Terrain analysis report

Introduction

The selected study area is the San Joaquin Valley area surrounding Fresno, California, US. The area spans a broad range of elevations, from the low and flat San Joaquin Valley to the elevated and rugged Sierra Nevada mountain ranges. The principal body of water in the region is the San Joaquin River Watershed. The objective of the study was to categorize flood risks into classes by using Digital Elevation Models (DEMs) that integrated terrain factors such as elevation, slope, and Topological Wetness Index (TWI) to identify sub-areas–especially cropland land covers–that are most vulnerable to flooding.

Methods

NASA JPL's Shuttle Radar Topography Mission, SRTMGL1 V3 product was used to obtain elevation values for further analysis. SRTMGL1 has a spatial resolution of approximately 30 meters per pixel at 1 arc-second.

The elevation values to calculate slope and TWI were smoothed to minimize the impact of tiny landform dips or peaks on the final analysis. The smoothing process involved two steps: Averaging SRTM elevation values for each pixel across 3x3 pixel windows then replacing each pixel with the minimum value from its surrounding neighbors. For slope, the rate of change of x and y values. For TWI values, the smoothed elevation values were used to calculate the upslope proxy areas of 3 pixels (~210 meter radius). This helps determine how much land slopes down into each pixel instead of using computationally-intensive flow-accumulation hydrology methods such as full D8 or D-infinity. Finally, the upslope proxy areas values and slope values (in radians) were inputted into TWI formula and used a small epsilon of 0.001 to avoid division by zero errors.

The 2021 National Land Cover Database (NLCD) from U.S. Geological Survey and other federal agencies were used to classify or isolate certain classes of land covers for *Fig. 2a.*, *Fig. 2b.*, and *Fig. 2c.*. *Fig. 2a.* presents all the different classes of land cover in the selected study area. *Fig. 2b.* presents only the cropland cover which is isolated by masking all other classes.

The study's application presented in *Fig. 4*, classified pixels based on flood risk. For each criteria that a pixel meets, the risk score increases by 1. There are 3 criterias:

- ➢ If pixel's elevation (non-smoothed) < 40 meters
- ➢ If pixel's slope < 5°
- ➢ If pixel's TWI > 12

Results

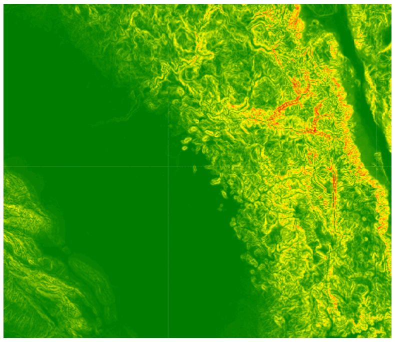

Fig. 1a. Slope in San Joaquin Valley region, CA from SRTMGL1

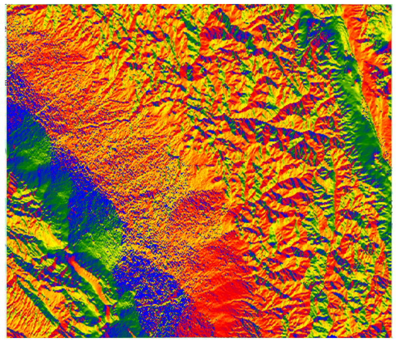

Fig. 1b. Aspect in San Joaquin Valley region, CA from SRTMGL1

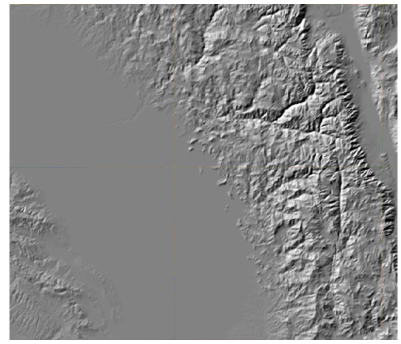

Fig. 1c. Hillshade in San Joaquin Valley region, CA from SRTMGL1

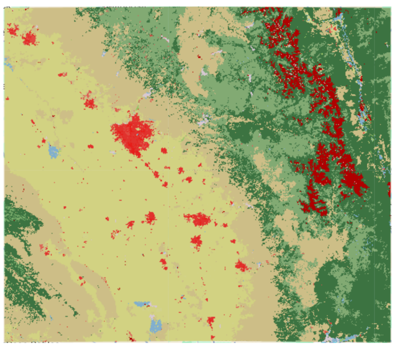

Fig. 2a. Land cover classes in San Joaquin Valley region from NLCD 2021

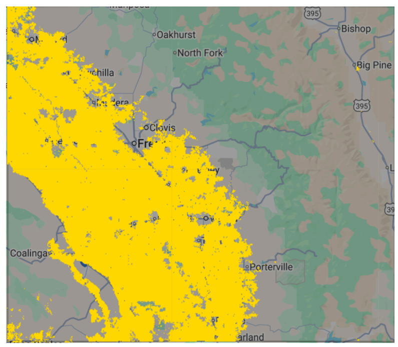

Fig. 2b. Cropland land cover in San Joaquin Valley region from NLCD 2021

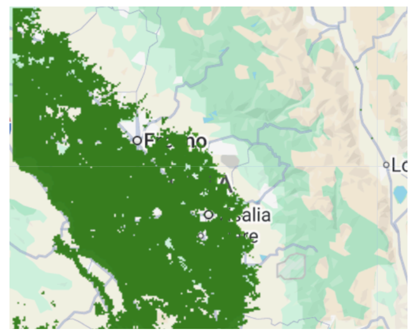

Fig. 2c. Slope of cropland land cover in San Joaquin Valley region from NLCD 2021

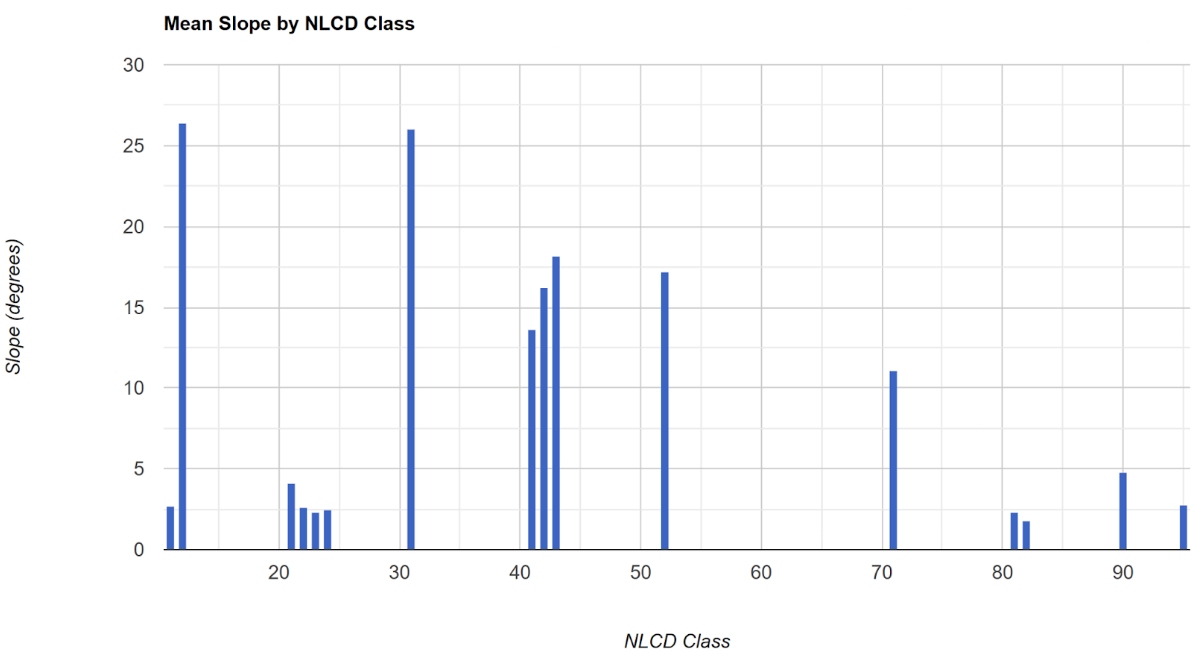

Fig. 3. Summary of each land cover classes' mean slopes derived from SRTMGL1 and NLCD 2021

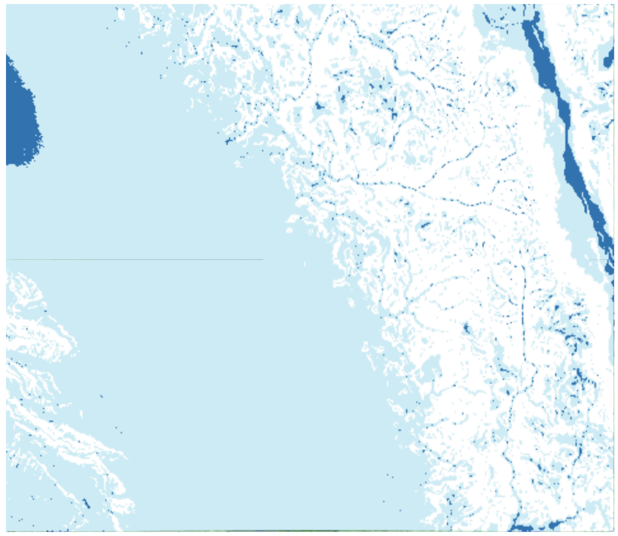

Fig. 4. Flood risk classification in San Joaquin Valley region, CA derived from SRTMGL1 and NLCD 2021

Discussion

Fig. 1a., *Fig. 1b.*, and *Fig. 1c.*. are the three terrain derivatives from SRTMGL1 data: slope, aspect, and hillshade, respectively. *Fig. 1a*. shows that the San Joaquin valley sub-area is green, meaning the slope there is close to 0° and the Sierra Nevada mountain ranges sub-area to the east has webs of yellow and red, meaning the slope there is close to 22.5° or 45°, respectively. The mean slope is 10.25°. *Fig. 1c*. shows that the San Joaquin valley sub-area is all gray, meaning the sun's angle is roughly perpendicular throughout and the Sierra Nevada mountain ranges vary from white (255) to black (0), meaning the sun's angle is directly facing towards the white regions and directly away in the black regions. The mean hillshade value is 179.88. It can be concluded from *Fig. 1a* and *Fig. 1c*. that the San Joaquin valley sub-area has a near-flat terrain while Sierra Nevada mountain ranges sub-area have a sloping terrain. *Fig. 1b.* shows that the left half of San Joaquin valley is mostly blue and green, meaning the compass direction of the maximum slope is north or east, respectively. The right half of the valley is red with specks of purple, meaning the compass direction of the maximum slope is south with specks of west. The mountain ranges show more green on the left side and red on the right side, meaning the compass direction of maximum slope is east on the left side and south on the right side. It can be concluded from *Fig. 1b.* that the San Joaquin valley sub-area has a mixture of maximum slope directions throughout with pockets of slopes towards the north or east whereas the Sierra Nevada mountain ranges sub-area has consistent slope direction throughout, sloping east or southwards on one or the other side of the mountain ranges.

Fig. 2a., *Fig. 2b.*, and *Fig. 2c.* show the land cover classes and terrain-land cover integration in the study area. *Fig. 2a.* shows that the San Joaquin sub-area is lime yellow with pockets of red, meaning the land covers there are categorized as cultivated crops with pockets of highly-developed urban land and that the Sierra Nevada mountain ranges sub-area is mostly light green and dark green, meaning the land covers there are categorized as deciduous forest or evergreen forest, respectively. *Fig. 2b.* isolates the land cover classified as cultivated crops (cropland) which is primarily in the San Joaquin Valley sub-area, taking up around 24818 pixels. *Fig. 2c.* presents the slope of the isolated cropland which is green, meaning the slope is around 0° in cropland areas.

Fig. 3. is a summary table of the mean slope values by land cover class. The maximum average slope is 26.4° and in Class 12, representing perennial ice or snow land cover. This could suggest that sub-areas with the steepest incline are near the peaks of mountain ranges, thus snow or ice is on the land cover because of the cold weather at that elevation. The minimum average slope is 1.8° and in Class 82, representing cultivated crops as land cover class. One possible explanation is that it is difficult for agriculture to grow successfully on sloped-terrain because water—whether from precipitation or irrigation—has a tendency to run off quickly. This prevents soil from absorbing it before it reaches the plants. Thus, why the study area’s cropland is found generally in the San Joaquin Valley sub-area, where the land cover has the lowest or flattest average slope.

Fig. 4. is the flood risk classification of the study area. The dark blue in Fig. 4. are in the northwest sub-area of the San Joaquin Valley, these are sub-areas where 2 or more of the 3 determined flood criteria were met, meaning high flood risk. There were around 1166111 pixels in this high-risk class. The light blue in Fig. 4. in the sub-areas other than the Sierra Nevada mountain ranges and the high-risk sub-areas represents sub-areas where 1 risk criteria was met. There were around 32549733 pixels in the lower-risk class. The white in Fig. 4. are at the Sierra Nevada mountain ranges, these sub-areas are where no flood risk criteria were met. There were around 32704220 pixels in the lowest-risk/no-risk class. The San Joaquin Valley sub-area, high-risk for flood, had lower elevation values (though not always below criteria of 40 meters), flatter slope values (mean of 1.8°), and higher TWI values. This could be because the flat slope values and high TWI values makes it more prone to water accumulation, thus, makes it an excellent area for cultivating crops but also flooding.

Conclusion

In conclusion, the northwest sub-area of the San Joaquin Valley has high flood-risk based on the determined criteria of having a slope less than 5° (had mean of 1.8°), and, or, a TWI value greater than 12. The 2021 NLCD classifies the sub-area's land as cultivated crops land cover. This can be considered good land management because it supports efficient agricultural irrigation practices by decreasing the likelihood of water runoff. However, land managers need to be aware that the agricultural benefits simultaneously increase flood vulnerability during heavy rainfall seasons or nearby flooding from San Joaquin river watersheds. In the future, precipitation indices could be included in flood risk classification criteria in order to improve the accuracy of flood-risk assessments.