The Ecosystem Monitoring and Management Application (EMMA) Workflow:

Automating Change Detection and Reporting in the Hyperdiverse Fynbos of South Africa

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The challenge:

- Much of the world is naturally open ecosystems, where trees are rare. Change detection in these ecosystems can be challenging due to dynamism from fire and seasonality.
- Here, we present a workflow to automate ecosystem change detection and reporting in one of the world's biodiversity hotspots, the Fynbos of South Africa (Figure 1), in an Open Science framework.
- The project has been co-developed with stakeholders, ensuring relevance to management needs.
- The workflow is publicly available via GitHub, and readily modifiable for other regions or modelling needs, providing a generalizable solution to change detection in open ecosystems.

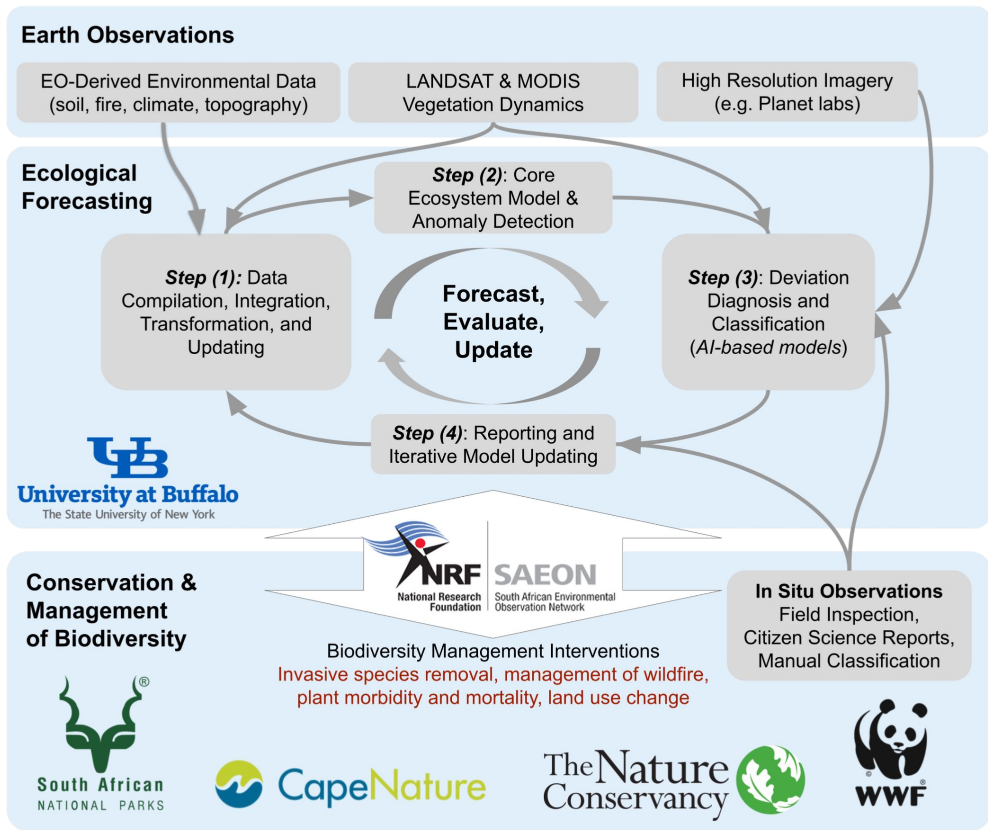

Figure 1. Conceptual diagram of the EMMA workflow. Our primary end-user is SAEON, but they will serve as a liaison to other provincial, national, and international organizations.

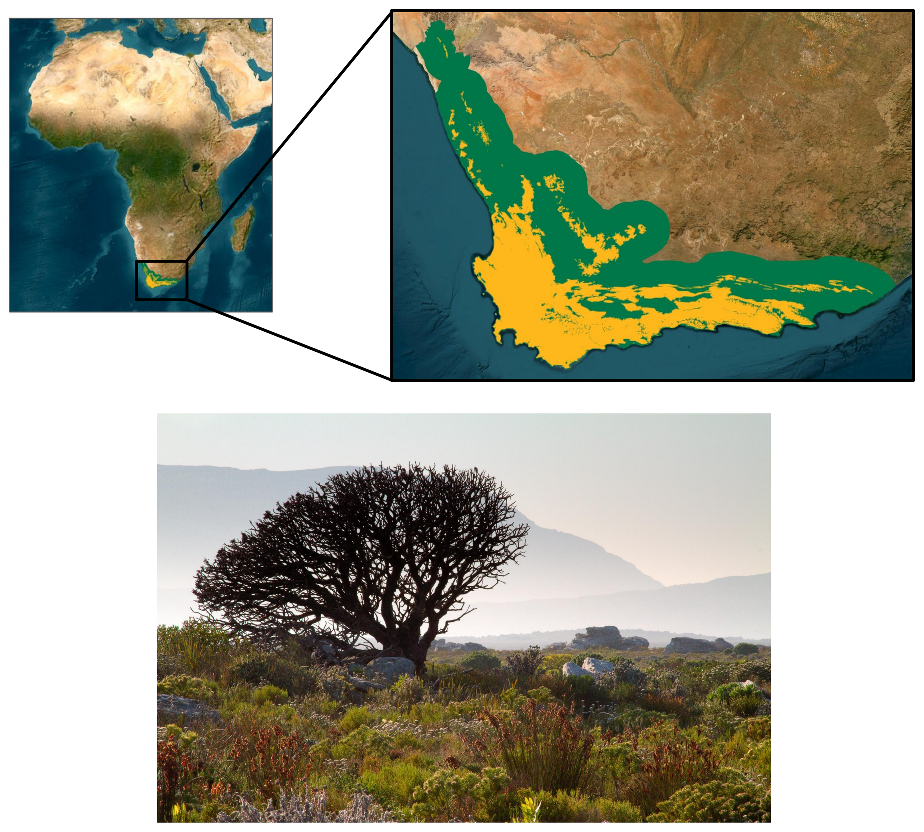

Figure 2. The study covers the BioScape domain including the fynbos biome (yellow) and surrounding areas within 50 km (green). Photo shows an example landscape on the Cape of Good Hope in the southwestern corner of the region.

Data Collection

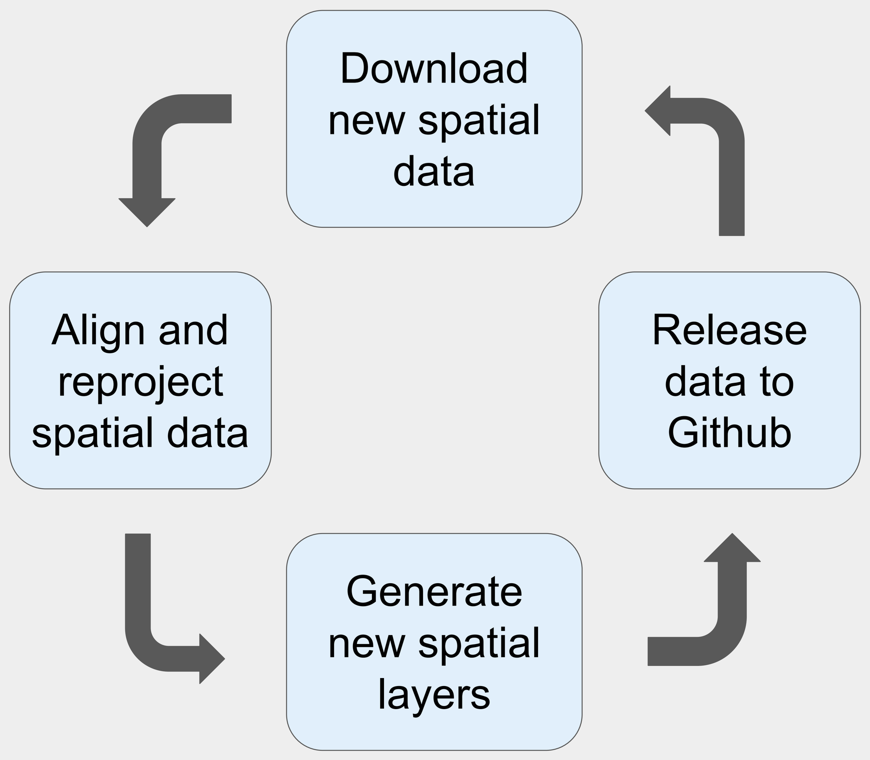

Figure 3. Diagram of data collection workflow.

Requirements:
Continuously-updated and analysis-ready spatial data for the modeling domain (Figure 1).

Implementation:

- R scripts running in a docker environment
- Automatically processes new data every 6 hours
  - Downloads new data
  - Transforms to a common resolution and projection
  - Quality checks are performed
  - Derived products are produced (e.g., time since fire)
- Module is memory conservative and can be run on any operating system
- Data are served freely via Github releases.

Code at: https://github.com/AdamWilsonLab/emma_envdata

Modelling

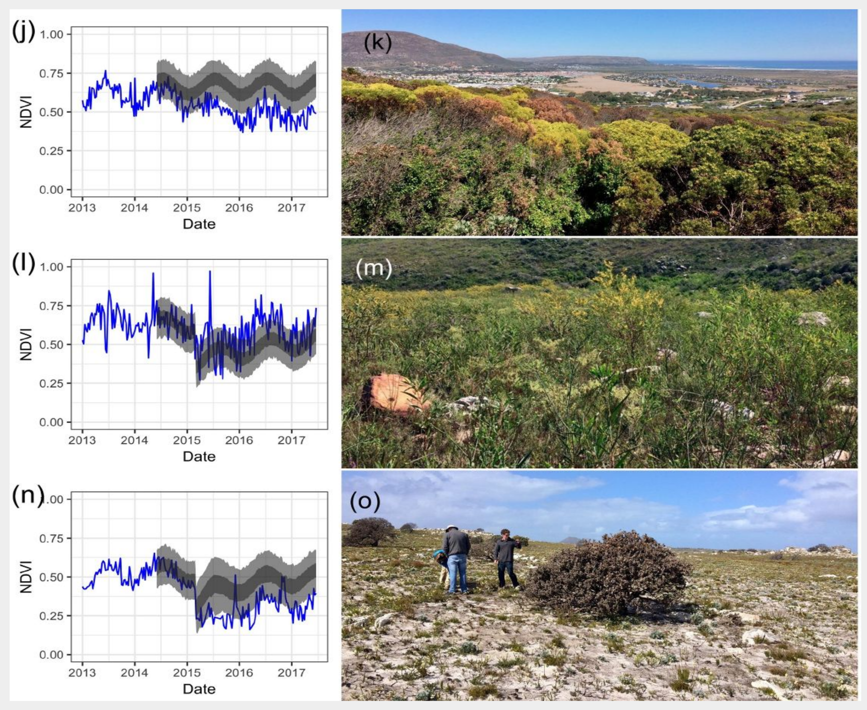

Figure 4. Estimated (grey) and observed (blue) NDVI (j, l, n). Causes of observed deviation: (k) high mortality, (m) alien invasion following fire, and (o) drought. See https://doi.org/10.1016/j.isprsjprs.2020.05.017 for more details.

Requirements:

1) A model of current NDVI as a function of past NDVI, season, fire history, and environmental covariates
2) Quantification of deviation from expected NDVI

Implementation:

- Hierarchical Bayesian Model
- Current NDVI modeled as a function of site age (time since last fire)
  - Additional level models the parameters of the negative exponential curve as a function of environmental variables
- Observed and Expected NDVI compared to detect changes
  - Change likelihood assessed using the Continuous Ranked Probability Score

Code at: https://github.com/AdamWilsonLab/emma_model

Change Classification

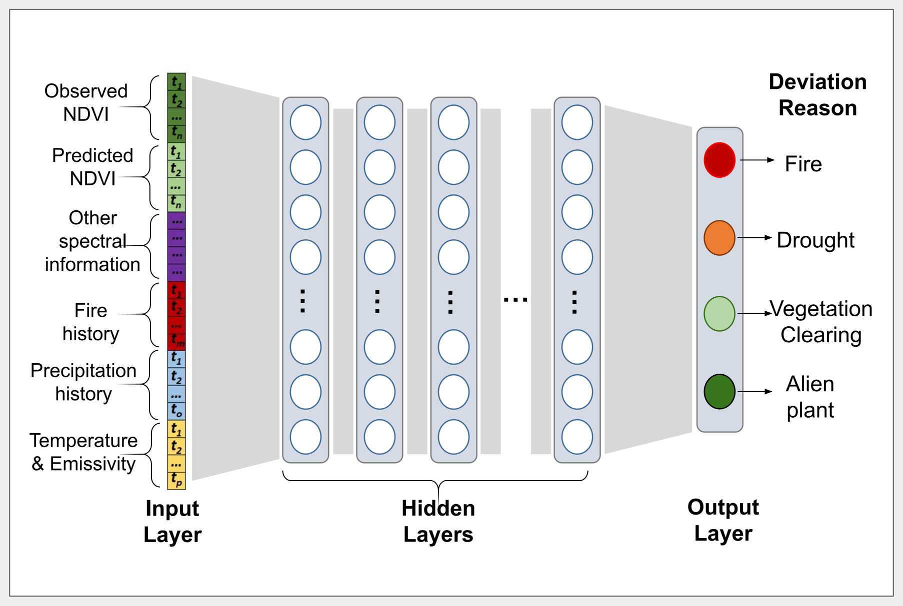

Figure 5. A general architecture of the proposed DNN model for classifying the factors causing deviations of vegetation states.

Requirements:
Assessment of likely causes of deviations from expected NDVI

Implementation:

- Deep neural network model that classifies the abnormal deviation locations (pixels) into several categories of interest.
- Model inputs are observed NDVI time series and estimated NDVI
- Other model covariates include:
  - additional spectral information
  - fire or burned area detection products
  - weather data
  - MODIS-derived land Surface Temperature and Emissivity
- Model outputs are land change categories:
  - fire (or ploughing)
  - drought
  - vegetation clearing
  - alien plant invasion

Code at:
https://github.com/AdamWilsonLab/emma_change_classification

Reporting

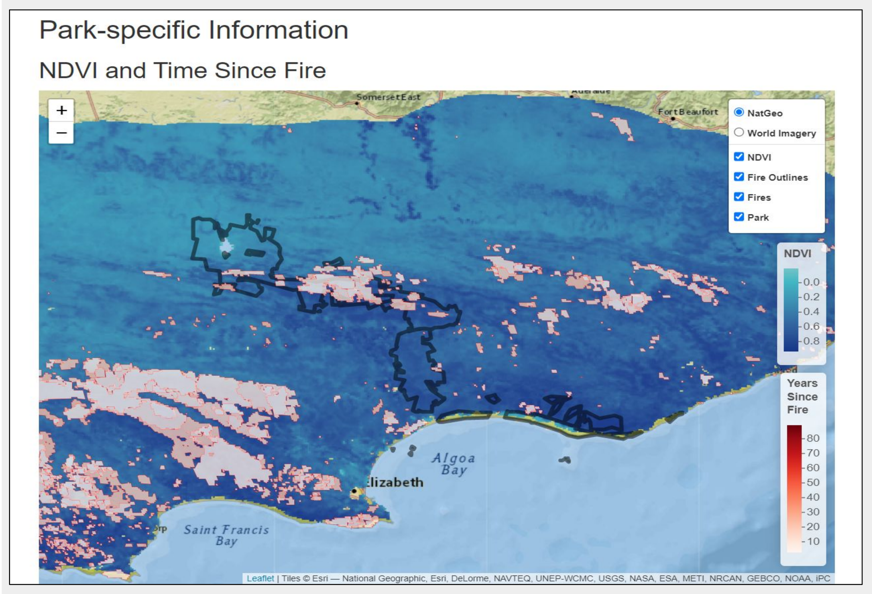

Figure 6. Example interactive park report illustrating current NDVI and vegetation age derived from MODIS.

Requirements:
A frequently-updated GUI containing park-specific information required by land manager and decision makers

Implementation:

- R scripts in a docker environment
- Data and park reports are updated daily
  - Reports contain interactive spatial and temporal data visualizations requested by park managers.
- Integrating reports into decision-making processes with partners and stakeholders
- Collecting feedback and revising system for decision-makers

Code at: https://github.com/AdamWilsonLab/emma_report

ECOSYSTEM MONITORING MANAGEMENT APPLICATION

BIOSCAPE Biodiversity Survey of the Cape

NRF National Research Foundation SAEON South African Environmental Observation Network

University of Cape Town · iYunivesithi yaseKapa · Universiteit van Kaapstad

University at Buffalo

NASA

Biological Diversity & Ecological Conservation