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GEG693
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Assessing Agricultural Land Suitability under Future Climate Scenarios in California's Central Valley: A GIS-Based Multi-Criteria Evaluation

1. Background & Objectives

Climate change is projected to alter temperature, precipitation, and water availability across the globe, which will apply significant pressure to agricultural industries internationally. Vulnerabilities such as droughts, groundwater depletion, salinization, and extreme heat can be devastating to crop productivity. In the United States, California's Central Valley region alone accounts for ¼ of the country's food (USGS), including the production of almost 50% of vegetables and over 75% of fruits and nuts (CDFA, 2025). Furthermore, over ¾ of all irrigated farmland in California lies in the Central Valley region (CBI), which makes the Central Valley region a critical agricultural region for the state of California and the United States as a whole (Fig 1). However, the region is highly sensitive to climate variability and long-term climate change. Rising temperatures, shifting precipitation patterns, and increased frequency of droughts threaten crop yields, water availability, and the economic viability of farming. The importance of this region, and the growing intensity of the effects of climate change, from gradual climatic shifts to increasing frequency of extreme weather events, underpins the motivation for this study.

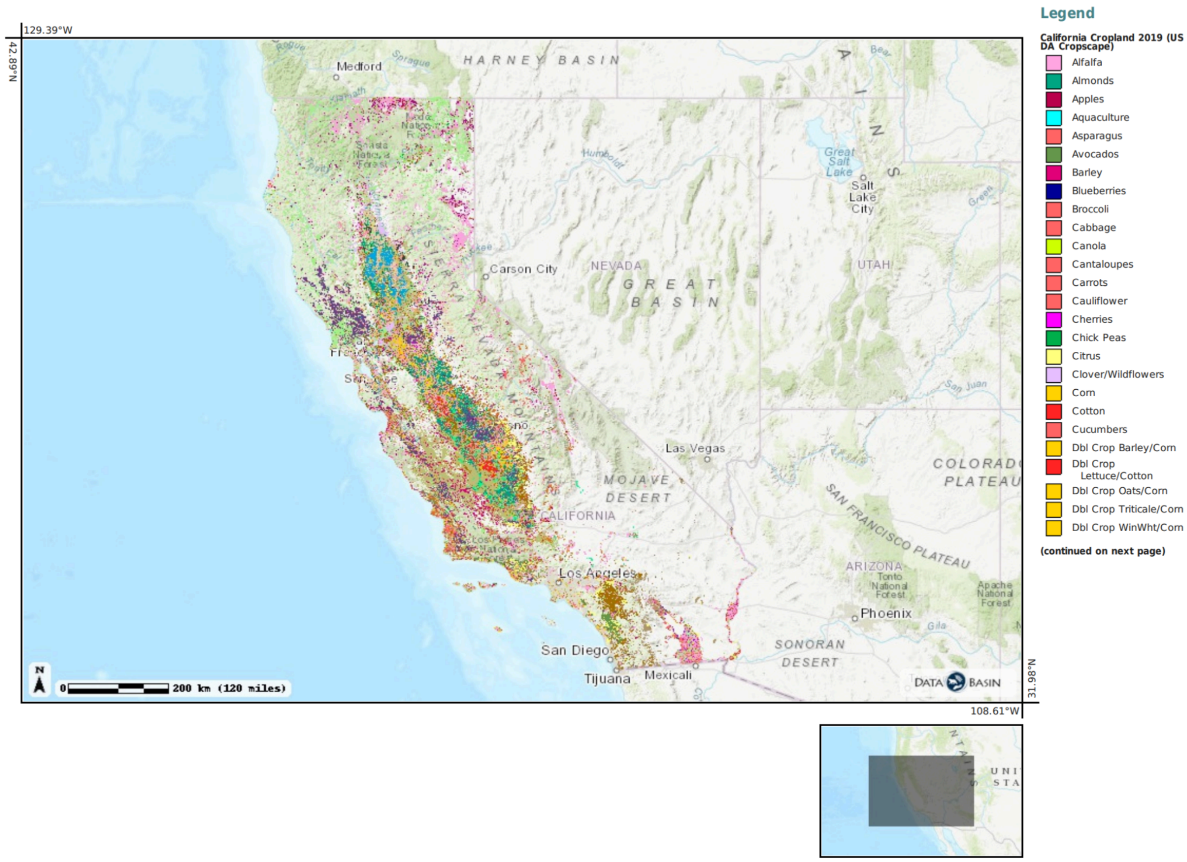

Figure 1. California's cropland by type of crop grown (CBI, 2019).

Due to the aforementioned significance of California's Central Valley region and the growing pressures from climate change on the agricultural industry, this study aims to evaluate the suitability of land in the Central Valley for agricultural use under current conditions and under projected climatic conditions with varying intensity levels. To support adaptation planning, there is a need for spatially explicit assessments of how climate change may affect the biophysical suitability of land for agriculture. Rather than focusing on a single crop, this project evaluates land suitability in a more general sense—based on core environmental requirements such as appropriate soils, adequate but not excessive water, favorable topography, and climate conditions that are not too hot, too cold, too dry, or too wet. Performing climate suitability mapping allows local governments and private farming operations to perform appropriate planning, resilience, and water management to adapt to the increasingly strenuous conditions. This project seeks to identify areas where agricultural land will remain suitable or become more vulnerable to enable long-term planning by developing a GIS-based multi-criteria evaluation (MCE) framework to map agricultural land suitability under a baseline climate and two future climate scenarios: SSP2-4.5, which assumes moderate stabilization of greenhouse gas emissions, and SSP5-8.5, which assumes minimal stabilization of emissions.

This study aims to answer the following research questions:

1. What is the current spatial distribution of suitable agricultural land in the Central Valley?
2. How will climate change alter suitability by 2050 (SSP245 vs. SSP585)?
3. Where are suitability gains, losses, or stable zones?
4. How can MCDA + GIS modeling produce an integrated suitability index?

In pursuit of answering the indicated research questions, this study aims to achieve the following objectives:

1. Integrate multiple environmental factors (soil, climate, elevation, hydrology, land cover) into a composite suitability index using a consistent and transparent methodology.
2. Build and compare three suitability models: baseline climate, SSP2-4.5 (medium stabilization), and SSP5-8.5 (high emissions).
3. Quantify and map changes in suitability between baseline and future scenarios using difference maps and spatial analysis techniques.
4. Provide a clear, step-by-step workflow that can be reproduced, critiqued, and extended in future work.

2. Data & Methodology

2.1. Study Area

The study focuses on California's Central Valley, encompassing the Sacramento, San Joaquin, and Tulare basins (Fig 2). This region is characterized by flat to gently sloping terrain, a Mediterranean climate with hot, dry summers and cool, wet winters, and some of the most intensively cultivated agricultural landscapes in the United States (USGS). The study area boundary was represented using a polygon mask that delineates the agricultural extent of the Central Valley and was applied to all datasets to ensure that analyses were restricted to land realistically available for agricultural production (Fig 3).

Figure 2. Locator map of California's Central Valley (Britannica, 2025).

2.2. Data Sources

Five primary factor groups were used to construct the agricultural suitability model: soil, climate, elevation/topography, hydrology, and land cover. All datasets were clipped to the Central Valley polygon boundary to reduce computational complexity. The data were initially standardized to a common spatial resolution of 30 arc-seconds and projection of NAD 1983 California Albers. When possible and applicable, archived data from 2020 was utilized to ensure temporal consistency with the WorldClim baseline data from 2000-2020.

Soil properties were obtained from publicly available gridded soil dataset, SoilGrids 2.0, including variables related to texture, depth, drainage, and salinity (SoilGrids 2.0). These properties were used to identify areas with biophysically favorable soil conditions for general crop production and to penalize areas with shallow, saline, or poorly drained soils.

Baseline climate data sourced from WorldClim v2.1 bioclimatic variables and future projections from CMIP6 models under SSP2-4.5 and SSP5-8.5 were used to capture both current conditions and projected mid-century changes (WorldClim). Variables included: BIO1(Mean Annual Temperature), BIO4 (Temperature Seasonality; standard deviation x 100), BIO5 (Max Temperature of Warmest Month), BIO12 (Annual Precipitation), BIO15 (Precipitation Seasonality; coefficient of variation), BIO18 (Precipitation of Warmest Quarter). For each scenario, temperature and precipitation deltas (Δ) were calculated relative to the baseline period to quantify climate change impacts on agricultural suitability.

A Digital Elevation Model (DEM) was used to derive both elevation and slope, with 3DEP DEM files sourced from USGS's "The National Map" database (USGS). Topographic variables were included to penalize steep terrain due to increased erosion risk and reduced mechanization feasibility, although much of the Central Valley is characterized by low relief.

Hydrologic datasets–downloaded from California's Department of Water Resources–included rivers, streams, and water bodies (DWR). Euclidean distance-to-water rasters were created to approximate potential access to surface water resources. Though the authors of this study acknowledge that irrigation infrastructure in the Central Valley is more complex than simple proximity, this approach is used as an approximation of available regional water.

Land cover data were obtained from the National Land Cover Database (NLCD) via ScienceBase. These data were used to identify existing croplands for an agricultural mask, and exclude permanently unsuitable areas such as urban development and open water. Agricultural land was retained, while non-agricultural categories were masked or assigned low suitability scores.

2.3. Data Preprocessing

All datasets were projected into NAD 1983 California Albers, a projected coordinate system suitable for area- and distance-based raster operations in California. A consistent cell size of 1 km was applied across all rasters. A climate raster was designated as the "snap raster" to ensure that all layers aligned with identical extents, cell origins, and cell boundaries. Rasters were resampled and visually inspected to confirm pixel-wise alignment, which is necessary for valid map algebra and weighted overlay operations. The agricultural land mask was constructed by recoding land cover classes into a binary raster (1 = cropland or potentially suitable open land; 0 = non-agricultural). This mask was applied at later stages to ensure that suitability scores reflect only the land realistically available for agriculture.

2.4. Factor Reclassification and Standardization

Each suitability factor was reclassified to a common 1–5 ordinal scale, where 5 represents very suitable conditions and 1 represents very unsuitable conditions. Thresholds were based on agronomic reasoning and observed data distributions.

Soils with favorable texture, good drainage, and adequate depth received high scores (4–5). Poorly drained, saline, rocky, or shallow soils were assigned low scores (1–2). Individual soil variables were aggregated into a composite soil suitability index and rescaled to the common 1–5 scale.

Climate suitability incorporated both baseline conditions and projected 2050 deltas. Small changes in temperature or precipitation were assigned high suitability scores (4-5). Moderate to large warming or drying resulted in lower scores (1-3). Excessively large increases in precipitation were also penalized due to potential disease, flooding, or management challenges (2). This produced climate-factor rasters for the baseline, SSP2-4.5, and SSP5-8.5 scenarios.

Elevation and slope were used to categorize terrain suitability. Flat and gently sloping areas received high scores, while steeper slopes were penalized. Distance-to-water rasters were classified so that areas closer to surface water sources received higher suitability scores. Larger distances, implying higher infrastructure and pumping costs, were assigned lower scores. Existing agricultural lands received high scores, while urban and other permanently unsuitable categories were assigned low scores or masked entirely.

To make all factors dimensionless and directly comparable, each 1–5 reclassified raster was linearly scaled to 0-1:

$$S_{0\text{–}1} = \frac{S_{1\text{–}5} - 1}{4}$$

This produced standardized factor layers for soil, climate (baseline and scenarios), elevation, hydrology, and land cover.

2.5. Composite Suitability Modeling

Factors were combined using a weighted linear overlay, with weights derived from agronomic literature and the relative influence of each factor on crop productivity: Soil: 0.40, Climate: 0.30, Elevation/Slope: 0.10, Hydrology: 0.10, and Land Cover: 0.10.

Soil received the highest weight due to its strong influence on crop performance and limited modifiability. Climate received the second-highest weight given its strong control over evapotranspiration, phenology, and stress exposure—particularly under climate change. Elevation, hydrology, and land cover were weighted lower due to their lesser spatial variability or more indirect influence on baseline suitability.

For each scenario, composite suitability was calculated as:

$$\text{Suitability}_{\text{scenario}} = (0.40 \cdot S_{\text{soil}}) + (0.30 \cdot S_{\text{climate,scenario}}) + (0.10 \cdot S_{\text{elevation}}) + (0.10 \cdot S_{\text{hydrology}}) + (0.10 \cdot S_{\text{landcover}})$$

Each composite raster was then masked to agricultural land:

$$\text{Suitability}_{\text{scenario, masked}} = \text{Con}(AgriMask = 1, \text{Suitability}_{\text{scenario}}, 0)$$

This produced three final suitability surfaces: Baseline, SSP2-4.5, and SSP5-8.5 (Fig 4).

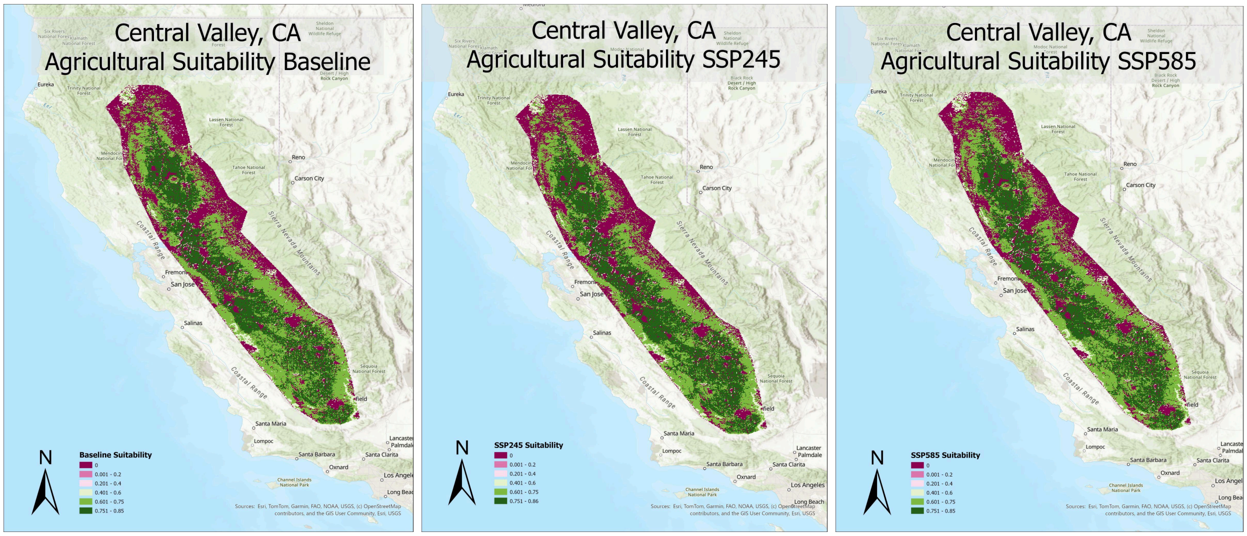

Figure 4. Raster of California's Central Valley agricultural suitability for Baseline, SSP2-4.5, and SSP5-8.5.

2.6. Scenario Comparison and Difference Mapping

Suitability change was quantified by subtracting the baseline raster from each future scenario raster:

$$\Delta\mathrm{Suit}_{245} = \mathrm{Suitability}_{245} - \mathrm{Suitability}_{\mathrm{baseline}}$$

$$\Delta\mathrm{Suit}_{585} = \mathrm{Suitability}_{585} - \mathrm{Suitability}_{\mathrm{baseline}}$$

These difference maps represent spatial patterns of suitability gains (positive values), stability (near zero), or losses (negative values) between the current baseline climate and projections for 2050 (Fig 5).

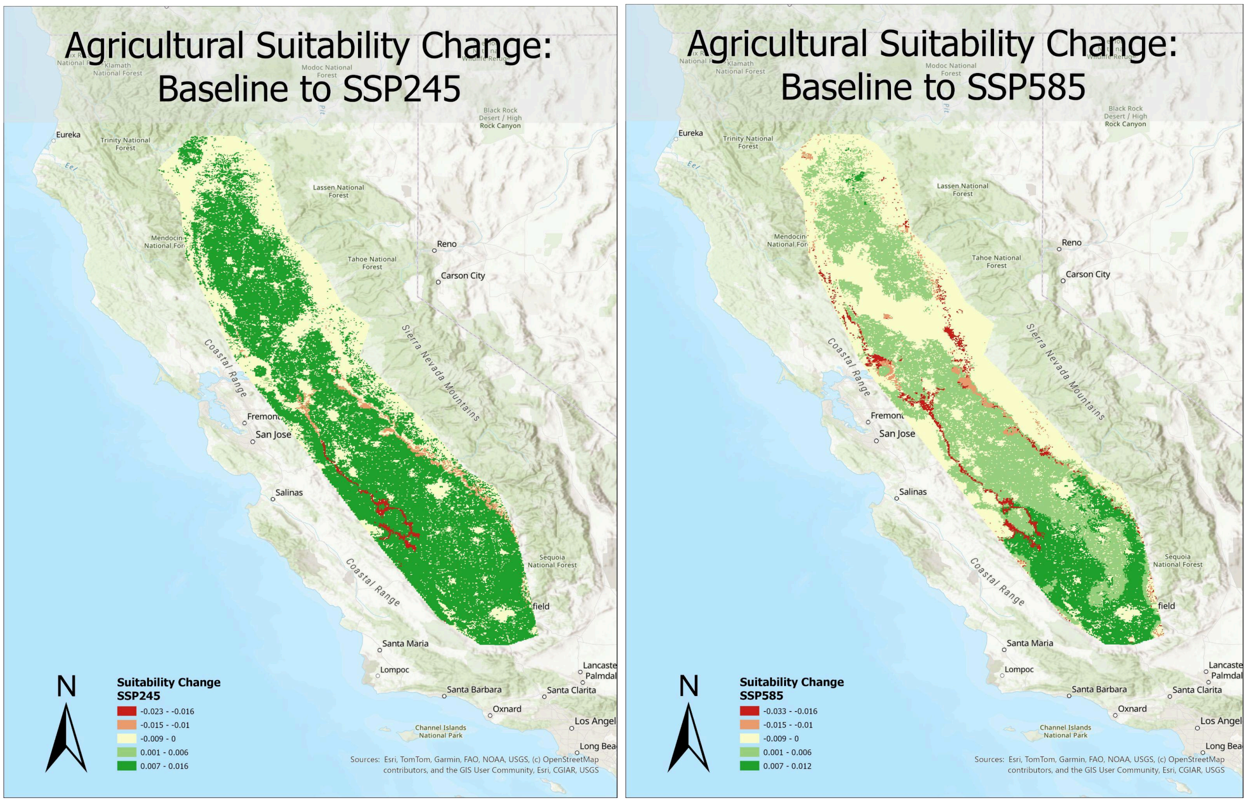

Figure 5. Change in suitability from Baseline to SSP2-4.5 and SSP5-8.5.

2.7. Spatial Analysis of Suitability Change

To evaluate the spatial structure of gains and losses, the difference rasters were converted into point datasets and subjected to local spatial statistics. Local Moran's I was used to identify statistically significant clusters and outliers of suitability change (Fig 6). Getis–Ord Gi* hotspot analysis was used to identify statistically significant hotspots and coldspots of suitability change (Fig 7). These local statistics provide insight into the spatial coherence and landscape-level patterns of climate-driven changes in agricultural suitability under both SSP2-4.5 and SSP5-8.5 scenarios.

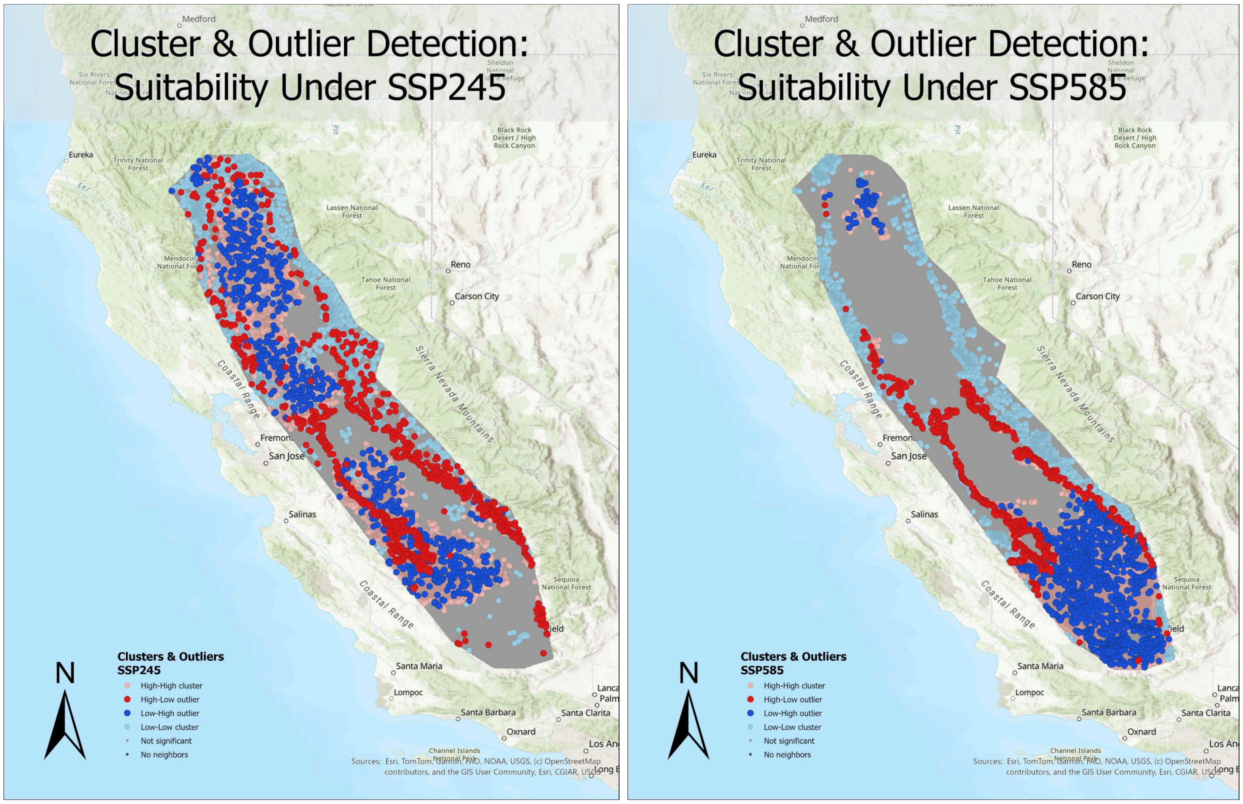

Figure 6. Local Moran's I–cluster and outlier spatial analysis of suitability changes under SSP2-4.5 and SSP5-8.5.

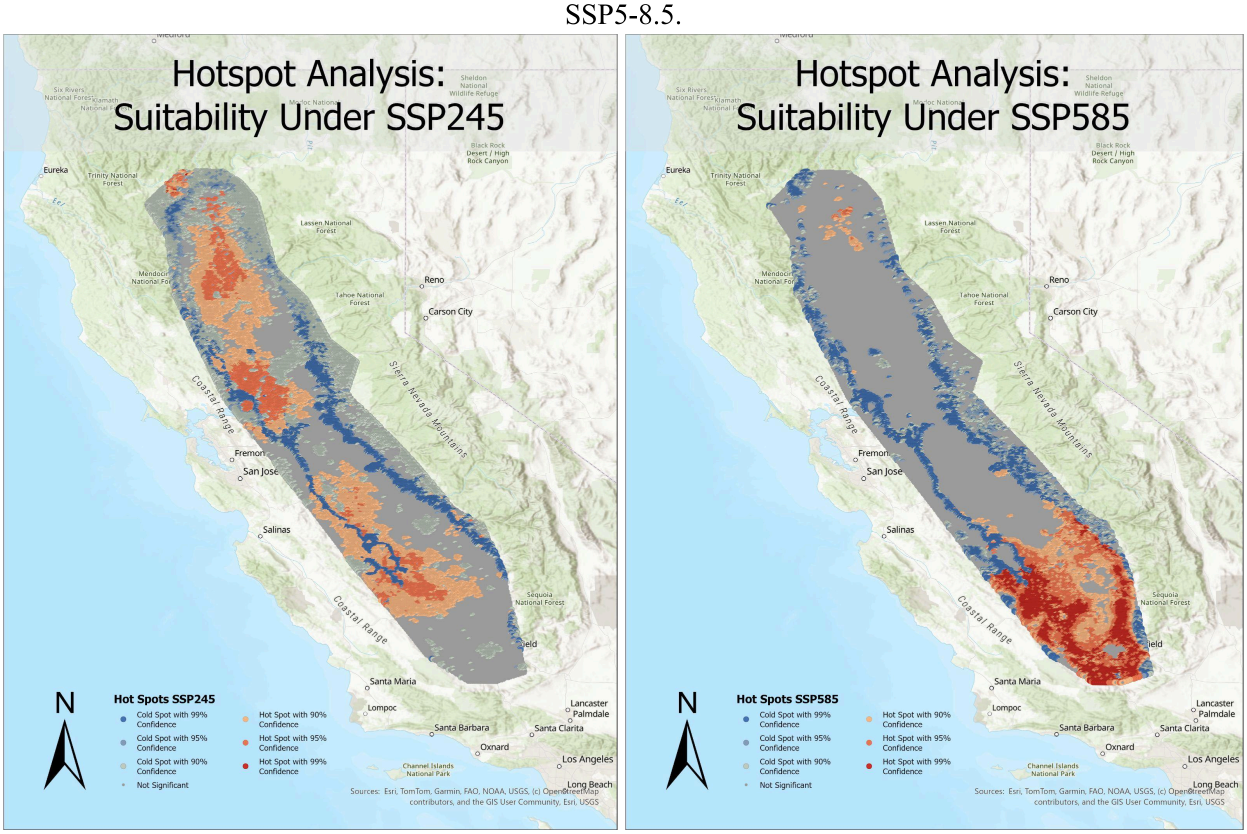

Figure 7. Getis-Ord Gi* hotspot analysis of suitability changes under SSP2-4.5 and SSP5-8.5.

3. Results & Interpretation

From the suitability maps, suitability difference maps, and the local spatial analyses, a variety of results emerge in regard to changes in agricultural suitability in the Central Valley region. Overall, the changes in suitability seen in this study's approach appear minimal from an initial review of the three suitability maps for baseline, SSP2-4.5, and SSP5-8.5. From the difference maps, spatial patterns begin to emerge. As expected, suitability decreased or stayed constant over more of the study region under the more extreme climate scenario than under the moderate climate scenario. Surprisingly, there are moderate increases in suitability across much of the study area under SSP2-4.5, which may be due to improved conditions due to increased consistency of precipitation or elevated temperatures. These improvements are visible under SSP5-8.5 as well, though these areas of improvement are found mainly in the southeastern region of the Central Valley. It is important to note that these differences are marginal, with delta values only at the decimal level.

Based on the Local Moran's I and Getis-Ord Gi* spatial analyses, the regions projected to gain or lose suitability show more distinct patterns. In both the SSP2-4.5 and the SSP5-8.5 scenarios, the rim of the valley is projected to decrease in suitability, with clear clustering of decreased suitability areas. Under SSP2-4.5, outliers around the rim of the valley appear across the board, with more concentrated regions to the south, while the SSP5-8.5 scenario shows outliers only in the southern half of the study area. Furthermore, under SSP2-4.5 there are 3 main clusters of improved suitability, 2 in the northern region and 1 in the southern region, all of which contain decreased suitability outlier points throughout. In contrast, under SSP5-8.5, there is only one main region of suitability improvement in the southernmost region of the valley and a small pocket at the northernmost point, also displaying decreasing suitability point outliers throughout the regions of improvement. The Gi* hotspot analysis supports these cluster and outlier results, reflecting similar patterns of confidence in regards to coldspot regions of decreased suitability around the rim of the valley under both scenarios and mirroring the same regions of suitability increase with more clarity as the hotspot areas.

From these results, the authors of this study conclude that the results are more nuanced than expected in regard to the effect of climate change on agricultural suitability. Given the suitability model and assumptions made to facilitate this study, the results indicate that shifts in climate may actually result in areas of increased agricultural suitability throughout the Central Valley region. The projected changes in suitability are minimal, which the authors attribute to soil as a stabilizing factor. The suitability model is heavily weighted toward the soil composition, and since soil properties are static over the time frame considered, regions with inherently good soils tend to maintain relatively high suitability even when climate conditions degrade somewhat. Overall, the projected impacts of climate change on agricultural suitability in the Central Valley region yield conflicting results, highlighting the complexity of predicting and adapting to climate change scenarios.

4. Challenges & Future Work

This project demonstrates the value of combining multiple environmental datasets into a single, interpretable suitability index, but several limitations must be acknowledged. First, the choice of factors and their weights reflects a specific interpretation of the driving forces behind general agricultural suitability. Alternative weighting schemes could shift these spatial patterns, particularly if climate is given more weight or if water availability is approached differently or emphasized more strongly. Second, soil and topography are treated as static in this study, but in reality management practices and erosion can alter soil properties and topography over time. Additionally, hydrology is captured via distance to water in this study, which is a proxy and does not account for the true complexity of reservoir storage, groundwater depletion and availability, or irrigation infrastructure. Third, climate models introduce an inherent level of uncertainty and different models or methods could produce different patterns of temperature and precipitation change. Fourth, this study is crop-generic and reflects overall environmental suitability rather than specific crop requirements, which could be addressed in future work. Fifth and finally, validation of these results against observed yield data, crop maps, or expert judgement has not been performed. To truly assess the applicability of the suitability mapping results, validation must be performed. Despite these limitations, the framework provides a transparent, step-by-step structure that can be refined as better data and more specific objectives become available.

Future work on this project could include suitability by crop-type, redefinition of classification thresholds using expert input and more in-depth research on agronomic literature, alternative weighting schemes such as Analytic Hierarchy Process (AHP), inclusion of groundwater level trends and irrigation infrastructure, and validation against observed yield data. The value of this study, beyond providing a general idea of the possible threat to food production from the effects of climate change, is to generate discussion and interest in climate suitability mapping as a means of building resilience to impending climatic shifts that will alter agricultural practices across the board, inherently affecting access to food for all people. This study serves as one stepping stone on the path towards creating frameworks and tools that aid stakeholders—farmers, water managers, and planners— in anticipating where adaptation strategies such as crop switching, irrigation upgrades, or land conservation may be most necessary under future climate conditions.

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