CS486C – Senior Capstone Design in Computer Science

Project Description

Project Title: Biomapper: a mobile biodiversity catalog	
Sponsor Information:	**Jenna Keany,** PhD Student Jk2254@nau.edu **Christopher Doughty,** Associate Professor Chris.doughty@nau.edu Megabiota lab - https://www.cdoughty.org/ School of Informatics, Computing, and Cyber Systems Northern Arizona University

Project Overview:

Climate change and loss of critical habitat due to human activities have led us to the brink of a historic wave of potential extinctions in the natural world, as well as threatening a fundamental change to both human and animal ecosystems on the planet. In this context, it is more important than ever to use every possible technological advantage to collect accurate data on the current state and trajectory of ecological systems in regions across the world and make these data and analysis of potential impacts and mitigation strategies easily accessible to local citizens and decision makers on the ground in those regions. As a concrete example, tropical forests account for 25% of global carbon storage and one third of terrestrial vegetation productivity on the planet, with some of the largest carbon stores occurring in the African tropics. Gabon, a small African nation sandwiched between the Atlantic Ocean and the Republic of Congo is home to old growth forests as well as high levels of biodiversity (elephants, gorillas, chimps, etc.). Along with prioritizing conservation and forest health, Gabon has permitted numerous research teams from across the globe to study forest structure, species mapping, and carbon storage. Many of these projects have assisted in the development of new methods for analyzing carbon sequestration by tropical forests in the Congo basin, new ideas on how megaherbivores such as forest elephants increase the carbon content of the region, and the ground truthing of remote sensing techniques such as light detection and ranging, or lidar.

Although on-the-ground fieldwork still has an important role to play, understanding local ecosystem dynamics in a broader regional or continental context requires accurate, high-volume remote sensing data typically provided by satellite-mounted platforms. These massive raw data collection efforts have been extremely successful: a

wealth of forest structure, land cover, precipitation, and deforestation data is produced each year by new NASA satellites. For example, the Global Ecosystem Dynamics Investigation (GEDI) project will collect approximately 10 billion lidar points containing structural information on the Earth's surface over a 2-year span. Similarly, the Sentinel-2 project collects multi-spectral images of the globe with a 10 meter spatial resolution every 5 days. These well-funded and very successful data collection efforts have yielded an enormously useful trove of environmental data covering many regions of our planet.

Unfortunately, local stakeholders, meaning local citizens, activist groups, courts, administrative decision makers, and so on, who need estimates of forest structure and carbon content often lack the technical skills to access these datasets, much less being able to apply even basic analysis and visualization techniques to help answer questions of vital local or regional concern. Coming back to the concrete case of our Gabonese partners, for instance, Gabonese researchers and policy makers might require canopy height metrics or estimates of above-ground biomass for their forests in order to estimate the carbon content of those areas, or to evaluate the potential impact of local land development activities. While there are now global canopy height and biomass estimates available from NASA's satellites on data storage services such as the LP DAAC (https://lpdaac.usgs.gov/), these data are difficult to navigate to, process, and crop to focus on a particular target area of interest. More specifically, accessing, filtering, and visualizing these large datasets requires remote sensing and informatics skills that a regional environmental policy maker or local educator might not have. What is needed is an easily-accessible, GUI-driven mechanism to provide a simple but powerful end-user interface to these growing environmental datasets.

Solution Vision: BioMapper: an end-user tool for accessing environmental data

To address the challenge of making large-scale environmental data relevant and accessible to local stakeholders, we envision a mobile application driven by a cloud-based computational infrastructure that allows non-technical users to easily locate and view environmental data for their region. The Biomapper system will index, process and visually present relevant data drawn from large-scale online datasets, so that the user can quickly and easily run useful statistics on issues such as deforestation and carbon storage, as well as providing graphical (visualization) summaries of these statistical analyses. Beyond land use and coverage information, the app would be useful to researchers interested in studying certain plant or animal species: knowing the climatic and land cover characteristics most attractive to that species, a researcher or educator could locate local regions where the species are most likely to be found, or fine-tune modeling and prediction of species response to a changing climate in the future.

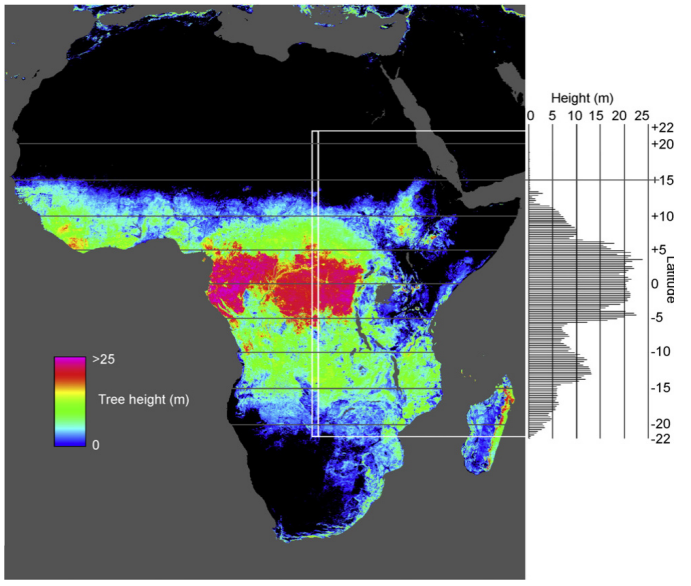

Figure 1. Forest height and biomass map of Central Africa from NASA's spaceborne lidar sensor GEDI. Credit: https://gedi.umd.edu/data/products/

As a specific focus for this project, our group at the Megabiota lab is collaborating with researchers at Lope National Park, Gabon, and the Wildlife Conservation Society; and we are interested in creating an ecological application that could be used by Gabonese scientists and educators in the field. This application would incorporate a map of Gabon with overlaying environmental layers such as canopy height and above ground biomass that were synthesized using spaceborne lidar from the Global Ecosystem Dynamics Investigation (or GEDI) led by NASA (Figure 1). Using location data from the user's smartphone, researchers would be able to quickly identify areas of the surrounding forest regions with highest biomass content and highest canopy height. Additional layers of

previous biomass estimates could be added to the map providing a time series analysis of carbon content in the African tropics for the region, highlighting areas with high and low deforestation. As a user friendly and freely available phone application, this project would assist in the dissemination of these data that are typically difficult to work with in a simple and effective manner.

Project Details: A cloud-based mobile app

Specifically, we envision BioMapper as a mobile application for Android or iOS smartphones, backed by a cloud-based data processing infrastructure; a minimal secure web application for configuring the system and other system administrative tasks will also be needed on the backend. To allow rapid progress, we will prioritize work on an Android application, but the team should use a modern cross-platform development framework (e.g. Ionic, Flutter, React Native, etc.) so that, once an Android app is functioning well, an iOS version could be generated from the same codebase near the end of the project. Although the functional and technical details will evolve as the team begins its work with us, some of the functions (and their priorities) that we would expect in a successful product include:.

Basics: (minimum viable product): barely proves the concept

- Modern mobile app architecture based on a mobile application backed by a cloud server
- A basic role-based user authentication system that supports admins, local authorities (which we'll call "Researchers" for simplicity), as well as public users.
- If available on the device, uses the GPS on the phone to automatically center display a precise location on the map. Other regions should be accessible for inspection by scrolling/zooming the map.
- A map displaying various environmental layers that can be toggled on and off, such as canopy height, above ground biomass, and canopy cover.
- An option to view each environmental layer over time, with basic statistics such as loss of canopy cover over the last xx years.

A complete solution: Features needed in a truly usable product

- A matching web application to provide public information and provide a GUI for easy administration and configuration of the system.
- The ability to screen for certain forest types. For instance, to screen for regions with canopy heights >40m which are where particular bird species tend to congregate.
- A "map feature" to guide the research to the regions of interest via the mobile app.
- Product uses best practices in "internationalization"; GUI can be switched to several languages; initial languages will include French and English. Clients will provide access to appropriate linguistic support.
- A more complete user management system with editable user profiles and preferences. Allows creation of new users by admins, as well as editing of certain profile fields by users.

Fancy extras (stretch goals)

- Ability for authorized users to use graphical tools to visualize and investigate deforestation/biomass over time for central Africa
- A functioning iOS version of the BioMapper app.

Knowledge, skills, and expertise required for this project:

- Knowledge of mobile application programming frameworks, with particular emphasis on cross-platform frameworks like Ionic and React Native.
- Knowledge of modern Web2.0 programming techniques required to develop the administrative web app
- Knowledge of back-end server and database technologies, with emphasis on configuration and deployment of cloud-based server resources.

Equipment Requirements:

- There should be no equipment or software required other than a development platform and software/tools freely available online.

- A cloud-based server will eventually be required as a deployment platform. Development can be done on a free-tier server available from AWS but a paid development platform can also be provided if necessary. At product delivery, the client will take over this server and any future costs.

Software and other Deliverables:

- The software applications as described above, deployed and tested successfully with simulated but realistic data. Must include a complete and clear User Manual for configuring and operating the software.
- A strong as-built report detailing the design and implementation of the product in a complete, clear and professional manner. This document should provide a strong basis for future development of the product.
- Complete professionally-documented codebase, delivered both as a repository in GitHub, BitBucket,or some other version control repository; and as a physical archive on a USB drive.