A Characterization of the Status and Dynamics of Land Cover in the Active Okavango Catchment Based on Various MODIS Products and Climate Data

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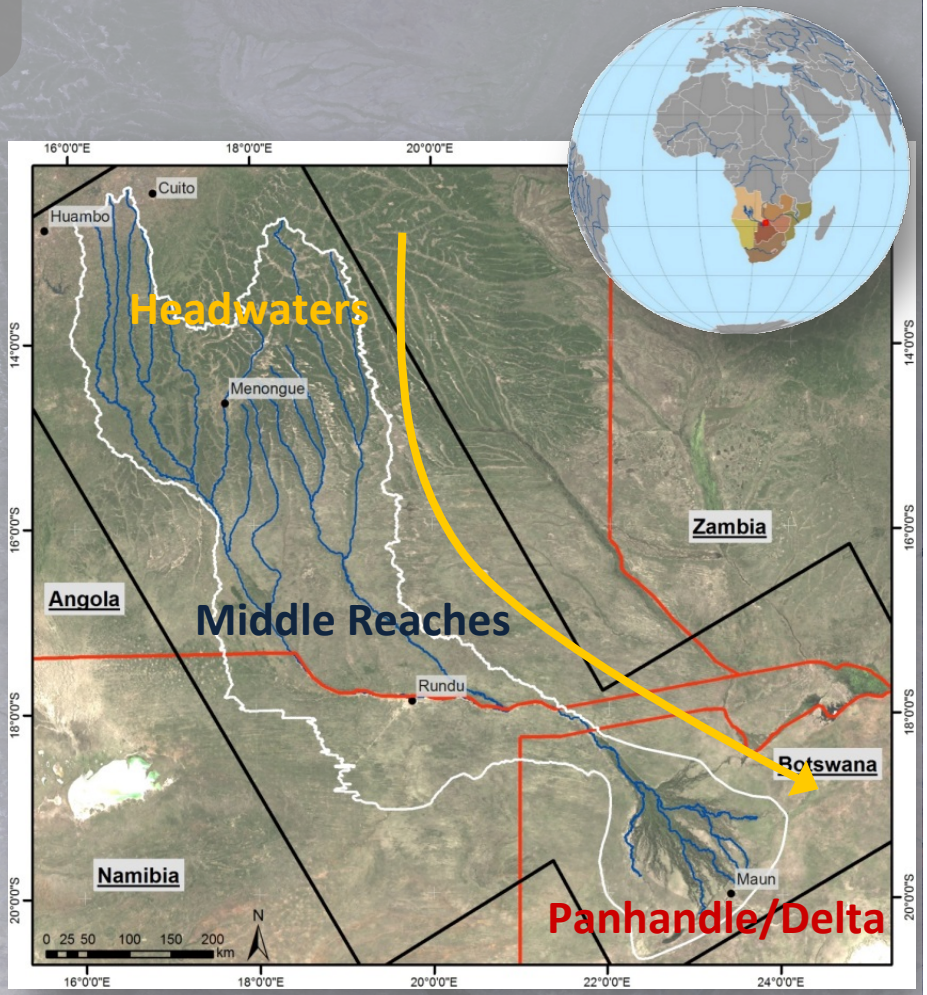
NACHHALTIGES LANDMANAGEMENT
Bundesministerium für Bildung und Forschung
FONA Forschung für Nachhaltige Entwicklungen BMBF
TFO THE FUTURE OKAVANGO
Universität Trier Environmental Remote Sensing & Geoinformatics

The Okavango catchment is a unique system of woodland savannas, floodplains and extended wetlands, and harbours an exceptional floral and faunal biodiversity

Okavango Cachment with its variety of savannah woodlands and wetland ecosystems is a potential hotspot of biodiversity loss and potential land use conflicts due to

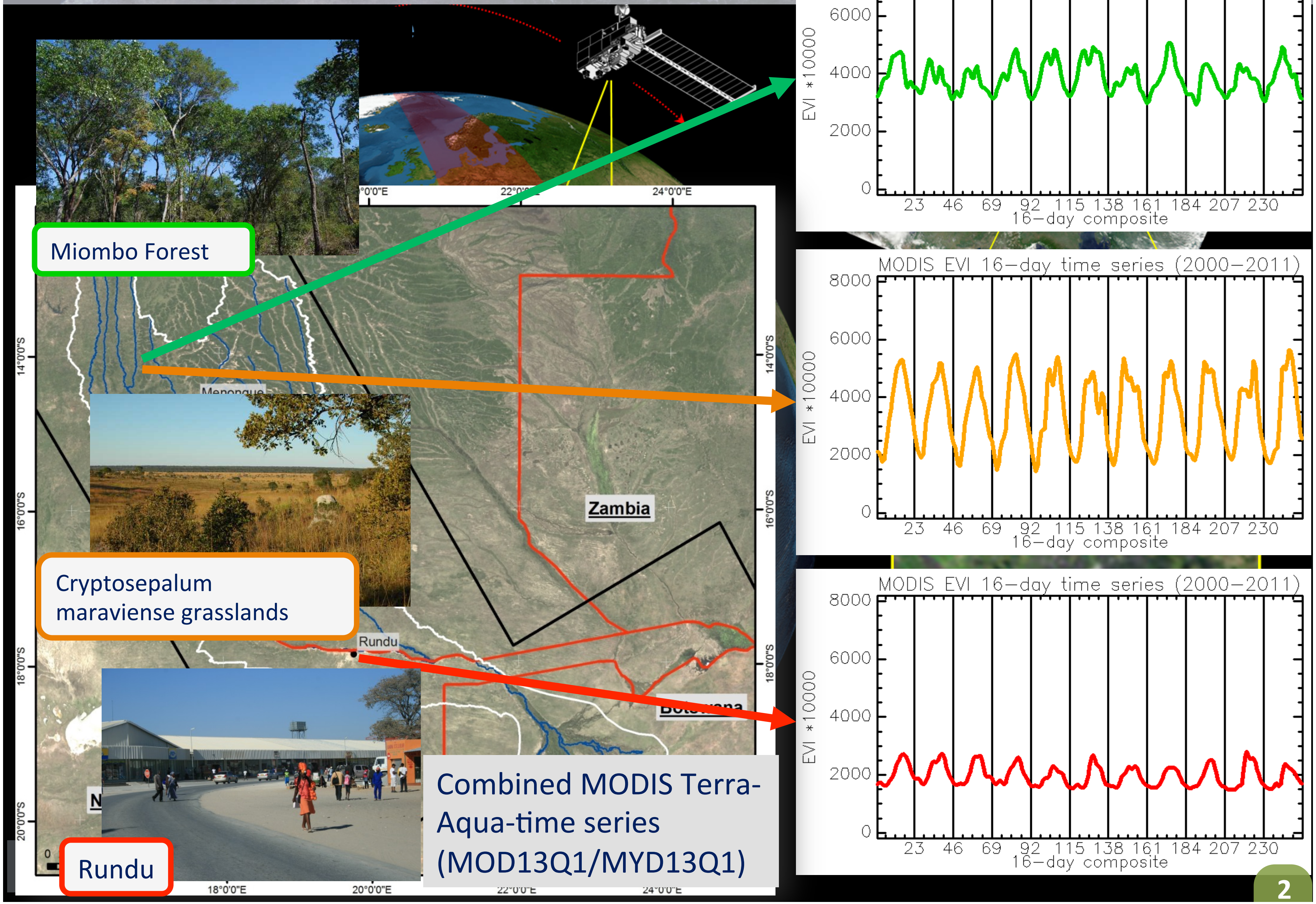
- climate change,
- population growth,
- anthropogenic over-utilization of natural resources.



→ Assessment of resources, particularly their spatial distribution, variability and long-term behavior may support sustainable land use management plans

→ Monitoring of land cover and its changes based on earth observation data

Land use /land cover and its dynamics



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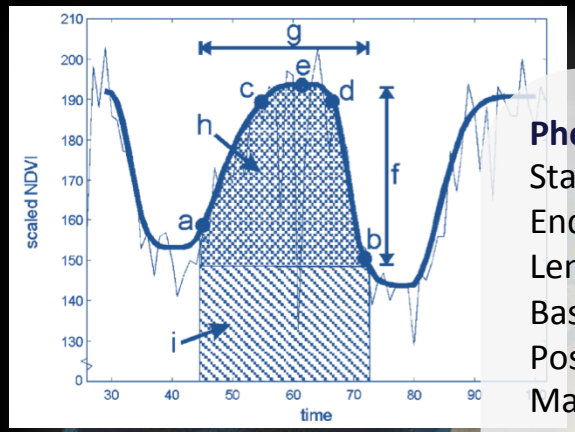


Jönsson & Eklundh 2002

Phenological descriptors

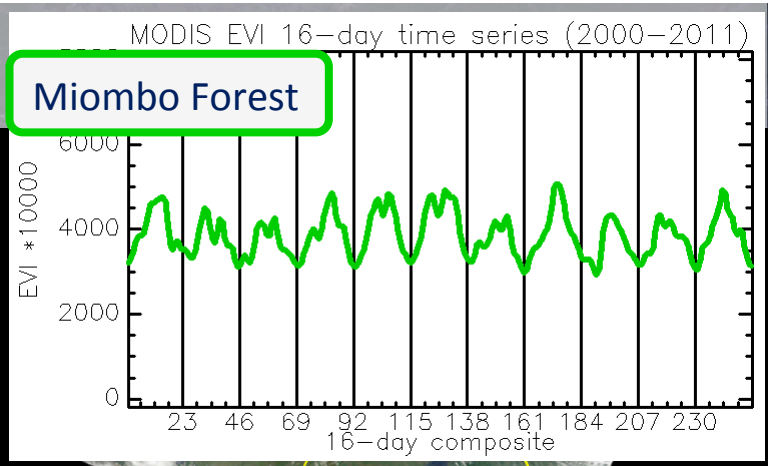
Start of season (a)
End of season (b)
Length of season (g)
Base value (b)
Position of middle of season (e)
Maximum of fitted data (e)
Amplitude (f)
Left derivative (a-c)
Right derivative (d-b)
Large/Total integral (i)
Small/Green integral (h)
Latent integral (i-h)

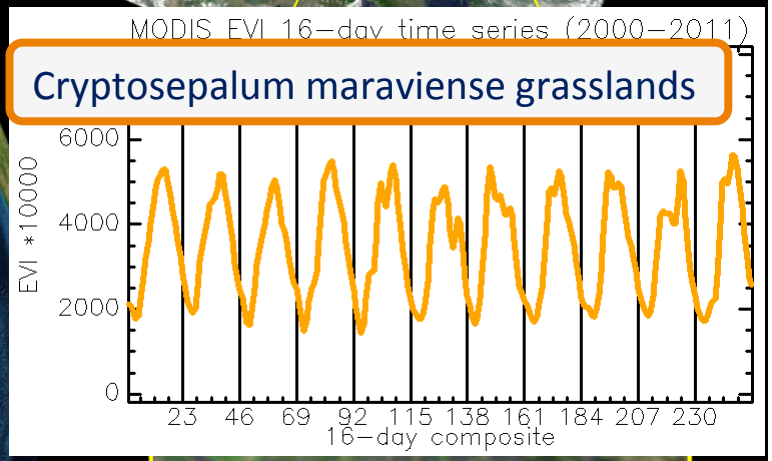
MODIS(Terra/Aqua)-EVI time series (2000-2013)

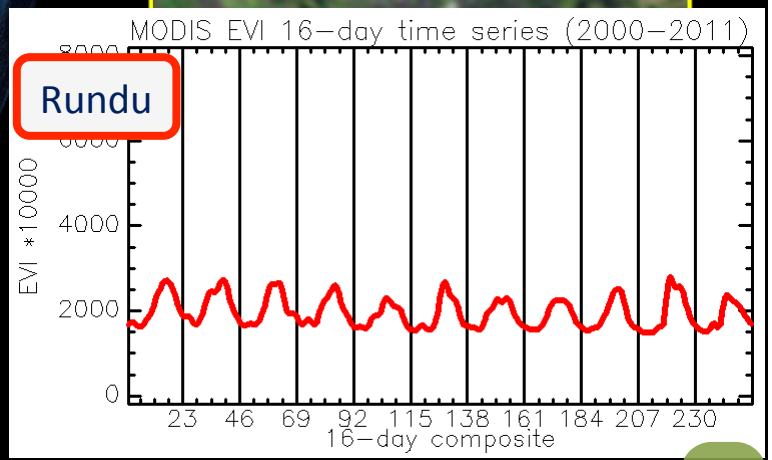
→ phenological descriptors (TIMESAT, Jönsson & Eklundh 2002; SPLITS, Mader 2012) were derived and used

1) in an unsupervised classification approach to derive dominant, broad scale land cover types with typical seasonal profiles and

2) to map land cover changes.







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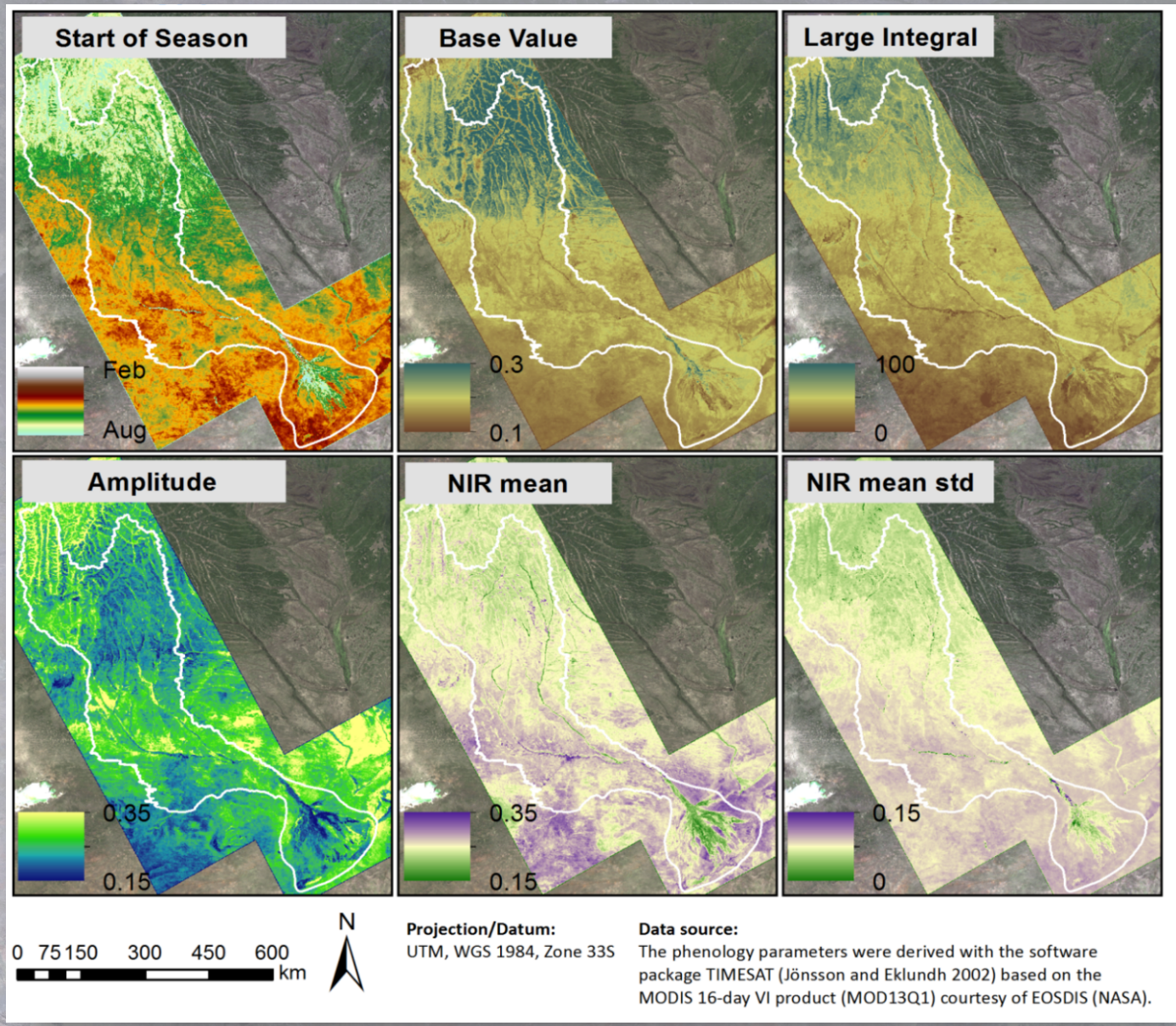

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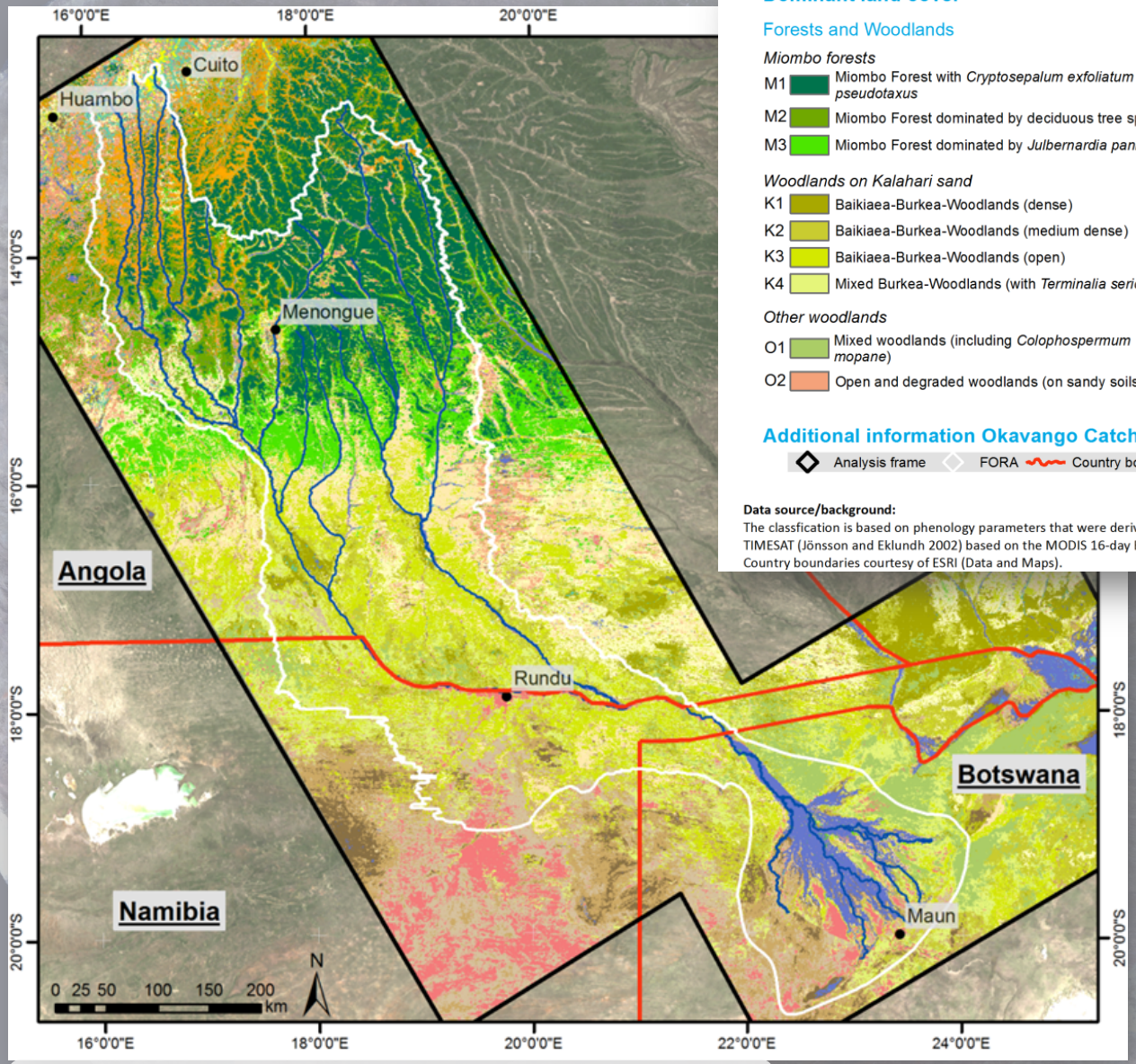


Dominant land cover

Forests and Woodlands

Miombo forests

- M1 Miombo Forest with *Cryptosepalum exfoliatum ssp. pseudotaxus*
- M2 Miombo Forest dominated by deciduous tree species
- M3 Miombo Forest dominated by *Julbernardia paniculata*

Woodlands on Kalahari sand

- K1 Baikiaea-Burkea-Woodlands (dense)
- K2 Baikiaea-Burkea-Woodlands (medium dense)
- K3 Baikiaea-Burkea-Woodlands (open)
- K4 Mixed Burkea-Woodlands (with *Terminalia sericea*)

Other woodlands

- O1 Mixed woodlands (including *Colophospermum mopane*)
- O2 Open and degraded woodlands (on sandy soils)

Thornbush savannah dominated by Acacia spp.

- T1 Thornbush savannah (with seasonally dense grass layer)
- T2 Thornbush savannah (medium dense)
- T3 Thornbush savannah (sparse)
- T4 Sparse shrubland or urban areas

Shrub- and Grasslands

- S1 Burkea-Baphia-Shrublands
- S2 Open shrublands on sandy soils
- G1 *Parinari capensis* grasslands (on humid sands)
- G2 *Cryptosepalum maraviense* grasslands (on ferralitic soils)
- G3 Forest grassland ecotone (with *Cryptosepalum maraviense*)

Wetlands

- W1 Seasanally flooded grasslands and reedbeds
- W2 Wet grasslands and peatlands

Additional information Okavango Catchment

Analysis frame FORA Country boundaries Main rivers

Data source/background:
The classfication is based on phenology parameters that were derived with the software package TIMESAT (Jönsson and Eklundh 2002) based on the MODIS 16-day EVI product (MOD13Q1) courtesy of EOSDIS-NASA. Country boundaries courtesy of ESRI (Data and Maps).

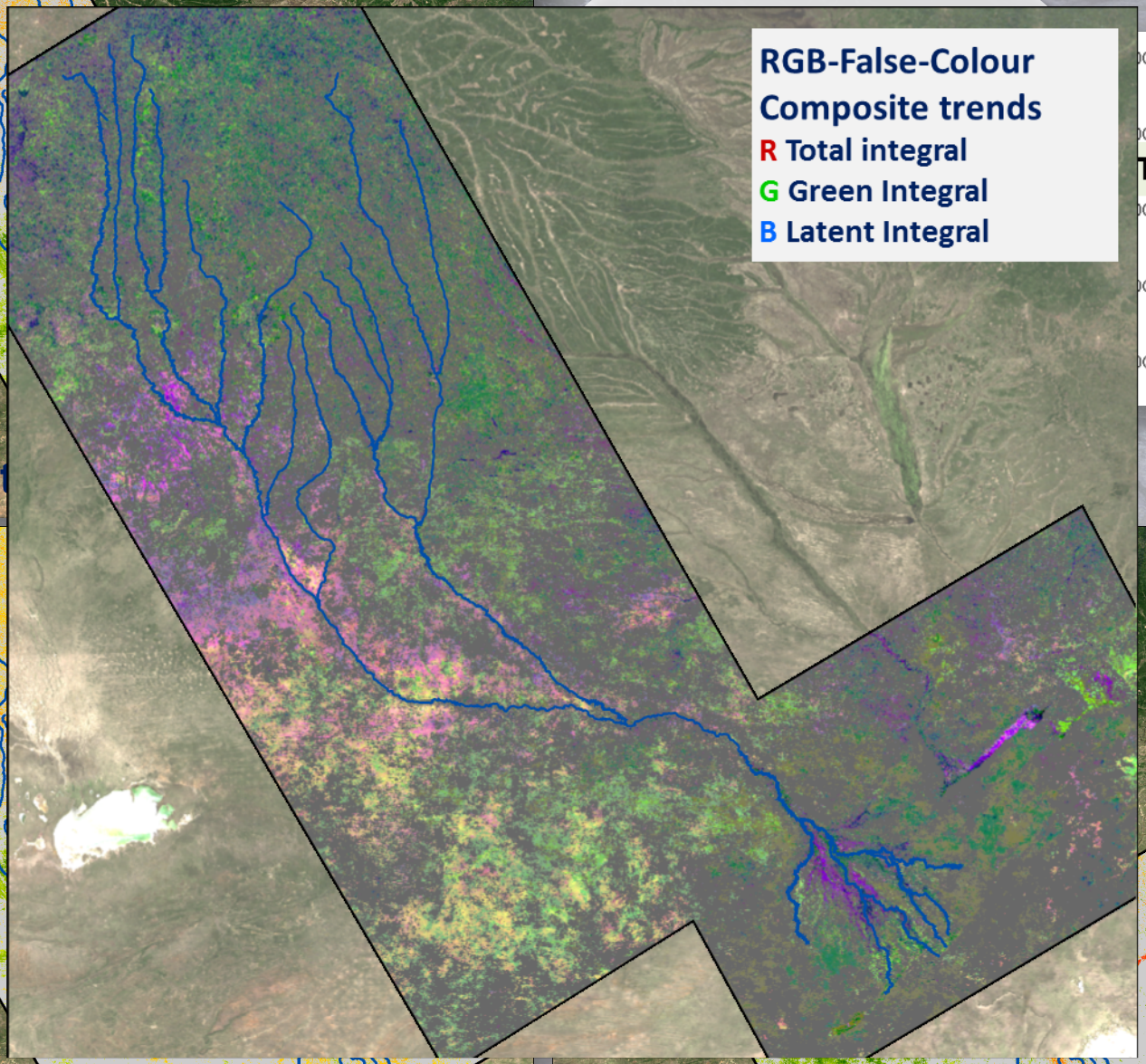
Projection/Datum:
UTM, WGS 1984
Zone 34S

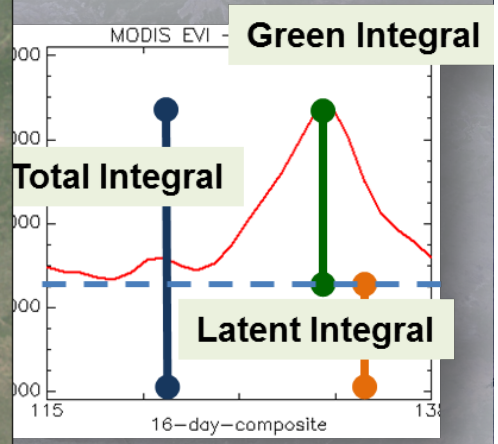
Dominant functional vegetation types

Stellmes et al. 2013

- Unsupervised classification (ISODATA) of mean phenology paramters
- Dominant land cover types were assigned by expert knowledge based on extensive vegetation sampling.

Land use /land cover and its dynamics





Total Int

Latent Integral

Green Integral

Regr. coeff.

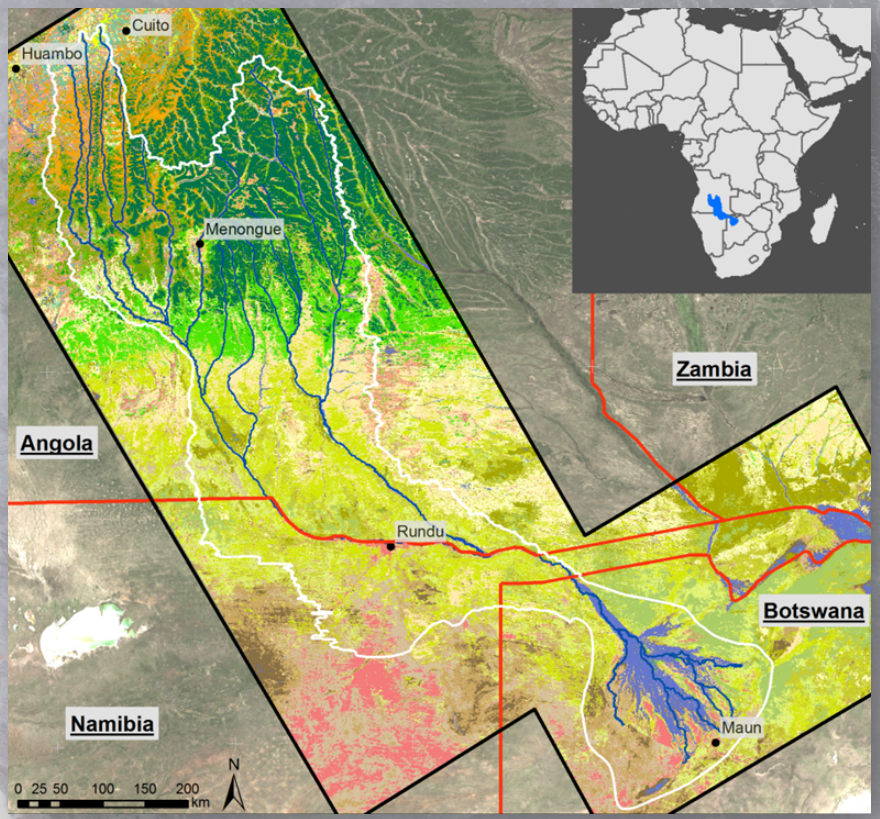
pos.

neg.

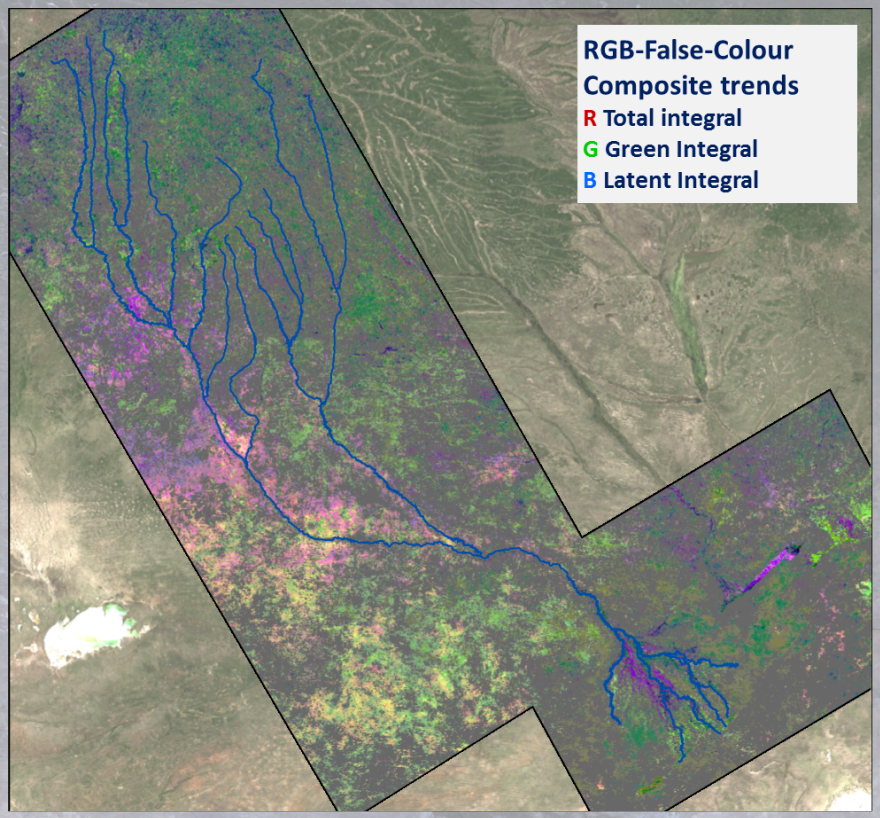
(alpha = 10%,
grey = not sign.)

Research Question

Dominant land cover type



Land cover changes (2000- 2014)



Linkage of the actual state and the observed trends to the underlying causes:
What are the main drivers and how do they manifest themselves throughout the catchment?

Data

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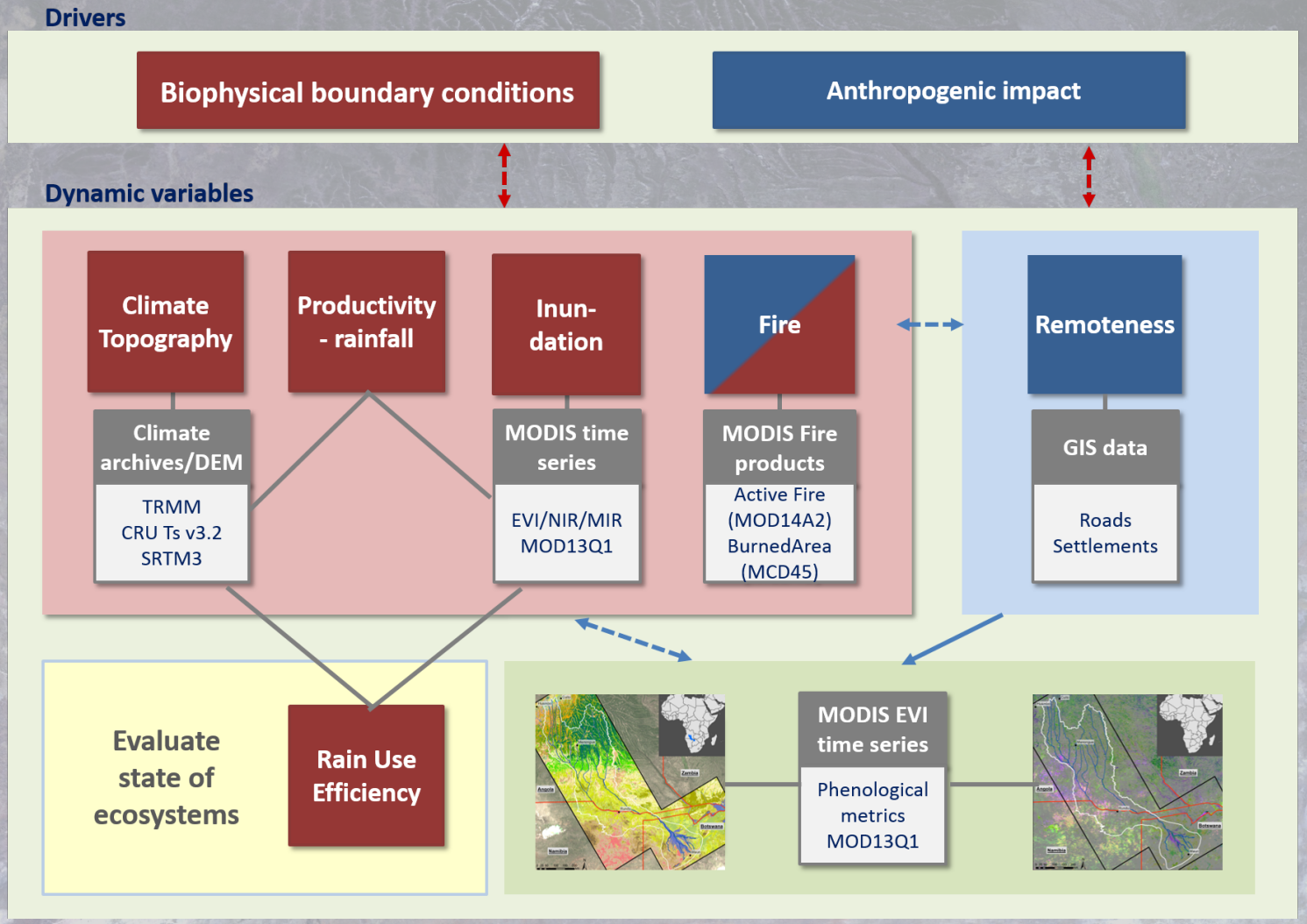

Data

Linkage c
What are the mai

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oughout the catchment?

Drivers

Biophy

Dynamic variables

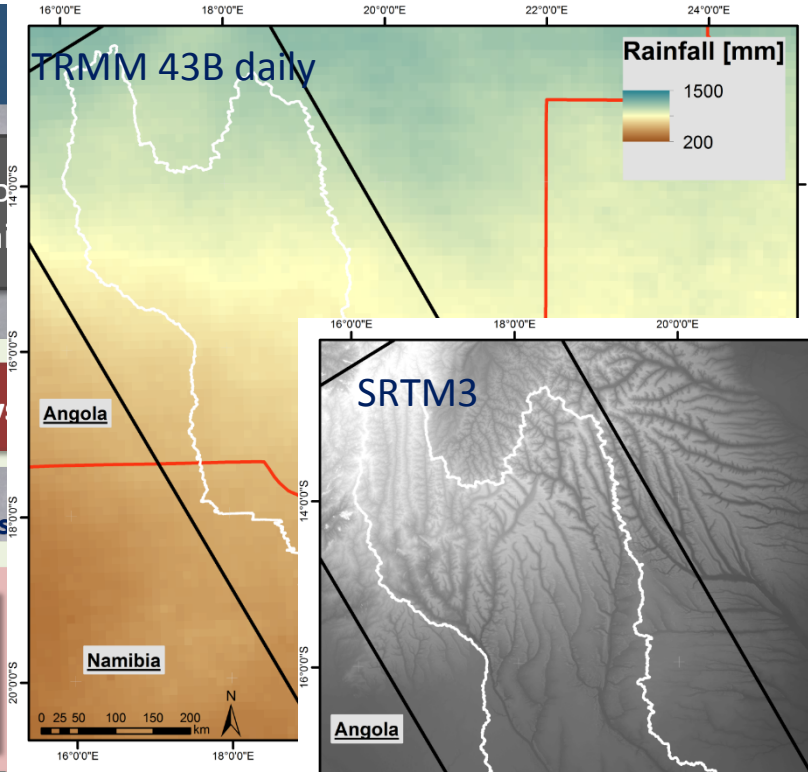
Climate Topography

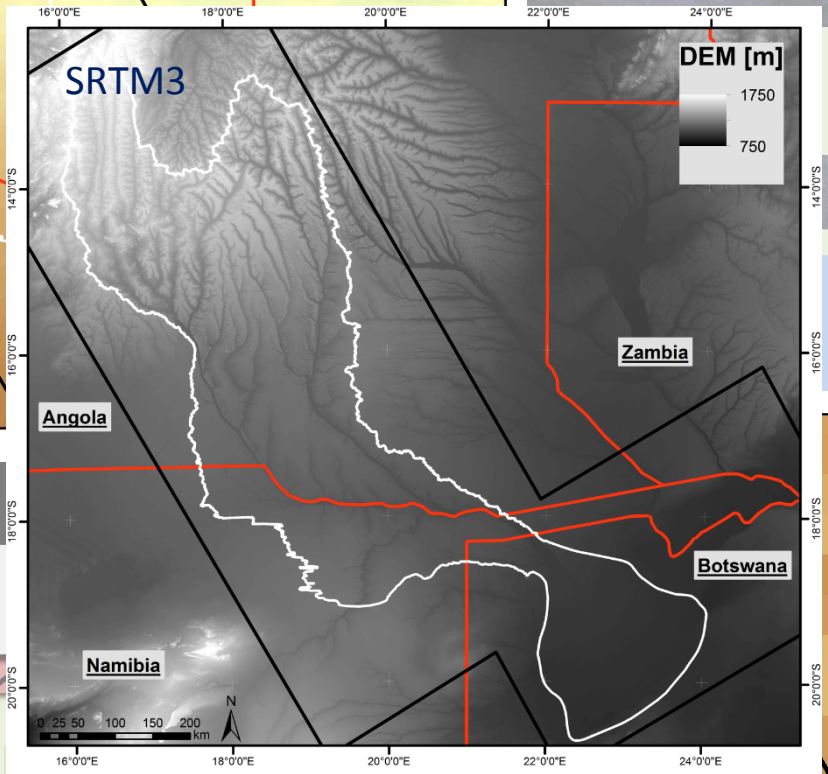
Climate archives/DEM

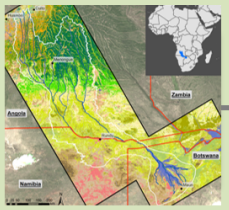
TRMM
CRU Ts v3.2
SRTM3

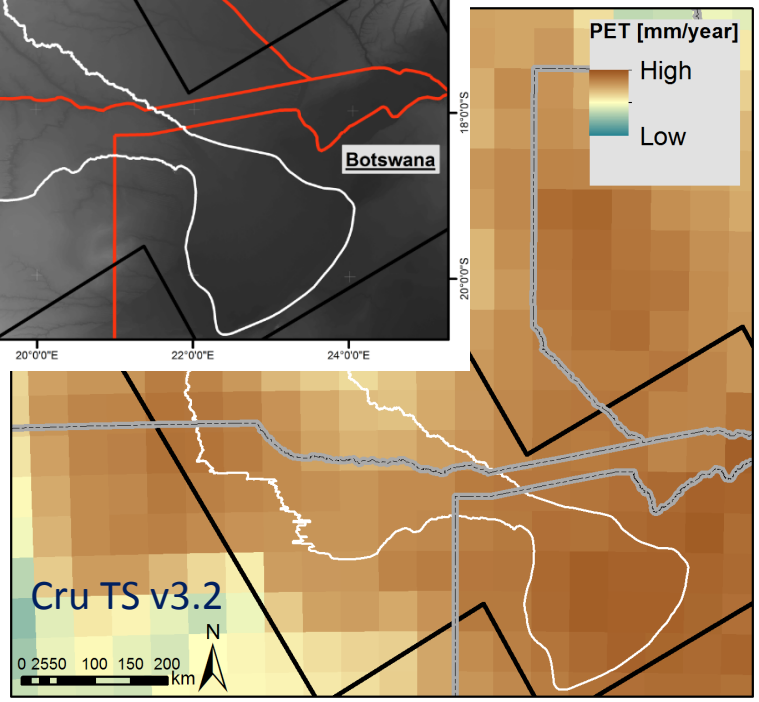
Evaluate state of ecosystems

Rain Use Efficiency









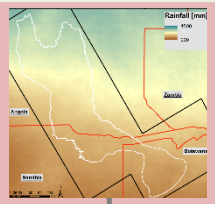
Data

Linkage of the actual state and the observed trends to the underlying causes:
What are the main drivers and how do they man

Drivers

Biophysical boundary conditions

Dynamic variables



Productivity - rainfall

Inun-dation

Climate archives/DEM

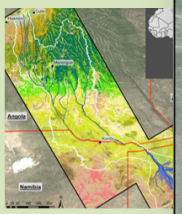
TRMM
CRU Ts v3.2
SRTM3

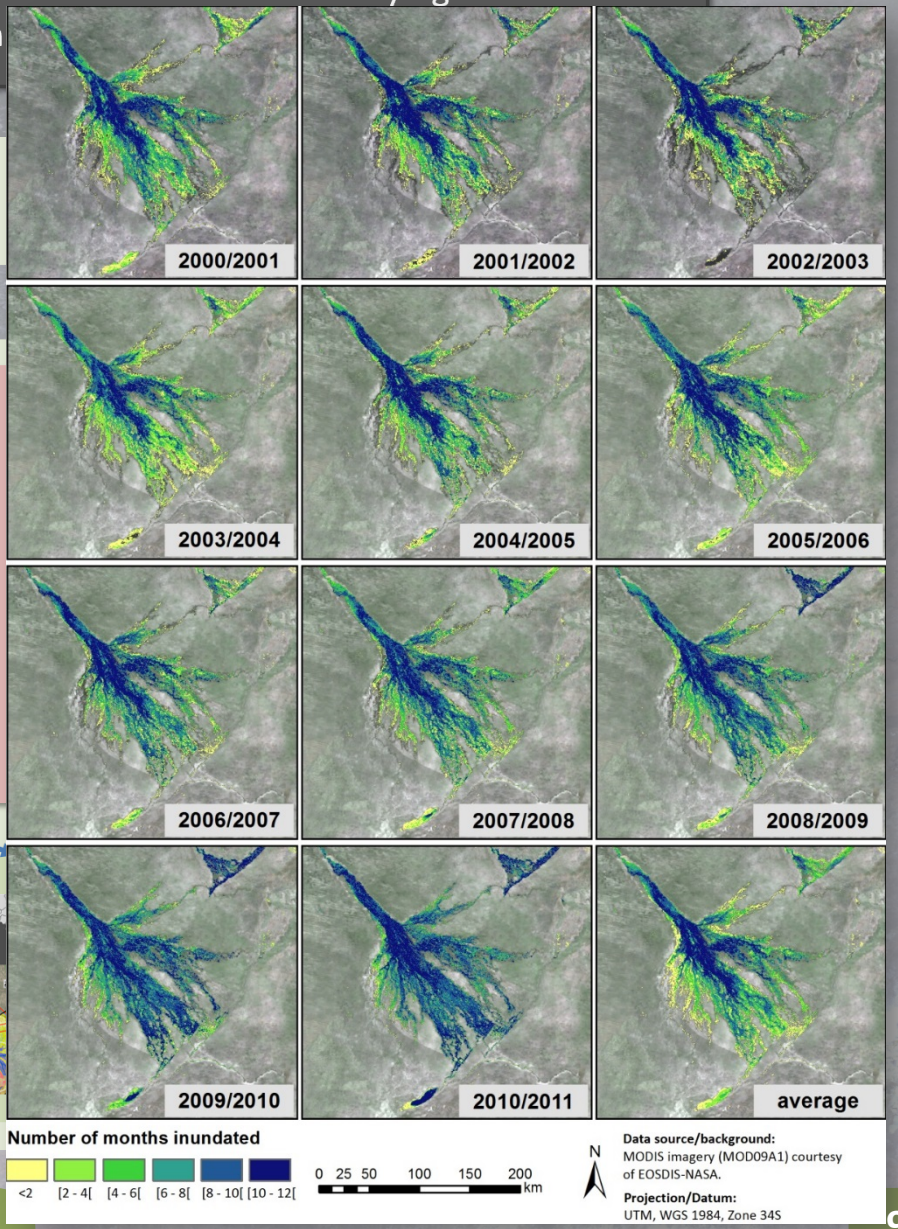
MODIS time series

EVI/NIR/MIR
MOD13Q1

Evaluate state of ecosystems

Rain Use Efficiency





Stellmes et al. 2013

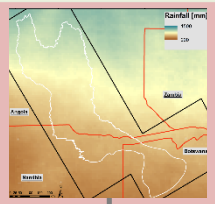
Data

Linkage of the actual stat
What are the main drivers and h

Drivers

Biophysical boundary c

Dynamic variables



Productivity - rainfall

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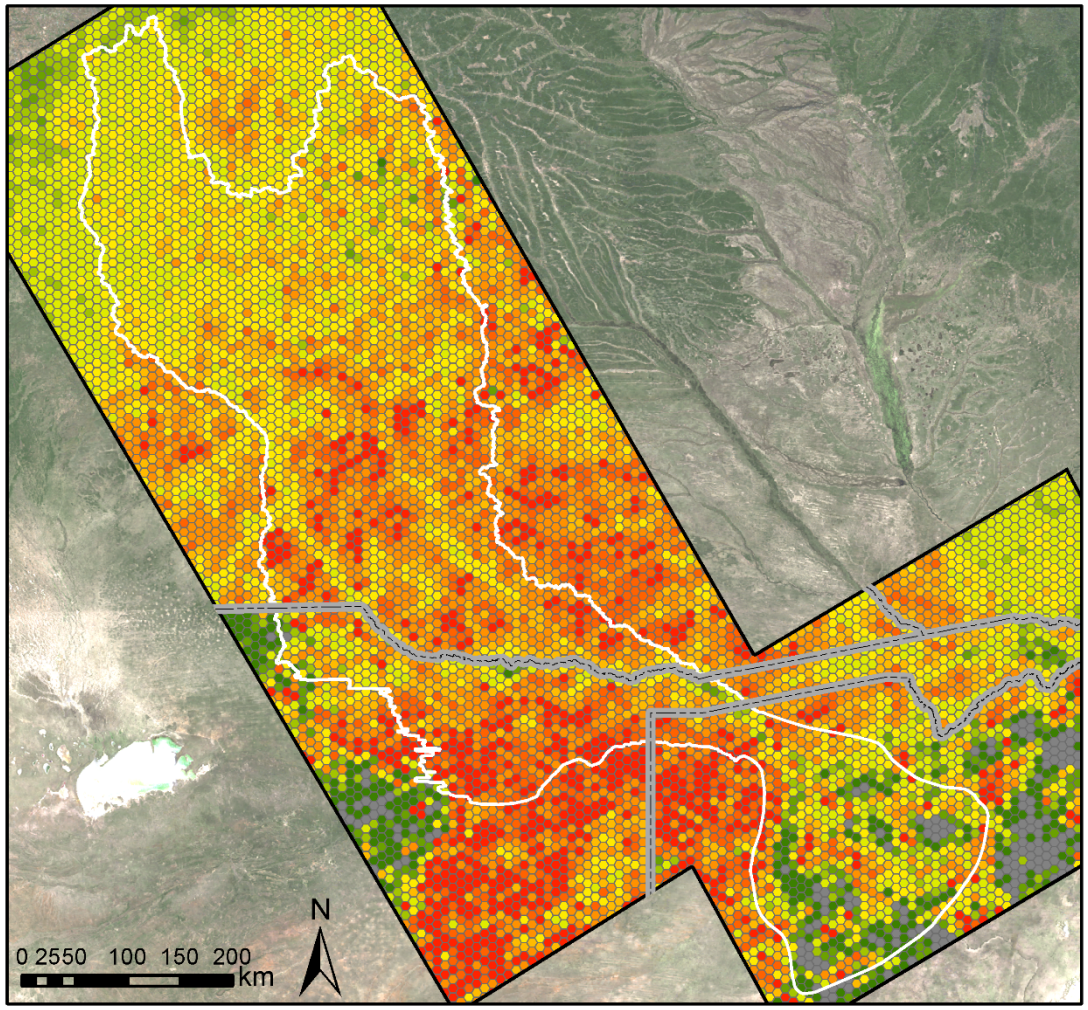
Evaluate state of ecosystems

Rain Use Efficiency



Mean fire radiative power FRP [MW]

No Fire | 1 - 10 | 11 - 20 | 21 - 30 | 31 - 50 | 51 - 70 | 71 - 90 | 91 - 120 | 121 - 150 | > 151

Stellmes et al. 2013 Frantz et al. In prep.

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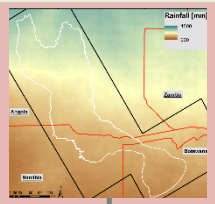
Biophysical boundary co

Dynamic variables



Productivity - rainfall

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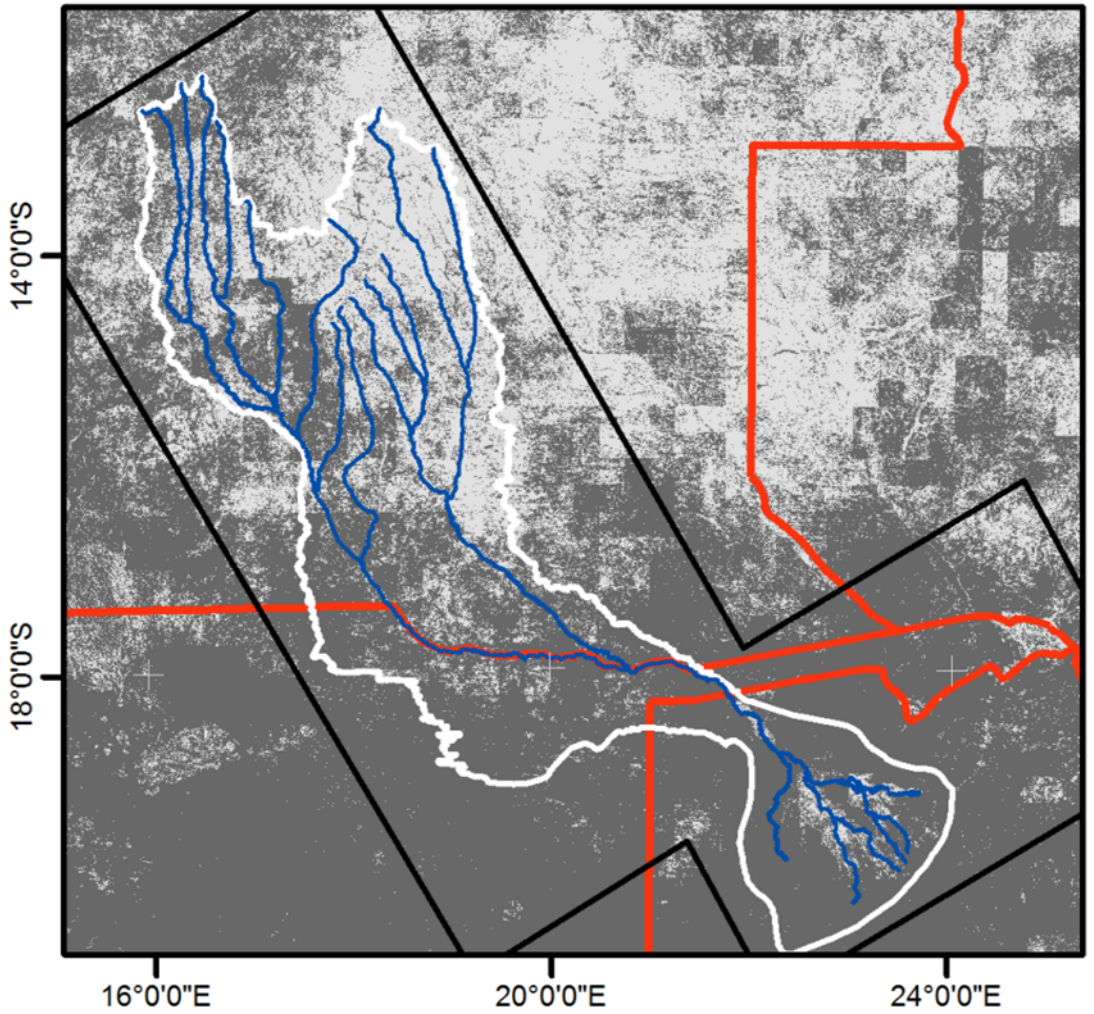
Evaluate state of ecosystems

Rain Use Efficiency



Udelhoven et al. 2015

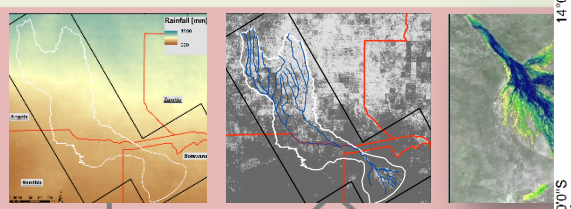
Data

Linkage of the actual state and the observed trends to the underlying causes:
What are the main drivers and how do they manifest themselves throughout the catchment?

Drivers

Biophysical boundary condition

Dynamic variables



Climate archives/DEM

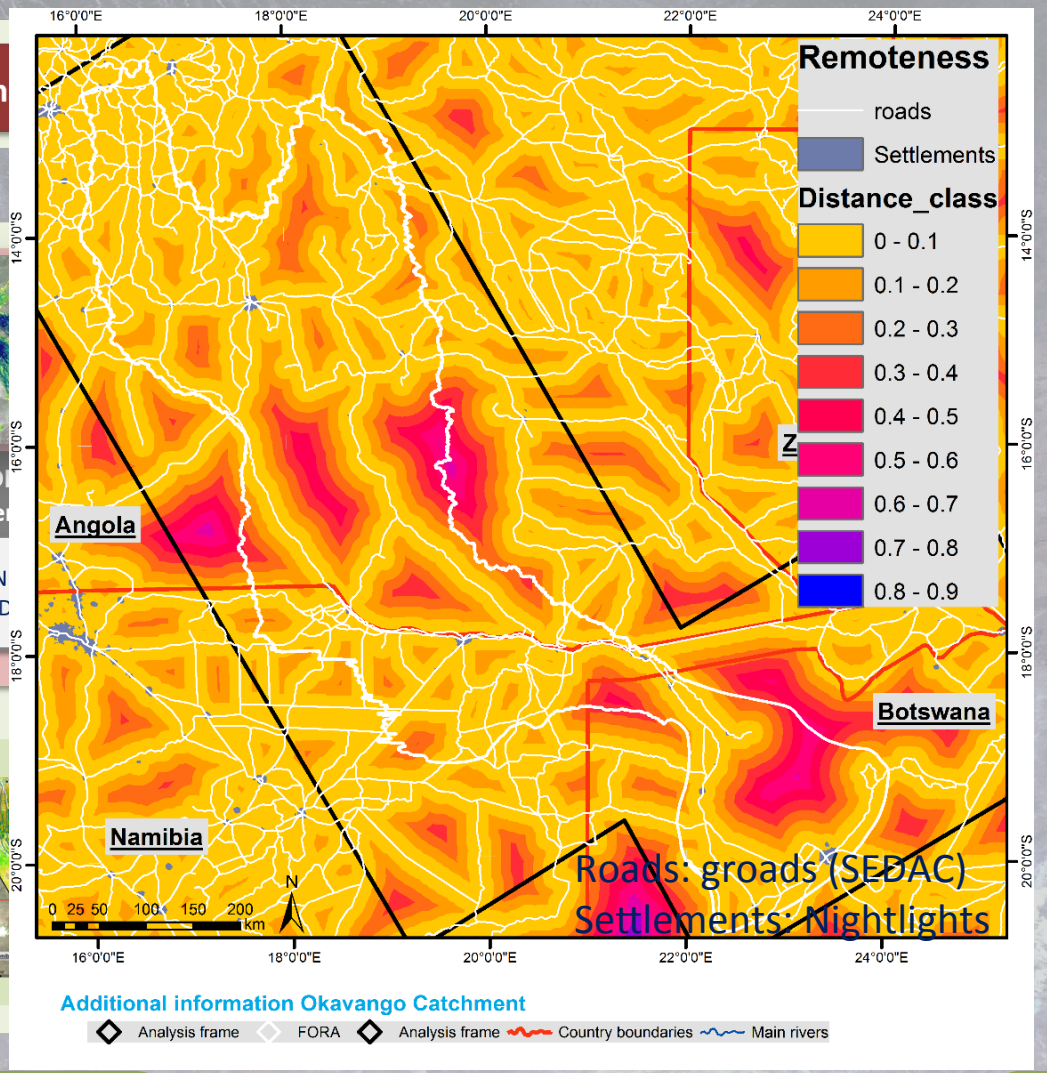
TRMM
CRU Ts v3.2
SRTM3

MODI
ser

EVI/N
MOD

Evaluate state of ecosystems

Rain Use Efficiency



Combined Analyses

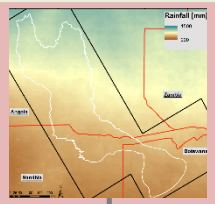
Linkage of the actual state and the observed trends to the underlying causes:
What are the main drivers and how do they manifest themselves throughout the catchment?

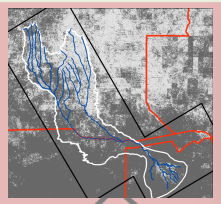
Drivers

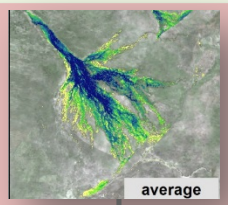
Biophysical boundary conditions

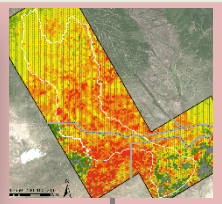
Anthropogenic impact

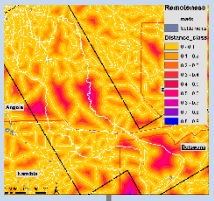
Dynamic variables











Climate archives/DEM

TRMM
CRU Ts v3.2
SRTM3

MODIS time series

EVI/NIR/MIR
MOD13Q1

MODIS Fire products

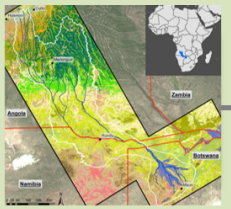
Active Fire
(MOD14A2)
BurnedArea
(MCD45)

GIS data

Roads
Settlements

Evaluate state of ecosystems

Rain Use Efficiency



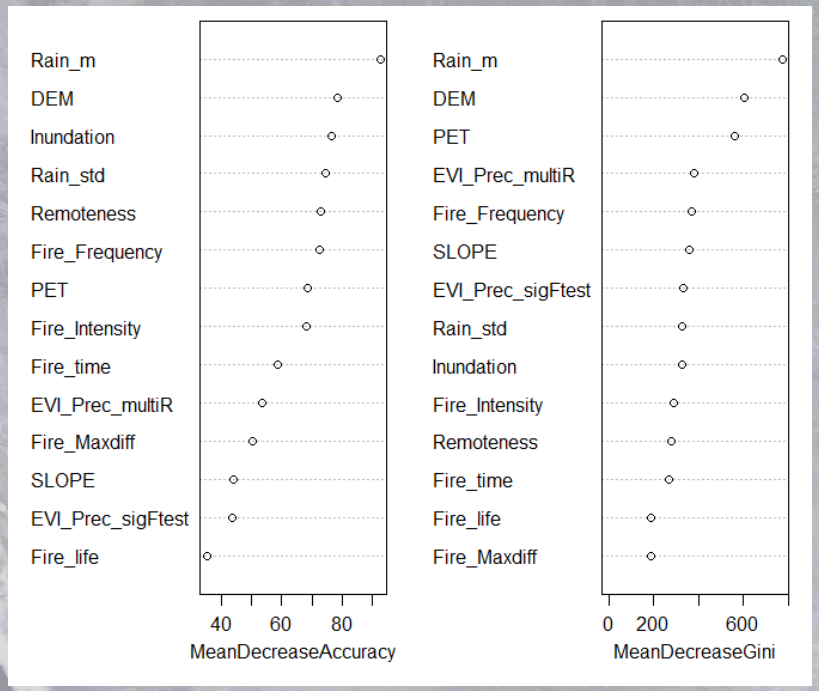
MODIS EVI time series

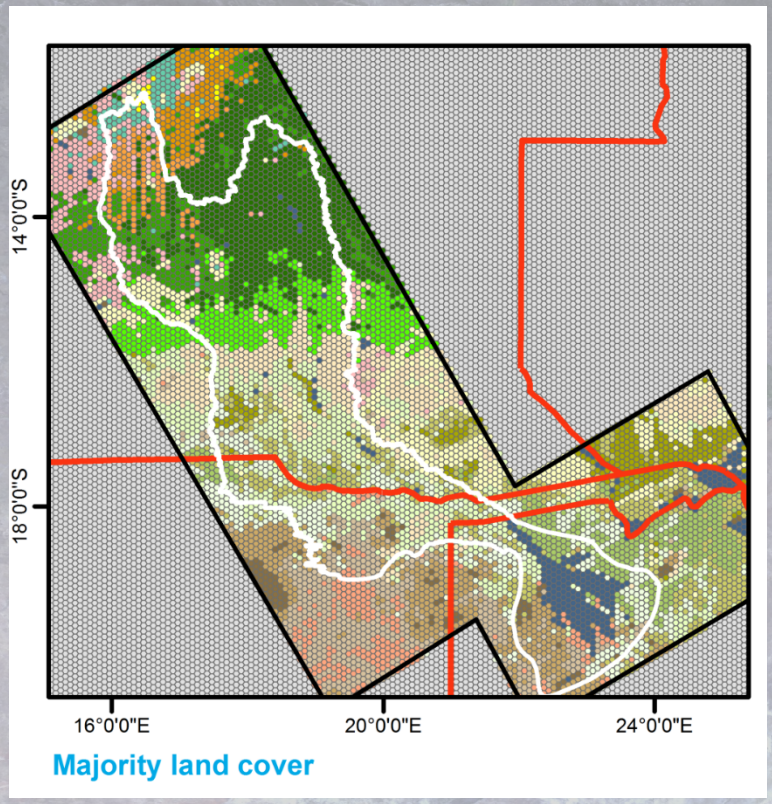
Phenological metrics
MOD13Q1

Evaluation of typical landscape patterns and their properties by directly linking the single elements.

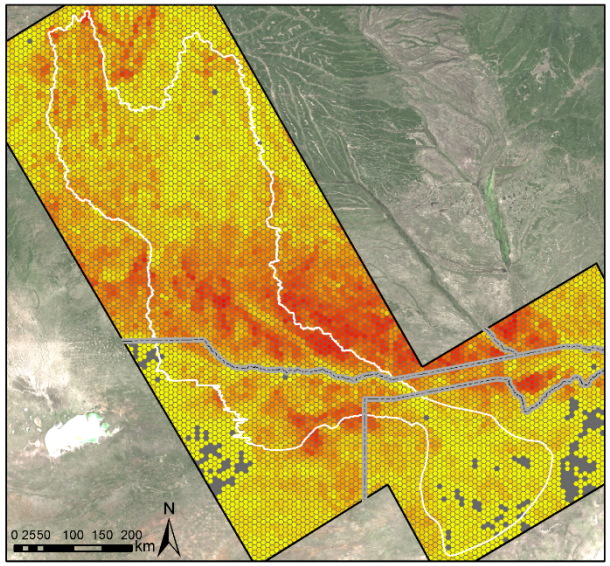
Combined Analyses: Random Forest

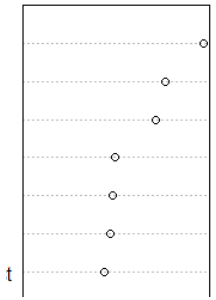
- R package randomForest
- Model: landcover ~ climate, DEM, inundation, EVI-rainfall, fire, remoteness

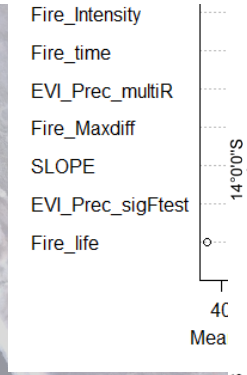


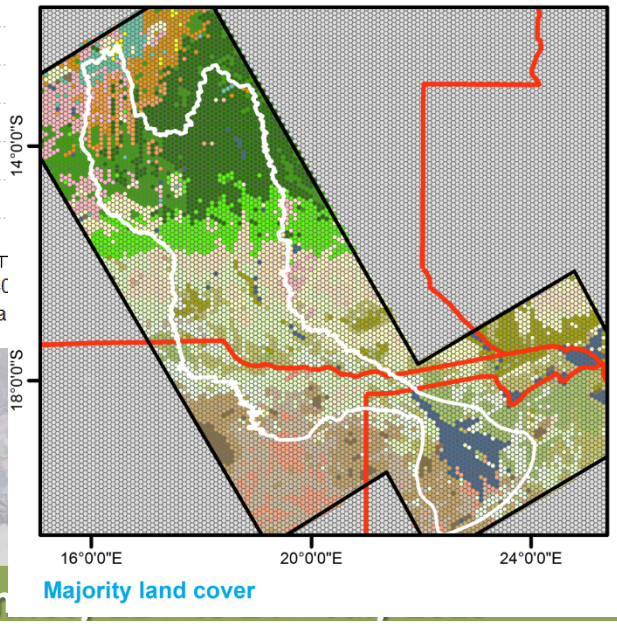


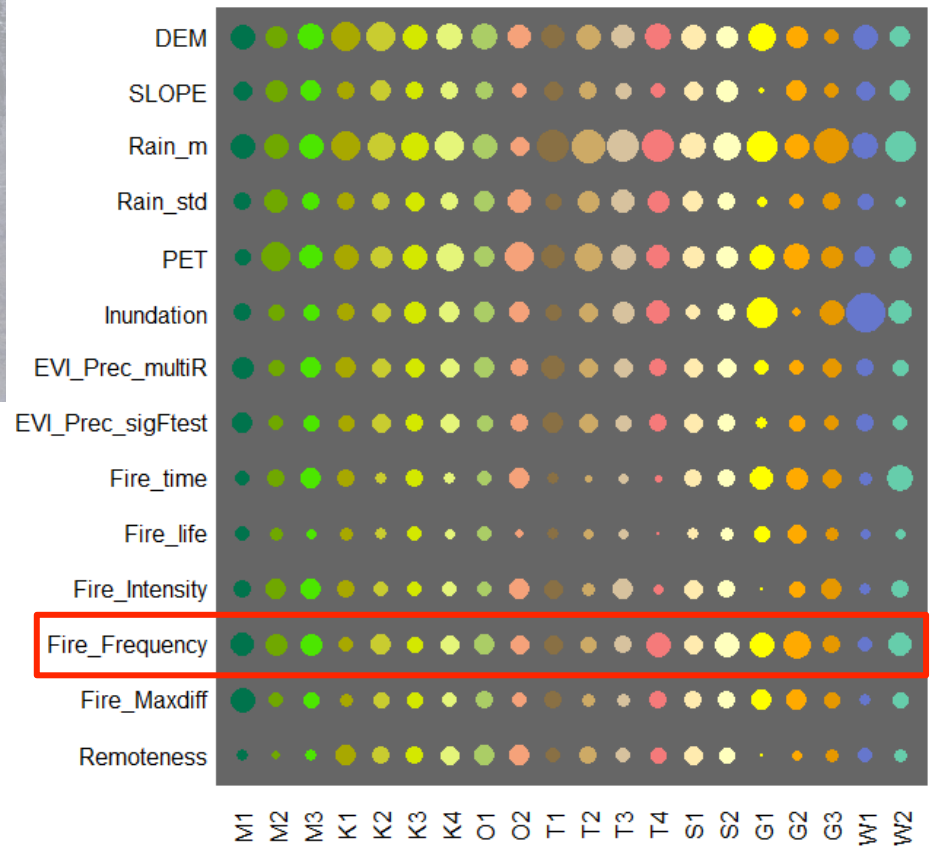
Random Forest









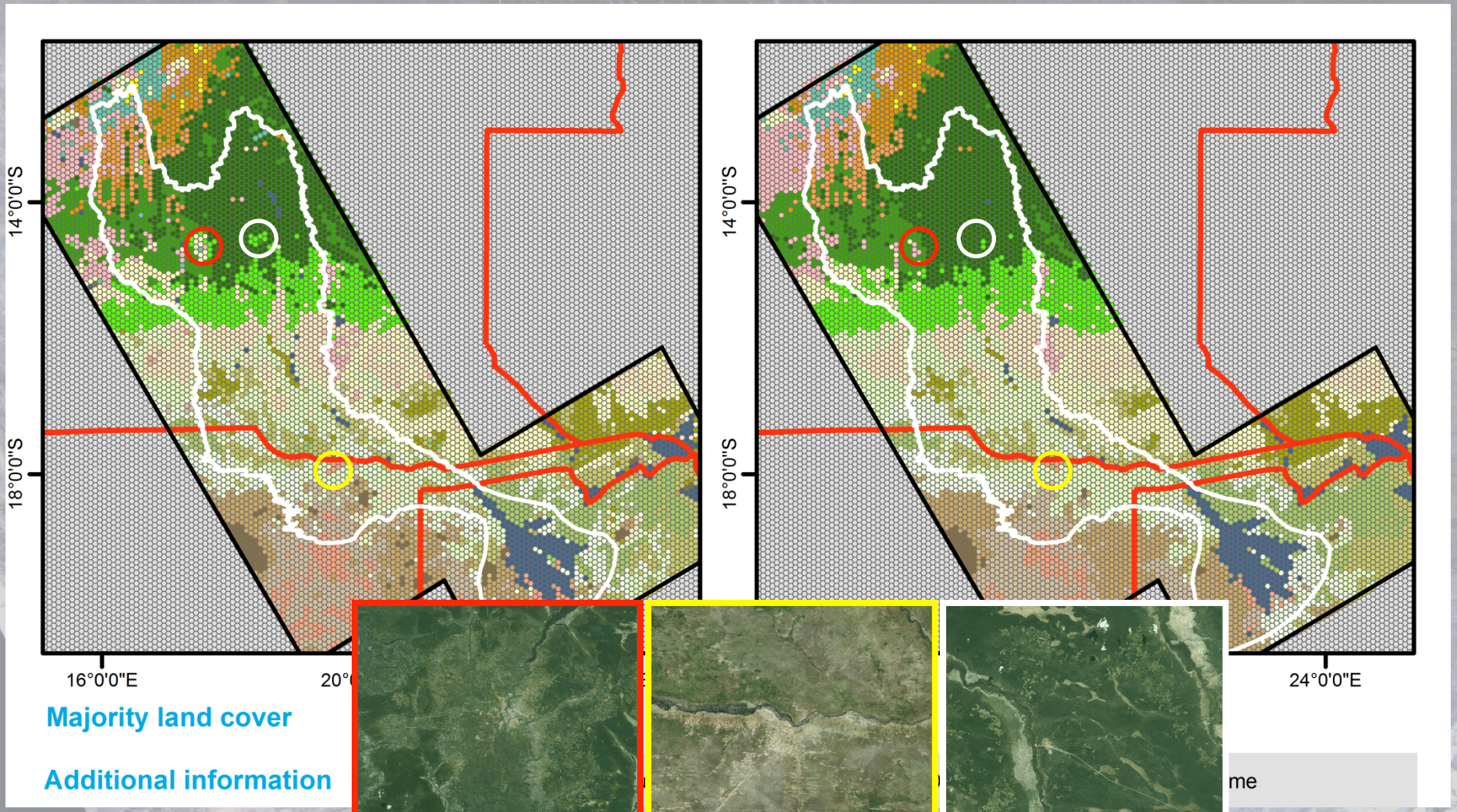


Random Forest
Confusion matrix

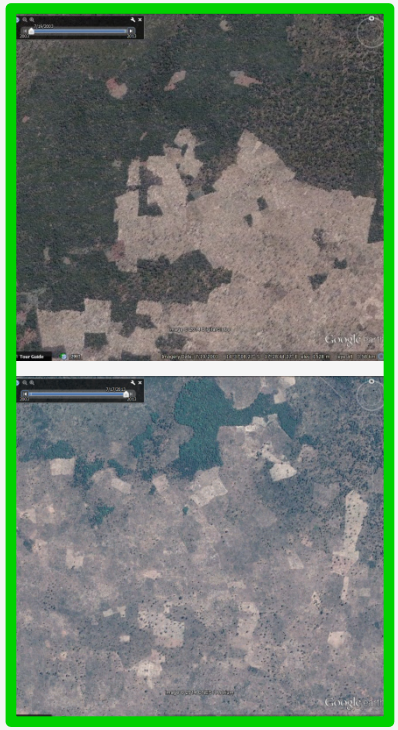
```
Call:
 randomForest(x = data[, c(2:9, 11:16)], y = as.factor(data[,      1]), replace = FALSE, import
               Type of random forest: classification
                     Number of trees: 500
No. of variables tried at each split: 3

        OOB estimate of  error rate: 29.82%
Confusion matrix:
     1   2   3   4   5   6   7   8   9 10  11  12  13  14  15 16  17  18  19 22 class.error
1  991  30  32   0   0   0   0   0   9  0   0   0   0   0   0  0   5   4   0  0  0.07469655
2   83 272  12   0   0   0   0   0  32  0   0   0   0   0   9  0  12  12   0  0  0.37037037
3   32   9 428   0   0   2   0   0   5  0   0   0   0  10   4  0   1   0   0  0  0.12830957
4    0   0   1 263  34  18   5   3   0  4   0   0   0   0  32  0   0   0  10  0  0.28918919
5    0   0   0  32 442  91  52  40   0  2  11   0   1   2  45  0   0   0   4  0  0.38781163
6    1   0  14   0  71 506  54  19   0  0  21  16   2  56  39  0   0   0   2  0  0.36828964
7    0   0   0   1  49  85 321  44   0  0  33  12   5   1   1  0   0   0   1  0  0.41952984
8    0   0   0   8  49   6  32 311   0  0   0   0   0   0   1  0   0   0   8  0  0.25060241
9    4  45   0   0   0   0   0   0 273  0   0   0   0  20  18  0   9   7   0 21  0.31234257
10   0   0   0  15   4   3   3   1   3 47  45   6   0   0   4  0   0   0   9  0  0.66428571
11   0   0   0   1  10  22  31   3   0  7 410  62   3   2   2  0   0   0   3  0  0.26258993
12   0   0   0   0   4  32  25   2   1  1  86 368  47   3   4  0   0   0   2  0  0.36000000
13   1   0   0   0   5   3   9   2   0  0  11  93 136   2   0  0   0   0   6  0  0.49253731
14   1   1  35   1   3  84   0   2  12  0   4   2   0 376  50  0   0   0   4  0  0.34608696
15   0  18  23  40  19  21   0   7  18  0   1   0   0  50 412  0   2   7   1  4  0.33868379
16   0   0   0   0   0   0   0   0   1  0   0   0   0   0   0 12   0   4   0  6  0.47826087
17   5   9   0   0   0   0   0   0  12  0   0   0   0   0   0  1 100   6   0  4  0.27007299
18  19  15   0   0   0   0   0   0  27  0   0   0   0   0   1  0   9 162   0  4  0.31645570
19   6   3   1   5   2   2   0   0   6  1   2   0   1   4   2  0   0   0 299  0  0.10479042
22   4   1   0   0   0   0   0   0  29  0   0   0   0   0   3  4   3  10   0 97  0.35761589
```

Miombo | Baikea-Burkea | Other woodlands | Savannah | Shrub-lands | Grass-lands | Wetlands

Combined Analyses: Random Forest



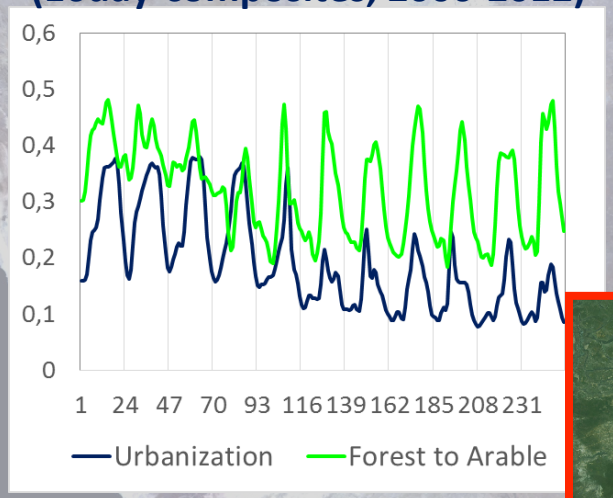
Example: Wider area Menongue

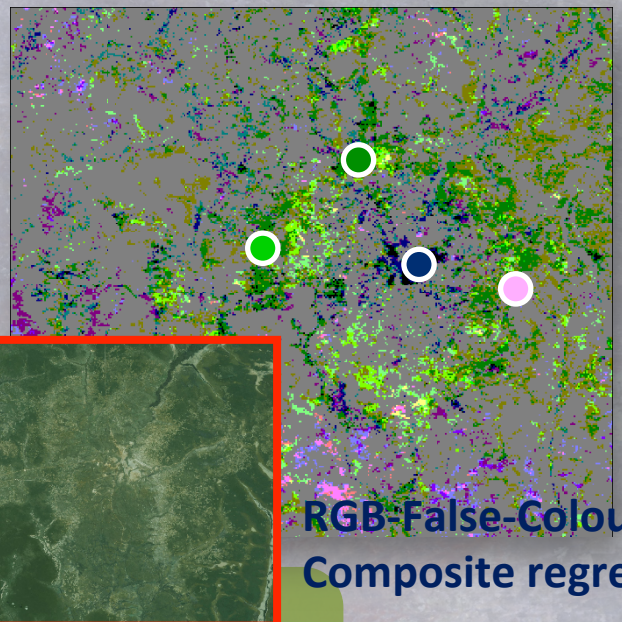


2003

2013

EVI time series (16day-composites, 2000-2012)

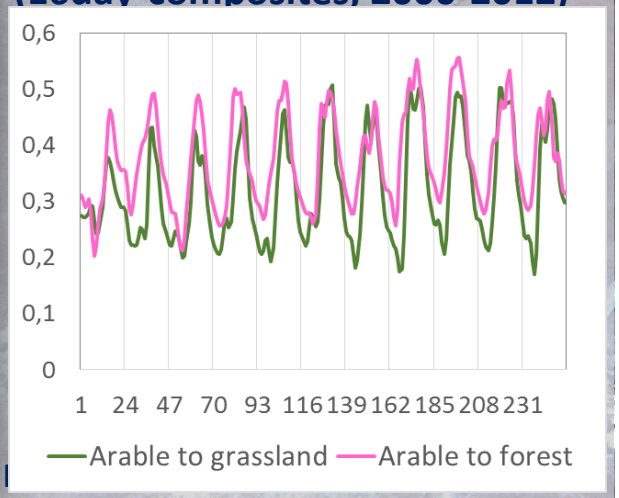




RGB-False-Colou

Composite regression coefficients

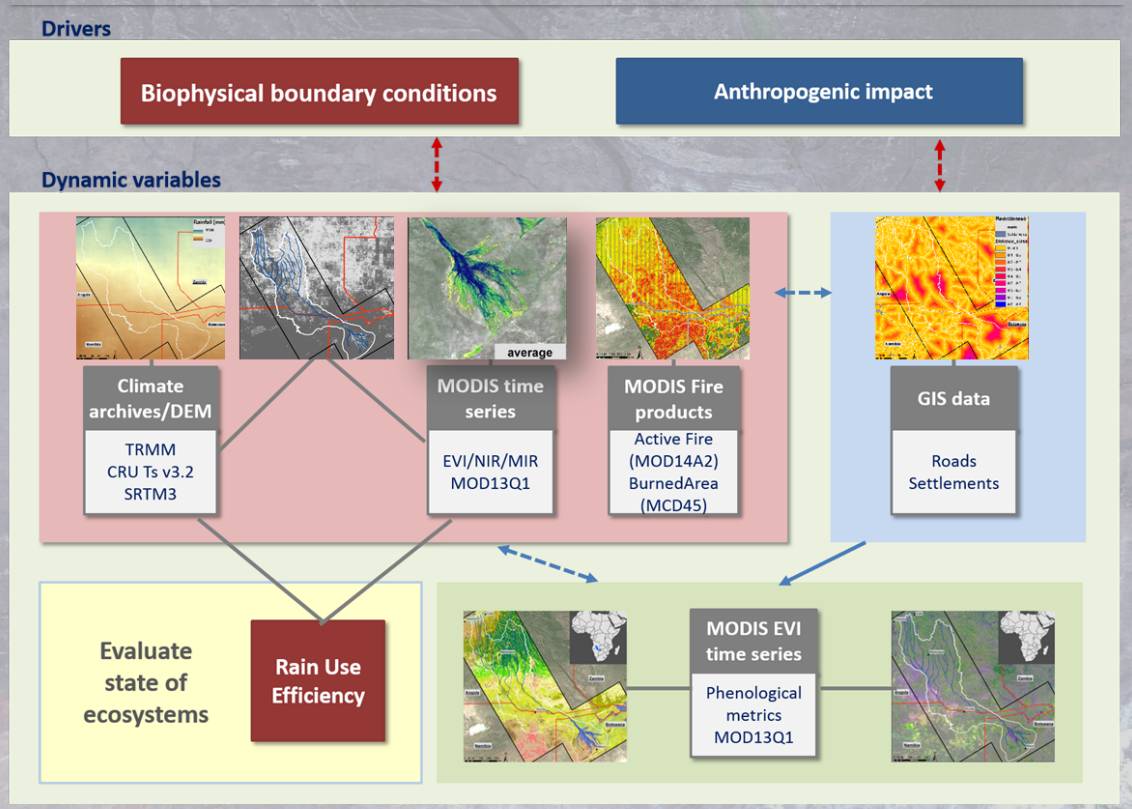
EVI time series (16day-composites, 2000-2012)



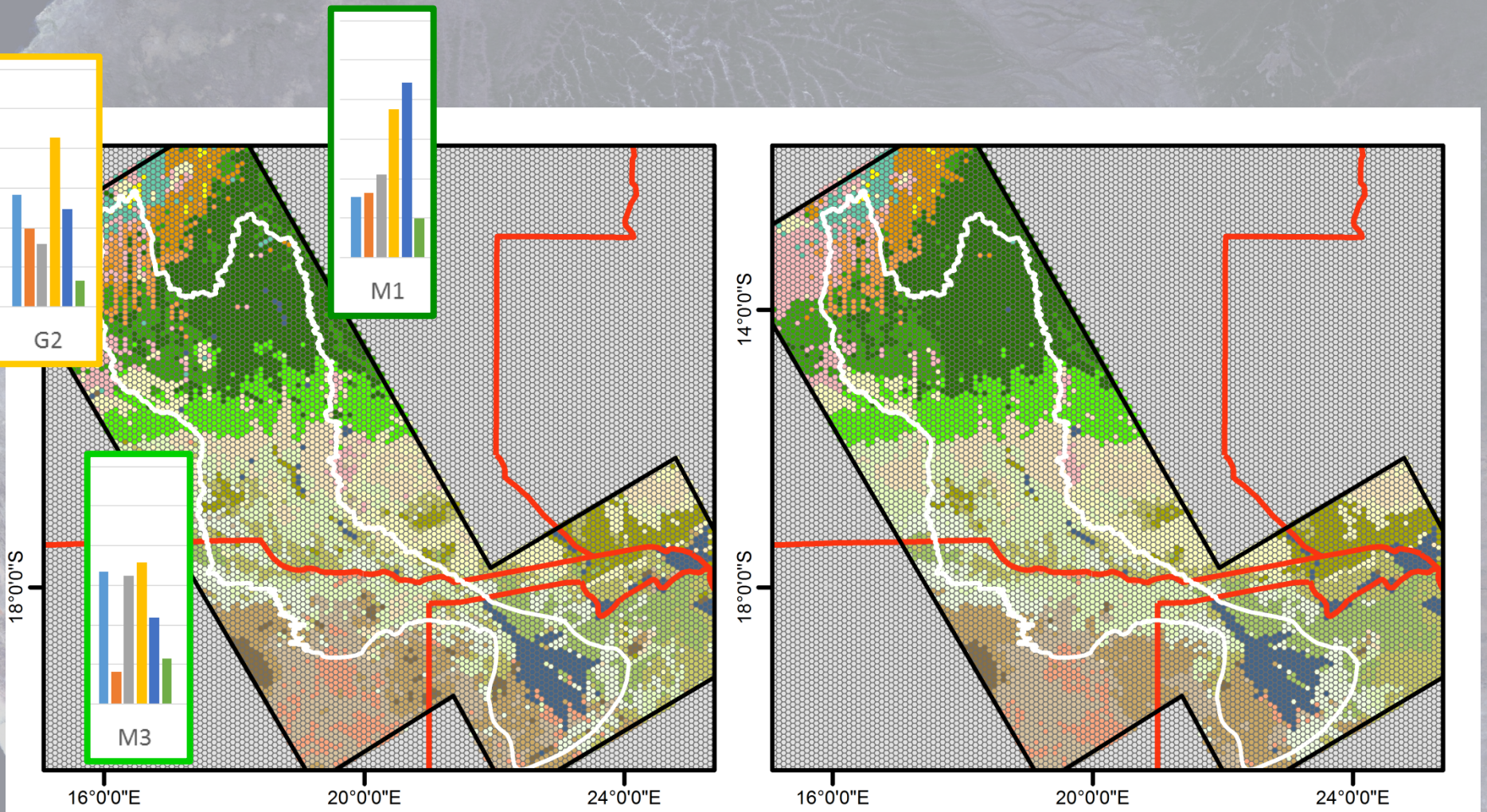
Summary and Outlook

- Important variables describing the ecosystems of the Okavango Catchment were derived and have to be further analysed regarding their patterns and inter-relationships
- Land cover was explained to a high degree by derived variables, nevertheless important variables may miss (e.g. soil information)

- Observed land cover dynamics will be analysed concerning the biophysical boundary conditions to distinguish land use change and “normal” variability.
- Mapping of typical land system patterns including their dynamics and underlying drivers
- Rain use efficiency as an indicator for ecosystem status

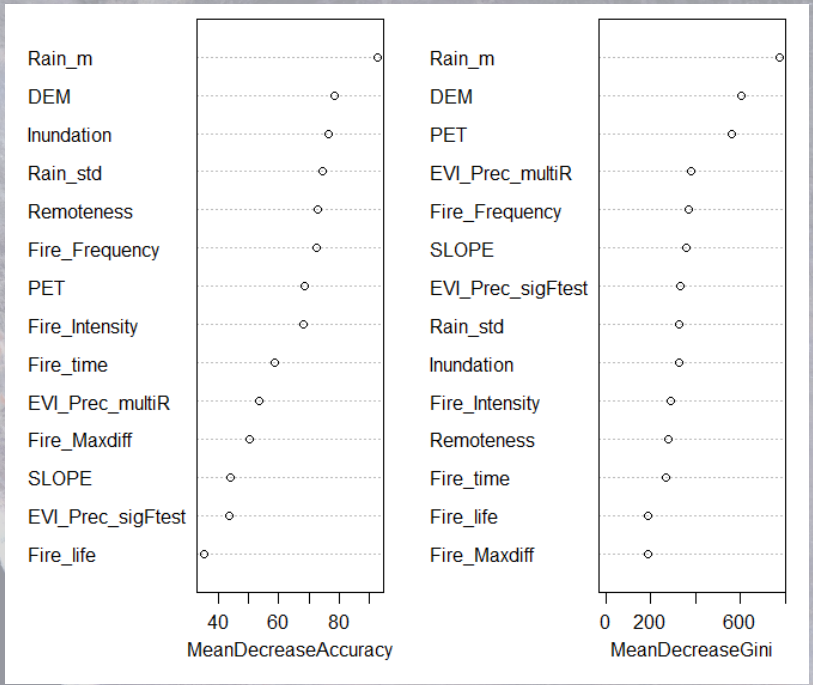


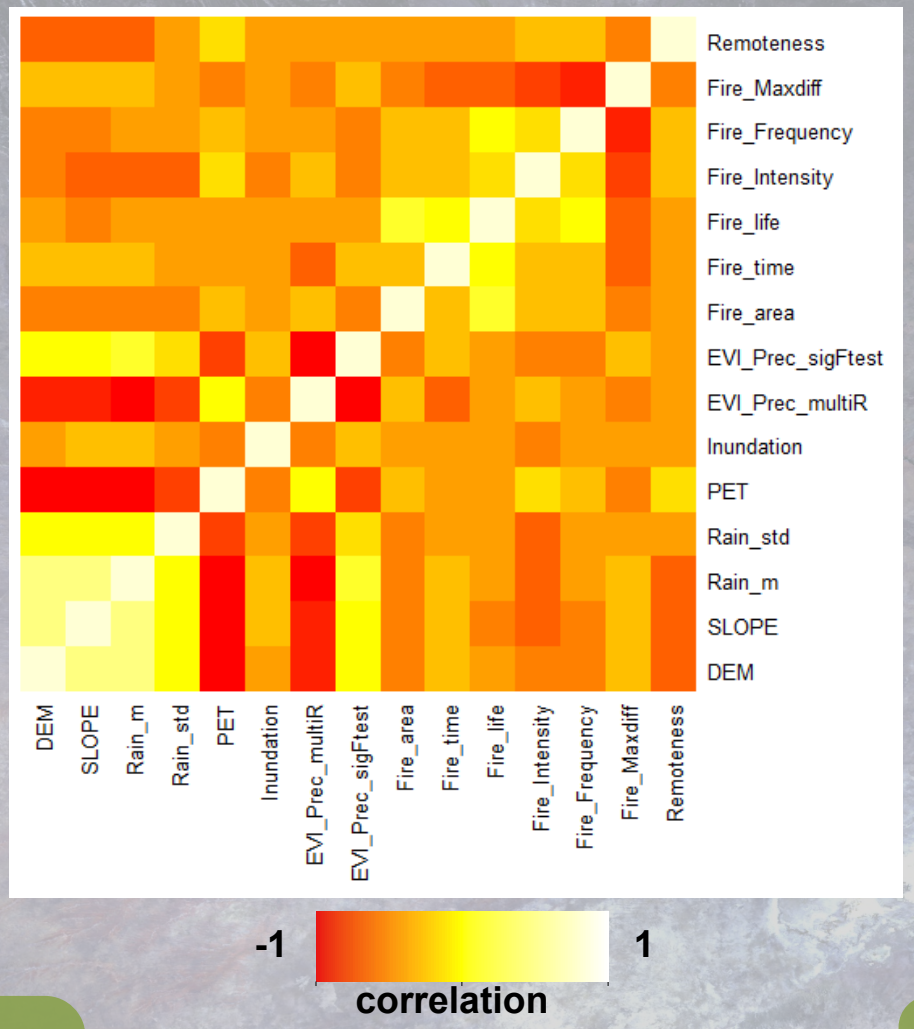
Combined Analyses: Random Forest

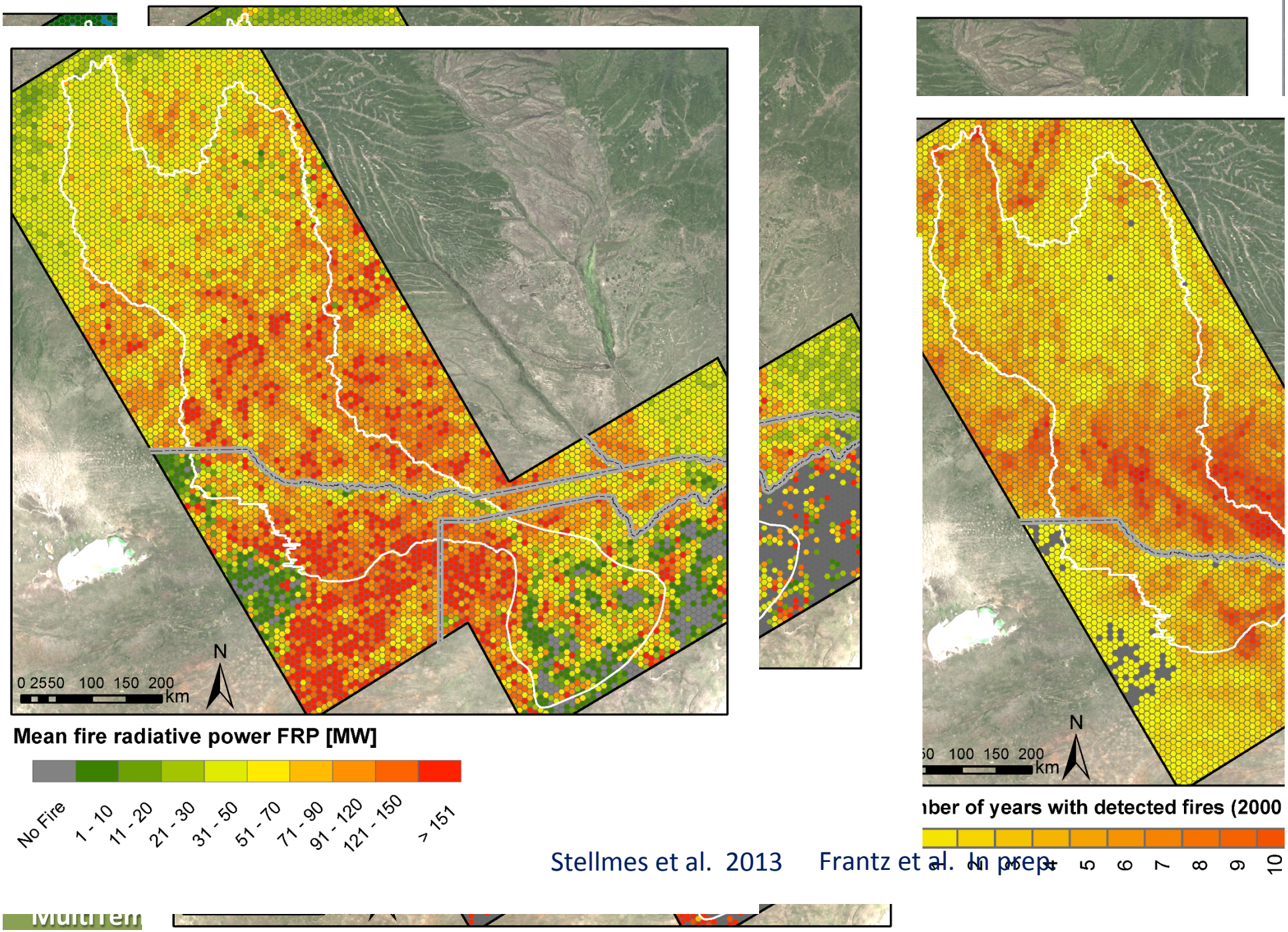


Combined Analyses: Random Forest

- R package randomForest
- Model: landcover ~ climate, DEM, inundation, EVI-rainfall, fire, remoteness







Stellmes et al. 2013 Frantz et al. In prep.