2018 Graduate Student Showcase | Conferences

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Vegetation Mapping in a Dryland Ecosystem Using Multi-Temporal Sentinel-2 Imagery and Ensemble Learning

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1. Background

Motivation:

- Mapping vegetation in dryland ecosystems is important for conservation and restoration efforts, rangeland management, and fire prediction.
- Relatively low fractions of vegetative cover (e.g. shrubs and bunchgrasses) make mapping and quantifying vegetation in dryland ecosystems challenging.
- New imaging systems, machine learning algorithms, and powerful computing platforms enable large-scale remote sensing studies of vegetation cover and phenology that can be quickly updated or modified.

Location:

- Our field study area is a National Conservation Area (NCA) that supports North America's highest density of nesting raptors.
- The NCA multi-use area has military training, grazing, power generation, and recreation
- Elevation ranges from 687 to 1111 m above sea level
- Annual precipitation is 0-20 cm in SW, to 30-36 cm in NE

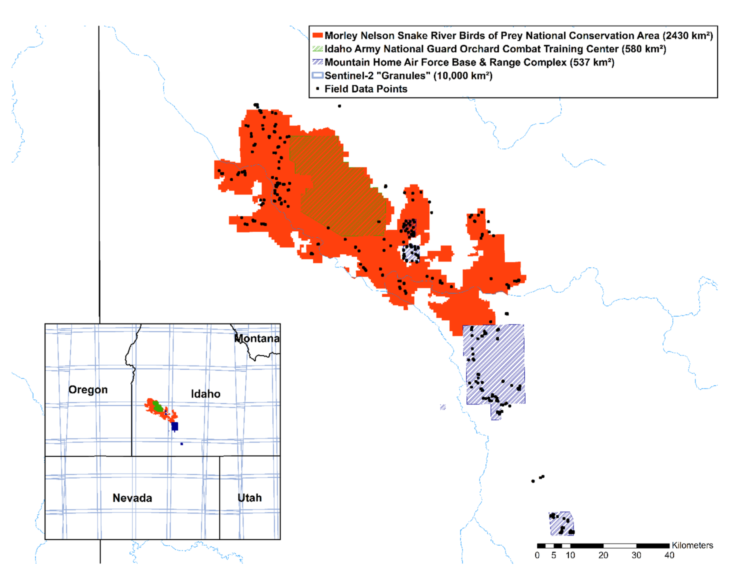


Figure 1: *Location*

Data:

- We used the following data in this study:
  - 8 cloud-free dates of Sentinel-2 satellite imagery *(Table 1)*
  - 34 spectral indices for each date (e.g. *Normalized Difference Vegetation Index*, or 'NDVI')
  - 215 field data 'signature plots' of vegetation and land cover types *(Figure 6* in **3. Results***)* for training and validation

Table 1: *Imaging Dates with < 10% Cloud Cover*

2016-03-30
2016-04-19
2016-06-28
2016-07-18
2016-07-28
2016-09-16
2016-09-26
2016-11-05

2. Methods

Processing Environment: Google Earth Engine

- Google Earth Engine (GEE) is a cloud-based platform developed to access and analyze remote sensing and other large-scale spatial data. *(Figure 2)*
- JavaScript or Python API
- Google servers host data, process script
- Free for research, education, and non-profit use

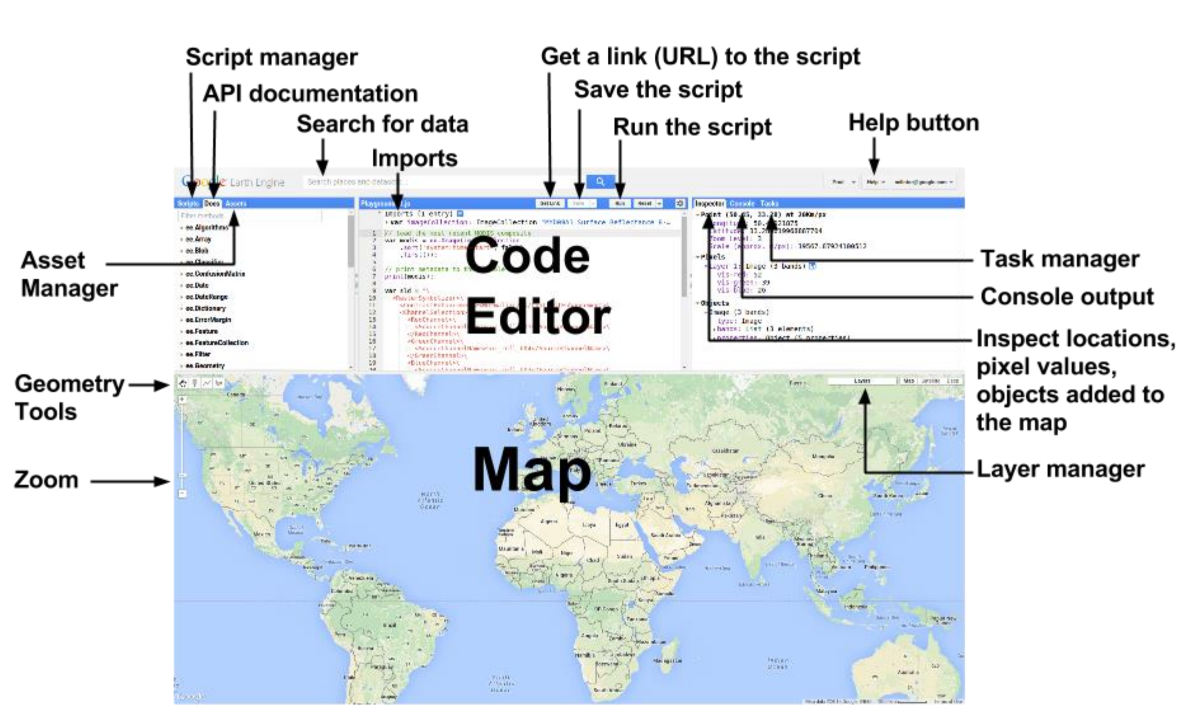


Figure 2: *Schematic of Google Earth Engine Code Editor interface* [5]

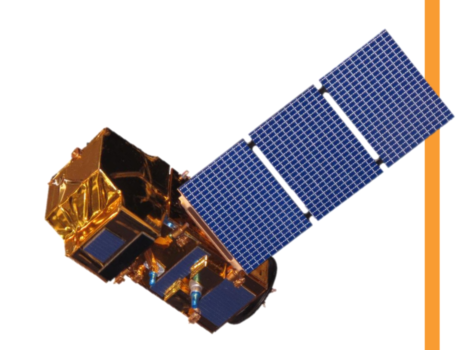
2. Methods *(continued)*

Remote Sensing Data: Sentinel-2

- The two Sentinel-2 satellites are part of the Global Monitoring for Environment and Security (GMES) programme, a joint initiative of the European Commission and the European Space Agency.
- Designed to monitor land cover and coastal waters as a continuation of the SPOT and Landsat missions. *(Table 2)*
- Sentinel-2A was launched on 23 June 2015, Sentinel-2B on 7 March 2017.[2]

Table 2: *Sentinel-2 Satellite Constellation and Sensor Characteristics* [2]

Number of Satellites	2
Orbit Altitude	786 km
Swath Width & Data-take Length	290 km by 15,000 km - *see Figure 5*
Revisit Time	**5** days (equator), **2-3** days (mid-latitudes) - *see Figure 4*
Spectral Instrument	13 in visible, near infrared, and shortwave infrared 12 bit - *see Figure 3*
Ground Sampling Distance	**10 m, 20 m, 60 m**
Products Levels	L1-B (Top-of-atmosphere radiance, 25 km by 23 km tiles or 'granules') L1-C (TOA reflectance, orthorectified and spatially-registered, 100 km by 100 km 'granules') L2-A (Bottom-of-atmosphere reflectance, 100 km by 100 km tiles) *processed user-side with SNAP Toolbox
Data Access	ESA's Copernicus Data Hub, USGS' Earth Explorer, Google Earth Engine, Sinergise Sentinel Hub



Model of Sentinel-2 Satellite. Photograph by Rama, Wikimedia Commons, Cc-by-sa-2.0-fr

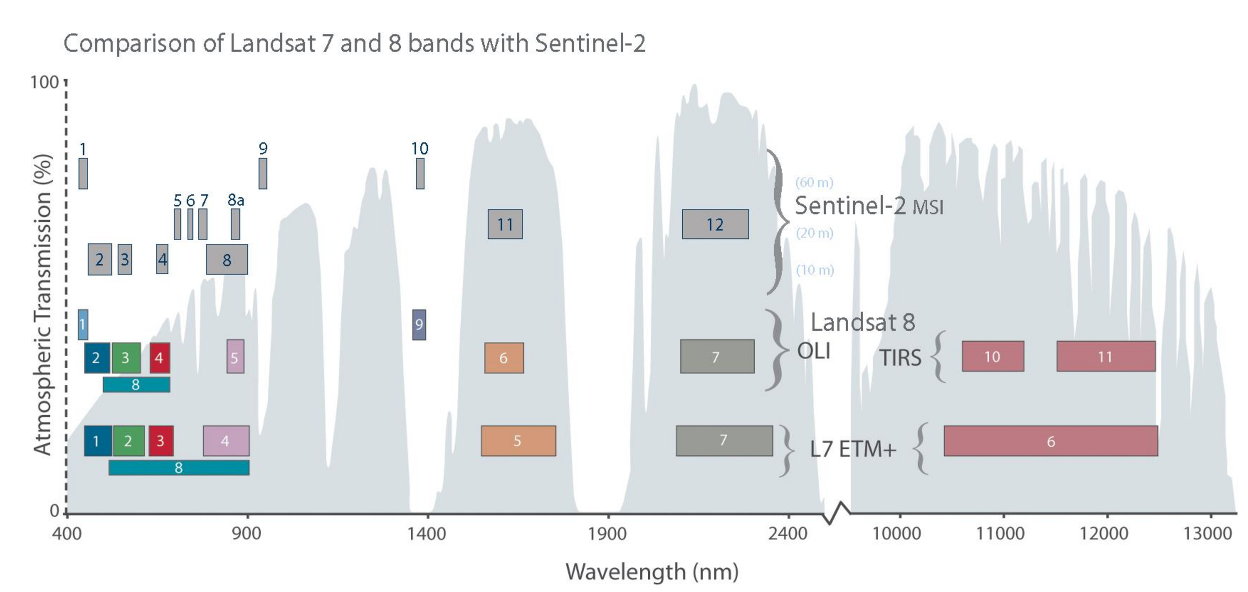


Figure 3: *Sentinel-2 Spectral and Spatial Resolution vs. Landsat 7 & 8* [3]

Caveats:

- S-2 naming changed after 6 December 2016; processing different
- Confusion between 'tile' and 'granule'; early revisit times not consistent
- S-2-specific algorithms in early stages of implementation

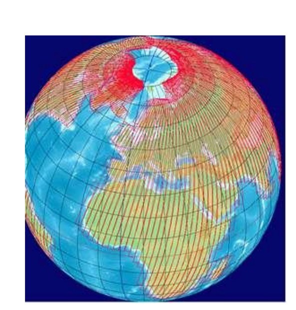


Figure 4: *Sentinel-2 Data-Take* [2]

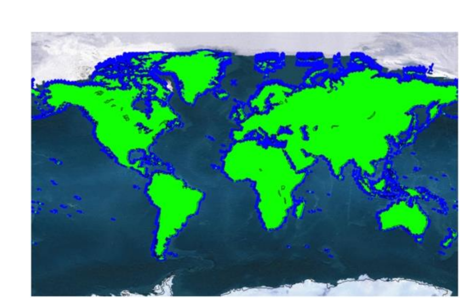


Figure 5: *Sentinel-2 Coverage* [2]

Classification Method: Random Forest

- Random Forests (RF) is an ensemble machine-learning algorithm that grows a 'forest' of decision trees. [1]
- RF uses bagging and random feature selection to select data for each tree, and 'votes' on the best decision tree. [1]
- Implementation:
  - Data randomly subset 70%
  - 500-tree forest, √number of variables per split, out-of-bag sampling
  - Independent validation with remaining 30% of training data

3. Results

Results: Classification

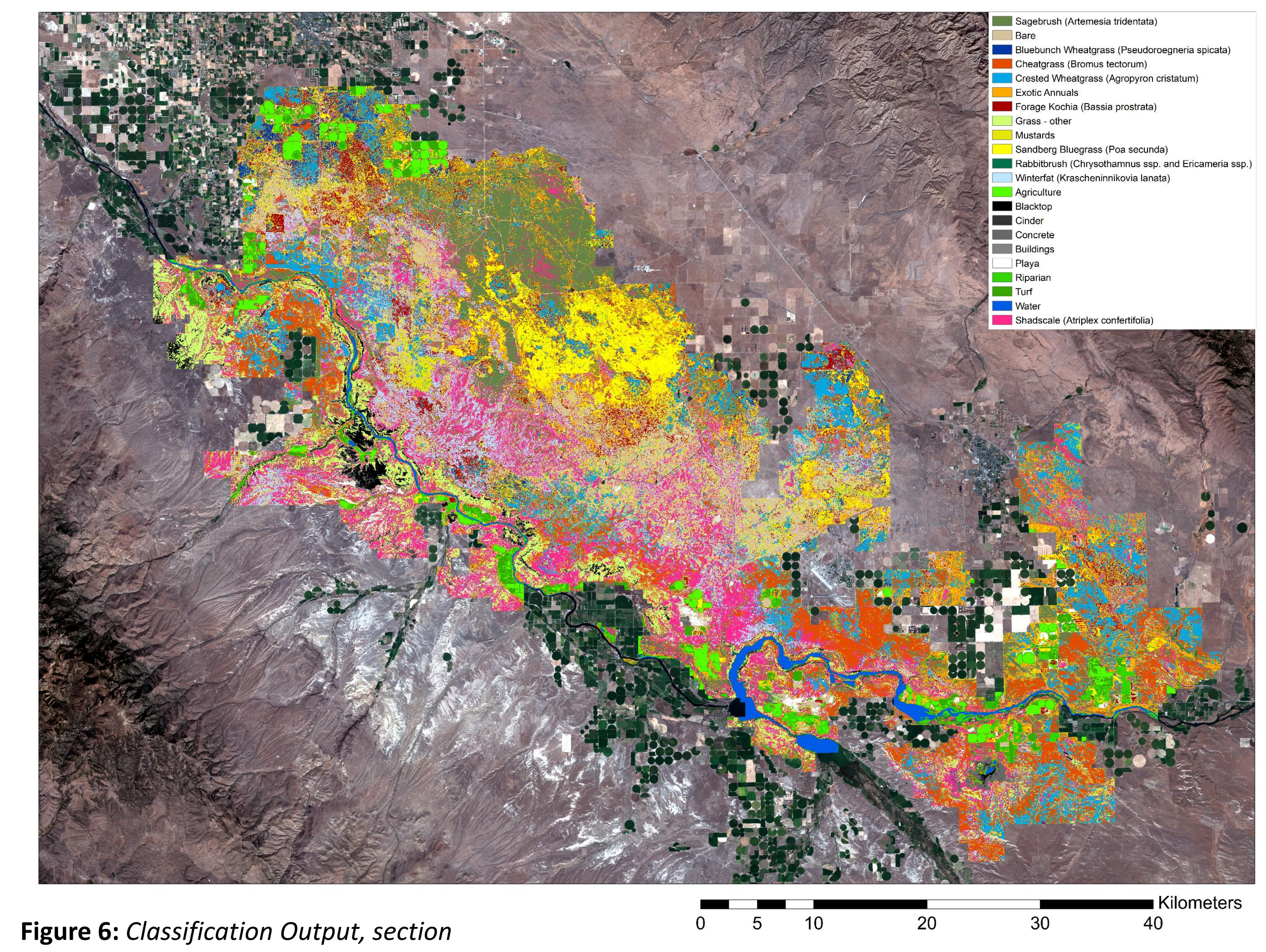


Figure 6: *Classification Output, section*

28,516 km^2 (10 m × 10 m) pixels → *300 million pixels in 1 hour*

4. Conclusions

Take-away Messages

- S-2 offers advantages over Landsat (higher temporal, spatial, and spectral resolution) and MODIS (higher spatial resolution)
- GEE is efficient for processing, enabling different approaches for difficult topics (e.g. dryland vegetation)
  - Classification method easily changed or compared (SVM, CART, etc.)
  - Study area and date range flexible
  - Can add ancillary data
- Multi-temporal imagery and Random Forests leverage differences in phenology between similar species (*Figure 7*)

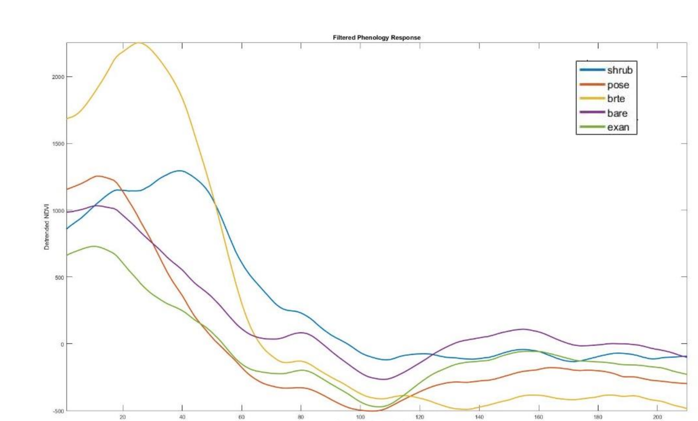


Figure 7: *Sample of phenology (by NDVI) from Feb-Sept, courtesy of Megan Gallagher* [4]

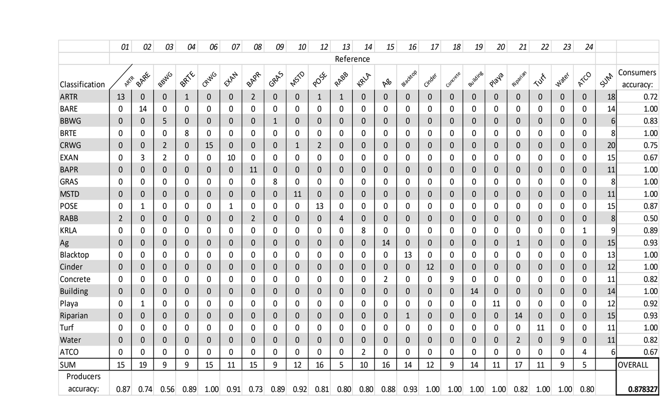


Figure 8: *Confusion Matrix*

Acknowledgements

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5. Gorelick, N., Hancher, M., Dixon, M., Ilyushchenko, S., Thau, D., & Moore, R. (2017). *Google Earth Engine: Planetary-scale geospatial analysis for everyone*. Remote Sensing of Environment.