A review on crop yield and pasture health monitoring and forecasting in East Africa

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Outline

- Rationale
- Some Crop Yield Monitoring and Forecasting approaches/Models
- Some successful cases
- Case study
- Way forward

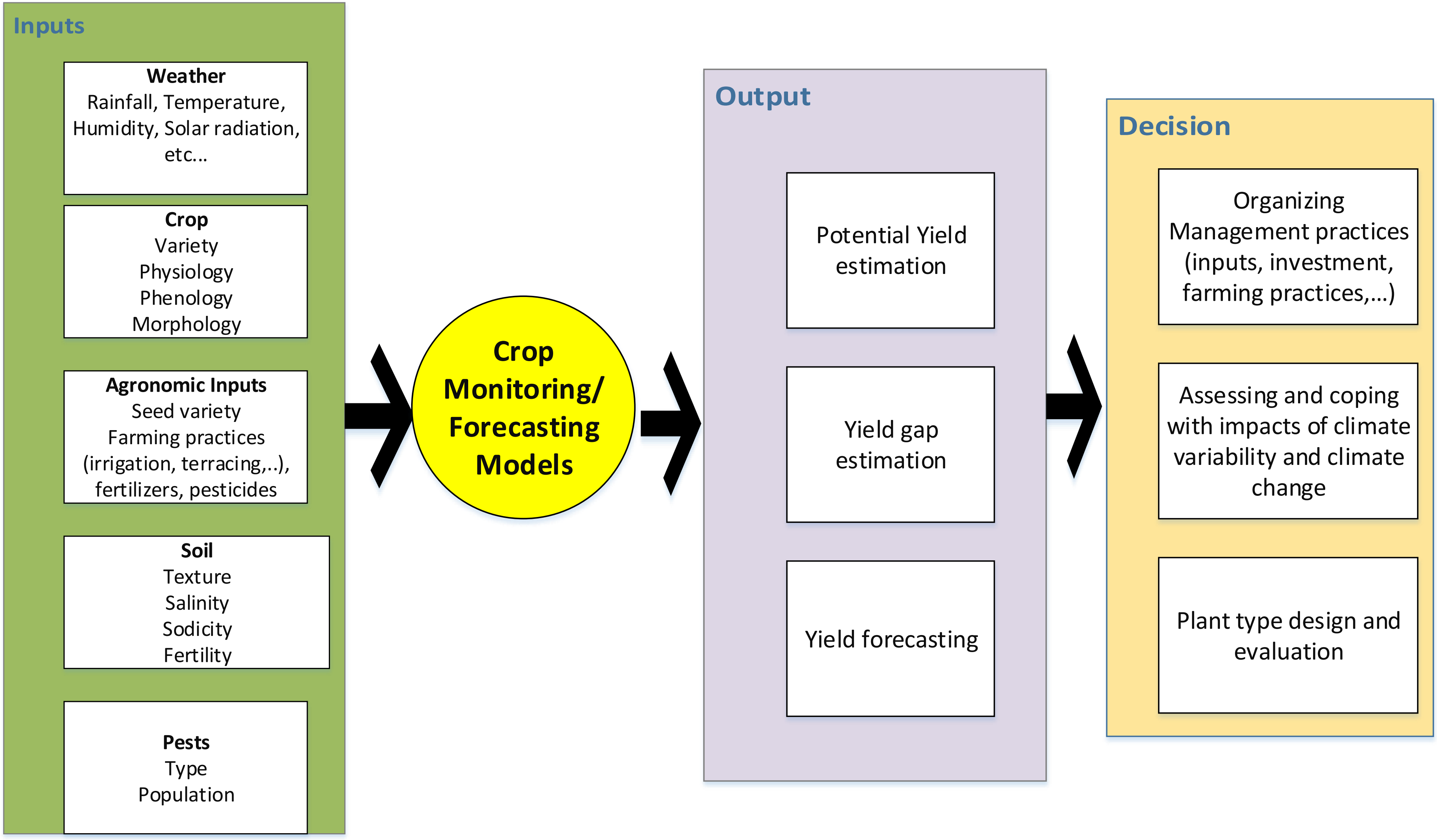
Rationale

- Since the last decades, people in the East Africa started shifting from subsistence to market-oriented agriculture.
- Huge investments have been put in new technologies such as irrigation and improved inputs especially tolerant seed varieties and fertilizers
- Need for strong crop/pasture Monitoring and yield forecasting tools which would combine environmental and farming practices in order to have a scientifically inspired business model.
- The mostly used models: Crop growth simulation, Crop weather and Empirical statistics

Rationale

- The advance in Geo-information helped the use of Multispectral and multi-temporal satellite images and various vegetation indices for a better monitoring/forecasting
- In East Africa, those models combining field based and remotely acquired data have been underexploited by Governments and only International Organizations such as FAO and IUCN have been using them with the challenge that they are relying on global data as inputs
- The current paper investigated different models that have been used for crop yield and pasture health monitoring and forecasting in East Africa

Major parameters for crop/pasture yield Monitoring and forecasting



Some models

- Crop-weather models: Combine inputs, farming practices and weather-it is the mostly used and helps to deal with crop calendar
- Crop growth models: simplified representation of the physical, chemical and physiological mechanisms underlying plant growth processes.
- Empirical statistical models: The weighting coefficients in these equations are by necessity obtained in an empirical manner using standard statistical procedures. It does not easily lead to an explanation of the cause and effect relationships but it is a very practical approach for the assessment or prediction of yields.

Earth Observation for crop monitoring and yield estimation

- The advance of Earth Observation helped to gather weather/climate, crop/pasture phenology at various spectral, spatial and temporal resolutions
- Course, medium and high resolution including UAVs have been useful for crop monitoring and yield forecast
- The multispectral remote sensing helps to collect many parameters at the same time
- The hyper temporal/time series data help to monitor crops/pastures at different phenological stages for better yield predictions

Earth Observation for crop monitoring and yield estimation

- Thanks to Earth Observation, various land uses/covers and vegetation indices could be easily retrieved
- Other indices concerning water and soil like SMI, etc…

Index	Reference	Scale	Parameter
NDVI (Normalized Difference Vegetation Index)	Rouse *et al.*, 1974	Canopy	Biomass; Vegetation Fraction
GNDVI (Green Normalized Difference Vegetation Index)	Gitelson *et al.*, 1996	Canopy	Chlorophyll; Vegetation Fraction
PRI (Photochemical Reflectance Index)	Gamon *et al.*, 1992	Canopy	Photosynthesis efficiency/ RUE
NDRE (Normalized Difference Red Edge)	Barnes *et al.*, 2000	Canopy	Chlorophyll/ Nitrogen
CCCI (Canopy Chlorophyll Content Index)	Fitzgerald *et al.*, 2006	Canopy	N Status/ Chlorophyll
RVI (Ratio Vegetation Index)	Jordan, 1969	Leaf	Biomass
EVI (Enhanced Vegetation Index)	Huete et al., 2002	Canopy/ Regional	Biomass/ Vegetation Cover
EVI 2 (Enhanced Vegetation Index 2)	Jiang et al., 2008	Canopy/ Regional	Biomass/ Vegetation Cover
VARIgreen (Visible Atmospherically Resistant Index)	Gitelson et al., 2002	Canopy/ Regional	Vegetation Fraction/ LAI
VARI700 (Visible Atmospherically Resistant Index; 700 nm)	Gitelson et al., 2002	Canopy/ Regional	Vegetation Fraction/ LAI
TVI (Triangular Vegetation Index)	Brodge and Leblanc, 2000	Canopy	Chlorophyll
MTVI 1(Modified Triangular Vegetation Index 1)	Haboudane et al., 2004	Canopy	Chlorophyll
MTVI 2 (Modified Triangular Vegetation Index 2)	Haboudane et al., 2004	Canopy	Chlorophyll
MTCI	Dash and Curran, 2007	Canopy	Chlorophyll

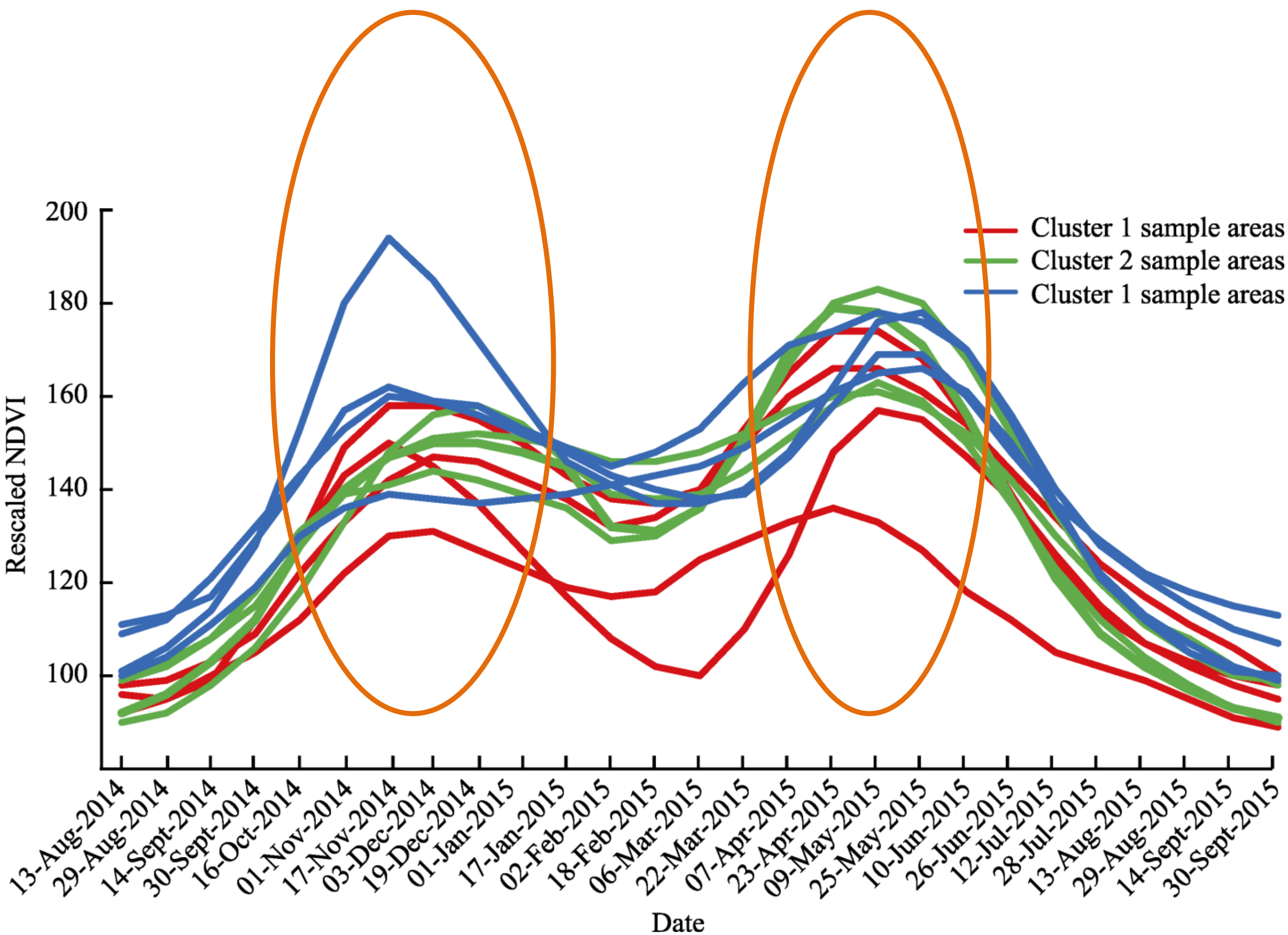
Application of Multi-Temporal MODIS NDVI Data to Assess Practiced Maize Calendars in Rwanda

- Mugabowindekwe et al. 2018 assessed crop calendar in Rwanda
- Focused on agro-ecosystems with differences in climate and soil properties
- Used a multi-temporal MODIS NDVI stratification

Agro-ecological Zone	Average Altitude (m)	Average Rainfall (mm)	Soil Type
Buberuka highlands	2000	1200	Oxisols at high altitude
Congo-Nile divide	2100	1600	Humic acid soils
Bugarama plain	1100	1200	Alluvial soils
Impala	1700	1400	Heavy clayey soils derived from basalt
Kivu lake	1600	1100	Gravely sandy loam soils
Kivu lake side	1600	1200	Clay loam soil
Mayaga	1450	1050	Clayey soils derived from shale
Bugesera	1400	900	Oxisols
Central plateaus	1700	1200	Humic soils at medium altitude
Eastern ridges and plateaus	1500	950	Oxisols with high iron oxide
Eastern savannah	1400	850	Old infertile soils with texture variable
Volcanic summits and high plains	2200	1500	Ultisols derived from volcanic materials

Source: Clay and Dejaegher (1987).

Application of Multi-Temporal MODIS NDVI Data to Assess Practiced Maize Calendars in Rwanda



- NDVI increases in between growing and harvesting seasons
- It is lower in planting and harvesting seasons
- The optimum in NDVI/Chlorophyll content justifies adequate crop health and optimal yield

Application of hypertemporal NDVI data in grassland mapping and biomass estimation in the Masai Mara ecosystem, Kenya

- From Onyango, O.D., 2015
- Analysis of hyper-temporal Modis terra NDVI data to monitor NDVI contents in rangelands of Massai Mara-Kenya

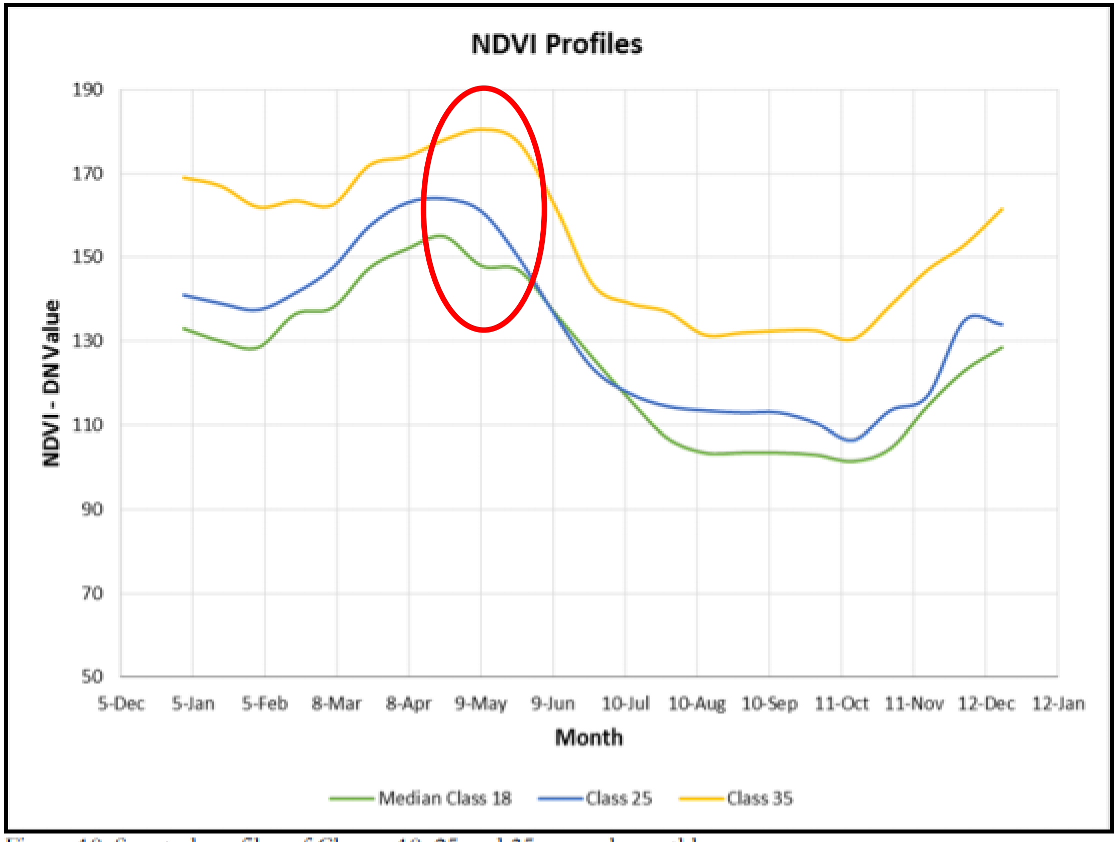


Figure 18: Spectral profiles of Classes 18, 25 and 35; annual monthly averages

Application of hypertemporal NDVI data in grassland mapping and biomass estimation in the Masai Mara ecosystem, Kenya

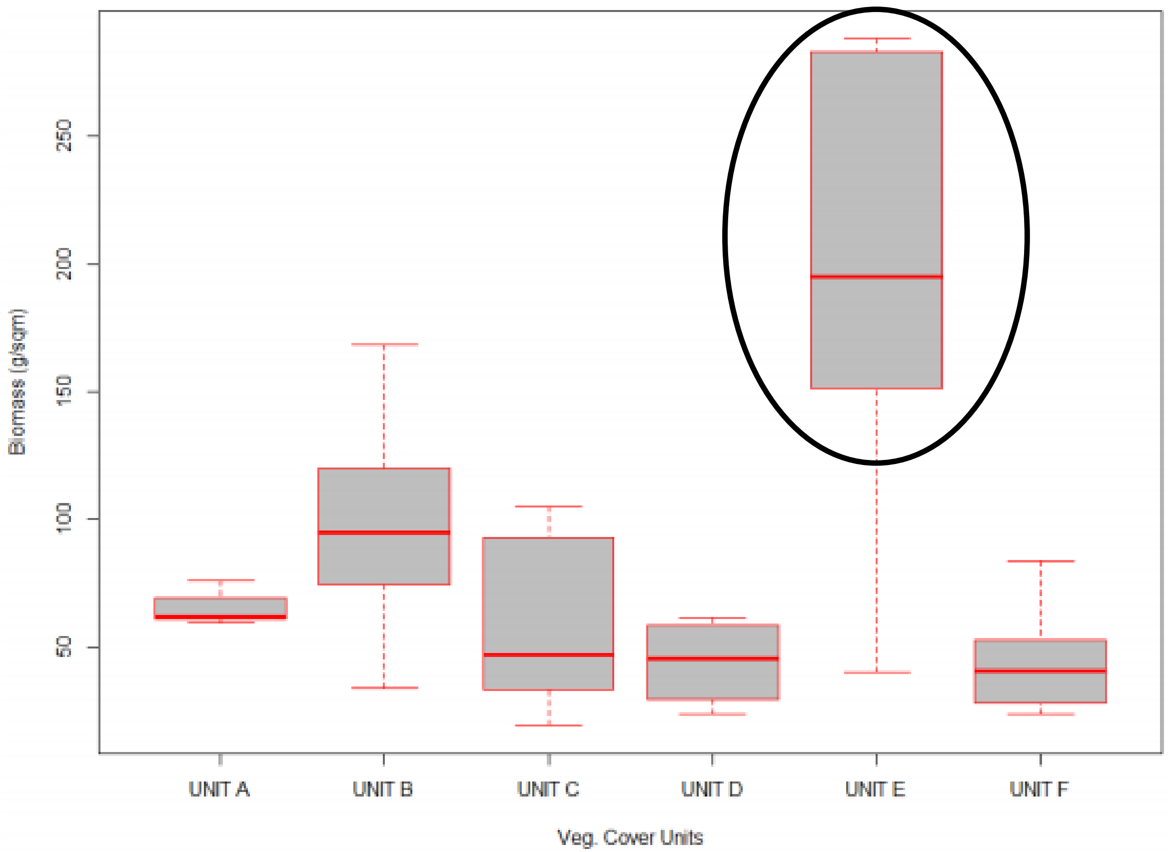


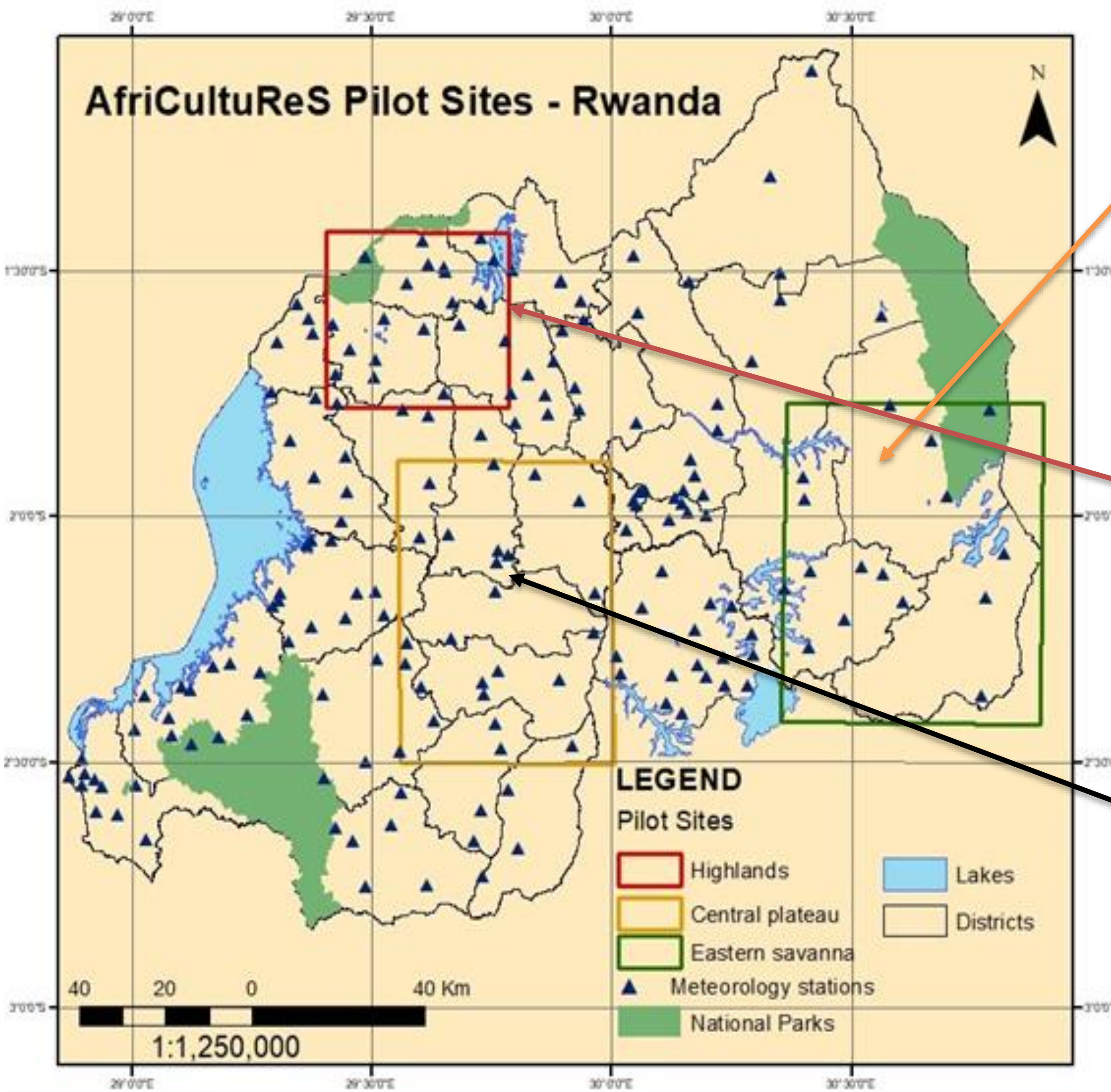
Figure 19: Boxplots of Biomass by grassland vegetation cover types

- Unit E: High Biomass
- E is dominantly found in Masai Mara National reserve while the others are dominant in the surrounding conservancies and community land around
- Human disturbance affected biomass

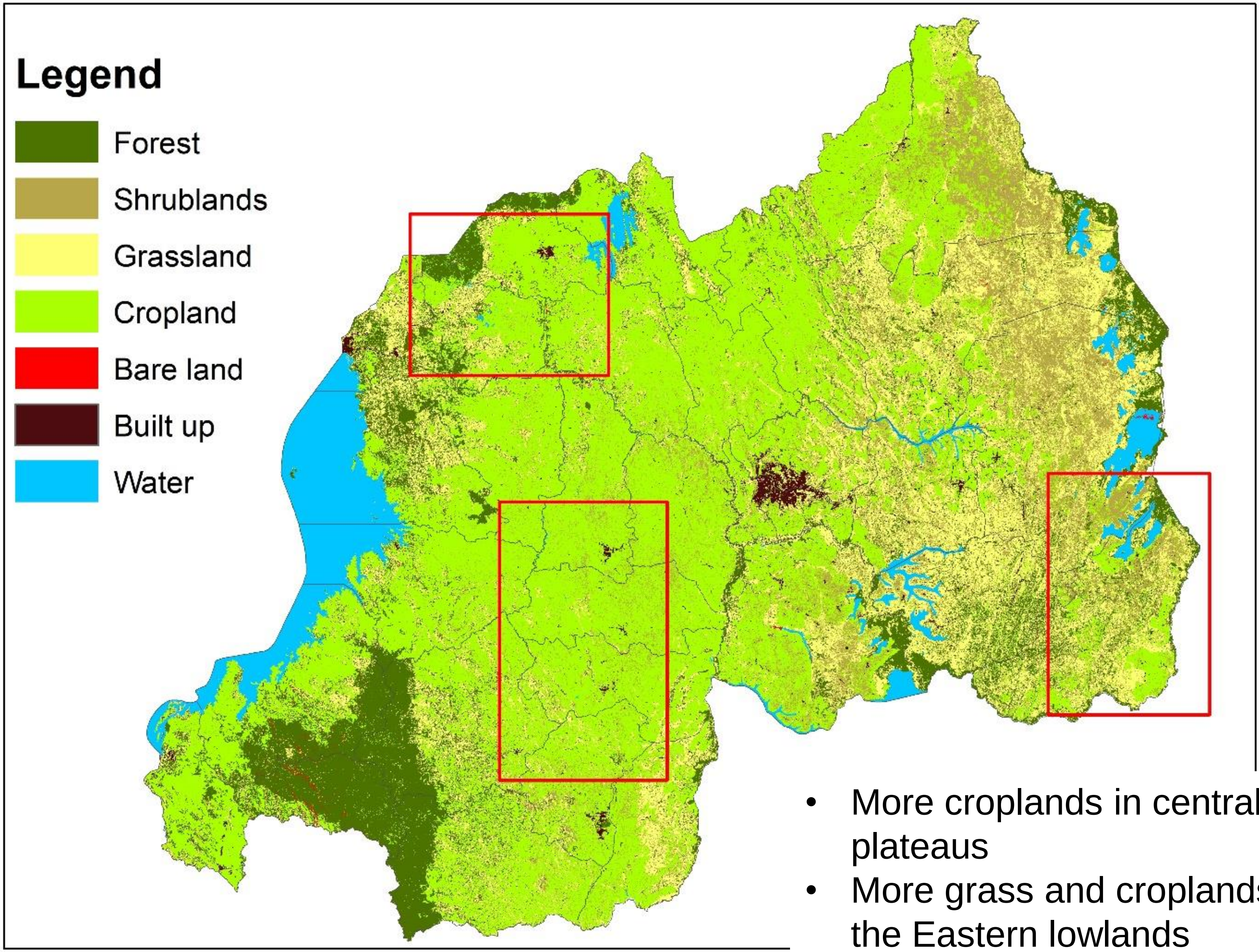
Case Study: Crop Monitoring Using Sentinel images in the framework of AfriCultuReS Project

- **AfriCultuReS:** Enhancing Food Security in AFRIcan AgriCULTUral Systems with the Support of REmote Sensing
- Duration: 1 Nov 2017 – 30 Oct 2021 (48 months)
- Different partners: Research Institutions and Private Companies from all Corners of Africa and Europe:
    - ✓ *Observatoire du Sahara et du Sahel (OSS) from Tunisia , LocateIT from Kenya, GeoSAS from Ethiopia, University of Rwanda, Centre for GIS and Remote Sensing (CGIS) from Rwanda, Centre for Remote Sensing and Geographic Information Services (CERSGIS) from Ghana for the Gulf of Guinea, Euardo Mondlane University (UEM) from Mozambique and South African National Space Agency (SANSA) from South Africa.*
    - ✓ *European Partners are GMV AEROSPACE AND DEFENCE SA (GMV) from Spain, Aristotelio Panepistimio Thessalonikis (AUTH) and Draxis Environmental S.A. (DRAXIS) from Greece, Noort Harmannus, Conradus Pieter (HCP) from the Netherlands, UNIVERSITA DEGLI Studi Di Roma La Sapienza (SIA) from Italy, Universidad De Cantabria (UC) from Spain, University of Leeds (UNIVLEEDS) and University of Sheffield (USFD) from the United Kingdom*.

Case Study: Crop Monitoring in Rwanda Using Sentinel images in the framework of AfriCultuReS Project



- Eastern lowlands with large monoculture of maize, banana and pasture lands
- Northern highlands with mosaic fields of crops including potatoes, climbing beans
- Southern and Central plateaus with a mixture of crops and large fields of cassava in Amayaga Region



- More croplands in central plateaus
- More grass and croplands in the Eastern lowlands
- More forest and crops in the Northern highlands

Conclusion and way forward

- It is clear that with Earth Observation, people can monitor crop health and forecast the yield
- The spectral, temporal and spatial resolutions of the used image have a big influence on the results
- What is next?
  - NDVI using Medium resolution images (This would work perfectly in the eastern lowlands and southern plateaus of Amayaga with large monoculture
  - Use High Resolution images even UAVs if possible to mosaic fields in the western highlands
  - Use crop weather simulation models to monitor not only the health by estimate the biomass


Thanks!