II. Scientific/Technical/Management Section

1. Objectives and Significance

Since the 1970s, the United States incarceration rate has increased by 700% (National Research Council 2014). This is also the highest incarceration rate in the world (Walmsley 2018), such that the U.S. constitutes 4% of the global human population but a staggering 25% of the world's prisoners (Pellow et al. 2020). Further, the population of incarcerated people does not represent the U.S. population. With approximately 1.6 million incarcerated, 3/5 of them are low-income and/or minorities (Hayes and Barnhorst 2020). Adults in poverty are three times more likely to be arrested than those who aren't, and people earning less than 150% of the federal poverty level are 15 times more likely to be charged with a felony—and thus a longer sentence—than people earning above that threshold (Texas Criminal Justice Coalition 2019). Black people are nearly six times more likely to be imprisoned than white people, Latinx people are over three times more likely, and Indigenous Americans are incarcerated at a rate 38% higher than the national average (Kaeble & Glaze 2016). With this overrepresentation of poor people and people of color, the U.S. prison system expands the current system of racial capitalism by exploiting unpaid/underpaid (and often dangerous) labor. This labor helps fund prison operations and generate revenue, while the expansion of prisons and prison programs is justified through claims of rehabilitation (Chennault and Sbicca, in review).

Within this system of inequitable incarceration and racial capitalism, inmates themselves have been forced to endure unjust environmental conditions. Documented abuses include climate extremes, air quality and toxic exposure incidents (Pellow et al. 2018; Veit 2018). For example, summer heat waves can create indoor heat indexes of nearly 150 degrees inside prison cells, which has led to adverse health effects and deaths of both inmates and staff (Holt 2015), yet lawmakers continue to shut down bills that would require implementing climate control in prisons (e.g., TX HB88). Additionally, prison locations are regularly chosen with little regard to their surrounding environment (Mohai et al. 2009; Ashby et al. 2020). For example, the Rikers Island jail complex in New York City is located on top of a landfill, and the Fayette prison in Pennsylvania is located next to a coal ash waste site; both site locations have led to adverse health effects in inmates and staff (Deutsch 2011; McDaniel et al. 2014).

While the exposure of these cases by journalists and activists has been vital in heightening awareness of environmental injustices prisoners face, **the examination of prisons as sites of environmental injustice is still relatively understudied** (Opsal and Malin 2019). Most prison facilities across the U.S. have not been scrutinized or evaluated for adverse environmental conditions and risks, likely given that prisoners are not often considered as EJ communities (Pellow 2017; 2018), and these injustices are therefore commonly ignored by authorities. **This presents an opportunity to address**

these vital equity and environmental justice (EEJ) issues by leveraging NASA's Earth science data - including satellite, land cover, climate, and air quality datasets - in a novel way to characterize the environmental harms faced by prisoners across the U.S. This work will heighten awareness of these widespread EEJ issues and inform actionable steps to tackle injustices that deserve more attention and legal action than they have received thus far. Therefore, the objectives of this proposal are to:

1) Quantify the environmental conditions at all state- and federally-run prisons in the U.S. (*n = 1,865*) using NASA's various Earth science datasets and geospatial analysis.
2) Calculate a standardized vulnerability index for each prison, creating a comparable metric of environmental risk faced by prisoners across the country that will result in geospatial data products.
3) Integrate this information with our extensive dataset and mapping platform on prison agriculture, which includes specific agriculture activities and their drivers (i.e., benefits to the prison system) for over 600 state-run prisons, to link racial capitalism of prison agriculture to environmental injustices (Pulido 2016).

2. Perceived Impact

This work fills gap analyses in two main contexts, having major societal impacts for both. First, it will be a vital addition to a comprehensive dataset on prison agriculture in the U.S. Second, it will provide a novel country-wide environmental vulnerability assessment for all state and federal prisons, with reproducible open-access methods to promote application of these assessments to other institutions such as jails and juvenile detention centers.

The Prison Agriculture Lab at Colorado State University (CSU; co-directed by Co-I Chennault) has put together the first ever country-wide dataset on U.S. prison agriculture, which includes 660 state-operated adult prisons that partake in some form of agricultural labor. Prison agriculture is a prime example of EEJ issues within the prison system, being criticized as exploitative and even an enduring form of slavery (Evans 2018; Baker et al. 2021). The work of the Prison Agriculture Lab contains data on prison agriculture activities and their intended purpose at each prison and places this information within local socioeconomic and demographic contexts. The dataset provides an opportunity to critically interrogate this set of relatively hidden practices and unpack the carceral consequences and conditions surrounding prison labor. What is missing from this dataset is the environmental context and its relationship with prison agriculture labor. The dataset produced from this proposed work will provide new and imperative information on the environmental conditions and risks faced by prisoners forced to partake in agriculture-related labor.

In a larger sense, this work will provide a broader context of environmental harms forced upon incarcerated people across the U.S. Despite the numerous cases of environmental injustices documented in U.S. prisons, prisoner living conditions have not received the attention it deserves (Opsal and Malin 2019), and these injustices need to be more deeply understood across the U.S. A major deliverable of this project is to heighten awareness of the negative environmental conditions faced by prisoners across the U.S. and give concrete reasons to demand environmental justice for prisoners. Leveraging NASA's Earth science data to calculate country-wide environmental vulnerability indices will pave a path to profoundly impact EJ prison communities and the social, economic, and biophysical landscapes that disproportionately incarcerate and harm poor and non-white people.

The end product of this work will be a GIS-enabled dataset that can be added to other EJ mapping interfaces and will be publicly available for others to see comparable environmental risks at thousands of prisons across the country. The environmental justice of prisons movement has shown some momentum towards recognizing prison communities as EEJ communities, which includes the EPA adding prison locations to its EJScreen mapping tool. However, no one has quantified the environmental risk at these prisons. EJScreen currently only shows locations of prisons and does not reveal concrete patterns of where prisons are most affected by environmental degradation. Our dataset will be imperative in highlighting the spatially differentiated types and levels of risk across counties, states, and the whole country, and would be a vital addition to the EJScreen tool.

3. Relevance to Program Element

This proposal is directly related to the NASA Earth Science Applications: Equity and Environmental Justice program element, specifically the Landscape Analyses element which calls for "landscape analyses to understand the broader EEJ community context to inform actionable next steps." **Prisons are by definition EEJ communities, as they are highly overrepresented by people of color, indigenous persons, and poor people, and recent work has highlighted that prisons are often subject to adverse environmental health threats (Perdue 2018; Pellow et al. 2020; Baker et al. 2021), of which prisoners have no choice but to endure**. However, these injustices receive little attention due to a combination of the profitability of free prison labor and some perceptions that the lives and health of disproportionately non-white and poor incarcerated people are worth less (Pellow 2019). For these reasons the prison system is a natural area of concern for EJ issues. This project will define to a fuller extent the adverse environmental conditions faced by prisoners across the U.S. by leveraging NASA Earth science datasets and products in combination with modern geospatial technologies to fill a vital gap in our knowledge of EEJ injustices forced upon prison communities. NASA's extensive satellite and ancillary data products uniquely provide gridded datasets that allow us to measure these environmental variables at the level of the prison boundaries. Our proposed methodology is also advantageous in that all environments will be characterized in a standardized, unbiased way, allowing for country-wide comparisons of environmental burdens. The result of this project will be a geospatial dataset with all calculated environmental variables and vulnerability indices for every prison, allowing users to view spatial patterns of all environmental indicators. The dataset created from this landscape analysis study will be completely novel and allow for activists, researchers, policy makers, government agencies and beyond to become aware of and make informed decisions to mitigate environmental injustices faced by prisoners across the U.S.

4. Technical Approach and Methodology

Our approach and methodology is broken into two main components: 1) characterizing the environmental conditions and risks at all state and federal prisons in the U.S., and 2) using those metrics to create a single environmental vulnerability index for all prisons.

<u>4.1 Characterizing environmental conditions</u>

To fit the scope and relatively short time frame for this program element we are limiting analyses to only state and federal prisons (Figure 1) as they hold the majority of prisoners in the U.S. (~66%; Sawyer and Wagner 2020), but the open-access code and documentation will allow this methodology to be applied to additional institutions such as jails and juvenile detention centers. The spatial boundary data for all of these prisons was downloaded from the Homeland Infrastructure Foundation-Level Data (HIFLD; https://hifld-geoplatform.opendata.arcgis.com/datasets/prison-boundaries/explore) open data platform. After excluding prisons that had a status of "closed" and/or no prison population reported, there are a total of 1,865 state and federal prisons across the U.S. that we will analyze (as of February 2022). We will develop three component scores to capture the environmental characteristics at each prison and to calculate a single environmental vulnerability index, namely: climate risk, environmental exposures and environmental effects. These components are modeled after multiple established

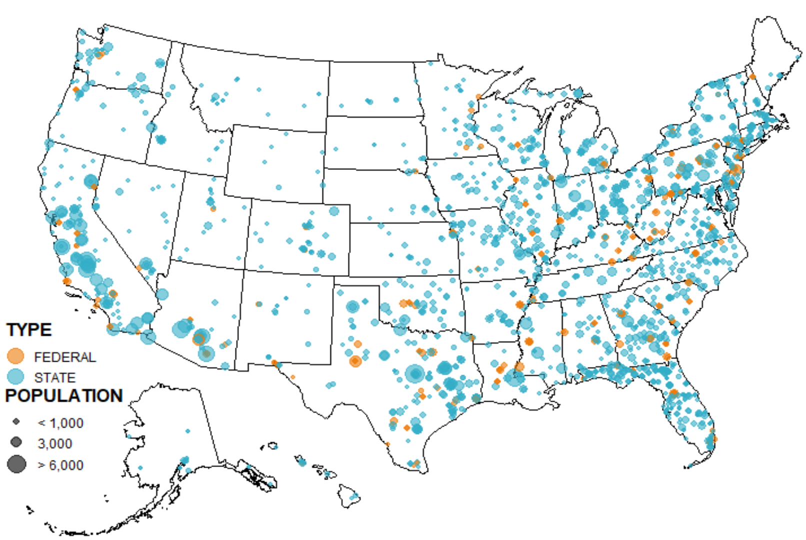

Figure 1. Map of all state and federal prisons in the United States that will be assessed for this study (n = 1,865). Points are sized by the most up-to-date data on total prisoner population.

methods for calculating environmental risk scores, including EJScreen's environmental justice index and California and Colorado Enviroscreen initiatives (Zeise & Blumenfeld 2021; https://cdphe.colorado.gov/enviroscreen), and are adapted to integrate NASA Earth observations and reflect the specific concerns of prison populations (Table 1).

Climate risk indicators include: heat index, percent canopy cover, wildfire risk, and flood risk. As climate change effects continue to amplify, prisoners faced with these perilous conditions will only worsen, and they have no choice but to stay and endure their adverse impacts. Extreme heat conditions are perhaps the most prominent climate-related injustice seen in prison communities, sometimes even leading to prisoner mortality (Holt 2015). Rising temperatures are exacerbated by the fact that many prisons lack air conditioning and proper ventilation (Holt 2015; Jones 2019), thus extreme heat events are inescapable. For example, during a heat wave in Texas in 2011, at least 10 prisoners died from overheating, yet the Texas Department of Criminal Justice refuses installation of air conditioning and proper ventilation, claiming it is too expensive (Thompson 2018). We will calculate the heat index using Landsat 8 Operational Land Imager (OLI) and Thermal Infrared Sensor (TIS) along with ECOsystem Spaceborne Thermal Radiometer Experiment on Space Station (ECOSTRESS) imagery for 2015-2020 summer months, and pixel values will be averaged within each prison boundary. Second, percent canopy cover within the prison boundaries will be calculated using the Global Ecosystem Dynamics Investigation (GEDI) percent canopy cover product for 2019-2020 at 25m resolution. Percent canopy cover has shown to be negatively correlated with heat index, such that an increase in canopy cover is able to increase the adaptive potential to reduce heat impacts (Ziter et al. 2019). Third, wildfire risk and flood hazard will be calculated for each prison. As these natural disaster events become more frequent and more intense (IPCC 2021), prisoners are perhaps the most vulnerable, as they have no control over when they are evacuated (and often aren't evacuated at all) and are sometimes even forced to fight on the front lines of these events to ensure the safety of others over their own (Thompson 2018;Brock 2020; Levin 2020).

Environmental exposure indicators include pollutants that a person would come in direct contact with and have known adverse health effects. For this project we will be measuring Ozone and fine particulate matter (PM 2.5) concentrations in the air, pesticide use and traffic density. Ozone and PM 2.5 are major contributors to air pollution-related morbidity and mortality (Fann et al. 2012), and are caused largely by emissions from vehicles, power plants, chemical plants and industrial facilities (EPA 2021a). Pesticide use has been shown to impact both indoor air quality (EPA 2021b) and quality of drinking water (Colli & Kolettis 2010). Such indicators will be particularly important for prisons in which we know prisoners are conducting outdoor agricultural labor.

Environmental effects are hazardous or toxic sites that people may not be directly exposed to, but they are known to cause environmental pollution and subsequent adverse health impacts. The indicators we will use include proximity to superfund sites, nuclear power plants, and hazardous waste facilities. Numerous reports have exposed the injustices of prisons being located on or near hazardous sites, thus trapping prisoners in toxic conditions and causing life-threatening diseases for both inmates and staff (e.g., Rikers Island jail complex on a landfill, Fayette prison surrounded by a coal ash waste site; Marcius 2019). Our proposed work will expand beyond these few reported cases and direct attention to many additional prisons that are facing similar burdens.

Table 1. List of proposed indicators, data source, and overlap with other environmental justice initiatives with mapping platforms

Indicator	Component	EJScreen	CA EnviroScreen	CO Enviroscreen	Source
Heat Index	Climate Risk	X	X	X	Landsat 8 OLI Landsat 8 TIS ECOSTRESS
Percent Canopy Cover					GEDI; Dubayah et al. 2020
Wildfire Risk				X	USDA; Scott et al. 2020
Flood Risk				X	NASA SEDAC; CHRR & CIESIN 2005
Ozone	Environmental Exposure	X	X	X	NASA SEDAC;Requia et al. 2021
PM 2.5		X	X	X	NASA SEDAC; Hammer et al. 2022
Traffic Density		X	X	X	USDOT
Pesticide Use			X		NASA SEDAC; Maggi et al. 2020
Superfund Sites, Nuclear Power Plants, Hazardous Waste Facilities	Environmental Effects	X	X	X	NASA SEDAC; US EPA et al. 2014; CIESIN 2015; ATSDR et al. 2014

4.2 Calculating each prison's environmental vulnerability index

In addition to providing raw values and percentile rankings on the individual environmental variables stated above, perhaps the most effective outcome of this project is developing a quantitative, comparable vulnerability index for all state and federal U.S. prisons. The method for calculating this index is based on previous methodologies calculating environmental risk scores for political geographies (i.e., state, county, census tract level, etc.), but is adapted for more specificity towards prisons. An overview of the methodology used to calculate this index is shown in Figure 2, such that each indicator listed above will be converted to a percentile based on values calculated for all prisons, and all percentiles will be averaged within their individual components (i.e., climate risk, environmental exposures and environmental effects). Then, the component scores will be averaged, producing a single percentile value comparable across all prisons, where higher values represent the more burdened/environmentally vulnerable prisons. This work will result in a geospatial dataset with raw indicator values, percentiles of each indicator, averaged percentile for each component, and a final vulnerability index tied to all state and federal prisons in the U.S. As a geospatial dataset it can be easily added to EJ mapping platforms (such as EPA's EJScreen), and will be added to our current geospatial mapping platform for our prison agriculture data.

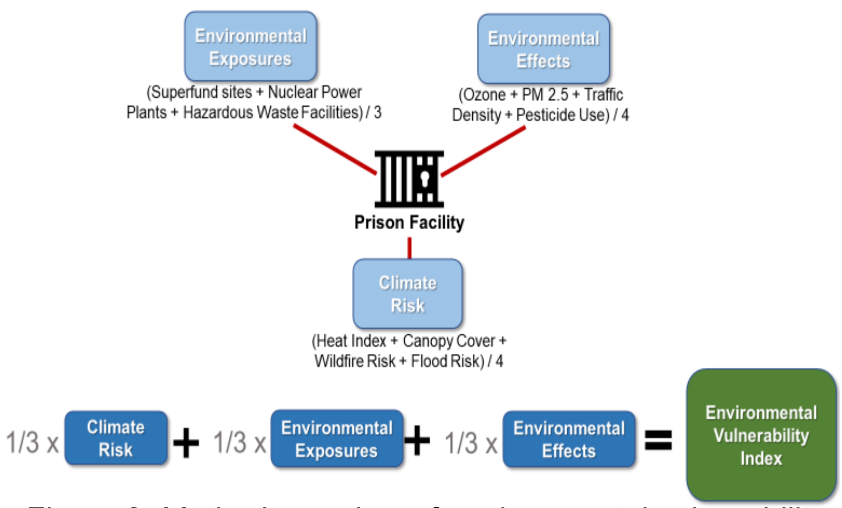

Figure 2. Method overview of environmental vulnerability index calculation, where the values for each individual indicator are their percentiles (calculated from raw values).

5. Potential Sources of Uncertainty and Mitigation Strategies

We are aware the proposed datasets will vary in their spatial and temporal resolution and spatial extent. For example, the proposed air quality datasets (Ozone and PM 2.5) have a 1km resolution, compared to the 10-30m resolution of the GEDI and Landsat products. We will prioritize using datasets with the highest spatial resolution to ensure the most accurate estimates of environmental conditions faced by prisoners. The same goes for temporal resolution, for example the environmental effects indicators have not been updated since 2014-2015. Additionally, datasets will need to have good coverage for the entire U.S., as any missing indicators may have consequences on that prisons' vulnerability score in comparison to others. Therefore, evaluating the comprehensiveness of each dataset will be a vital part of the data compilation task. We will conduct an extensive search for each indicator to ensure we are using the highest quality data available.

6. Roles of Team Members

The proposed work is a unique, interdisciplinary collaborative effort between the Geospatial Centroid (CSU's center for geospatial technologies) and the Prison

Agriculture Lab, bringing together advanced expertise in geospatial technologies and analysis and a strong knowledge base of injustices within prisons. PI Mothes is responsible for overall management of team members, including two student research assistants that will be hired for this proposed work, and will lead project implementation. Co-I Chennault will provide conceptual advice during project development and implementation, guide usage and integration of this project's data products with the current prison agriculture dataset and take part in manuscript preparation. Co-I Carver has extensive experience working with environmental hazard data and risk calculation, leading the risk score development for Colorado's Enviroscreen project, and will assist with data collection, calculation of raw indicator values for each prison, and calculation of the overall vulnerability index.

7. Work Plan, Milestones, Management Structure

Our work plan includes three major tasks: gathering and processing input data, calculating the environmental vulnerability index for all prisons, and producing an open-source publication, code, and data products. The completion of each task signifies a major milestone. Each task will be led by PI Mothes, with help from a student research assistant for each major task. Co-I Chennault will provide conceptual advice throughout task implementation and contribute significantly to manuscript preparation, sharing results within a network of prison activists and policy makers, and integrating the results with other prison data (i.e., the U.S. prison agriculture dataset). Co-I Carver will provide consultation on the data inputs and assist with methodology and student mentorship.

Task	Aug - Oct 2022	Nov 2022 - Jan 2023	Feb - Apr 2023
Gather and process data inputs	X		
Calculate environmental vulnerability indices		X	
Manuscript preparation and submission for publication		X	X
Prepare code, documentation, and final dataset for open-access sharing			X

8. Data Sharing Plan

Following NASA's open science data policy, we will make all data and code publicly available at the time of publication of any resulting peer-reviewed articles. All articles will be placed in the NASA publication repository. Code and detailed documentation to allow for transparency and reproducibility of methodology will be hosted on GitHub (an open-access code hosting platform for version control and collaboration) and data products will be placed in an open repository, such as Zenodo or Figshare. See the detailed data management plan below.

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