NASA SEES EARTH SYSTEM EXPLORERS 2024

Analyzing the Impact of Solar Arrays on Surrounding Vegetation in Agrivoltaic Farming for Performance Optimization

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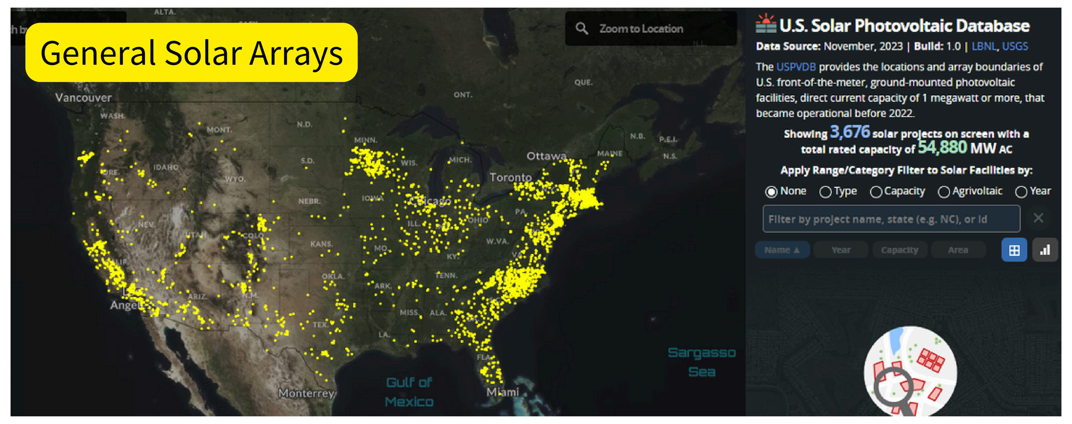
Abstract

This project investigates the impact of solar arrays on surrounding vegetation within agrivoltaic systems to enhance operational efficiency. Agrivoltaics, which combines agricultural practices with solar energy production on the same land, offers a sustainable alternative to exclusive solar installations on agricultural land. By diversifying income for farmers and addressing energy equity issues in less grid-connected areas, agrivoltaics can play a crucial role in sustainable energy and rural economic development. The study focuses on understanding the intricate balance between energy production and agricultural yield in agrivoltaic sites. Solar panels create microclimates that influence plant growth dynamics, necessitating a comprehensive analysis of these effects. The primary research question explores the feasibility of using remote sensing tools and satellite data to assess the impact of solar arrays on vegetation health and productivity, thereby informing future agrivoltaic projects. The first step was identifying agrivoltaic sites across the United States by integrating global observer AOI data with the US Solar Photovoltaic Database (USPVDB). Then, LANDSAT satellite imagery is used to analyze these locations, leveraging NDVI, spectral wavelengths (particularly red wavelengths indicative of photosynthesis), and TCG data to monitor changes in vegetation over time from before and after solar array installation. The data from each location is then combined to evaluate average changes across the points. The results showed an 18.5% decrease in NDVI and a 54.2% decrease in TCG, suggesting a decline in overall vegetation health and photosynthetic activity following the installation of solar panels , while the 40.6% decrease in Band 4 suggests potential for enhanced photosynthesis under certain conditions due to the solar panels. These results highlight the complex relationship between solar arrays and surrounding vegetation in agrivoltaics and provide valuable insight into the factors to be considered for the successful implementation of agrivoltaic projects.

Background

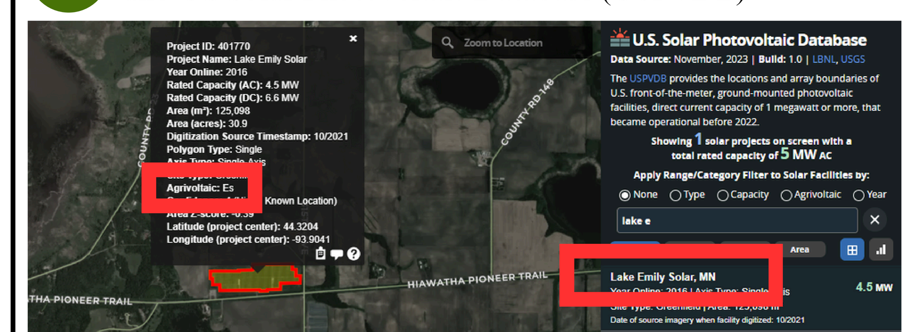
Agrivoltaics: The practice of using **the same land** for both agriculture and solar energy production. Also known as low-impact solar.

Value: This co-location practice can potentially address both **energy inequity** by supplying solar energy in locations less-centered on the electricity grid, while also **helping farmers diversify income** through land-lease payments and other business models. Agrivoltaics can **sustain rural farmland economies**, which have an especially growing need for support. Further, **only 2% of large solar array projects in the US are agrivoltaic,** highlighting the potential for growth of this practice.



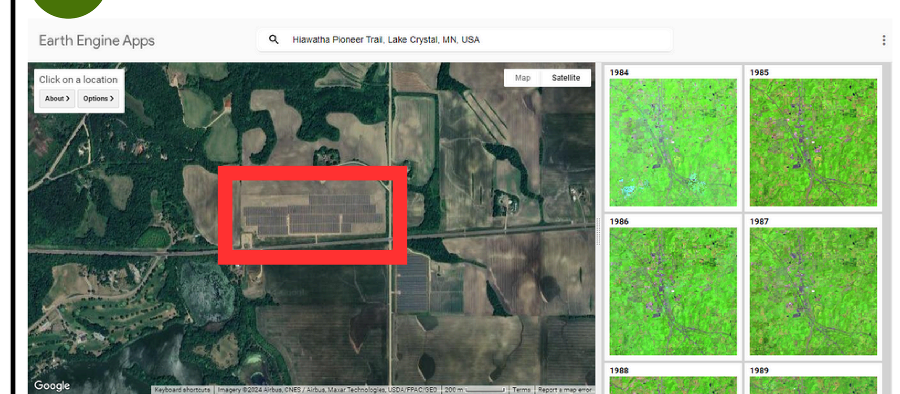
Methodology

01 Identifying Area of Interest (AOI) using Globe Observer and US Solar Photovoltaic Database (USPVDB)



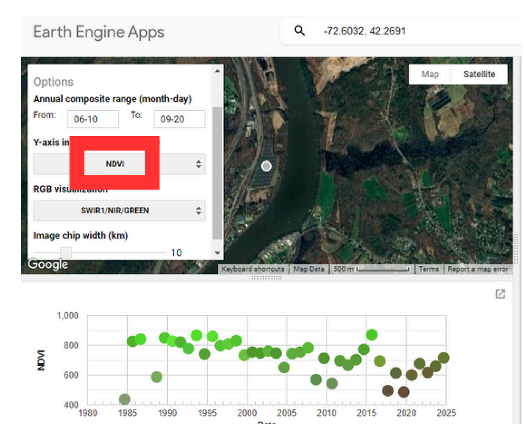
Agrivoltaic solar projects in the US were identified by first sorting through the globe observer AOI points to identify areas with solar panels, overlaying them with the USPVDB, and filtering to find agrivoltaic projects.

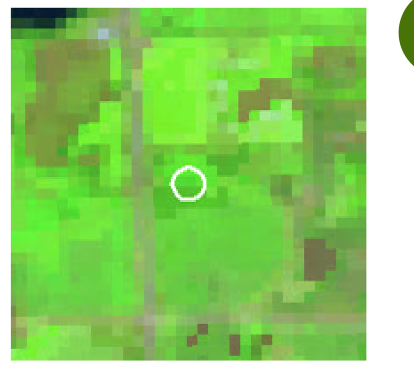
02 Matching USPVDB sites with LANDSAT Time Observer



After identifying the specific locations on the USPVDB, they are matched up with data on the LANDSAT time observer database to identify the locations of interest and extract time series data.

03 Data collection





Using the LANDSAT Time Observer tool, the changes in time of NDVI, spectral wavelengths, and TCG with the agrivoltaic sites were explored. These factors can be indicators of vegetation health and levels of photosynthesis.

Shown above is the vegetation change of an agrivoltaic site. The site changes in greenness over time, signifying trends in change of vegetation health after the installation of the solar array.

The LANDSAT tool was used to construct graphs for analysis of trends and changes in the factors realtive to the year of the solar array installation.

01 **NDVI**
Normalized Difference Vegetation Index - reveals the amount and health of vegetation on land
***NDVI=(NIR-VIS)/(NIR+VIS)**

02 **Spectral Wavelengths**
Band 4 data: taken from LANDSAT 8 and used for analyzing reflected red light
***Lower reflectance = more photosynthesis**

03 **TCG**
Tasseled Cap Greenness - analyzes abundance of photosynthesis through green reflectance of vegetation

04 Data Combination

01 **Collecting**
The combination starts by reading and parsing the data from the CSV files provided by the LandSat Time Series.

02 **Centering**
Data is then centered around the year the solar farm is constructed and data is recorded -15 years and up to +10 years.

03 **Averaging**
The data is then averaged and exported to be graphed using Google Sheets. **Code snippet shown below.**

```
def fix(data: list):
    fixed = data[0]
    for i in range(1, len(data)):
        line = [data[i][0]+data[i][1]]
        line.extend(data[i][2:])
        fixed.append(line)

    return fixed

def extract(data: list):
    extracted = []
    start = False
    for i in range(1, len(data)):
        if start or "1990" in data[i][0] or "1991" in data[i][0]:
            start = True
            for j in range(1, len(data[i])):
                if data[i][j] != '':
                    # print(data[i])
                    extracted.append((int(data[i][0].split(" ")[2][:-1]), float(data[i][j].replace('"',
''))))
    return extracted

def clip(data: list, build: int):
    start = build - 15
    end = 2023

    return [x for x in data if x[0] >= start and x[0] <= end]


dataFiles = [[y.split(",") for y in open('./data/'+x).read().replace('"1,', '"1').replace('"2,',
'"2').replace('"3,', '"3').replace('"4,', '"4').replace('"5,', '"5').replace('"6,',
'"6').replace('"7,', '"7').replace('"8,', '"8').replace('"9,', '"9').replace('"10,',
'"10').split("\n")] for x in os.listdir('./data')] # read from all files in the data folder
dates = [int(''.join(filter(lambda x: x.isdigit(), x.replace("B2", '').replace("B4", '')))) for x in
os.listdir('./data')] # cursed list comprehension
```

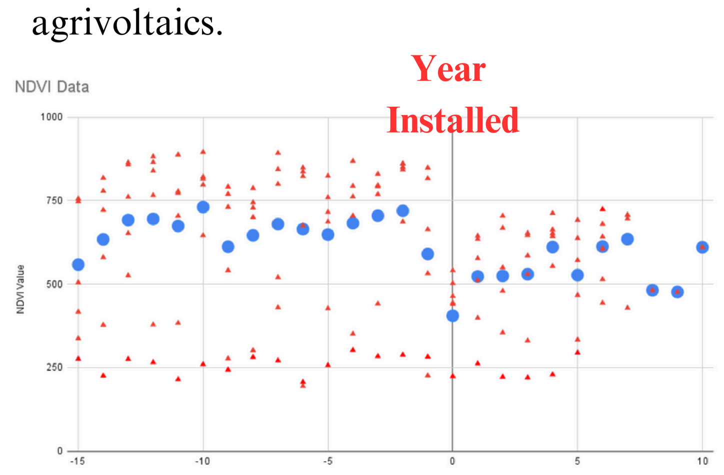
Conclusions

- Results highlight the critical insights necessary for **optimizing agrivoltaic systems**
- Observed 18.5% decrease in NDVI and 54.2% decrease in TCG suggests a **decline in overall vegetation health and photosynthetic activity** following the installation of solar panels
- The 40.6% decrease in Band 4 suggests **potential for enhanced photosynthesis** under certain conditions due to solar panels
- These results illustrate the **complex interactions between solar arrays and surrounding vegetation,** providing essential data to inform future agrivoltaic projects
- Understanding these dynamics allows us to balance energy production more efficiently with agricultural output to support rural economies and **facilitate the sustainable growth of agrivoltaics**

Data and Analysis

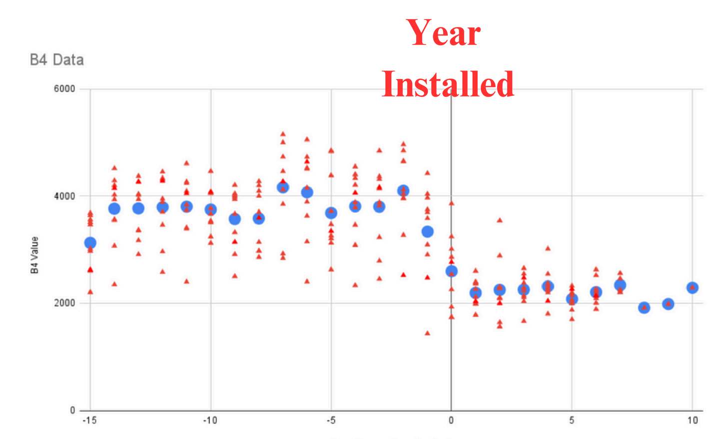
NDVI

The NDVI data shows a **decrease of 18.5% after the installation of solar panels,** indicating that vegetation health decreases with the implementation of agrivoltaics. The data also shows that NDVI levels gradually return to previous levels. This temporary change in NDVI could explain that the significance of worse vegetation health is not entirely the cause of agrivoltaics but instead could be due to the construction and renovation practices that take place during the implementation of agrivoltaics. This emphasizes the value of non-invasive construction practices in agrivoltaics.



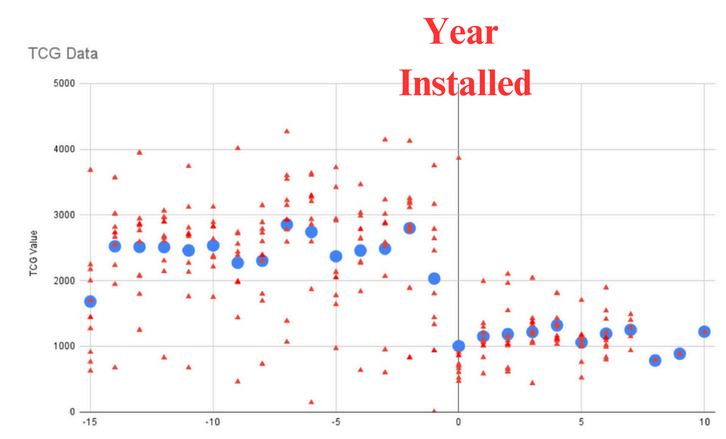
Spectral Wavelength B4

Band 4 represents the reflectivity of red wavelengths (0.64 - 0.67 µm). Less reflected red wavelengths means more photosynthesis is occurring as plants absorb this energy. Data shows that **band 4 decreased by 40.6% after the installation of solar panels.** Instead of plant photosynthesis, however, this change can likely be attributed to increase in red light absorption from the solar panels. Due to solar panels absorbing more red light, vegetation health suffers as plants are exposed to less energy to perform photosynthesis.

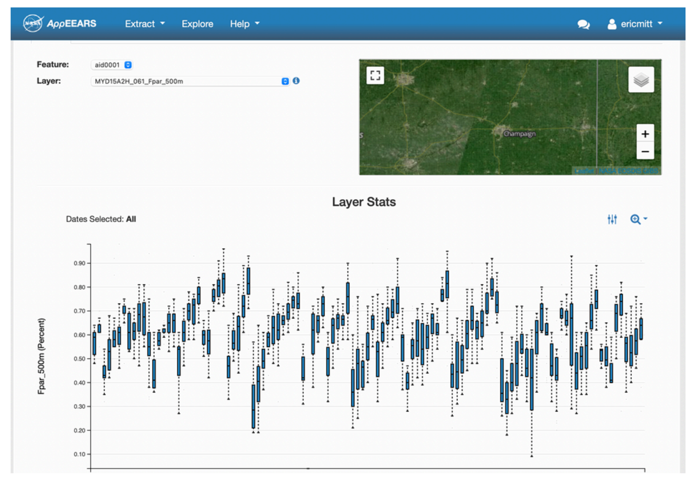


TCG

Data shows that **TCG decreased by 54.2% after the installation of solar panels,** indicating that photosynthesis decreased after implementation of agrivoltaics, signaling possible vegetation health decrease. The decrease in greenness is attributed to plants having lower exposure to solar energy to perform photosynthesis. This data correlates with the patterns shown in band 4 and helps to form a cohesive understanding that vegetation health weakens after the implementation of agrivoltaics.



Future Work



Application

We aim to create an application that can predict **solar power potential in agrivoltaics** based on different factors including relative position to the sun, area, or elevation to assist with optimal solar array placement along with vegetation health factors. Allowing farmers to combine all factors can potentially revolutionize agrivoltaics and energy production.

Variation

The next step for the team will be to evaluate the differences in vegetation health change for each agrivoltaic site, identify site differences between each AOI, and understand the reasons for the variation in changes by using the NASA AppEEARS application. This will provide information on what attributes of an agrivoltaic site contribute to its success.