From Water Dynamics to Rainfed Landscapes with GRASS GIS

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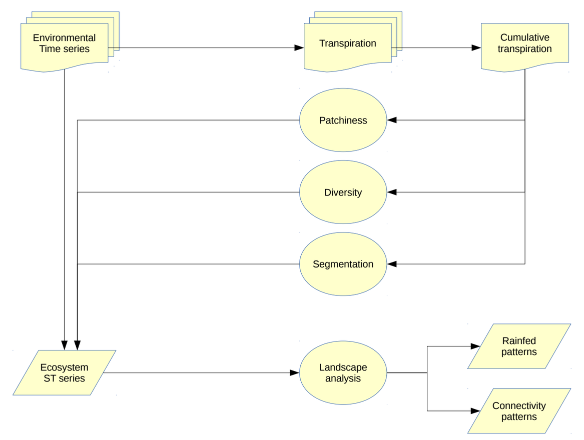
Abstract

Variability in water availability is a key determinant of risk and constraint to productivity in rainfed agricultural systems. Understanding the dynamics of water availability across both spatial and temporal scales is essential to manage water and optimize production. This research proposes to look at both the physical measurement of water availability and water user perceptions of landscapes and water availability.

Evapotranspiration makes up about three quarters of the transiting water in a landscape, it is composed of evaporation (water bodies, soil) and transpiration, the vegetation biomass growing quantity. This work will develop a methodology for defining landscapes based on water dynamics to be used at the interface of WLE research. The GRASS GIS [1] Imagery (i.*), Landscape (r.li.*) and Temporal (t.*) toolkits form the basis of the methodological development, from evapotranspiration modeling and landscape analysis to spatio-temporal analysis.

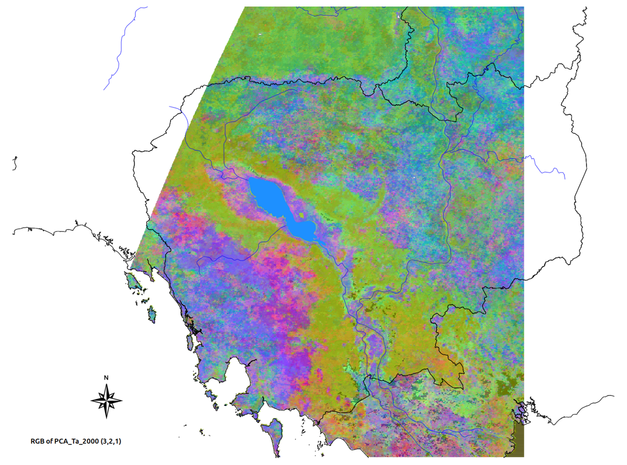
The methodology will be complemented by time series analysis spanning 14 years up to near real-time (2000-2014) of MODIS vegetation index data, capable of distinguishing seasonal and long term trends in these landscapes. This analysis will be developed into a routine that can be executed in open source GIS (GDAL [2] tools and GRASS GIS [1]), providing a robust and readily available application for monitoring medium to large scale land use and land cover change over any desired area.

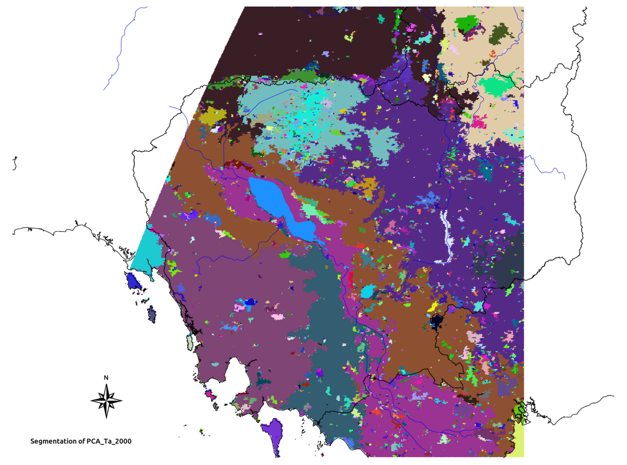
Transpiration and the search for rainfed landscapes



The transpiration data is created from energy balance modelling [3] modules (i.eb.*, i.evapo.*) within GRASS GIS version 7, by partitioning the net radiation (r.sun) into soil heat flux (i.eb.soilheatflux), sensible heat flux (i.eb.h.*) and the residual being the energy needed to evaporate water (i.eb.evapfr, i.eb.eta). This information is then fractionated into biotic (transpiration) and abiotic (evaporation) parts using vegetation fraction.

The accumulated transpiration (t.rast.aggregate) is subjected to Landscape analysis (r.li.*, inspired from [4]) for search of patchiness and diversity indices (not shown). Further analysis of transpiration is also done with the object oriented classifier (i.segment) for spatiotemporal objects within the transpiration original dataset, the accumulated one and the Landscape indices, respectively.





Using the 50 first PCA components of the Transpiration data for year 2000, the object types that can be extracted by object-based classification were analysed. It turns out that the recession cropping around Tonle Sap and the rainfed cropping systems of Eastern Thailand are clearly extracted. However, the recession cropping in Tonle Sap only has one main class, which is different when using 2000-2014 EVI PCA classification (central part of the poster). It is thought that both the 500x500m resolution and the yearly changes in flooding height in Tonle Sap are driving the separation of the recession cropping area, thus not seen here with one year (2000) and 1x1km pixel size.

References

[1] Neteler & Bowman & Landa & Metz, 2012. Environment & Modeling Software, 31:124-130
[2] GDAL, 2014. http://gdal.osgeo.org
[3] Chemin, 2012. Chapter 19, DOI: 10.5772/23571 (http://bit.ly/16qJ0ep)
[4] McGarigal & Marks, 1995. FRAGSTATS. USDA For. Serv. Gen. Tech. Rep. PNW-351.
[5] Momsen & Metz, 2012. GSoC project: Segmentation algorithm.
[6] Eastman & Fulk, 1993. Photogramm. Eng. Remote Sens. 59(8), 1307-1312.
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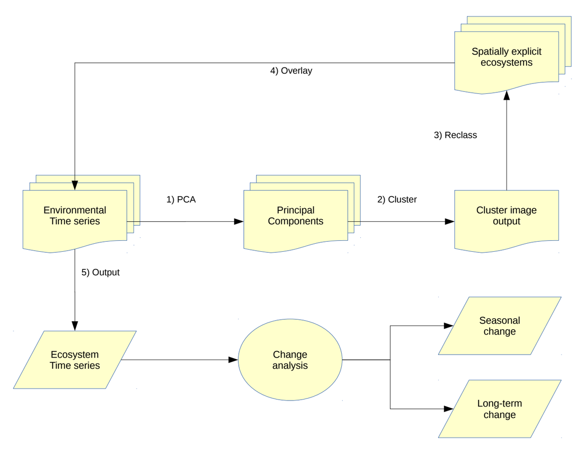
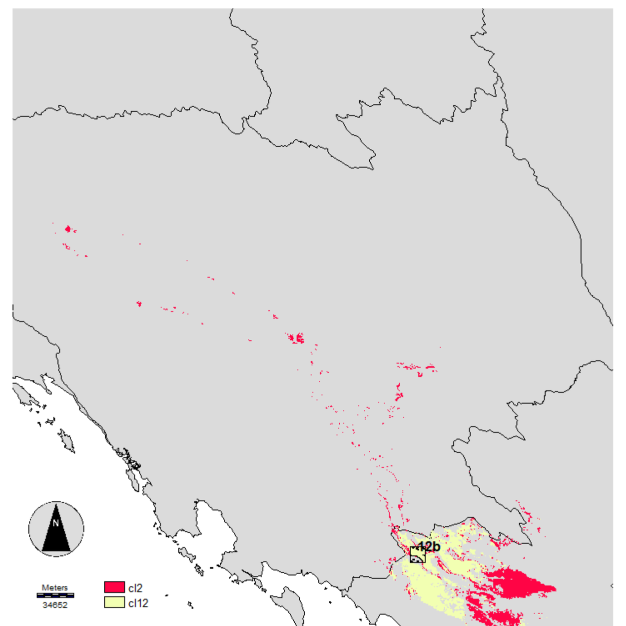
Temporal PCA-based classification

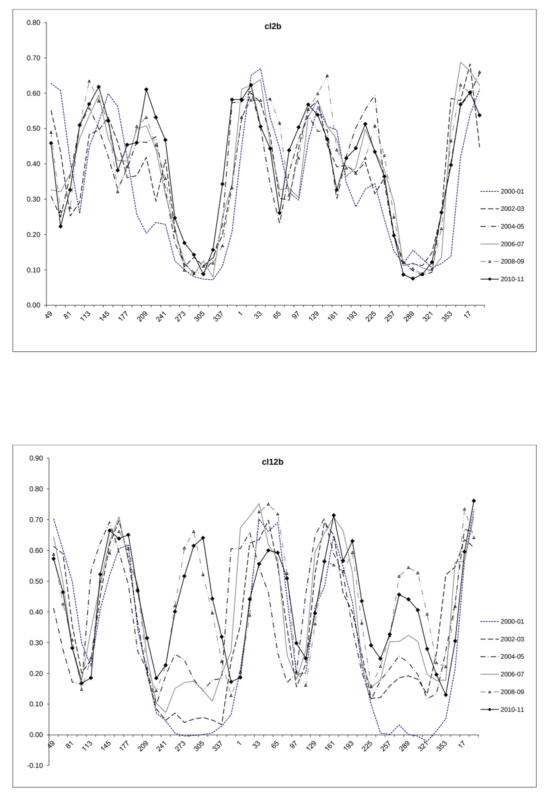


Long sequence time series PCA provides a comprehensive indicator of change events in time series of spatial environmental data (Eastman & Fulk 1993)1. Principal Components Analysis undertakes linear transformation of a set of image bands to create a new set of images that are uncorrelated. This set of principal component images can be considered equivalent to bands of a multi-spectral image. Each image represents a different portion of spectral variability in the original image data set. The clusters yielded by subjecting the PCA component images to iterative self-organising cluster routine each express a particular signature, corresponding to a unique combination of characteristics in terms of the environmental variable under study.

The methodology involves the following steps: 1) a time series of EVI composites is subjected to PCA; 2) the Principal Component images explaining most (ca. 95%) of spatio-temporal variation in the time series, are used as input layers or 'bands' in the iterative self-organising cluster routine; 3) for each spatial cluster in the image output a Boolean mask is created and 4) overlaid (multiplied) with the original time series, which results in 5) a VI time series for each cluster in the output. Analysis of the temporal signature for each cluster reveals seasonal or long-term trends in VI that occur within the system.

Temporal PCA-based classification





This application employs a time series of MODIS EVI 16-day composites at 500 m resolution (MOD13A1) running over 14 years (2000 to near real-time). The h28v07 tile covers large part of the Mekong River Basin in Southeast Asia. We analyse a subset covering the Vietnamese Mekong Delta (VMD) and the Tonle Sap in Cambodia (TSC).
The results discern large areas in VMD dominated by irrigated triple crop rice agro-ecosystems, followed by seasonal flooding near the end of each year, as well as long-term change from double cropping to triple cropping in adjacent areas from 2008 onward.

Acknowledgements

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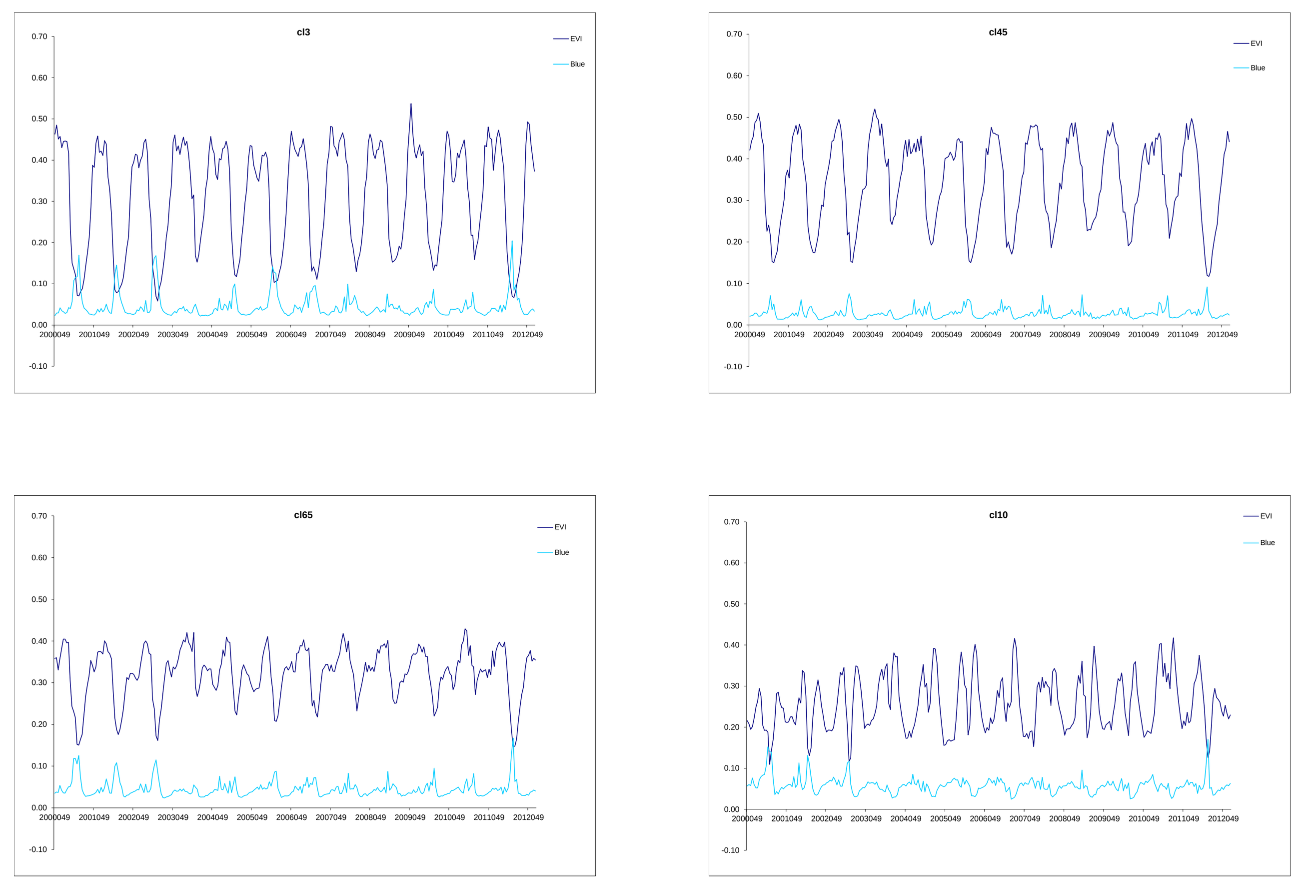
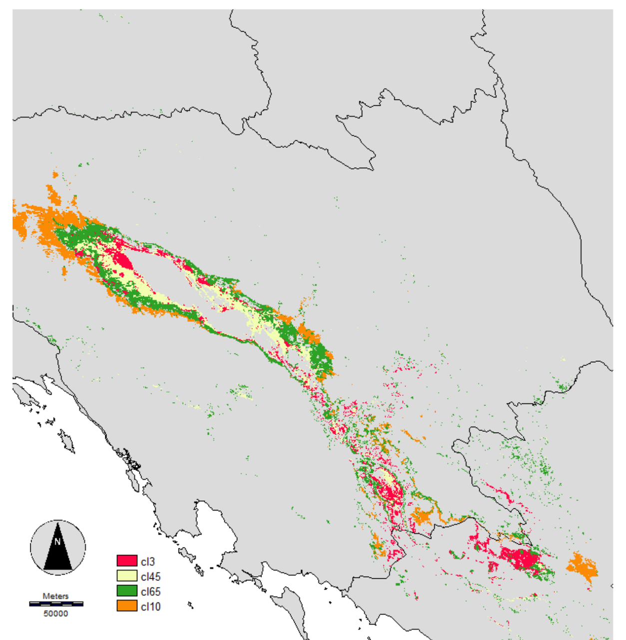
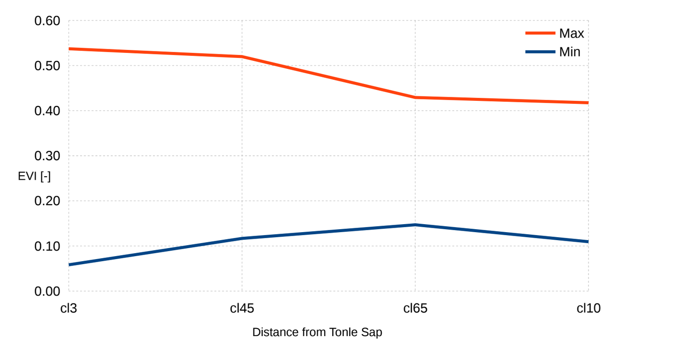
From recession cropping (UL) to natural vegetation (LR)



Temporal patterns of recession cropping & natural vegetation



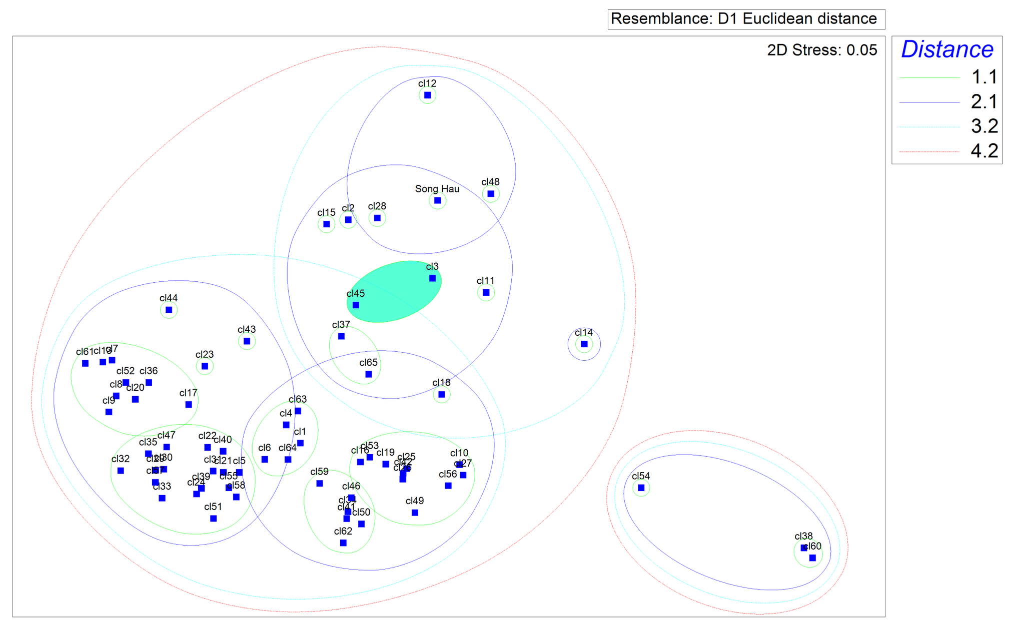


The results for TSC show that the range between EVI_{min} and EVI_{max} in floodplains surrounding the Tonle Sap Lake decreases spatially with distance from dry season margins of the lake. This pattern is indicative of flood recession cropping systems and seasonally flooded natural vegetation around the lake, which expands dramatically in size during the wet season each year, inundating large areas of floodplain, which drain towards the dry season. We used the blue band of MOD13 to provide an additional indicator of flooding, handling the assumption of seasonal flood occurrence if 'Blue' approaches or exceeds 'EVI'. The results in TSC do not discern any long-term trends in land cover and land use.

GRASS GIS script for MODIS PCA & segmentation of PCA

```
#Select MODIS EVI archive
i.group group=pca_group input=$(g.mlist type=rast pattern=*h28v07*EVI)
#Run the PCA on the EVI archive
i.pca input=pca_group output_prefix=pca percent=99 --o
#As an example, you can select the 1st to the 9th PCA members
i.group group=ta_group input=$(g.mlist type=rast pattern=pca.[123456789] sep=,)
#and run an object-based classification analysis on them
i.segment group=ta_group output=seg_ta threshold=0.9 memory=5000 iterations=50 --o &
```

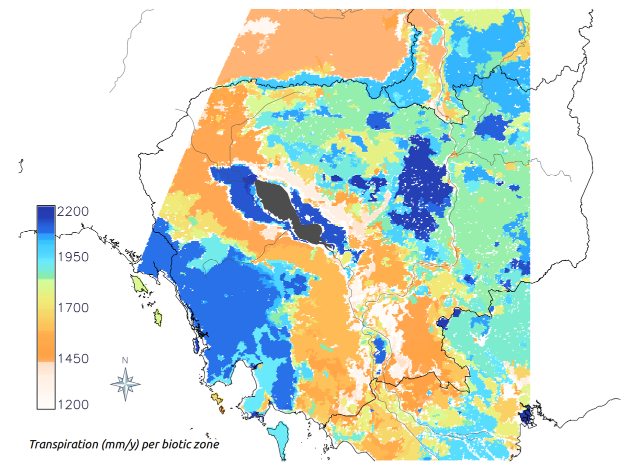
Non-metric multidimensional scaling

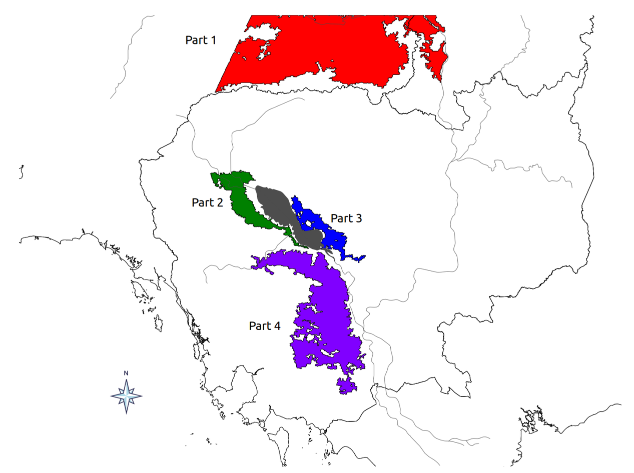


We employ a non-parametric multivariate method to display the relative dissimilarity between these a priori defined clusters [7]. This non-metric multidimensional scaling (MDS) configuration depicts graphically the dissimilarity between spatio-temporal signatures of the systems under study, from which distinct clusters of landscapes emerge. Similar landscape groups can be distinguished at Euclidean distance of 2.1 or less.

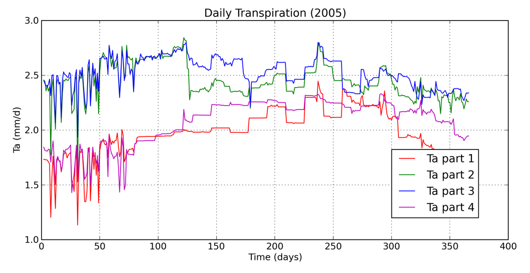
Biotic Zoning

Object based classification (*i.segment*) of the sum transpiration for each year has been done and merged, resulting areas were clumped (*r.clump*) and averaged statistics of yearly transpiration extracted (*r.stats.zonal*).
Rainfed cropping in Isarn (Part 1) is clearly identified from the low transpiration signal (red colour), recession cropping areas around Tonle Sap (Part 2 & 3) have high signals (blue and green) with both noise and a negative impact on transpiration in Part 2 around mid-year (green signal drop). A southern area (Part 4), most probably rainfed, benefits from flood to some extent, it is proposed that some kind of recession cropping is practised, as there is a mid-year transpiration signal raise (violet).





This perspective proposes that irrigated areas along the Mekong may not be transpiring as much as the recession cropping areas around Tonle Sap. Whether the transpiration in recession zones is actually used by crops all the time depends on the opportunity of farming intensification and risk avoidance.



Conclusions

The last ten years have seen intensification of cropping systems in the lower Mekong, where some triple cropping started to be practised. Landscapes relating to non-irrigated cropping systems are rainfed (as found in Isarn) or recession cropping (as found around Tonle Sap). There is a decrease of vegetation index range proportionally to the distance from Tonle Sap, interpreted as the transient surface water creating a reduction of the signal.