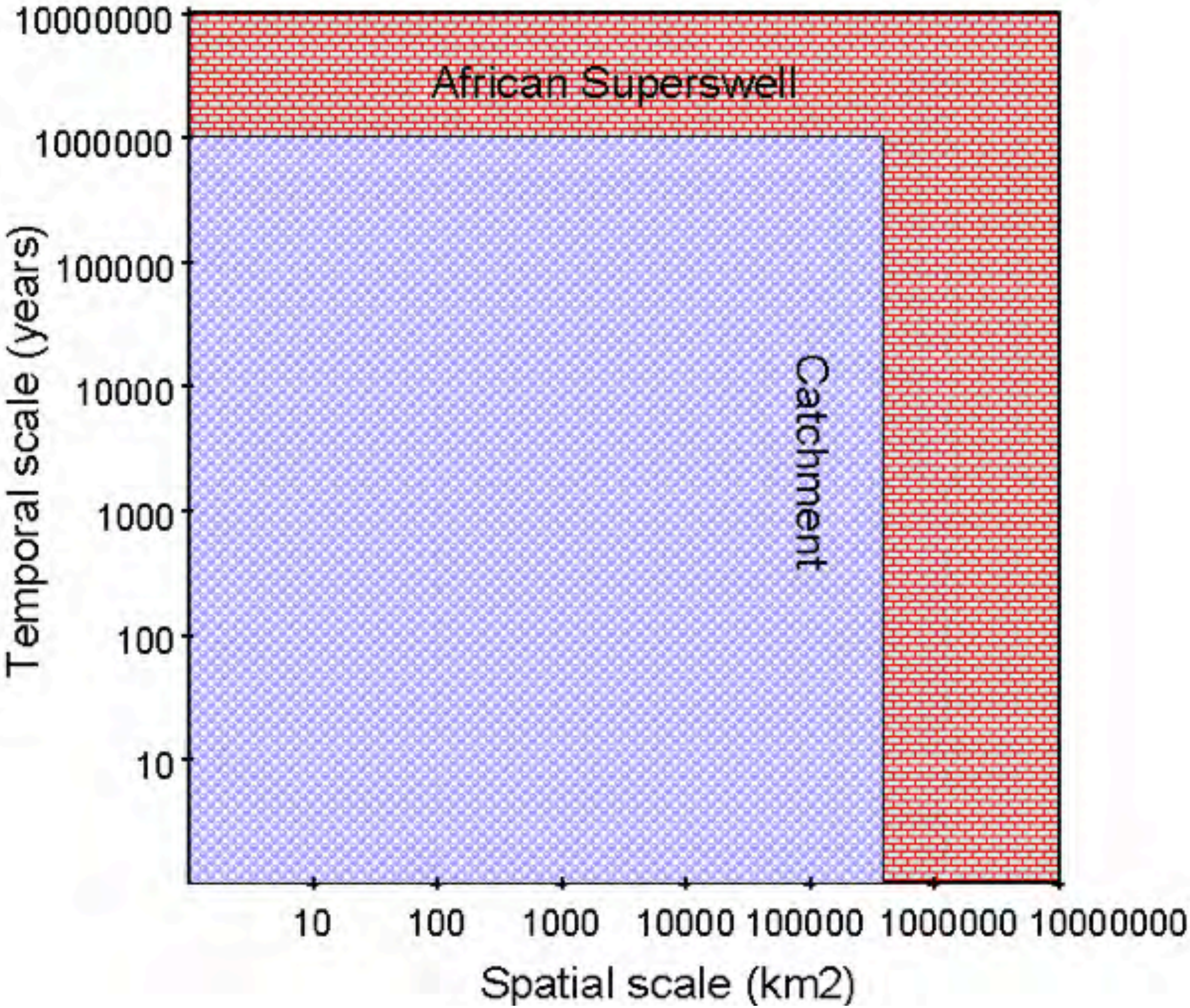
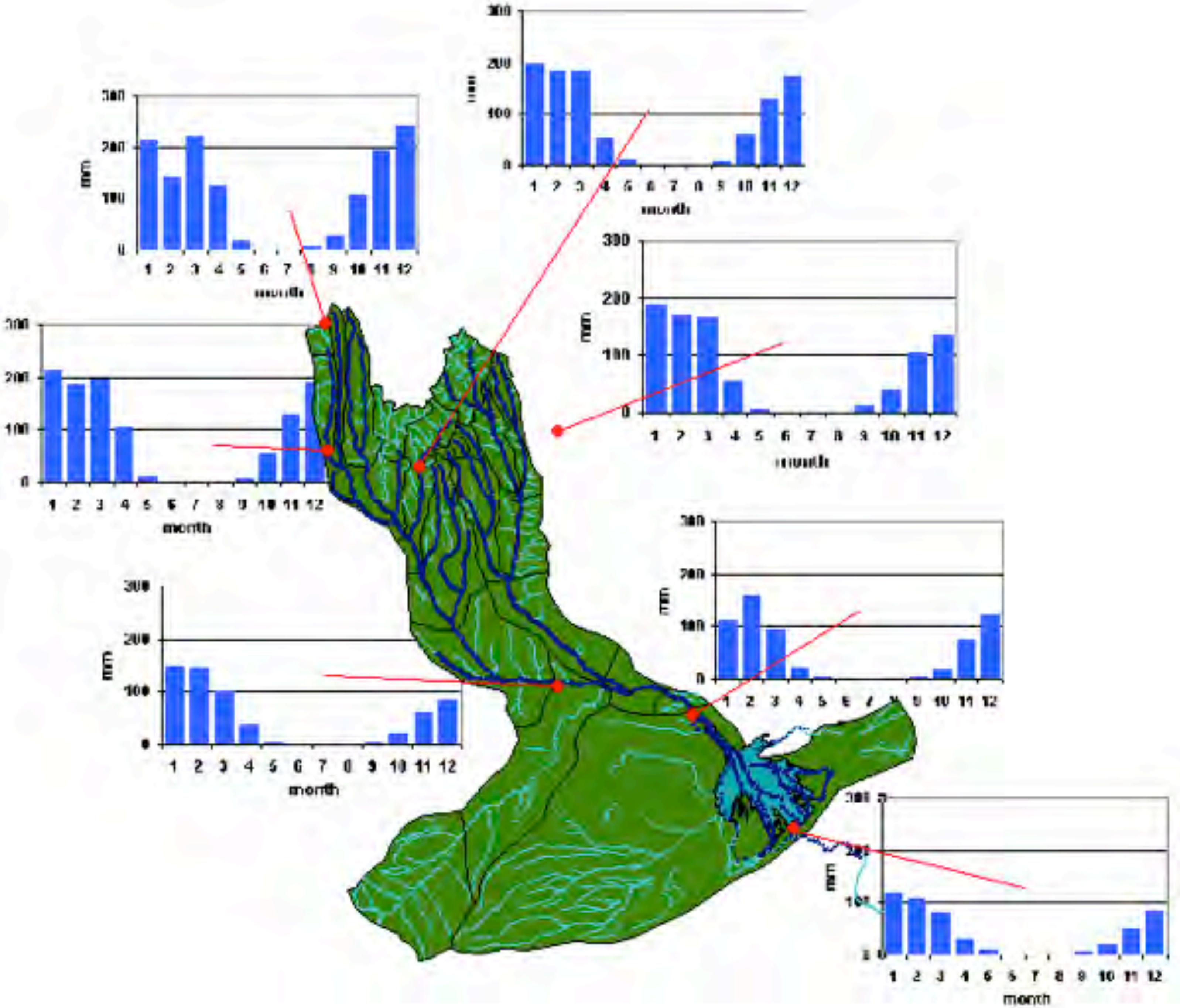
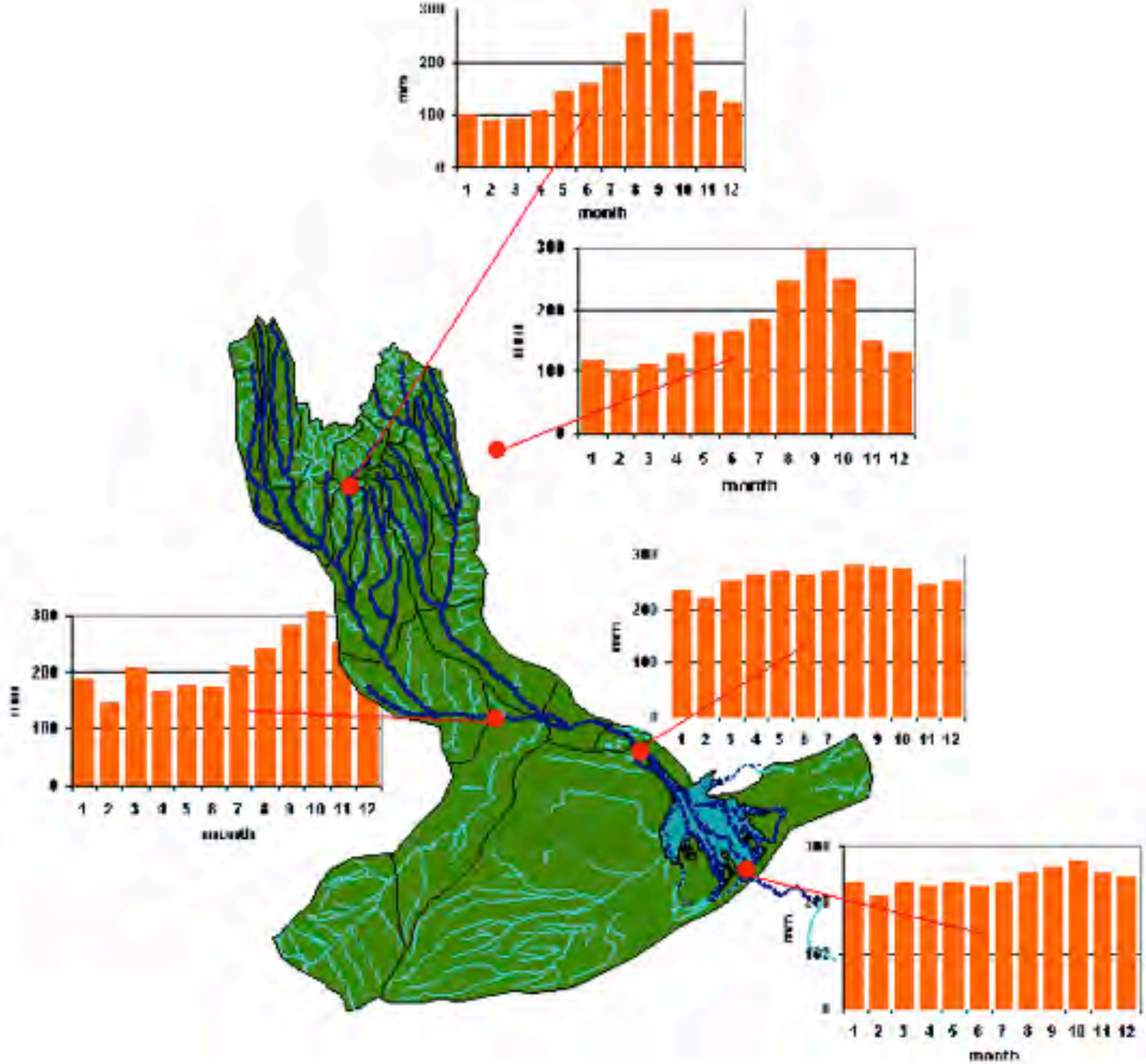
Zambezi
Kafue
Cuando
Cubango
Cuito
Okavango
Mkgadikgadik
Limpopo


Chambeshi
Zambezi
Kafue
Cubango
Cuito
Cuando
Okavango
Mkgadikgadik
Limpopo

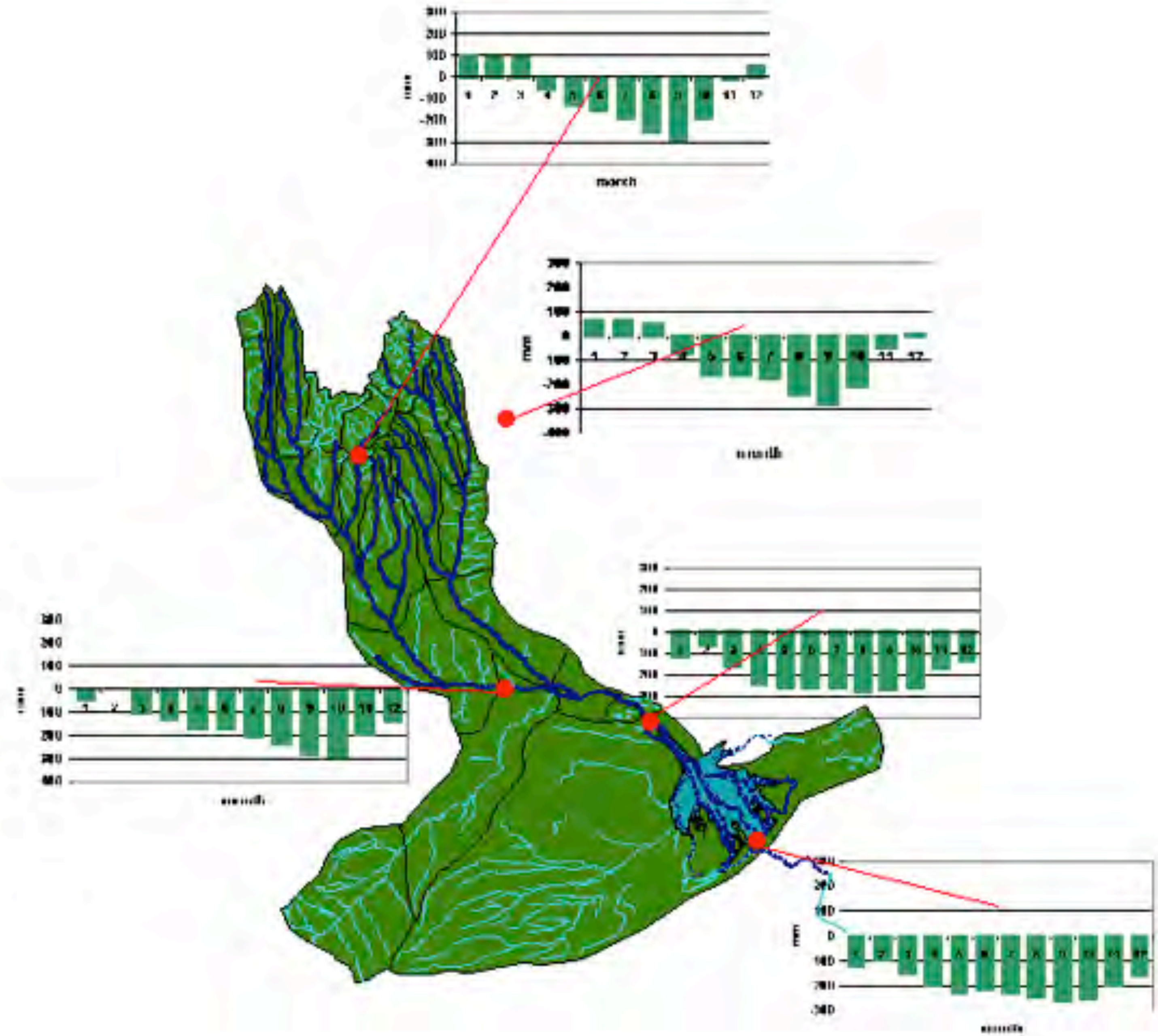


African Superswell
Catchment
Temporal scale (years)
10000000
1000000
100000
10000
1000
100
10
Spatial scale (km2)
10
100
1000
10000
100000
1000000
10000000

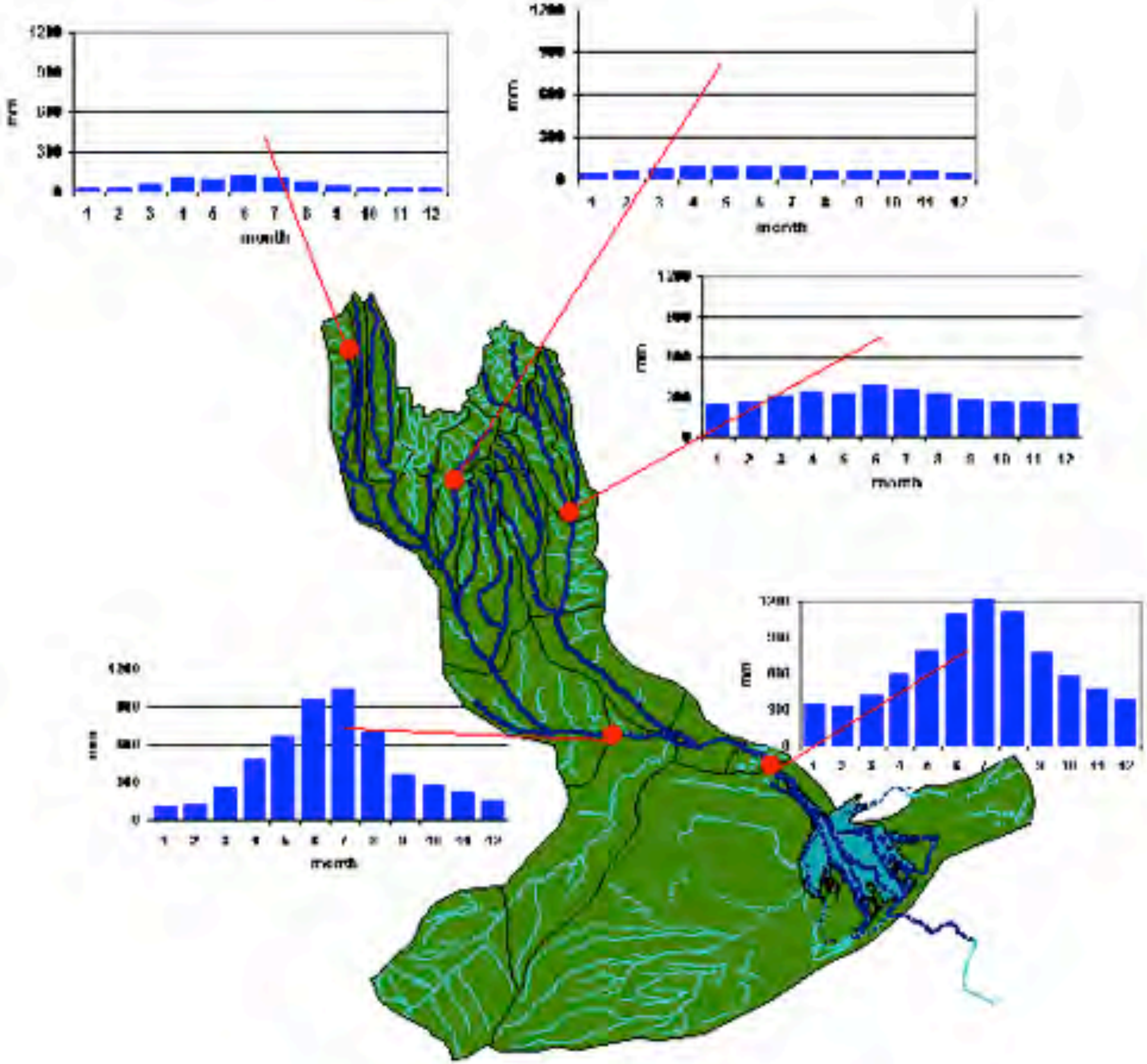

300
200
100
0
mm
1 2 3 4 5 6 7 8 9 10 11 12
month



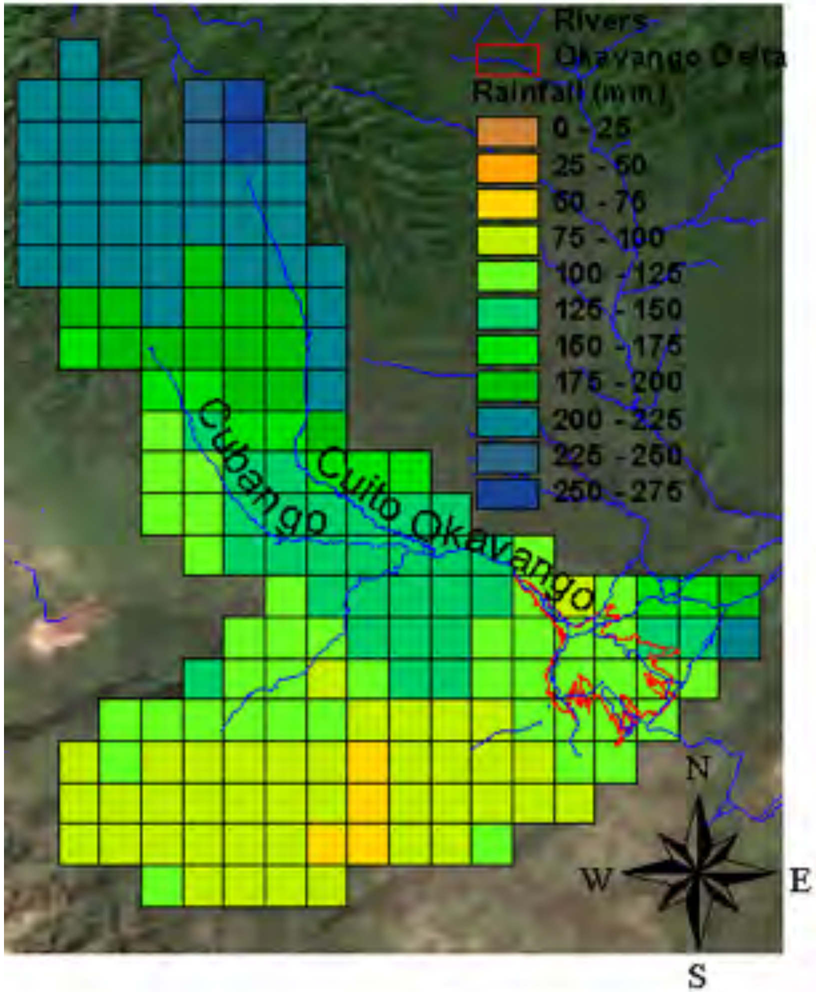
mm
300
200
100
0
1 2 3 4 5 6 7 8 9 10 11 12
month



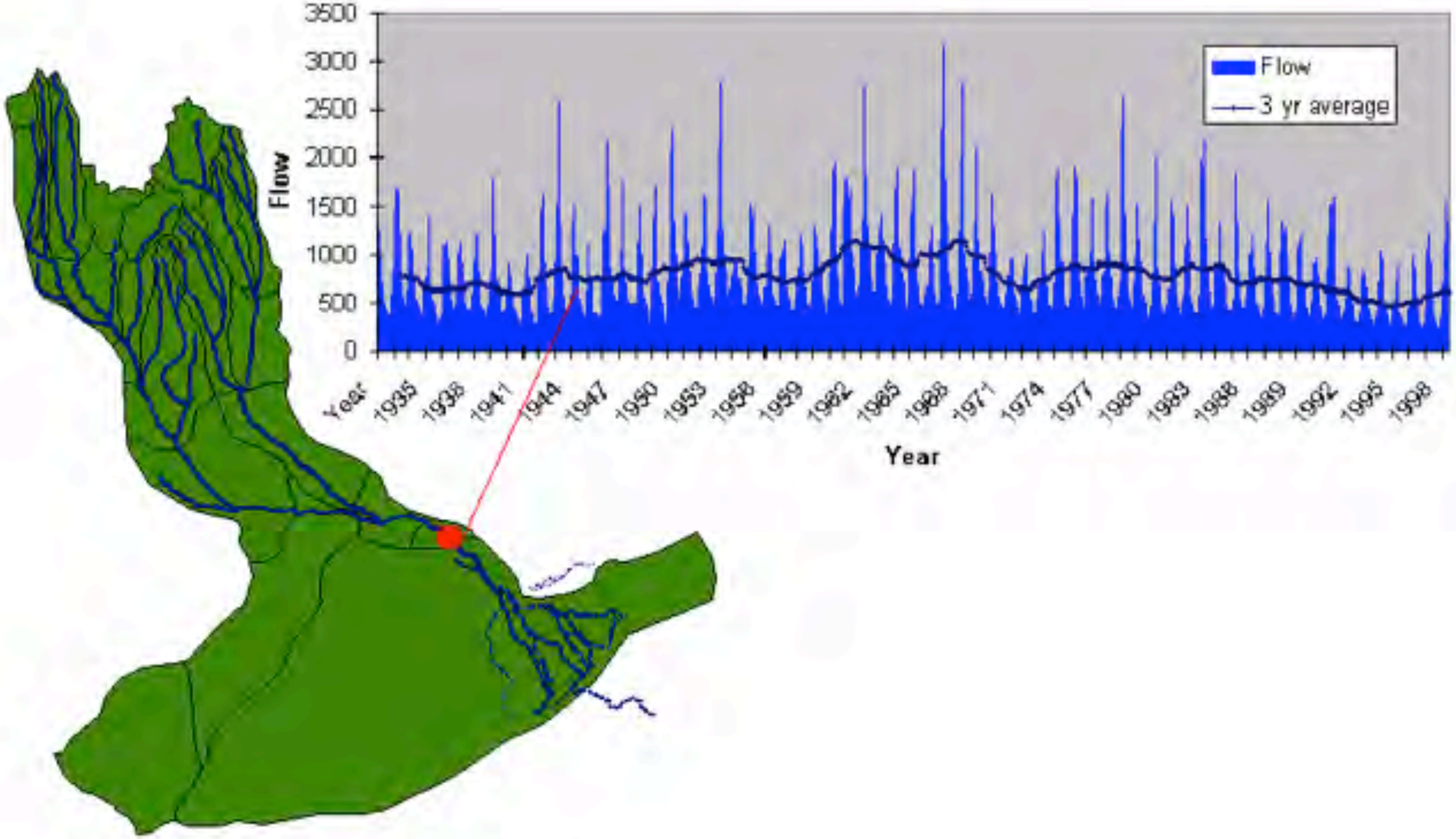
mm
month


mm
month
1 2 3 4 5 6 7 8 9 10 11 12
1200

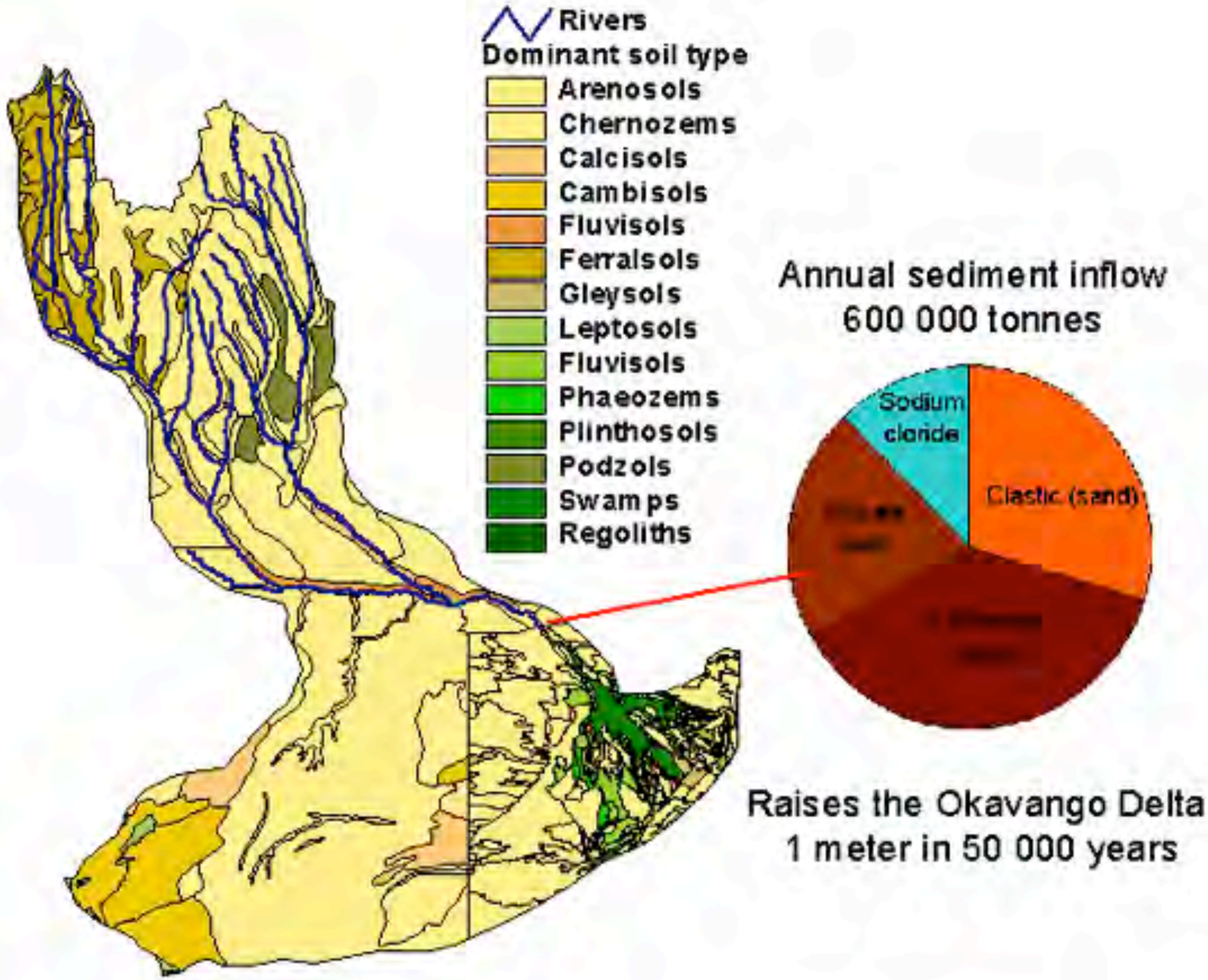
Rainfall and flooding - Okavango Delta

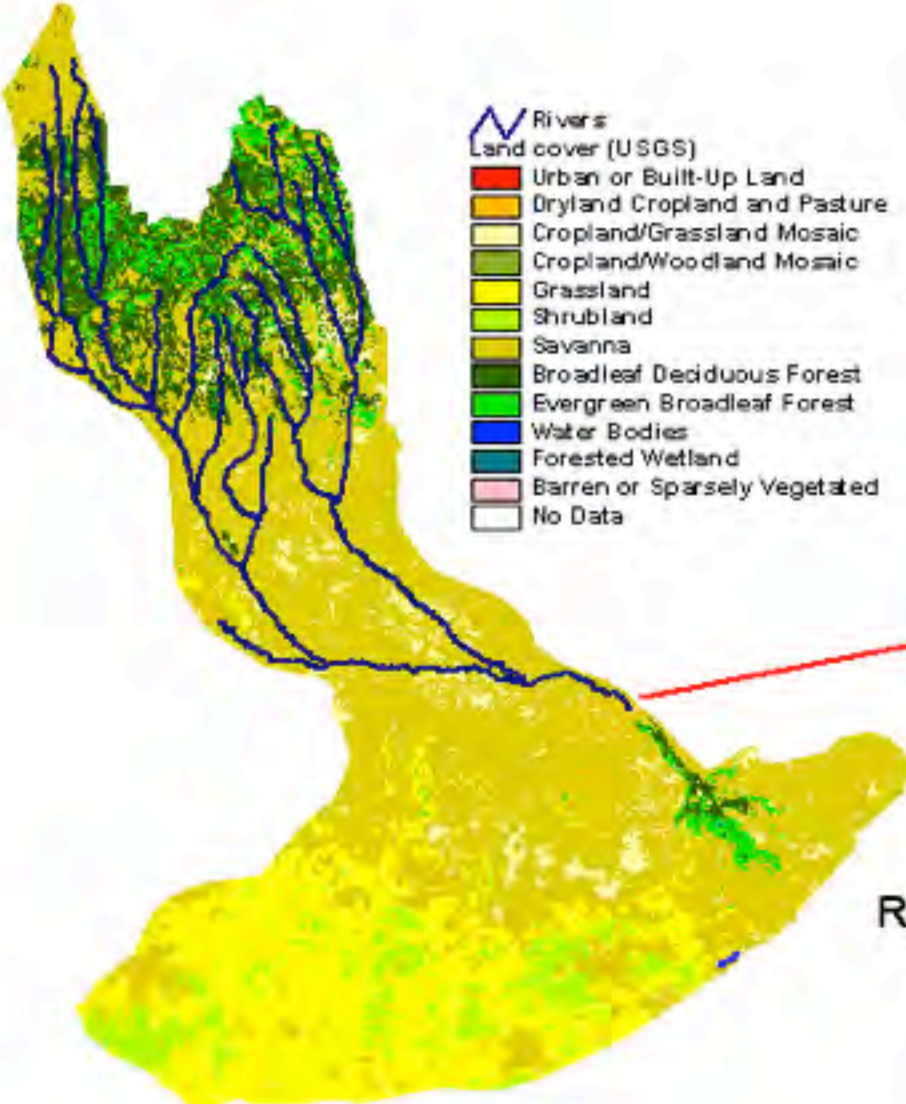


J F M A M J J A S O N D



Flow
3 yr average
Flow
Year
3500
3000
2500
2000
1500
1000
500
0
Year 1935 1938 1941 1944 1947 1950 1953 1956 1959 1962 1965 1968 1971 1974 1977 1980 1983 1986 1989 1992 1995 1998

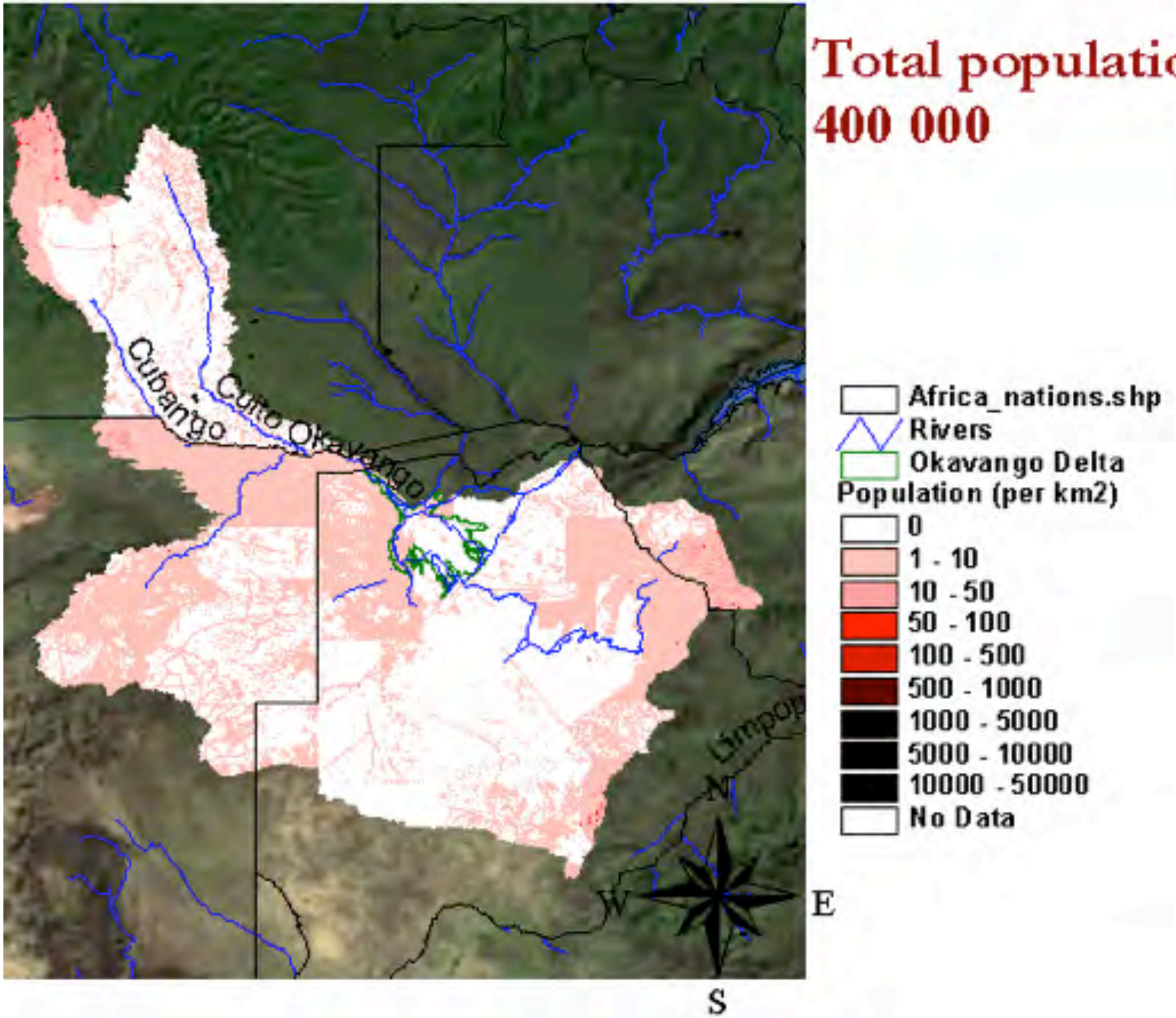

Rivers
Dominant soil type
Arenosols
Chernozems
Calcisols
Cambisols
Fluvisols
Ferralsols
Gleysols
Leptosols
Fluvisols
Phaeozems
Plinthosols
Podzols
Swamps
Regoliths
Annual sediment inflow
600 000 tonnes
Sodium cloride
Clastic (sand)
Raises the Okavango Delta
1 meter in 50 000 years



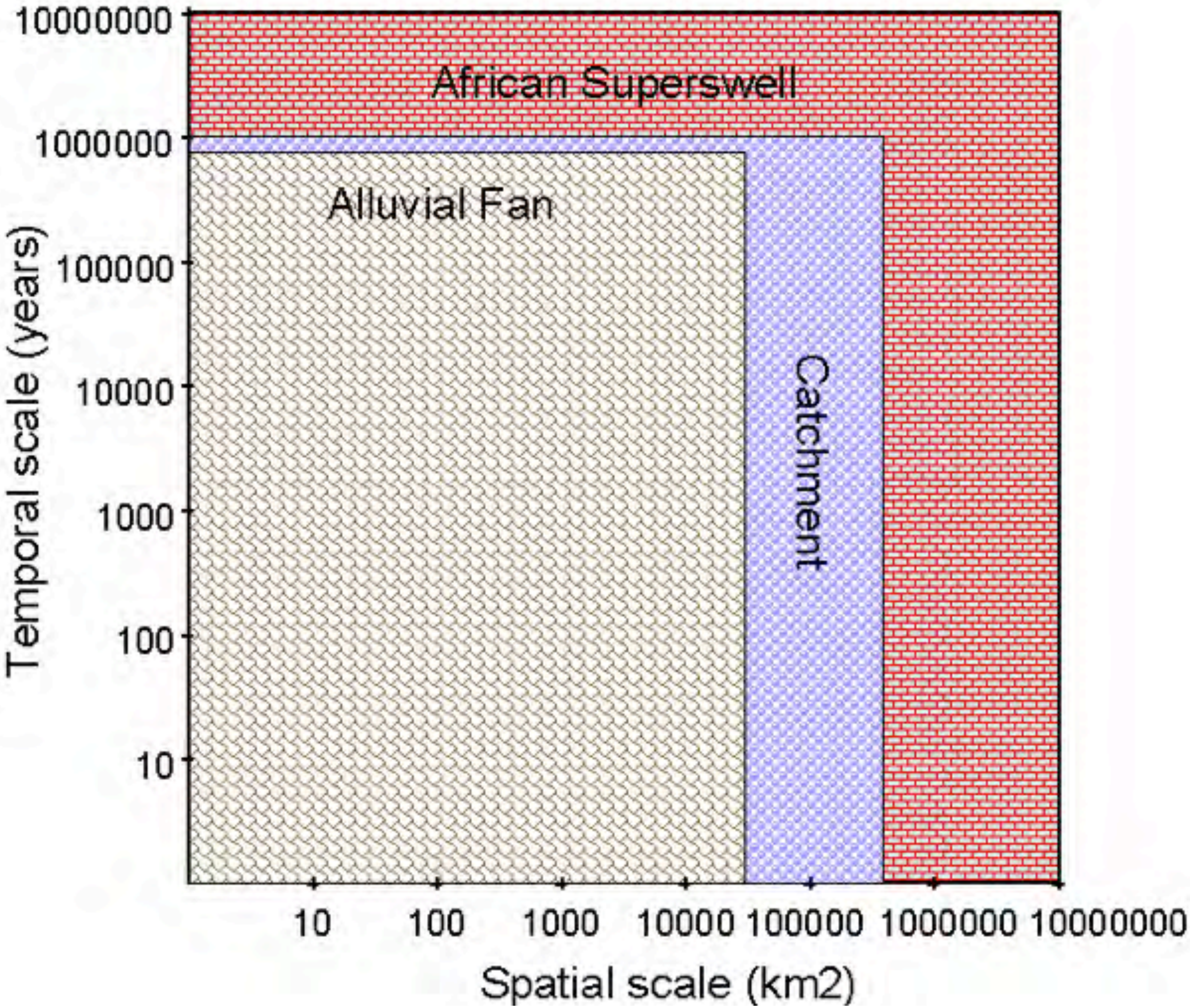
Annual sediment inflow
600 000 tonnes

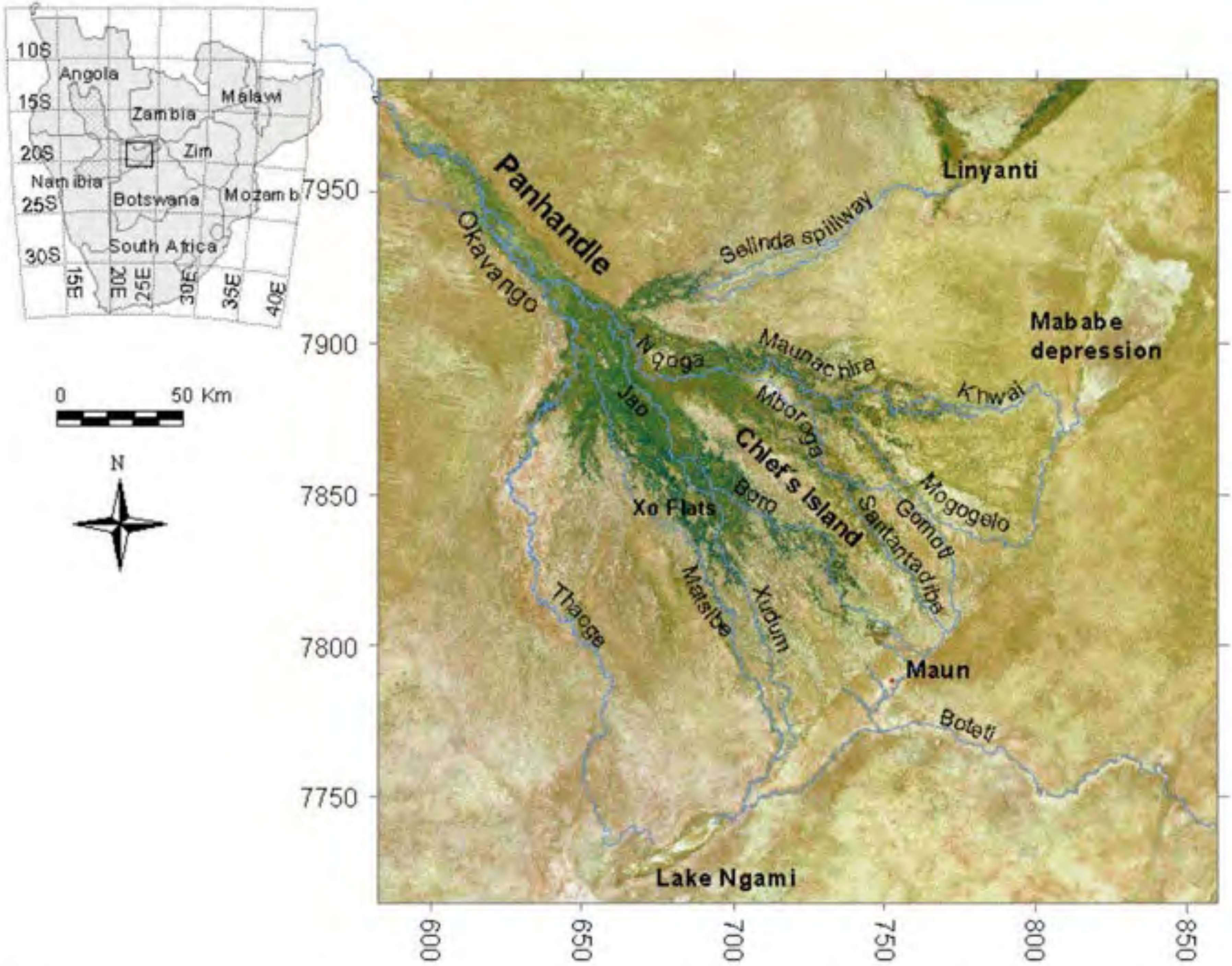
Raises the Okavango Delta
1 meter in 50 000 years

Population - Okavango Basin

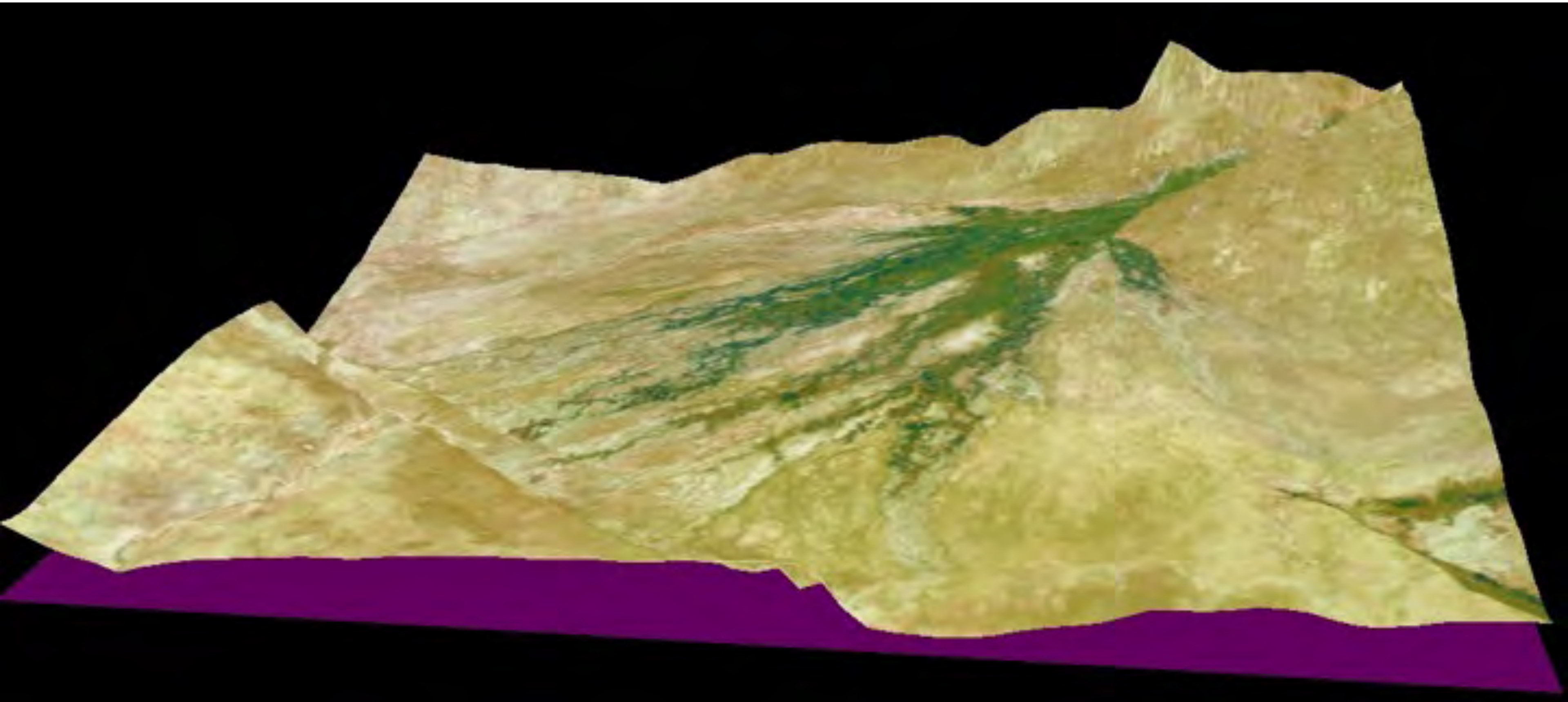


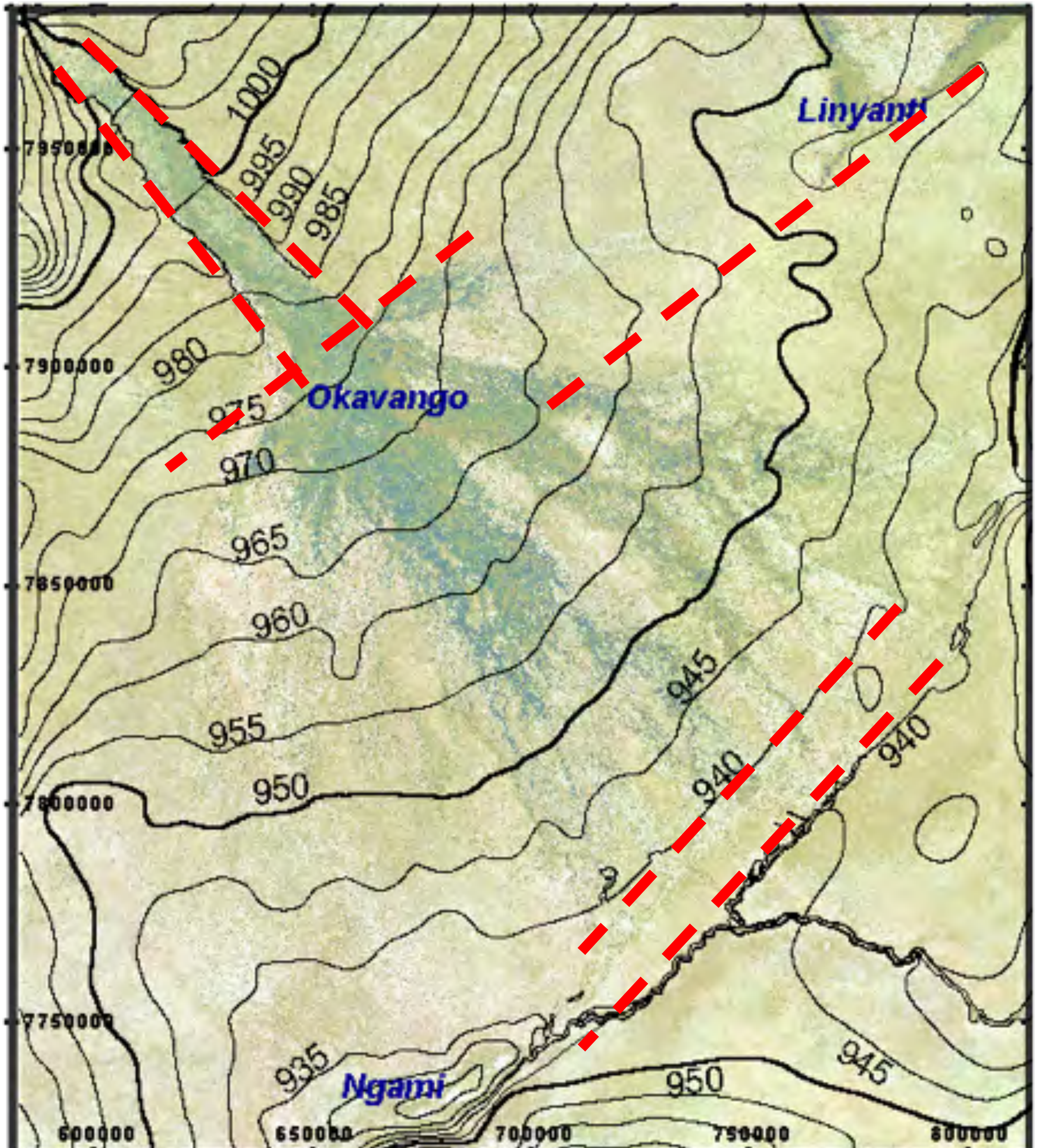
Total population: 400 000

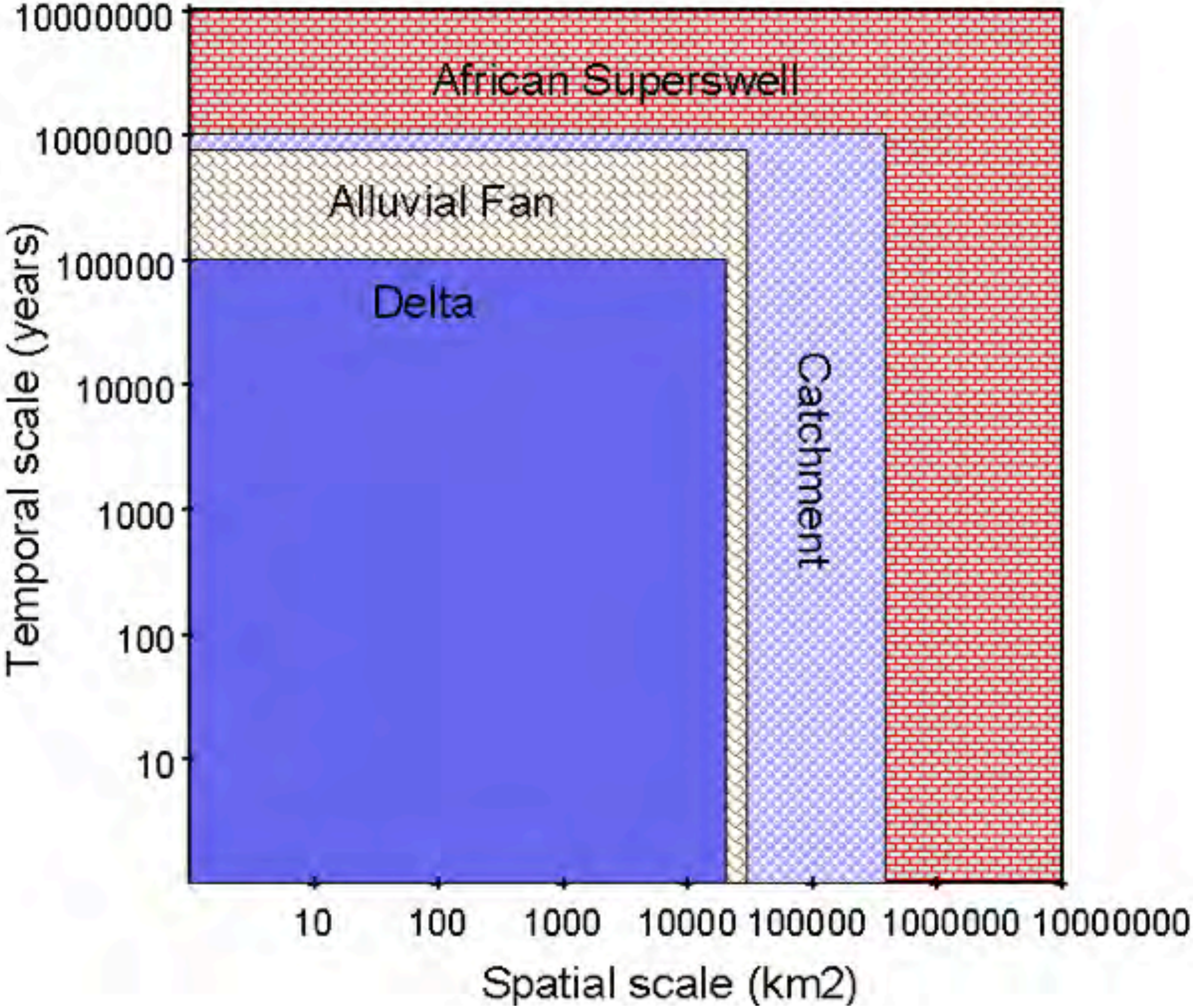

African Superswell
Alluvial Fan
Catchment
Temporal scale (years)
10000000
1000000
100000
10000
1000
100
10
10
100
1000
10000
100000
1000000
10000000
Spatial scale (km2)



10S
15S
20S
25S
30S
Angola
Zambia
Malawi
Zim
Namibia
Botswana
Mozamb
South Africa
15E
20E
25E
30E
35E
40E
0
50 Km
N
7950
7900
7850
7800
7750
600
650
700
750
800
850
Panhandle
Okavango
Linyanti
Selinda spillway
Mababe depression
Nqoga
Maunachira
Khwai
Jao
Mboroga
Chief's Island
Mogogelo
Boro
Gomoti
Santantadibe
Xo Flats
Thaoge
Matsibe
Xudum
Maun
Boteti
Lake Ngami

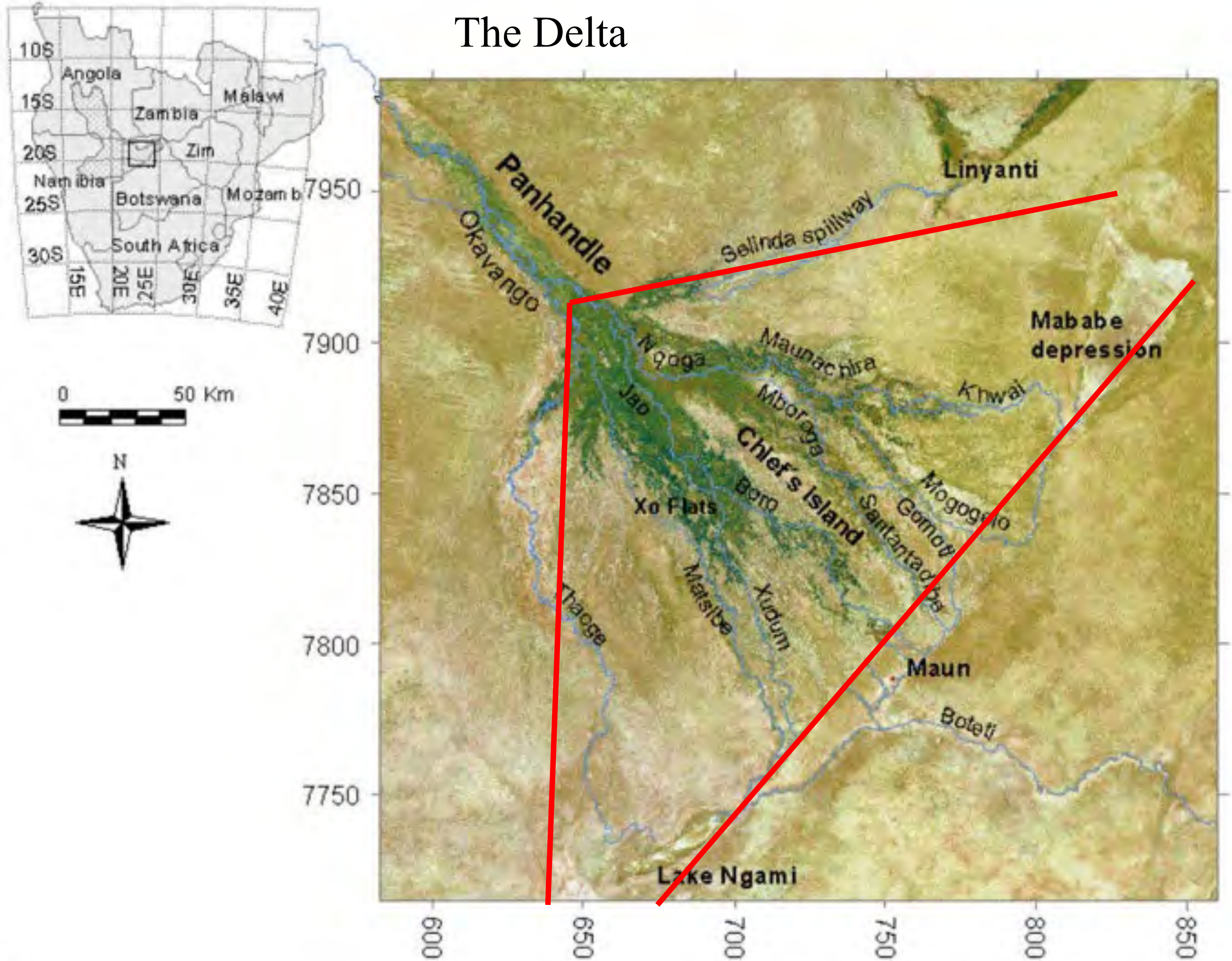



Linyanti
Okavango
Ngami
1000
995
990
985
980
975
970
965
960
955
950
945
940
940
935
950
945
7950000
7900000
7850000
7800000
7750000
600000
650000
700000
750000
800000

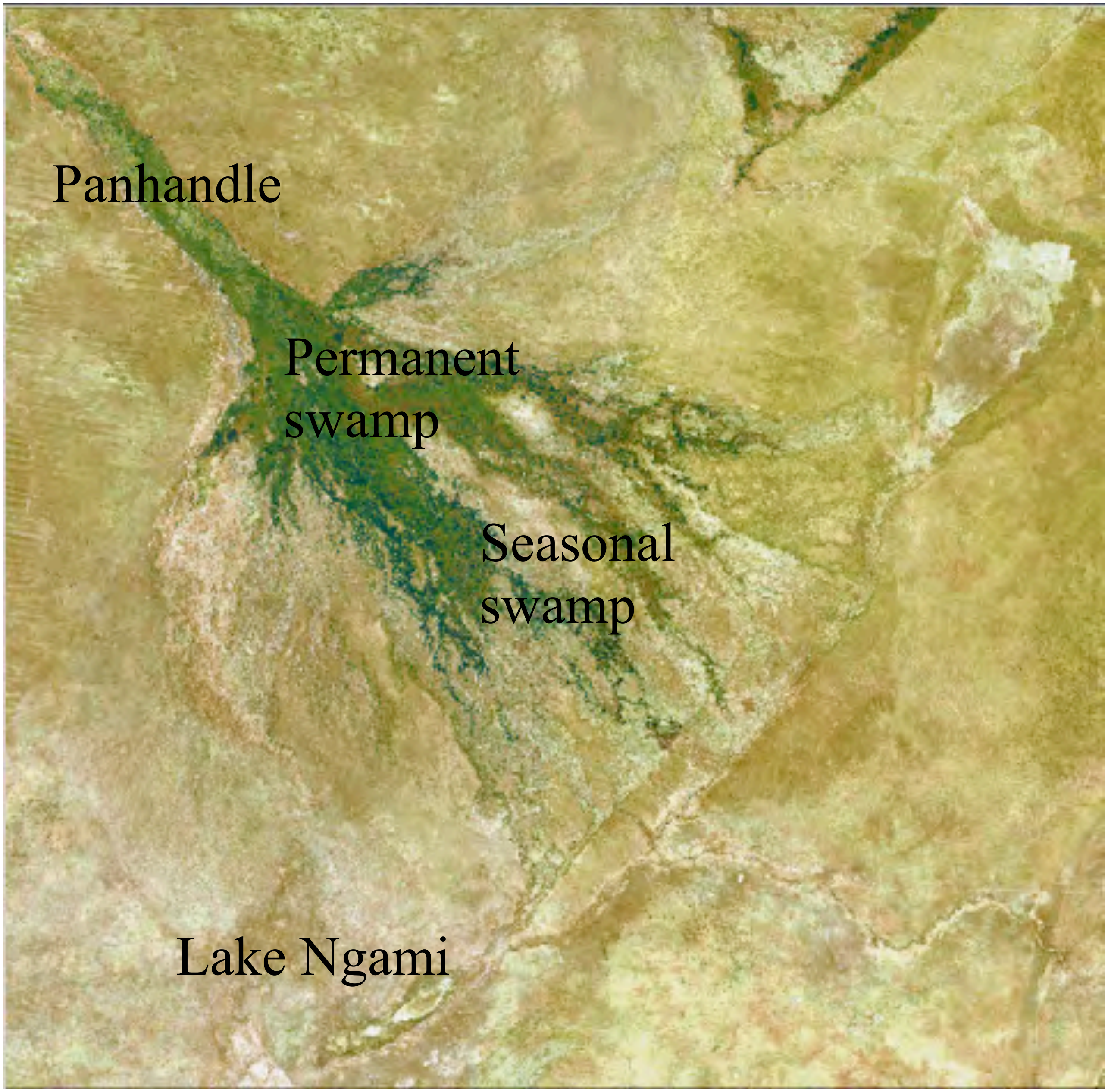


African Superswell
Alluvial Fan
Delta
Catchment
Temporal scale (years)
10000000
1000000
100000
10000
1000
100
10
10
100
1000
10000
100000
1000000
10000000
Spatial scale (km2)

The Delta

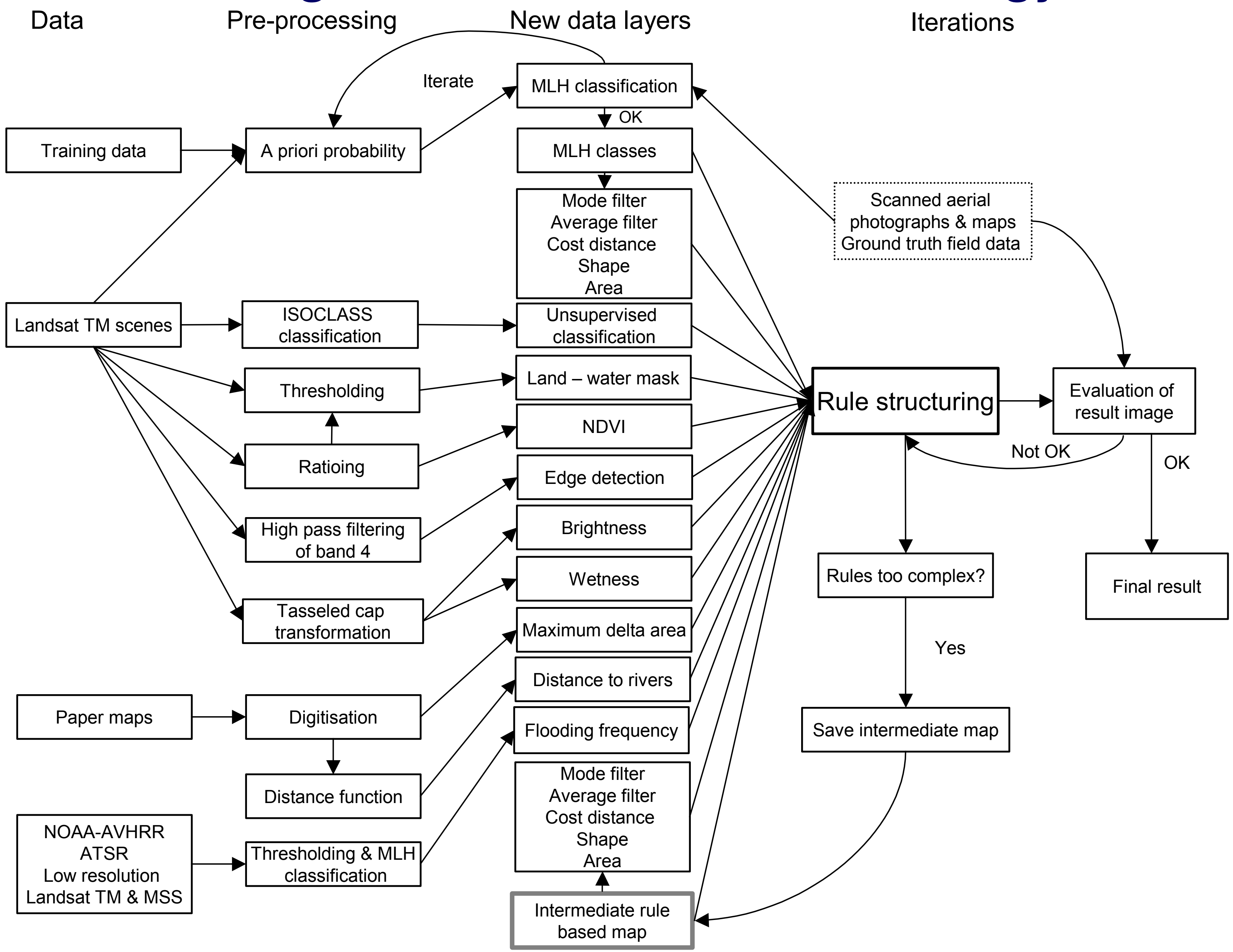


10S
15S
20S
25S
30S
Angola
Zambia
Malawi
Zim
Namibia
Botswana
Mozamb
South Africa
15E
20E
25E
30E
35E
40E
0
50 Km
N
7950
7900
7850
7800
7750
600
650
700
750
800
850
Panhandle
Okavango
Linyanti
Selinda spillway
Mababe depression
Nqoga
Maunachira
Khwai
Jao
Mboroga
Chief's Island
Boro
Xo Flats
Mogogelo
Gomoti
Santantadibe
Thaoge
Matsibe
Xudum
Maun
Boteti
Lake Ngami



Psst!

Ecoregion Classification methodology



Water = 2.5 m below reference level

Permanent Swamp = 2.0 m below reference level

Primary floodplain = 1.5 m below reference level

Secondary floodplain = 1.0 m below reference level


Secondary Floodplain (in flood)

Grassland = reference level

Grassland

Salt pan = 0.5 m below reference level

Dry Grassland/Salt Pan

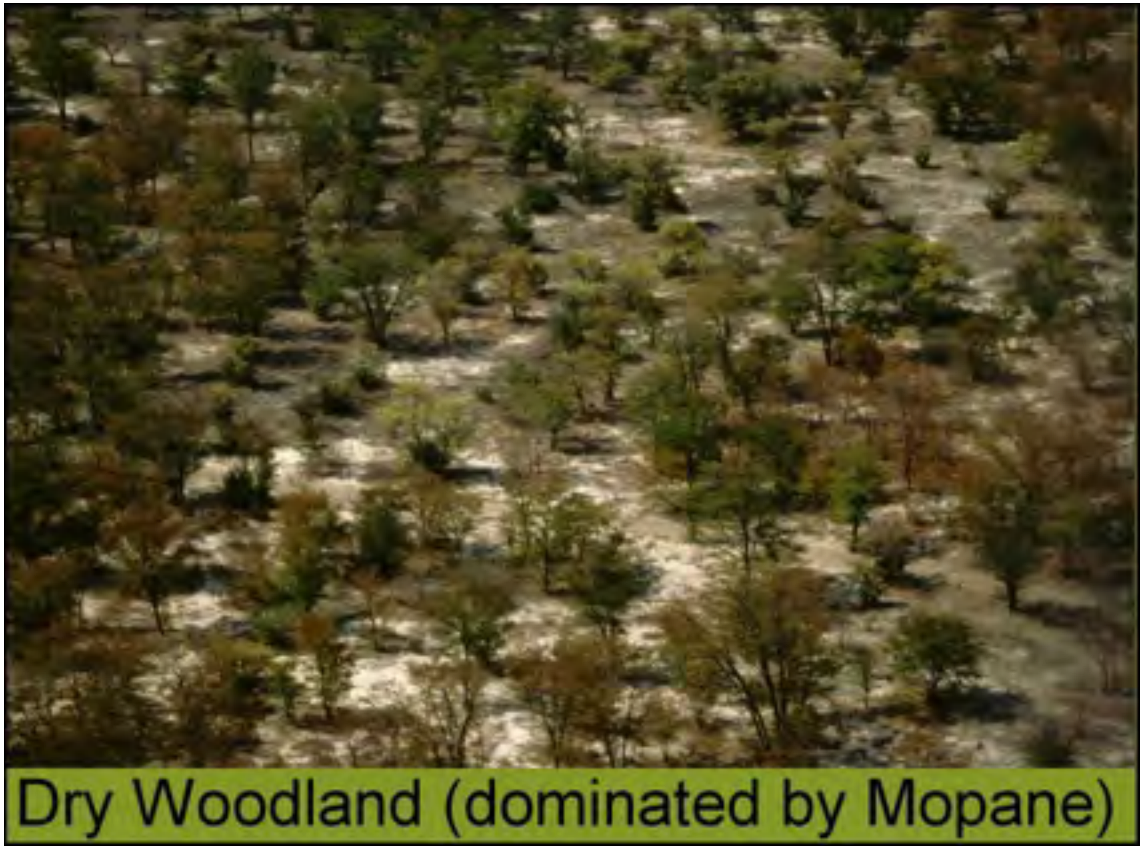
Occasionally flooded grassland = 0.5 m below reference level

Salt pan = 0.5 m below reference level

Dry Grassland/Salt Pan (with flooding)

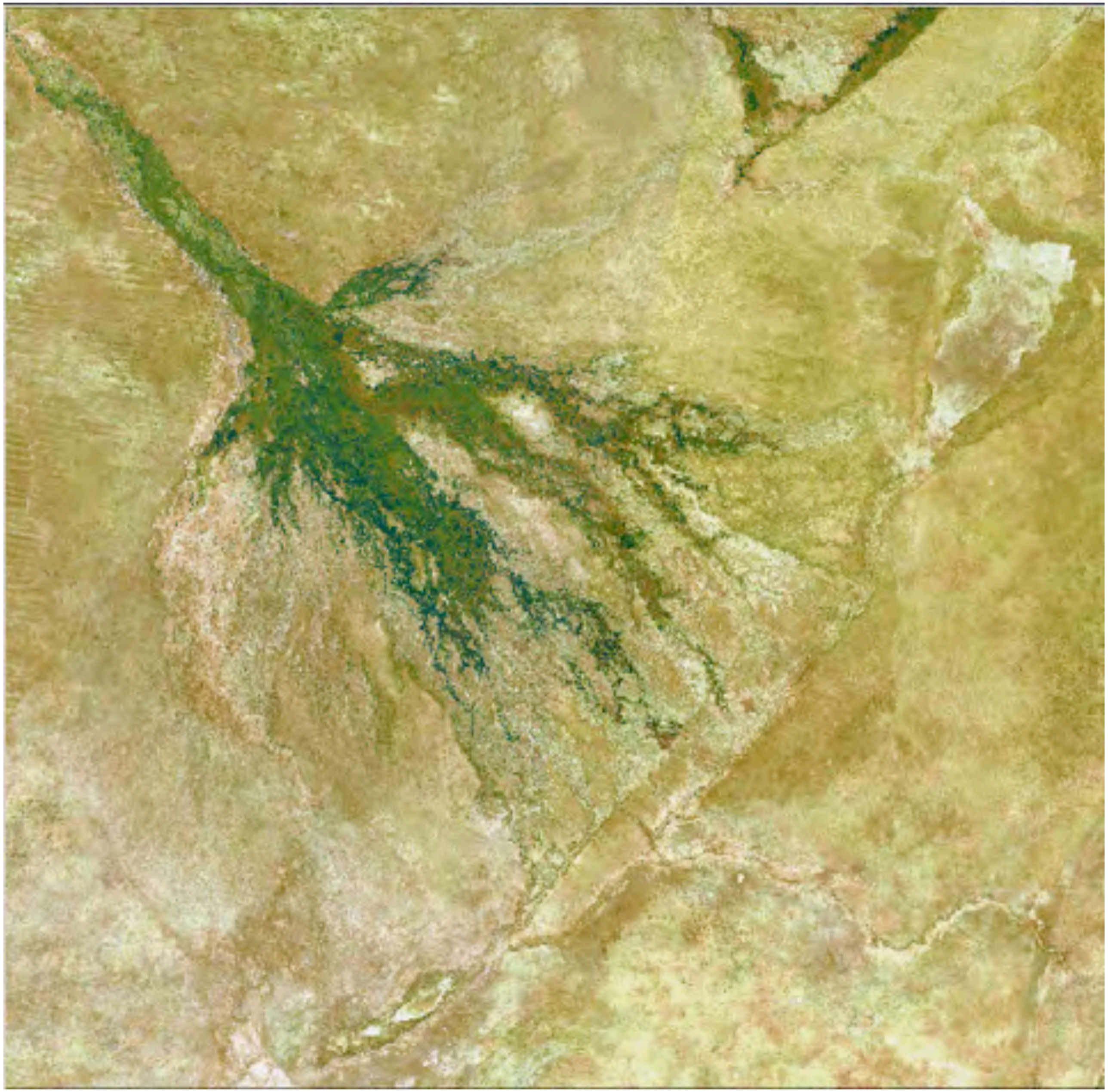
Riverine forest = 1.2 m above reference level

Dry woodland = reference level



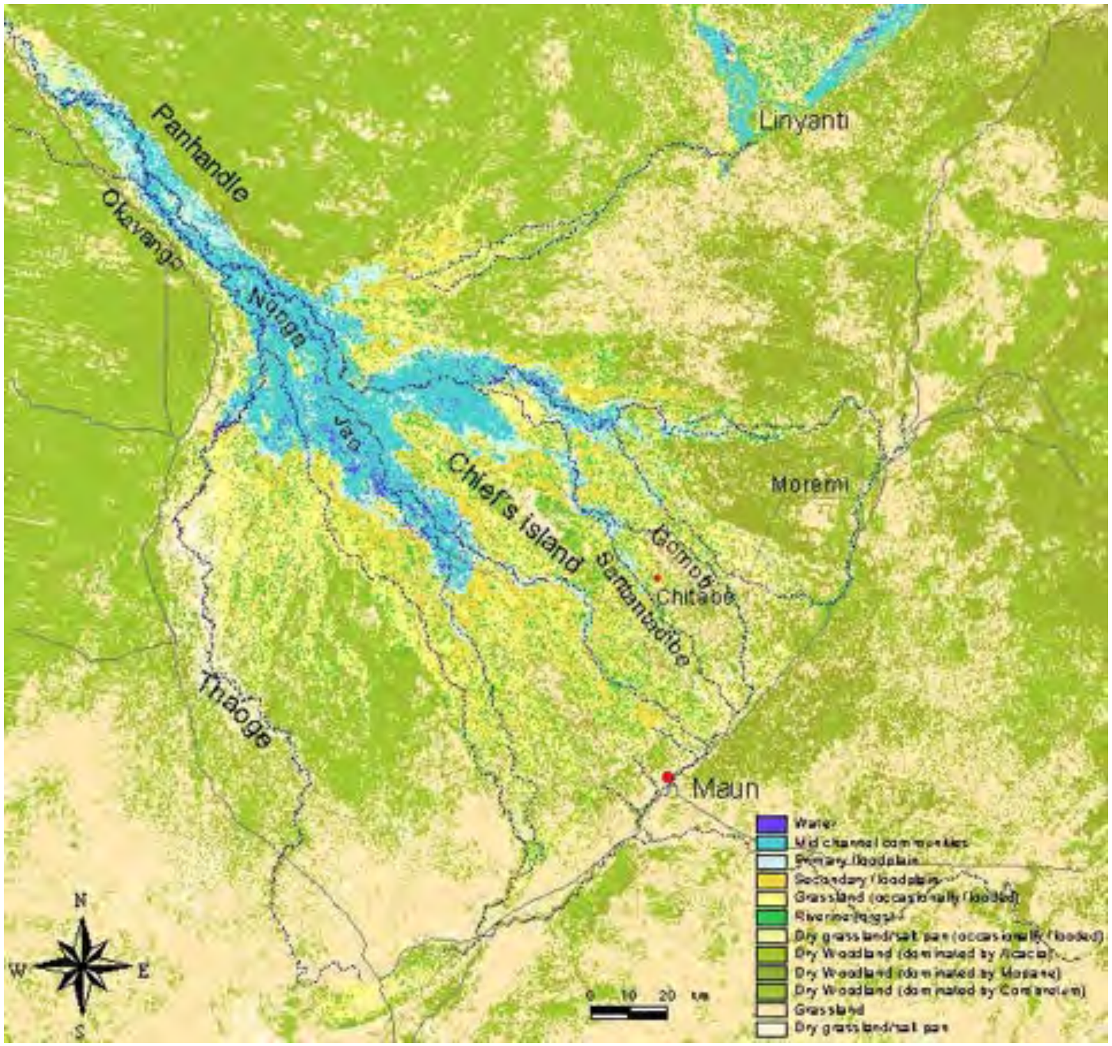
Dry woodland = reference level

Dry Woodland (dominated by Acacia)

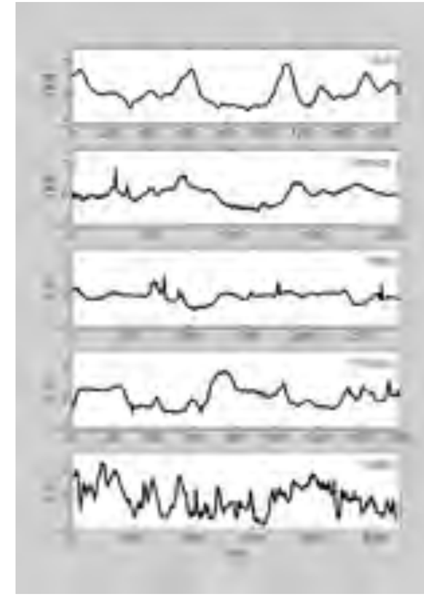


Landcover ecoregions

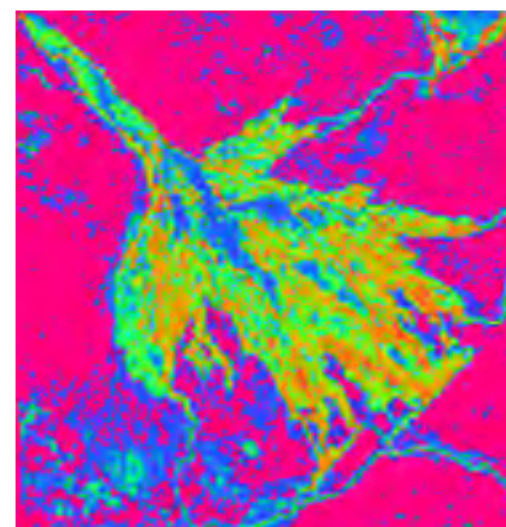
Landcover ecoregions



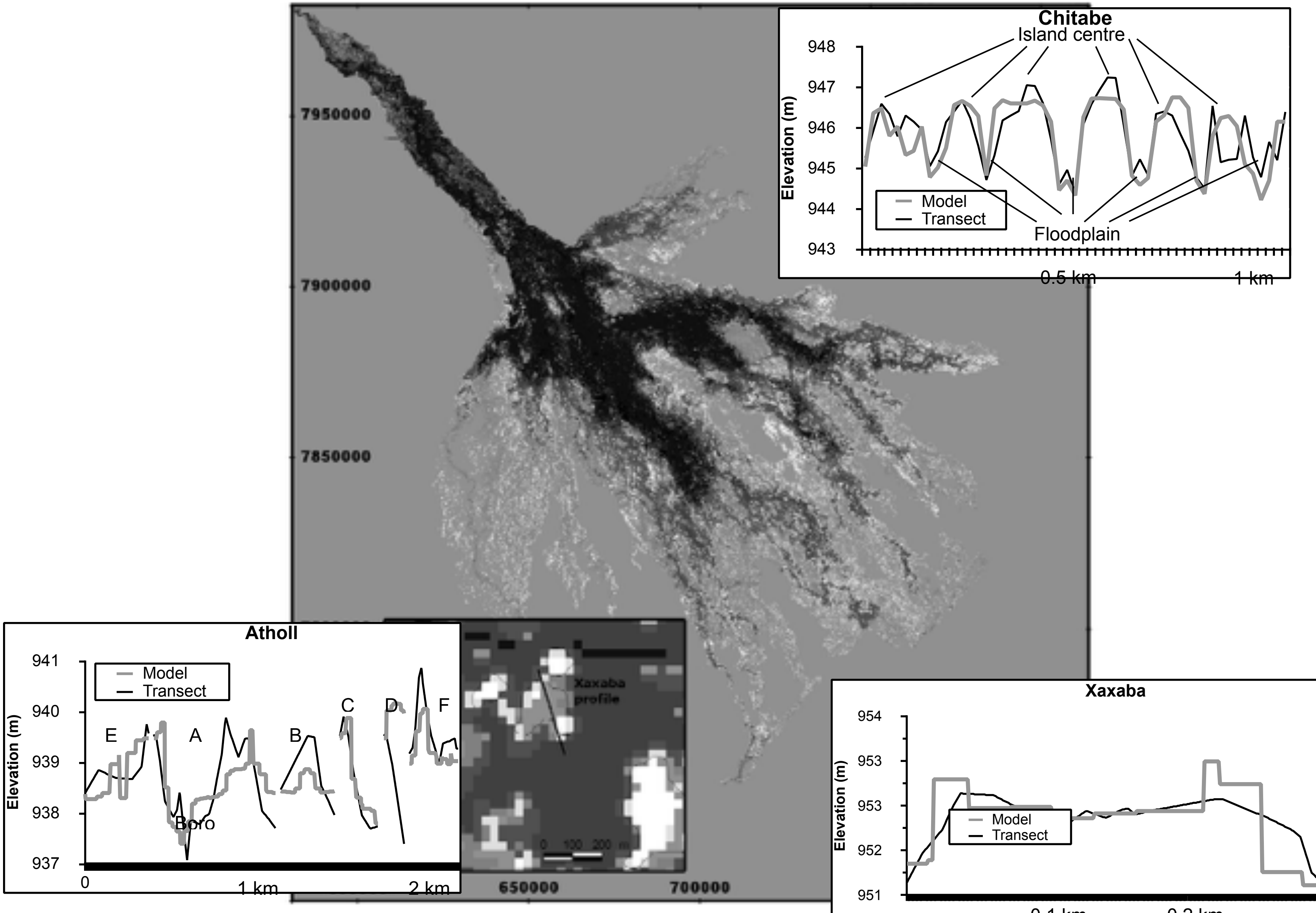
Surveyed profiles

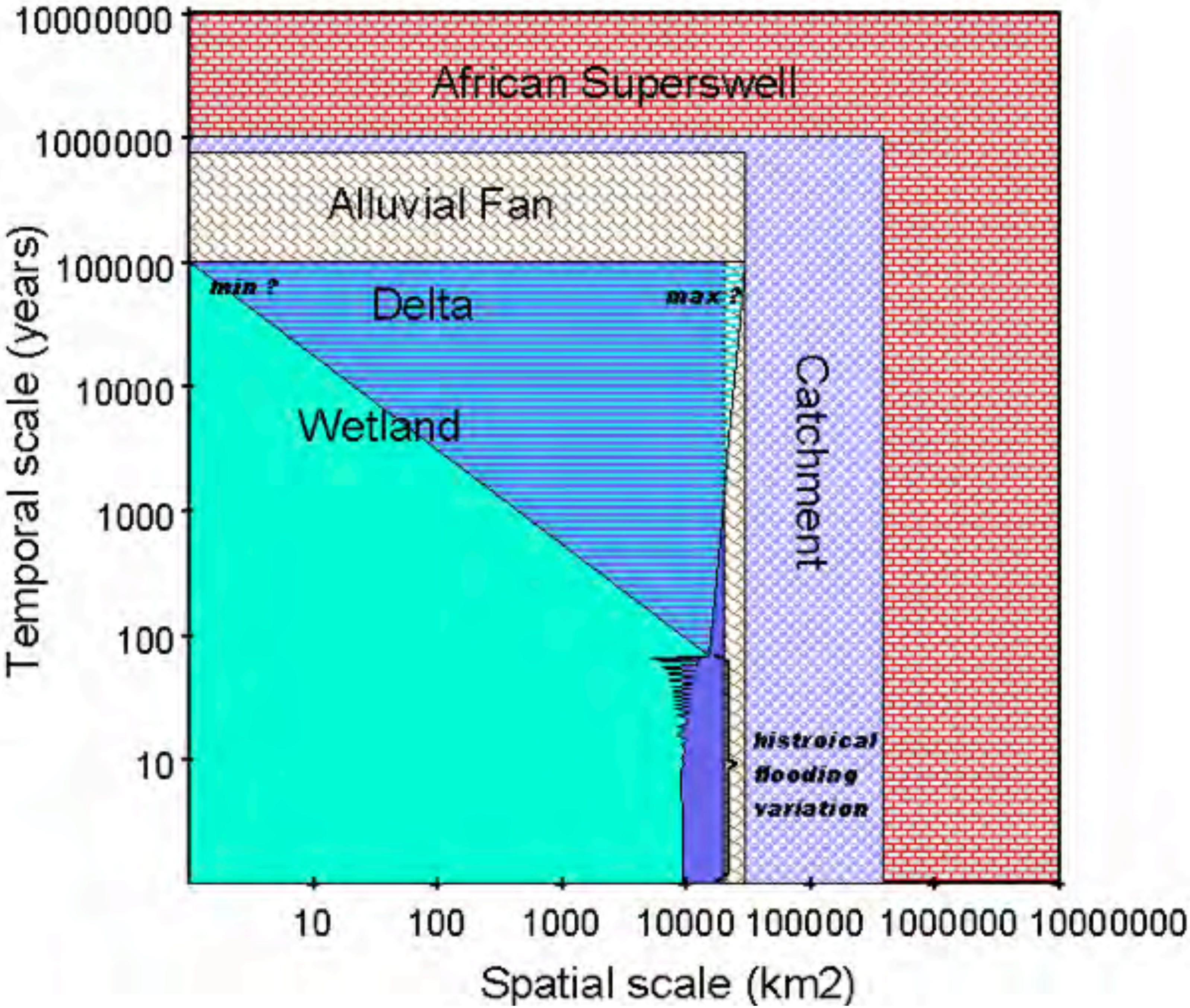


Microtopography

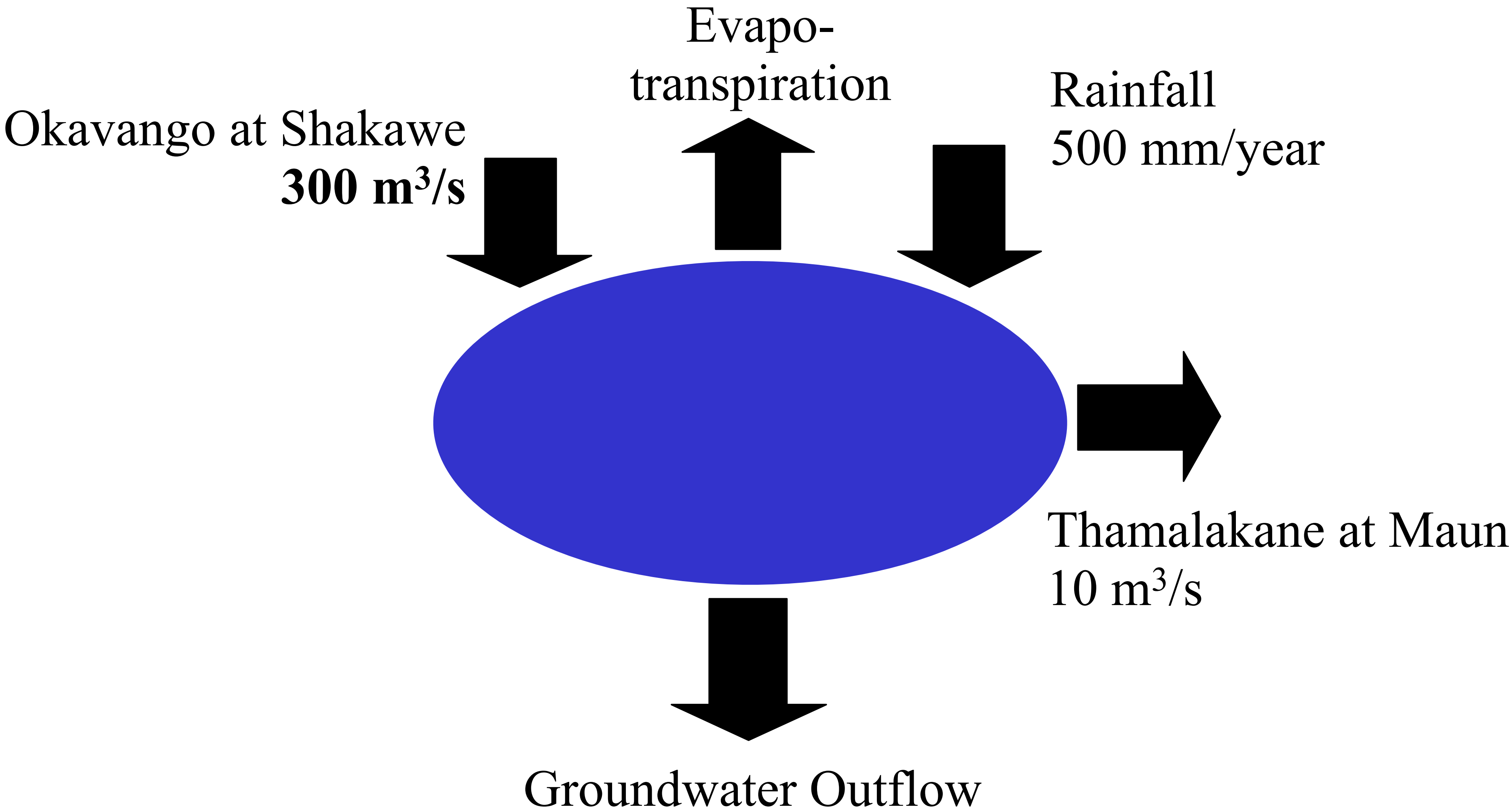


Relative microtopography of the Okavango Delta



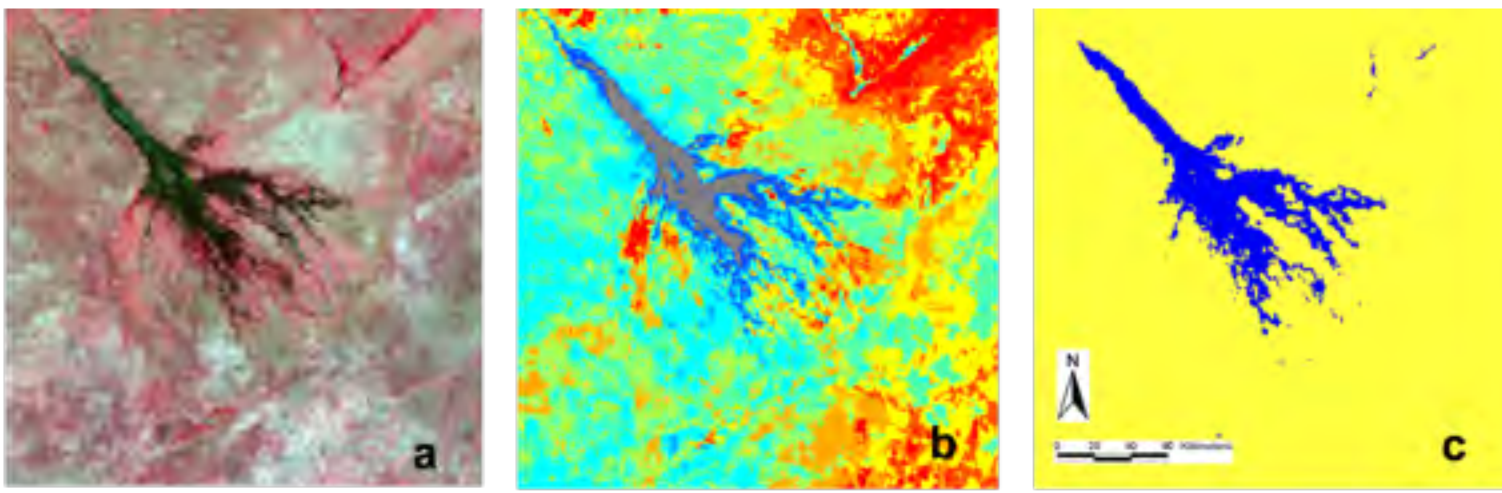

African Superswell
Alluvial Fan
Delta
min ?
max ?
Wetland
Catchment
histroical
flooding
variation
Temporal scale (years)
10000000
1000000
100000
10000
1000
100
10
Spatial scale (km2)
10
100
1000
10000
100000
1000000
10000000

Okavango Delta water balance



Classification of historical flood area

Unsupervised classification of ~ 400 satellite images (NOAA AVHRR, ERS-2 ATSR), and supervised classification of Landsat MSS / TM (subset of ~ 3000 images)

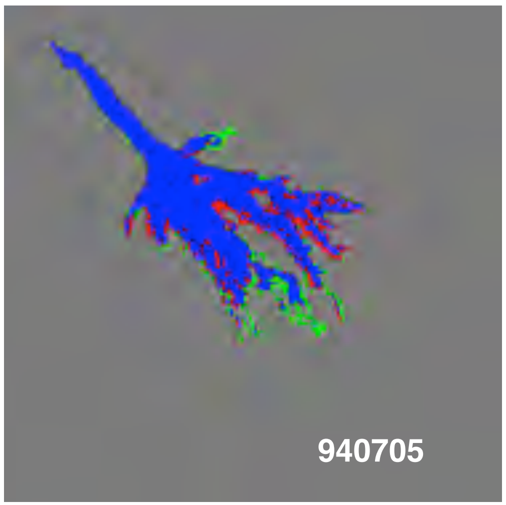


AVHRR

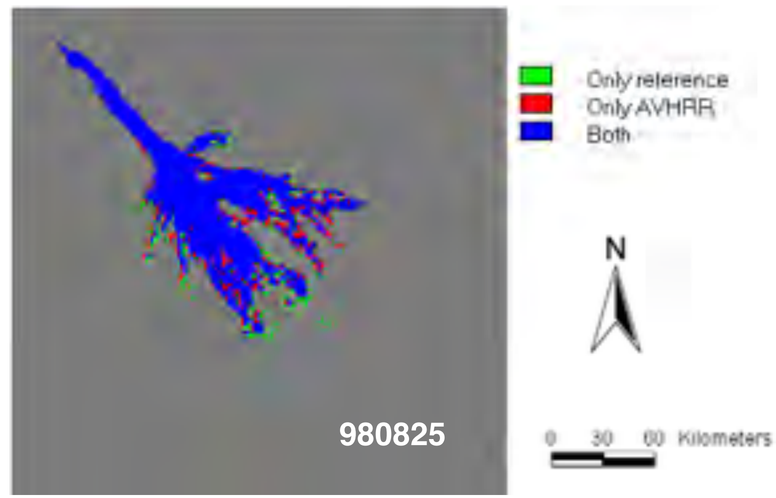
Unsupervised classification

Manual reclassification

Evaluation of AVHRR against Landsat TM & ATSR

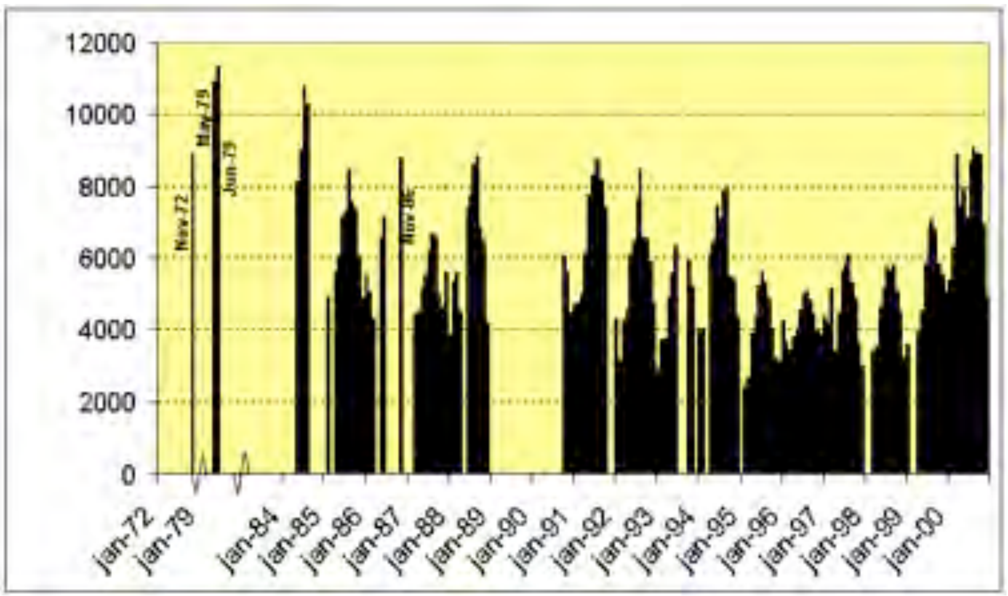


AVHRR vs. Landsat TM

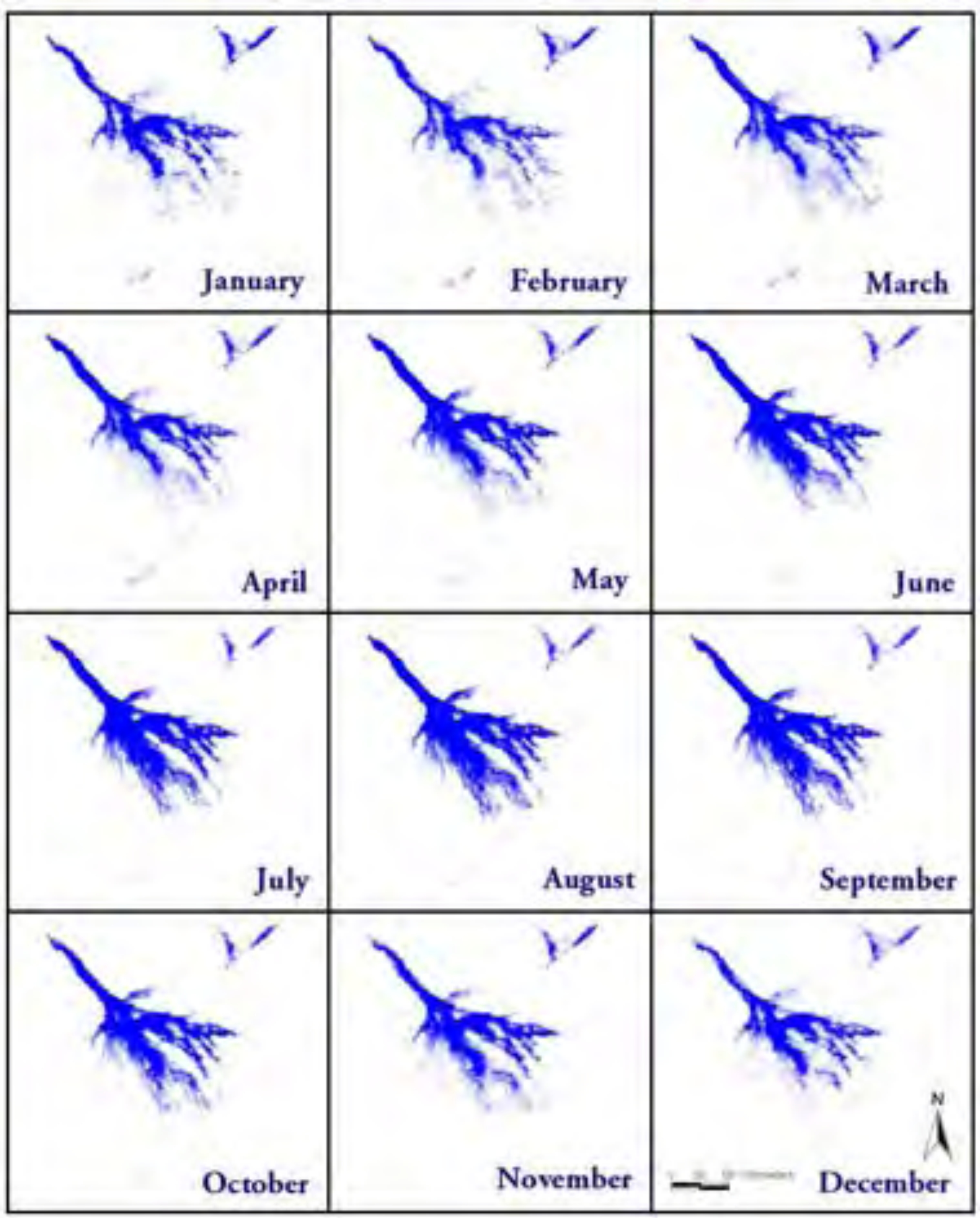


AVHRR vs. ATSR

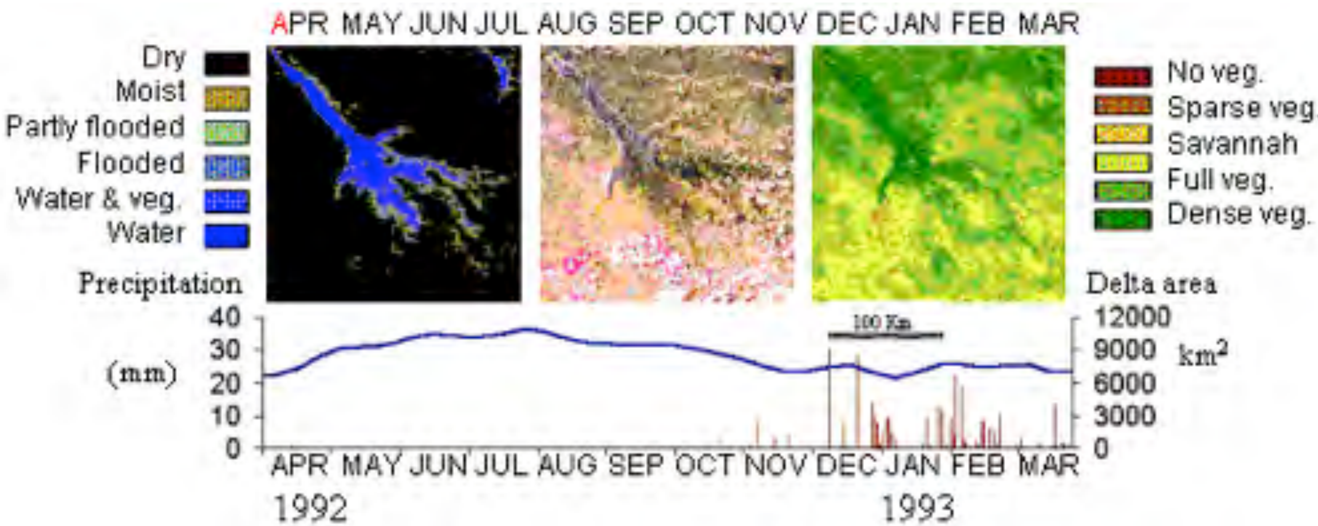
Flooding, years (1985-2000)



Flooding, month (1985-2000)



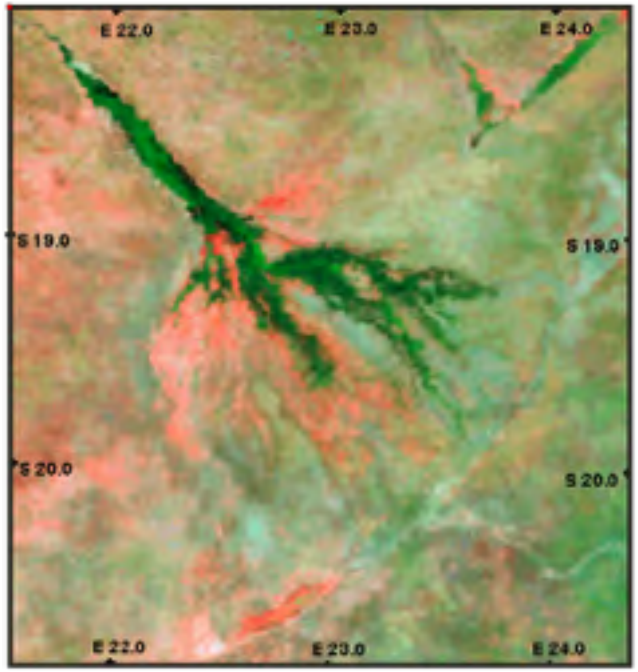
Okavango Delta water balance 1992/93

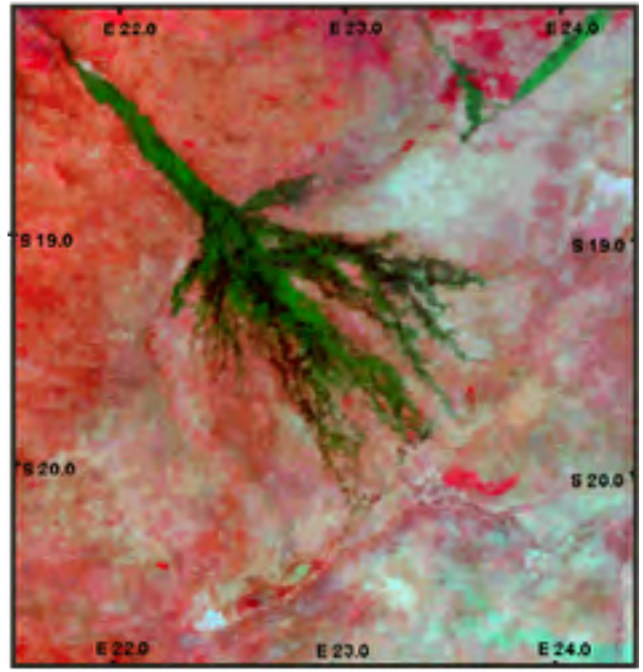


3 ways to model the water flow in the Okavango Delta

1. Statistically by using historical data
2. Mathematical description of outflow and inflow of small cubes (like a checker-board)
3. Mathematical description of outflow and inflow of “natural” compartments

Statistical modelling of the Okavango Delta annual flooding

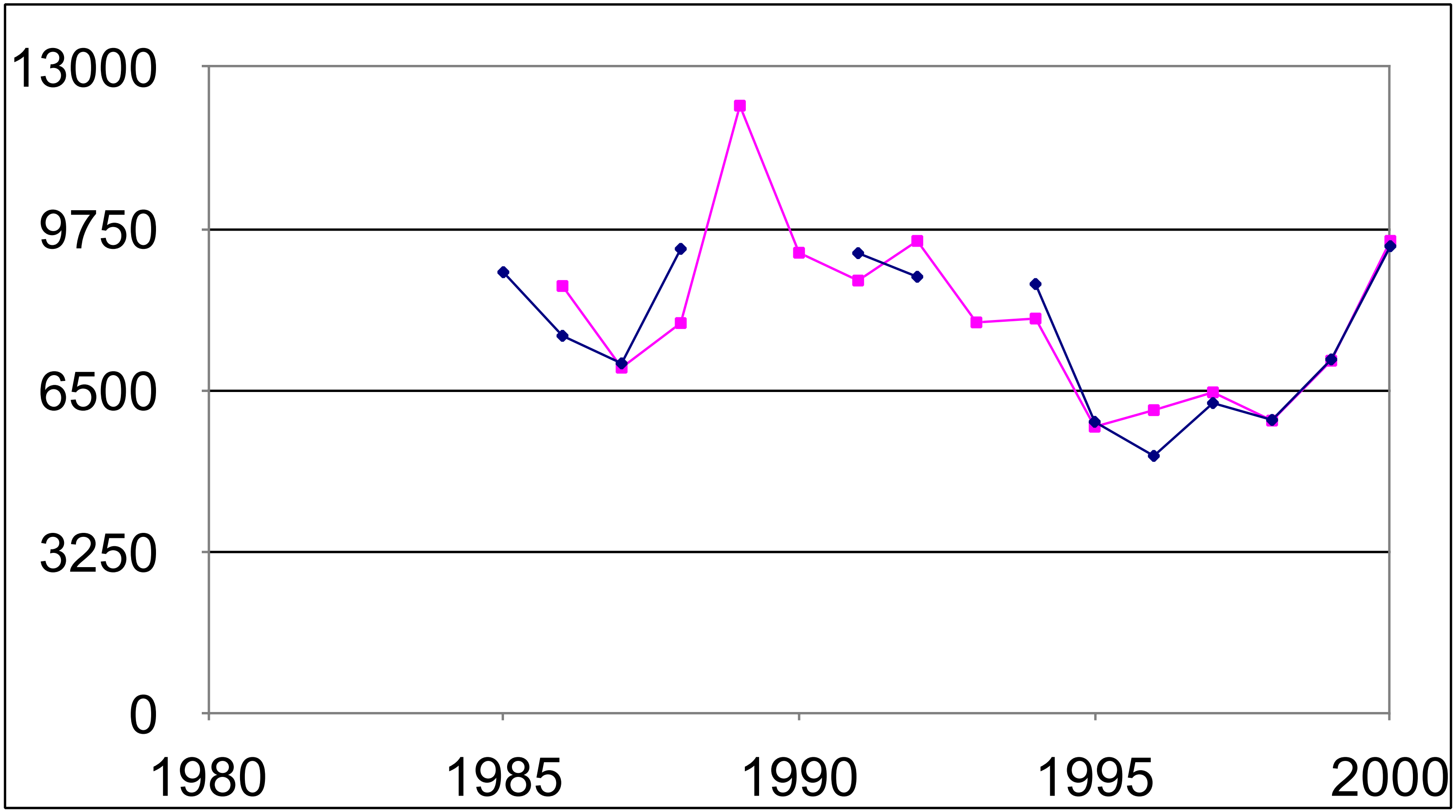




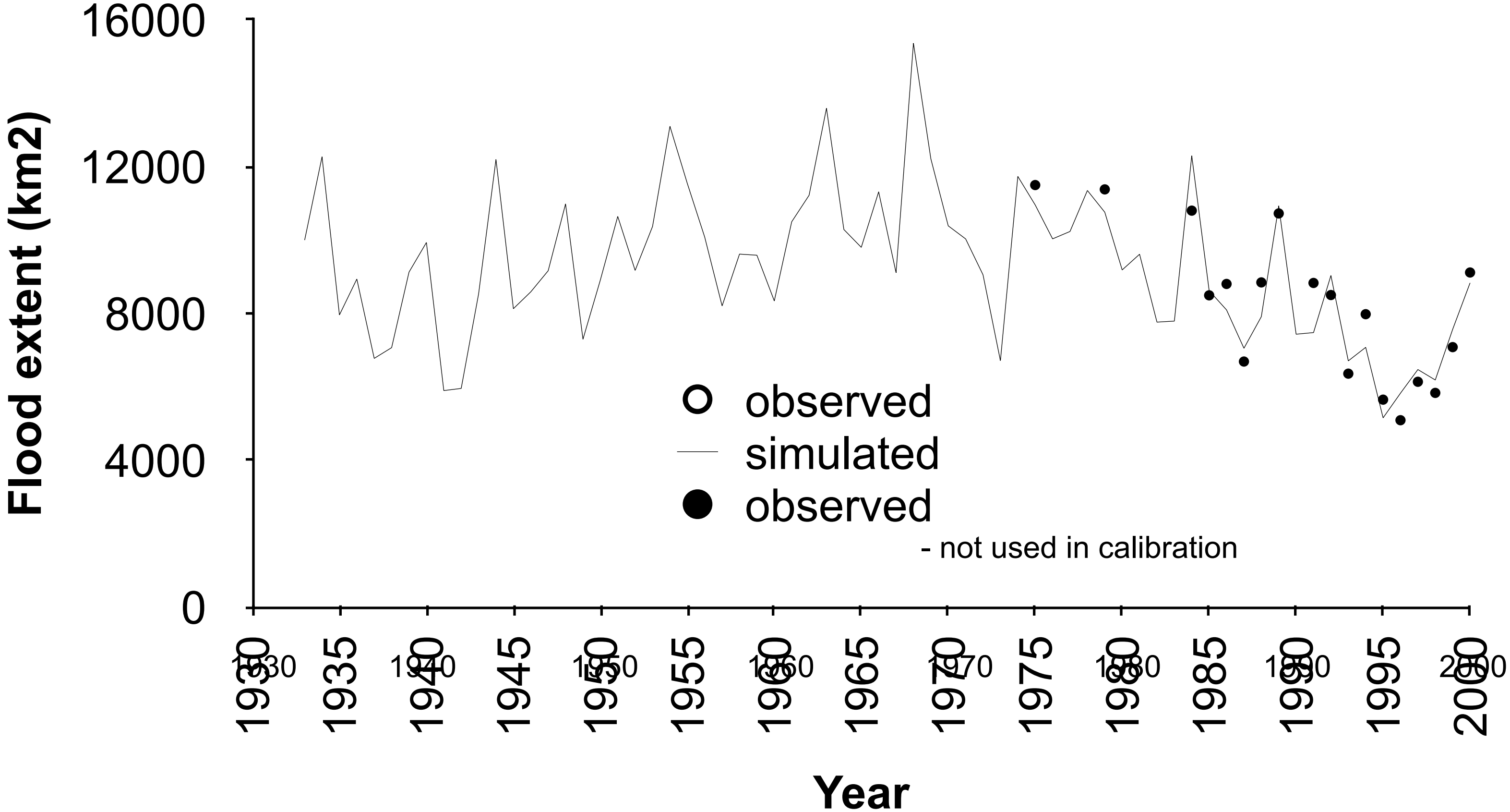
Data needed:

- Inflow at Panhandle
- Rainfall over the Delta
- Area of flooding (to be predicted)

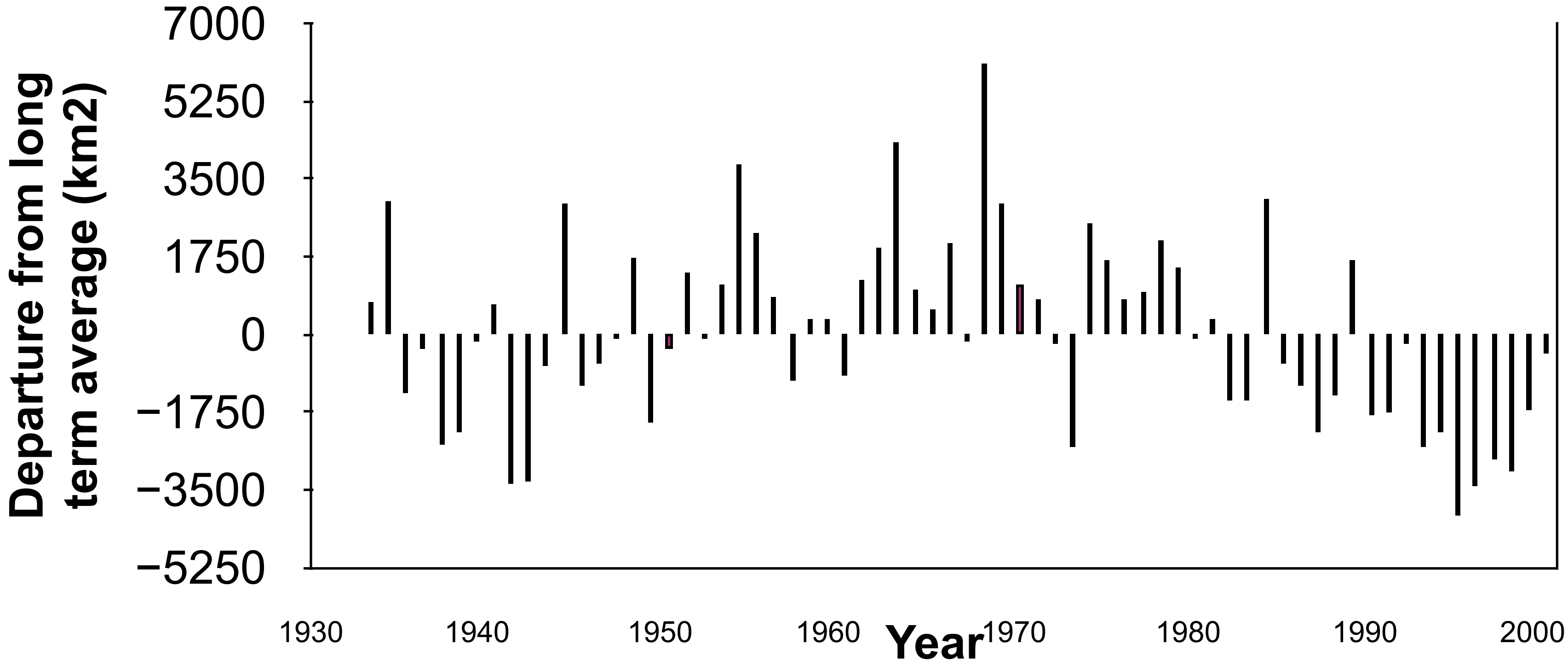
Area of flooding =
  Inflow at the Panhandle +
  local precipitation +
  previous years flood



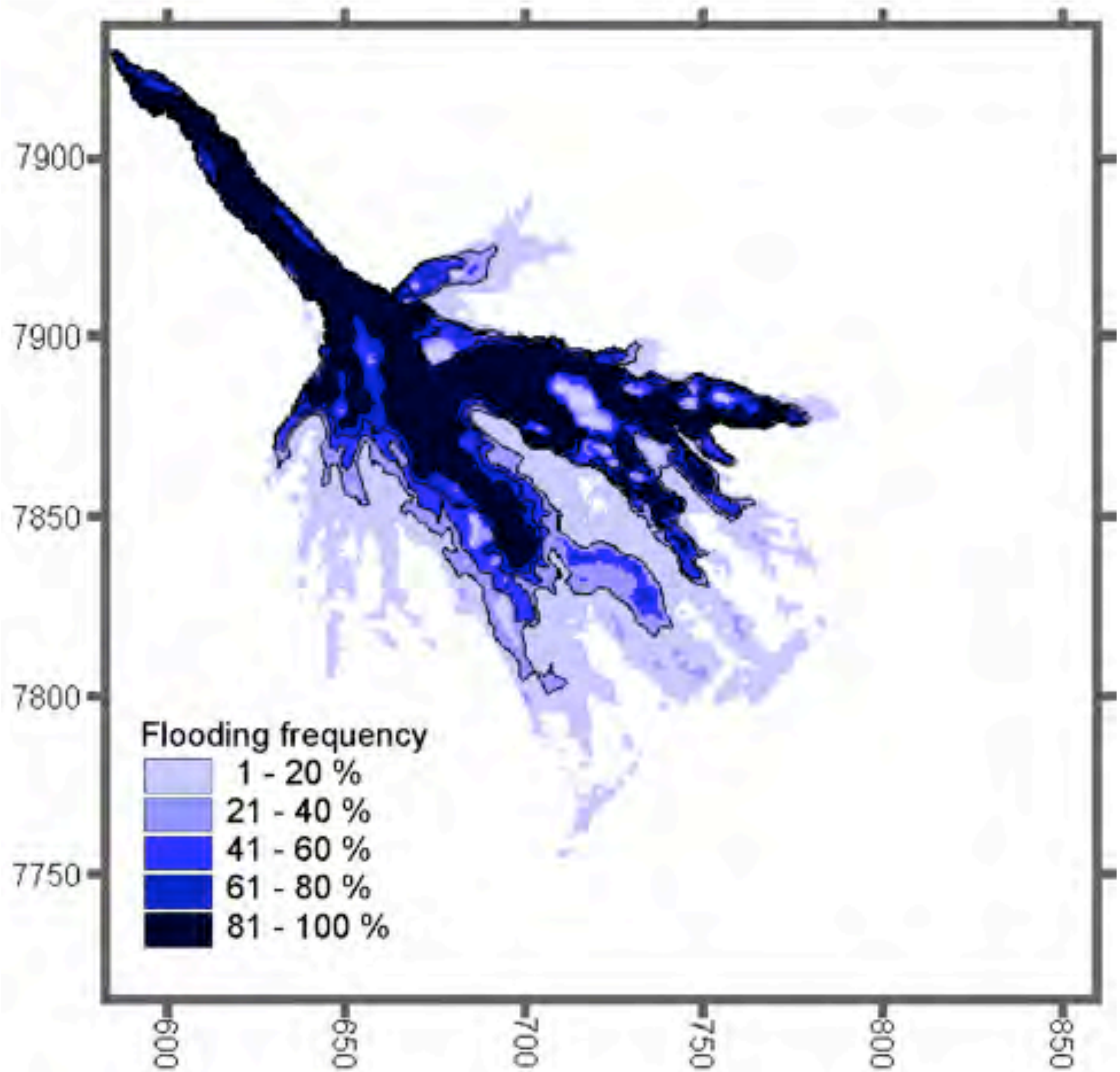
13000
9750
6500
3250
0
1980
1985
1990
1995
2000



Flood extent (km2)
16000
12000
8000
4000
0
observed
simulated
observed
- not used in calibration
1930
1935
1940
1945
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
Year



Departure from long term average (km2)
7000
5250
3500
1750
0
−1750
−3500
−5250
1930
1940
1950
1960
1970
1980
1990
2000
Year


7900
7900
7850
7800
7750
600
650
700
750
800
850
Flooding frequency
1 - 20 %
21 - 40 %
41 - 60 %
61 - 80 %
81 - 100 %

4500 km^2

5000 km^2

5500 km^2

6000 km^2

6500 km^2

7000 km^2

7500 km^2

8000 km^2

8500 km²

9000 km^2

9500 km^2

10000 km^2

10500 km^2

11000 km^2

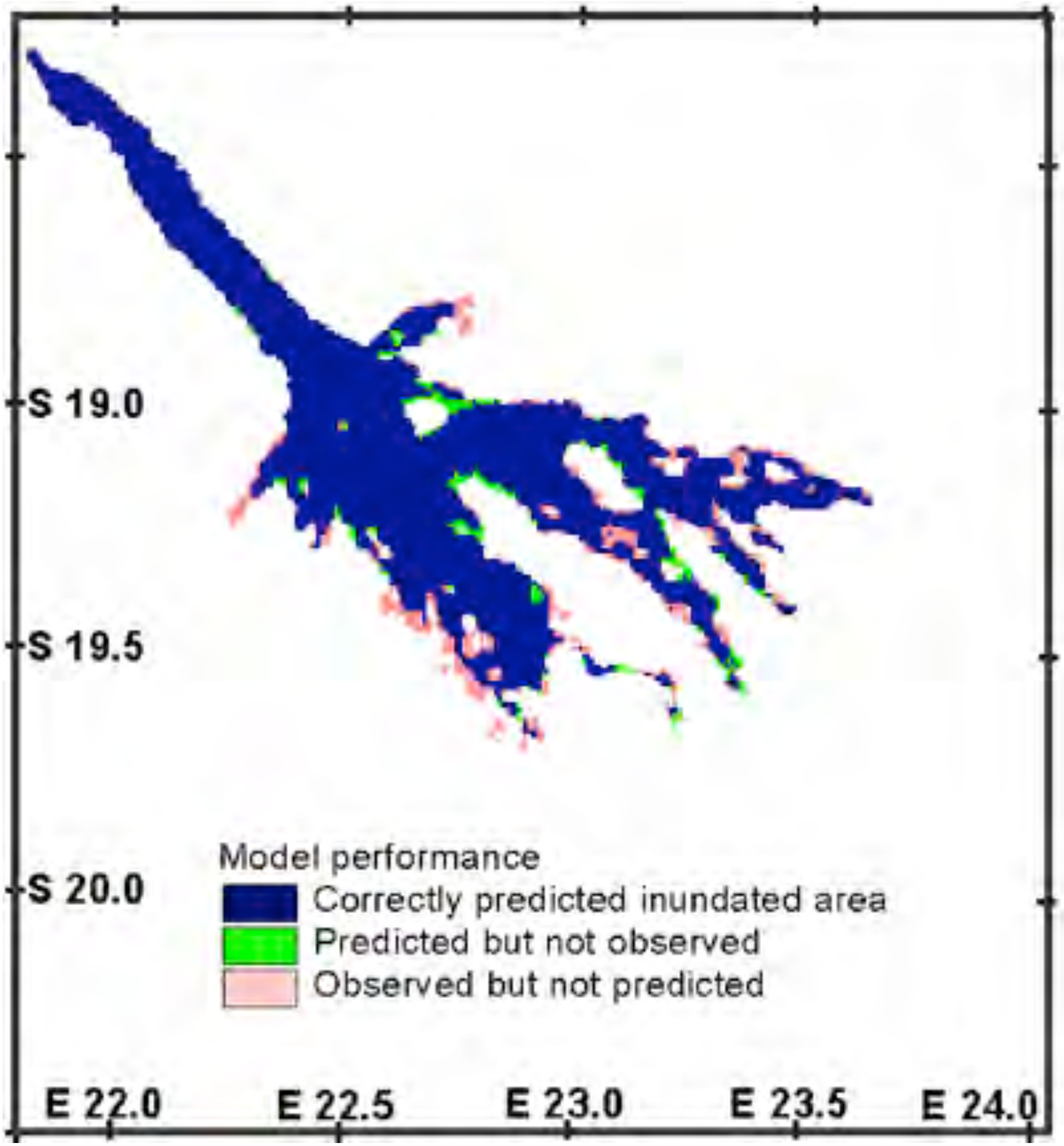
11500 km^2

12000 km^2

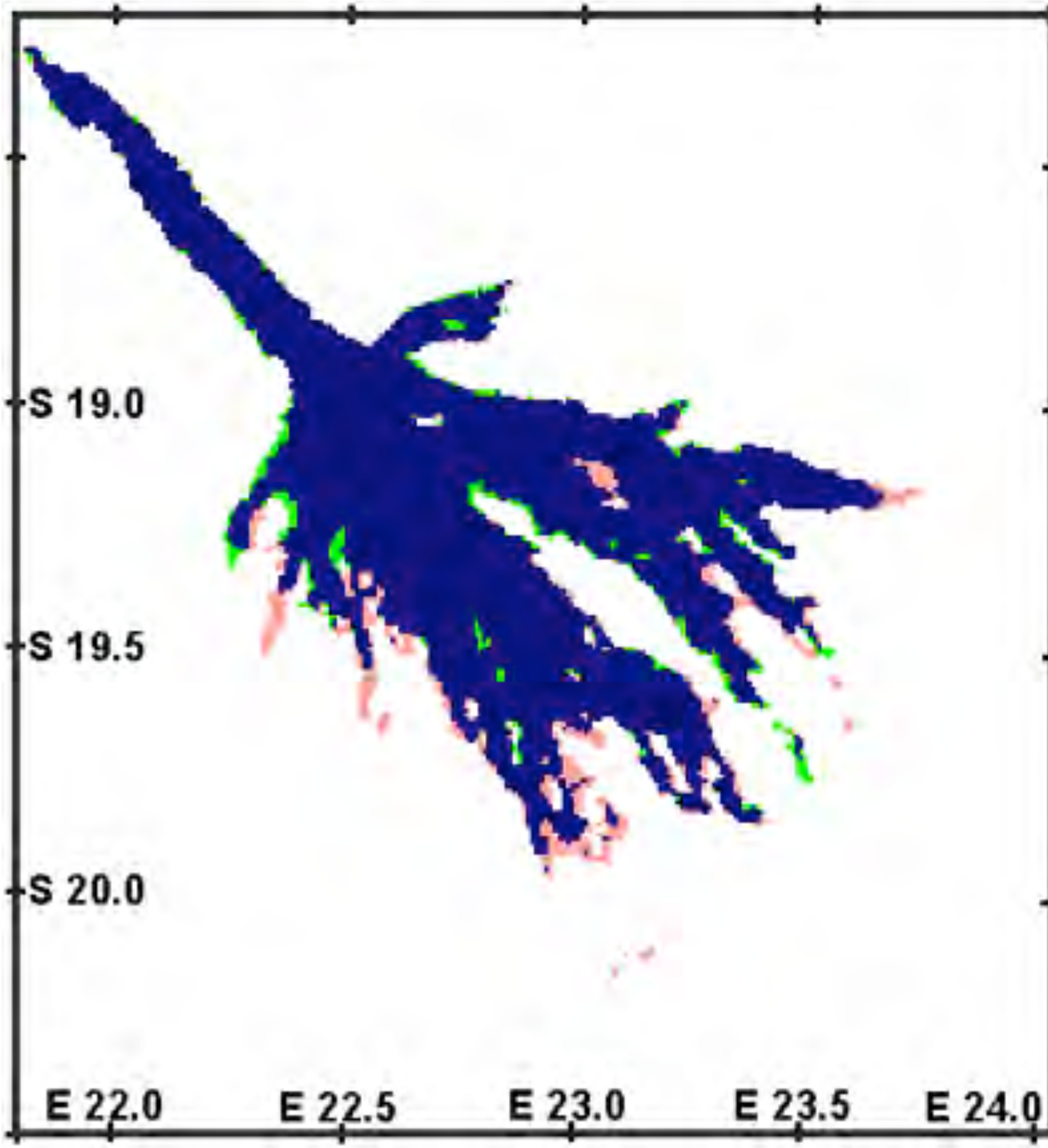
12500 km^2

13000 km^2

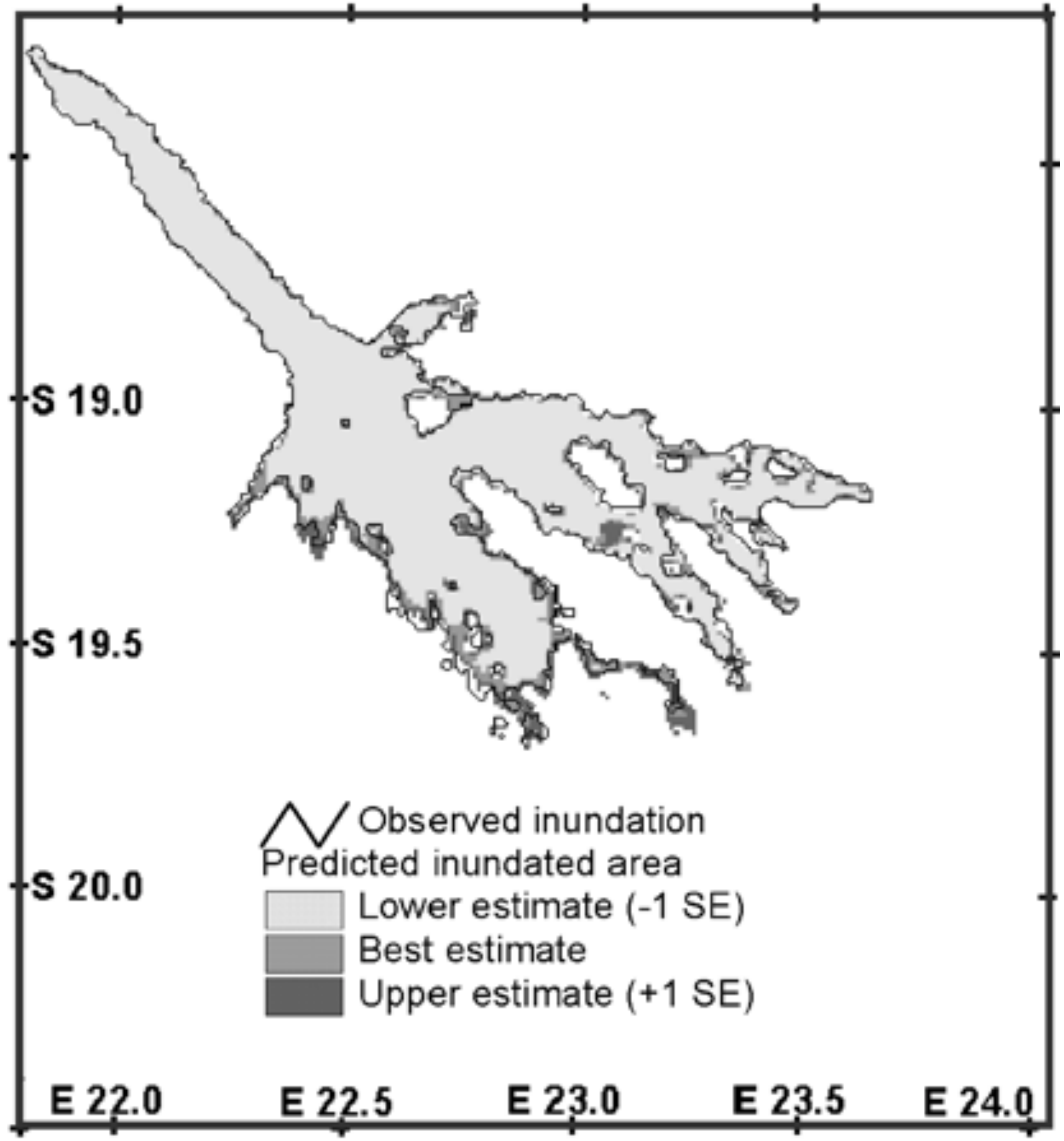
1995

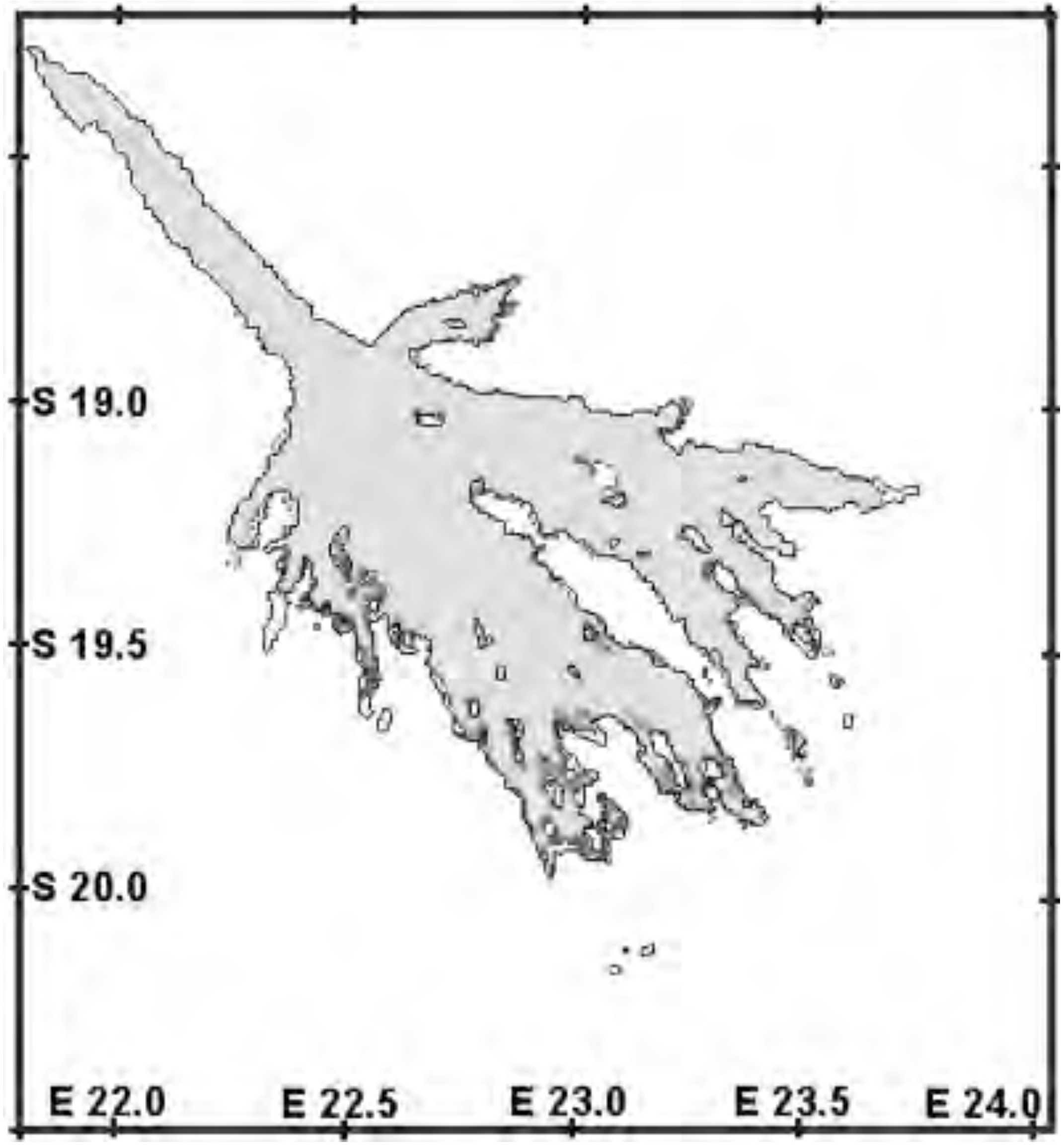

S 19.0
S 19.5
S 20.0
E 22.0
E 22.5
E 23.0
E 23.5
E 24.0
Model performance
Correctly predicted inundated area
Predicted but not observed
Observed but not predicted

2000



1995


S 19.0
S 19.5
S 20.0
E 22.0
E 22.5
E 23.0
E 23.5
E 24.0
Observed inundation
Predicted inundated area
Lower estimate (-1 SE)
Best estimate
Upper estimate (+1 SE)

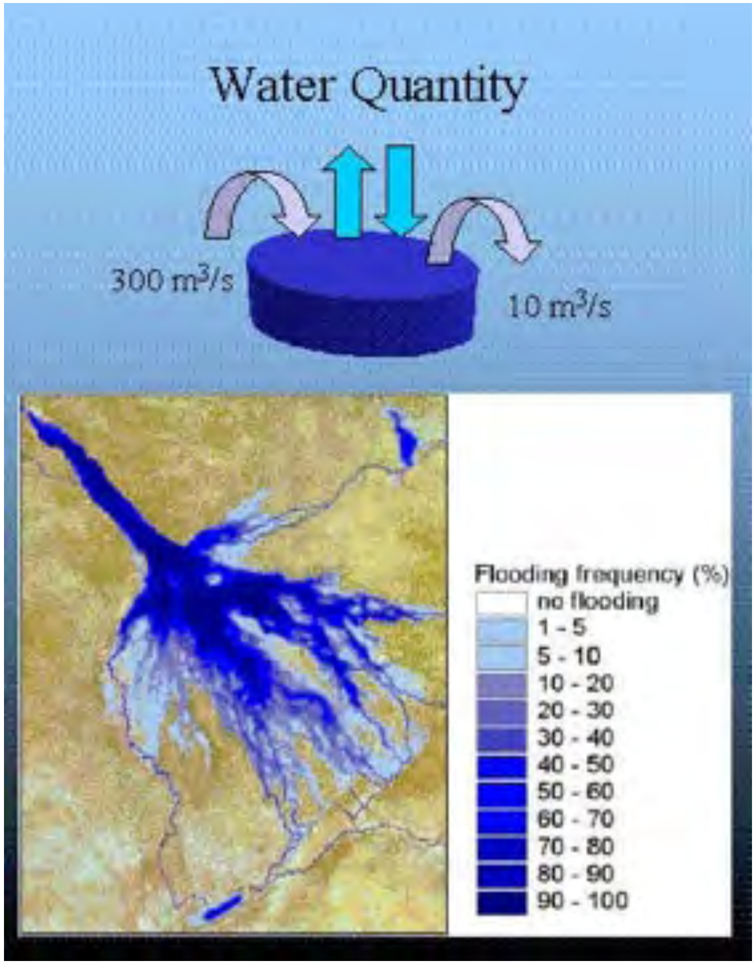

S 19.0
S 19.5
S 20.0
E 22.0
E 22.5
E 23.0
E 23.5
E 24.0

Fully distributed modelling of the Okavango Delta hydrology

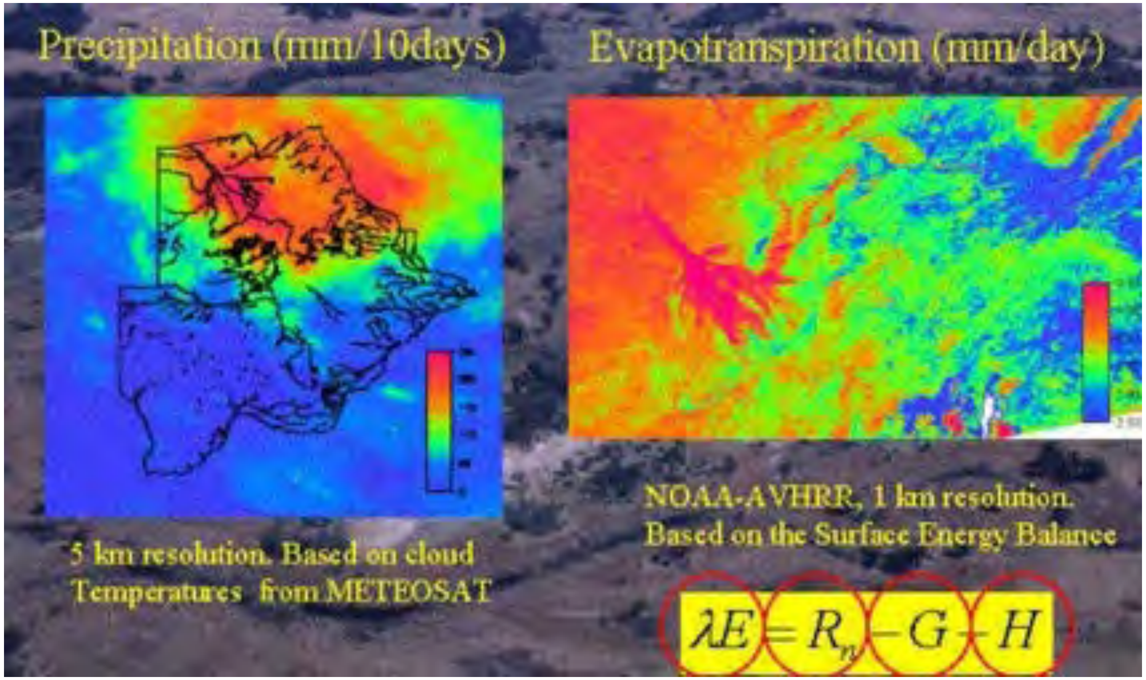
Data needed:

- Inflow at Panhandle
- Rainfall over the Delta (in each checker board “cube”)
- Area of flooding (to be predicted)
- Regional and detailed topography (for each “cube”)
- Evapotranspiration in each “cube”
- Water storage in each “cube”
- Water flow resistance properties in each “cube”

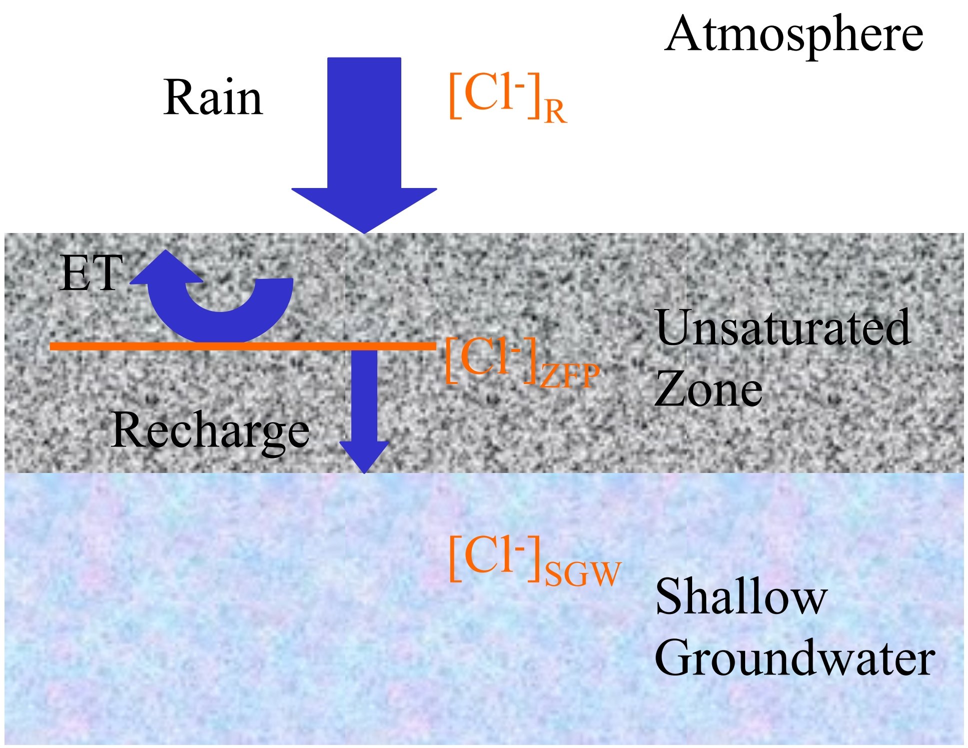
Precipitation and evapotranspiration – driving variables of the Delta water balance



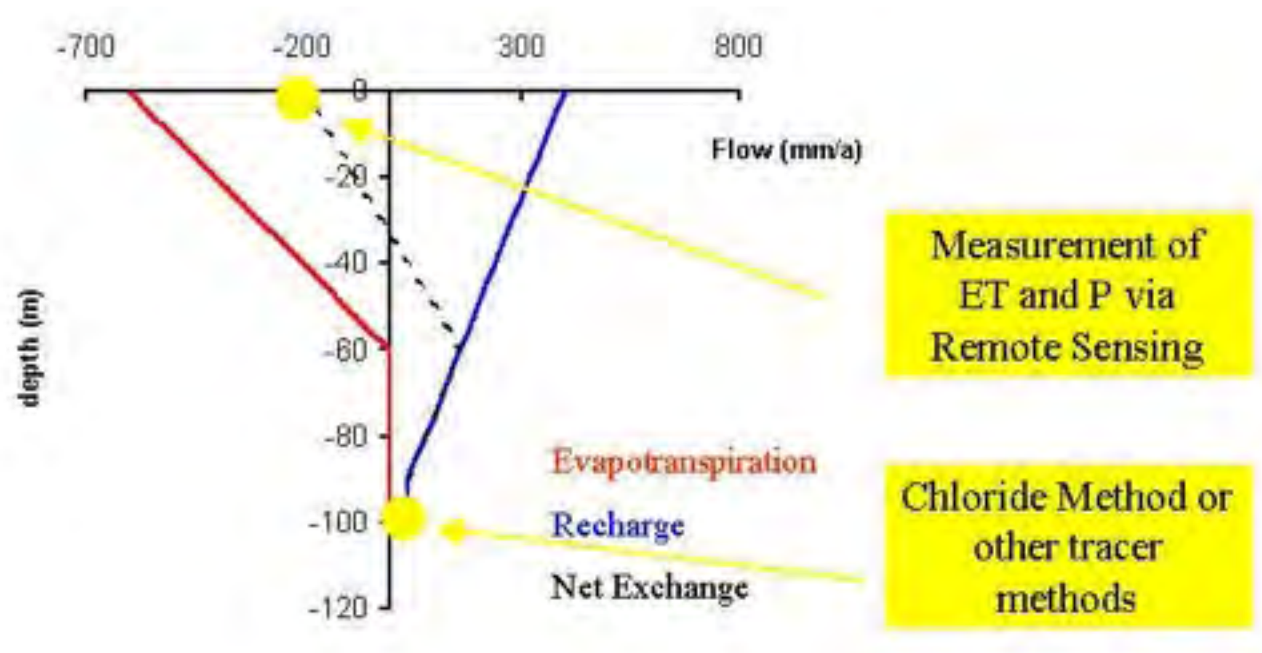
Remote sensing for estimating spatial distribution of precipitation and evapotranspiration



Field data for estimation of net recharge



Parameterisation of evapotranspiration, recharge and net exchange



Field data for accurate point measurements of surface energy balance (evapotranspiration)

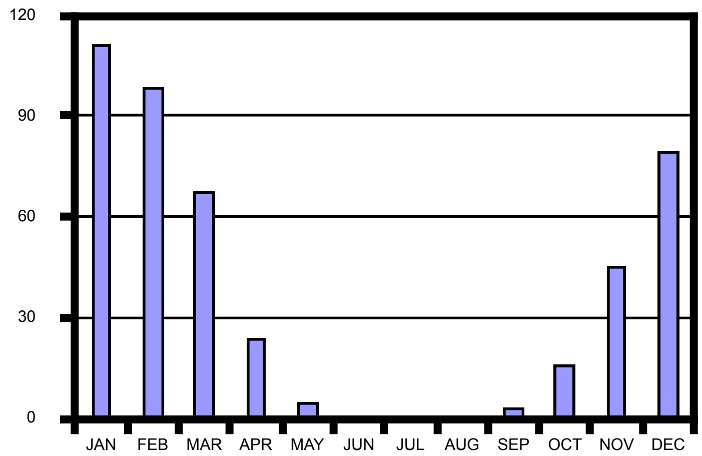
Net radiometre

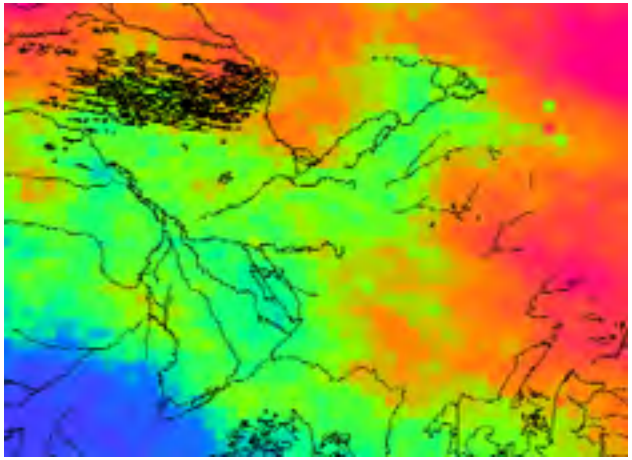
Microclimate station

At least 1 station for each land cover class

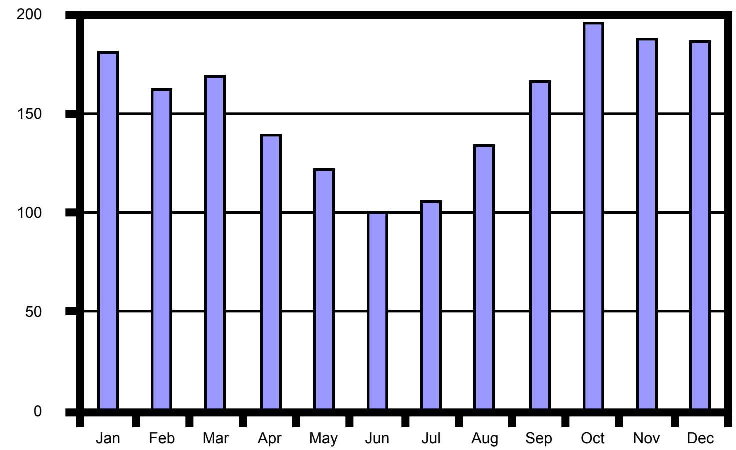
Vertical water balance of the Okavango Delta

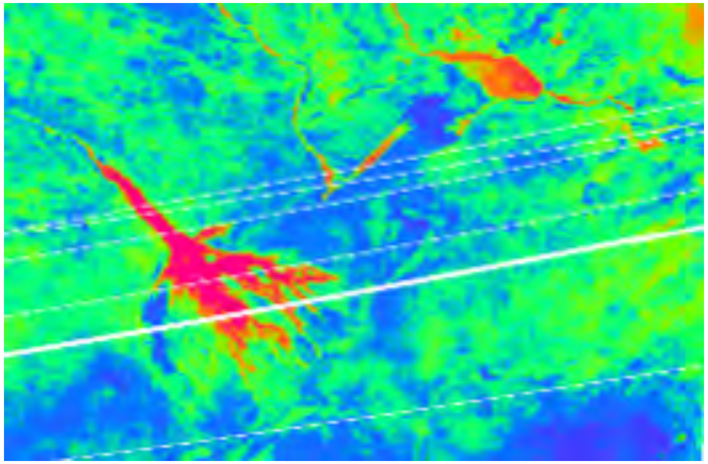
Rain



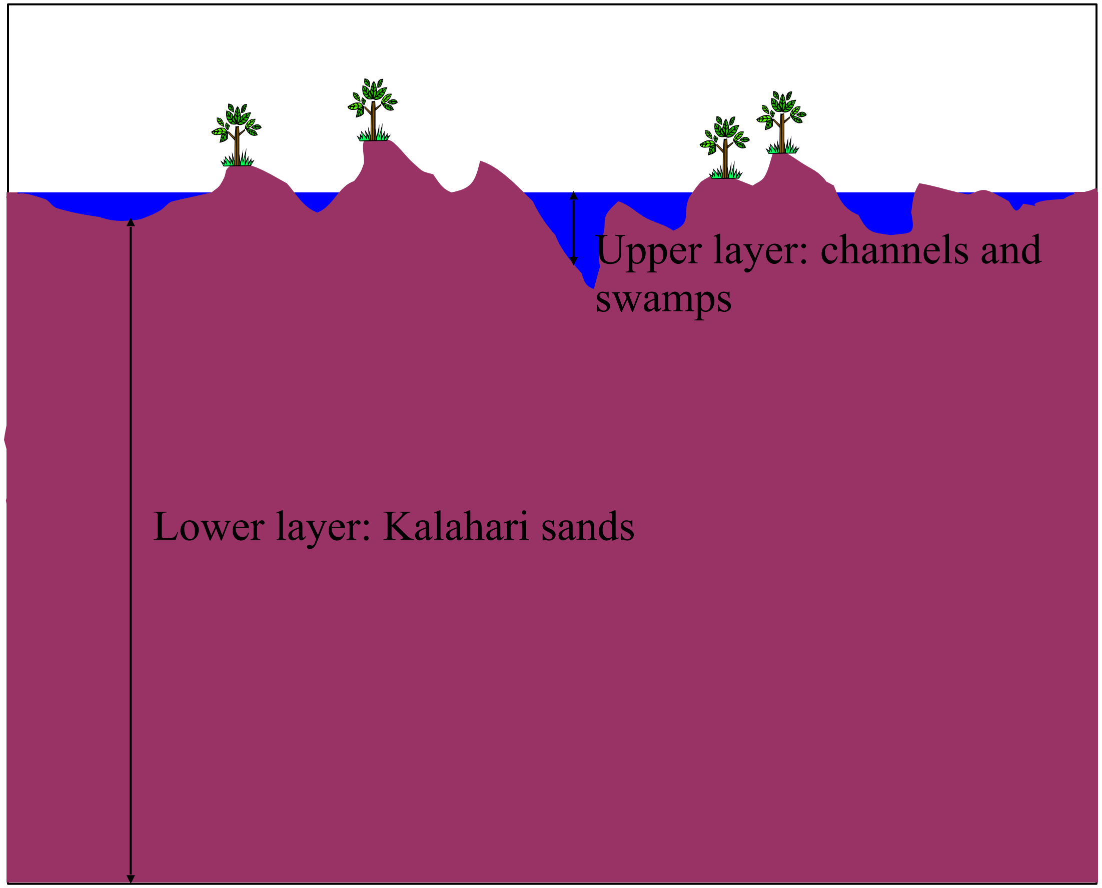


PET

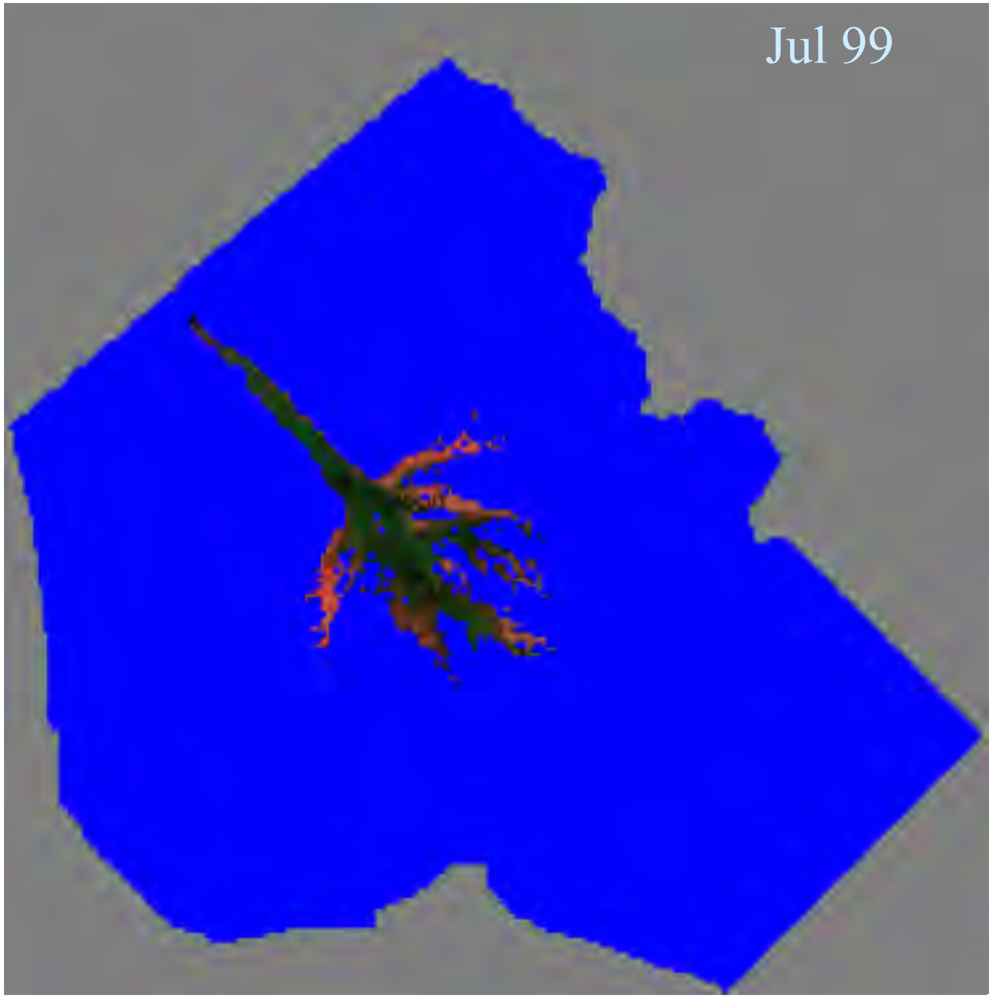




2 layer modflow model of the Okavango Delta



2 layer modflow model of the Okavango Delta
Preliminary tests



Semi distributed modelling of the Okavango Delta hydrology

Data needed:

•Inflow at Panhandle

•Rainfall over the Delta (in each compartment

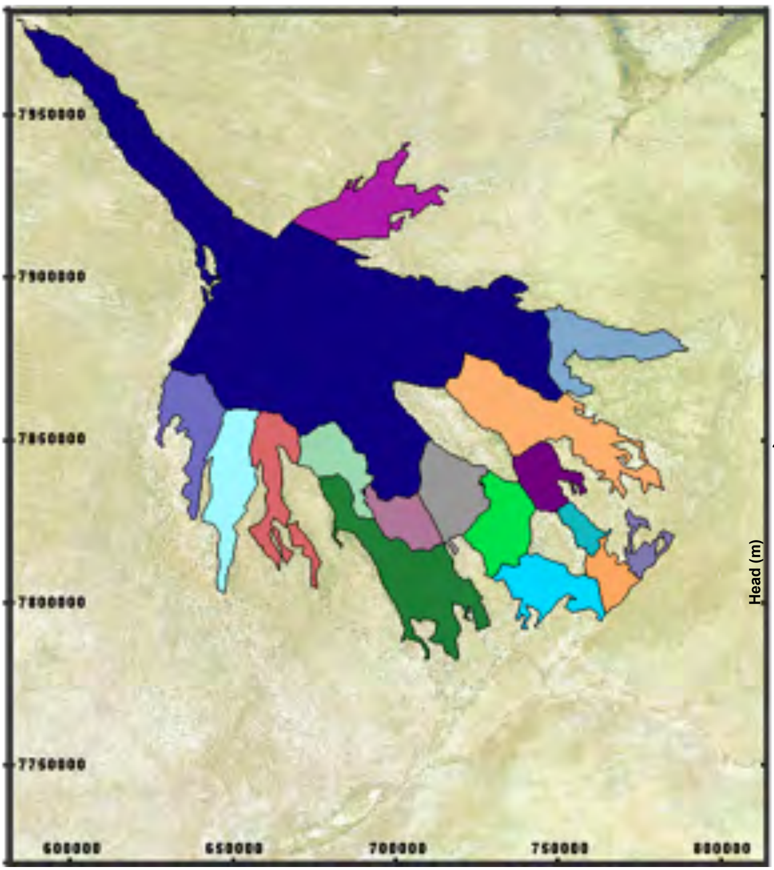
•Area of flooding (to be predicted)

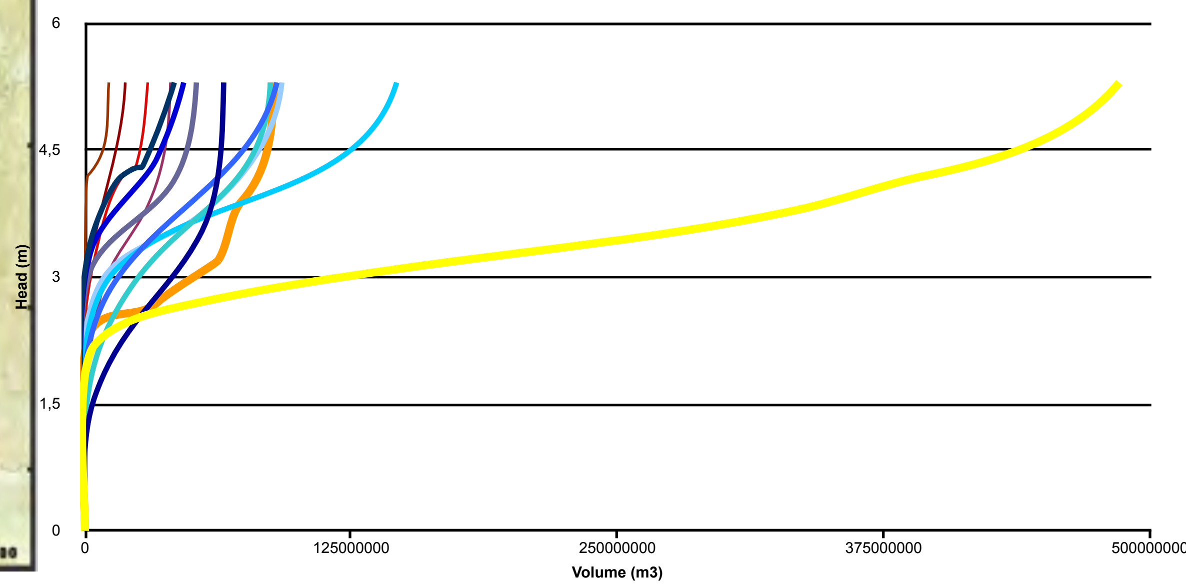
•Detailed topography (in each compartment)

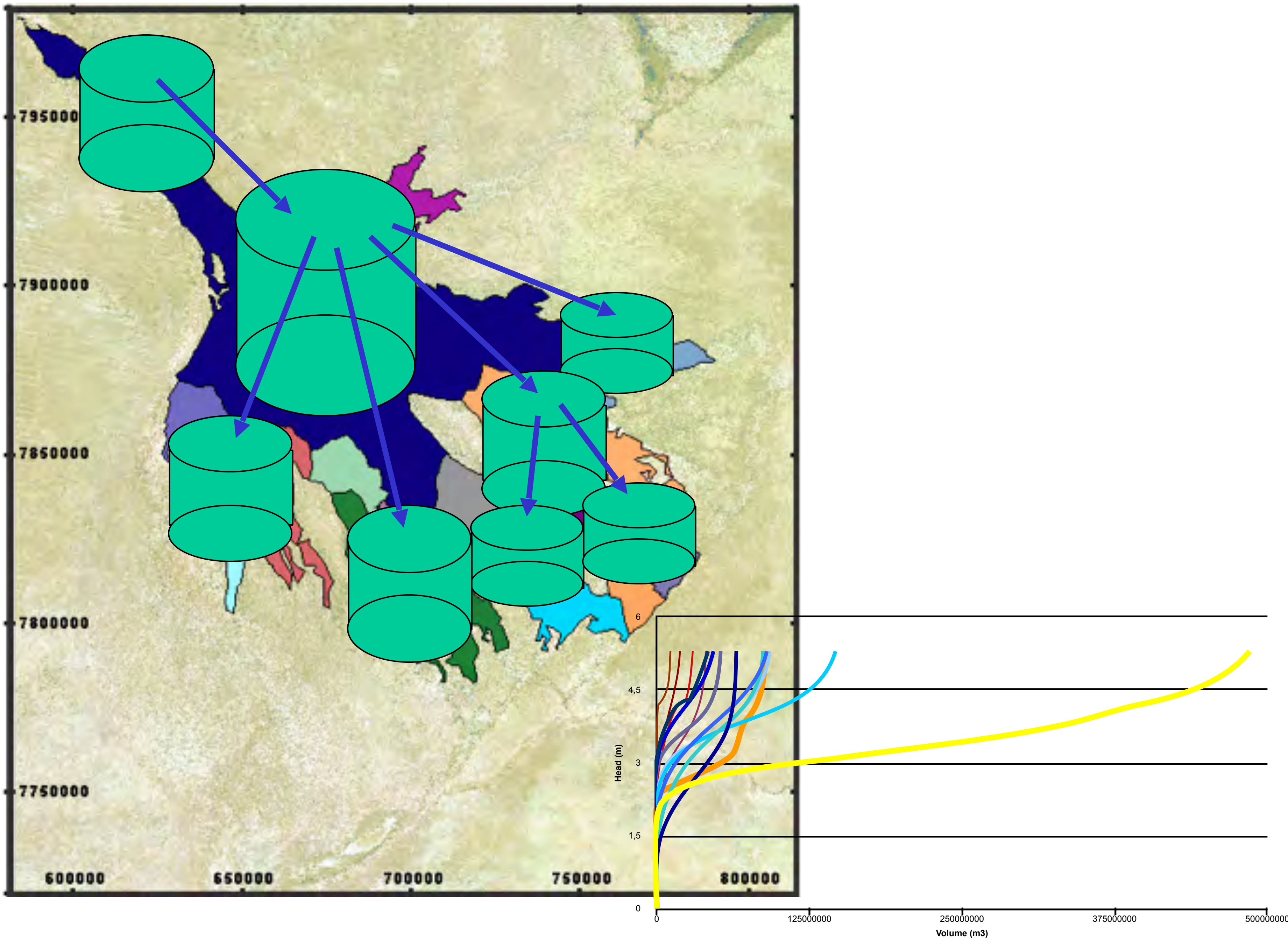
•Evapotranspiration (for each compartment)

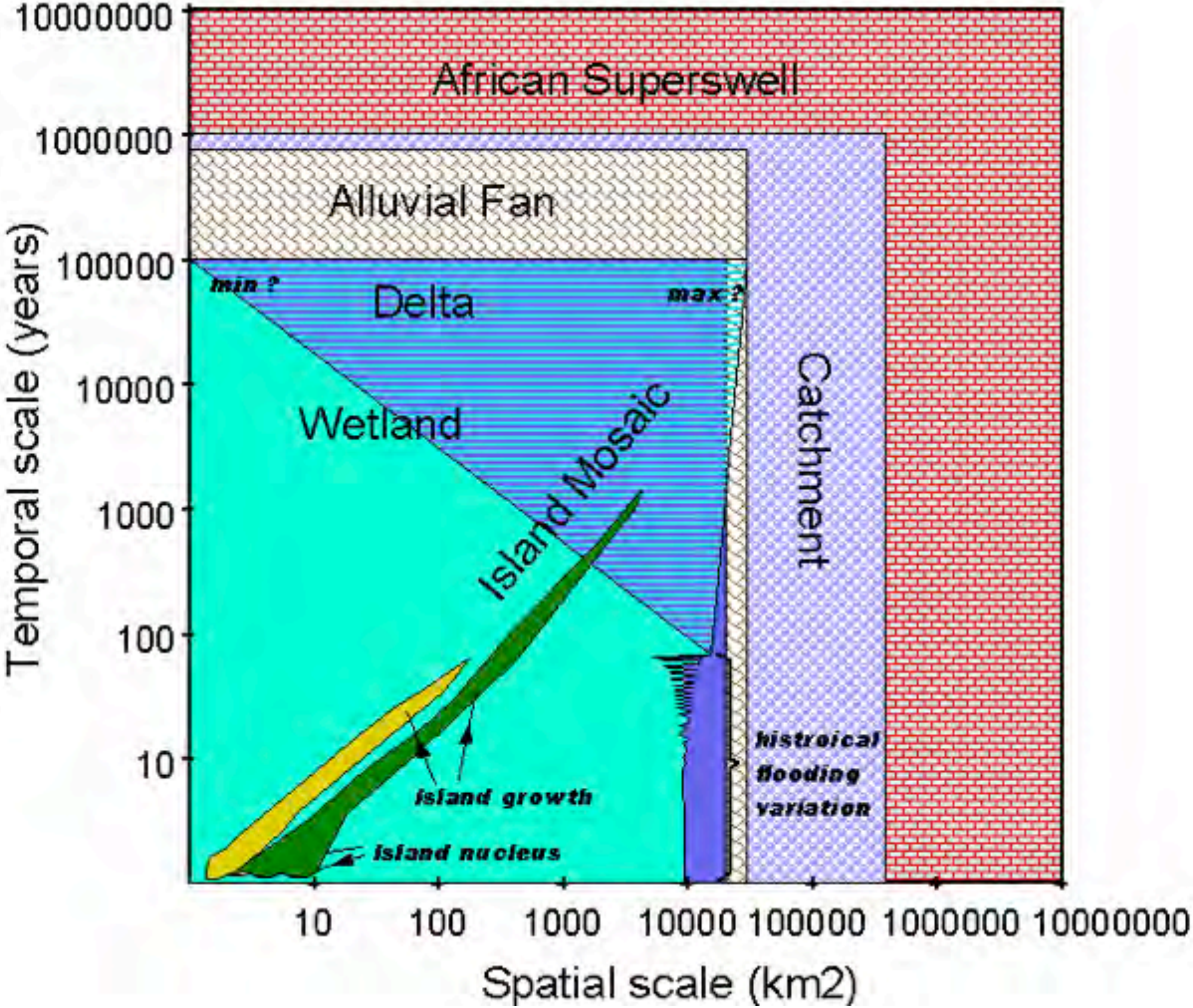
•Water storage in each compartment

•Water flow resistance between each compartment



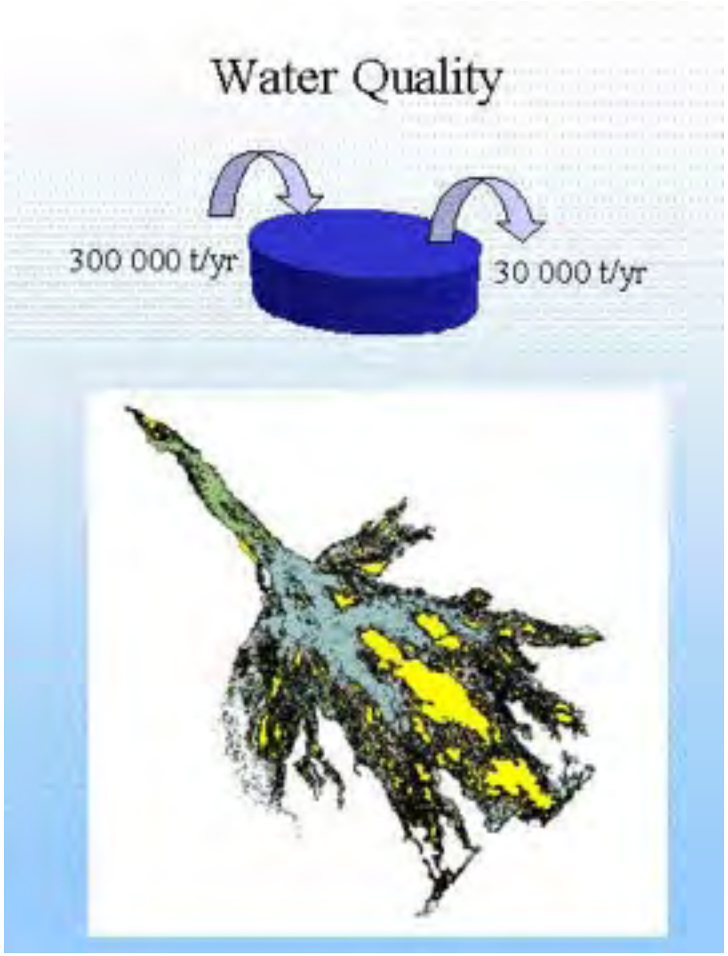

6
4,5
3
1,5
0
Head (m)
0
125000000
250000000
375000000
500000000
Volume (m3)


7950000
7900000
7850000
7800000
7750000
600000
650000
700000
750000
800000
Head (m)
6
4,5
3
1,5
0
0
125000000
250000000
375000000
Volume (m3)



African Superswell
Alluvial Fan
Delta
Wetland
Island Mosaic
Catchment
min ?
max ?
island growth
island nucleus
histroical
flooding
variation
Temporal scale (years)
10000000
1000000
100000
10000
1000
100
10
10
100
1000
10000
100000
1000000
10000000
Spatial scale (km2)

Matter balance and islands – redirecting water flow on different time scales



Primary islands built from accumulation of clastic sediments

Island types

Inverted channel island

Primary islands built from accumulation of clastic sediments

Island types

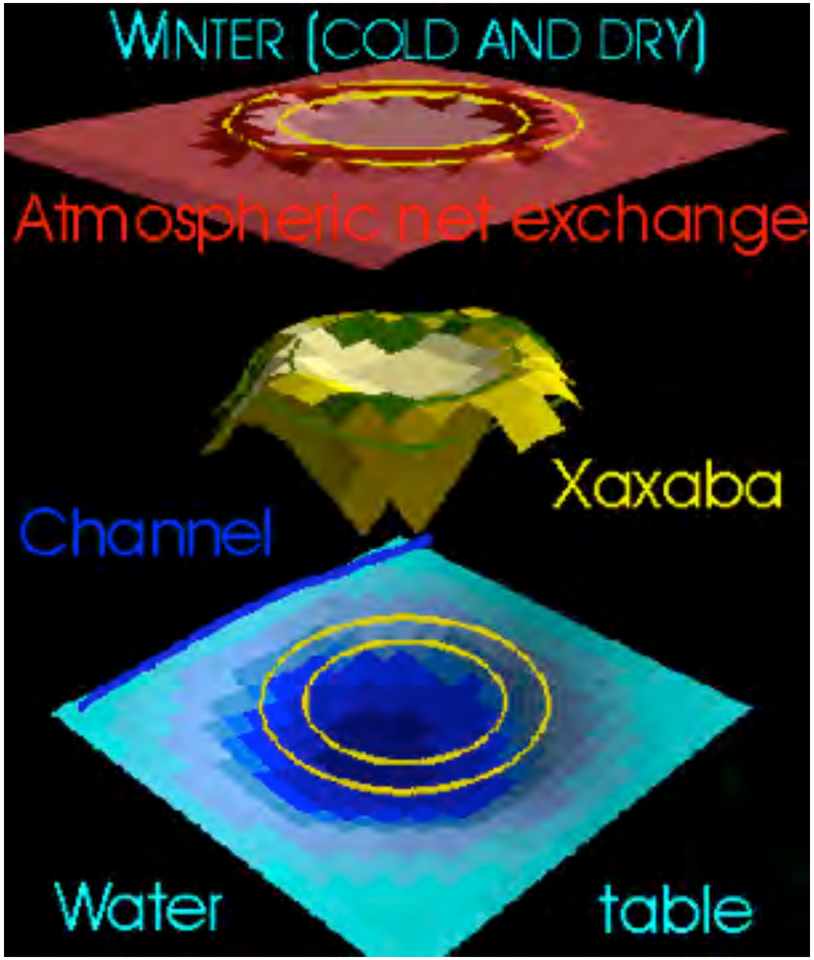
Scroll bar island

Primary islands built from accumulation of clastic sediments

Island types

Anthill island

Evapotranspiration, salinity balance and island secondary growth



Secondary islands grown from precipitation of chemical sediments

Island types

Riparian forest island

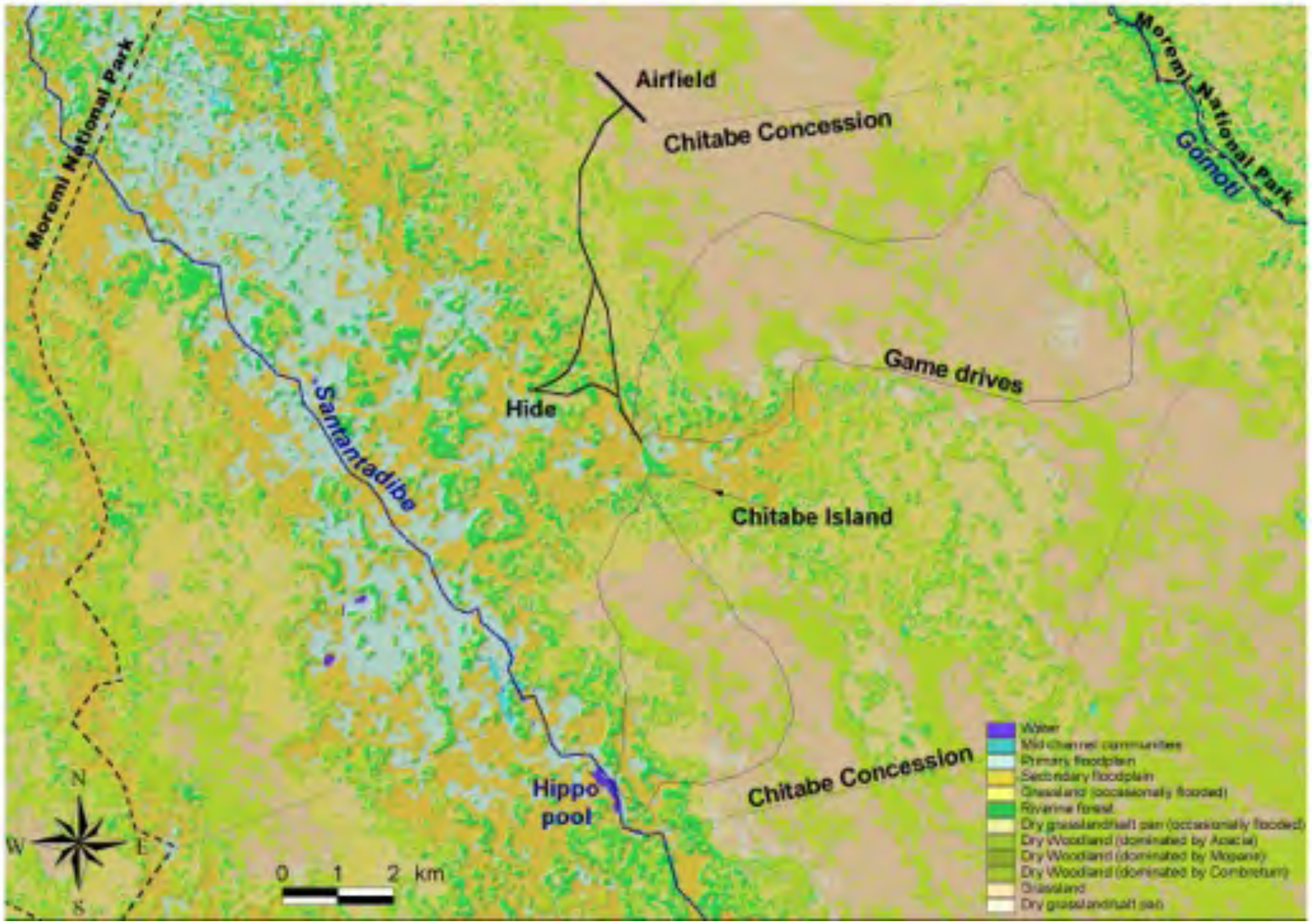
Secondary islands grown from precipitation of chemical sediments

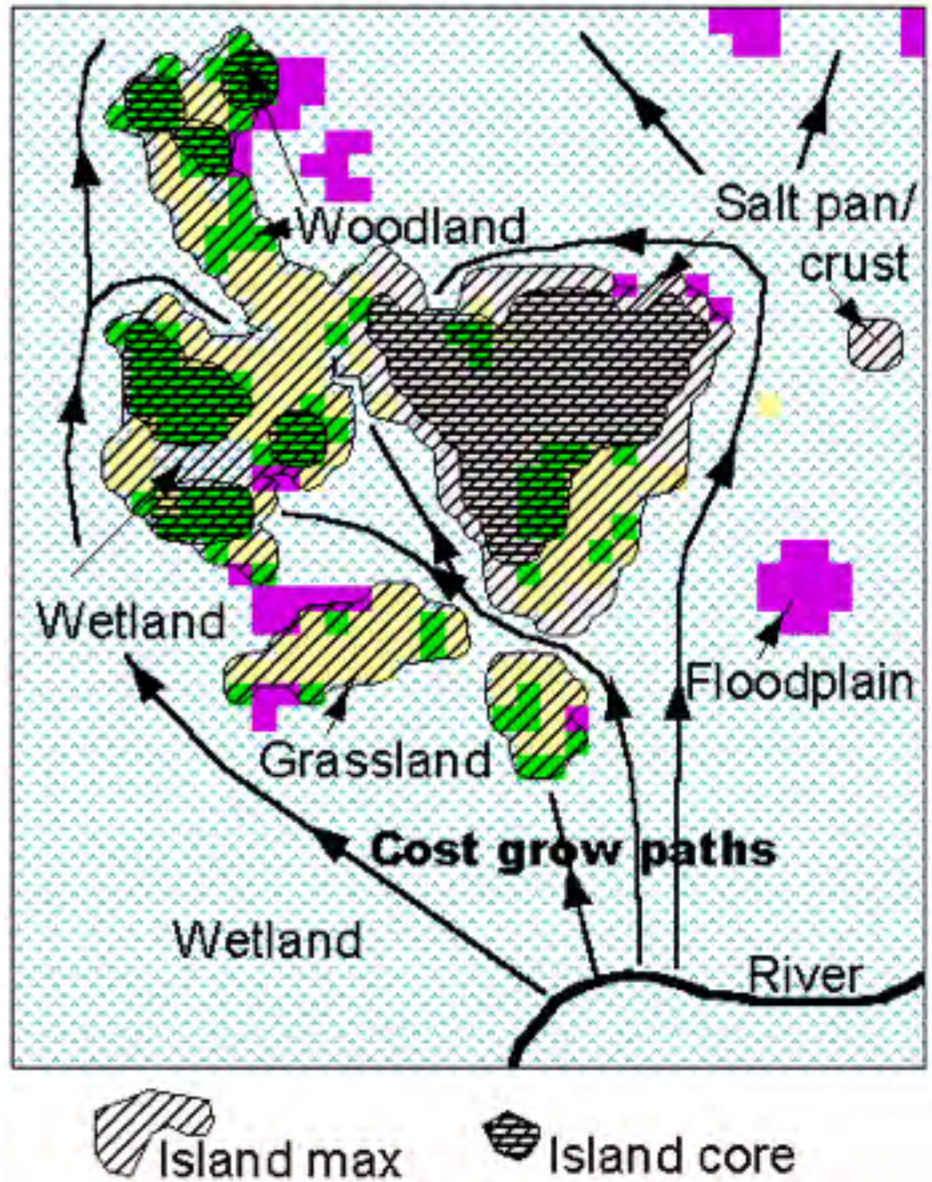
Island types

Salt islands

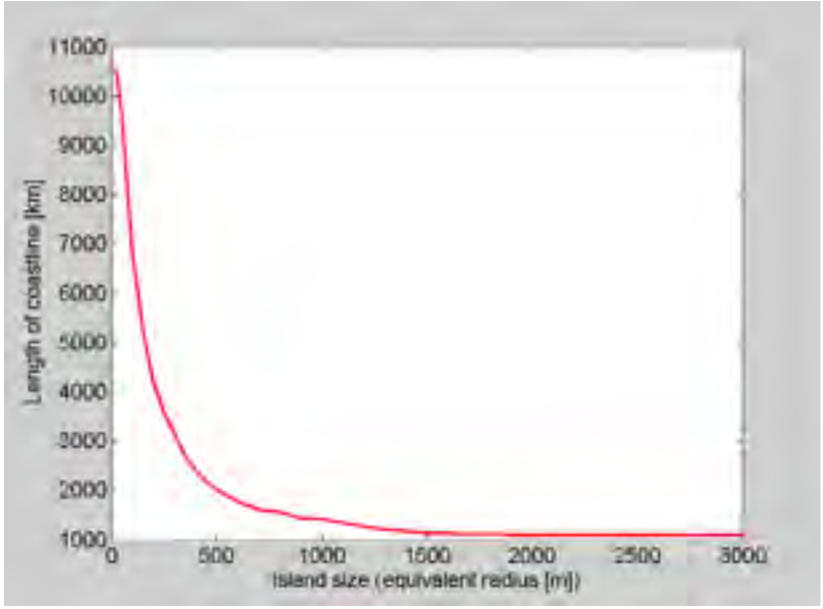
Detail of the Chitabe area

Detailed relief of the Chitabe area

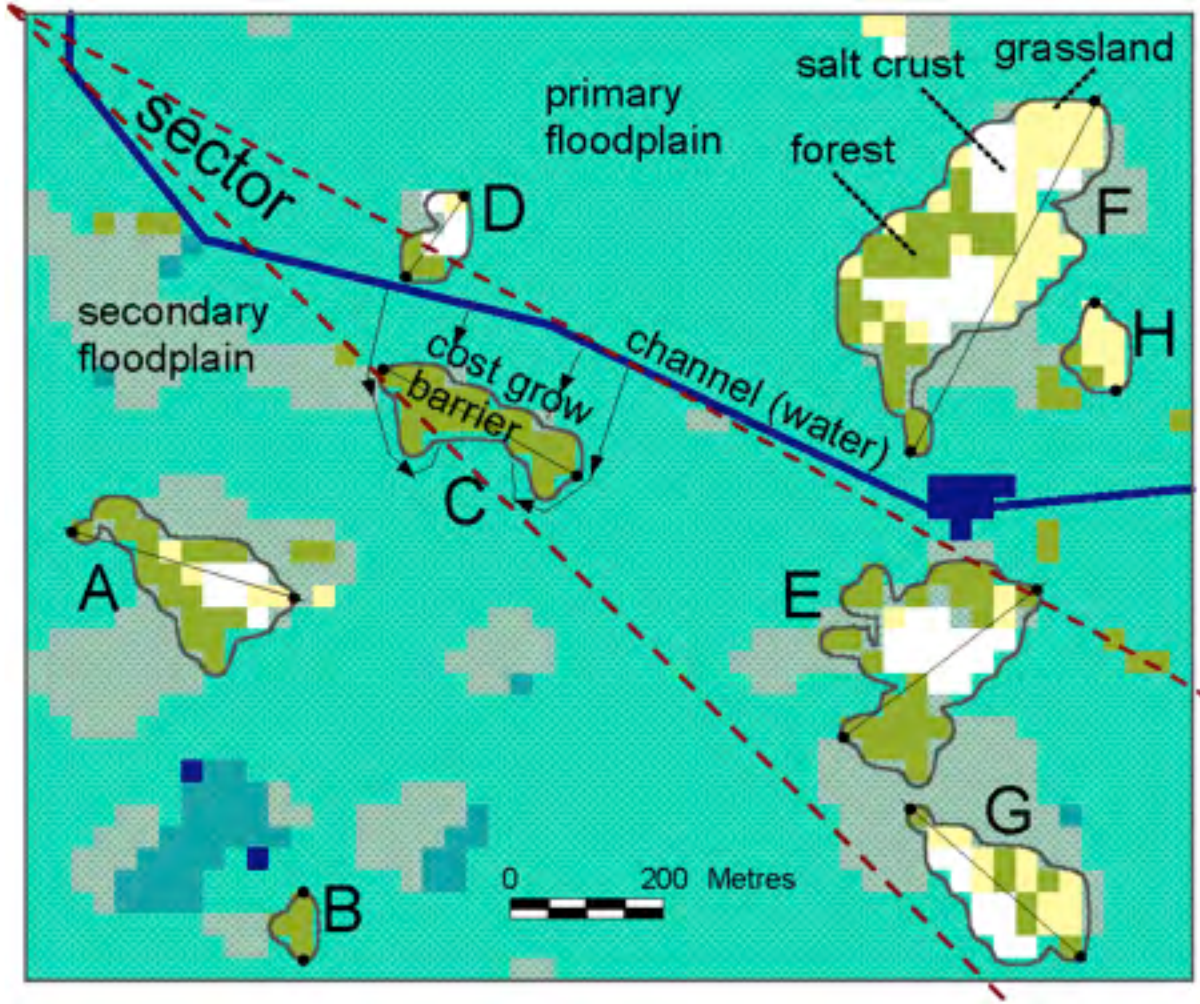



Woodland
Salt pan/
crust
Wetland
Floodplain
Grassland
Cost grow paths
Wetland
River
Island max
Island core

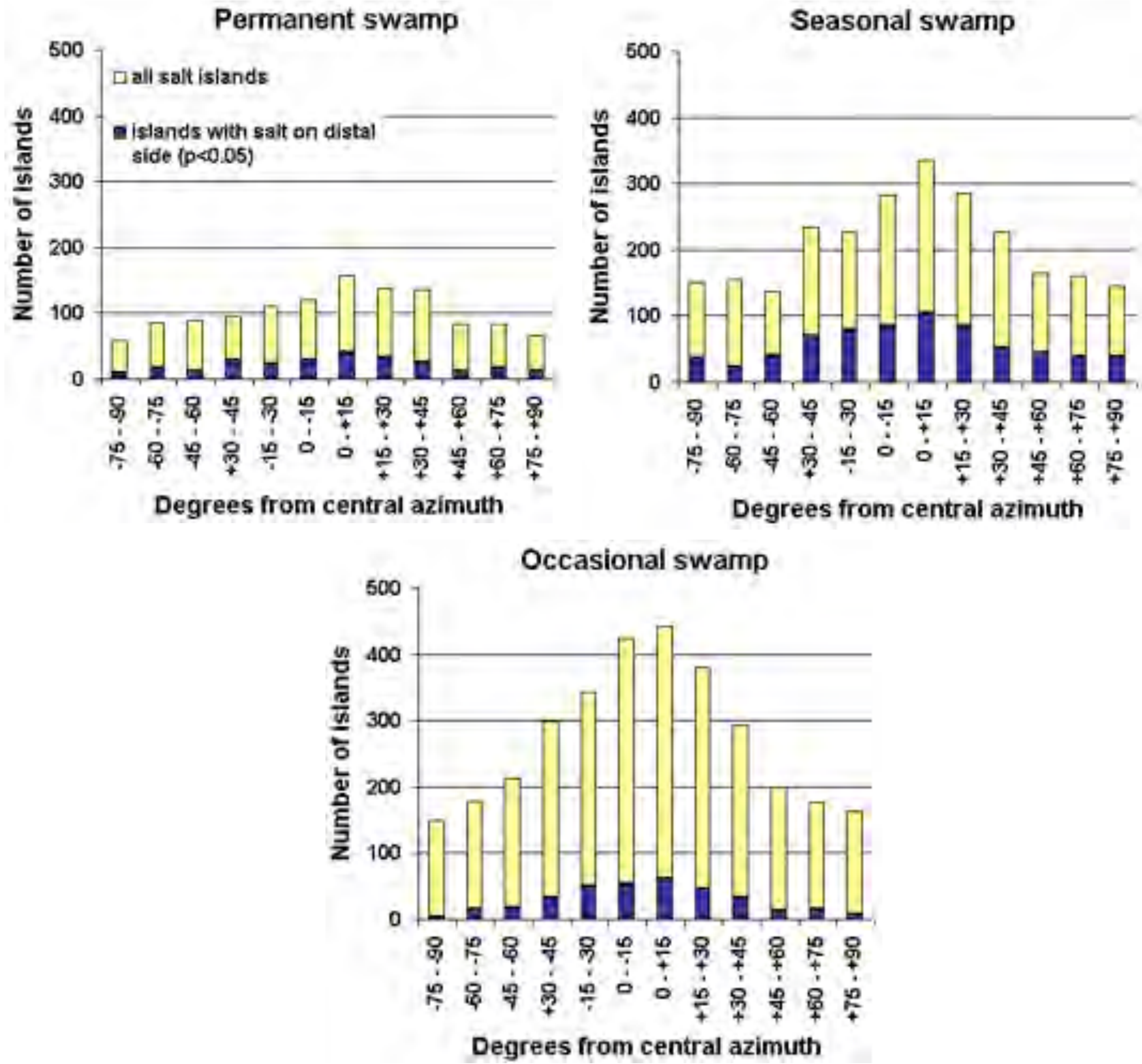
Salt Balance: Coastline from Remote Sensing



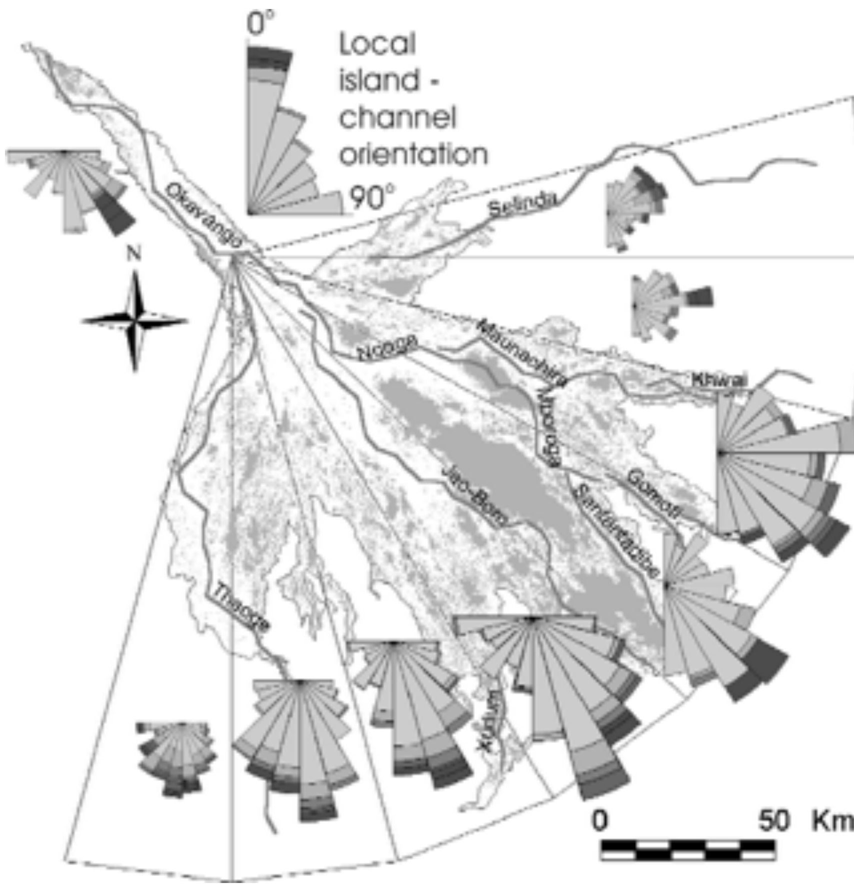
Order of magnitude correct



	A	B	C	D	E	F	G	H
Roundness	0.49	0.91	0.51	0.48	0.36	0.47	0.58	0.92
Regional salt position	distal*	na	na	proximal	distal	equal	proximal	na
Channel salt position	front	na	na	back	back	back	back*	na


Permanent swamp
all salt islands
islands with salt on distal side (p<0.05)
Number of islands
Degrees from central azimuth
0
100
200
300
400
500
-75 - -90
-60 - -75
-45 - -60
+30 - -45
-15 - -30
0 - -15
0 - +15
+15 - +30
+30 - +45
+45 - +60
+60 - +75
+75 - +90
Seasonal swamp
Occasional swamp

Island orientation – interacting with water flow over the Delta surface



Summary

The Rift Vallley and the Superswell created the Okavango and its Basin

The Basin feeds the Alluvial fan with sediments that keeps the surface flat

The Basin feeds clean water to the Delta that sits on the Alluvial fan

The living Wetland is sustained by the shifts in the Delta and Alluvial Fan

The Islands are born from the shifts in the Delta and Alluvial Fan

The Islands are the kidneys of the Okavango – removing salt from the Wetland

Conclusion

The Superswell will eventually divert the Okavango to the Zambezi

Clean water and sediments from the Basin is a must for the Okavango to live

Loss of water inflow would decrease the size of the Delta and Wetland

Loss os sediment inflow would disrupt the changes sustaning the living Wetland

Loss of sediment inflow would disrupt the Island birth and growth process

The growth of the Alluvial Fan preserves the flatness sustaining the Delta

The death and birth of channels is a creative destruction sustaining the living Wetland

Island birth and growth is needed for removing salt from the Wetland

Acknowledgements

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