Outline:

# Introduction

BIODIVERSITY

Currently, extinctions rates across the globe are thought to be significantly higher than previous levels. This is having significant impacts on the prevalence of ecosystem services and functions and changing the status of ecosystems across the globe. In order to combat this, the Group for Earth Observation Biodiversity Observation Network (GEOBON) has advocated for the creation of Essential Biodiversity Variables, or EBVs. These EBVs are based on the framework created by the Essential Climate Variables, with the variable’s key criterion being feasibility, reliability, and information maturity. EBVs are datasets schematically located between raw data (in-situ observations & remote sensing data) and indicators (trends in species populations or community compositions). Six EBV classes have been defined, genetic composition, species populations, species traits, community composition, ecosystem function, and ecosystem structure. Satellite remote sensing is providing access to most EBV classes at regional to global scales. Genetic composition is not currently possible to be assessed via satellite remote sensing.

For the remaining EBV classes, satellite remote sensing is incredibly well suited to assess ecosystem structure and function, especially in forested environments. Recent advances in spaceborne sensors and data fusion approaches are allowing for forest productivity (ecosystem function EBV) and forest structural diversity metrics (ecosystem structure EBV) to be generated across large swaths of land at a medium spatial resolution. While other EBV classes can be assessed using remote sensing, it is more difficult to assess them at a regional-global scale as they require finer spatial resolution data. Further, it is important to ensure that the datasets utilized in EBVs are complementary to one another and are not simply duplicating the same information within multiple datasets.

Another biodiversity adjacent framework – ecological integrity – has recently seen a large amount of uptake in both conservation literature and government policy. Ecological integrity is, as defined by Parks Canada, “[…] respect to a park, a condition that is determined to be characteristic of its natural region and likely to persist, including abiotic components and the composition and abundance of native species and biological communities, rates of change and supporting processes”. Within a scientific framework, ecological integrity generally include ecosystem structure, function, and composition [@hansen2021]. These three ecological integrity facets align closely with the ecosystem based EBVs, namely ecosystem structure, ecosystem function, and community composition [book source]. Mid-resolution satellite imagery is well suited to examine these facets of ecological integrity, and recent advances in computational resources and open-data policies are allowing regional-to-global assessments to be made.

Two relatively easily accessible remote sensing derived EBVs in forested environments are forest structure and forest productivity. Both datasets have been linked to biodiversity using various methods at various scales. High forest structural diversity is thought to lead to an increased amount of niche availability, allowing for higher species richness than areas with lower forest structural diversity. A number of hypotheses have been explored linking productivity and biodiversity, including: the species-energy hypothesis, the environmental stability hypothesis, and the environmental stress hypothesis. These hypotheses have been examined at length using remote sensing data at a global extent [@radeloff2018]

Key to the implementation of the EBV framework is ensuring that the datasets are complementary, and not containing the same information. As an example, forest productivity has been shown to be linked to leaf area index (Huete 2002?), a measure of forest structure. Recent advances in lidar technology and spatial modelling have allowed for additional forest structural diversity metrics to be imputed across large areas by combining optical remote sensing data with airborne laser scanning derived point clouds. These structural metrics can then be used to assess complementarity with another potential EBV the dynamic habitat indices (DHIs). The dynamic habitat indices summarize vegetation indices over the course of a year, examining the total available energy (species energy hypothesis), the minimum available energy over a year (environmental stress hypothesis), and the variability in energy availability (environmental stability hypothesis). The DHIs have been linked to a number of biodiversity metrics, including species richness, abundance, and beta diversity across a number of different clades, as well as ecoregionalizations (sources).

British Columbia, Canada, is a province on the western coast of Canada. The province is subdivided into 16 ecosystems, with a large range of variation in temperature, precipitation, and elevation in the biogeoclimatic ecosystem classification system. This makes it an ideal candidate for assessing ecoregional differences in linkages between forest structure and productivity. structure and productivity. It is expected that total available energy (the cumulative DHI) will be linked to the amount of forest cover in an ecosystem, which can be easily linked to forest structural diversity as derived by airborne laser scanning. The other metrics (energy variability and minimum energy), are likely to be linked primarily to climate. In this paper, we seek to assess the complementarity of two potential EBVs, namely forest structural diversity metrics and the DHIs (representing forest productivity). To do this, we will be using path analysis, a statistical method capable of examining the direct and indirect causal relationships between endogenous and exogenous variables across the forested ecosystems of British Columbia. Models will be assessed on a forest type scale (coniferous, broadleaf, mixed wood, and wetland-treed), in order to assess the impacts of structure on cumulative productivity, and across the BEC system of British Columbia, to assess climatic effects on energy variability and minimums.

MONITORING THROUGH EBVS

PRODUCTIVITY and STRUCTURE as biodiversity indicators

PRODUCTIVITY and STRUCTURE linkages (Huete, Russian dude, etc)

DHI productivity by forest type vs bec zone

Forest type: seasonality

Bec zone: climate

Not looking at intersection

COMPLEMENTARITY

BC – variety is the spice of life, as well as forest trypes

What I am planning to do – assess complementarity of two potential EBVs in a province with lots of ecosystem diversity, in both ecosystems and forest types.

# Methods

## Data

BEC, LC, FSD

## Study Area

BC

Figure – study area w/ excluded zones in some grey

## Sampling

We sampled 3000 points from each BEC zone and forest type across the province of BC. A minimum sampling distance of 1000 m was implemented to reduce the effects of spatial autocorrelation [CITE]. To minimize artefacts from data generation, we ran a focal analysis, using Queen’s contiguity, on the land cover, Lorey’s height, and canopy cover. Each sampled pixel had to be surrounded by the same land cover class to be sampled, and the coefficient of variation in surrounding pixels for both Lorey’s height and canopy cover had to be less than 0.5. This allowed us to sample 3000 pixels from all included BEC zones, except for Ponderosa Pine and Coastal Douglas Fir. To be able to accurately compare between models, we then downsampled all other BEC zones to be equal to the minimum number found across BEC zones (454 found in Ponderosa Pine).

Excluded bec zones and why

3000 samples from suitable zones

Figure?

## Analysis

We ran two scales of analysis, BEC zones, and forest types. Identical models were ran for each [Figure x shows the directed acyclic graphs analzyed]. We used path analysis for this study, as it allows for the interpretation of both direct and indirect effects. We sought to assess the influence of commonly derived forest structure metrics (canopy height, canopy cover) on yearly vegetation productivity summaries at the same spatial scale.

Model validity was interpreted using goodness of fit indices. While Kline (book) advocates for structural equation modelling and, by extension, path analysis to be a suitable method for large samples sizes, commonly used goodness of fit indices are known to saturate within these methods with large samples sizes. Specifically, we choose to not report the Chi-square value as a global measurement of fit, due to its sensitivity to sample size. We report the comparative fit index (CFI) (Fan, Thompson & Wang 1999), the root mean square error of approximation (RMSEA), and the standardized root mean square residual (SRMR).

To test our hypothesis that forest structure and forest productivity are decoupled at the Landsat grain size (30 m pixels), we used path analysis to examine various directed acyclic graphs across each forested BEC zone and forest type within British Columbia.

If models do not fit our analysis

Figure – paths of hypotheses to be examined

**Results**

Figure – path significance proportions

Figure – map showing which have significant relations

**Discussion**

Are productivity/structure complementary

**Conclusion**

We set out to determine if productivity and structure are suitable complementary ecosystem ebv’s. we found that blah blah blah in x ecosystems