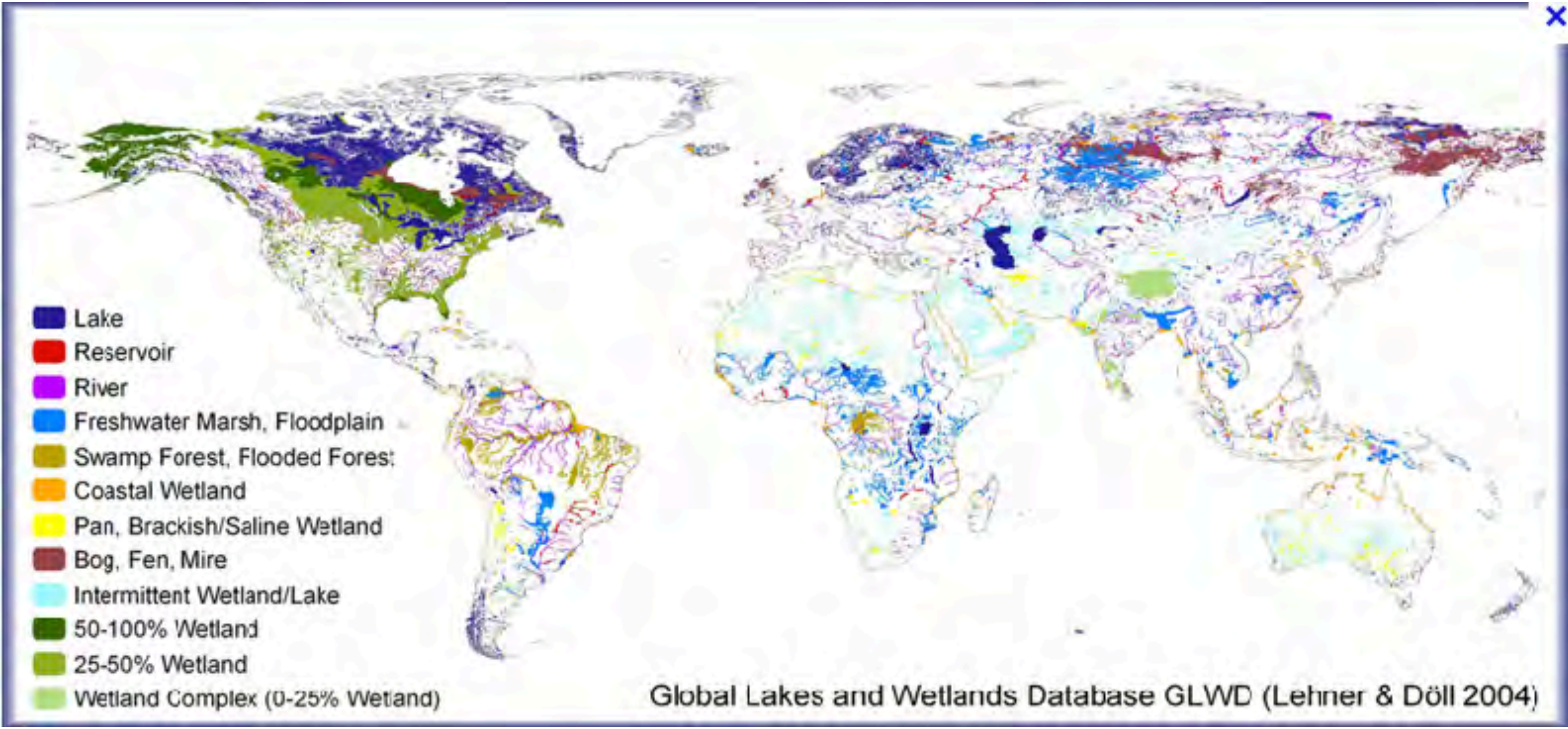
Mapping global tropical wetlands

Part of the CIFOR research program TWINCAM

TROPICAL WETLANDS INITIATIVE FOR CLIMATE ADAPTION AND MITIGATION

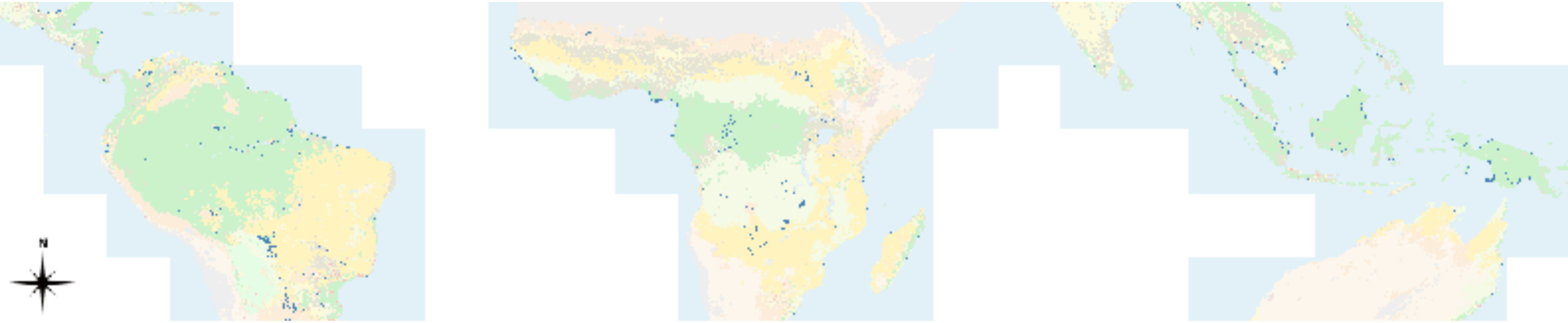
Thomas Gumbricht
Karttur AB
For CIFOR and ICRAF

Mapping global tropical wetlands



At present there is no globally consistent wetland map available

Mapping global tropical wetlands



The standard MODIS land cover product (MCD12Q1 version 051) for the tropics, 2010. permanent wetlands have fully saturated (blue) color, other land cover classes have the default hue used for the IGBP classification scheme of MCD12Q1, but with faded saturation.

Data sources for wetland mapping

Wetlands can be mapped from a variety of data sources:

- Ground survey (older topographic maps)
- Aerial photos (modern topographic maps)
- Optical satellite images
- Thermal satellite images
- Radar satellite images
- Microwave satellite images
- Elevation data (e.g. from radar or lidar satellite images)
- Gravimetric data (large water bodies with volume changes)
- Combinations of 2 or more of the above

Data sources for wetland mapping

Advantages and disadvantages with different data sources:

- Ground survey – too labor intense

Older topographic maps stem out of military mapping needs. Wetlands where important, and are hence usually well represented on topographic maps. But topographic maps are seldom publicly available (for free), the mapping across countries is not consistent, and updating is irregular.

Data sources for wetland mapping

Advantages and disadvantages with different data sources:

- Aerial photos – labor intense, not consistent

Global mapping of wetlands using aerial photo interpretation would be very labor intense. The number of interpreters involved is prohibiting. Using Landsat data instead of aerial photos, a semi-manual photo-interpretation approach has been used to map the global extent of mangroves (Giri et al., 2010). Perhaps it is possible to map all wetlands in a similar manner as well.

Data sources for wetland mapping

Advantages and disadvantages with different data sources:

- Optical satellite images – demands reference data, cloud contamination in the tropics

Traditional (statistical) classification methods require (local) reference sites – preferably falling in the same scene. Globally this is difficult to acquire. Cloud contamination, especially in the tropics, is a problem. Generic indexes that relate to wetlands (e.g. soil wetness or vegetation phenology), is a possible alternative, and was developed as part of the TWINCAM mapping effort.

Data sources for wetland mapping

Advantages and disadvantages with different data sources:

- Thermal satellite images – cloud contamination in the tropics, no unique wetland signal

Wetlands have a higher latent (and lower sensible) heat flux compared to drier land. Wetlands can be detected as (sustained) cool-spots in the landscape. Dense vegetation with shallow ground water can give similar heat fluxes as wetlands, and the same is true for moist forests (with non-histosolic soils). But thermal satellite images have a potential for wetland mapping in combination with other data.

Data sources for wetland mapping

Advantages and disadvantages with different data sources:

- Radar satellite images – demands reference data and time series, poor availability

Radar images are not disturbed by clouds, a great advantage. But availability of global radar images is limited. The interpretation of radar images is not trivial and demands both reference sites, as well as time series (if mapping of surface wetness conditions is required). In the TWINCAM project an attempt was made to use publicly available global radar (PALSAR) data, but the data set turned out to be inconsistent, and not useful.

Data sources for wetland mapping

Advantages and disadvantages with different data sources:

- Microwave satellite images – coarse spatial resolution, vegetation disturbances

Microwave images are very useful for mapping the soil surface wetness (0-5 cm), but the soil wetness is masked out if under dense and wet vegetation. Readily available microwave images are of coarse resolution (10-50 km pixel size), which is too coarse for mapping wetlands.

Data sources for wetland mapping

Advantages and disadvantages with different data sources:

- Elevation data – promising results in a per-basin approach

Topographic wetness can be extracted from any elevation data source as the accumulated drainage (upstream) area of each cell divided by the cell size and the cell slope and/or curvature. It demands that climate is consistent within the basin. To be used as a global index, rainfall/runoff needs to be considered, as well as the difference in soil hydraulic response in various soils. As part of TWINCAM a generic global topographic-runoff wetness index has been developed.

Data sources for wetland mapping

Advantages and disadvantages with different data sources:

- Gravimetric data – most wetlands too small to generate any detectable signal

Publicly available gravimetric data from the twin-satellite GRACE can be used for detecting volumetric changes in earth surface water content. Most wetlands are, however too small for any change in the gravity to be detected. Large water reservoirs can be detected. As part of the TWINCAM project GRACE data was tried out for large wetlands like e.g. the Okavango inland delta in Botswana. But no useful results could be obtained.

Data sources for wetland mapping

Advantages and disadvantages with different data sources:

- Combinations of 2 or more of the above – the most promising approach

Bwangoy et al (2010) combined optical, radar and topographic data to map the wetlands of the Central Congo Basin. Their approach is still based on local reference conditions, and would demand re-calibration for each (sub)basin. The alternative is to use generic indicators that represent similar conditions globally. This has been the aim of the wetland mapping effort within TWINCAM.

The TWINCAM mapping approach

The approach used within TWINCAM:

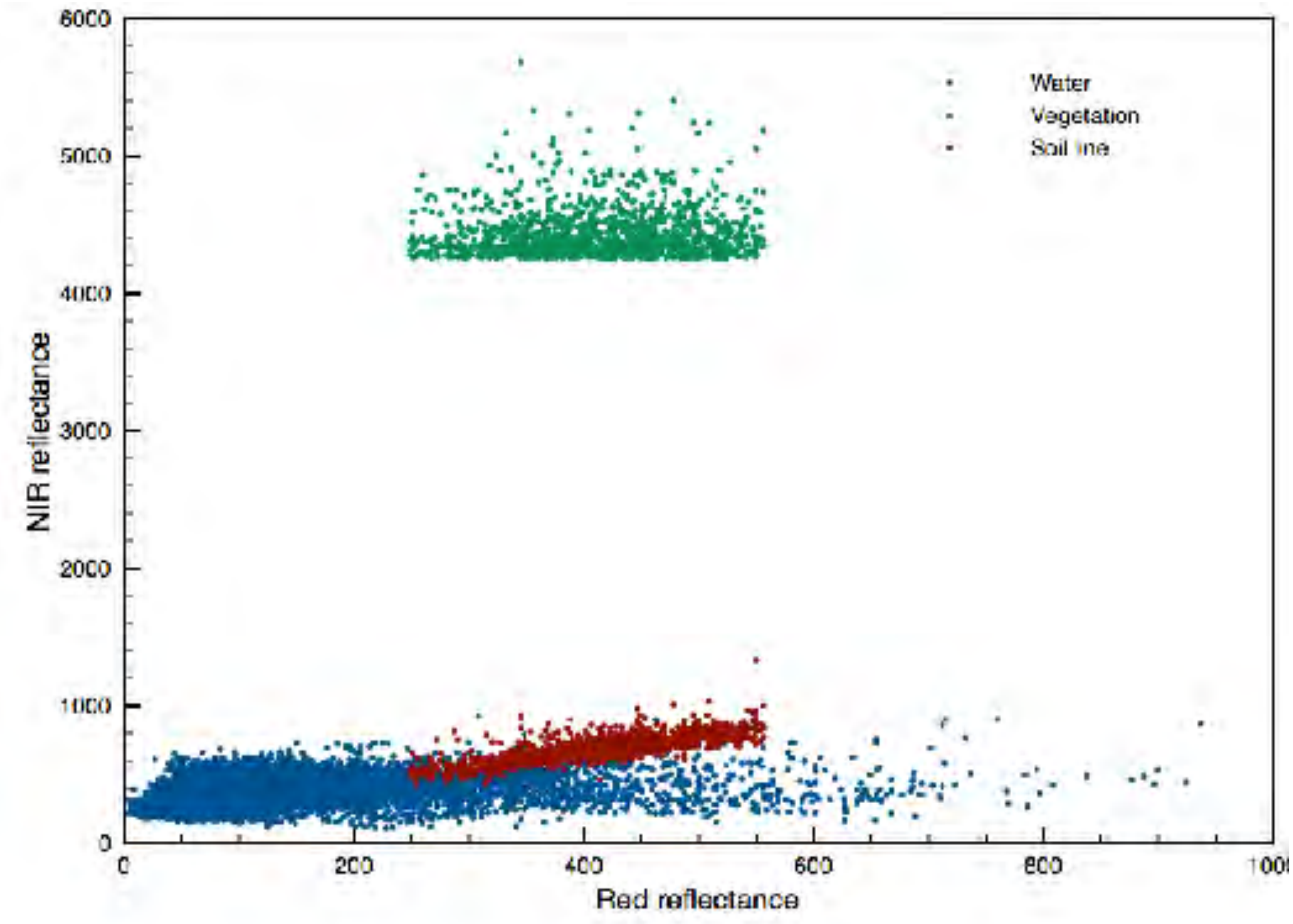
- Adopt times-series images at medium resolution to allow phenological analysis = MODIS (done!)
- Develop generic index for surface wetness to analyze annual wetness phenology (done!)
- Combine rainfall/runoff data and elevation data to develop a generic climate-topographic wetness index (done!)
- Chronological classification of local wetlands based on local reference sites (tool developed, data lacking!)
- So far so good, but lack of quality assured ground reference data has hitherto prevented project fruition.

VIS/NIR soil wetness mapping

Generic soil wetness index:

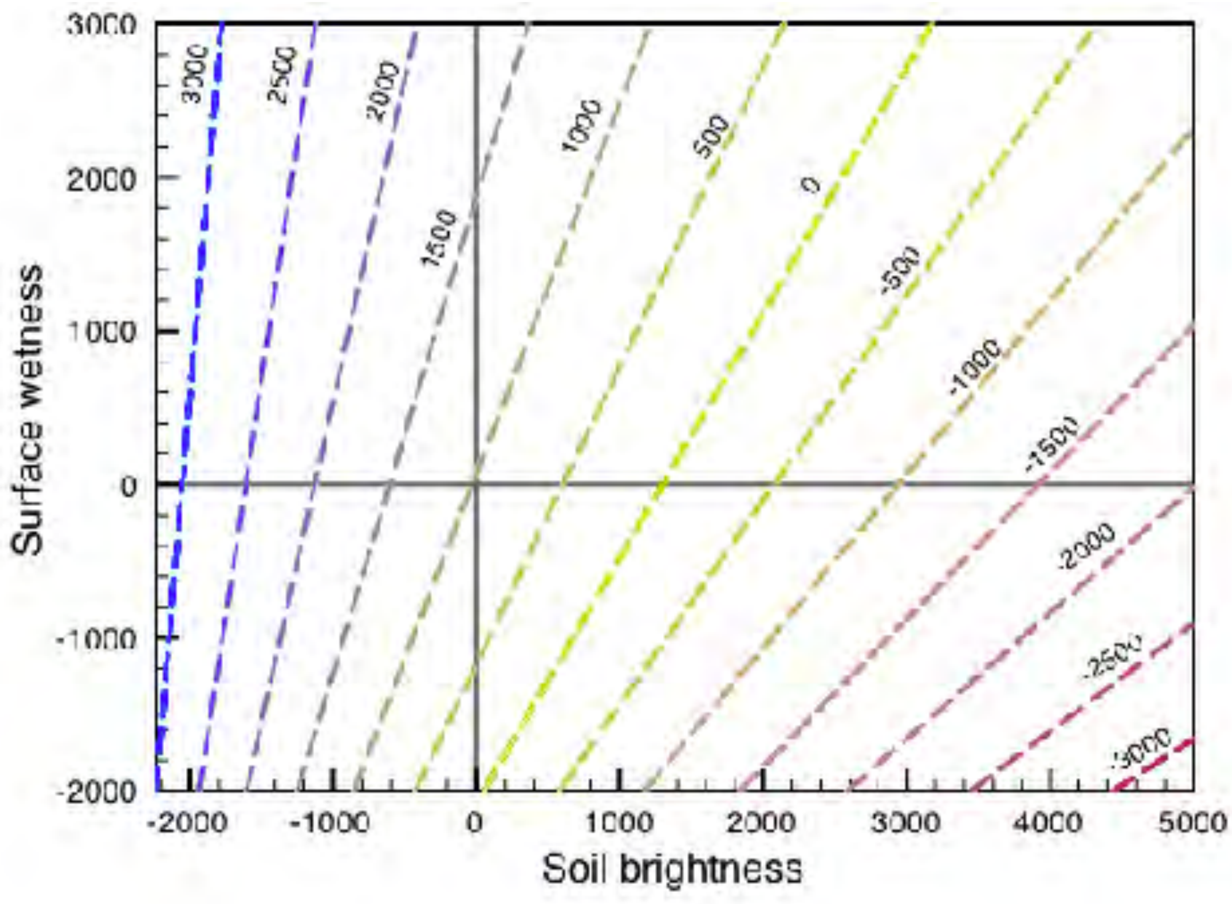
- Extraction of global tropical spectral end-members
- Definition of eigen vectors for a PCA transformation to biophysical features, aiming at separating dry and wet soil surface conditions
- Analysis of non-linearity in the normalized difference ratio between PC1 (soil brightness) and PC4 (surface wetness)
- Phenological analysis of global soil wetness for 2001 and 2011
- *Could be improved by inclusion of e.g. thermal emissivity data*

VIS/NIR soil wetness mapping



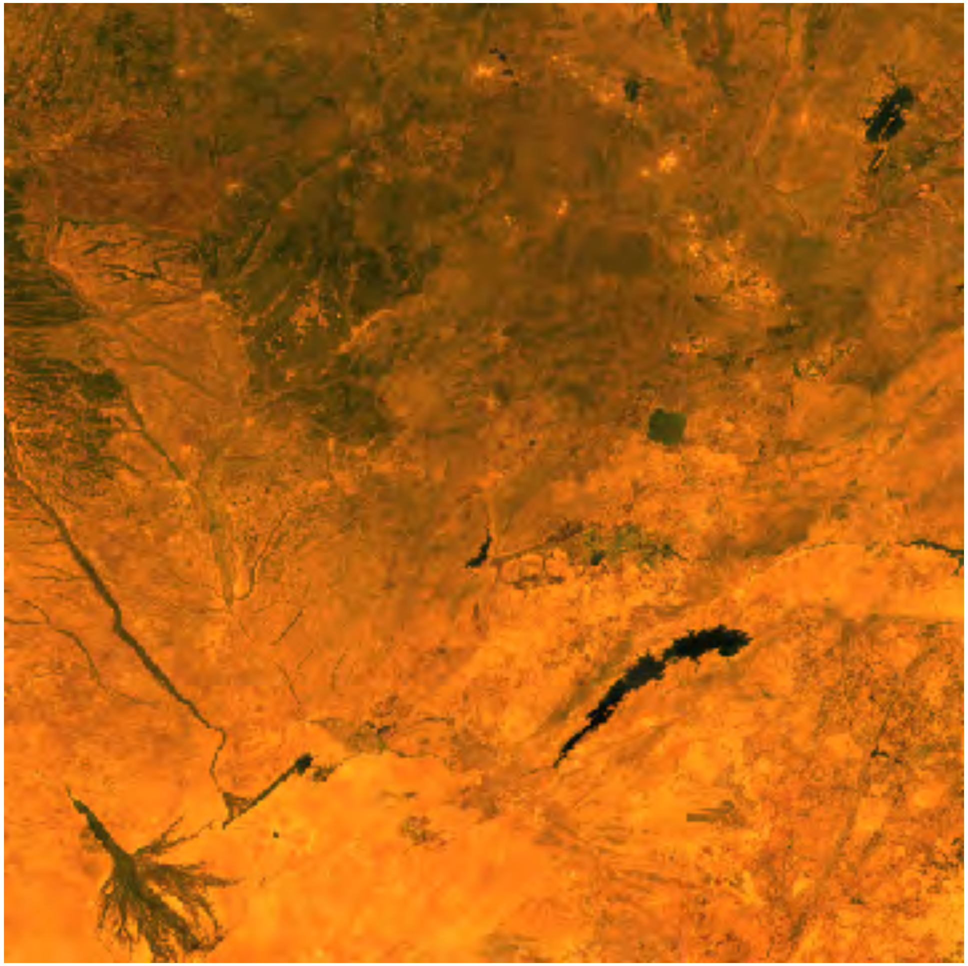
Spectral end-members for parts of Indonesia and Malaysia

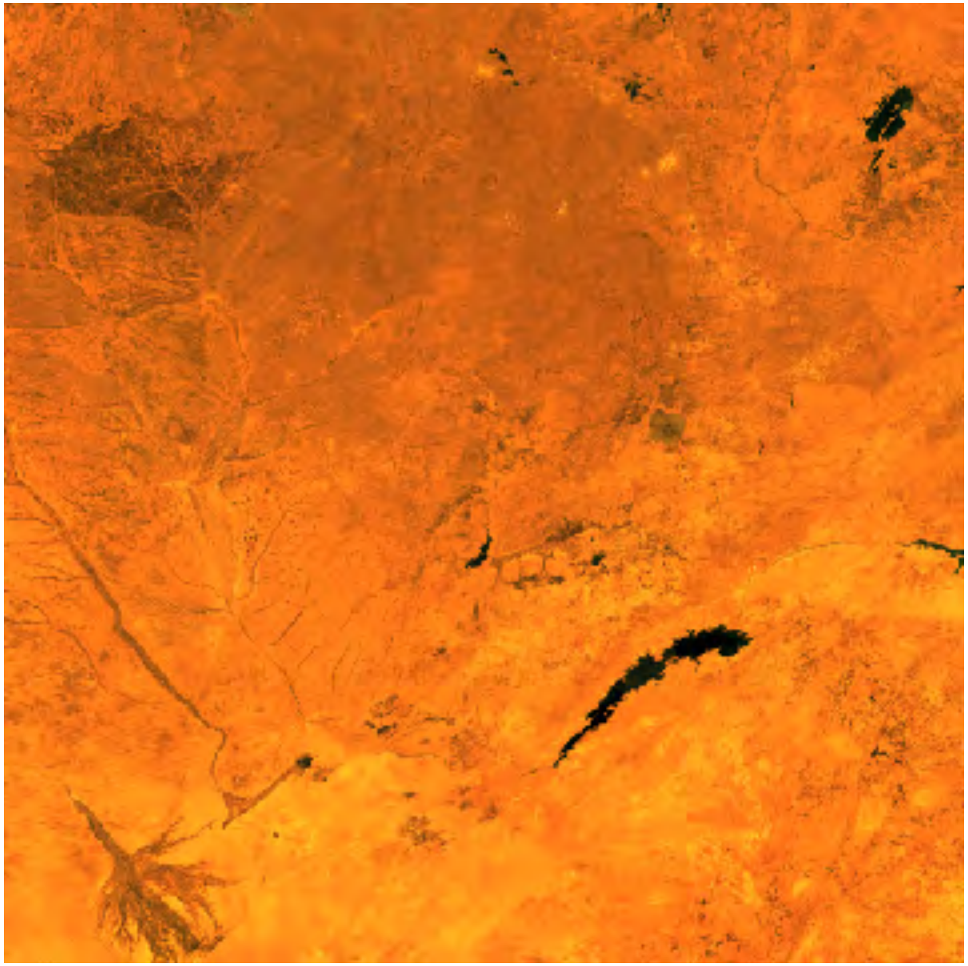
VIS/NIR soil wetness mapping



Isolines of soil wetness as defined by soil brightness (PC1) and surface wetness (PC4)

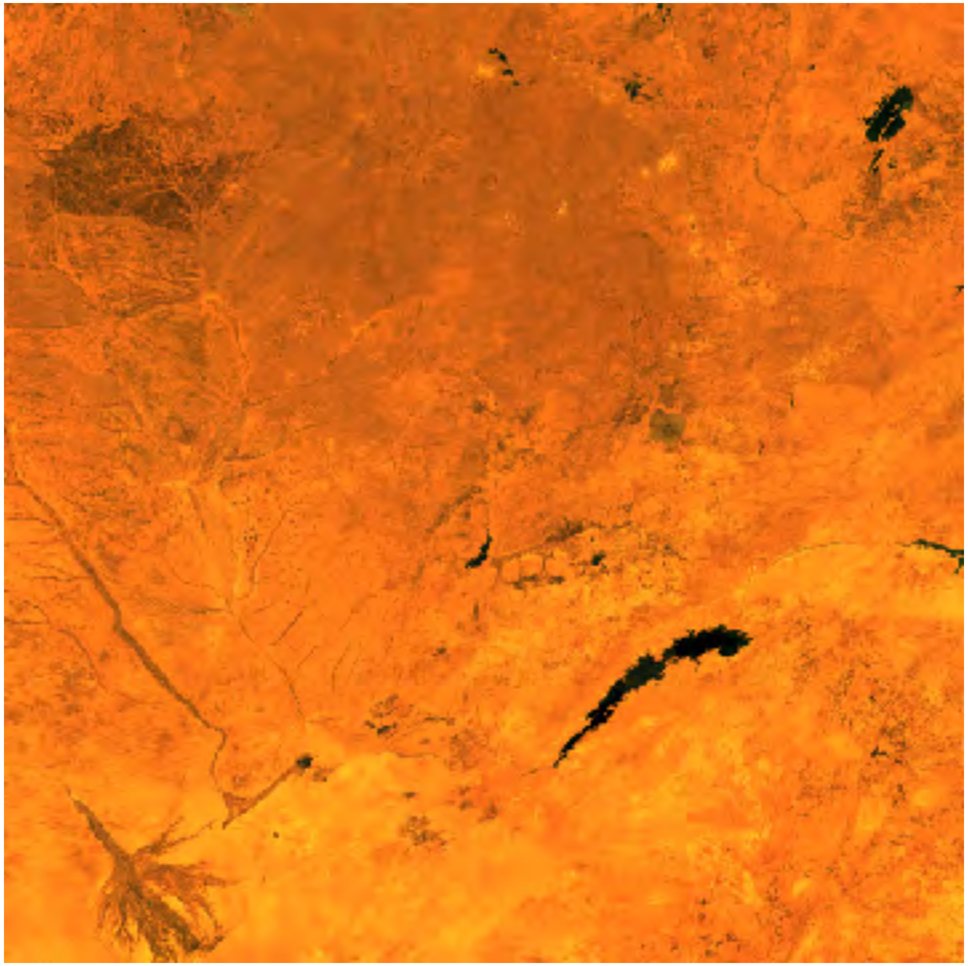
VIS/NIR soil wetness mapping

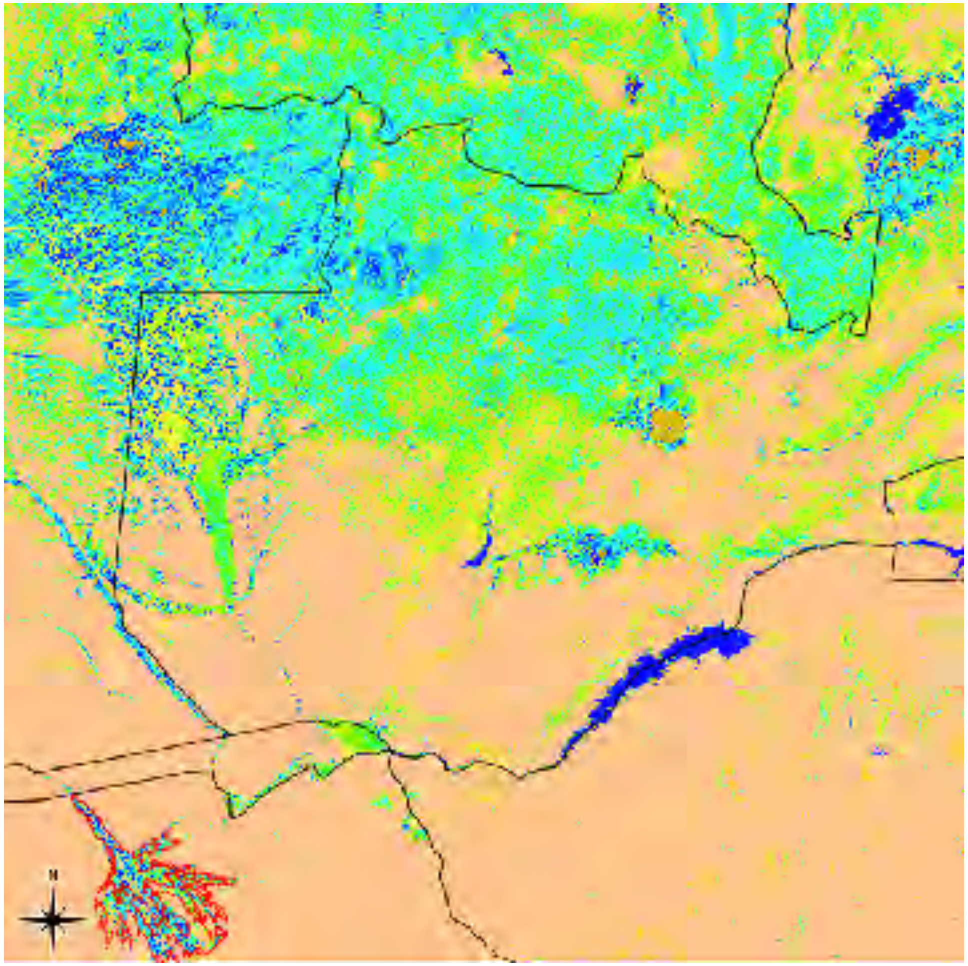




The adoption of PCA can be regarded as a kind of pixel-unmixing, where the vegetation parts of the optical VIS/NIR reflectance is removed. The soil wetness index is based on the image to the right (recomposed from the PCs, excluding vegetation components).

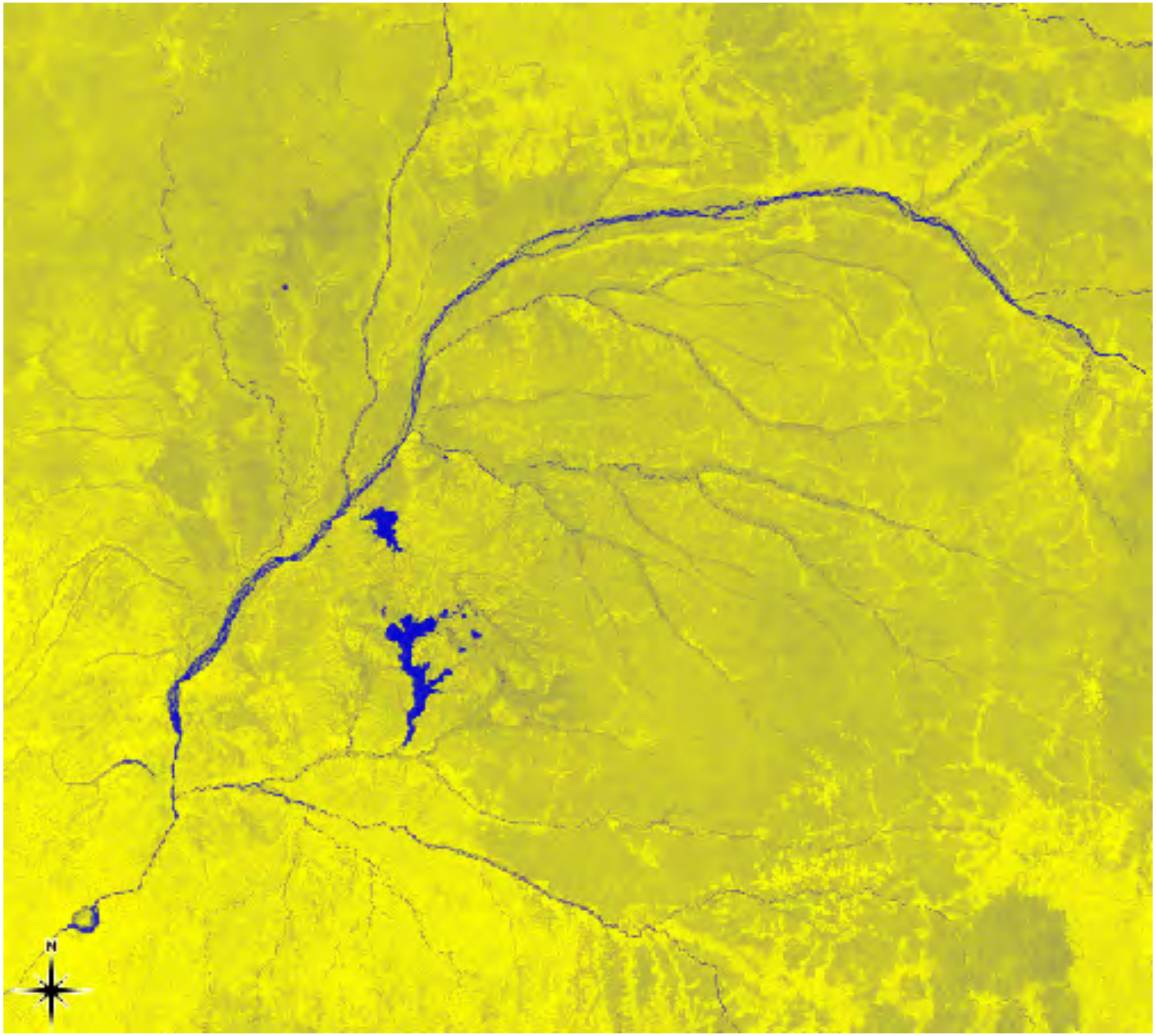
VIS/NIR soil wetness mapping





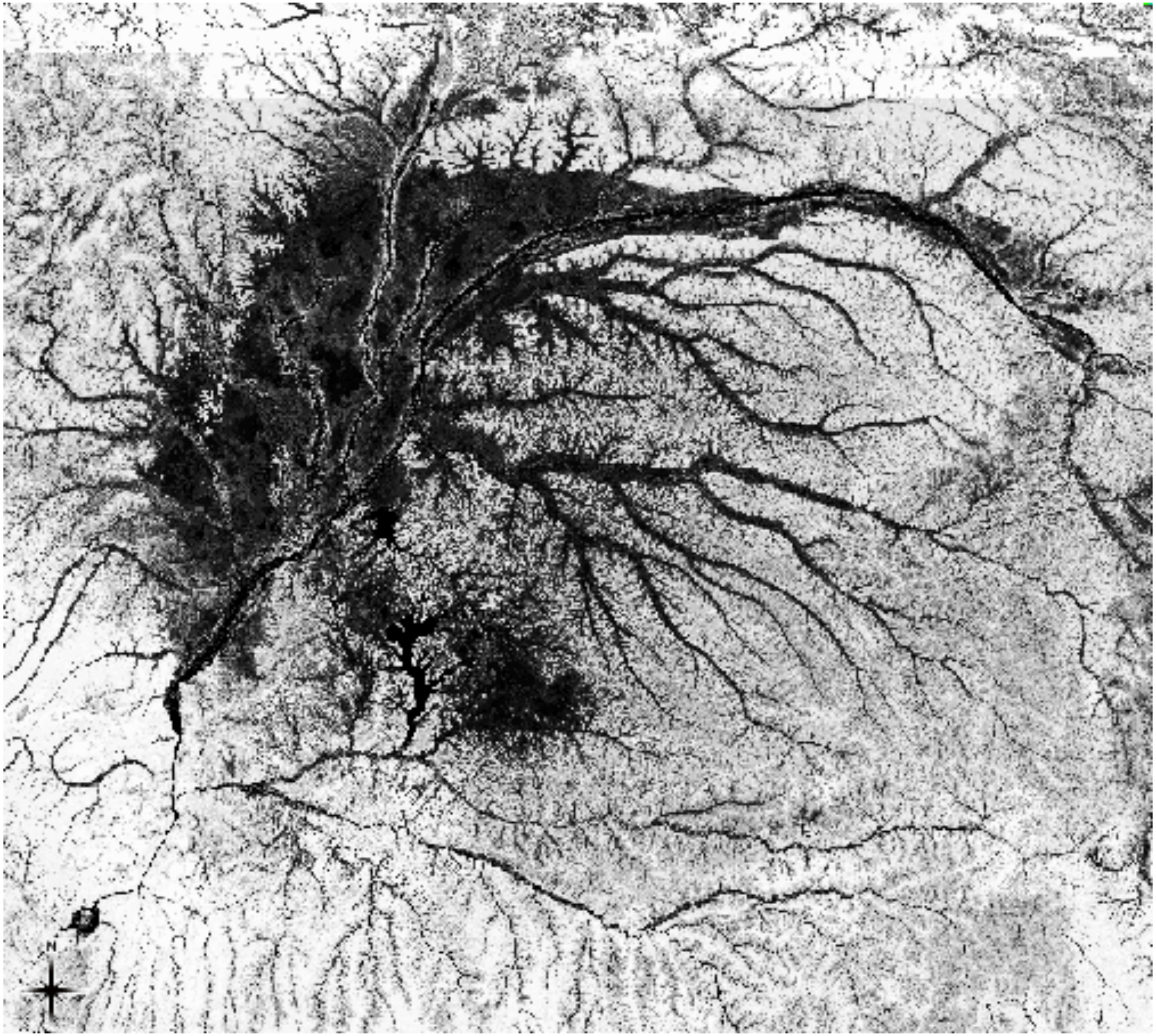
Wetness volume for 2011, tile h20v10 (Angola, Botswana, Namibia, Zambia and Zimbabwe), the Okavango Delta (Botswana) is outlined in red (lower left corner). The Okavango Delta is captured as a wet environment midst the dry Kalahari Desert..

VIS/NIR soil wetness mapping



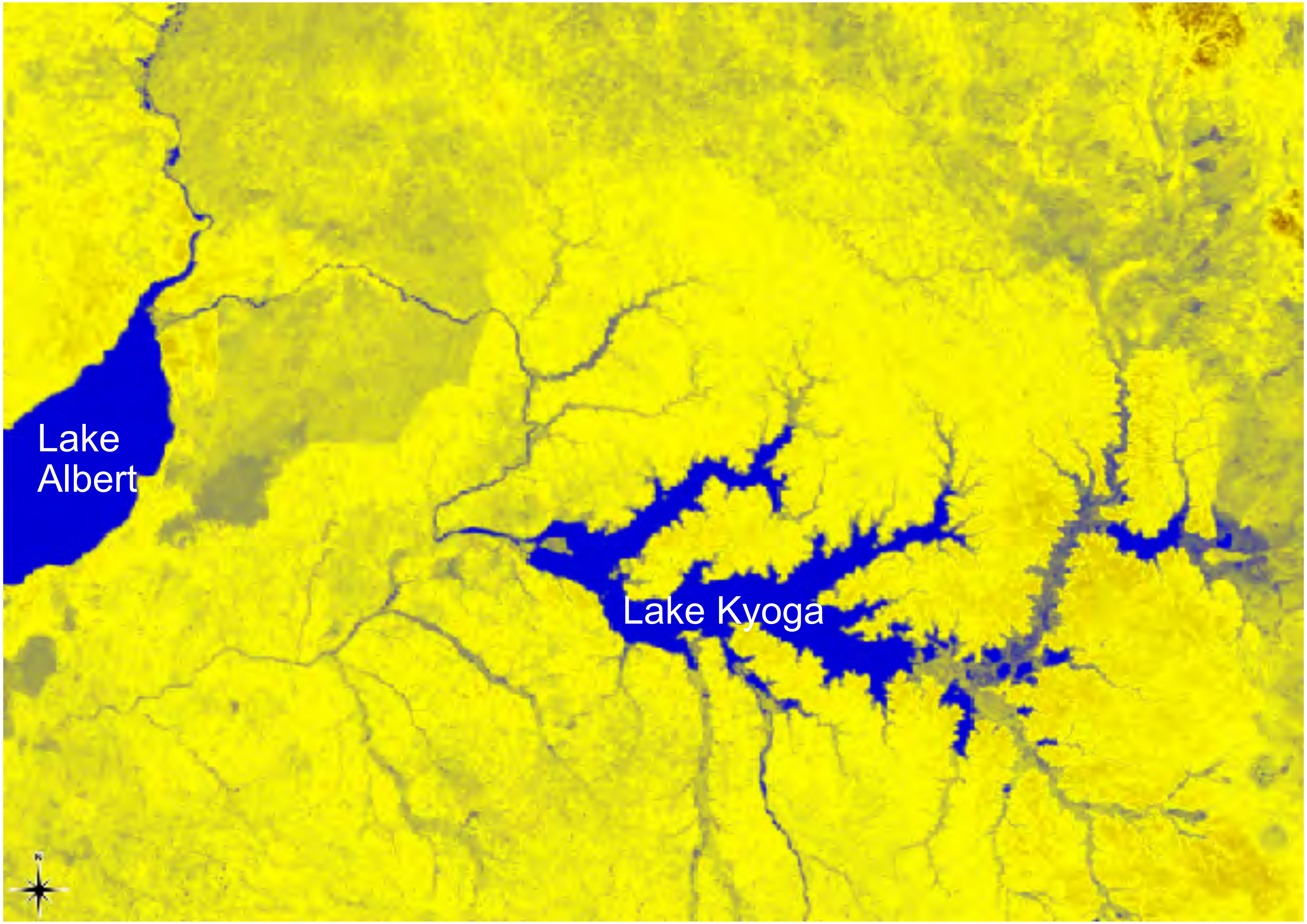
Soil wetness (wetness volume, 2011) for the central Congo Basin. Darker (blue) indicates wetter conditions.

VIS/NIR soil wetness mapping



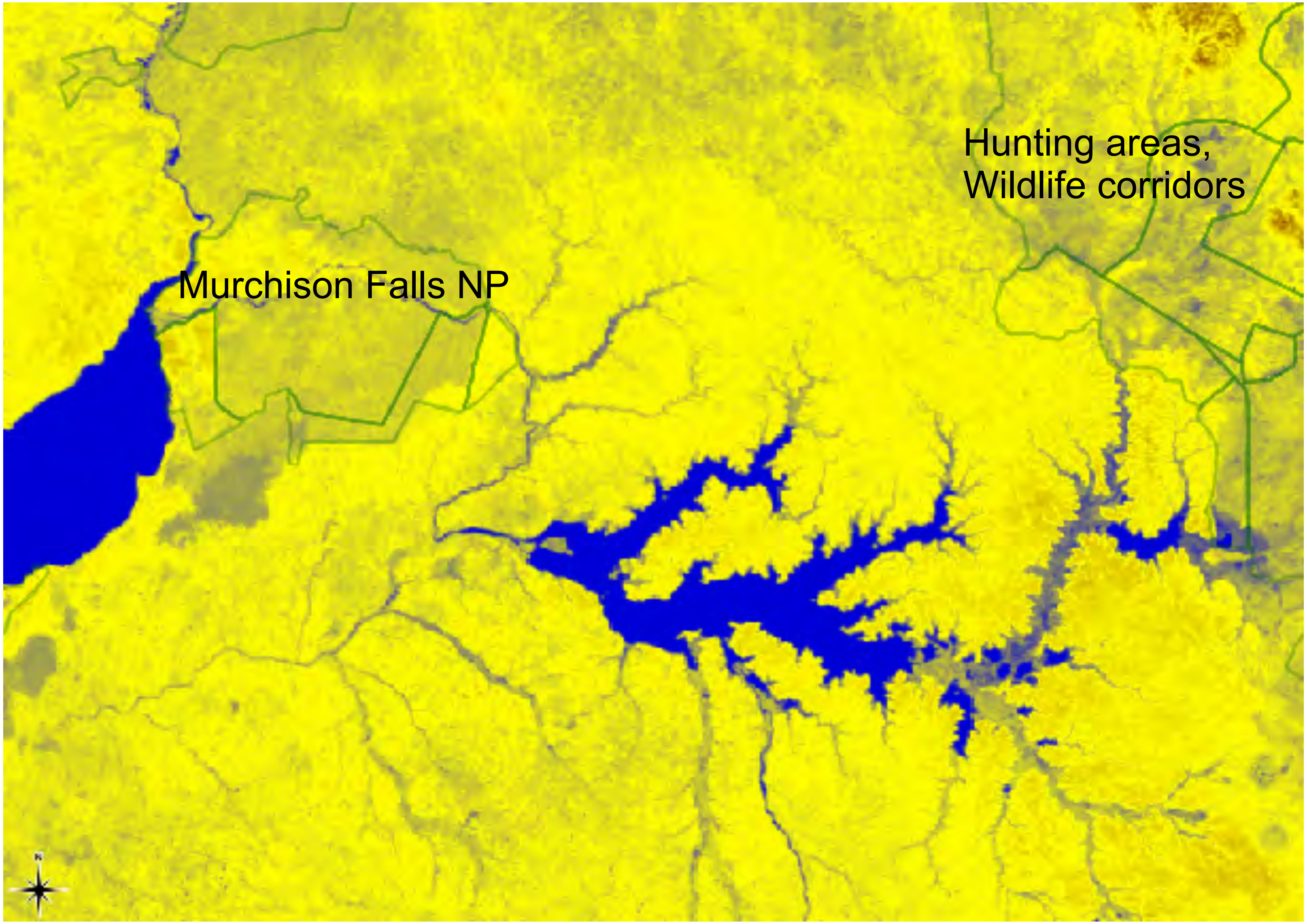
Wetland likelihood map from Bwangoy et al (2010) over the central Congo basin.

VIS/NIR soil wetness mapping



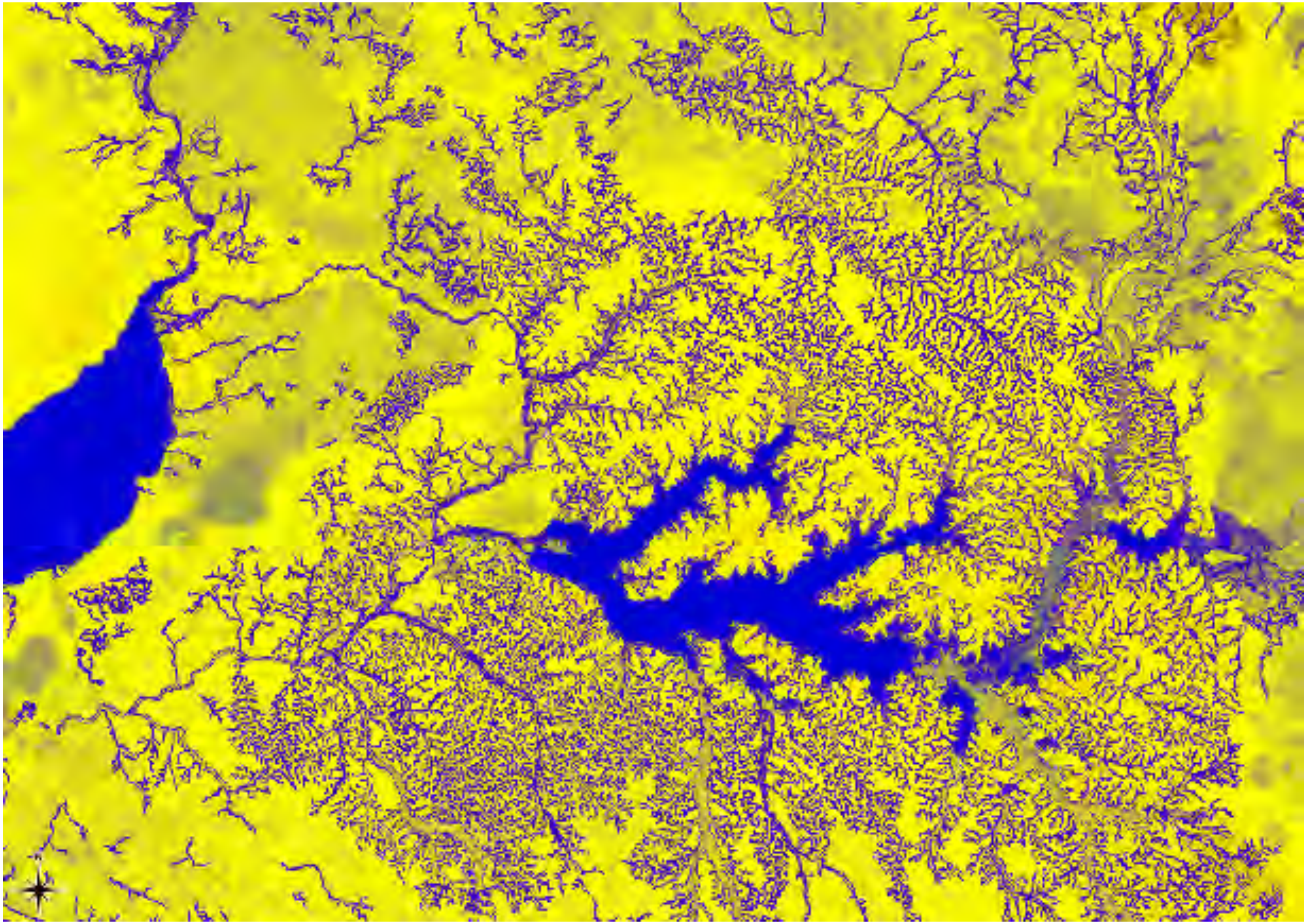
Soil wetness (maximum wetness, 2011) for central Uganda
(Lakes Kyoga and Albert)

VIS/NIR soil wetness mapping



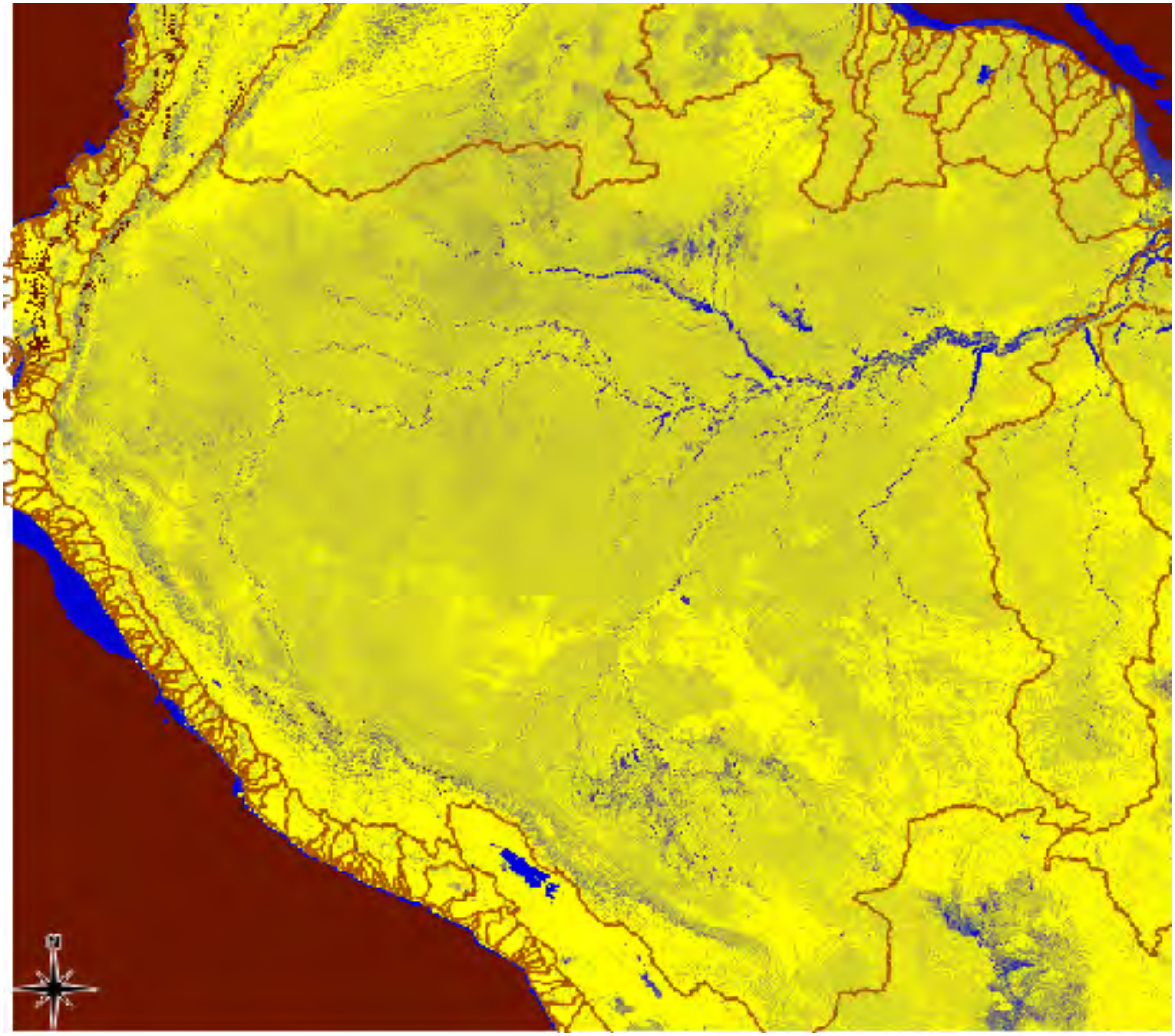
Soil wetness (maximum wetness, 2011) for central Uganda (Lakes Kyoga and Albert)

VIS/NIR soil wetness mapping



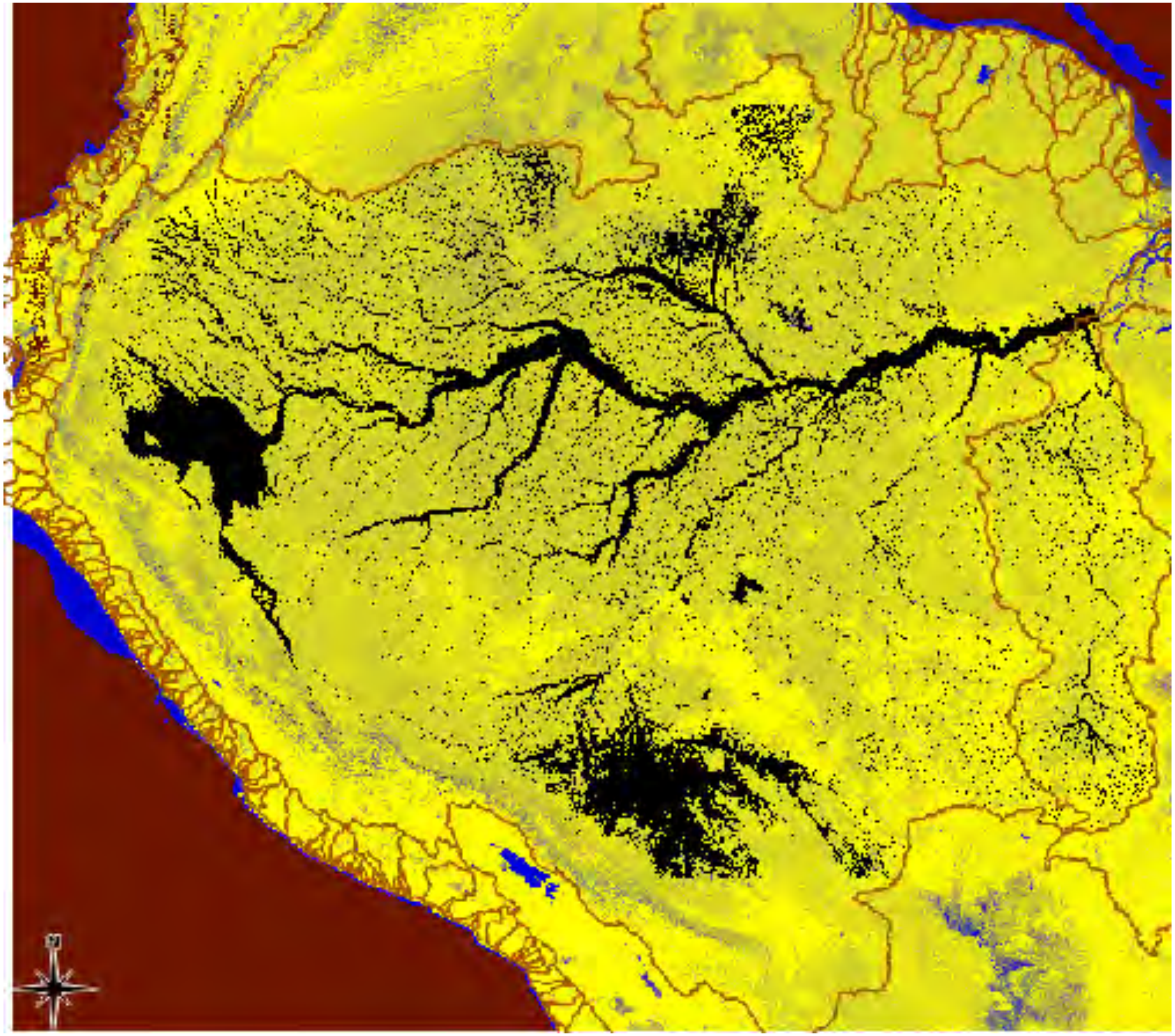
Soil wetness (maximum wetness, 2011) for central Uganda (Lakes Kyoga and Albert) – Africover wetlands

VIS/NIR soil wetness mapping



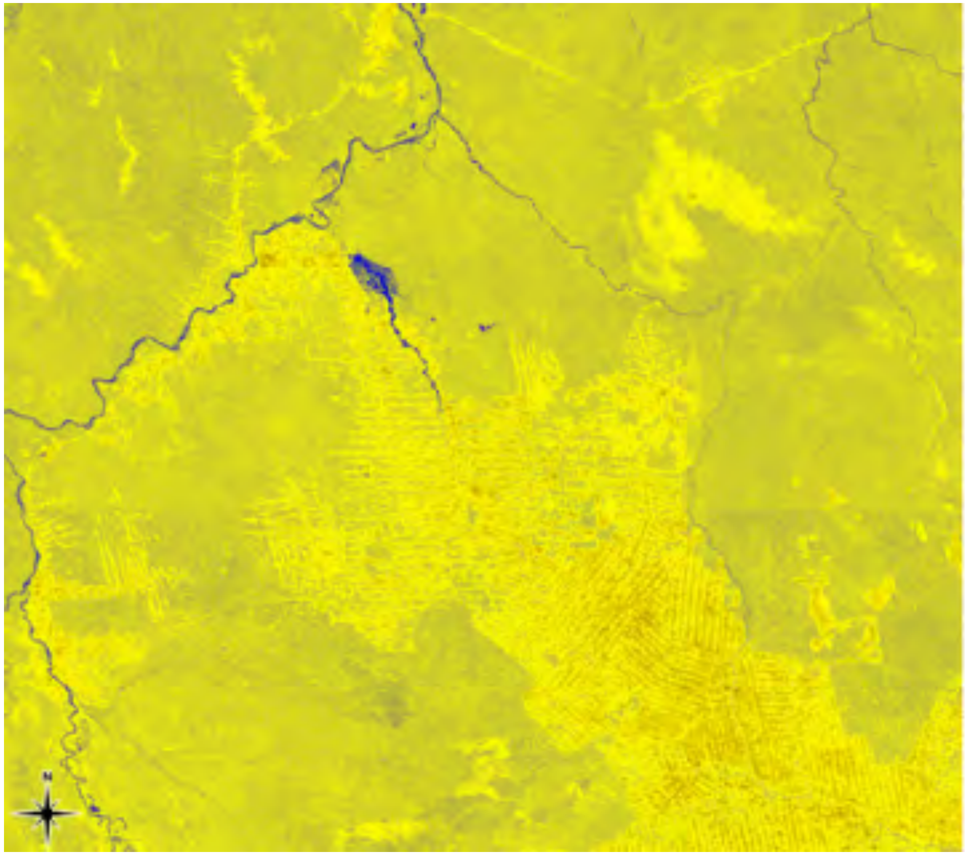
Soil wetness (wetness volume, 2011) for the Amazon Basin

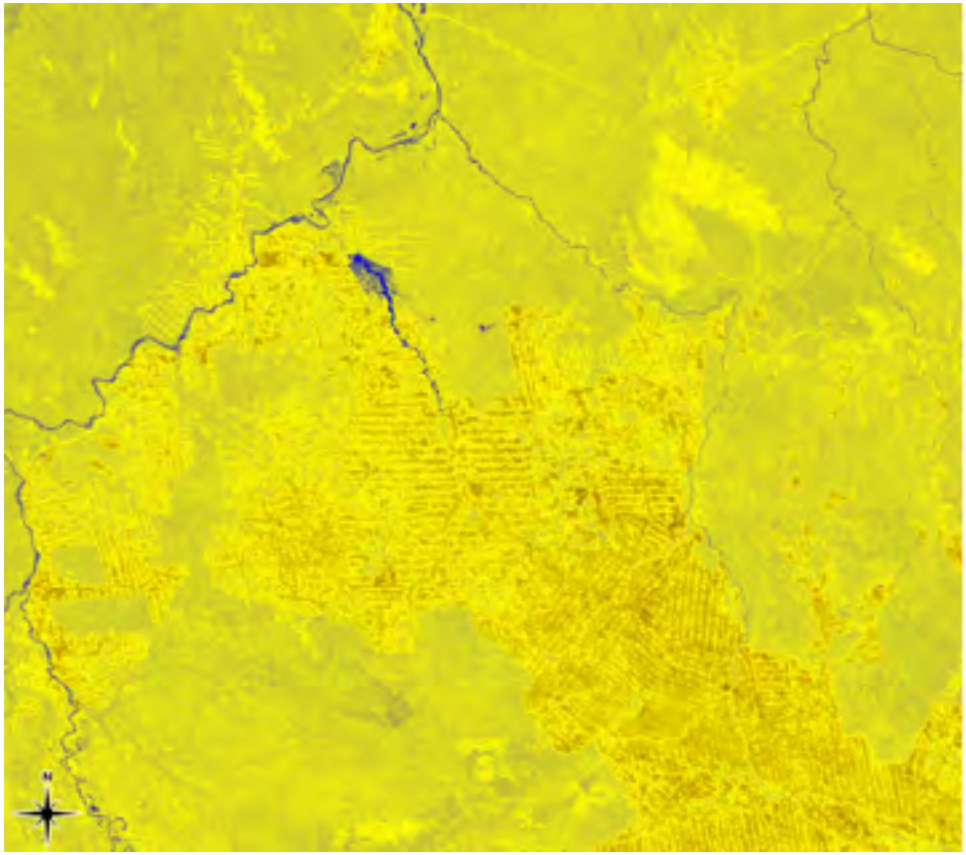
VIS/NIR soil wetness mapping



Soil wetness (wetness volume, 2011) for the Amazon Basin. Black area is the ORNL radar derived wetland (boolean) map from 2000.

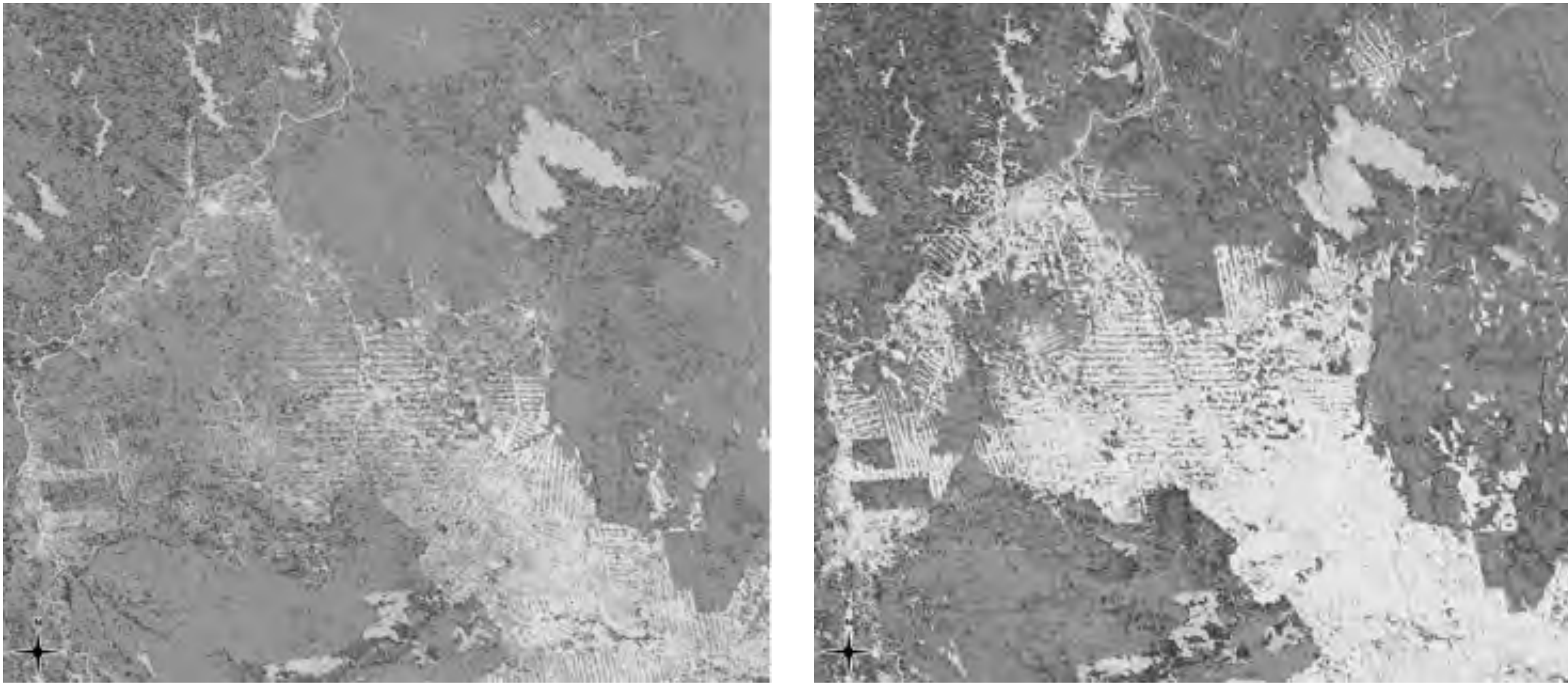
VIS/NIR soil wetness mapping





Change in soil wetness between 2001 (left) and 2011 (right)
for an area in the Central Amazon Basin

Mapping SOC from VIS/NIR spectra



Soil Organic Carbon content 2001 (left) and 2011 (right), mapped from the VIS/NIR reflectance data using a decision tree approach calibrated with data from AfSIS. Image courtesy of Tor-Gunnar Vågen, ICRAF, Kenya.

Climate-Topographic wetness

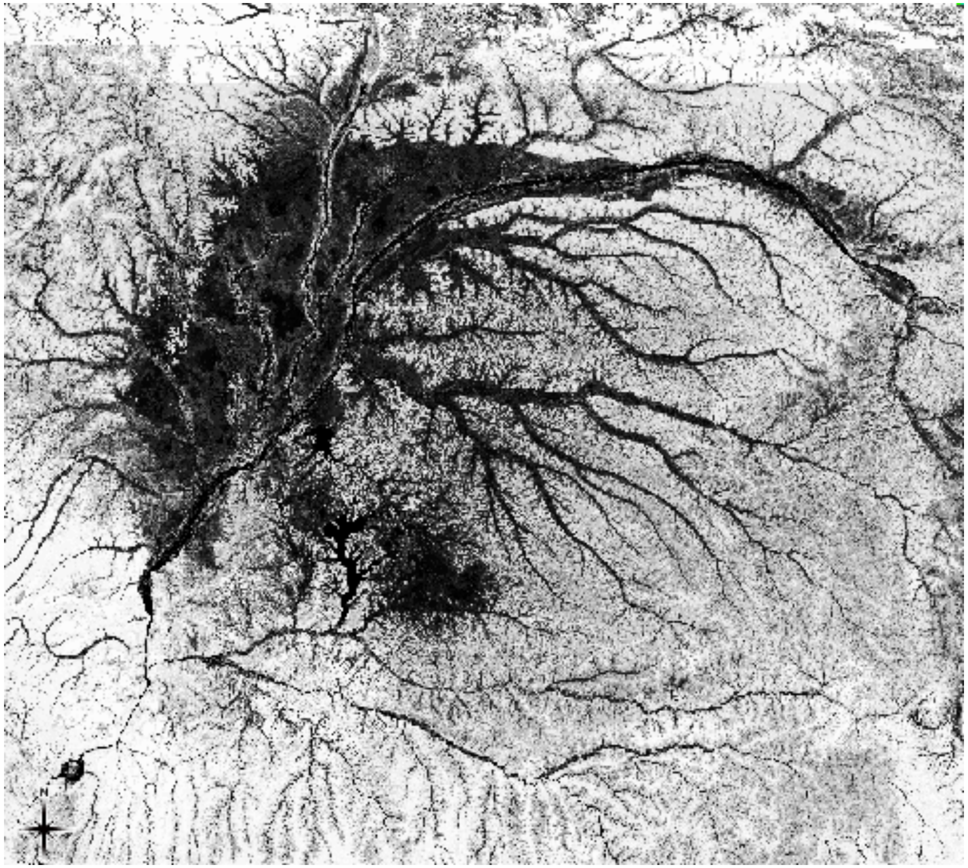
Generic Climate-Topographic wetness index:

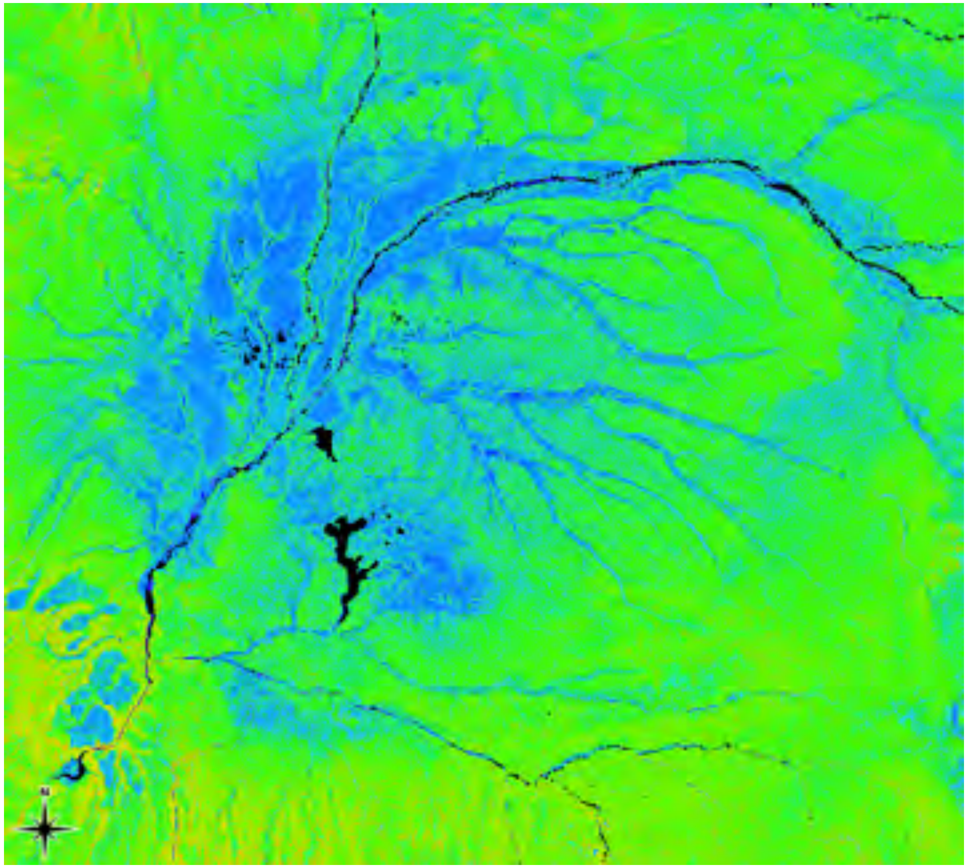
- Global estimations of runoff per cell and river basin
- Local landscape element definition
- Combination of upstream inflow, neighborhood runon and local cell rainfall, curvature and slope.

$$GTI = \ln\left[\frac{\left(\frac{Rrun * \sqrt{A_u}}{b} + \frac{Retadj * \sqrt{A_n}}{b} + Ret * 0.5\right)}{(\tan \mathrm{B} * Curvfac)}\right]$$

where A_u is the upstream contributing area, A_n is the neighboring contributing area, *b* is the contour length, *Retadj* is the fraction of [total precipitation – efficient precipitation] falling on adjacent (neighboring) cells that reach the local cell, *Ret* is the fraction of local rainfall that is later evapotranspirated, and *Curvfac* is a curvature factor (unity when the curvature in planar, and < 1 when curvature is concave, > 1 when curvature is convex)

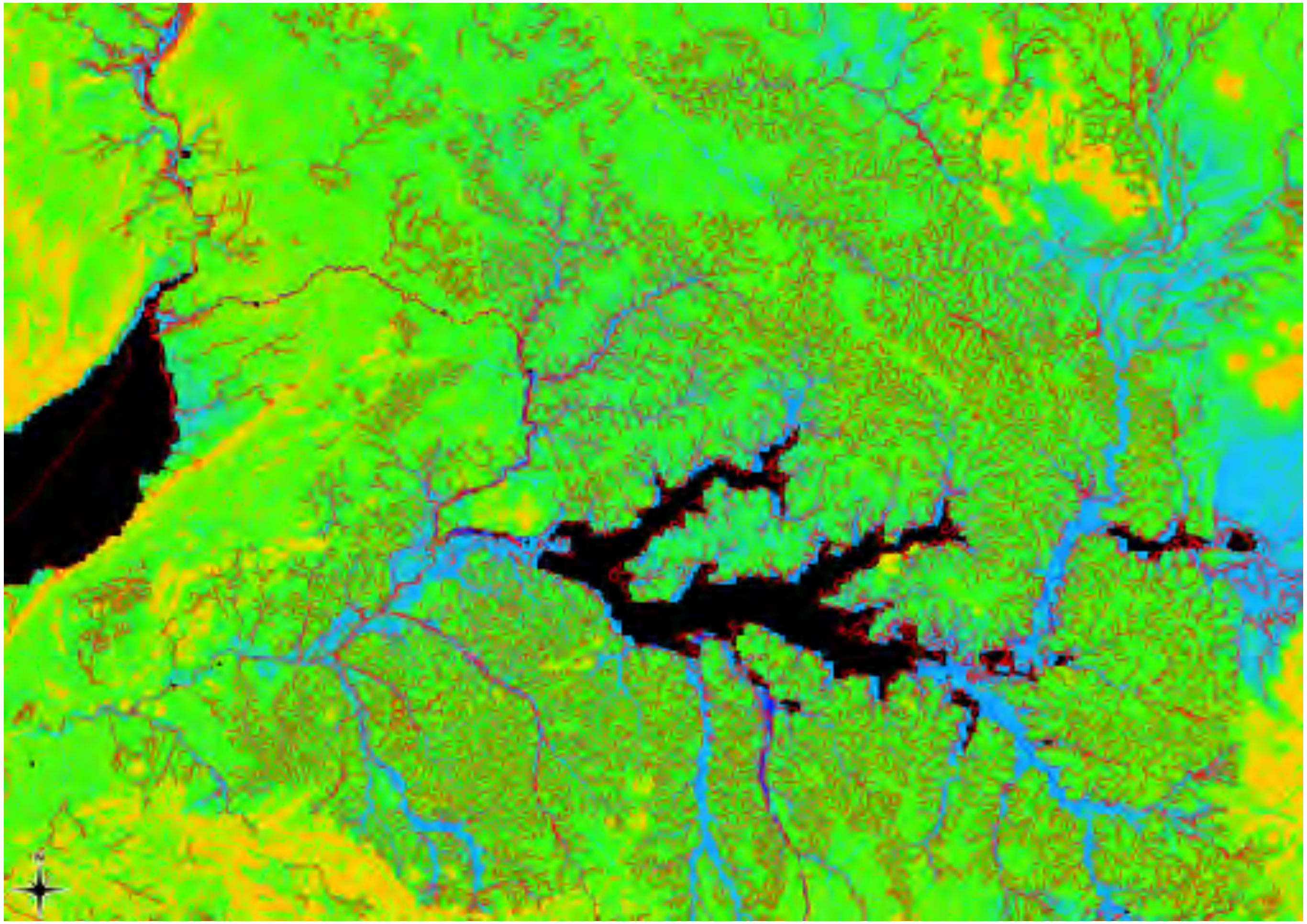
Climate-Topographic wetness

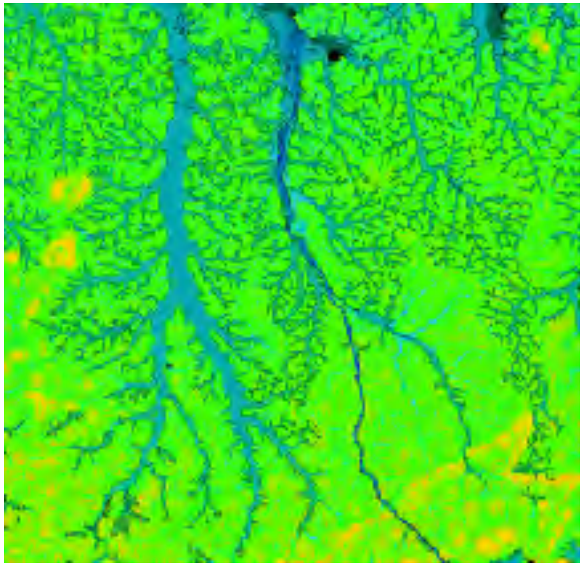




Wetland likelihood map from Bwangoy et al (2010, and the climate-topographic wetness index. Central Congo Basin..

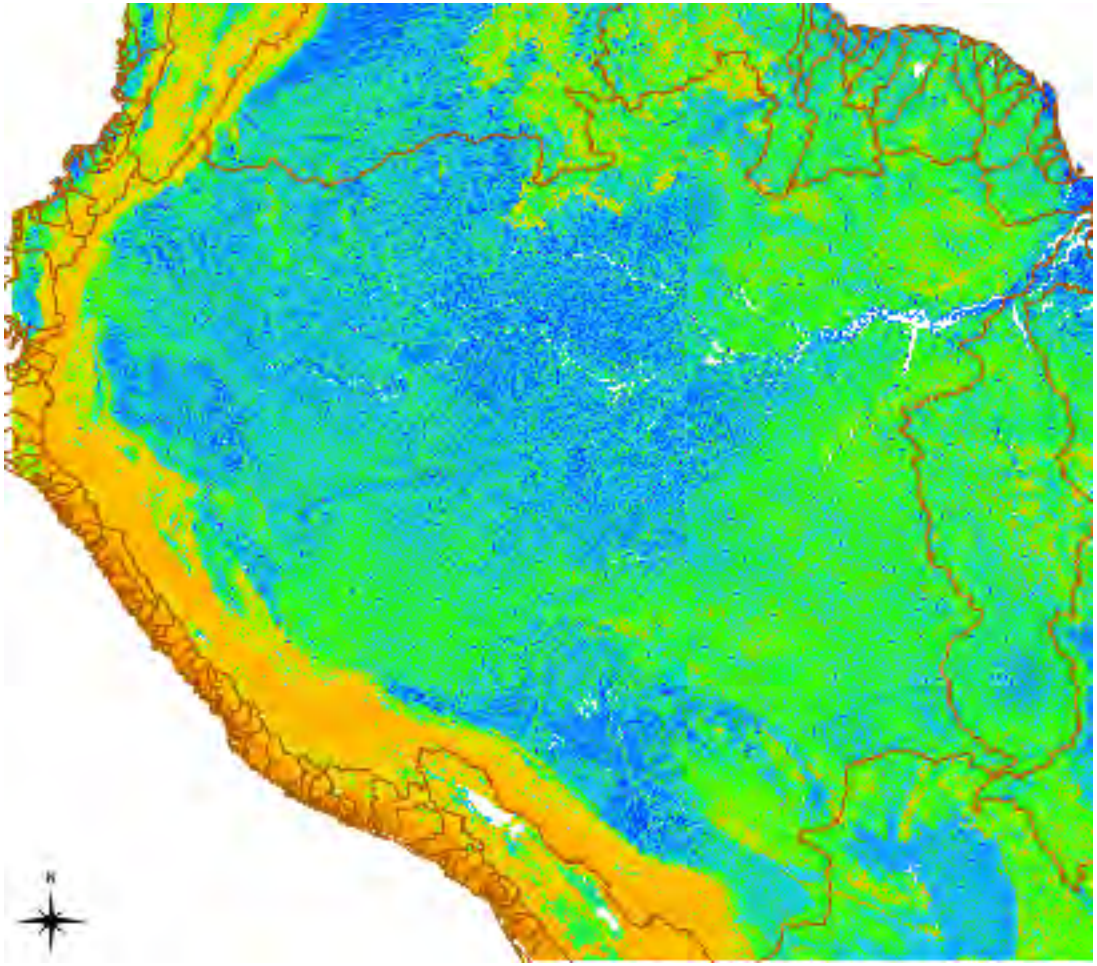
Climate-Topographic wetness





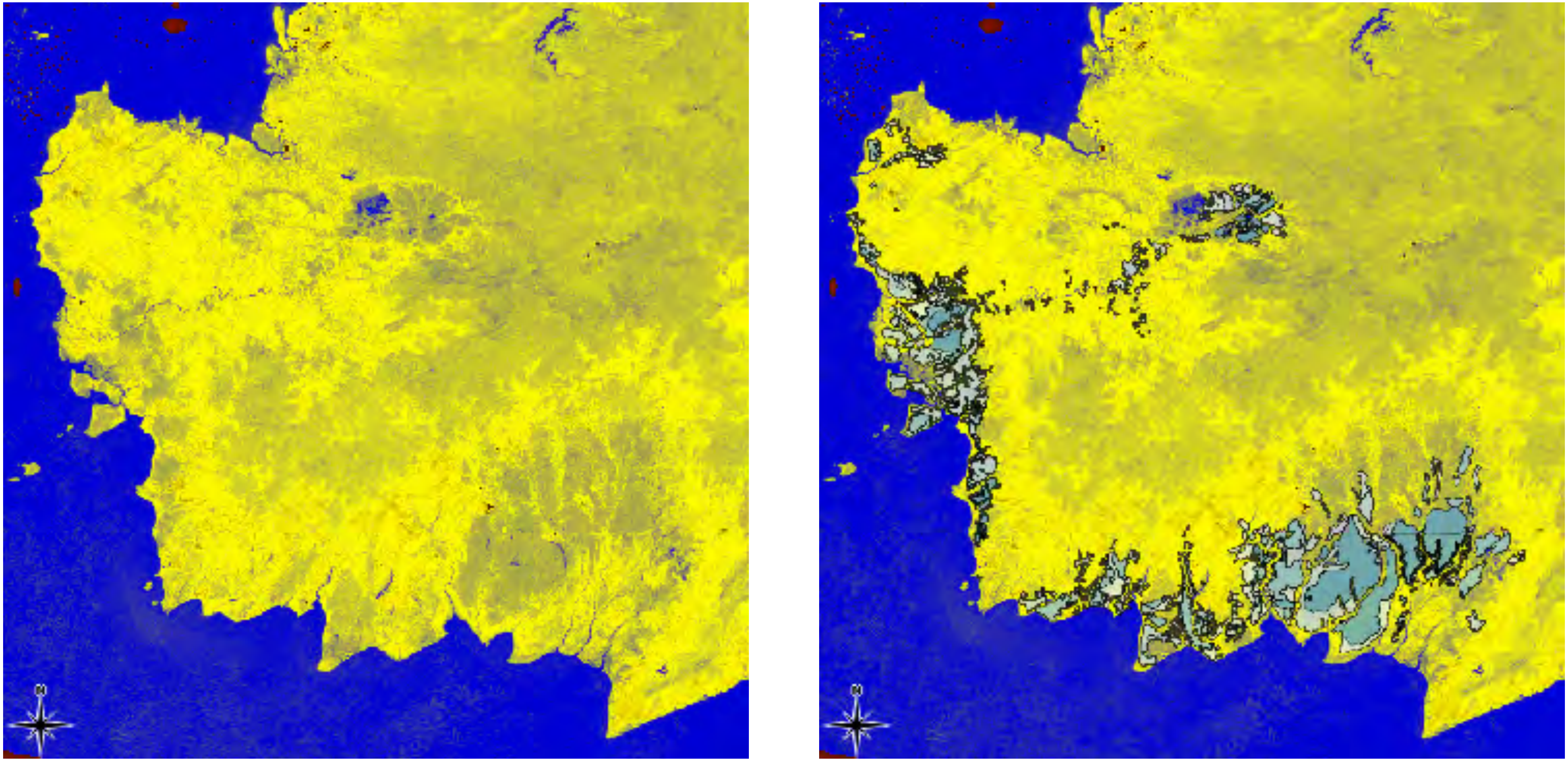
Climate-topographic wetness index for central Uganda (Lakes Albert and Kyoga). Overlay is the wetland class from the FAO Africover dataset. Detail to the right.

Climate-Topographic wetness



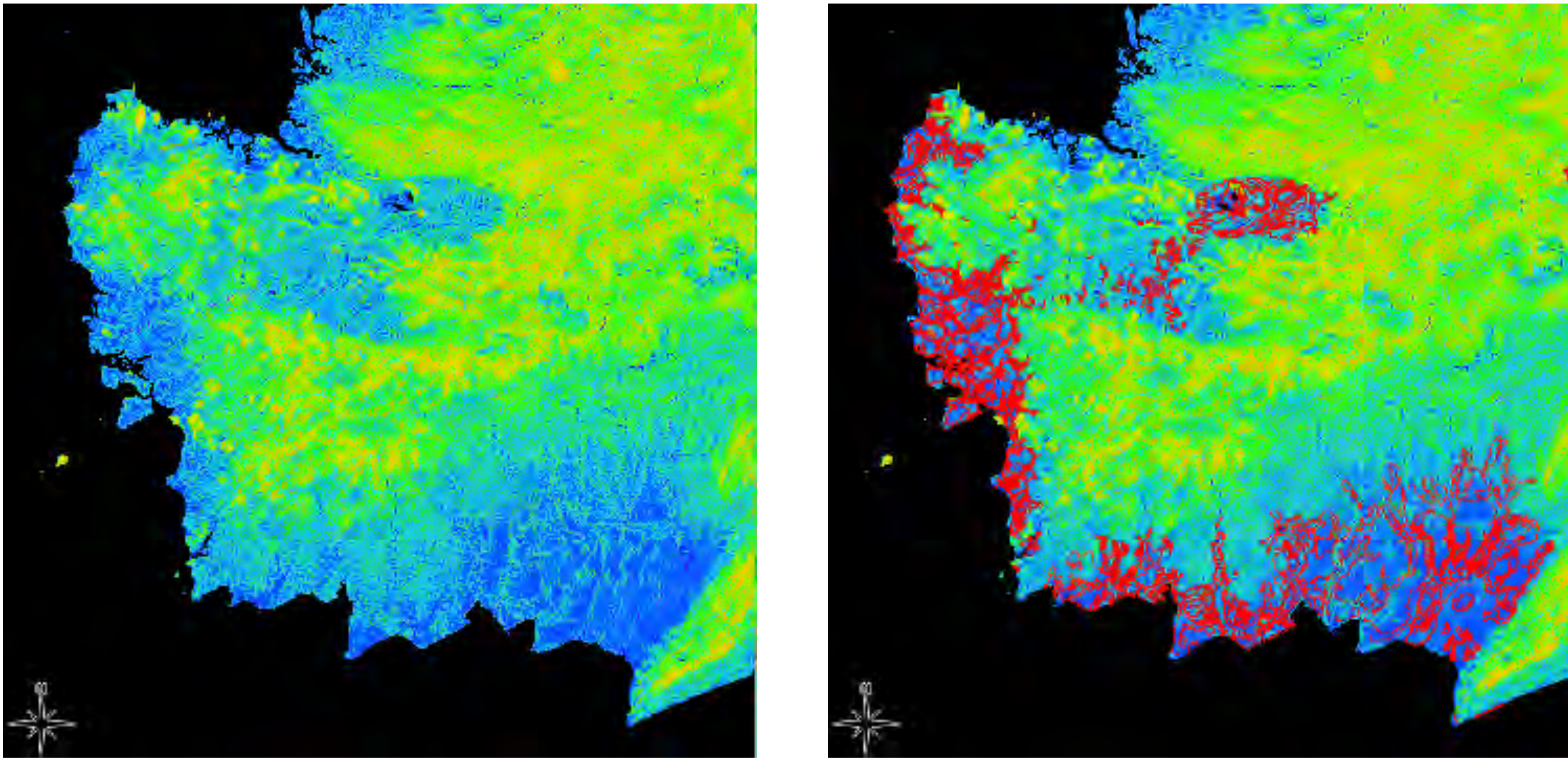
Climate-topographic wetness index for the Amazon Basin.

VIS/NIR soil wetness mapping



Soil wetness index for parts of Kalimantan, Indonesia (2011). Image to the right shows peatlands from the Ministry of Agriculture.

Climate-Topographic wetness



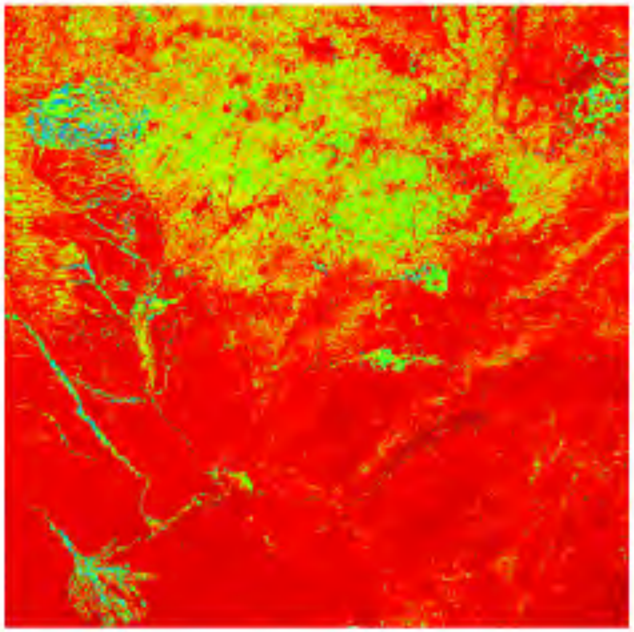
Climate topographic index for parts of Kalimantan, Indonesia (2011). Image to the right shows peatlands from the Ministry of Agriculture.

Chronological SAM classification

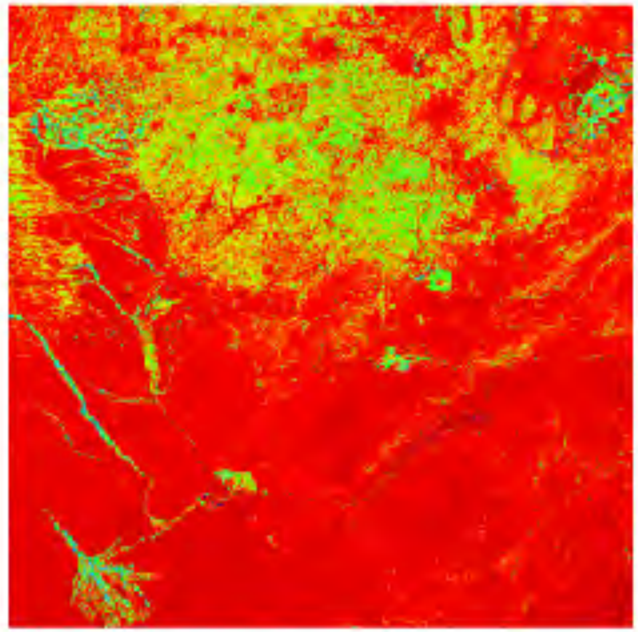
Spectral Angle Mapper (SAM) Chrono-sequence classifier:

- Ground truthed reference sites need to be identified
- For each time-step in a chrono-sequence, images (or regions) are classified based on the reference signal for that particular date
- The accumulated SAM similarity over an annual cycle is used to assign classes to each pixel.
- The system is designed for using reflectance data as input, but ratio-based indices can also be used.
- *Lack of quality assured reference sites has hitherto prevented the actual classification to be performed.*

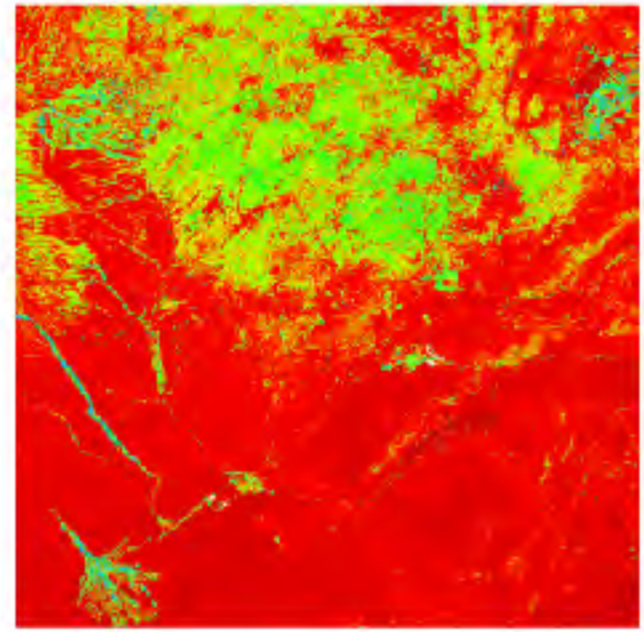
Chronological SAM classification



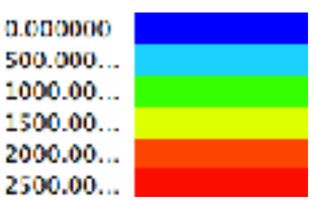
DOY 129



DOY 145



DOY 163



Mapping global tropical wetlands

Concluding remarks:

- The whole system was first developed for using Landsat data, and can in principle adopt any optical sensor data
- I have all the data at global coverage (not just tropical)
- Improvements that could be done include; combining the VIS/NIR wetness index with other remote sensing data like thermal emissivity, radar or microwave images; adoption of better rainfall-runoff data and models.
- Above all, it is the lack of reference data for wetlands (extension, wetness phenology, carbon content, peat depths), that is holding the project finalization back.
- Thanks, and hopefully I did not faint.