October 2022

Regreening Earth:

*Monitoring reforestation projects and identifying new potential locations using **Zazu***

Analysis

[]BEBR

Zazu: a reforestation support-tool

Regreening earth

The effects of climate change on the world around us are beginning to become evermore apparent. Temperatures increase, dangerous weather conditions such as droughts, storms and heat waves are becoming more frequent and intense, sea levels rise, and glaciers are melting at accelerated rates [1, 2].

All of this has detrimental effects on biodiversity, the availability of food, public health and poverty [3]. Although the most effective method to mitigate climate change might be to reduce greenhouse emissions, people are also looking for methods to reduce the amount of carbon dioxide already in the air [4].

Of the proposed methods, **Reforestation**, the effort of replanting forests and shrublands that have vanished due to farming and general land degradation, has been hailed as one of the most attainable and cost-effective strategies [5]. Forests sequester carbon from the atmosphere by the formation of biomass and soil organic carbon. To this end, a multitude of reforestation and regreening efforts have been started over the past decade(s).

Zazu

Over the past few years, [BEBR] has developed **Zazu**, a remote sensing application that can support reforestation efforts by addressing **2 main business questions**:

MEASURE

How do you **quantify** the positive effect that the reforestation or regreening efforts have on the local vegetation?

FIND

How do you **identify** where to focus your reforestation or regreening activities when resources such as labour and funding are scarce?

Zazu uses **satellite imagery** to monitor existing projects of reforestation organisations, resulting in quantifiable measurements on the impact of the projects. Additionally, by enriching this with open source data, Zazu can use the specifications of successful projects to identify potential new areas.

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In this paper, we showcase the capabilities of Zazu by presenting an analysis that was performed on a regreening project by the organisation Justdiggit in the Dodoma region of Tanzania near Pembamoto. In this analysis, we used Zazu to monitor the effects of the regreening project over time and show how Zazu can be used to identify new potential land in Kenya, using the specifications of this successful project.

REFERENCES

[1] PÖRTNER, Hans-Otto, et al. Climate change 2022: Impacts, adaptation and vulnerability. *IPCC Sixth Assessment Report*, 2022.

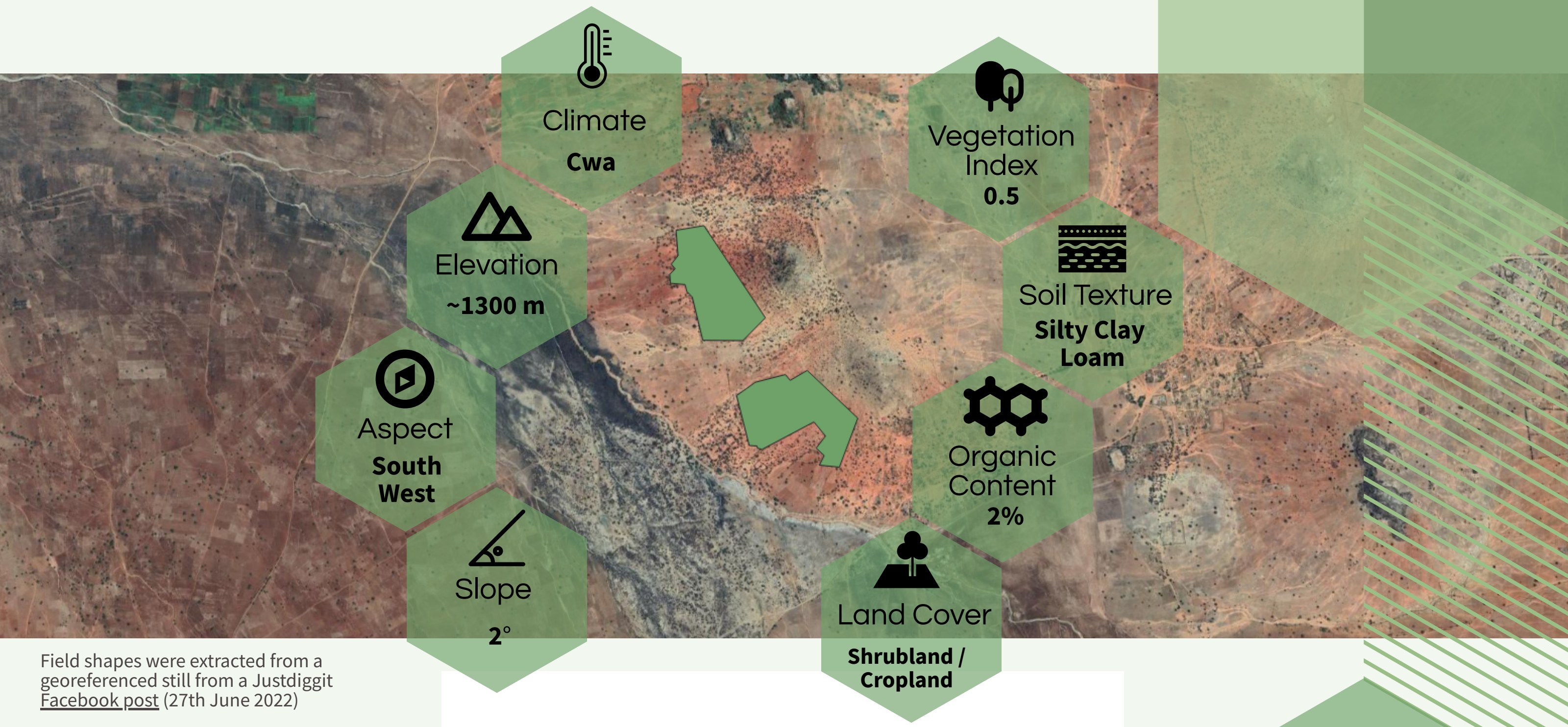
[2] HUGONNET, Romain, et al. Accelerated global glacier mass loss in the early twenty-first century. *Nature*, 2021, 592.7856: 726-731.

[3] The Effects of Climate Change. *NASA.gov*, 21 February 2022.

[4] ADOPTED, I. P. C. C. Climate change 2014 synthesis report. *IPCC: Geneva, Szwitzerland*, 2014.

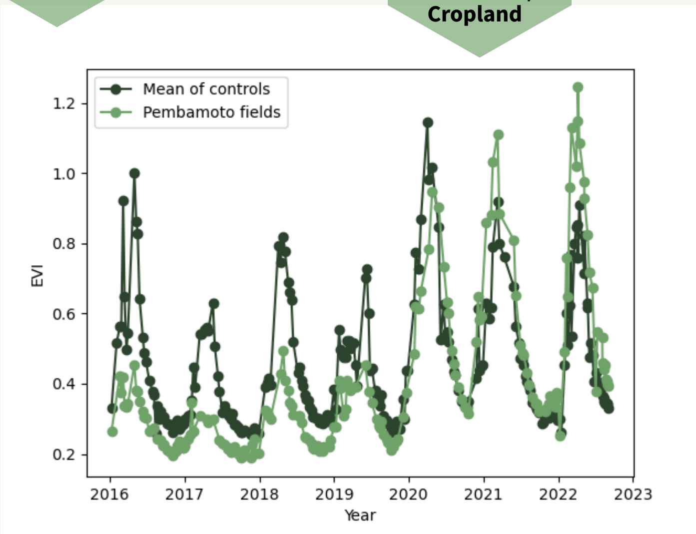
[5] BUSCH, Jonah, et al. Potential for low-cost carbon dioxide removal through tropical reforestation. *Nature Climate Change*, 2019, 9.6: 463-466.

Analyzing and Monitoring project conditions in the Pembamoto project



Field shapes were extracted from a georeferenced still from a Justdiggit Facebook post (27th June 2022)

Impact of the Pembamoto project in Dodoma, Tanzania



Enhanced Vegetation Index (EVI)

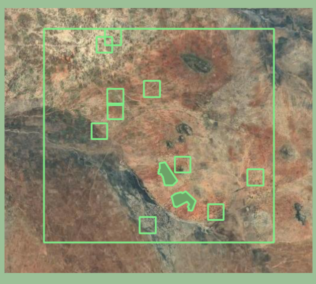
- General measure of 'vegetation greenness' obtained through satellite imagery;
- An optimized index developed to enhance the vegetation signal and to reduce any atmospheric influence;
- Can be used for estimations of plant-based carbon capture within a region.

In order to make the impact of the Justdiggit efforts **quantifiable**, the development of the area's '**greenness**' was measured over time by extracting the areas **EVI**. Each satellite pass over the area gives a new measurement point in time of the EVI (see 'Image Processing Pipeline' section). When the derived EVI measurements are aligned chronologically, a graph like the one shown above is created. Such techniques can therefore be used to **monitor** the regreening efforts over time.

From the graph we can see a clear **seasonal trend** with peaks in rain season and throughs in the dry season. In the years before the project (2016-2018) the average EVI indicates that the project area was **highly degraded** with peak EVI not surpassing 0.4. The EVI of the surrounding lands was consistently higher. After digging of the bunds in 2018 the impact on the Pembamoto fields can be clearly seen in the EVI. In the years 2021 and 2022 the summer EVI peaks are even higher than the control fields. But most importantly, while there is a **clear rising trend** visible in the EVI of the Pembamoto field, such a trend is not visible in the controls, indicating that the rise in EVI is **due to the reforestation effort** and can not be ascribed to a general regreening of the area. On average, the EVI **tripled** in the years under consideration for the Pembamoto project.

Measuring EVI baseline using randomized controls

To measure the impact of the reforestation project, the evolution in vegetation index was measured against a randomly generated set of fields of the same size as the Pembamoto fields within a bounding box around the subject field to control for overall regreening of the area. This experiment was repeated several times and the results were averaged. Redrawing control fields resulted in similar results.

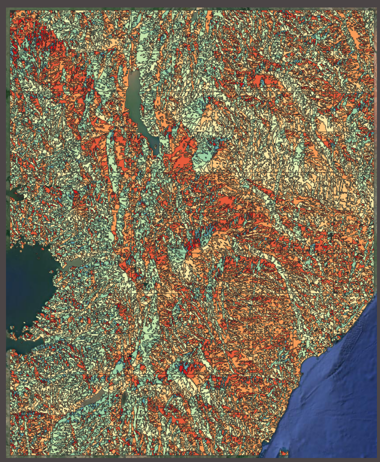


Using Pembamoto data to find new areas

Considering the evident positive effect of the Pembamoto project, we can analyze the characteristics of the landscape to find similar areas where Justdiggit could achieve similar positive results. For this analysis, the following data layers are used:

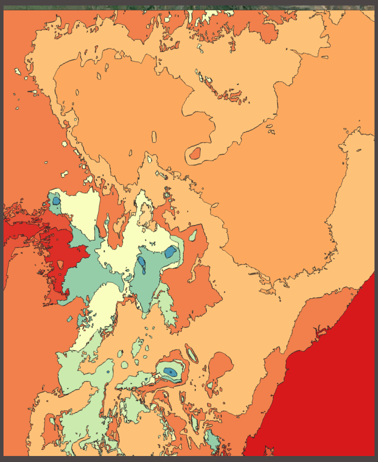
Aspect

Aspect describes the direction of the slope of the landscape in degrees. It is derived from a Digital Elevation Model (DEM).



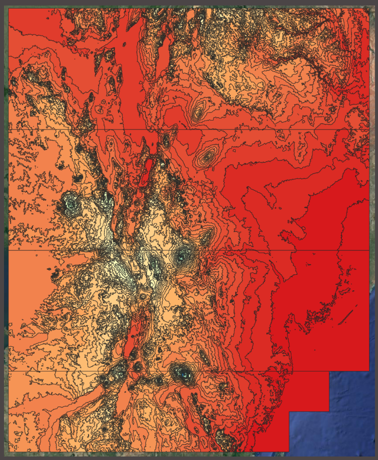
Climate

Climate describes the local long term weather conditions according to the Koppen-Geiger Climate Classification.



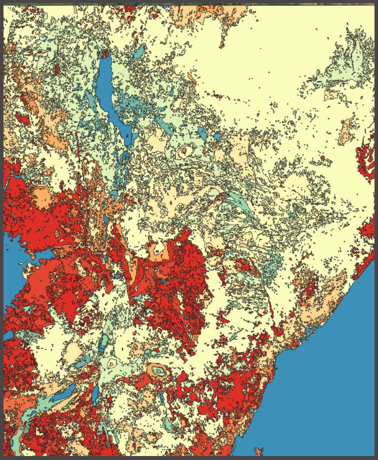
Elevation

Elevation describes the height of the landscape in meters above sealevel. It is derived from a DEM.



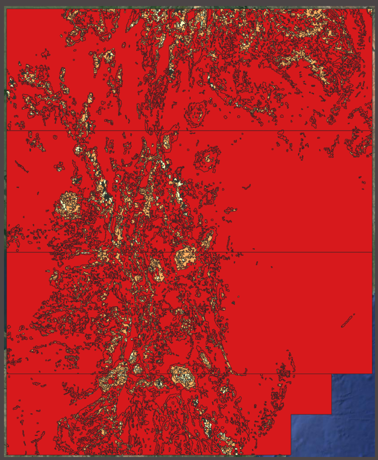
Land Cover

Land Cover describes the terrain use and type of vegetation. The data is produced by ESA and follows their classification system. It is a categorical layer.



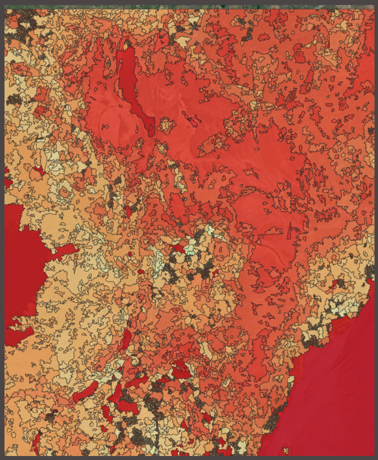
Slope

Slope describes the steepness of the landscape in degrees. It is derived from a DEM.



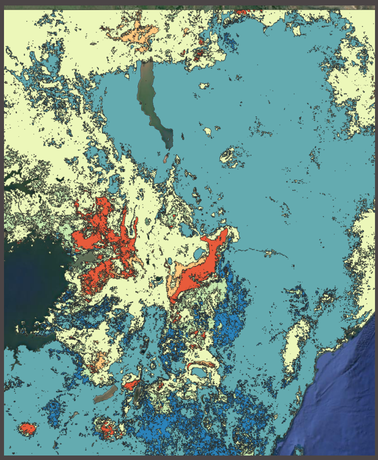
Vegetation Index

Vegetation Index describes the peak EVI. It is generated from the Landsat-8 spectral images. Its unit is dimensionless.



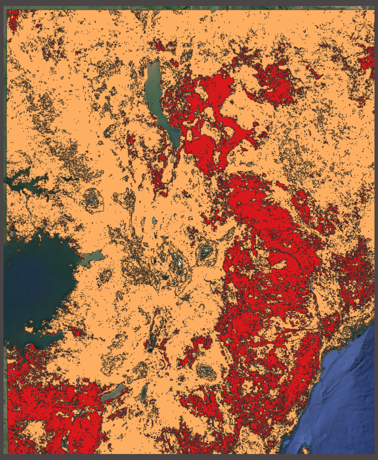
Soil Texture

Soil Texture describes the predominant quality of the soil and follows the USDA Soil Classification standard. The layer is derived from the SoilGrids database. It is a categorical feature.



Soil Organic Content

Soil Organic Content describes the percentage of soil consisting of organic carbon. The layer is derived from the SoilGrids database.

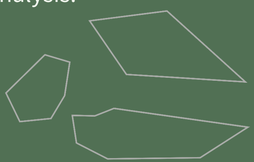


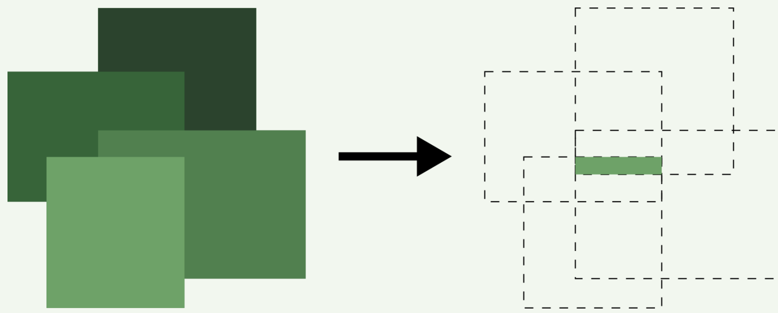
Analyzing Data Layers

After collecting the important data layers, they can be analyzed to identify the most suitable areas for new projects. By applying the conditions found in the successful Pembamoto project as filters to the datalayers, we can infer where this potential new land is situated.

Polygons

Are geometrical figures in multiple shapes used for analysis.





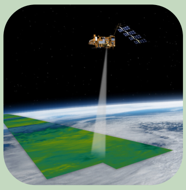
Calculating the intersection of 4 overlapping polygons

How to process the data layers?

An important step in the Zazu analysis process is the conversion of data layers into **polygonized** feature layers. Traditionally, the most common data format for processing spectral images is the geo-tagged image file format (**GeoTIFF**). Think of this image format as a spreadsheet where each cell corresponds to a pixel value of the image. This type of data is therefore also called **raster data.** While this data format is very efficient for **storing** data, it is not suitable to do calculations on. For this we need **feature** data, where each unit in the layer is described as a set of connected x, y-coordinates. These sets of data are called polygons and they are great for calculations, but the size of the data will increase.

In order to derive polygons from the raster data that are acquired from the source, the data needs to be polygonized. This can be done using polygonization algorithms.

Image Processing Pipeline



1

Acquire Images

From Nasa Sentinel Satellites

2

Clean up layers

Remove clouds using Fmask Algorithm and bad pixels using Gaussian filters

3

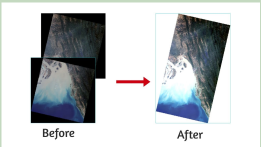
Feature Extraction

Use stacked layer data to calculate the output layer

4

Transform

Into polygons for final analysis



5

Combine bands

Into one data layer and persist to storage

6

Storage

Ready for Zazu

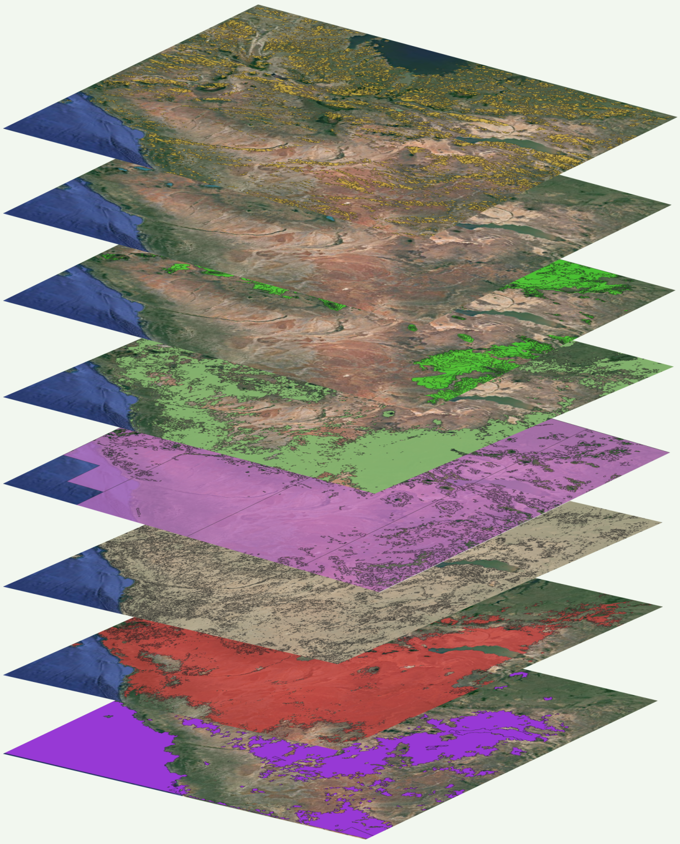
Potential new project areas

Once these polygon layers are obtained, the data is ready for the final processing step, where the intersection of all layers is calculated. The resulting layer is a collection of polygons that satisfy all the conditions set by the filters. For example, when we analyze the elevation layer with a filter condition between 1200m - 1400m and the land cover filter is set to shrubland, the analysis layer will be those area's of land that are both between 1.2km and 1.4km above sea level AND are vegetated by shrubs. In the current analyses all layers described above were under consideration using the filter settings. In the figures below, the overlayed filter layers (left) and the resulting analysis layer are shown (right).

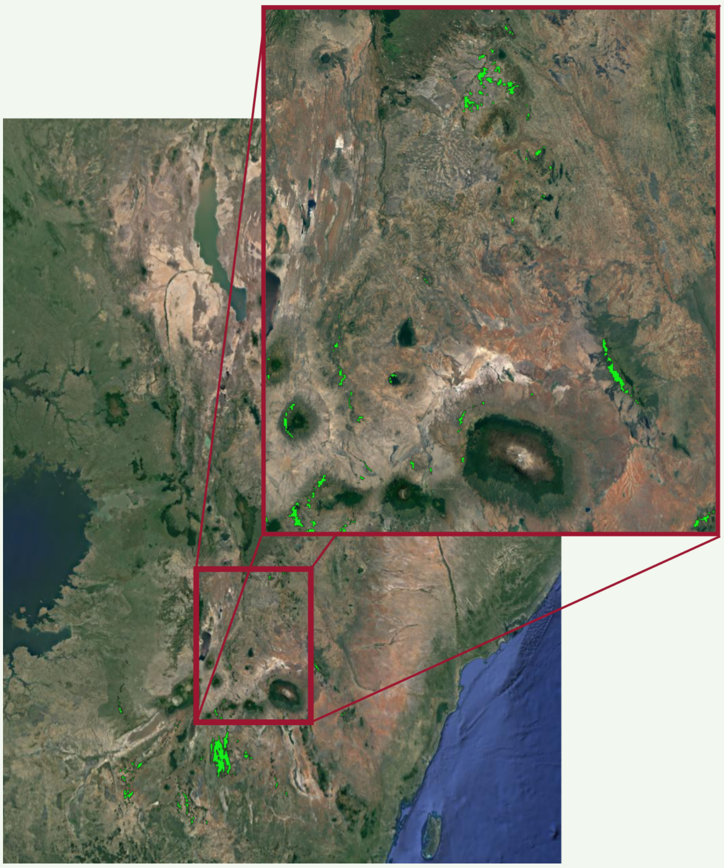
The analysis resulted in more than 500 areas, varying in size from a couple hectares to 1342 km^2. Looking at the results, we can see potential new project areas for example around the south-west slopes of large mountains, probably in part due to the elevation and climate constraint. Importantly, these areas are often degraded as they are intrinsically susceptible to soil erosion [6]. They would therefore be interesting prospects for future efforts.

In future analyses, the combination of BEBR's data analytics and the expertise of reforestation agencies can be used to set even more suitable filters to identify more potential areas.

Potential new project areas based on (filter settings):
- Soil Type: Silty Clay
- Soil Organic Content: 2%
- Climate Type: Temperate, dry winter, hot/warm summer
- Elevation: ~ 1300 masl (meters above sea level)
- Slope: 2°
- Aspect: South West
- Land Use: Rainfed Cropland, Shrubland
- Vegetation Density:~0.5 peak EVI



All layers applied



Potential new project areas: intersection of the 8 layers (green)

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[BEBR] started as a small team of scientists aiming to apply scientific concepts and ideas to solve real-world business problems. Over the past years, we have grown into a company specialized in developing solutions that connect today's challenges using IT, AI & Big Data. In this, BEBR is strong in bridging the gap between reality and technology and we are able to maximize the value of data within organizations. One of the products in our portfolio is Zazu: an earth-monitoring platform, which combines proprietary Machine Learning models with spectral imagery from the Sentinel and Landsat satellites to identify areas that are suitable for reforestation and regreening efforts.