Protection Pioneers: An Analysis into the Impact of Federal Land Protection on Environmental Quality

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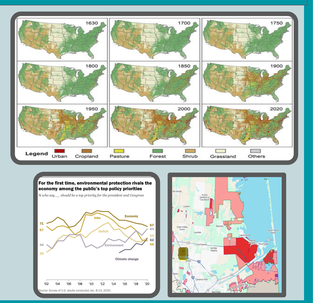
Abstract

Protected land, like federal preserves and national parks, is often thought to be ecologically healthier than unprotected areas, but this might not actually be the truth in some cases. Protected land is often large and unmanageable, especially due to recent national park unemployment rates and cuts in funding for nature preserves nationwide. Unprotected land, on the other hand, normally has constant new environmentally friendly developments such as landscaping and green infrastructure. So this raises the question: "What are the land cover trends and environmental quality changes over time when comparing protected and unprotected areas across different locations?" The majority of our team lives in suburban areas, areas that as shown on Earth Map's Dynamic World layer, are over 50% built-up; so, with our local knowledge of our AOI's that came from collecting land cover data using GLOBE observer, we wanted to research just how different our AOI's were in terms of ecosystem health from similar protected areas. As Protection Pioneers, our research is dedicated to studying the ecosystem health, in terms of terms of plant and soil water loss, which indicates more vegetation(ET), land surface temperature(LST), photosynthesis and plant growth(GPP), and the measurement of how healthy vegetation is in an area(NDVI), of protected and unprotected areas from 2002-2022 using a coded analysis tool that will compare the metrics of the unprotected areas we live in and protected areas with similar environmental conditions like similar temperatures, elevation, and precipitation. The tool then generates downloadable line graphs comparing environmental quality metrics between the AOI and its best-matched protected site. From the research we have already done, we have found that there are distinct differences between areas of protected and unprotected land from our definition of ecosystem health like higher plant productivity(GPP), higher averages of vegetation health(NDVI), lower land surface temperatures(LST), and more water loss(ET). In the future, we as a team hope to expand our research by collecting data at other AOI's near us. As the land cover in the United States is ever-evolving, it is important to continue monitoring the changes underway to use research like ours to create healthy environments anywhere.

Introduction

Remote sensing enables scientists to act as time travelers, and for our team, traveling into the past and future was crucial for our understanding of protected and unprotected areas. Protected areas are meant to slow down habitat loss, deforestation, and declining animal populations, but how effective is this protection? There can be a lot of arguments about how well, or how not well, protected areas can do their jobs, and this paper will compare the ecosystem health metrics of an unprotected area and a protected area related to that area in terms of plant and soil water loss(ET), land surface temperature, photosynthesis and plant growth(GPP), and the measurement of green vegetation in an area(NDVI).



Research Question

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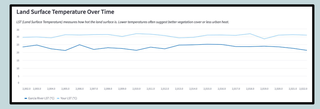
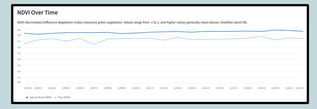
Methodology

In order to complete this analysis, every team member started by selecting an Area of Interest (AOI) and received an assigned 3km by 3km grid surrounding that area to collect data. These grids contain 37 specific locations, and each member travelled to each location and recorded a GLOBE Observer Land Cover Observation, for a total of 37 per person and 370 between the entire group. Each observation consisted of a land cover description, where ground moisture, tree cover percentage, water content, along with 6 photographs, facing up, down, north, east, south, and west. Whilst collecting GLOBE data, members also emphasized observing the forms of land use in their AOI in order to draw connections and correlations between the usage of land and the environmental health factors.

To draw the most accurate comparisons between protected and unprotected areas, we developed an automated program that identifies the most ecologically similar protected area to the given unprotected AOI. The tool then generates downloadable line graphs comparing environmental quality metrics between the AOI and its best-matched protected site over the years 2002-2022. Once each user completes their comparison, we combine all results for an aggregate analysis. From this, we test statistical significance for differences in environmental conditions between protected and unprotected areas, temporal trends (i.e., whether conditions improve over time with development), and differences in variability (volatility) between protected and unprotected areas.

About Our Tool



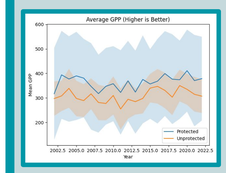


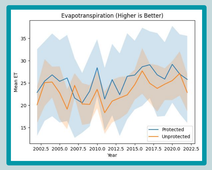
With a comprehensive database of protected lands in the US and their respective relevant climate data, we developed a Python-based web application, coded through GitHub Codespaces, and deployed via Streamlit. Once we gather the climate and elevation data from the user's location, we compare it to all the protected areas in our dataset to find the most similar one. To ensure a fair comparison, we first convert each variable – including temperature, rainfall, and elevation – into z-scores, which show how typical or unusual each value is compared to the rest of the dataset.

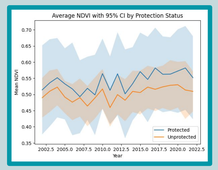
To actually find the best match, we use the Euclidean Nearest Neighbors algorithm simply meaning it looks for the straight-line distance between two points, and "Nearest Neighbors" meaning it ranks which protected areas are closest in terms of overall ecological similarity. The result is a ranked list of protected areas, with the top match selected for deeper comparison. The app then generates line graphs comparing the user's location to the best similar protected area from 2002–2022 across the following environmental indicators: NDVI (vegetation health), ET (water use), LST (surface temp), and GPP (plant growth).

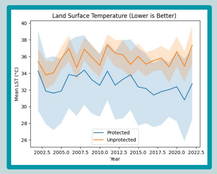
Results

While protected areas maintained superior conditions, our graphs show that ecological metrics increased over time in both protected and unprotected areas with no meaningful difference in rate of increase—suggesting protection was not the primary driver of higher averages. Protected areas consistently exhibited greater variability across all metrics compared to unprotected areas. Variability remained relatively constant within each protected and unprotected area over time. These findings suggest that protected lands display increased environmental instability, in contrast to unprotected lands, which remained considerably stable environmentally.

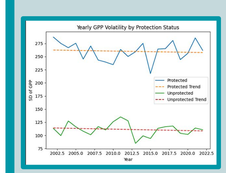


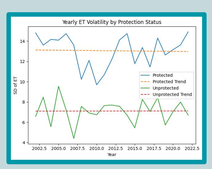


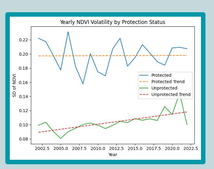


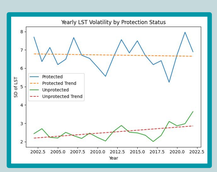


Protected areas consistently had more variance, as affirmed by consistently box plots, standard deviation graphs, and Levene's test; suggests unprotected lands are more environmentally stable, possibly due to land use that would control for certain environmental outcomes like crop output, while protected areas remain variable—perhaps due to varying protection enforcement.







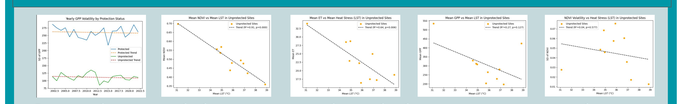


- Protection appears to preserve both environmental quality and temporal stability, maintaining variance .

Limitations:

- Low sample size (10 people total, with one person's protected area returning null et & GPP vals)
- Spatial resolution constraint: Each protected area was analyzed using only a 3 km × 3 km section centered within the site, meaning the analysis does not represent the full extent of the protected land and may miss ecological variation at the periphery.

Conclusions



Our analysis revealed consistent ecological advantages in protected areas, which exhibited higher average vegetation health (NDVI), plant productivity (GPP), and evapotranspiration (ET), alongside lower land surface temperatures (LST). These differences were statistically significant when comparing matched sites, reinforcing the general effectiveness of protected areas in maintaining stronger environmental conditions. Protected areas also demonstrated higher internal variability across all metrics, with consistently greater standard deviations and significantly higher variance confirmed by Levene's tests. This could reflect differences in management quality or ecosystem diversity within protected zones. Conversely, unprotected areas, though environmentally weaker on average, showed lower variability and more stability over time—perhaps due to more uniform land use practices.

Acknowledgements

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