Climate Change and Predicting Hydrological Dynamics: Future Archaeological sites in Flood-Prone Areas

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Abstract

Introduction: Flood zones offer archaeological potential due to erosion and sedimentation. This study assesses climate change effects on flood risks in inland California and their impact on archaeological site identification.

Methodology: Utilizing GIS and climate projection data, the research predicts future flood patterns and identifies potential archaeological sites through flow accumulation modeling and floodplain mapping.

Results: A projected 2°C temperature rise by 2050 could increase Sierra Nevada snowmelt volume by 35%, highlighting potential archaeological zones around the San Joaquin and Sacramento Rivers.

Discussion: Climate change may affect artifact preservation, with expected shifts between flash floods and droughts. Improved modeling techniques are needed to predict snowmelt and flood dynamics accurately.

Conclusion: Climate change presents opportunities for archaeological discovery in flood-prone areas. Future research should refine modeling techniques and explore sediment depths for hidden artifacts.

Recommendations: Further study should focus on refining hydrological modeling techniques and predicting floodwater distribution on non-flat terrain to enhance archaeological site predictions.

Introduction

Uncovering artifacts in flooded areas

Flood zones present unique opportunities for archaeologists due to the dynamic processes of erosion, sediment deposition, and movement inherent in these areas. Over time, floods can reshape landscapes, exposing buried artifacts and depositing them downstream (Turnbaugh). The constant shifting of sediments within floodplains can uncover previously buried artifacts or carry them downstream, offering a glimpse into past human activities (Wescott and R. Joe Brandon) Thus, identifying and mapping flood zones, archaeologists can strategically focus their efforts on areas where erosion and sediment movement are likely to unearth archaeological sites.

Flood Risks and Climate Change

Inland California faces growing flood risks due to climate change. By 2050, temperatures are expected to rise in CA by 1.64°C to 3.22°C (Stott and Kettleborough). With higher temperatures, snow will melt earlier and faster, primarily during winter storms (Milly et al.), leading to increased snow runoff and exacerbating flood risks in inland California. Studies analyzing N. California predict significant reductions in snow water equivalent (SWE) and snowfall to precipitation (S/P) ratio (Ishida et al.). For instance, snowmelt between December and March is projected to increase by 37% during the middle 21st century and 81% during the late 21st century (Ishida et al.).

Despite the role of increased precipitation, warming is expected to decrease spring snowmelt over much of the affected area, regardless of precipitation change (Milly et al.). This suggests that even with moderate precipitation changes, decreased snowpack could reduce warm-season runoff. **With verifying rising temperatures in the Sierra Nevada, watershed modeling can give insight to which watersheds are most at risk with flooding from increased in snow runoff in 2050 and thus give insight to potential archaeological sites locations**

QGIS and Datasets

QGIS: 3.34 Prizren (2023)
- Free GRASS extension

NEX-GDDP: NASA Earth Exchange Global Daily Downscaled Climate Projections:
- Geotiff Raster data export via google earth engine
- Set my projection for 2050 and geometry around CA

MERIT Hydro: Global Hydrography Datasets
- Geotiff Raster data export via google earth engine
- Flow Direction (Local Drainage Direction) band: *dir*
- Set geometry around CA

DEM: USGS Western US
- Raster Geotiff data of elevation

CA shapefile: CA.gov Open Data Portal
- Vector data of California state boundaries

FEMA California Floodplain Map:
- Vector Shapefile

Methodology

Verifying increase by 2*C in Sierra Nevada region

- Why? To estimate increase snowmelt

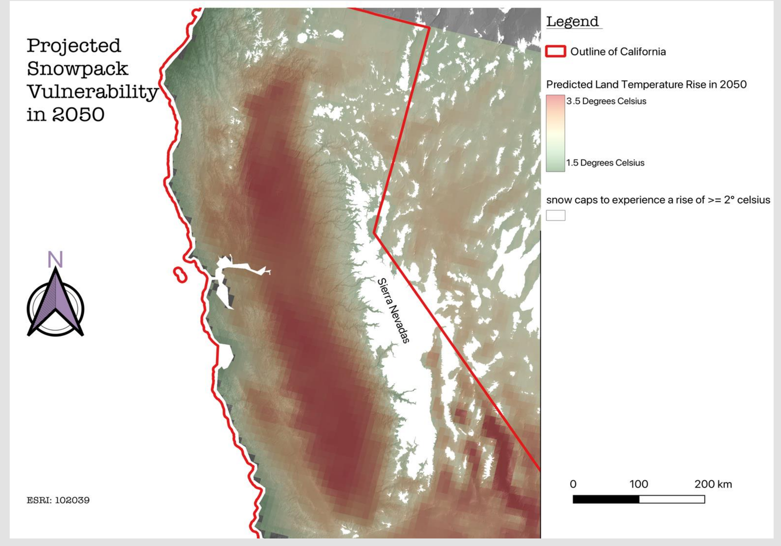
1. Reclassed the DEM using *Reclass by Table* to generate a binary layer of only pixels at 1.8km and up: our potential snowpacks.
2. Using raster calculator: create a binary layer of snowpack pixels that intersect with >= 2 ° C pixels temp layer
3. Using Raster calculator found only 0.8% of the potential snowpack region was below 2 ° C.

Flow Accumulation model

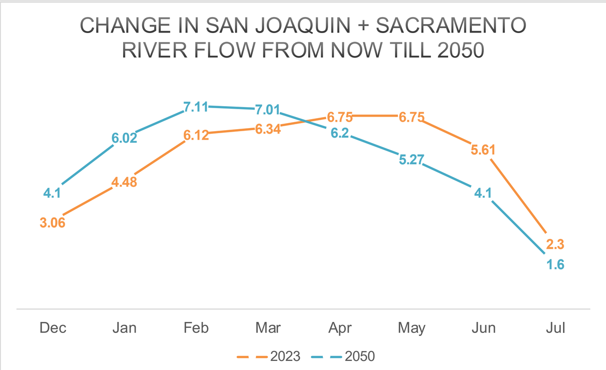
1. Used r.terraflow tool from GRASS to form flow accumulation layer with parameter MERIT Flow Direction model
2. Reclassified by table tool to create a binary layer to only show areas with a very "high" chance of water accumulation only(and hence immense flash floods) as that would move the most sediment. (at a value of 9260.28 kJ of energy and above (*MERIT Hydro*), then polygonised the result.
3. Using our California flood zones, used Select by Location Intersect to show which flood zones will be impacted by the High Accumulation watersheds and classified the zone types.
4. Creating temporary 15km buffers off flood zones shapefiles, dissolved the result, and used that as the extent in raster calculator when identifying pixels in slope of 0°
5. Then using the raster calculator again, identified slope 0 ° areas that are at or below the average elevation of the rivers (109.7m)

Results

Verifying increase by 2*C in Sierra Nevada region



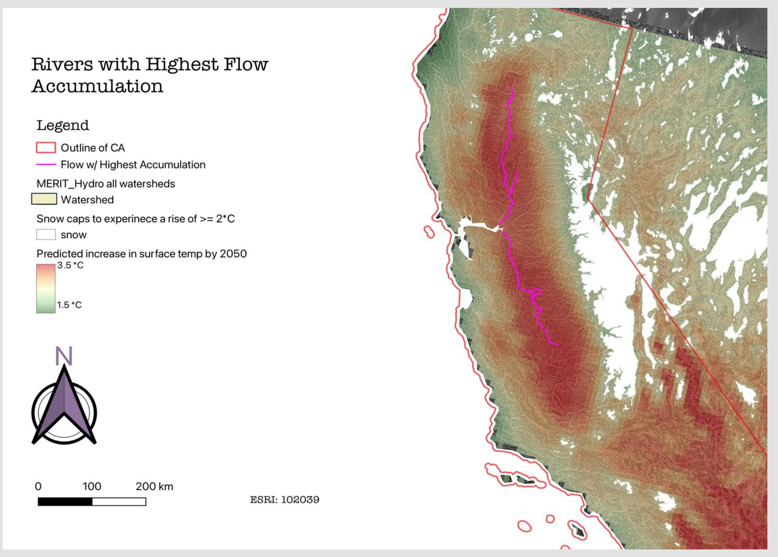
Calculations:



- Current Sierra Nevada snow melt is 20M acre feet per winter season (NOAA Fisheries). Knowing that snow melts at 1 to 4 mm/degC-day, a 2 ° C increase estimates that total Sierra runoff could be increase from 3.75M to 5.8M acre feet during winter months.
- About an 35% increase in volume of winter runoff
- Found that 99.2% of snowpacks will experience a 2 ° C change or more, so we can apply the increase of snow melt speed to practically all snowpacks

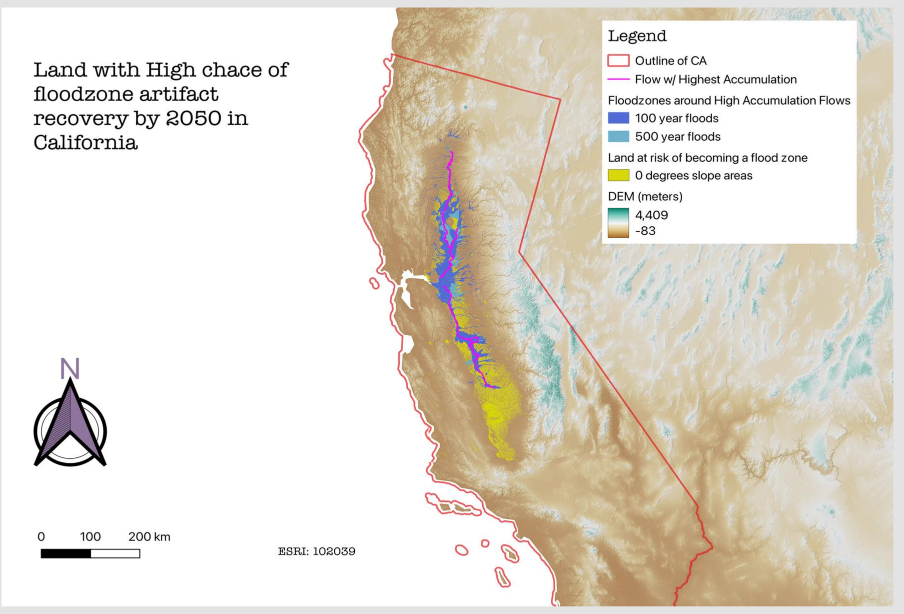
Flow Accumulation model

1. High Accumulation Watershed >= 9260.28kJ



Map of found highest accumulated Sierra Nevada Mt. Range watersheds (pink)

2. Land with chance of flood zone artifact recovery by 2050

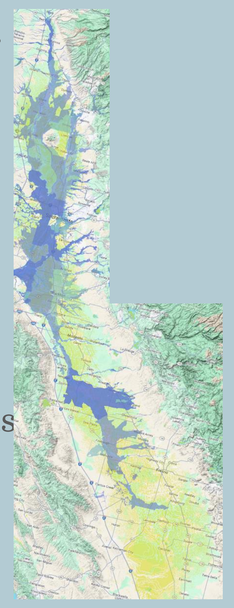


Defined zones of potential archaeological sites: land with 0 slope at or below the average elevation of the 2 rivers, bordering at 1km from our watersheds

Discussion

Highest Accumulation: 2 largest river sheds that intake runoff from the Sierra: The San Joaquin and the Sacramento Rivers.

Possible Future Sites



After placing a terrain base map, we see that our predicted area for archaeological sites (shaded yellow) encompasses a much larger area of the central valley than the existing flood zones. Some notable areas that are predicted to flood as thus could be prime to find Archaeological sites are:
- East around the Sutter Buttes Mt. range
- Modesto, CA
- Fresno CA
- A lot of area north of Bakersfield

The use of a 15km buffer around each watershed was simply a way to highlight flat region bordering our watersheds, utilizing any number for that buffer could present different results.

Artifact Recovery Notes

When looking at our predicted temperature increase map, we see that the central valley generally region temperatures will also rise the highest here, so evaporation will occur too but that won't lessen the risk of immense flash flooding. Thus in 2050, a future of immense switch between flash floods and droughts in this area are to be expected which could be bad for preservation of certain artifacts (Craft et al.)

Snow melt estimates

In estimating where the snowpacks are in the Sierra Nevada Range , elevation is not the only factor that will determine where snow falls. This was simply a method to see where snow could be (an upper bound) and seeing how much of that upper bound even could be in the 2*C and up zone to estimate increase runoff. Further the 2*C and up is exactly that, snow experiencing more than 2 degrees will melt faster.

Further these estimates are only accounting for how much the temperature increase will fasten the melt of snow. This does not account for an increase of snow accumulation from Climate Change and does not account for changes in the snow to precipitation ratio. Further, it is completely unknown how increase evaporation levels due to the intense increase in temperature will impact runoff or precipitation levels. This model simply generates that given increase winter runoff, where potential archaeological site could be found.

Conclusions

South of Sutter Buttes, the water sheds are very calm and have little turbidity (sediment displacement) and thus already has less chance for buried site discovery (NOAA Fisheries). However, with Climate change in our future, it is evident that most if not all the Sierra Nevada snowpacks will experience a 2*C increase or more in temperature which will shift more of the spring melt off to winter. Specifically, a current peak of runoff from Apr-May to instead Feb-Mar due to Climate Change (NOAA Fisheries). This potentially could cause increased mass flooding by 35% come 2050 and thus sparks potential for being areas of archeological discovery in the future.

If the flooding occurs over new land or simply floods by a large amount, we can predict that the areas highlighted in yellow here could be areas where we could unearth historical sites. Further, sediments that underlie specifically the lower San Joaquin River are extremely deep and range from 9.7 to 15.3 km and such more movement from massive flash floods could unveil artifacts hidden under river sediment.

Recommendations

Further studies should more accurately predicting floodwater distribution on *non-flat terrain* to enhance archaeological site predictions as this was only a basic-level project. Low level predictions can only take us so far with how water will distribute Further, more climate modeling should be research into more rising temperatures and precipitation would interact at once