ECOSYSTEM MONITORING MANAGEMENT APPLICATION

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Near-Real-Time Forecasting and Change Detection for a Fire-Prone Shrubland Ecosystem

(NASA 80NSSC21K1183)

Adam M. Wilson[1], Yingjie Hu[1], Jasper A. Slingsby[2,3], Glenn R. Moncrieff[3], Brian Maitner[1]

[1]University at Buffalo, NY, USA
[2]Biological Sciences & SEEC, University of Cape Town
[3]SAEON Fynbos Node

science & innovation
Department:
Science and Innovation
REPUBLIC OF SOUTH AFRICA

BIOSCAPE
Biodiversity Survey of the Cape

NASA

University at Buffalo

South African NATIONAL PARKS

CapeNature

SEEC - Statistics in Ecology, Environment and Conservation

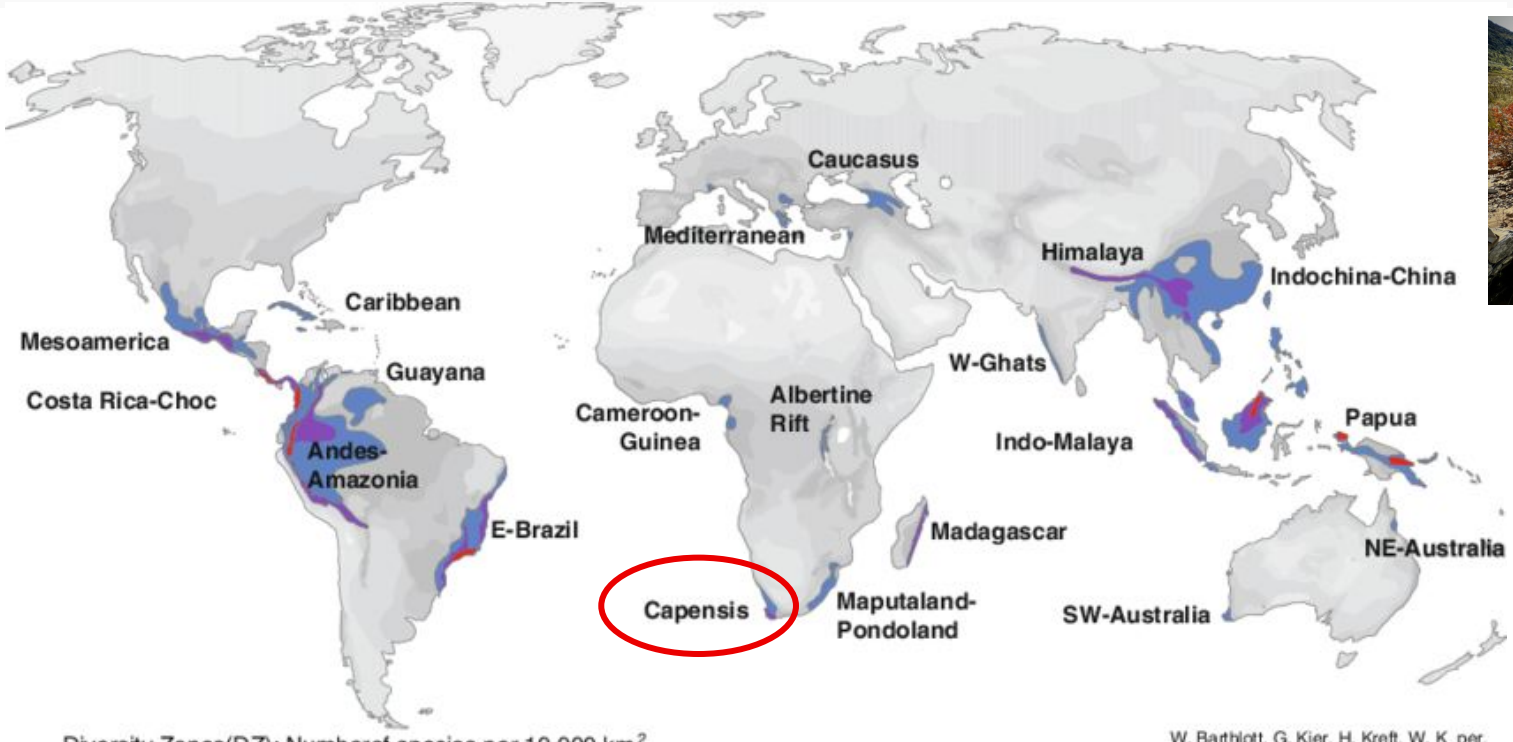
The Nature Conservancy

University of Cape Town · Kaapstad · iYunivesithi yaseKapa · Universiteit van Kaapstad

NRF National Research Foundation

SAEON South African Environmental Observation Network

Global Biodiversity Hotspots

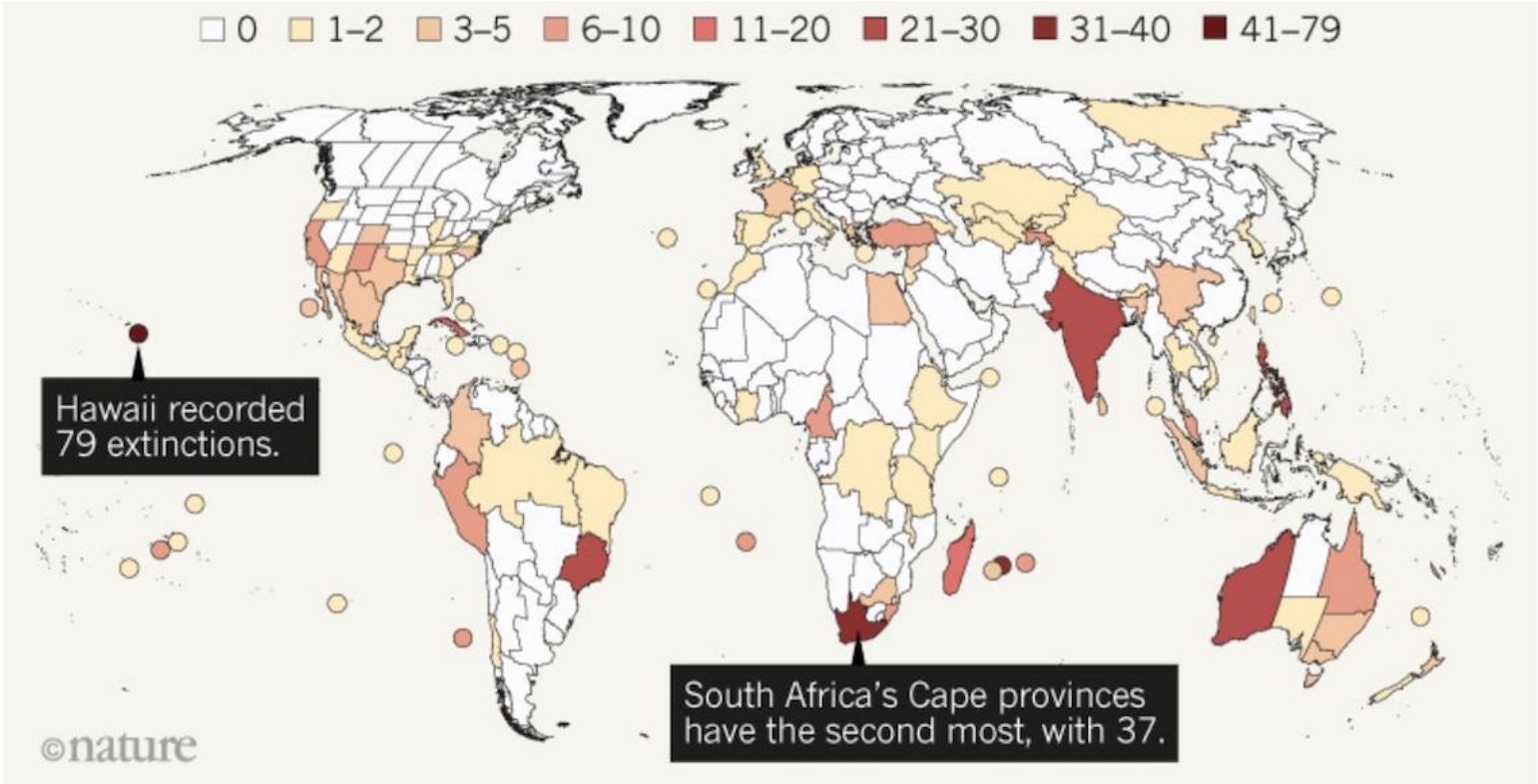


Semi-arid shrubland

Global map of species richness of vascular plants highlighting the 20 centres of highest species richness. Vascular Plant Diversity in a Changing World: Global Centres and Biome-Specific Patterns (2011) DOI:10.1007/978-3-642-20992-5_5

Global Extinction Hotspot!

Seed-bearing plant species lost since 1900



Humphreys et al. 2019

Near-real-time monitoring and forecasts of ecosystem state

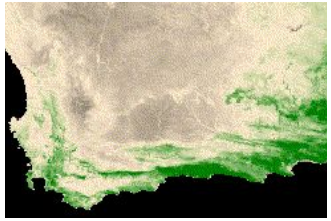
ECOSYSTEM MONITORING MANAGEMENT APPLICATION

Use satellite time-series to identify fire, recovery, invasion, and change

Fire

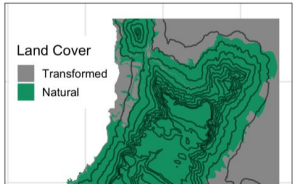
Regrowth

Seasonality



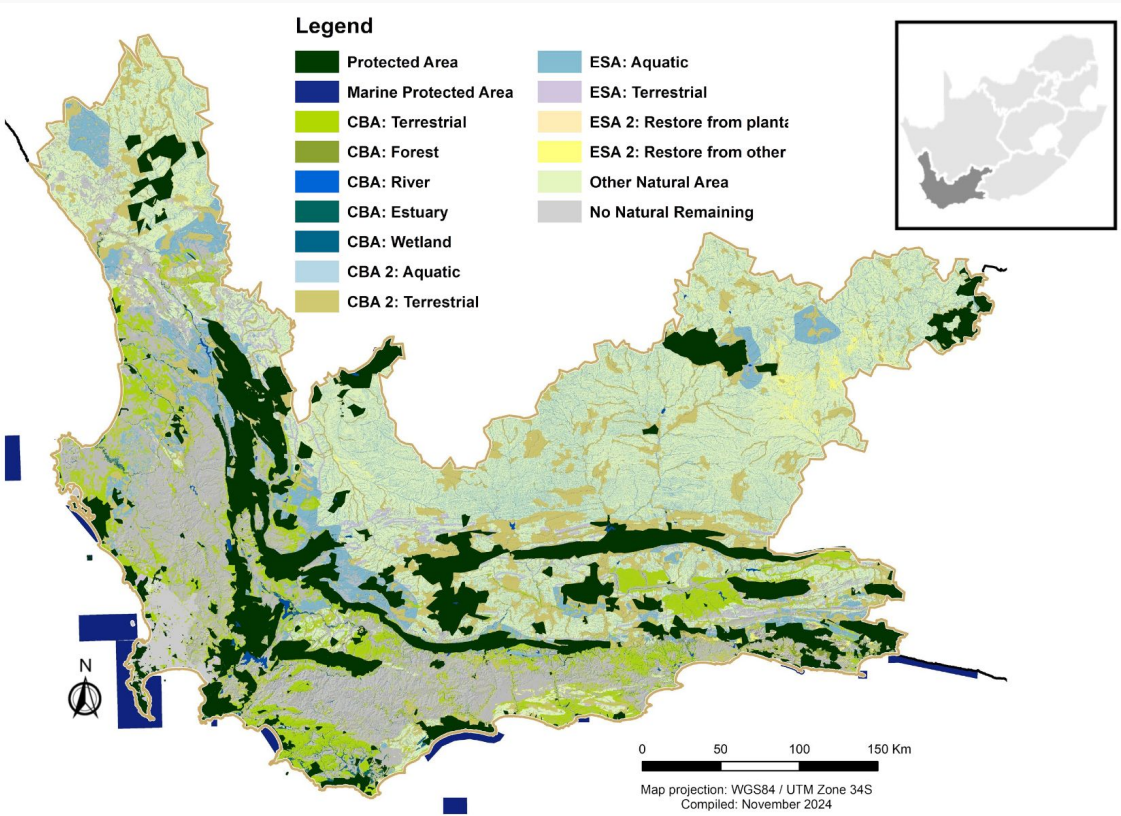
Habitat loss

Invasives



Climate & Fire

Park system and management practices



2023 Western Cape Biodiversity Spatial Plan Map of Biodiversity Priority Areas

CapeNature

South African NATIONAL PARKS

SANBI
Biodiversity for Life
South African National Biodiversity Institute

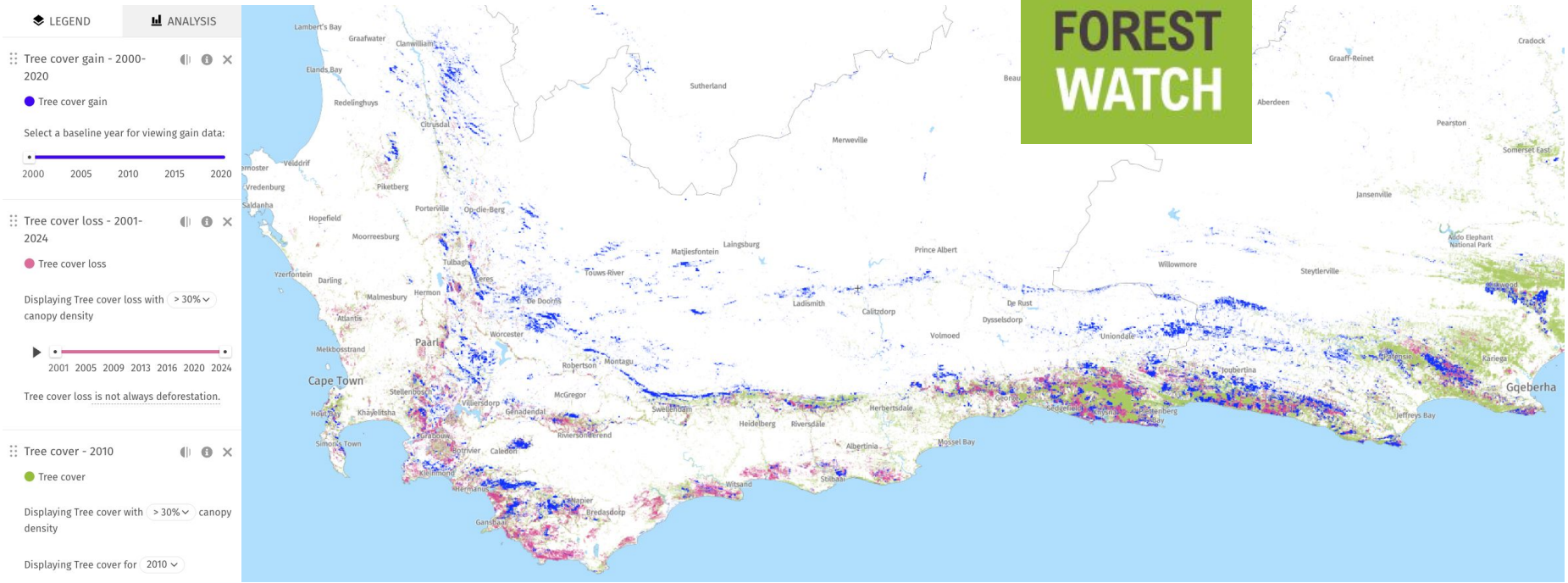
The Nature Conservancy

NRF National Research Foundation | SAEON South African Environmental Observation Network

Existing tools don’t work well here…

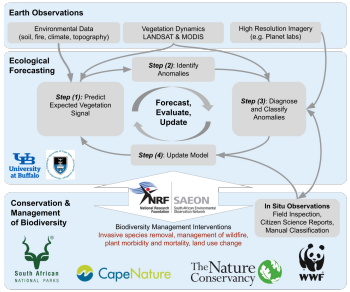
GLOBAL FOREST WATCH

Great tool, just not so great in this system…



2021 Fynbos Forum: *Satellite monitoring of the Fynbos biome: identifying user needs*

~80 Participants from a variety of organizations across South Africa



Breakout Rooms

1. Fire management
2. Monitoring species and ecosystems
3. Invasive Species
4. Hydrology
5. Illegal vegetation clearing

User Requests:

- Records of past changes
- Current ecosystem status *in context*
- Spatial resolutions < 1 km
- Regular updates

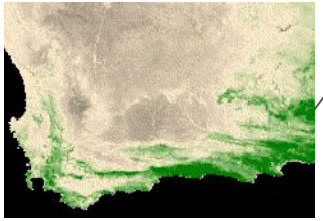
Modeling Fynbos Dynamics

ECOSYSTEM MONITORING MANAGEMENT APPLICATION

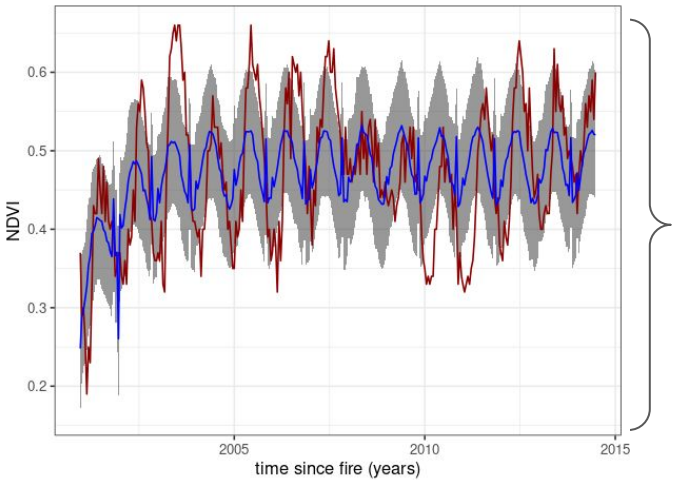
Fire

Regrowth

Seasonality



Postfire recovery trajectory
(satellite NDVI)



Grey is model forecast, red is observed vegetation activity

Dynamism makes detecting change very difficult

RS signal from healthy fynbos can vary dramatically

Modeling Fynbos Dynamics

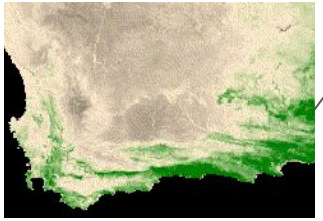
ECOSYSTEM MONITORING MANAGEMENT APPLICATION

Historical context of current status (time series) reveal ecological shifts

Fire

Regrowth

Seasonality



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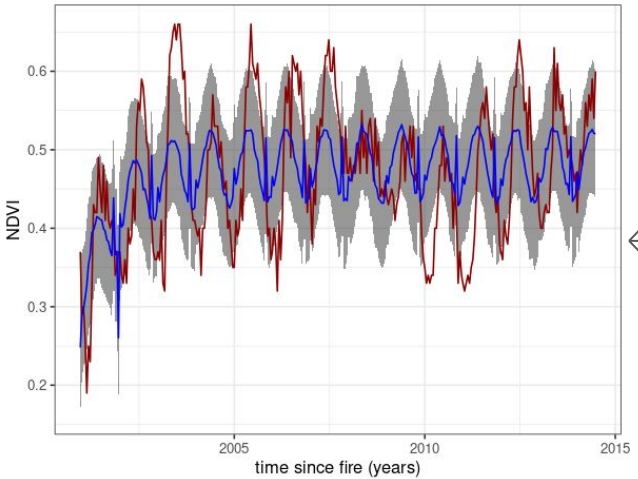

Habitat loss

Invasives

Climate

Near-real-time monitoring and forecasts of ecosystem state

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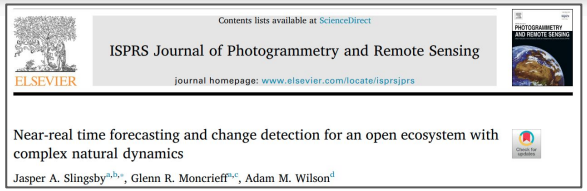
Contents lists available at ScienceDirect

ISPRS Journal of Photogrammetry and Remote Sensing

journal homepage: www.elsevier.com/locate/isprsjprs

Near-real time forecasting and change detection for an open ecosystem with complex natural dynamics

Jasper A. Slingsby[a,b,*], Glenn R. Moncrieff[a,c], Adam M. Wilson[d]

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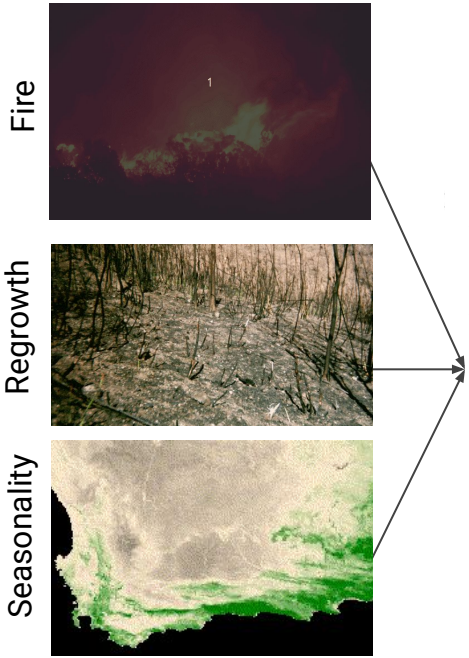

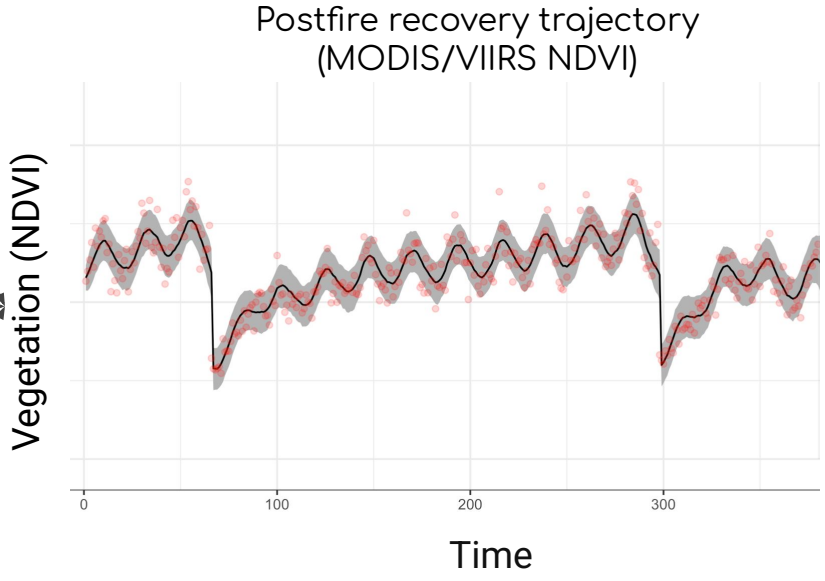

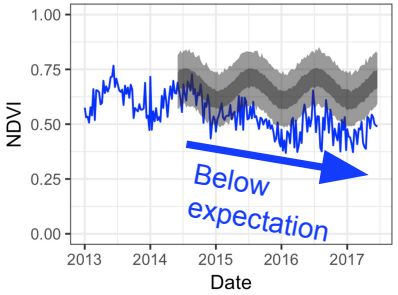

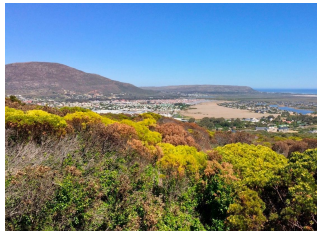

Shrub Mortality due to drought

Comparing bayesian, state-space, & AI methods

Near-real-time monitoring and forecasts of ecosystem state

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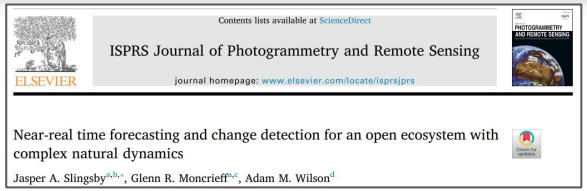
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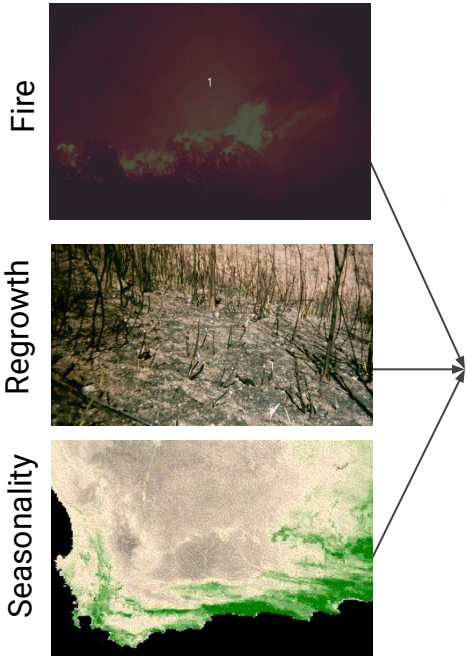

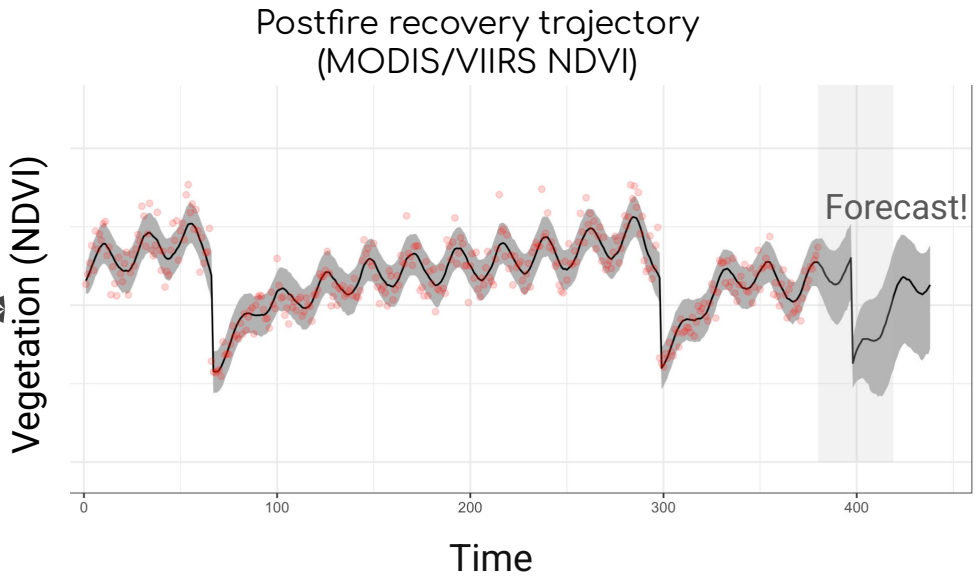

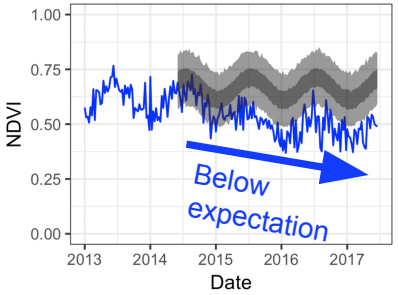

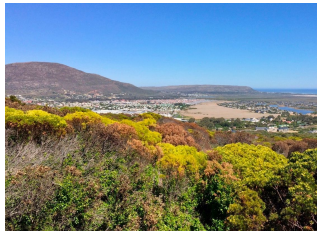

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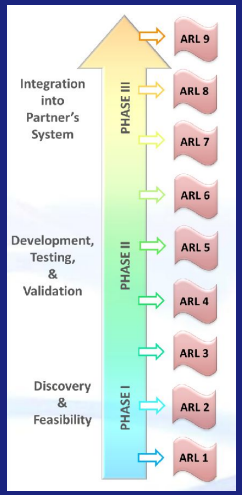
ECOSYSTEM MONITORING MANAGEMENT APPLICATION

Partnering with regional stakeholders to develop an operational monitoring system in a dynamic ecosystem



NASA Application Readiness Levels (ARL)

4: Validation
↑
2: Feasibility

Earth Observations

Environmental Data (soil, fire, climate, topography)

Vegetation Dynamics LANDSAT & MODIS

High Resolution Imagery (e.g. Planet labs)

Ecological Forecasting

Step (1): Predict Expected Vegetation Signal

Step (2): Identify Anomalies

Step (3): Diagnose and Classify Anomalies

Forecast, Evaluate, Update

Step (4): Update Model

University at Buffalo

Conservation & Management of Biodiversity

NRF National Research Foundation | SAEON South African Environmental Observation Network

In Situ Observations
Field Inspection, Citizen Science Reports, Manual Classification

Biodiversity Management Interventions
Invasive species removal, management of wildfire, plant morbidity and mortality, land use change

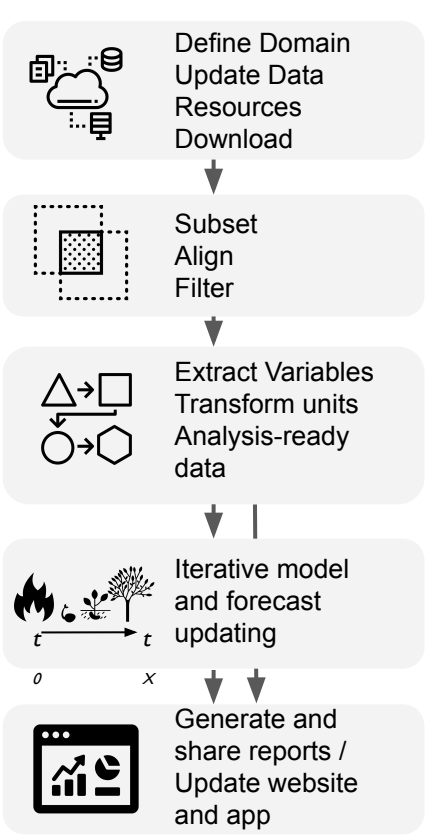
South African National Parks

CapeNature

The Nature Conservancy

WWF

Informatics pipeline from data ingest to reporting interface



Container with custom software to run identically on (virtually) any platform (laptop, cloud, hpc, etc.)

APIs, raster data processing, modelling

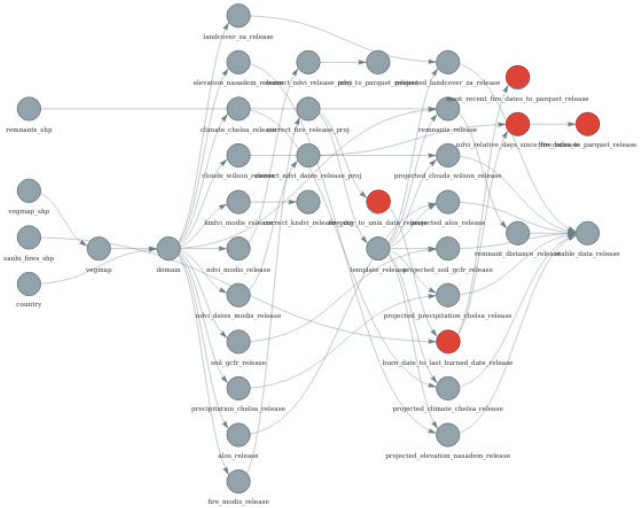
Targets package for pipeline management
Track dependencies and only update when needed

Automated website generation and publishing

Track code changes, store (small) data through git-lfs and releases, continuous integration to process data and generate web-based reports, publish website

Key Milestones: automated data processing and reporting

Github/Targets reproducible workflow



main / emma_report / report_prototype.qmd

Code | Blame

```
694
695   ff2 %>%
696     mutate(gte20 = years_since_fire >= 20) %>%
697     group_by(year,gte20) %>%
698     count()%>%
699     ungroup()%>%
700     group_by(year)%>%
701     mutate(total=sum(n))%>%
702     mutate(fraction = n/total)%>%
703     filter(gte20)-> unburned_summary
```

Make change anywhere in the pipeline
(locally or via web interface)

AdamWilsonLab / emma_report

Code | Issues 5 | Pull requests | Discussions | Actions | Projects | Wiki

Actions | New workflow

All workflows

pages-build-deployment

targets

Management: Caches, Deployments, Attestations, Runners, Usage metrics, Performance metrics

All workflows
Showing runs from all workflows

728 workflow runs

Event | Status | Branch | Actor

- add CNAME file to prevent custo... — targets #1133: Commit 6b4fa65 pushed by adammwilson — main — 1 hour ago — In progress
- pages build and deployment — pages-build-deployment #633: by adammwilson — main-runs — 1 hour ago — 1m 26s
- pages build and deployment — pages-build-deployment #632: by github-pages bot — main-runs — 12 hours ago — 1m 0s

Git commit triggers needed reprocessing and report generation & publishing

Informatics pipeline: Regional & Park-level Reporting

Define Domain
Update Data Resources
Download

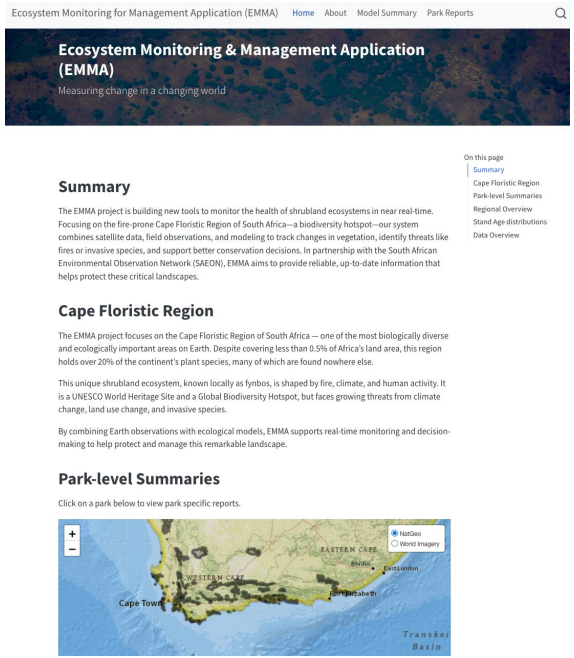
Subset
Align
Filter

Extract Variables
Transform units
Analysis-ready data

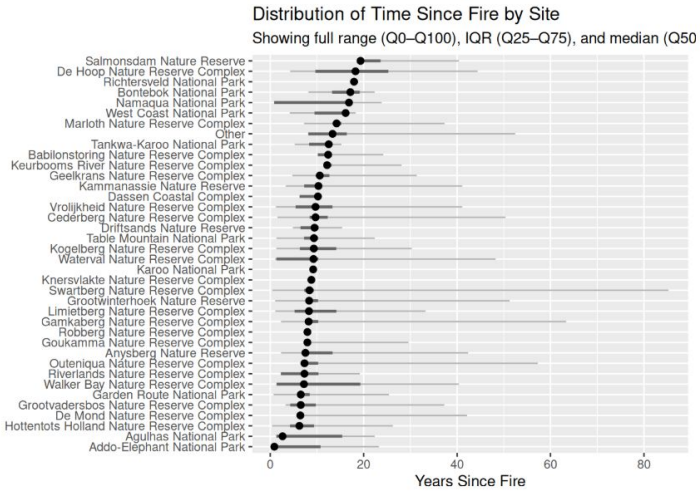
Iterative model and forecast updating

Generate and share reports / Update website and app

Regional summaries



Stand Age distributions



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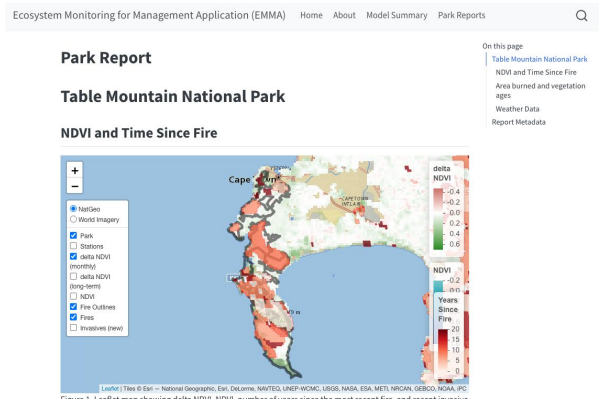
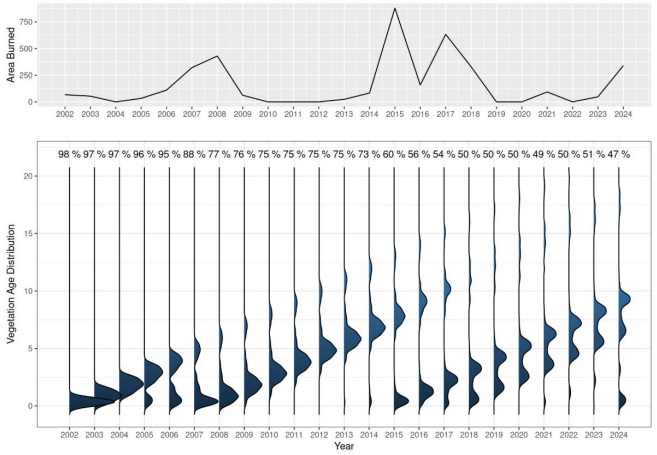
Park-level Reports



Area burned and vegetation ages



Weather Data

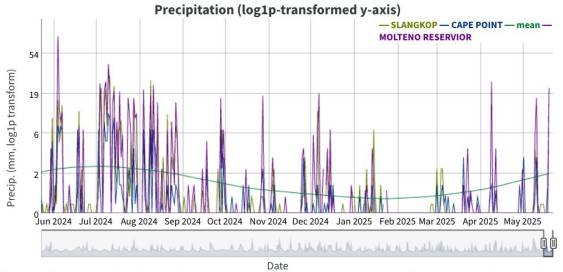
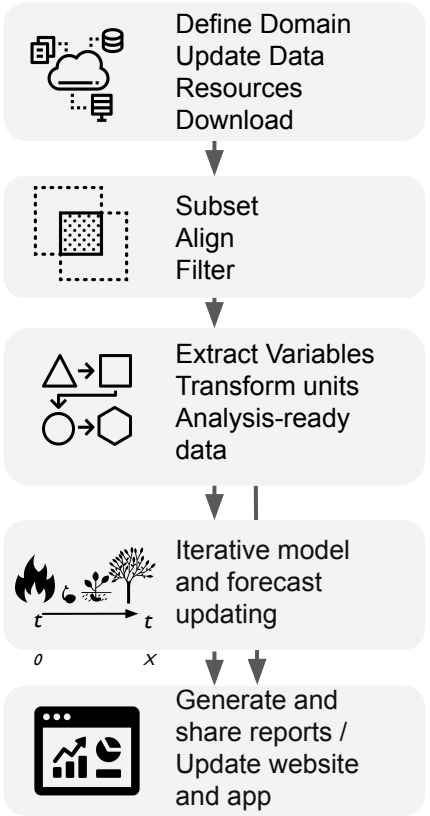


Figure 4. Climate Data from GSOD. Mean data is a long-term average for each day of the year across these weather stations.

Next Steps

- Continue refining value-added products
  - e.g. stand age, vegetation anomalies
- Stakeholder Organization (SAEON) will communicate tool to downstream stakeholders for further use and refinement
- Transition from Google Earth Engine to new NASA APIs (Appears, EarthData, etc.)?



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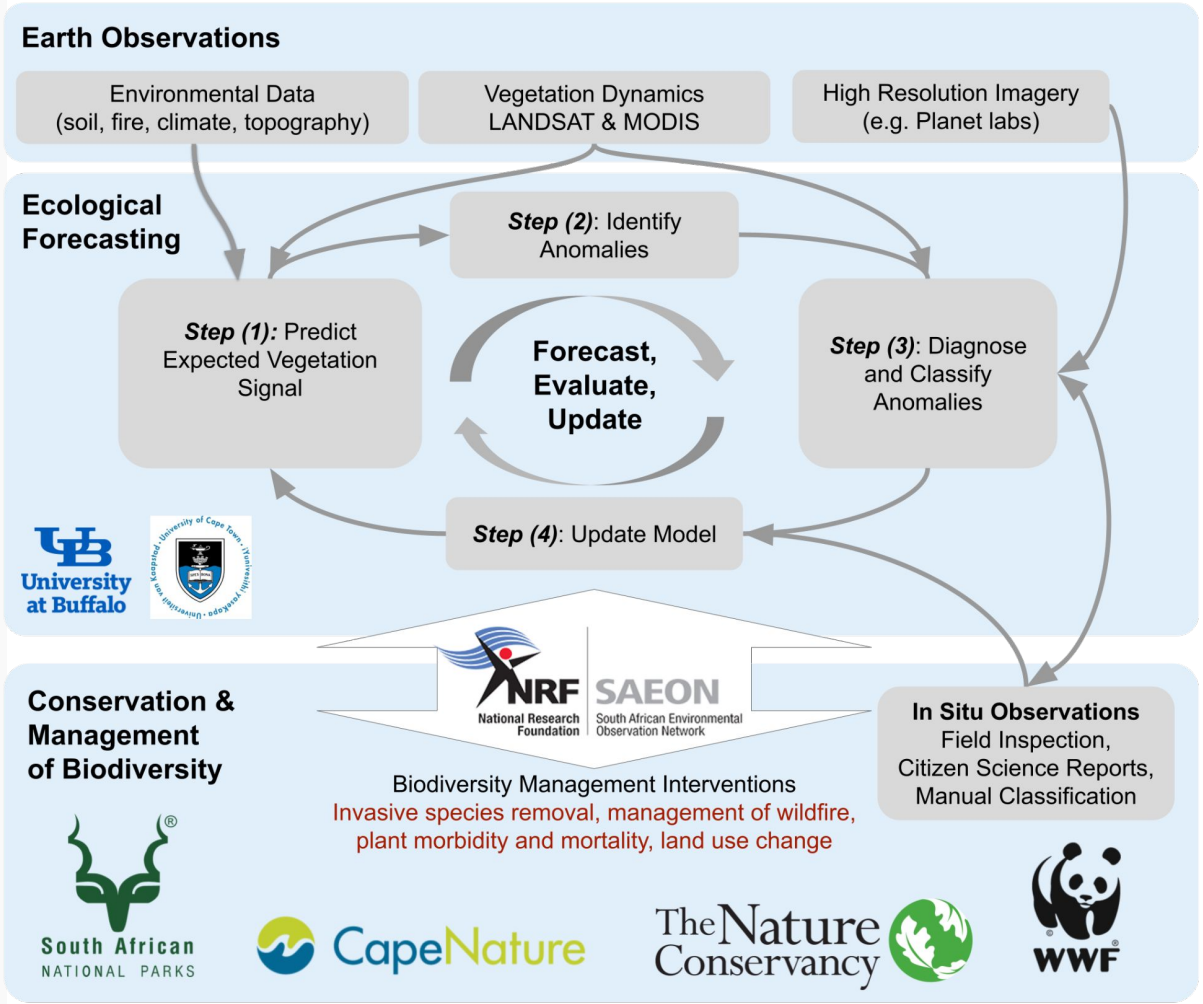
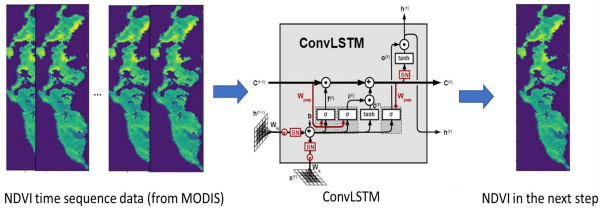


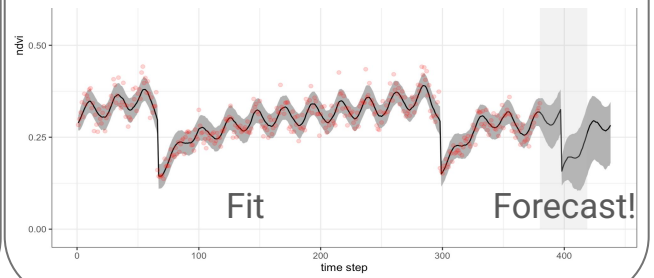
Model Development

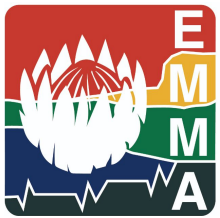
- Less computationally intensive
- More stable
- AI approaches (esp to diagnose deviations)
- Other satellite products

Using a Convolutional Long Short-Term Memory (ConvLSTM) model for prediction



Hierarchical state-space model





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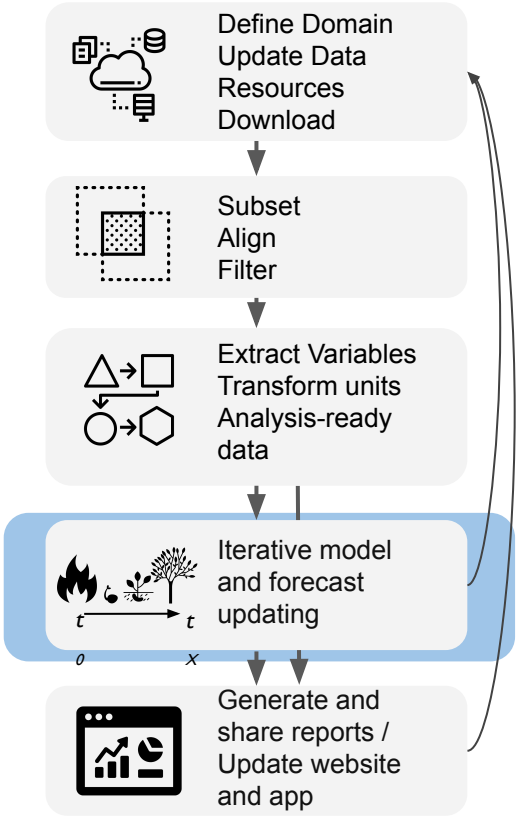
We want this working well before we go online!!!



CapeNature protected areas = 1 054 183 hectares.
WC province = 12 946 200 hectares
900 employees
Budget = R381 million (±$20 million)