BIOSPHERE 2 RESEARCH EXPERIENCES FOR UNDERGRADUATES SITE: EARTH SYSTEMS RESEARCH FOR ENVIRONMENTAL SOLUTIONS (B2 REU)

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ABSTRACT: Agrivoltaics is a dual land use strategy that uses the space under solar panels for crop production, which provides a mutually beneficial environment. Agrivoltaics land use increases water-use efficiency, improves solar panel efficiency, and increases the yield and lifespan of many crops. Agrivoltaics has been proposed as one solution to the food-energy-water nexus issues of the future. However, the food-energy-water nexus currently overlooks the critical component of soil health, on which this study focuses. Agrivoltaics plots showed lower average pH, total carbon, and nitrogen levels when compared to their full sun control plots. Midday soil temperature averages from July 5th-13th are 3.4 °C hotter in the full sun control plots, while soil moisture averages for the same timeframe are 0.070 m³/m³ lower in the control plots. Higher soil pH is correlated to increased aridity and temperature, which may explain the higher pH readings in the control plots. These higher pH readings result in lower absorption of nutrients with the optimal range for most critical macro and micronutrients falling between a pH of 6.5-7. Additionally, agrivoltaics extends production season and yields higher plant biomass. This increased yield partnered with biomass removal correlates with lower soil nutrients like carbon and nitrogen in agrivoltaics plots.
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Impacts of Warming on Frozen Soil Permeability over the Ohio River Basin through Recession Flow Analysis

ABSTRACT: There has been preliminary research into the use of recession flow analysis of catchment areas to measure permafrost thawing rates due to warming. These results indicate a correlation between changes in permafrost depth and coverage and recession flow data in regions that support frozen soils. Here, we aim to test this hypothesis in the Ohio-Tennessee combined river basin—a snowmelt-dominated watershed in the US to further generalize these relationships. The Ohio-Tennessee River Basin in North America covers a large area in the Midwestern United States, from the Appalachian range to the Mississippi River basin and from the Great Lakes region to just south of Tennessee. The basin covers 189,422 square miles (490,600 km²), the 8th largest in the US, with the 2nd largest discharge rate. The USGS has a network of stream gage sites throughout the Basin that have discharge flow rates from as far back as 1933, well before the current warming period that began approximately in the 1980s. Having such an elaborate dataset will prove to be valuable for demonstrating the efficacy of recession flow analysis in catchment areas that lie below subarctic latitudes (below 50°N latitude). Changes in recession of the streamflow (drainage of groundwater) due to warming should be reflected in higher permeability of frozen soil due to lower ice content. Recession flow analysis of seventy-year long stream flows from eleven stream gages spread throughout the Ohio-Tennessee River basin showed decreasing trends in nine gauges for permeability over time with the greatest changes coming from stream gages within the largest sub-basins and the strongest trend correlations due to latitude. In the future, further research goals may include an analysis over other river basins that are more affected by frozen soil in higher latitudes to further test the effects of latitude on results. Additionally, running analyses of air temperature and snow depth using mechanistic modeling (with process-based land surface models) could provide more information on the overall shift in climate of a basin area.
Chemical Analysis of Soil Affected by Wildfire and Drought
Bighorn Fire and Biosphere 2 Rainforest Drought

ABSTRACT: From June to July 2020, the Bighorn fire in the Tucson Catalina Mountains burned over 40,400 hectares, with 4% of land experiencing high severity burns as described by the Burn Area Emergency Response Team (BAER 2020). In 2019, over 906,000 hectares of the Amazon Rainforest was burned during an unusually long dry season and deforestation. At Biosphere 2, the 1,900 m$^2$ rainforest was used to create a controlled drought environment for the Water, Atmosphere and Life Dynamics (WALD) project which focused on analyzing all components of the effects of a 66-day drought. In collaboration with the WALD project and Arizona Geological Survey, this research project focuses on comparing how drought and fire affects soil chemistry across different biomes. For the drought portion of soil chemical analysis, focus was placed on the rhizosphere of the *Arenga Pinnata* (Sugar Palm) tree located in the lowlands of the Biosphere 2 rainforest. Analysis found that in comparison to a control area outside of the palm rhizosphere, soil salinity was higher and had larger variation throughout the drought. For pH, the palm rhizosphere experienced an overall lower pH than its control area counterpart; additionally, pH was found to rise during the most severe drought period in surface soils of the palm rhizosphere. When investigating the fire soils, comparing two vegetation sites across three burn severities, both vegetation sites had significantly different results across most analyses. pH of the Madrean Pine-Oak Woodlands sites decreased with fire severity while Ponderosa Pine Forest sites rose significantly. Electrical Conductivity of both sites experienced an increase with fire severity, but the Madrean site experienced a larger change than the Ponderosa site. Finally, major differences in the sites appeared most significantly in the carbon and nitrogen analysis. The Madrean site had a decline in carbon by weight as fire severity increased; however, Ponderosa site soil carbon reached its highest in high severity fire.
The Potential for Agrivoltaics to Decrease Temperature Sensitivity in Food Crops

ABSTRACT: The impacts of climate change extend to new patterns in weather and seasonality that constrain conventional agriculture in the Southwest United States. Agrivoltaics: the combination of photovoltaic panels and food crop growth better sustain smaller diurnal temperature shifts in soil and air, thus combating the effects of climate change. Plant stress response to harsh environments include early flowering, crop death/failure, and decreased productivity. To understand the effect of temperature stress on photosynthetic rates, transpiration, and water use efficiency Anasazi red beans and Caribe` potatoes were tested using LI-COR 6400 on clear and sunny days in the mid-summer season. Both crops in Agrivoltaics performed at near constant rates of photosynthesis across water treatments. Crops under control conditions outperformed Agrivoltaics crops 75% of the time for photosynthetic rates. Similarly, control crops exhibited higher rates of transpiration 75% of the time across both water treatments. Ultimately, the water use efficiency of crops reflects greater success in Agrivoltaics. Severely high temperatures impair a plants ability to photosynthesize efficiently as greater water loss occurs during the process. A milder microclimate in Agrivoltaics curbs the loss of water, allowing crops to maintain levels of photosynthesis under sever temperature conditions. As climate change continues to impact local and global seasonality, an Agrivoltaics approach to large scale agriculture holds great potential in plant efficiency and production.