Time Series Analysis of Forest Cover Change in Southern Somalia and Identifying Possible Causes

This study uses Landsat 8 surface reflectance data from the OLI/TIRS sensors and MODIS Terra satellite imagery to create a time-series analysis of forest cover change in an area of Southern Somalia, which the terrorist group Al Shabab controls. Although past studies have investigated the effects of Al Shabaab's charcoal production activities on Somalia's forests (Bolognesi et al. 2015; Kengni, 2013; Rembold et al. 2013; Ogallo et al. 2018), previous studies have not accounted for naturogenic causes of environmental degradation (e.g. drought), which may also affect forest cover and productivity. Therefore, this study used an area of Northeastern Kenya immediately across the border from Southern Somalia as a 'control' to address the potential influence of climate stress on forests. Northeastern Kenya was considered an appropriate control site since it has a similar land cover and climate to Southern Somalia (Farah et al. 2004).

In addition, two national parks, Lag Badana-Bush-bush National Park in Somalia and Boni Forest on the Kenyan side, are across one another along the border in the study area (Gedow et al. 2017; Ngare et al. 2022). The main differentiating factor between these two similar forested areas is that a stable government on Kenyan territory can enforce environmental protection laws (Ndwega, 2018). Furthermore, Al Shabab has repeatedly conducted attacks within Kenya since the Kenyan invasion of Somalia in 2011 but controls no territory in Kenya to carry out deforestation activities (Jureńczyk, 2021).

Objectives & Hypothesis

The first objective of this study was to quantify forest cover change in Southern Somalia, where Al-Shabab holds territory, using various vegetation productivity indices, including Normalized Difference Vegetation Index (NDVI), Bare Soil Index (BSI), and Net Primary Productivity (NPP). Additionally, the potential effect of Al-Shabab vs. climate perturbations on forest cover was assessed by contrasting vegetation cover in Somalia with an equivalent area in Kenya. This study tested the hypothesis that forest cover change has been more significant in Southern Somalia than in Northeastern Kenya from 2013-2021 due to Al Shabab's control of the former. This study also addresses previous studies' shortcomings in failing to consider the possibility that natural causes have contributed to cover change in Southern Somalia.

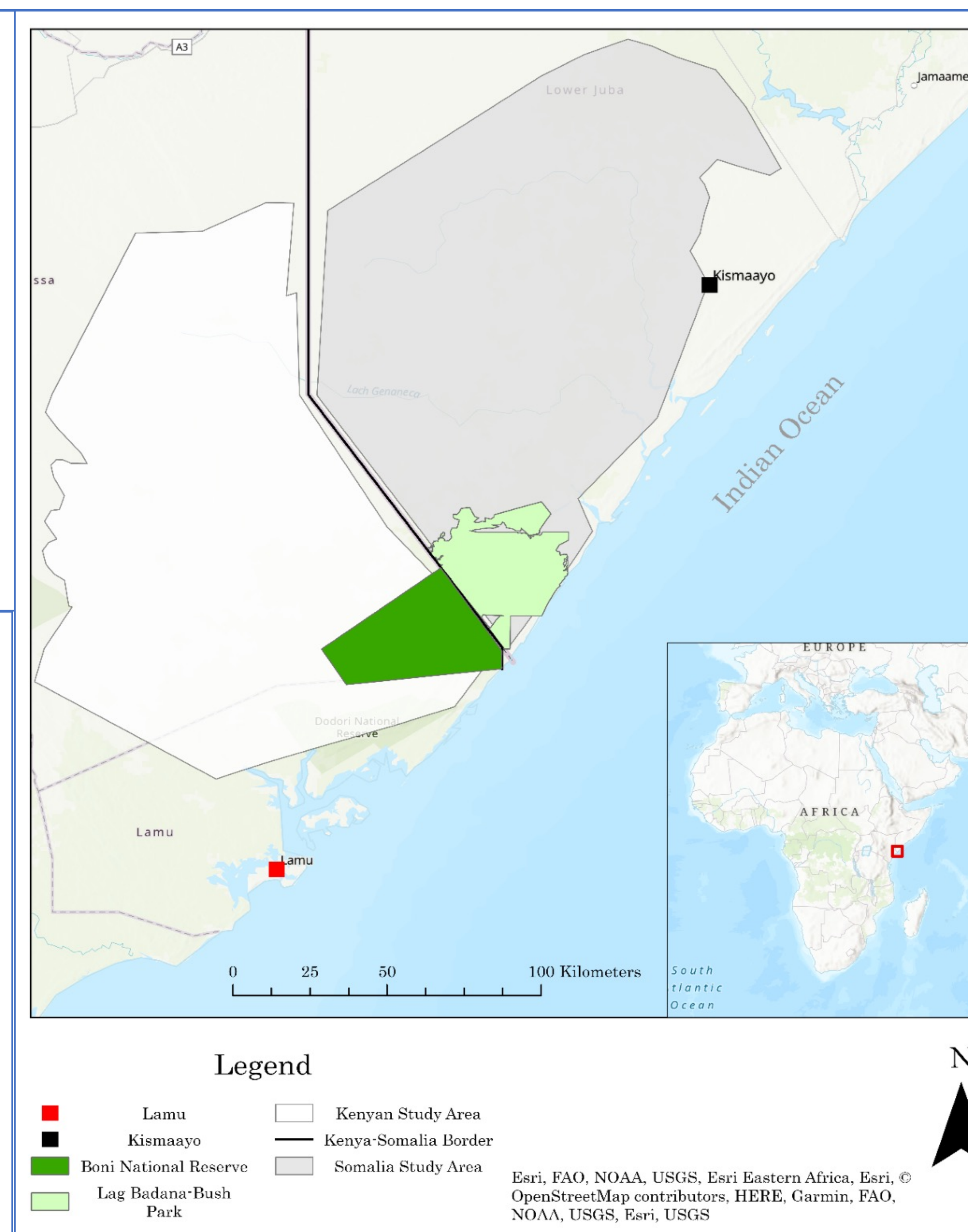

Fig 1: Boni National Reserve and Lag Badana-Bush Bush National Park Within Southern Somalia & Northeastern Kenya Study Areas.

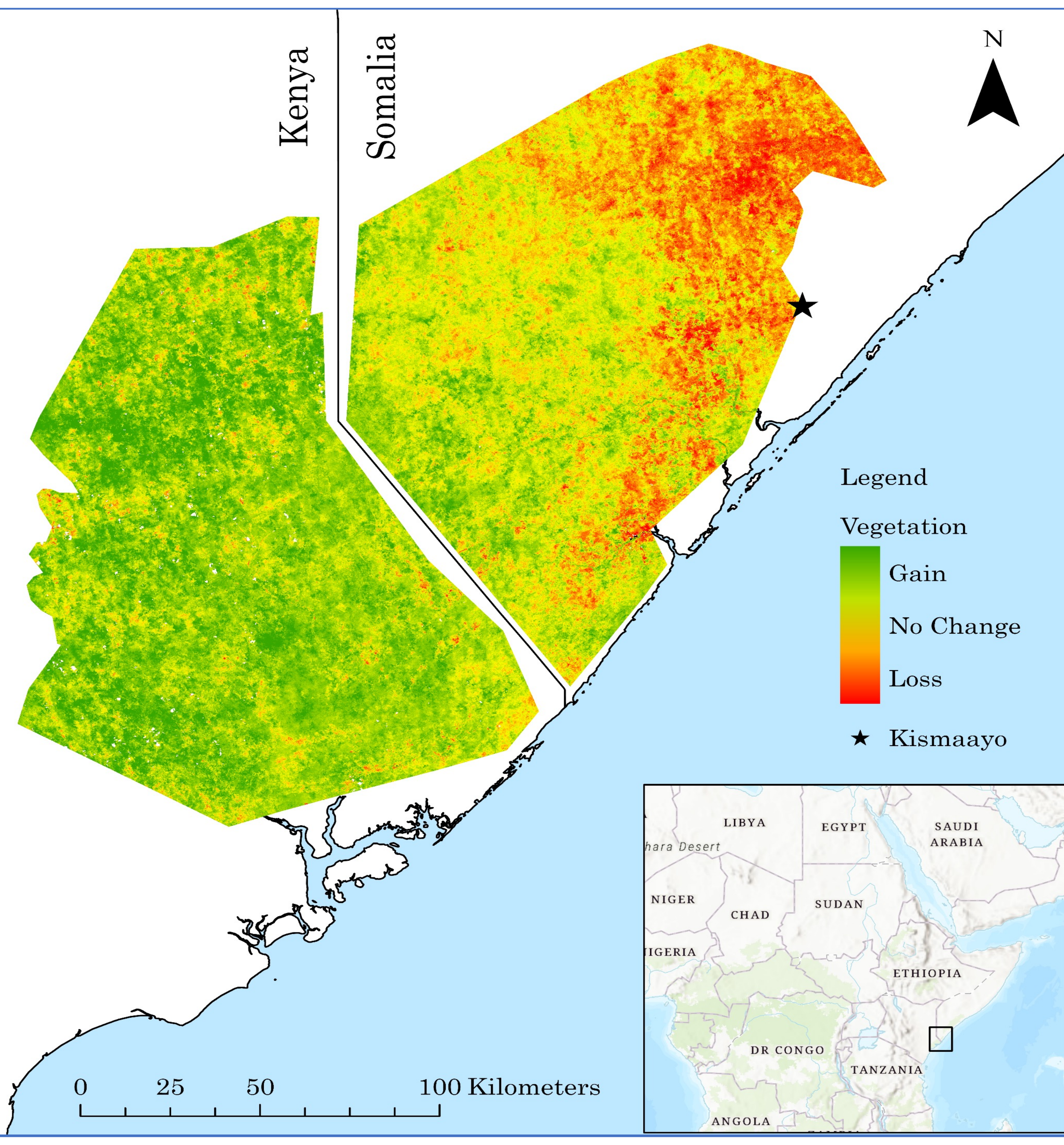

Fig 2: NDVI Change Detection Map for 2013-2021 in Southern Somalia & Northeastern Kenya

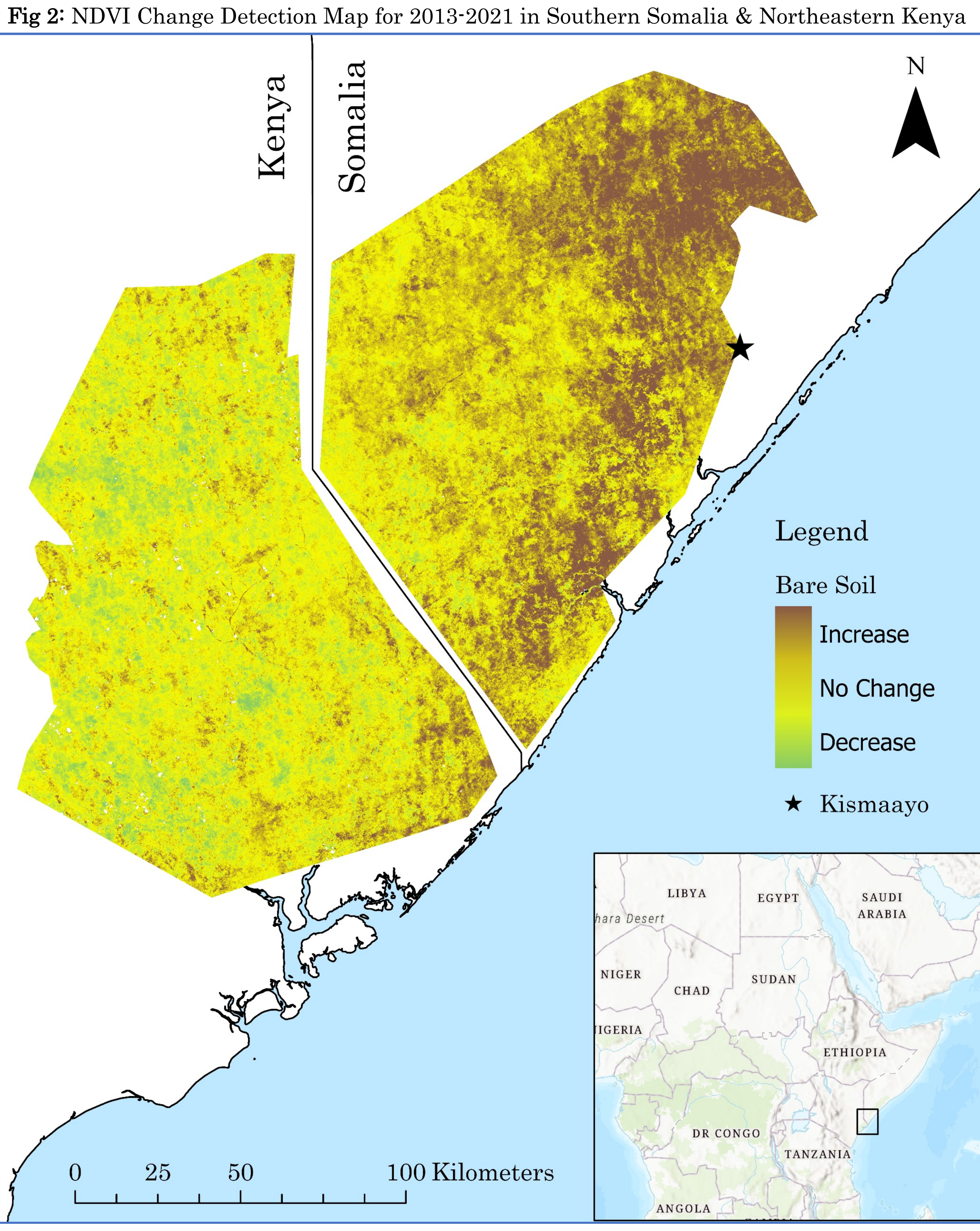

Fig 3: BSI Change Detection Map for 2013-2021 in Southern Somalia & Northeastern Kenya

Methods

- Yearly composites of the Landsat 8 images were made for both study regions from 2013-2021 in Google Earth Engine (GEE) and then exported into ESRI's ArcGIS Pro v3.0.
- MODIS NPP images were already prepared as yearly composites and were also exported into ArcGIS Pro.
- NDVI and BSI analysis were done using the raster calculator tool in ArcGIS Pro.
- Change detection maps were also made using the raster calculator tool in ESRI software by subtracting 2021 images from 2013 and using appropriate symbology to highlight the differences noted in this study
- Lastly, map frames were imported into a layout to add a legend, scale bar, north arrow, and extent indicators.

Temporal Patterns of Forest Cover, Bare Soil, and Forest Productivity

- The NDVI (Normalized Difference Vegetation Index) in southern Somalia decreased by 34% between 2012 and 2013, peaked in 2013, and continued a downward trend until 2019, then recovered briefly before a 30.5% decrease in 2020-21.
- NDVI loss in the Kenyan study area was significantly lower at 12% within the same time frame, and by the end of the study, the Somali region had lower NDVI values than the Kenyan region by almost 5%.
- The Bare Soil Index (BSI), a complementary indicator of vegetation loss, increased significantly (116%) in the Somali region between 2013 and 2021, with the most significant year-to-year increase of 89% occurring in 2020-21.
- The BSI in the Kenyan study region increased by 24% between 2013 and 2021, and a significant increase of 74% in BSI was recorded between 2020-21.
- Net Primary Production (NPP), a measure of the difference between total photosynthesis and total respiration in an ecosystem, decreased by 12% in both southern Somalia and the Kenyan study area between 2013 and 2021.
- A mixed-model ANOVA with random effect was conducted for each of the three indicators: NDVI, BSI, and NPP. This consistently showed significant differences ($p < 0.01$) between the Somali and Kenyan study areas every year except 2020.
- Both the NDVI and BSI analysis results support the hypothesis of a higher forest cover loss in Somalia, specifically in Al Shabab's controlled territory, compared to northeastern Kenya between 2013 and 2021.

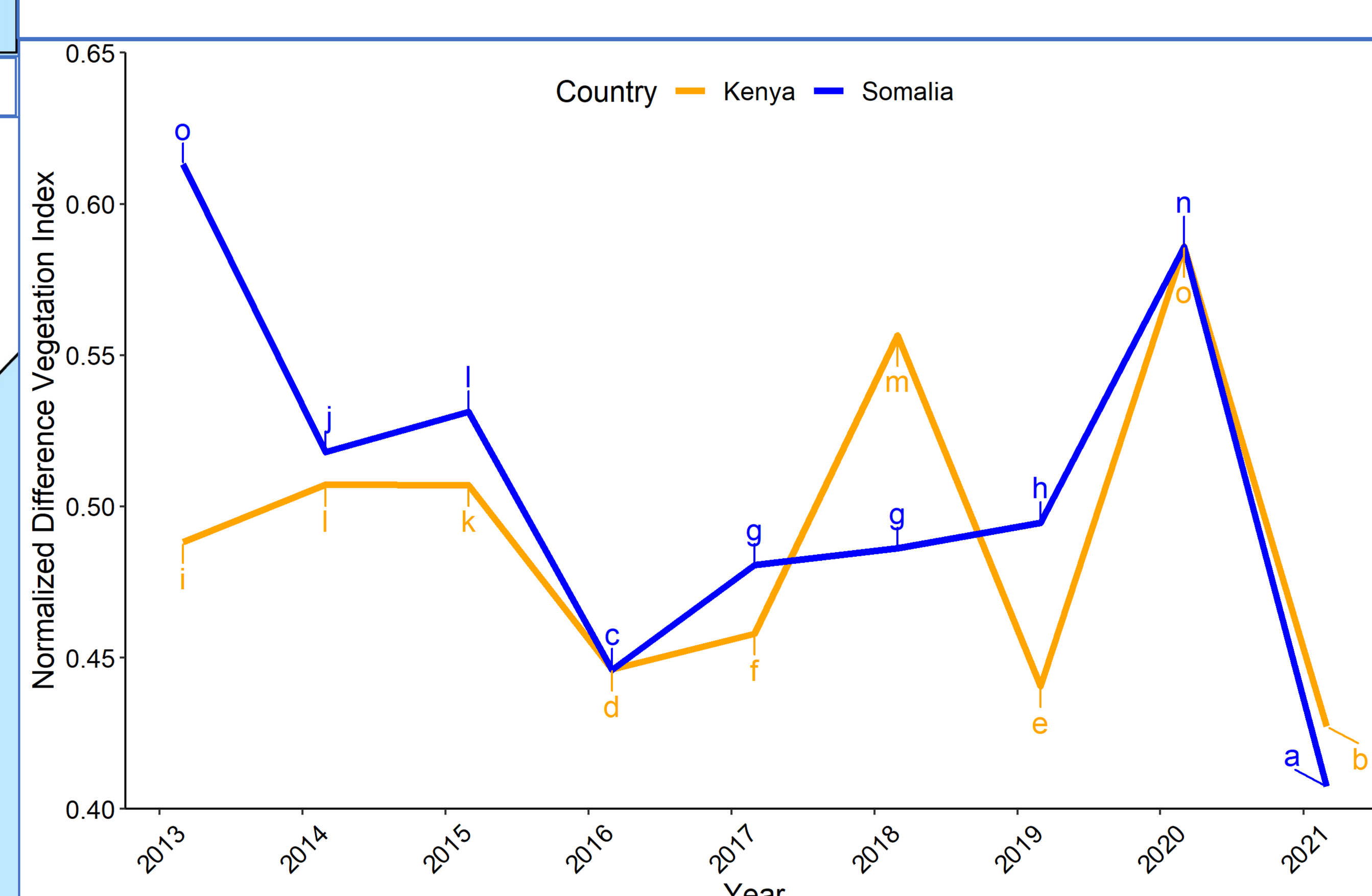

Fig 4: Line graph representing significant statistical differences ($p < 0.01$) between average NDVI values within and between all pixels in each study area.

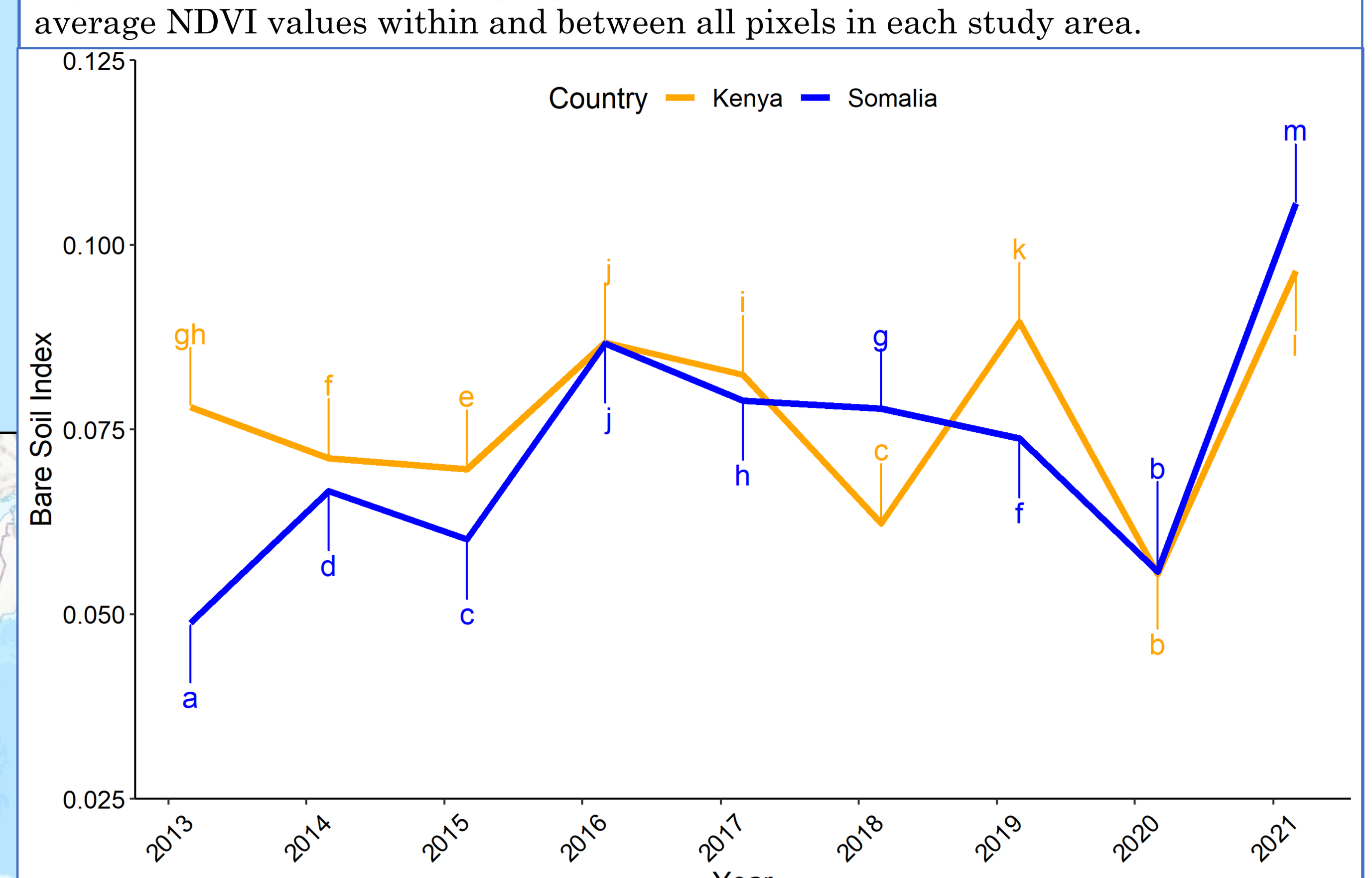

Fig 5: Line graph representing significant statistical differences ($p < 0.01$) between average BSI values within and between all pixels in each study area.

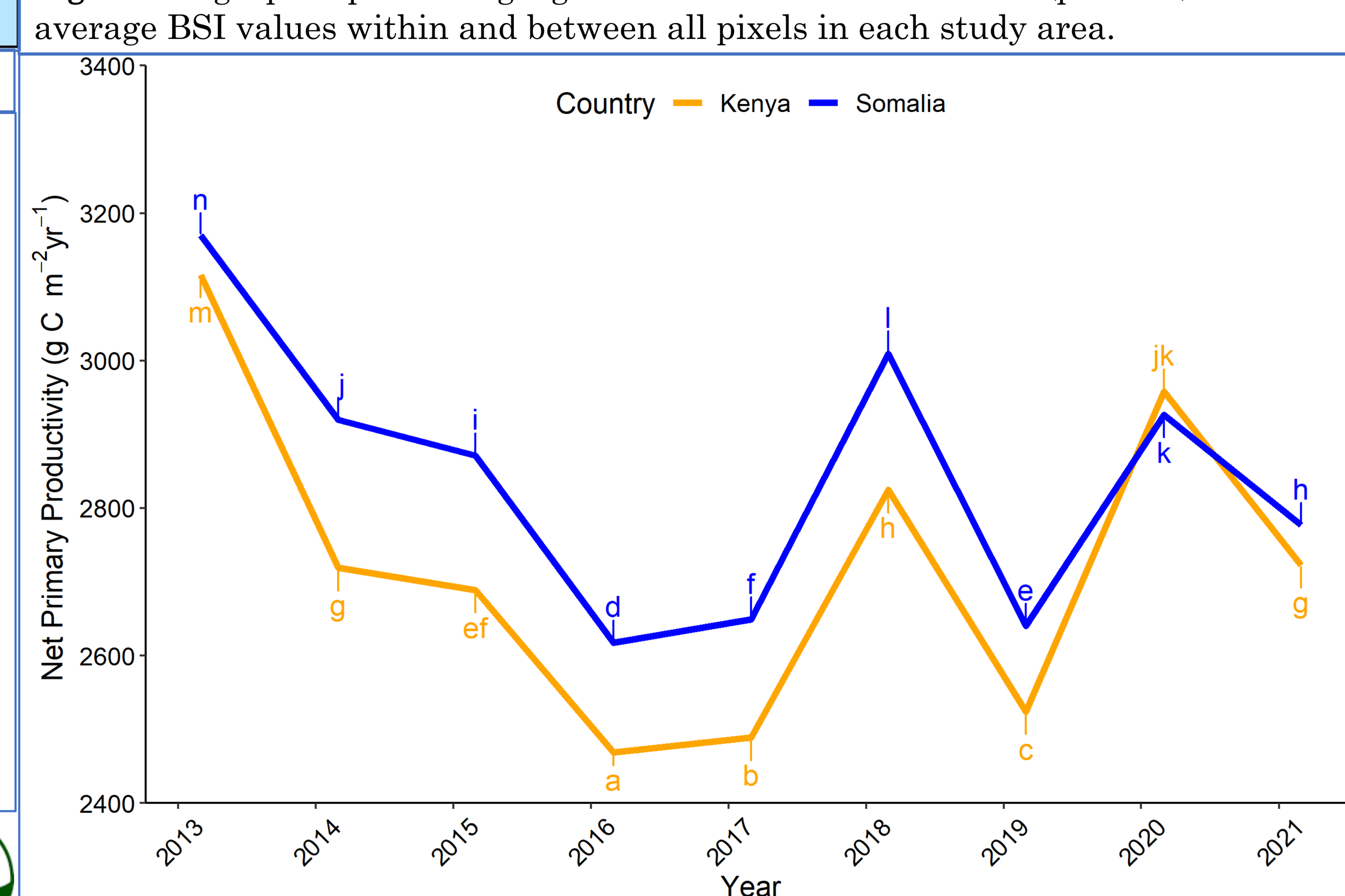

Fig 6: Line graph representing significant statistical differences ($p < 0.01$) between average NPP values within and between all pixels in each study area.

Spatial Patterns of Forest Cover & Bare Soil

- A consistent decrease in forest cover and increase in bare soil were observed in Southern Somalia compared to Northeastern Kenya, as indicated by all three indicators: NDVI, BSI, NPP (Fig 2; Fig 3; Fig 4; Fig 5).
- The loss of forest cover was especially noticeable in the eastern part of the Southern Somalia study region, as demonstrated by NDVI and BSI indicators (Fig 2; Fig 3).
- Change detection maps confirmed the findings of Rembold et al. (2013) and Bolognesi et al. (2015), indicating high levels of charcoal production and subsequent forest degradation near Kismaayo port, the primary exit point for charcoal export (Fig 1; Fig 3). This is despite the UN Security Council's 2012 ban on Somali charcoal export (UN resolution 2036),
- The NDVI and BSI analyses support the hypothesis that the forest cover loss in Southern Somalia is significantly influenced by Al Shabab's control of the area.
- Charcoal production, believed to have started between 2006 and 2010, is a significant contributor to the forest cover changes observed in this study, as it overlaps with areas in Southern Somalia previously identified as charcoal production sites (Fig 2; Fig 3).

Conclusions

- Somalia and the Horn of Africa have experienced cyclical drought since 1998, with four consecutive failed rainy seasons since 2019 causing large-scale displacement. These natural causes likely contribute to the observed forest cover loss, but cannot fully explain the loss, given similar conditions in the Kenyan area of the study (Devi, 2022; Ogallo et al. 2018).
- The study's limitations include reliance on remotely sensed data, which may not capture the full complexity of the study area, and security issues that prevent ground truthing in Al Shabab controlled territories. The study was also limited to data starting from 2013 due to errors in earlier imagery.
- Future research could include a climate model or drought index, on-the-ground meta-analysis studies, field-based measurements for validation, and examination of other potential causes of forest degradation, such as population growth and land-use changes.
- The study's findings are valuable to various stakeholders, including policymakers, environmental organizations, international aid and humanitarian agencies, and researchers, helping guide policy development, future research, and aid strategies.
- The study concluded that forest cover changes in southern Somalia were statistically more significant ($p < 0.01$) than in northeastern Kenya from 2013-2021, supporting the hypothesis that charcoal production in Al Shabaab-held territories is a primary driver of forest cover change in Somalia. The areas showing the most change were near Kismaayo, a primary port for charcoal export.
- Extreme weather events are already contributing to forest degradation, and Somalia's future landscape and climate are at risk due to the charcoal trade. Despite study limitations, the research is crucial for understanding and combating deforestation activities in Somalia and their impacts on local people and the environment (Ogallo et al. 2018).

Maps and spatial analysis in this poster were created with ArcGIS Pro v3.0, © 2022 ESRI, released on June 23, 2022.

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