

The Biodiversity Survey of the Cape (BioSCape): Towards Inclusive International Biodiversity Science

Anabelle W. Cardoso^{1,2}; Erin L. Hestir³; Jasper A. Slingsby^{4,5}; Cherie J. Forbes^{1,2}; Glenn Moncrieff⁶; Woody Turner⁷; Andrew Skowno^{2,8}; Jacob Nessler³; Philip G. Brodrick⁹; Keith Gaddis⁷; Adam M. Wilson¹

¹*Department of Geography, University at Buffalo, Buffalo, NY, USA*

²*Department of Biological Sciences, University of Cape Town, Cape Town, South Africa*

³*Department of Civil and Environmental Engineering, University of California Merced, Merced, CA, USA*

⁴*Department of Biological Sciences, and Centre for Statistics in Ecology, Environment, and Conservation, University of Cape Town, Cape Town, South Africa*

⁵*Fynbos Node, South African Environmental Observation Network, Cape Town, South Africa*

⁶*The Nature Conservancy, Cape Town, South Africa*

⁷*Earth Science Division, NASA Headquarters, Washington, DC, USA*

⁸*South African National Biodiversity Institute, Cape Town, South Africa*

⁹*Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA, USA*

Abstract

The Biodiversity Survey of the Cape (BioSCape) is a concerted effort to test the limits and potential of remote sensing for biodiversity applications. Integrating field biodiversity measurements and local knowledge with advanced remote sensing, BioSCape brings us one step closer to measuring key biodiversity variables globally from space.

Main Text

Biodiversity loss jeopardizes human wellbeing and sustainable development, and addressing this loss is the target of all global conservation and many human development goals, including those in the Kunming-Montreal Global Biodiversity Framework (Conference of the Parties to the Convention on Biological Diversity, 2022). Tracking progress towards these goals requires biodiversity data at a scale and latency not feasible for traditional field observations alone. Remote sensing can augment field data, and recent and expected developments including satellite-borne radar, LiDAR, and imaging spectroscopy, have enhanced what can be observed from above. However, because ecosystem properties can be highly site-specific, many of the biodiversity variables we are most interested in cannot be captured with remote sensing data exclusively (Cavender-Bares et al., 2022). To observe the idiosyncrasies of an ecosystem at spatial and temporal scales necessary to monitor and manage biodiversity, we need to integrate field and remote sensing datasets (Turner, 2014).

Advancing the capability of integrated field and remotely sensed datasets to measure, monitor, and explain the patterns of biodiversity and its drivers across diverse ecosystems globally is an urgent priority in the face of the global biodiversity crisis. This need motivated NASA's first-ever field campaign focused on terrestrial, freshwater, and marine biodiversity: the Biodiversity Survey of the Cape (BioSCape). BioSCape combines local knowledge with global remote sensing technology to produce openly accessible data products. Here, we introduce BioSCape,

with emphasis on the importance of integrated data and inclusive international collaboration for biodiversity conservation globally.

What is BioSCape?

BioSCape is an integrated satellite/airborne remote sensing and field campaign conducted in the Greater Cape Floristic Region (GCFR) of South Africa in late 2023. The GCFR includes the intersections of eight terrestrial and six marine biomes, is home to two of the world's richest biodiversity hotspots, and has exceptional levels of terrestrial and aquatic endemism (de Moor & Day, 2013; Harris et al., 2019; Manning & Goldblatt, 2012). The astonishing biodiversity of the GCFR is threatened by a range of factors, including drought, invasive alien plants, changes to ocean chemistry and currents, and complex pressures from human populations (James et al., 2013; Slingsby et al., 2017; Sydeman et al., 2014; Underwood et al., 2009). The GCFR is a microcosm of global challenges - it is a highly biodiverse region that needs to support sustainable human development while surviving the threat of climate change. Luckily, the region has a long history of data-informed conservation and provides learning opportunities that can inform the management of similar regions worldwide (Balmford, 2003).

Integrated Data to Measure Biodiversity

During BioSCape, airborne imaging spectroscopy (also known as hyperspectral remote sensing) and light detection and ranging (LiDAR) data were acquired over terrestrial and aquatic (freshwater and marine) study areas. Imaging spectroscopy measures reflected and emitted solar radiation across the electromagnetic spectrum at high spectral resolution, resulting in a high-dimensionality data set from which certain biodiversity information can be retrieved (Skidmore et al., 2021). When these spectroscopic measurements are combined with LiDAR measurements of the three-dimensional structure of terrestrial ecosystems, even more opportunities arise for the remote sensing of biodiversity (Asner et al., 2012). BioSCape's airborne dataset, with three imaging spectrometers and two LiDAR instruments, is unprecedented in its level of detail - with coverage of much of the ultraviolet (UV), visible to shortwave infrared (VSWIR), and thermal infrared (TIR) ranges of the electromagnetic spectrum and coincident LiDAR acquisitions. This combined spectral and structural airborne dataset is necessary to explore the potential that satellite remote sensing has to measure and monitor global biodiversity (Dierssen et al., 2023).

BioSCape's airborne dataset is accompanied by a diverse range of field measurements on land and in water. Field data were collected by 19 individually funded PI-led research projects, each with its own objectives. These include:

- Mapping marine and freshwater biodiversity, including phytoplankton, kelp, and harmful algal blooms.
- Quantifying how ocean chemistry changes and sea-level rise associated with climate change will affect aquatic ecosystems, specifically estuaries and kelp forests.
- Mapping terrestrial ecosystem properties including evapotranspiration, plant traits, vegetation 3D structure, and mineralogy.
- Quantifying the spatial variation and drivers of plant community assembly and ecosystem function, including alien plant invasions.

- Combining novel field methods, including eDNA and acoustic indices, with remotely sensed data to estimate the composition and diversity of biotic communities.

Although diverse, BioSCape's research projects all aim to better understand the structure, function, and composition of the region's ecosystems, and to learn about how and why they are changing in time and space. The research projects will integrate and analyze remote sensing and field data and advance models and algorithms for measuring and monitoring biodiversity at multiple scales. By combining satellite, airborne, and field-based measurements, BioSCape explores and expands the capacity of such integrated datasets to produce accurate and scalable findings and help biodiversity conservation reach its potential efficacy. The GCFR's high levels of species richness and endemism along with the open and often scrubby nature of the vegetation make remote sensing challenging. In this sense, BioSCape will be testing the limits and potential of remote sensing for biodiversity applications worldwide. As a team member noted, "if we can do it in the GCFR, we can do it anywhere."

Inclusive Collaboration for Increased Impact

Joining global perspectives and technology with local context requires international collaboration. Collaboration has mutual benefits, including increased scientific impact and applicability (Choi & Oh, 2020; Ocampo-Ariza et al., 2023). However, international collaboration can be challenging as the Global North and South may have different skills and access to resources. When such differences exist, extra care must be taken to ensure the collaboration is inclusive and benefits everyone involved.

Since its conception, BioSCape emphasized creating and maintaining deep and meaningful collaboration between researchers in the U.S. and South Africa and always emphasized the importance of co-developing research. Early inclusion of South Africans in the design of both airborne and field components of BioSCape led to a diverse Science Team of ~150 members, of which approximately half are affiliated with South African institutions and half with U.S. institutions. The U.S. participation on the team ensured global applicability, access to best-in-class technology, and bridged gaps in capacity. The strong South African presence on the team ensured that the research agenda for BioSCape was locally relevant and that local ecological expertise was incorporated.

Because biodiversity is intrinsically site-specific, effective conservation ultimately hinges on local knowledge and regionally-tailored actions. In the GCFR, strong personal and institutional relationships among scientific research institutes, environmental management authorities, and conservation managers have led to rapid dissemination and uptake of novel science relevant to decision-making. South Africa is also a well-known early adopter of systematic conservation planning, has been relatively successful in operationalizing conservation planning into government policy and decision-making, and has a reputation for having "set the standard" for using scientific information in conservation planning and implementation (Balmford, 2003; Botts et al., 2019; Buschke et al., 2019). As a result, the data products BioSCape creates will help inform biodiversity conservation and environmental decision-making and policy in South Africa, and guide the management of similar ecosystems worldwide (Skowno et al., 2019) (**FIGURE 1**).

Conclusion

The GCFR's megadiversity, established pathway from science to application, and diverse threats to biodiversity make the region a microcosm of global biodiversity challenges and opportunities. BioSCape provides a proof of concept for remote sensing of biodiversity as satellite acquisitions of rich, highly dimensional data types improve in area coverage, spatial resolution, and temporal latency in the coming years. BioSCape has begun an ambitious array of approaches characterizing dimensions of biodiversity using imaging spectroscopy and LiDAR, along with several complementary field techniques. While many of BioSCape's planned approaches may fail, we expect they will teach us almost as much about the remote sensing of biodiversity as the successes, not to mention the serendipitous discoveries.

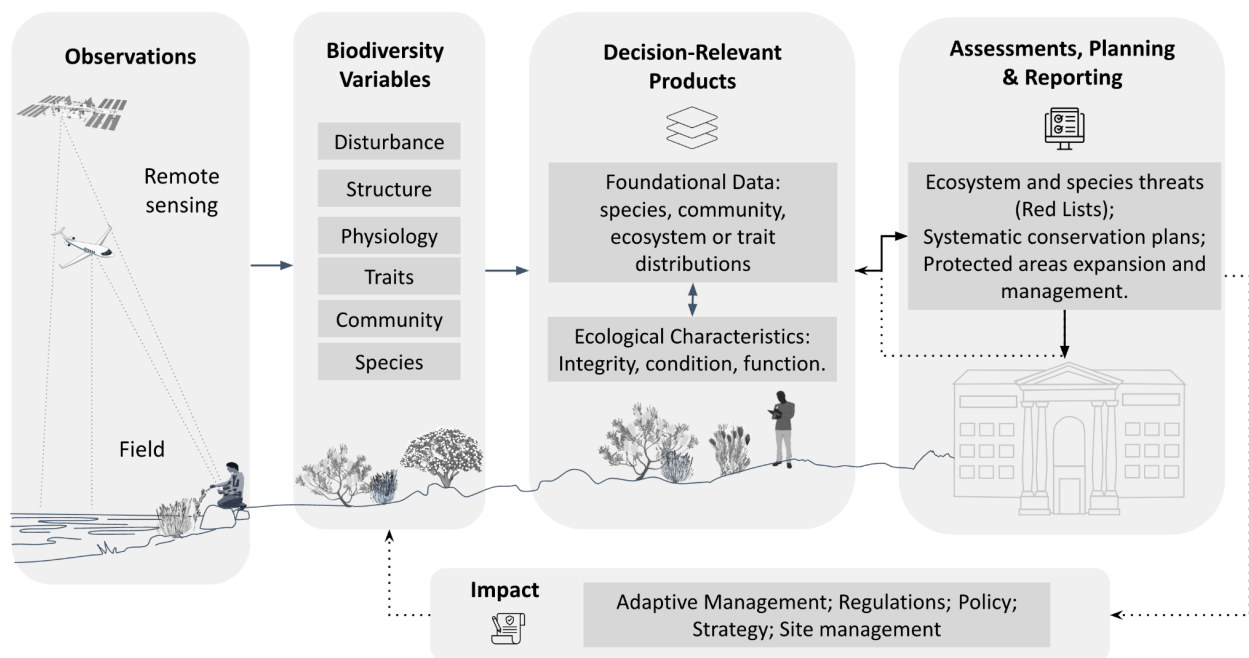


FIGURE 1: Measuring and monitoring biodiversity variables in campaigns like BioSCape can directly impact biodiversity conservation. For example, in South Africa, relevant data products are used to inform biodiversity assessment, planning, and reporting, which directly affect biodiversity policy and conservation management decisions. For this reason, the most impactful research projects are co-designed with local stakeholders.

CRedit author statement

Anabelle W. Cardoso: conceptualization; methodology; investigation; writing (original draft); writing (review and editing); visualization; project administration; and funding acquisition.

Erin L. Hestir: conceptualization; methodology; investigation; writing (reviewing and editing); visualization; resources; supervision; project administration; and funding acquisition.

Jasper Slingsby: conceptualization; methodology; investigation; writing (review and editing); project administration.

Cherie J. Forbes: writing (review and editing)

Glenn Moncrieff: conceptualization, investigation, writing (review and editing).

Andrew Skowno: writing (review and editing); visualization

Woody Turner: writing (review and editing); conceptualization; methodology; resources; supervision; project administration; and funding acquisition.

Keith Gaddis: conceptualization; methodology; resources; supervision; project administration; and funding acquisition.

Philip G. Brodrick: methodology, investigation, writing (reviewing and editing)

Jacob Nesslage: investigation; writing (review and editing); visualization

Adam M Wilson: conceptualization; methodology; investigation; resources; writing (review and editing); visualization; supervision; project administration; and funding acquisition.

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