# Land Use and Land Cover Variability at Lago Patillas

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## 1. Introduction

Lago Patillas is an important reservoir constructed in 1914, **Figure 1**, near the "Río Grande de Patillas" and "Río Marín" in southern Puerto Rico. Currently operated by the Puerto Rico Electric Power Authority (PREPA), the reservoir original intent was to support irrigation demands across the southern coastal plain, serving agricultural activities in the municipalities of Arroyo, Guayama, Patillas, and Salinas. Over time, Lago Patillas has also played a role on regional water management and watershed dynamics. Conducted sediment accumulation studies by the United States Geological Survey (USGS) have reported a trending loss of storage capacity in Lago Patillas. Where approximately 27% of total capacity has been lost between 1961 and 2019 as presented in **Table 1 [1-3]**. This long term decline indicates sustained sediment accumulation within the reservoir. Natural erosion processes contribute to sediment inflow, while anthropogenic activities within the drainage area such as land expansion, infrastructure development, and land cover modification can significantly amplify runoff, erosion, and sediment transport toward the reservoir **[3]**.

**Table 1.** USGS Sediment Accumulation studies in Lago Patillas.

| | **1961** | **1977** | **1997** | **2007** | **2019** |
|---|---|---|---|---|---|
| Total capacity (Mm^3 | 17.64 | 16.90 | 13.84 | 13.57 | 12.96 |
| Years since construction | 47 | 63 | 83 | 93 | 105 |
| Storage loss since 1961 (%) | - | 4 | 22 | 23 | 27 |

Land use and land cover (LULC) changes help identify, type of soil, vegetation, and human activities that influence watersheds. Urban development and surface when high, increase runoff, while vegetation disturbance reduces soil balance. In which this effects may accelerate sediment delivery to reservoirs. Therefore, this study evaluates LULC changes within the Lago Patillas drainage area between 2000 and 2020 using satellite remote sensing data acquired from the USGS EarthExplorer platform, and examines their relationship with elevation variability, census population trends, and potential anthropogenic impacts.

## 2. Materials and methods

### 2.1 Study area

The study area consists of the Lago Patillas drainage area, including the reservoir and all upstream drainage network area (**Figure 1**). The watershed boundary was delineated and applied consistently across all spatial datasets to ensure comparability among land cover, elevation, and demographic analyses.

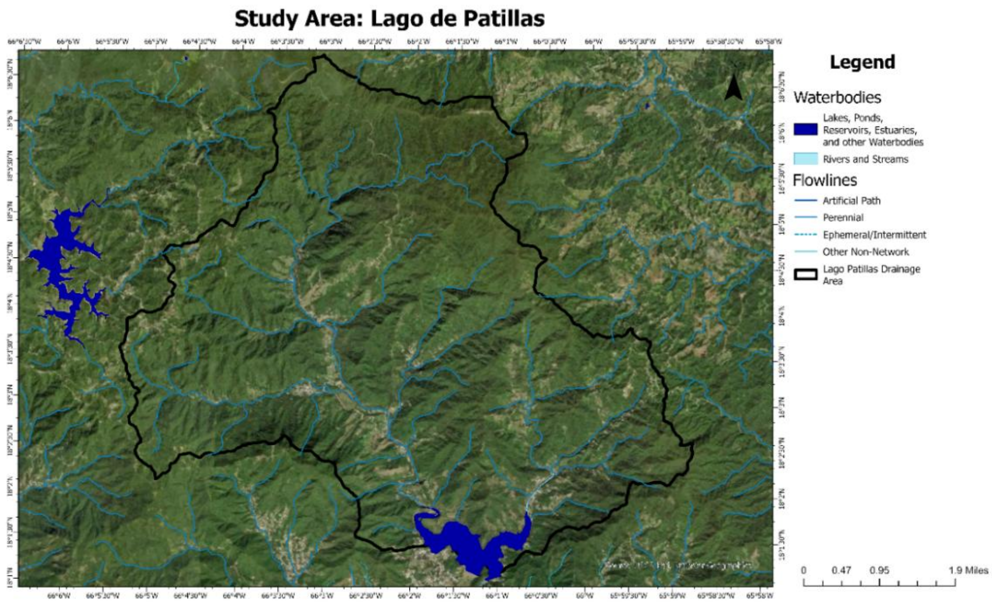


**Fig 1.** Lago de Patillas drainage area and reservoir highlighted.

### 2.2 Landsat Images

Landsat imagery was obtained from the USGS EarthExplorer database **[4]**. Landsat 7 imagery was used to represent conditions around the year 2000, **Figure 2**, while Landsat 8 image for present conditions around 2020. Raw imagery was clipped, **Figure 3**, to the drainage area and to prevent cloud obstruction they were masked manually.

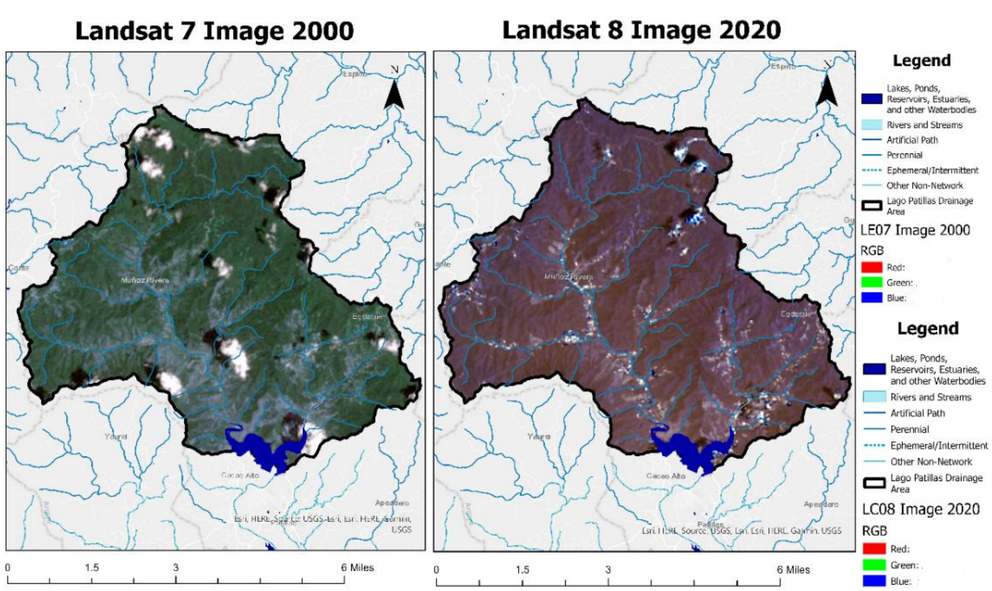


**Fig 2.** Raw Landsat images from 2000 and 2020.

An unsupervised classification using the Iso Cluster method was used first to identify general spectral groupings across the study area. Then, supervised classification was done, using Random Trees algorithm to improve classification between water, developed, and vegetation classes. In this study, the developed class are areas dominated by built infrastructure, including residential and commercial structures, roads, paved surfaces, and other features related to human activity. This class therefore captures the spatial extent of anthropogenic land cover within the watershed. To have a quantitative measurement pixel count for each land cover class were obtained from raster attribute tables. Finally, determined percent change between years, to quantify temporal variations in land cover distribution.

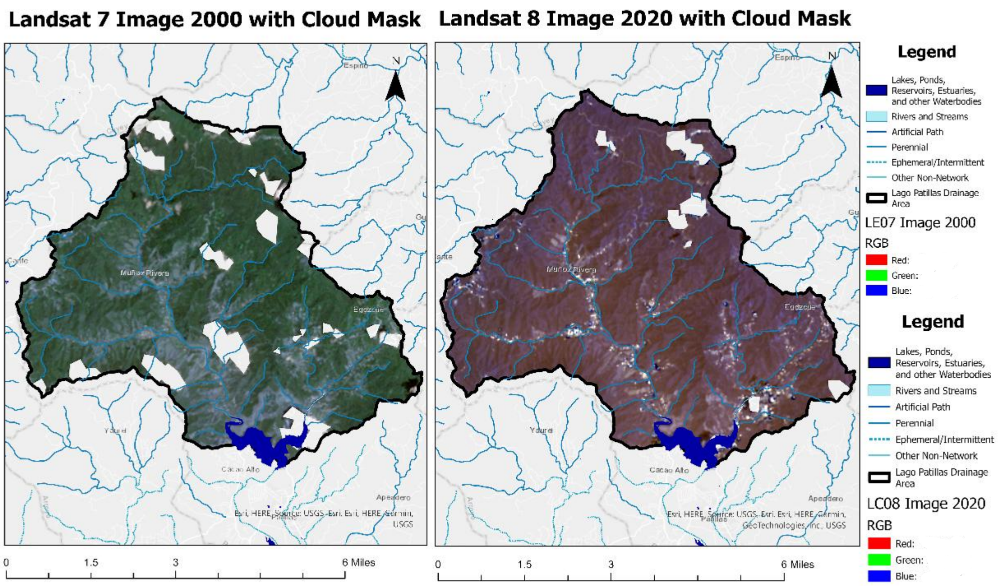


**Fig 3.** Landsat images with manual cloud masked apply.

## 2.3 Elevation dataset

Elevation data for both years were obtained from the GIS Puerto Rico data portal **[5]**. Digital elevation rasters were clipped to the study area and resampled to have consistent spatial resolution to be able to apply calculations. Raster calculations were performed, using **Equation 1**, to evaluate elevation differences between time periods. Where $V_1$ represents the initial elevation and $V_2$ the final elevation. This analysis allowed identification of areas potentially affected by erosion, deposition, or anthropogenic terrain modification.

$$Percent\ Change = \frac{(V_2 - V_1)}{|V_1|} * 100 \qquad (1)$$

## 2.4 Census dataset

Population data was obtained from the U.S. Census Bureau for GEOID 72109290100, corresponding to Census Tract 290100 within County Code 109, for the years 2000 and 2020 **[6,7]**. The selected tract selected aligns with the Lago Patillas drainage area, allowing demographic accessibility of study area without the need for additional spatial interpolation or population mapping. The population counts were compared between census years to assess temporal changes in population size. The GEOID is a code assigned by the Bureau to identify specific geographic entities. Tracts are subdivisions of counties to represent homogeneous population characteristics.

## 3. Results and Discussion

### 3.1 Supervised Classification and Land Cover Change

Staring with **Figure 4** shows the results of the unsupervised land cover classification using the Iso Cluster approach. Where the software identifies based just on spectral similarity without knowing what typer of object is each pixel. Classification gave highlights in a general over the Lago Patillas drainage basin.   Class boundaries are similar, and theres misunderstanding on bare soil and built regions among the terrain types.   As a result, the unsupervised classification served the aim provided of assisting acquire an overview of the study area and what similar pixels it contained. The supervised classification using the Random Trees method (**Figure 5**) provided a stronger and clear representation of the content within the Lago Patillas drainage area compared to the unsupervised approach. Quantitative pixel evaluation from classification, **Table 3,** indicated a substantial increase in developed land (+69.89%) between 2000 and 2020, despite a simultaneous 33.13% decrease in population (**Table 2**).

**Table 2.** Census population count around the drainage area of Lago Patillas.

| 2000 | 2020 | Percent Change (%) |
|---|---|---|
| 5,297 | 3,542 | -33.13 |

This may show that development within the watershed is not directly connected to population growth but may be attributed to changes in land use practices, infrastructural expansion, or geographical redistribution of human activities.

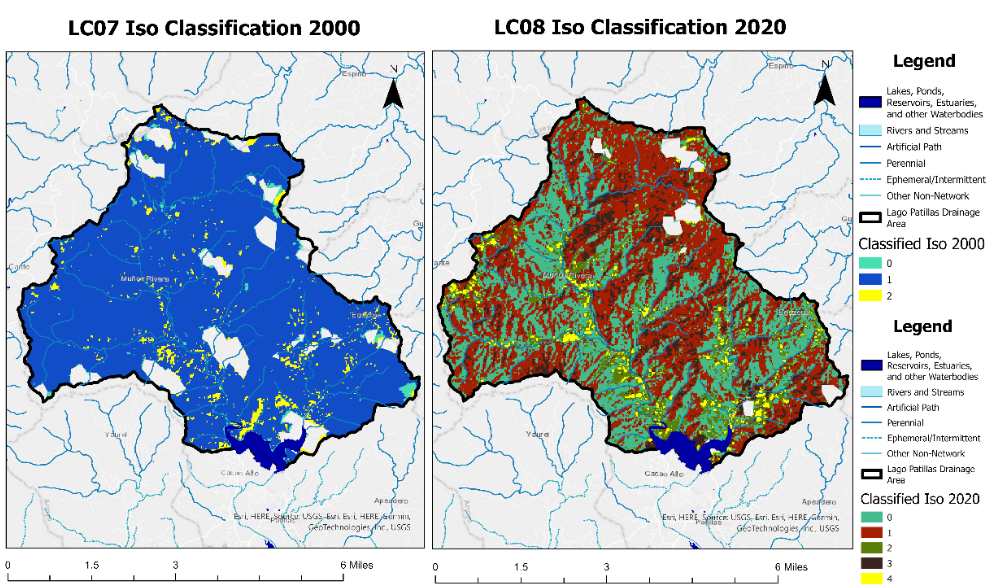


**Fig 4.** Unsupervised classification for 2000 and 2020 using Iso Cluster method.

From a hydrologic perspective, the expansion of developed land is particularly significant. Developed surfaces typically increase impervious cover, reducing infiltration and increasing surface runoff. Within a mountainous watershed such as Lago Patillas, increased runoff can enhance flow velocity along drainage channels, increasing the capacity of streams, and transport sediment downstream. Even moderate increases in impervious or compacted surfaces can have disproportionate effects on sediment yield, particularly during high intensity rainfall events common in southern Puerto Rico.

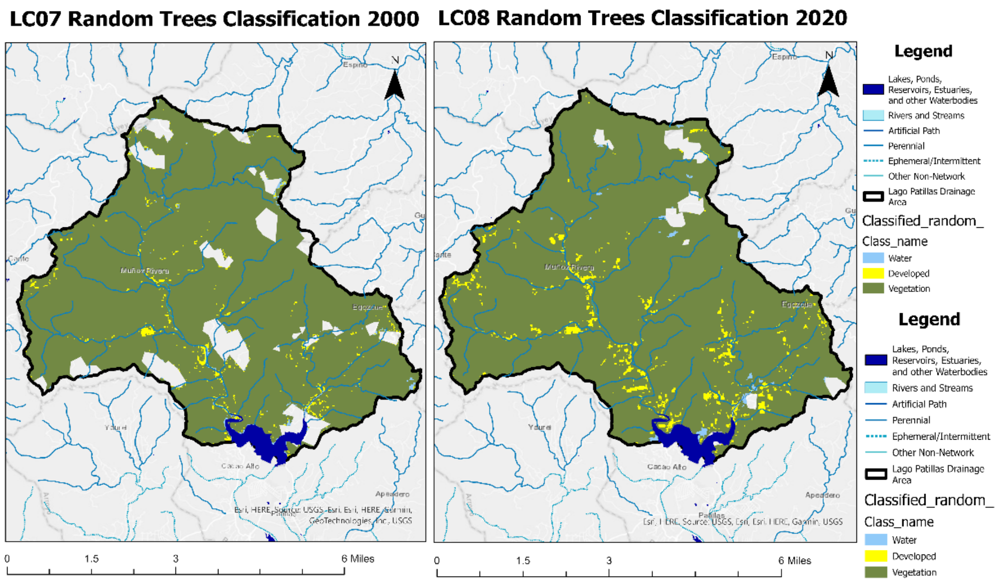


**Fig 5.** Supervised classification for 2000 and 2020 images using Random Trees method.

The 28.32% decrease in surface water area may me due to changes in reservoir extent or associated with sediment infilling. As sediment accumulates within the reservoir, storage capacity decreases, which can reduce apparent water surface area during certain conditions. Vegetation cover stayed the same at watershed scale, and vegetation disturbance was observed near developed areas may still contribute to increased soil exposure and erosion.

**Table 3.** Supervised classification pixel count for each category.

| Classification | 2000 | 2020 | Percent Change (%) |
|---|---|---|---|
| Water | 2341 | 1678 | -28.32 |
| Developed | 1518 | 2579 | +69.89 |
| Vegetation | 70,319 | 69,921 | -0.57 |

### 3.3 Elevation Variability and Geomorphic Implications

Prepared elevation datasets for 2000 and 2020, on **Figure 6**, revealed that the around the drainage area the elevation seems similar, but it differs slightly around the edges of rivers where decrease can be seen. The elevation percent change map (**Figure 7**) highlights areas of increased variability, where steeper slopes may be present due to change. These zones are critical from a sediment transport perspective, as they represent pathways through which eroded material can be efficiently delivered to downstream water bodies.

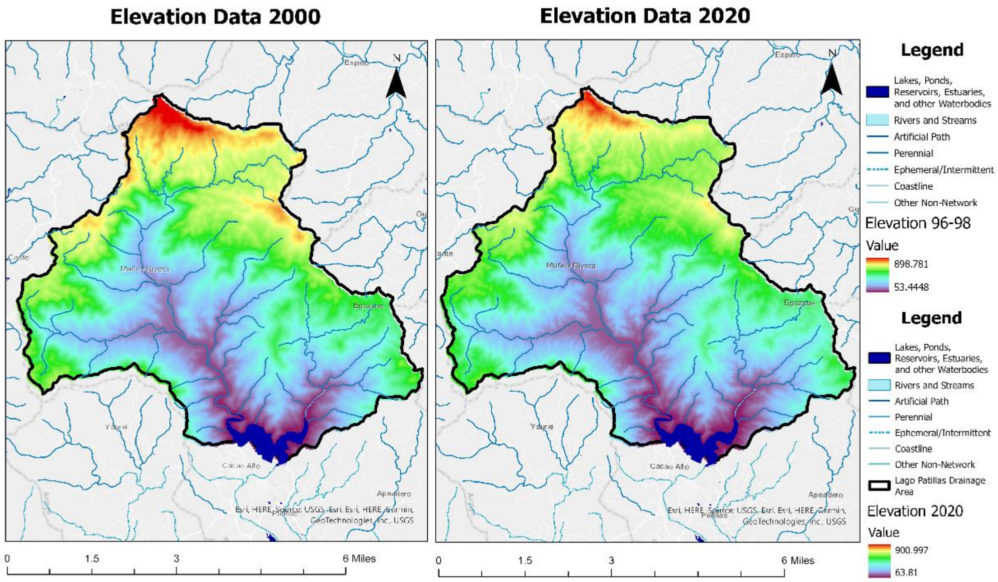


**Fig 6.** Processed elevation datasets for 2000 and 2020.

While large scale elevation change across the watershed is not expected over short time periods, localized changes can be indicative of erosion, deposition, or anthropogenic modification. Activities such as road construction, land grading, and slope alteration associated with development can modify surface topography and disrupt natural drainage patterns. These modifications may concentrate runoff, increase slope instability, and enhance sediment mobilization during storm events.

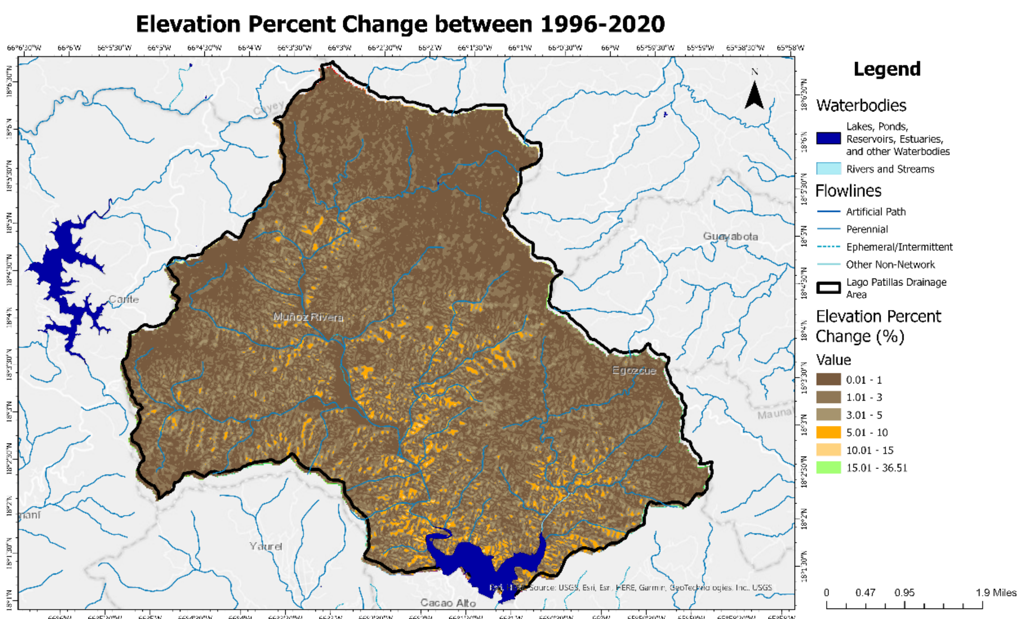


**Fig 7.** Elevation percent change between 1996 and 2020.

The spatial distribution of elevation change suggests that sediment redistribution is not uniform across the watershed, but rather concentrated in specific zones where natural topography intersects with human-modified land surfaces. This pattern supports the hypothesis that anthropogenic land use plays a role in amplifying geomorphic processes that influence sediment delivery to Lago Patillas.

### 3.4 Integrated Analysis: Land Cover, Elevation, and Population

The comparison between elevation changes with supervised classification (**Figure 8**) it can be observed the interaction between human activity and landscape adjustments. Where areas classified as developed or may be transitioning from vegetated to developed, coincide with areas of elevation large variability. Which may indicate potential links between land use change and geomorphic response.

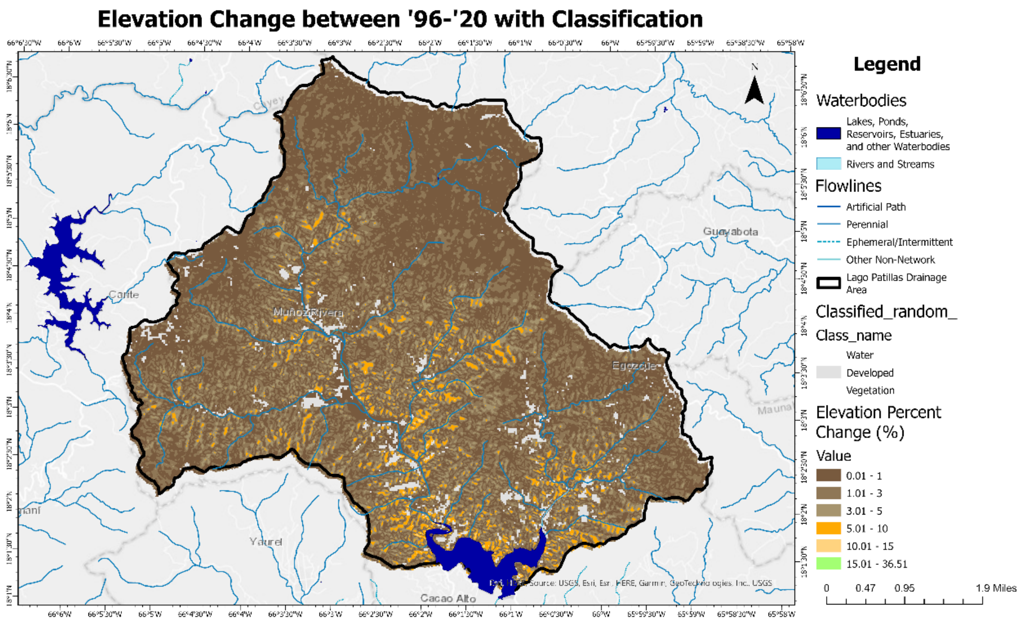


**Fig 8.** Elevation percent changes between 1996 and 2020 with Classification.

With declined population, and an increase in developed land, this suggests a change towards land use intensification instead of increment due to population. From a watershed perspective, these findings demonstrate that sediment accumulation in reservoirs does not occur only by population amount but also by how land is managed. Where an increased runoff efficiency, reduced infiltration, and drainage connectivity can accelerate sediment transport even in areas experiencing population decline. The combined results indicate that anthropogenic land cover changes, when compared with terrain characteristics, likely contribute to the long term sedimentation accumulation observed in Lago Patillas. Declining population does not mean that an impact was made two decades ago.

## 4. Conclusions

This study highlighted that Lago Patillas drainage area has experienced significant land use and land cover changes between 2000 and 2020. Where using classification method combined with population and elevation changes resulted in an interesting approach to show cause and effect. These anthropogenic changes may have alter runoff and contribute to sediment accumulation within the reservoir. Elevation analysis highlighted terrain variability which may reflect erosion or human induced modification. When considered alongside historical sedimentation data from USGS reports, the results suggest that land use transformation within the watershed may play an important role in long-term storage capacity loss at Lago Patillas.

**References**


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