Utilization of a Riparian Recruitment Model along the Lower Yuba River

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Abstract

Rivers in California have degraded due to anthropogenic influences including dams, diversion of flow, and climate change impacts. Many rivers can no longer sustain healthy ecosystems, making the ability to accurately model ecological processes within fluvial systems necessary for river management and restoration practices. The Lower Yuba River (LYR) within the Central Valley of California is a river that has been heavily damaged from sustained anthropogenic practices, creating a need to restore the riparian forests along the LYR. The Fremont cottonwood (*Populus fremontii)* is a pioneer species essential for stabilizing channels, providing habitat, and contributing nutrients to the river system. A riparian recruitment tool within an open source software called River Architect will be used to model the natural establishment potential of cottonwoods within the first year after germination along a segment of the LYR. This provides input into cottonwood response to changes in river flows and produces information useful for restoration projects.

Introduction (Literature Review)

Changes to natural fluvial systems for human management have altered and degraded rivers in California and around the world. Many rivers can no longer sustain healthy ecosystems or support native species that may be less tolerant to variations within the very system which they have evolved for (Naiman et al., 1995). The ability to accurately model ecological processes within rivers is needed for river management and restoration projects, biodiversity conservation, and to provide resilience against climate change. Specifically, there is a need to better understand and evaluate the relationships between flows and riparian vegetation conditions.

Riparian corridors are a dynamic region at the intersection between terrestrial and aquatic ecosystems, consisting of a varied collection of environments, landforms, and biological communities (Gregory et al., 1991). Interactions between riparian vegetation and hydraulic processes are driven by the flow regime, which is also a primary driver in the morphological patterns and ecological integrity of a fluvial system (Poff et al., 1997).

This creates an intricate and dynamic relationship between riparian vegetation, flow, geomorphic processes, climate shifts, and other upstream influences. Effective riparian management may improve issues related to decreasing environmental quality from changing land uses, indicating it should be included in the restoration and planning of river management (Naiman et al., 1993).

The riparian forests of California's Central Valley include the Fremont cottonwood (*Populus fremontii*) and other hardwood species. Fremont Cottonwood is a rapidly growing pioneer species, colonizing gravel bars and floodplains quickly and can grow into dense riparian forest, making the ecological and hydrological integrity of an area linked to the population dynamics of the cottonwood (Reedy et al., 2016). Cottonwood forests support a more diverse biological understory than other similar riparian types, stabilize channel banks and promote sediment deposition, and create vertical layering for wildlife habitat (Stromberg 1993, Camporeale et al., 2013). The Fremont cottonwood also improve water quality through filtration of water and trapping of sediment, provide shade and shelter, create a source of nutrient input to the system when uprooted and decaying, and provides habitat and contributes to the geomorphic processes by being a source of large woody debris in channels (Gregory et al., 1991).
These factors make the Fremont cottonwood an ideal species to try to predict seedling establishment for restoration projects.

The Central Valley of California is over 450 miles long, with the Sacramento River and San Joaquin River respectively draining the northern and southern portion of the valley. In the northern half, the Yuba River drains a portion of the Western slopes of the Sierra Nevada before joining the Feather River (Fig 1), which is the largest tributary of the Sacramento River (Ghoshal et al., 2010). Sustained anthropogenic factors from the 1800s have greatly impacted flows, sediment, and aquatic habitat conditions of rivers in this region (Griggs and Lorenzato, 2020). Looking to the future, understanding regional impacts from climate change, especially relating to water supply, are of growing importance (IPCC, 2013). Climate models are predicting California will become hotter and more arid, with increasing variation in precipitation and less snowpack available to feed tributaries flowing into the Valley (Mirchi et al, 2013).

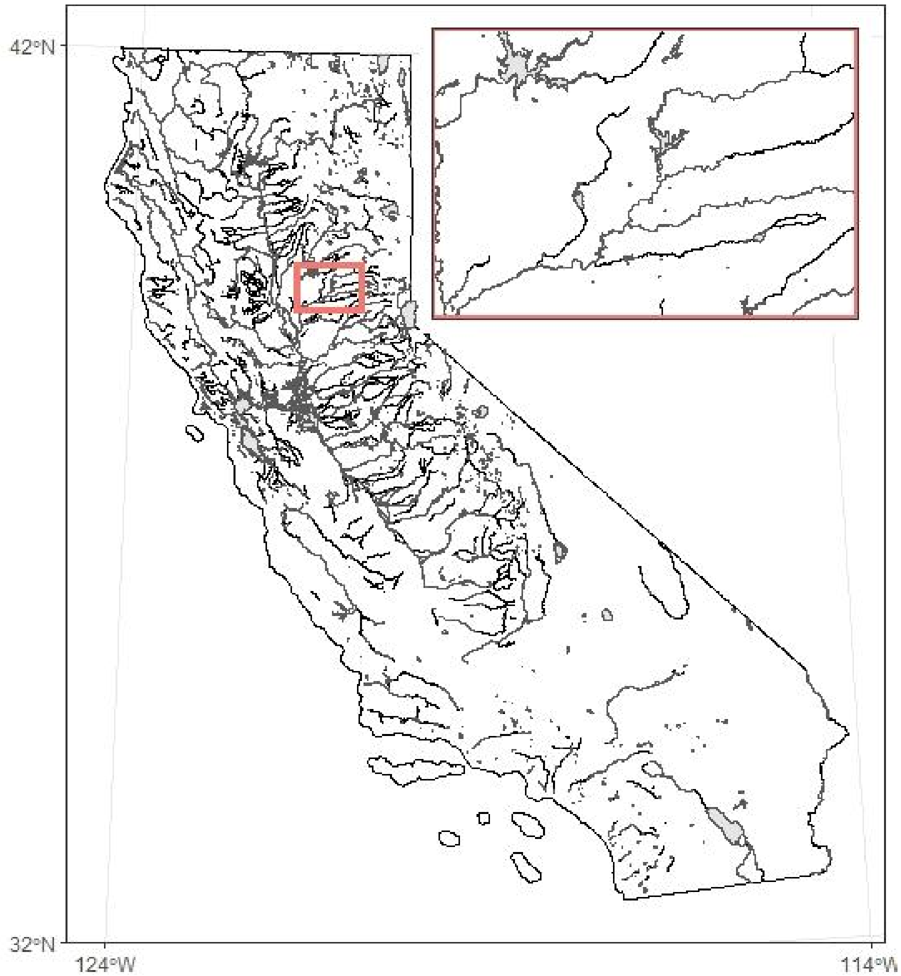

Figure 1: Map of California with rivers and reservoirs. The zoomed in box focuses on the Yuba River.

The study site is within the Lower Yuba River (LYR), which is a gravel/cobble river and runs 24 miles from the U.S. Army Corps of Engineer's Englebright Dam to its confluence with the Feather River in Marysville, California. Flows to the LYR are regulated with consideration to the Lower Yuba River Accord, intended to enhance fisheries and local water supply reliability (SWRCB, 2008). The LYR is an important river for supporting anadromous fish, including both the federally threatened spring-run Chinook salmon and steelhead trout. Due to the hydraulic mining of sediments, historic gold mining and dredging, the installment of dams and reservoirs, and the diversion of flow for agriculture, the LYR has been severely impacted.

Objectives

The main objective of this project is to utilize an open access, Python based software called River Architect to model the natural potential establishment of Fremont cottonwoods along a segment of the LYR (Schwindt et al., 2020). The site length along the channel is about 5,895 feet long and is adjacent to mined goldfields (figure 2). Topographic data from 2017 will be used with flow data from 2017 to create cottonwood recruitment potential maps in ArcGIS. Hydraulic, sediment, and topographic rasters will be collected to run the riparian recruitment tool within River Architect. The amount of area and locations with high recruitment potential will then be analyzed.

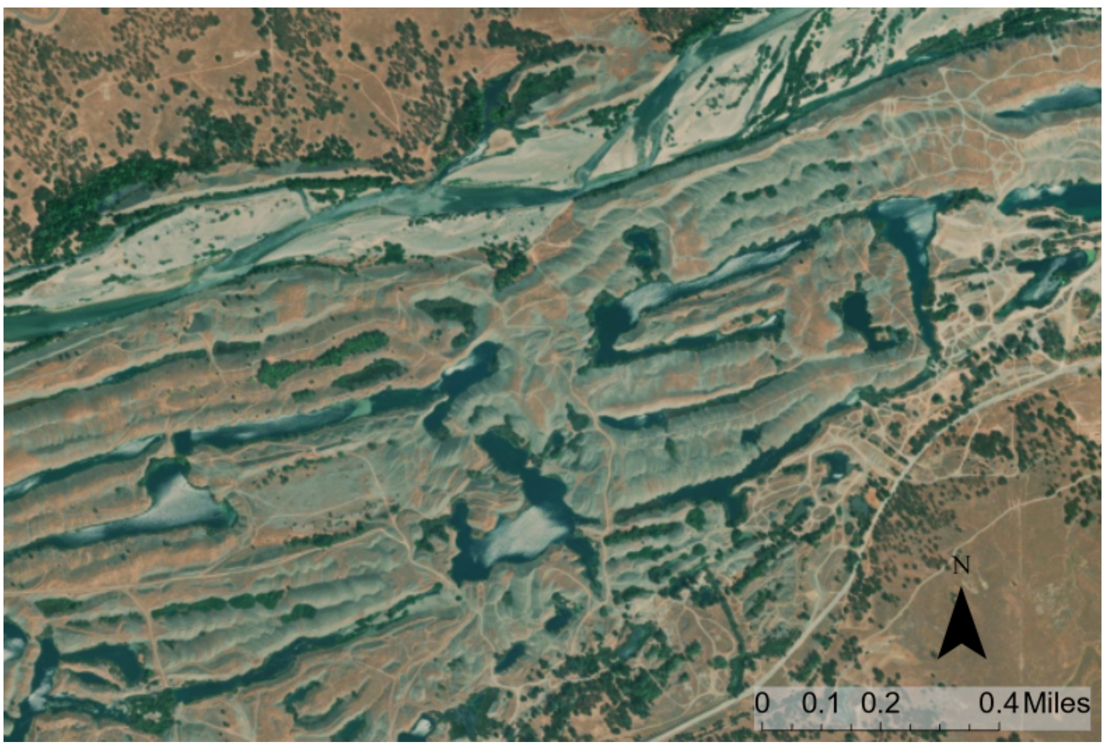

Figure 2: Chosen segment of the LYR for analysis.

Methods

Before the riparian recruitment tool could be used, the rasters needed had to be collected and prepared. The rasters were created by using the model TUFLOW and present flow conditions under different discharge scenarios from 300 - 84,400 cfs. Initial rasters collected were velocity, depth, and water surface elevation (WSE). The water surface elevation rasters and a digital elevation model (DEM) of the river were used to interpolate for the groundwater level elevation (WLE). Each of these rasters were resampled to have the same coordinate system, projection, cell size, and were aligned to the same DEM raster.

An average grain size raster (Dmean) was also required for the riparian recruitment tool. The existing mean grain size raster was used, but had regions with no data that had to be filled in. Average grain sizes within the inundation zone (300 to 5,000 cfs) and at highest discharge conditions were calculated separately using the zonal statistics tool within ArcGIS. This data was then merged with the existing mean grain size raster to fill in the empty areas.

Average daily discharge was collected by downloading data from the USGS Smartsville gage (11418000) and Deer Creek gage (11418500) and were added together. The resampled velocity, depth, WSE, WLE, Dmean, DEM, and vegetation height rasters were then used with the riparian recruitment tool.

Results/Discussion

The tool produced a bed preparation raster, a maximum inundation days raster, an inundation survival raster, and a recession rate raster. Each of these had binned values of 0, 0.5, and 1, indicating categories of lethal, favorable, and optimal respectively. These four rasters were then multiplied together to produce the riparian recruitment potential raster, with a cell size of 3x3 ft (figure 4). The areas of each recruitment category were summed together to compare the areas (table 1, figure 3).

Table 1: The summed area for each recruitment potential category.

Category	Value	Area (ft^2)
Lethal	0	1668213
Tolerable	0.125	74.3
Stressful	0.25	4315.5
Favorable	0.5	29713.5
Optimal	1	978.75

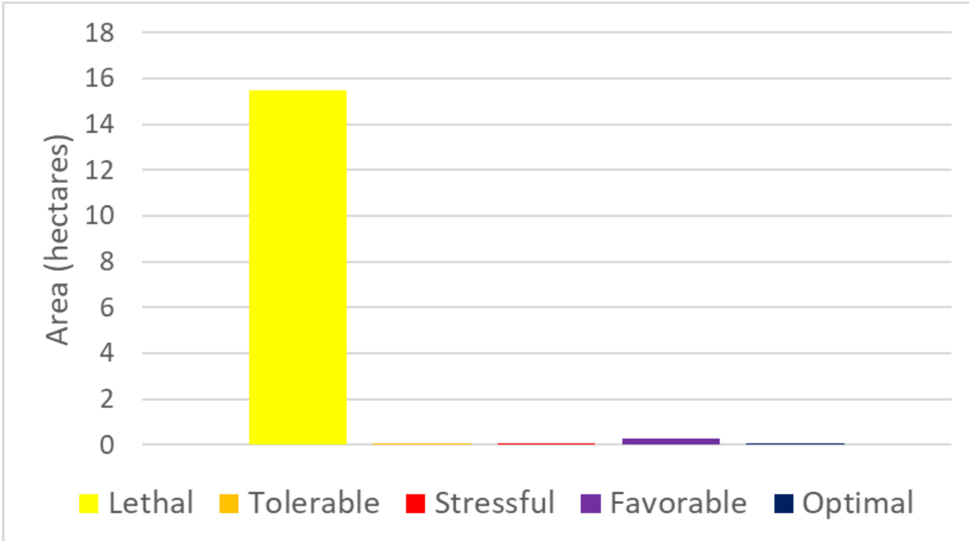

Figure 3: The areas, converted to hectares, for each recruitment potential category.

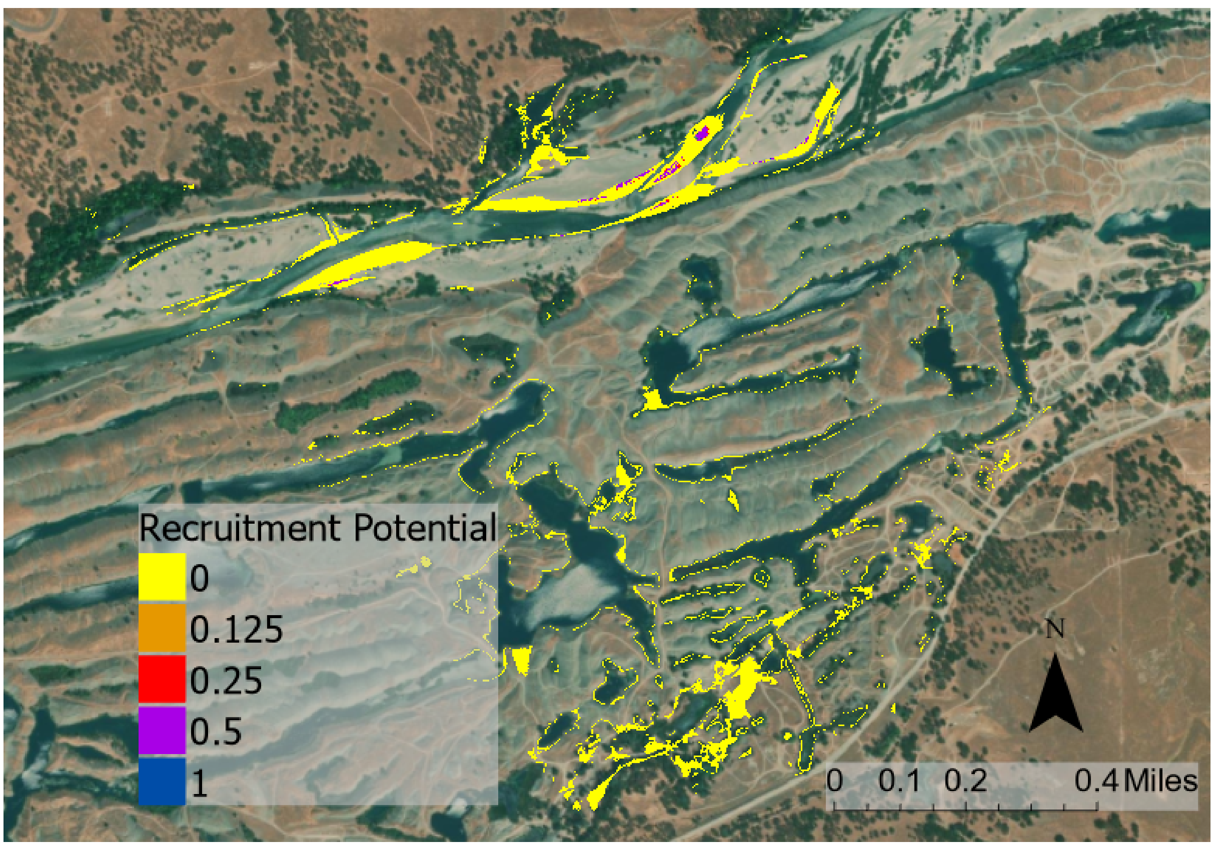

Figure 4: Cottonwood recruitment potential results.

The lethal category had the largest summed area and is the most abundant category in figure 4. Dynamic areas close to the channel and areas with vegetation already present were sections that were lethal, indicating no recruitment potential. The edges of the ponds and wetted areas in the goldfields also produced lethal areas. Lethal areas within the goldfields are likely the result of hydraulic rasters not having wetted areas that extend to this region, while the DEM and vegetation rasters did.

Favorable regions can be observed when zoomed in to the gravel bars around the main channel (figure 5). These occur mostly along the outer edge of the lethal zones away from the dynamic region near the main channel, though some favorable and optimal areas occur in the middle of lethal areas. Small or moderate floods are needed to promote natural cottonwood establishment (Mahoney and Rood, 1998). The average daily discharge in 2017 was 6,012 cfs and the median was 2,660 cfs, while these favorable regions align with the outer edge of the wetted areas of the 8,000 - 15,000 cfs discharge range, reflecting this need for small floods. Favorable recruitment is also predicted in thin lines, which matches up with the edges of the higher discharge wetted area rasters.

2017 topography and input rasters were used, but the background imagery included is current. Even from 2017, a change in the outline and shape of the channel can be seen. In some areas of figure 5, there is recruitment potential occurring in what appears to be the main channel. This is not possible as a cottonwood seedling could not establish in flowing water and indicates an area where the channel has evolved.

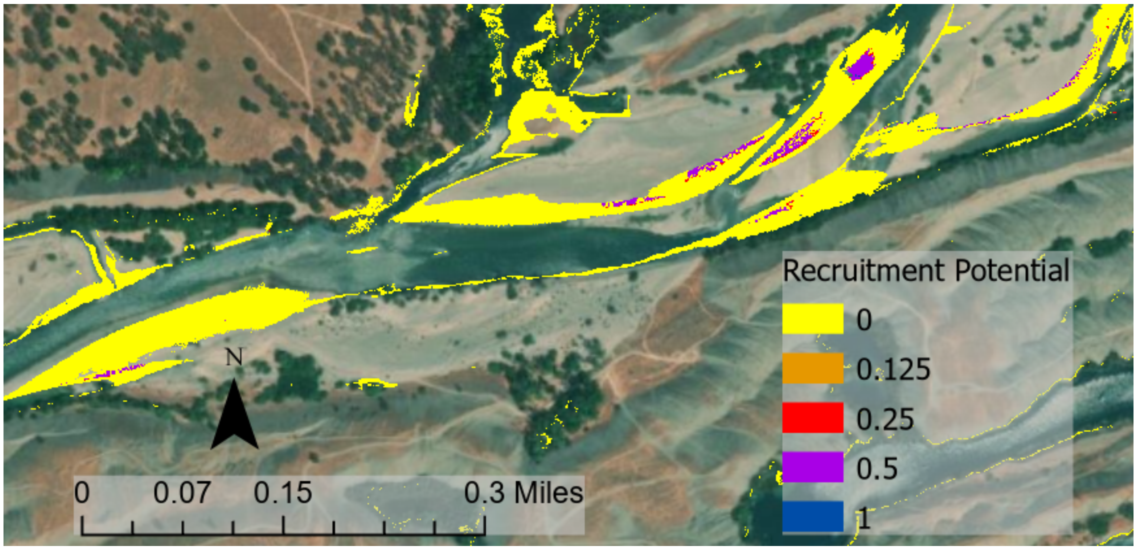

Figure 5: The recruitment potential raster zoomed in to areas just around the main channel.

Conclusion

The riparian recruitment tool offers a way to assess the potential for natural cottonwood establishment along a river, providing a method that can be used with restoration efforts. The tool predicted mostly lethal areas of recruitment, indicating that most viable areas near the channel do not have the right requirements for cottonwood establishment. Areas with favorable recruitment occurred along the boundary of the wetted areas for higher discharges and in more sheltered regions of gravel bars away from dynamic zones. As environmental and climate pressures continue to increase due to anthropogenic causes, the natural function of ecosystems should be encouraged and promoted to combat these impending stresses. Riparian vegetation offers a natural solution to help mitigate flood damage, channel migration, and poor water quality, while also offering habitat for threatened and socially important fish species.

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