Monitoring vegetation dynamics and ecosystem service provision in semi-arid Bobirwa sub-district of Botswana

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Introduction & Study Area

Vegetation dynamics provide a novel way to understand the effect of climate change and human pressure on the delivery of key ecosystem services in data poor regions. Coarse scale analyses using GIMMS NDVI3g data fail to fully account for local level trends. We present a step-by-step methodology to authenticate recent trends (Brandt et. al, 2014) and explain the implications on the delivery of provisioning ecosystem services in semi-arid Bobirwa sub-district in the Limpopo Basin part of Botswana.

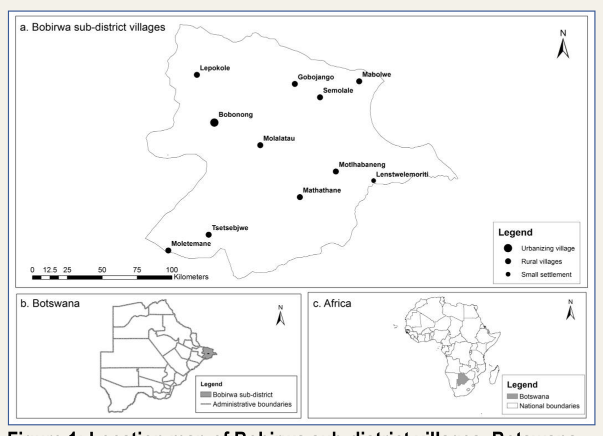

Figure 1: Location map of Bobirwa sub-district villages, Botswana

- Located 21° 58′14″S and 28° 25′24″E
- 7 543.67 sqr. kms in land size
- Elevation: 590-886m
- Semi-arid
  - Mean annual rainfall: 300-400 mm
  - Mean annual temperature: >22° C
- 8 villages used for this study

1. Long term time series

Initially, long-term, coarse-scale vegetation trends were derived and analyzed. We used the 15 day composites of the Global Inventory Modelling and Monitoring Studies (GIMMS) dataset, covering the period 1982-2015 with a temporal resolution of 15 days and a spatial resolution of 8 km. GIMMS is currently thought to be sensor-corrected, being consistent with NDVI from SPOT Vegetation and MODIS Terra satellites (Tucker et al. 2005).

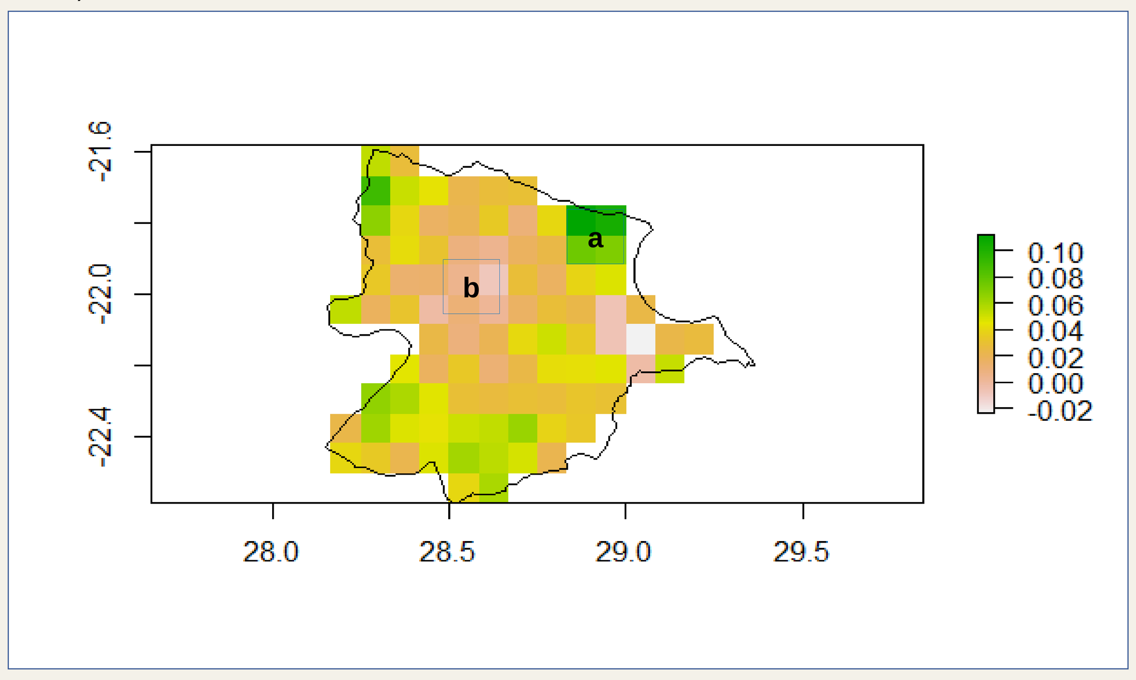

Figure 2. Spatial trends in annual maximum GIMMS NDVI for Bobirwa sub-district for the period 1982-2015. Spatial variations can be observed at a scale of approximately 8km

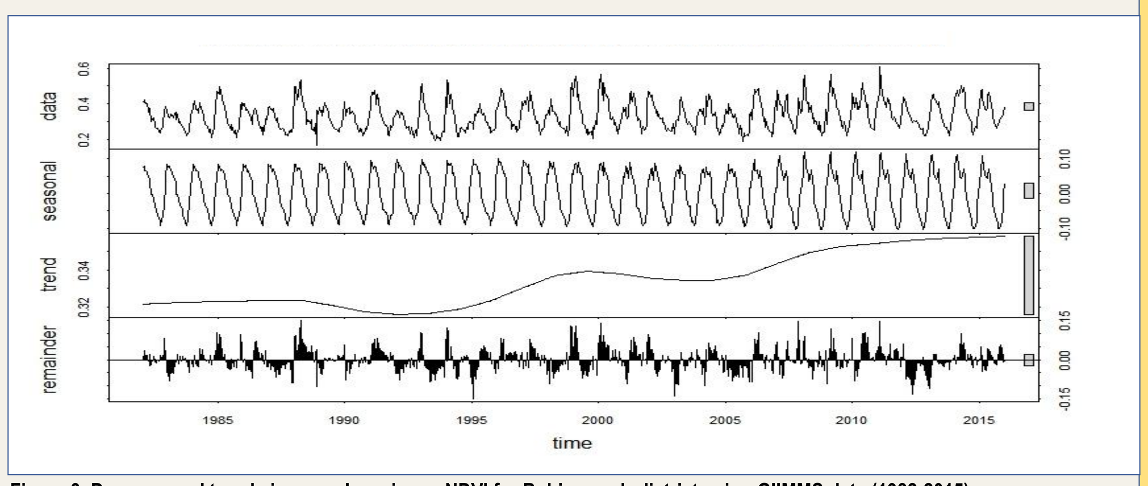

Figure 3. Decomposed trends in annual maximum NDVI for Bobirwa sub-district using GIIMMS data (1982-2015)

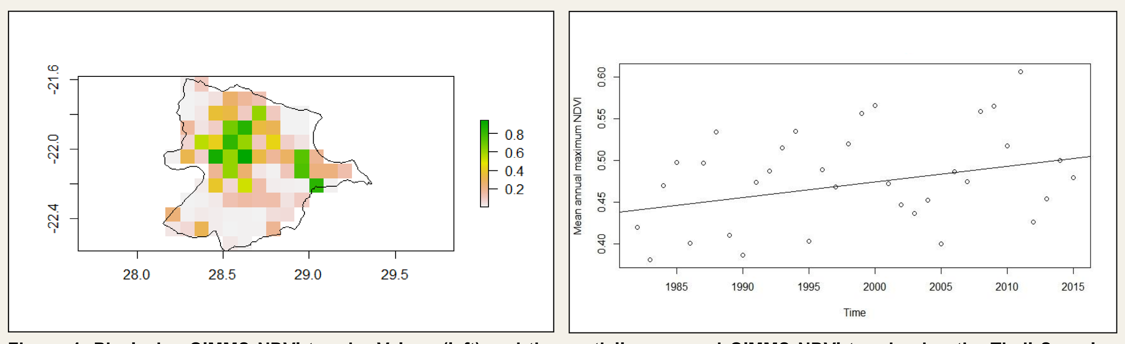

Figure 4: Pixel-wise GIMMS NDVI trend p-Values (left) and the spatially averaged GIMMS NDVI trend using the Theil Sen slope estimator (right) for the period 1982-2015

2. Medium resolution time series

Secondly, areas showing both negative and positive trends are further analyzed using Moderate Resolution Imaging Spectroradiometer (MODIS) time-series dataset. The dataset has a spatial resolution of 250m hence trends can be observed at the village/community level. We used a smoothed Maximum Value Composite (MVC) for the period 2000-2015.

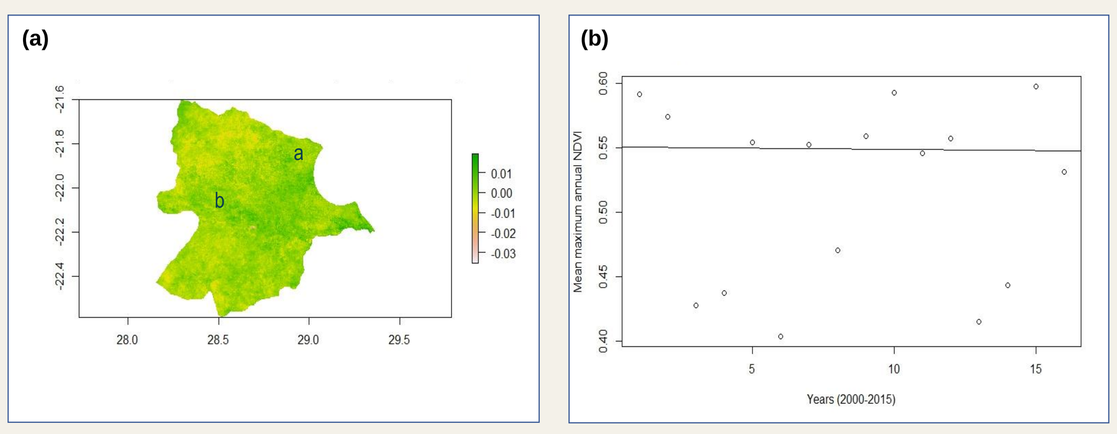

Figure 5a. Spatial variability MODIS NDVI Sen slope trends for Bobirwa for the period 2000-2015. Spatial variations can be observed at a scale of 250 m for smaller areas (Fig. 4)

Figure 5b. Spatially averaged MODIS NDVI Sen slope trend for Bobirwa for the period 2000-2015. Spatial variations can be observed at a scale of 250 m for smaller areas (Fig. 4)

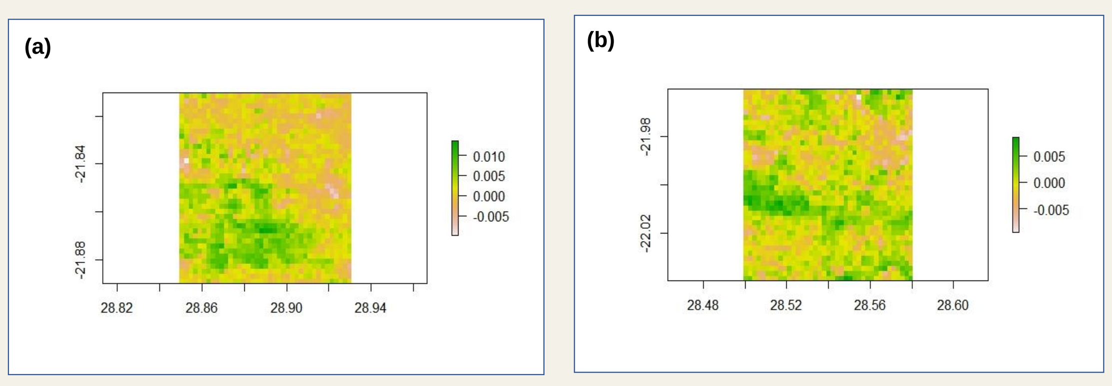

Figure 6. (a) and (b) correspond to areas marked a and b (respectively) in Fig. 2 and 5 (a) and show more diverse and varied NDVI trends at 250m spatial resolution using MODIS time series (2000-2015). This shows that GIMMS NDVI trends (Fig. 2) mask several processes into one pixel hence the need for further inquiry to explain these patterns.

3. Very high resolution time series

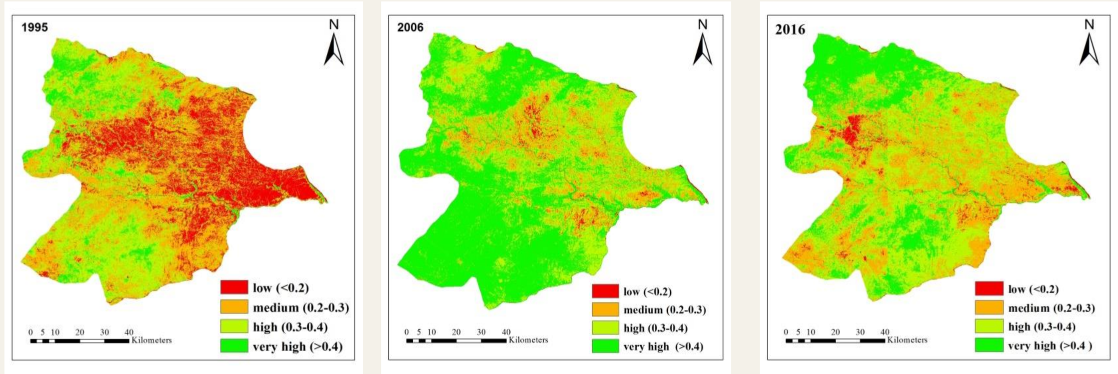

Figure 7. Spatial variability in decadal NDVI using post-rainy season (March/April) Landsat images for the years 1995, 2006 and 2016. Spatial variations can be observed at a scale of 30m

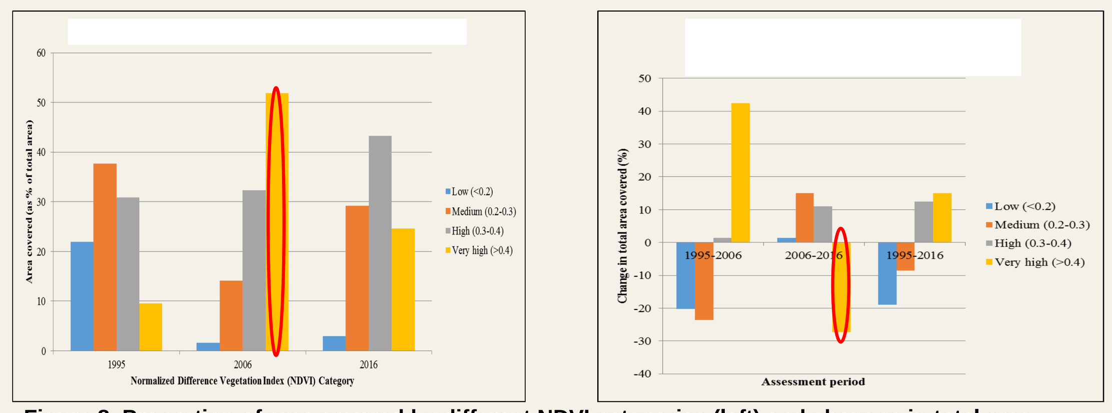

Figure 8. Proportion of area covered by different NDVI categories (left) and changes in total area covered by NDVI categories (right) (based on Figure 7 NDVI classification). These changes in NDVI categories may be linked to changes in land-use

4. Field observations

Field observations around 8 villages revealed various land-uses, land-cover and vegetation types as well as prevailing ecosystem conditions. Signs of the impacts of climate extremes, drought and human pressure were also visible. Vast areas of bare land, gullies and spreading *Acacia* shrubs were observed around the villages. It was common practice to leave important trees (e.g. *Colophospermum mopane, Sclerocarya birrea and Adansonia digitata*) around the village settlements, homesteads and on crop fields. Trees and shrubs around crop fields were also left uncleared. Dry land farming was also being 'illegally' practiced at the 'cattle posts' (communal grazing area). Irrigated farming mostly on privately owned farms and protected (wildlife) areas were also other land-uses observed. Nonetheless, actual cause of the trends were not obvious from field observations alone.

Figure 9. Various land-uses and/or land-cover types observed during field observations (images taken during fieldwork in February 2018)

5. Participatory mapping of local provisioning ecosystem services

a. Wild fruits sold along main road to generate income (October, 2016)

b. Basketry products (from palm leaves) on sale at a basketry cooperative shop (October, 2016)

d. Fresh agricultural produce sold at local markets (March, 2015)

d. Mopane caterpillars crawling down to another Mopane tree with more herbage (April, 2018)

Figure 10 a-d. Some of the locally important provisioning ecosystem services. The participatory mapping exercises identified 15 provisioning ecosystem services in Bobirwa sub-district; Cultivated crop and fodder production; Livestock production; Capture fisheries; Wild fruits; Mopane caterpillars; Game meat; Timber/poles; Thatch; Palm leaves; Medicinal plants (natural medicines); Natural pastures; Fresh water (surface and underground); Biomass fuel (firewood & animal dung); Dyes/plant juices/extracts.

6. Community insights

A combination of participatory mapping exercises, focus group discussions and one-on-one interviews with the local communities concurred that the surrounding environment was deteriorating. The local communities explained vegetation loss and degradation as mainly due to:

- Recurring droughts almost every 3-4 years
- Erratic and poorly distributed rainfall (both spatially and temporally)
- Legal and illegal clearing of woodland for crop production and firewood
- Overgrazing especially from increasing livestock population
- Erosion and gullies from sudden heavy downpours
- Damming of major rivers upstream

However, they also explained the greening on some parts as due to:

- Proliferation and spreading of more drought tolerant vegetation species (especially *Acacias and Hyphaenae petersiana*)
- Conservation of woodlands and important tree species
- Several river channels in the sub-district some of which drain into Limpopo River

The community expressed concern that recurring droughts, damming of rivers upstream, FMD-induced overstocking and population pressure could further deteriorate vegetation conditions and ES delivery.

a. Livestock farmer also growing crops at 'cattle posts'

b. Destructive tapping of palm wine from palm plants

c. Ground water used for small scale vegetable production

d. *Mopane* poles used to fence around household

e. Cattle farmer showing bare land in a grazing area

f. Participatory mapping of local ecosystem services

Figure 11 a-e. Various engagements and discussions with local community (February, 2018)

Conclusions

Our study highlights the importance of vegetation conditions and how a combination of participatory and non-participatory techniques improve understanding of recent trends in key provisioning ES in Bobirwa sub-district. Local knowledge is shown to be critical for explaining observed trends in remotely-sensed vegetation conditions.

Although climate comes out as one of the most important driver of vegetation condition, hence ES provision, human pressure is also contributing to these spatial variations. However, our study shows that the actual drivers of change can be pin-pointed through field observations and insights from the local community who are closely connected to the natural environment. Hence, vegetation patterns alone give inconclusive evidence to explain trends in the delivery of local provisioning ES.

A further study underway on land-use and/or land-cover change in Bobirwa sub-district will also help us expand our knowledge and understanding of environmental change in Bobirwa sub-district.

Acknowledgements

This work was carried out under the Adaptation at Scale in Semi-Arid Regions project (ASSAR). ASSAR is one of five research programmes funded under the Collaborative Adaptation Research Initiative in Africa and Asia (CARIAA), with financial support from the UK Government's Department for International Development (DfID) and the International Development Research Centre (IDRC), Canada. The views expressed in this work are those of the creators and do not necessarily represent those of DfID and IDRC or its Board of Governors.

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