



EarthLENS: A Novel Drone-based Citizen Science Tool for Land Cover Observation and Analysis



Introduction

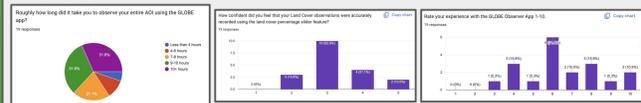
Studying and collecting **land cover data** is essential for monitoring environmental change, modeling ecosystems, and supporting a wide range of environmental analyses. **Citizen science** platforms, such as NASA's GLOBE Observer app, extend the ability to collect valuable land cover data to the public by enabling users to collect and contribute photographic observations and encouraging preliminary data analytics.

However, during the 2025 NASA STEM Enhancement in Earth Science (SEES) research project, which compared satellite-derived land cover data to ground observations made through the GLOBE system, we identified **significant limitations** in the tools available to citizen scientists. SEES interns reported a **multitude of challenges** they faced while using the GLOBE app, including frequent **loss of observations** during upload, **severe image compression** upon upload to the GLOBE visualization tool (<1 MP), inconsistent GPS accuracy, **low confidence** in the accuracy of the land cover percentage-slider interface, and large amounts of time required for observations.



These insights were reinforced through a survey conducted among SEES interns, where key findings included:

- Median GLOBE Experience Rating: 6.0 / 10
- Median Land Cover Percentage-Slider Feature Confidence: 3.0 / 5
- Average Time to Complete Observations: 8.74 hours
- Respondents Who Took More Than 9 Hours to Complete Observations: 63.2%



Figures 4-6 SEES Earth System Explorers 2025 Survey Results

Though valuable land cover data was gathered with the GLOBE tools, these findings highlight a **critical gap** between the potential of citizen science and the limitations imposed by existing tools. To **address these challenges** and enable more accurate, efficient, and powerful land cover data collection methods, we began developing **EarthLENS**, a drone- and app-based system designed to **modernize, improve, and enhance** the ability of citizen scientists to collect and analyze data.

Engineering Objectives

- 1) **Ensure Stable and Reliable Drone Operation** - Develop a lightweight drone platform capable of safely carrying research payloads, validating power distribution, communication, and flight performance through controlled test flights.
- 2) **Develop a Companion Mobile App Architecture** - Create an application capable of communicating with the drone system, collecting observation data, packaging and tagging observations, and enabling users to access, organize, and share their observations.
- 3) **Integrate Remote Sensing Technologies** - Incorporate sensors such as NASA STELLA devices to collect spectral data to enable accurate land cover discrimination and enhance compatibility with satellite-derived products.
- 4) **Capture High-Quality and Low Compression Imagery** - Use lightweight onboard cameras to produce photos suitable for land cover classification and spectral comparison between other sources of data.
- 5) **Collect Precise Geospatial and Flight Metadata** - Measure factors such as airspeed, groundspeed, pitch, roll, yaw, latitude, longitude, altitude, and temperature to provide a more complete description of observing conditions and standardize observation methodologies.
- 6) **Eliminate Data Loss** - Design a drone-app-based system that won't offload data from observations to a database before it has been stored locally.

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NASA SEES Internship Program

Engineering Methodology

Hardware Design

Scientific Payload:

- Adafruit AS7265x TRIAD Spectral Sensor (from STELLA Q2) (410-940 nm)
- Adafruit AS7341 spectrometer (from HelioSTELLA) (415-680 nm)
- Raspberry Pi 8MP Camera

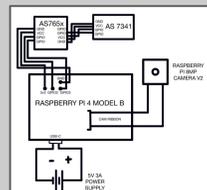


Figure 7: Scientific Payload Informal Schematic

Flight Components:

- Holybro Kakute H7 v1.5 Tekko32 F4 Metal 4in1 65A ESC Flight Controller Stack
- Flamewheel F450 Style Frame Kit
- Matek GPS & Compass Module M9N-5883
- 2216 Brushless Motors 950 KV (x4)
- 10x4.5 Nylon Propellers



Figure 9: Finished Scientific Payload (land/sky spectrometers, 8MP camera)



Figure 8: Drone Frame Layout with Motors on Arms



Figure 10: Flight Controller (FC) and Electronic Speed Controller (ESC) Stack with ExpressLRS Receiver

Programming/Flight Software:

- Betaflight replaced with INAV for better future GPS control and potential autonomous flight
- Headless SSH connection via Windows Powershell to Pi (2.4 Ghz Hotspot Network)
- Power via 5V/3A Source (later through 5V voltage regulator to LiPo)

Figure 11: Motor with Mounted Propellor

Data accessible via MicroSD adapter to phone
Capture to be induced by app API call

Software Design

Processes:

- App built using **Thunkable** drag and drop blocks for easy interface design
- Screens organized by function
- Data sync and cloud storage set up for seamless saving and retrieval

Drone Pairing with Software:

- App connects to drone via Wifi or Bluetooth
- Users can control flight paths or triggers for image capture
- Real live feed from the drone camera displayed on the app
- Automatic syncing of drone data

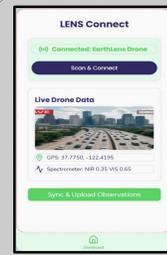


Figure 12: LENS Connect enables communication between app and drone



Figure 13: EarthLENS App Logo



Figure 14: LensLink, a built in social platform, connects citizen scientists

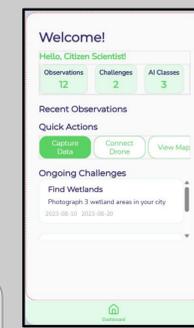


Figure 15: Dashboard and Main Screen of the EarthLENS

App Experiences:

- Interactive map view of collected land cover data
- Survey forms of field observations and manual entries
- Data visualization
- User friendly interface for students and citizen scientists

Results

Platform	Landstats 5-9	WorldView-4	Sentinel-1/2				GLOBE Observer					Coriell Earth Online	EarthLENS Drone Capture
Primary Sample Unit	Landstat Time Series Graph	1m Tree Canopy Meta	World Cover 10m	Dynamic World 10m	ESRI 10m	Up	Down	west	south	east	north	High resolution image interpretation	land
6													

Figure 16: Raw JSON output from AS 7341 (8 channel) and AS7265x (18 channel) spectrometers. Saved to Computer via curl command.

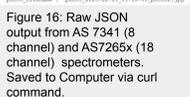
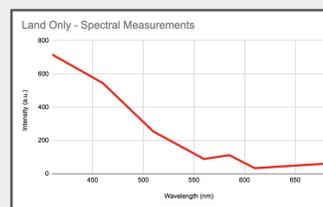
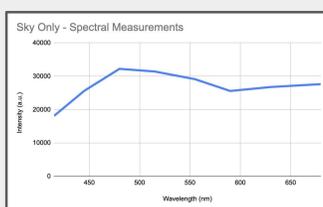
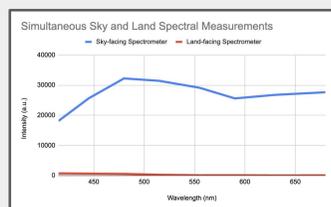


Figure 18: 3280 x 2464 image recorded via Raspberry Pi 8MP Camera V2

Summary: Higher resolution imagery is generated using the Raspberry Pi Camera and 26 data points are near simultaneously captured and stored in a JSON file for easy analysis and export to other applications.

Proposed Additional Adopt-A-Pixel 3km Poster Template Column

Sample Drone-Derived Data Analysis



Figures 19-22: Simultaneous spectral measurements from upward-facing (HelioSTELLA) and downward-facing (Q2) STELLA spectrometers collected during a single research payload test. Comparable wavelength bands were aligned based on STELLA band-center specifications to illustrate differences between incoming illumination and surface-reflected radiance. Measurements were acquired under clear-sky conditions over a snow-covered surface, resulting in high incoming visible-light intensity and elevated surface reflectance at shorter wavelengths, as expected for high albedo terrain (reflective land cover resulting in a greater level of ambient light, like snow). These preliminary results demonstrate the system's ability to capture paired illumination and surface spectra, which will be beneficial in supporting future normalization and land-cover analysis workflows.

Conclusion

EarthLENS addresses **critical limitations** in existing citizen science tools for land cover data collection. By combining a lightweight, sensor-equipped drone with a companion app, EarthLENS **enables** high quality imagery, precise GPS data, and efficient observation workflows. The system aims to **minimize** data loss, **integrate** real time drone control, and **provide** interactive maps, surveys, and analysis to **enhance** land cover classification. EarthLENS **empowers citizen scientists** to collect, organize, and share accurate environmental data more **efficiently**, bridging the gap between ground observations and satellite derived products, and supporting robust environmental monitoring research.

Further Work

AI Classification Automation

Standardized Land cover and environmental data

Machine Learning Model

Classification Output

Benefits:

- Improves classification accuracy over time based on user-corrected observations
- Increases efficiency by eliminating the need for manual classification

Methods:

- Develop standard AI model native to application that analyzes data from observations and outputs classifications
- Train model on standardized data to maintain accuracy

Automated Flight

Reduce need for manual navigation of the drone system

Eliminates possibility of human-caused collisions leading to waste of resources

Benefits:

- Reduce need for manual navigation of the drone system
- Eliminates possibility of human-caused collisions leading to waste of resources

Methods:

- Implement system that flies drone on a pre-determined path
- Makes use of in-built radar or existing instrumentation to navigate away from potential obstacles, maintaining safety

Integration with External Platforms

Enable data sharing and open access portals to allow scientists and educators to access collected data en masse

Improve compatibility with satellite observations and standardize data

Benefits:

- Enable data sharing and open access portals to allow scientists and educators to access collected data en masse
- Improve compatibility with satellite observations and standardize data

Methods:

- Collaboration with NASA STELLA and other citizen science platforms
- Collaborate with National Labs and other large research institutions

Long Term Expansion

With expansion, EarthLENS can reach a national or even global scale of citizen science engagement

Standardize land cover and environmental data collection

Benefits:

- With expansion, EarthLENS can reach a national or even global scale of citizen science engagement
- Standardize land cover and environmental data collection

Methods:

- Establish constant methodology for drone production
- Enable policy and conservation in observations to maximize data reproducibility
- Further decrease costs and increase accessibility

Key References

- Low RD, Nelson PV, Soeffing C, Clark A and SEES 2020 Mosquito Mappers Research Team (2021) Adopt a Pixel 3 km: A Multiscale Data Set Linking Remotely Sensed Land Cover Imagery With Field Based Citizen Science Observation. Front. Clim. 3:658063. doi: 10.3389/fclim.2021.658063