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FOREST PATCHES IN WEST AFRICA

Forest structure, biomass, and management

Samuel Hepner, University of Bern, samuel.hepner@unibe.ch

1. Introduction

Tropical forests are being cleared worldwide; in West Africa in particular, **deforestation is taking place at an alarming rate** (Poorter et al., 2021). However, deforestation is often incomplete, and forest patches remain without formal protection in the agricultural landscape (Schelhas & Greenberg, 1996). It is unclear why these forest patches still persist, resisting disturbances like land use change, climate change or forest fires. Closely linked with the fate of those forest patches are the local people which depend on forest products such as timber, fuelwood or bushmeat and appreciate the forest for recreational or religious purposes (Poorter et al., 2004). Forest structure **(stand structure complexity index: ssci) and aboveground biomass (AGB)** are the result of a complex interplay of social, environmental, spatial, and allometric factors and the sustainability of the management. Thus, forest structure and AGB are **important indicators of the intactness of forests**, mirroring the impacts of disturbances, showing forest resilience, and are **particularly relevant regarding biodiversity, the carbon cycle and global warming**. Comparable and measurable units, such as forest structure and AGB are needed to assess and monitor the intactness of forest ecosystems (IUCN, 2022). However, such data is rare to find in West Africa (Lewis et al., 2013) and global estimates have a coarse spatial resolution and are therefore inaccurate for small-scale forest patches.
The project SUSTAINFORESTS defines forest patches as between 0.5 and 1000ha large areas with at least 10% canopy cover and trees higher than 5m (FAO, 2016). This study addresses the fundamental lack of knowledge concerning forest structure and AGB of small forest patches in Togo, Benin, Nigeria, and Cameroon. Preserving forests and its associated biodiversity is an **important and low-cost climate change mitigation strategy.**

Fig. 1: Tropical forests provide several ecosystem services. Tagged trees with Terrestrial Laser Scanner in the sacred, but heavily degraded Ewe-Adakplame forest in Benin.

2. Methods

2.1 Study sites

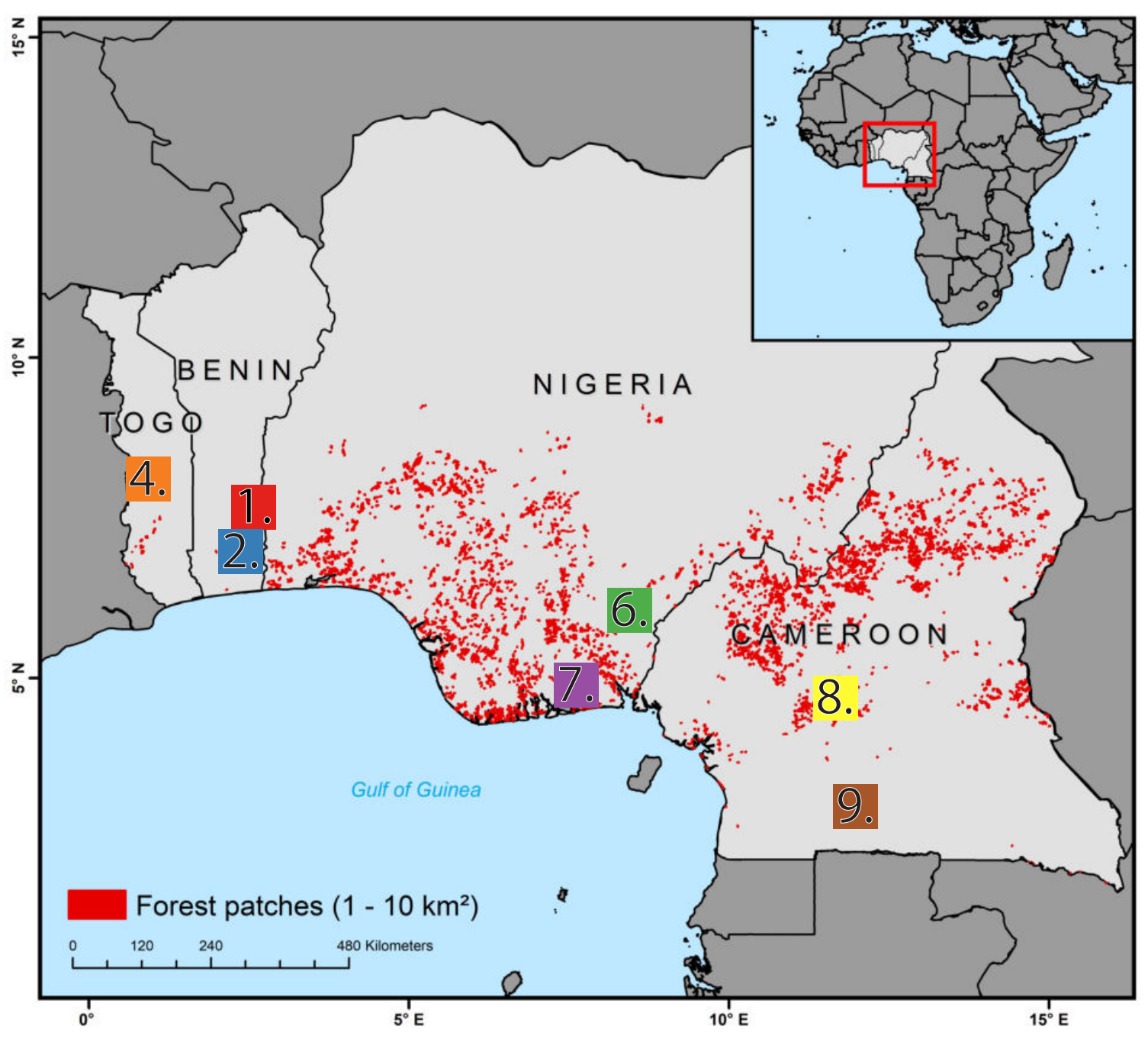


Fig. 2: The study area comprises Togo, Benin, Nigeria, and Cameroon, which have around 4000 formally unprotected forest patches (Wingate et al., 2022). Seven of them were selected for in-depth insights (see Fig. 5).

2.2 Data collection

Nine forest patches in Togo, Benin, Nigeria, and Cameroon were selected and visited in 2022 and 2023. Randomly distributed **plots of 50x50m²** were installed in order to represent the whole forest patch. With a Terrestrial Laser Scanner (FARO M70) **single scans** (resolution: 43.7Mpts, 0.035°/pt) were taken in the four corners and in the center. In a **25x25m² subplot** all the trees with a diameter at breast height (DBH) >10cm were tagged with a number and a marker. The **continuous chain** approach (each 5m) was applied to scan (resolution: 24.2MPts, 0.044°/pt, colorized) the subplot reducing omission. Additionally, a forest inventory was conducted with manual DBH measurements, tree species identification and regeneration assessment. Soil samples were collected, drones took lidar and multispectral imagery and the people of the surrounding villages were interviewed.

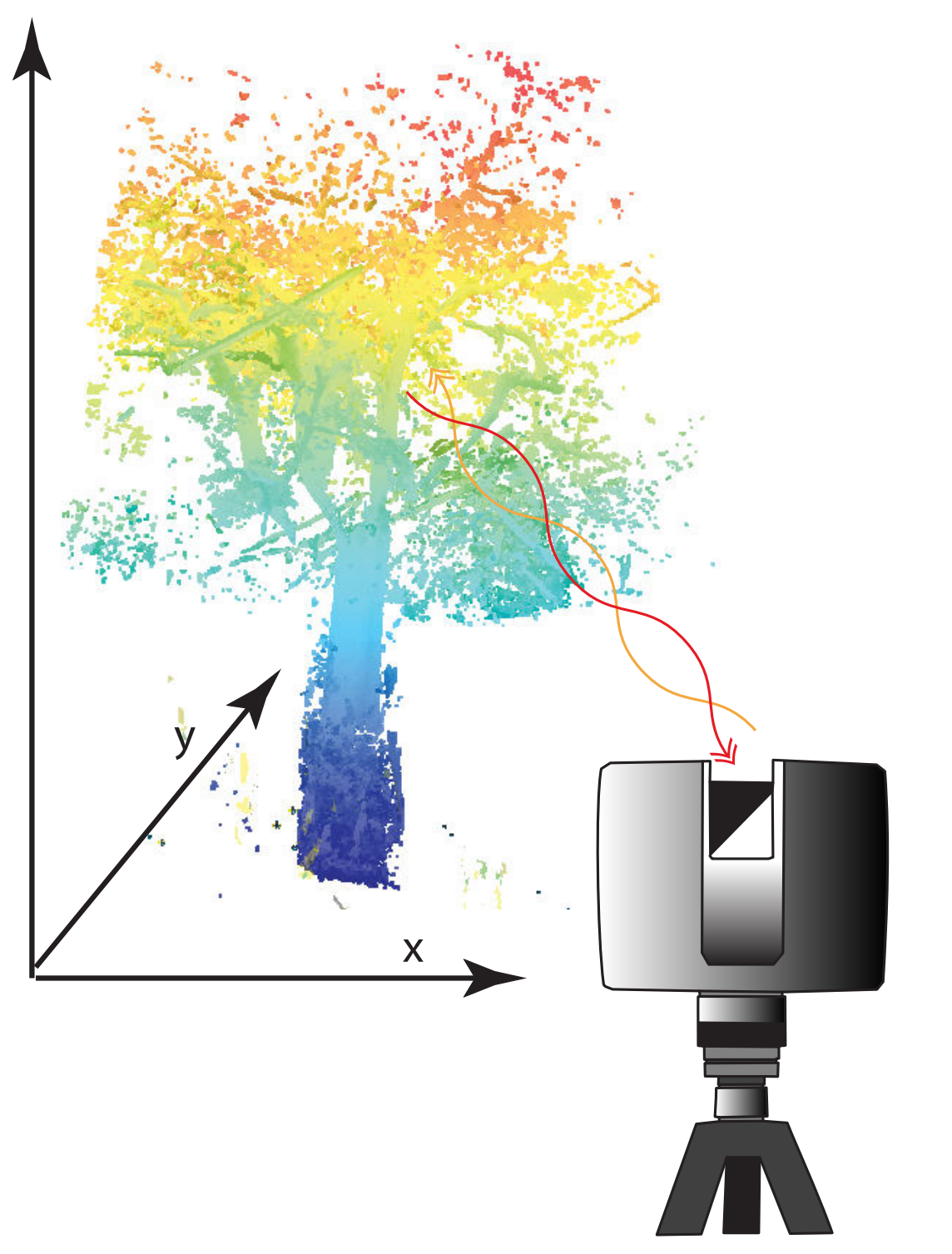


Fig. 3: The TLS emits and receives light waves and is able to measure the dimensions of trees accurately. The color grade corresponds to the z-axis respectively the height of a 40m-tall *Ceiba pentandra*.

2.3 Data analysis

The scans of 105 plots (600Gb) were processed in FARO Scene (version 2023.0.1) on a Windows 10 computer (RAM: 32Gb). The single scans were subsampled by 4, exported as .xyz and the ssci-code (Ehbrecht et al., 2017) was run in R. Stand point clouds of 60 subplots (25x25m², .las-format, ~10Gb/plot) are processed in the software FSCT to generate the number of trees, the diameter at breast height, volume and individual heights. This allows precise calculations of the plot biomass.

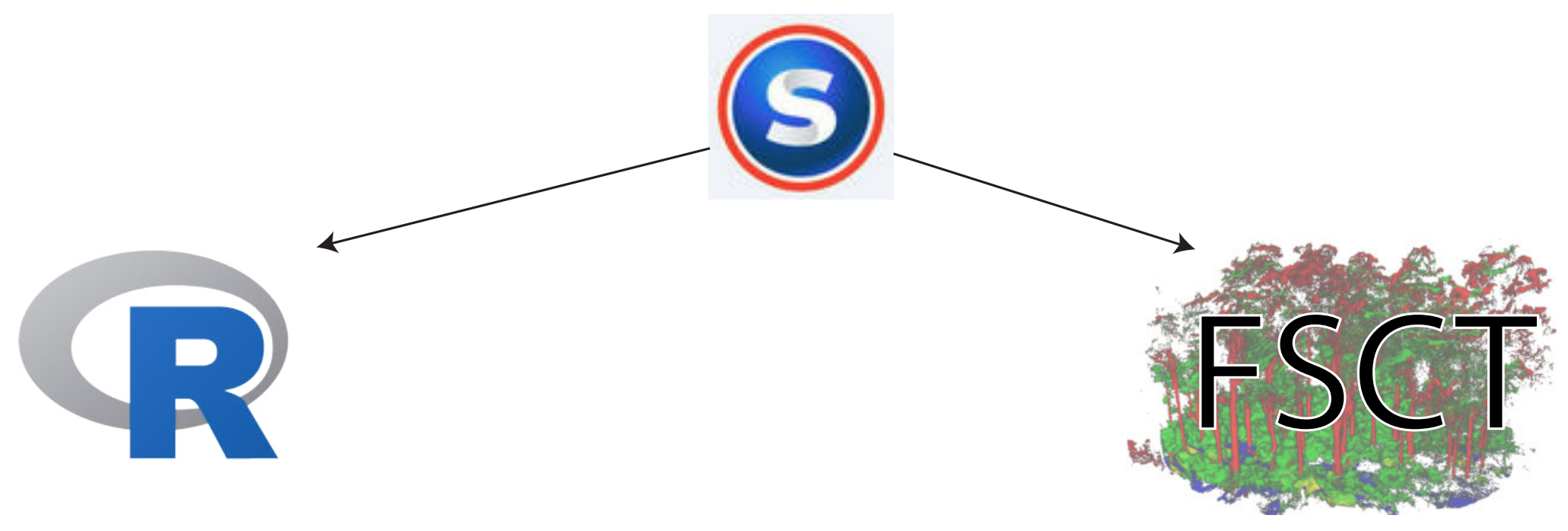


Fig. 4: FARO Scene and R with RStudio were used to analyse the scans derived from the single-scan approach. Forest Structure Complexity Tool (FSCT) is used to calculate the forest stand volume resp. the biomass from the forest stand point clouds derived by the multi-scan approach.

3. First results

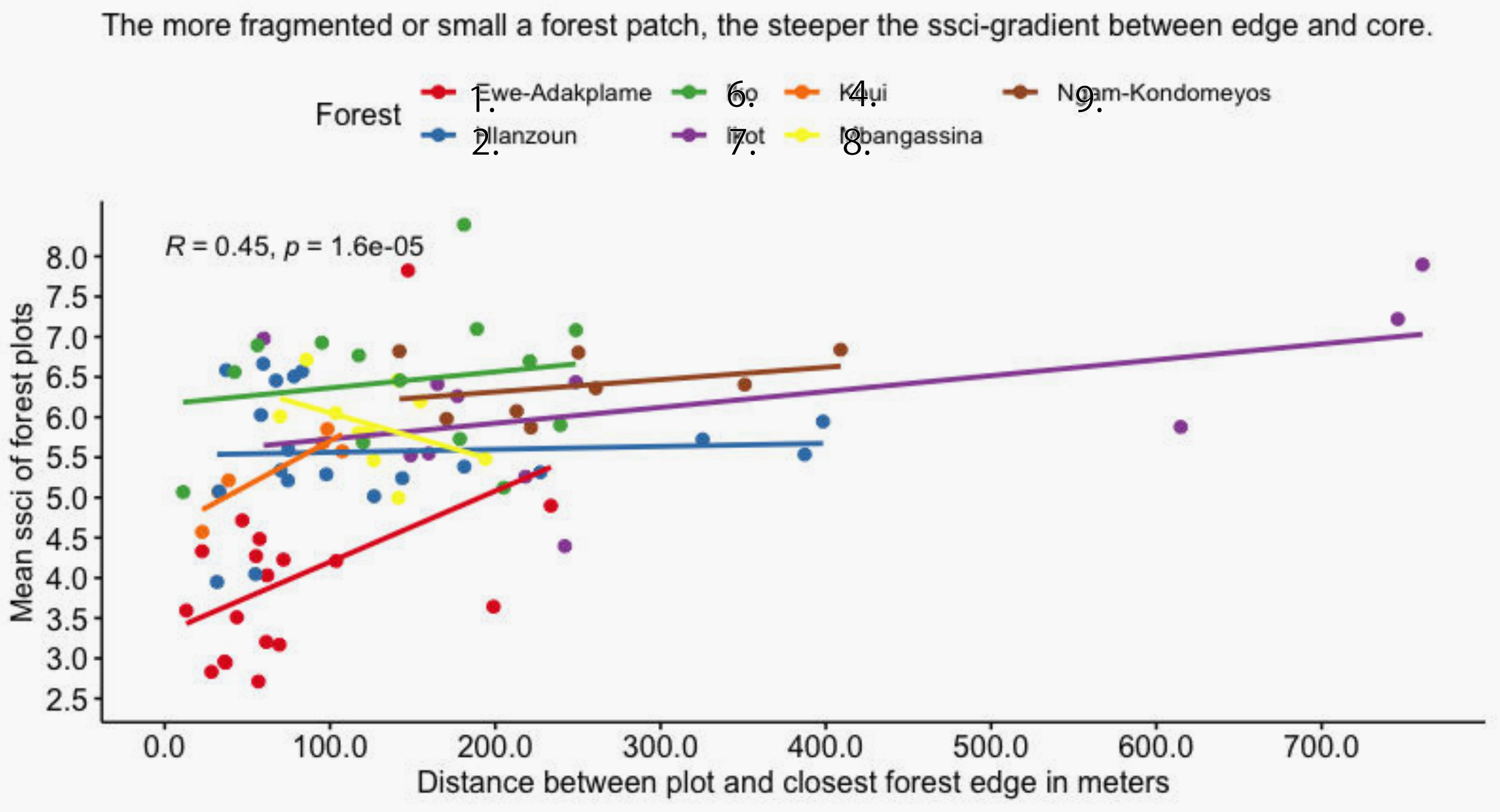


Fig. 5: The Stand Structural Complexity Index (ssci) increases from the forest edge to the forest core. The smaller and the more fragmented a forest patch, the more pronounced is this effect (e.g., 1. Ewe-Adakplame, 4. Koui)..

3.1 First insights:

- Stand structural complexity index (ssci) is significantly **lower at the edge** (<100m) than in the core of forests
- The smaller and the more fragmented a forest patch, the more pronounced is this effect (Fig. 5).
- Forest **disturbances** (e.g., logging, fire) lower the ssci
- **Liana infestations** can increase ssci
- Agroforestry can keep ssci high despite changed land use
- More forest gaps and higher openness decreases ssci (Fig. 6).
- **Inaccessibility** through natural (e.g., swamps) or cultural (e.g., sacredness) bareers can decrease pressure on forests
- The more biomass the harder to measure it accurately due to occlusion (Fig. 7)

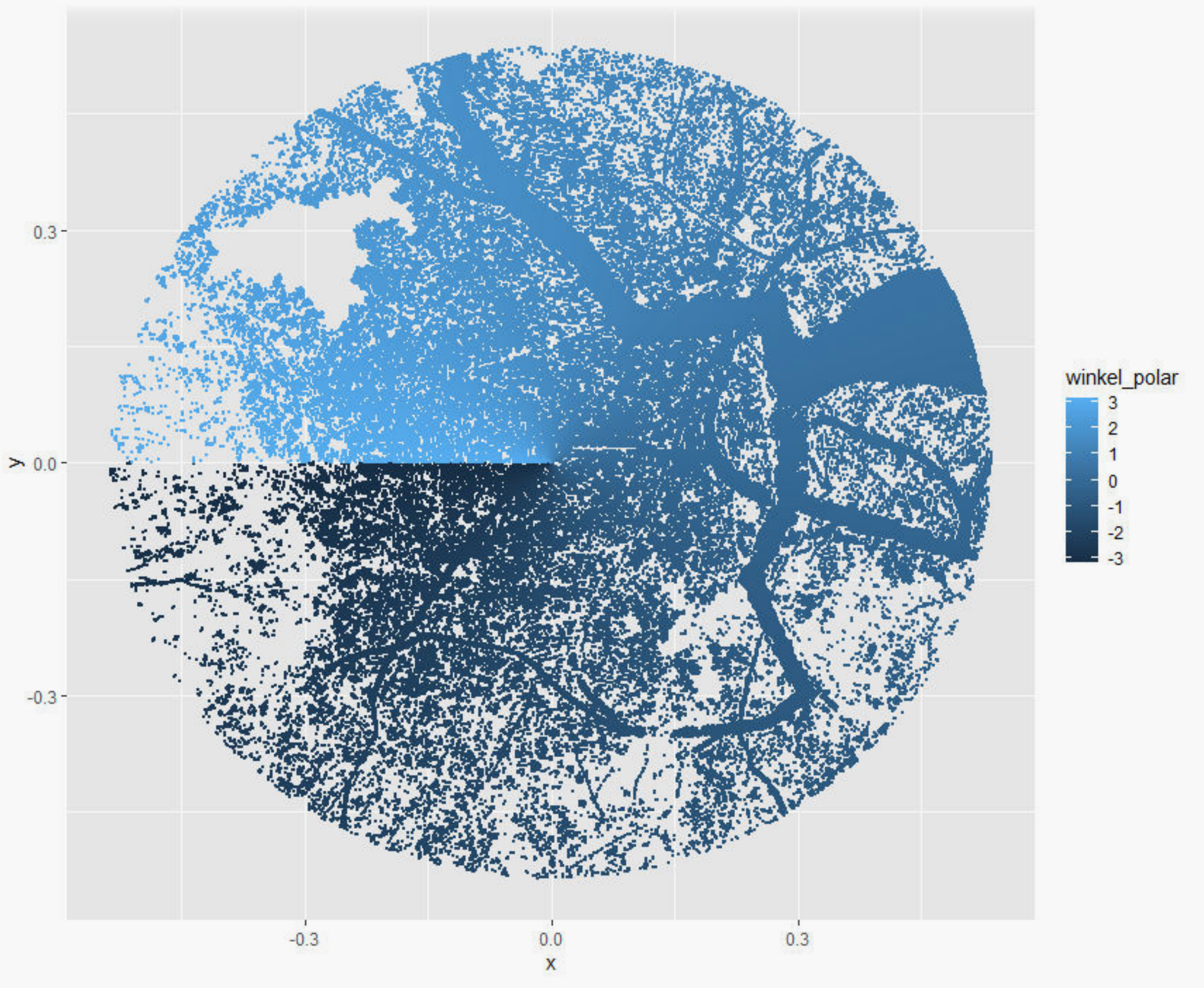


Fig. 6: This single scan (horizontal 360°, vertical 60° towards the zenith) shows a canopy openness of 20% in Ewe-Adakplamè (1.), Benin. Degraded forests often show increased size and frequency of gaps due to disturbances such as fire or logging. The blue gradient shows the scan direction.

Fig. 7: Leaf-on forest point cloud of 25x25m² plot in the swamp forest of Hlanzoun, Benin. The point cloud is colored according to x-, y-, and z-axis.

4. Further steps

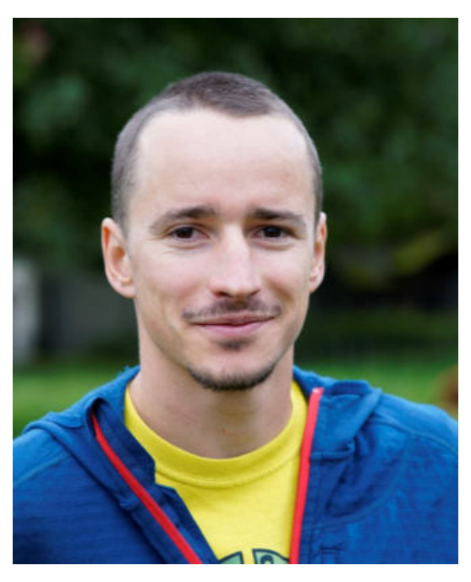
- Integrate more data into analysis:
  - Forest variables (e.g., tree species richness)
  - Climate data (e.g., annual mean precipitation, temperature variation)
  - Environmental data (e.g., soil parameters, elevation)
  - Spatial data (e.g., forest edge/area index, distance to roads)
  - Social data (e.g., population density in surrounding area, management intensity)
- Plotwise extraction of biomass-data
- Extrapolation of plot results to forests
- Extract more data from point clouds
  - Leaf area index (Indirabai et al., 2020)
- Integrate interview data

Take away message

Tropical forest fragmentation is high and stands before a collapse (Taubert et al., 2018). Terrestrial Laser Scanners allow to quantify forest degradation in a quick and standardized way. Any efforts to conserve tropical forest patches with their ecosystem services and associated biodiversity is highly encouraged.

5. References

EHBRECHT, M., Schall, P., Ammer, C., & Seidel, D. (2017). Quantifying stand structural complexity and its relationship with forest management, tree species diversity and microclimate. Agricultural and Forest Meteorology, 242, 1–9. https://doi.org/10.1016/j.agrformet.2017.04.012
FAO. (2016). Global Forest Resources Assessment 2015: How are the world's forests changing? (2nd ed.). http://www.fao.org/3/a-i4793e.pdf.
INDIRABAI, I., Nair, M. H., Nair, J. R., & Nidamanuri, R. R. (2020). Direct estimation of leaf area index of tropical forests using LiDAR point cloud. Remote Sensing Applications: Society and Environment, 18, 100295.
IUCN. (2022). IUCN's position. 9. https://www.iucn.org/sites/dev/files/iucn_position_paper_resumed_cbd_sbstta24-sbi3-oewg3_.pdf
LEWIS, S. L., Sonké, B., Sunderland, T., Begne, S. K., Lopez-Gonzalez, G., van der Heijden, G. M. F., Phillips, O. L., Affum-Baffoe, K., Baker, T. R., Banin, L., Bastin, J.-F., Beeckman, H., Boeckx, P., Bogaert, J., De Cannière, C., Chezeaux, E., Clark, C. J., Collins, M., Djagbletey, G., … Zemagho, L. (2013). Above-ground biomass and structure of 260 African tropical forests. Philosophical Transactions of the Royal Society B: Biological Sciences, 368(1625), 20120295. https://doi.org/10.1098/rstb.2012.0295
POORTER, L., Bongers, F., Kouamé, F. Y. N., & Hawthorne, W. D. (2004). Biodiversity of West African Forests: An Ecological Atlas of Woody Plant Species (L. Poorter, F. Bongers, F. Y. N. Kouamé, & W. D. Hawthorne, Eds.). CABI Publishing.
SCHELHAS, J., & GREENBERG, R. S. (1996). Forest Patches in Tropical Landscapes (J. Schelhas & R. S. Greenberg, Eds.). Island Press.
TAUBERT, F., Fischer, R., Groeneveld, J., Lehmann, S., Müller, M. S., Rödig, E., Wiegand, T., & Huth, A. (2018). Global patterns of tropical forest fragmentation. Nature, 554(7693), 519–522. https://doi.org/10.1038/nature25508
WINGATE, V. R., Akinyemi, F. O., Iheaturu, C. J., & Ifejika Speranza, C. (2022). A Remote Sensing-Based Inventory of West Africa Tropical Forest Patches: A Basis for Enhancing Their Conservation and Sustainable Use. Remote Sensing, 14(24), 6251. https://doi.org/10.3390/rs14246251



Contact:
Samuel Hepner
PhD student in Geography and Sustainable Development
Institute of Geography, University of Bern

www.sustainforests.giub.unibe.ch

samuel.hepner@unibe.ch