NM WRRI Student Water Research Grant Final Report

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2. **Project title**: Relationship between Tree Canopy Cover and Discharge of Upper Gallinas Watershed, NM, 1939 - 2015

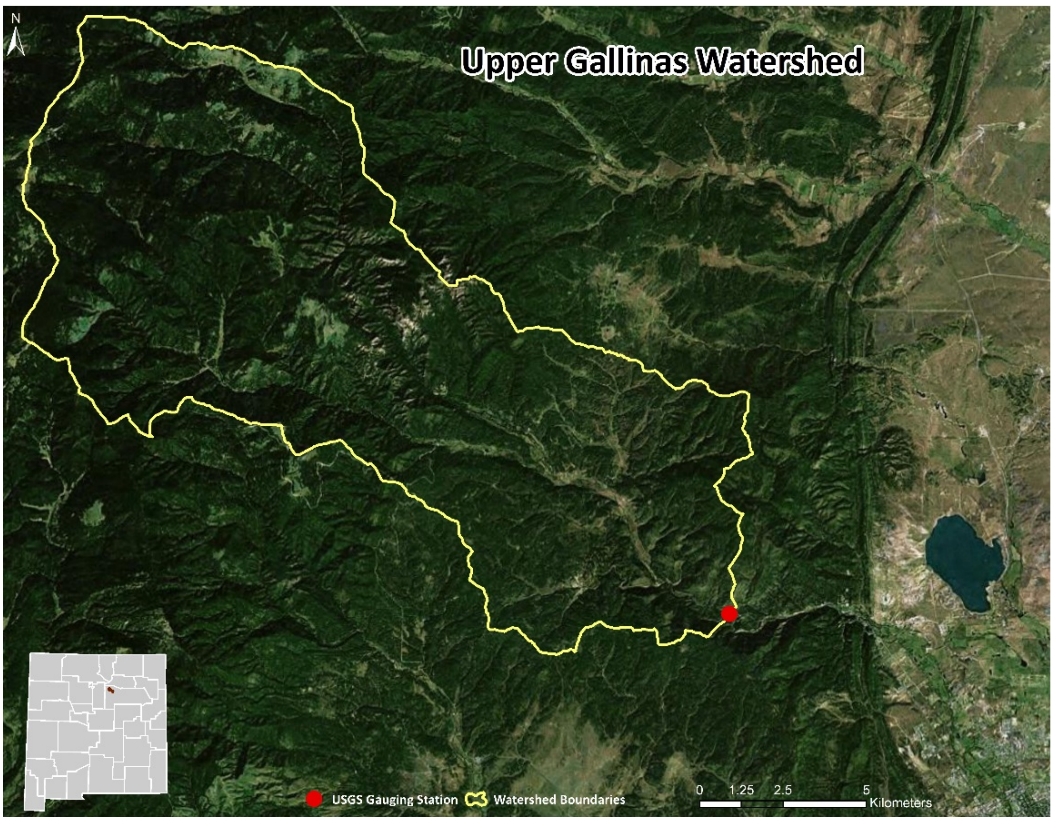
3. Description of research problem and research objectives.

Climate change results in Land use changes which affect the vegetation-cover patterns. With the advent of climate change, it is expected that the US Southwest will experience warmer average temperatures in all seasons, longer summers, shorter winters, and reduced snowpack in the higher elevations. The general trend of land use in the US Southwest from 1945 to 1992 indicates decreases in forests, increases in urban areas and decreases in pastures (U.S. Geological Survey). The state of New Mexico, in particular, will experience warmer temperatures which will reduce mountain snow packs, and peak spring runoff will shift to earlier in the season. In the northeastern part of the state, the City of Las Vegas has been dealing with the threat of water shortage since the beginning of the 21st century. The Gallinas River is the primary source of potable water (95%) for the approximately 14,000 residents of Las Vegas. In response Las Vegas has turned to periodic conservation measures such as educating residents on how to conserve water, banning lawn irrigation, using gray water, and encouraging residents to switch to xeriscaping and low flow fixtures. These situations may be an indicator of water resource problems yet to come to the rural villages of New Mexico due to climate change.

The Gallinas River is a tributary of the Pecos River System and is located in northeastern New Mexico, yielding an average of 3,100 acre-feet of water annually. The area of the upper watershed is approximately 76 mi^2, from its headwaters on Elk Mountain (11,600 ft. elevation) to USGS gauging station near Montezuma (4,900 ft.). Land use of the upper watershed has transitioned from agriculture, focusing on timber, livestock, and hay production, to primarily full-time and part-time residential use and summer recreation over the past few decades.

The purpose of this study is to determine if a correlation exists between tree canopy cover, precipitation, and temperature and the Gallinas River discharge from 1939 to 2015.

Study objectives include:
1. Determine the percentage of tree canopy cover of the upper watershed for each decade from 1939 to 2015;
2. Determine the relationship between Gallinas River discharge, precipitation trends (snow, rainfall) and temperature; and
3. Determine the relationship between the percentage of tree canopy cover and the discharge of the river from 1939 to 2015.



The above image shows the boundary of the study area.

4. Description of methodology employed.

Aerial photography and Geographic Information System (GIS) techniques were used to determine the percentage of tree canopy cover in Gallinas watershed from 1939 to 2015.

1. Geographic Information System (GIS)

a. Watershed Delineation

Aerial photography and GIS-based techniques were used to determine the percentage of tree canopy cover in the upper Gallinas watershed from 1939 to 2015.
Upper Gallinas watershed boundary was delineated using the Hydrology toolset in ArcMap 10.4 with the USGS (United States Geological Survey) gauging station near Montezuma as the pour point. The Fill tool was used to fill the sinks in the surface raster to remove small imperfections in the data. The Flow Direction was computed for each cell using the Digital Elevation Model (DEM). The Flow Accumulation tool was used to calculate the number of cells flowing into each cell. The Snap Pour Point tool was then used to snap the USGS gauging station point to the nearest area of high flow accumulation followed by the Watershed tool to delineate the boundary of the upper Gallinas watershed. The total study area was then calculated which is about 76 square miles.

b. Canopy Extraction

- Obtaining & Geo-referencing Images

Two sets of Gallinas watershed images from 1939 to 2014, above the USGS gauging station at Montezuma (latitude 35°39’ 07.18”, longitude105°19’ 07.79”, No. 08380500, HUC Eight Digit Code: 13060001), with 1-meter resolution, were obtained for conducting this project. The 1939 to 1986 images, which were not geo-referenced, were purchased from Earth Data Analysis Center (EDAC) and the images of 1997 to 2014, which were geo-referenced, were downloaded from Resource Geographic Information System (RGIS) website. Historical aerial photos of the study area were located in the quads including Elk Mountain, Honey Boy Ranch, Rociada, El Porvenir and Montezuma.

ERDAS Imagine software was used to geo-reference the 1939-1986 images. As the study area is mostly forested (92% forest), for increasing the accuracy and minimizing the error in geo-referencing procedure, Ground Control Points (GCPs) were chosen for each image separately, to rectify them by comparing to the 1997 geo-referenced aerial photo of the study area.
ERDAS Imagine software was then used to mosaic the historical images of each decade. Each image was then clipped to the watershed boundary.

- Classification

eCognition Developer software was used to classify each image as Canopy and Non-Canopy separately. Image segmentation was used to divide each image into homogenous objects, at the scale parameters, imagery, and any ancillary GIS Layers. Two rule sets were developed for the black/white and color images, separately. Thresholds were modified to get the best classification as canopy and non-canopy. Normalized Difference Vegetation Index (NDVI), as well as the brightness value of each segment, were used for the color images to classify them as canopy and non-canopy.

NDVI = (NIR – Red)/ (NIR +Red)

Each image was diced into smaller areas before running the classification procedure. The rule sets were then examined for few subsets in different parts of the watershed area before applying for the total watershed. ERDAS was then used to mosaic the diced classified images. The classification accuracy and visual appearances were compared to evaluate the correctness of the results. ArcMap was used to reclassify each image as canopy=1, non-canopy=0, and shadow=0. Random empty polygons (10m x10m) and zonal statistics were used to calculate the total tree canopy area.

2. Discharge Data

Online daily discharge data for Gallinas River, precipitation, and temperature data were obtained from two local gauging stations: Montezuma (latitude 35° 39’ 07.18”, longitude 105°19’ 07.79”,

No. 08380500, HUC Eight Digit Code: 13060001) and Weather Station located at Las Vegas Municipal Airport (NOAA).

5. Description of results; include findings, conclusions, and recommendations for further research.

The results of the canopy classification suggest that the area covered with tree canopy has been increased from 1939 to 2014 (Figure 1). The percentage of tree canopy cover in the 1930s is 36.6% (27.8 mi^2) which has increased dramatically in 1951 to 65.96% (50.2 mi^2). This can be due to reduced logging and grazing in the watershed area during this period. On the other hand, comparing the canopy cover from 2011 and 2014 indicates a decrease in the canopy cover which can be related to the thinning projects have been conducted in the area in the last few years.

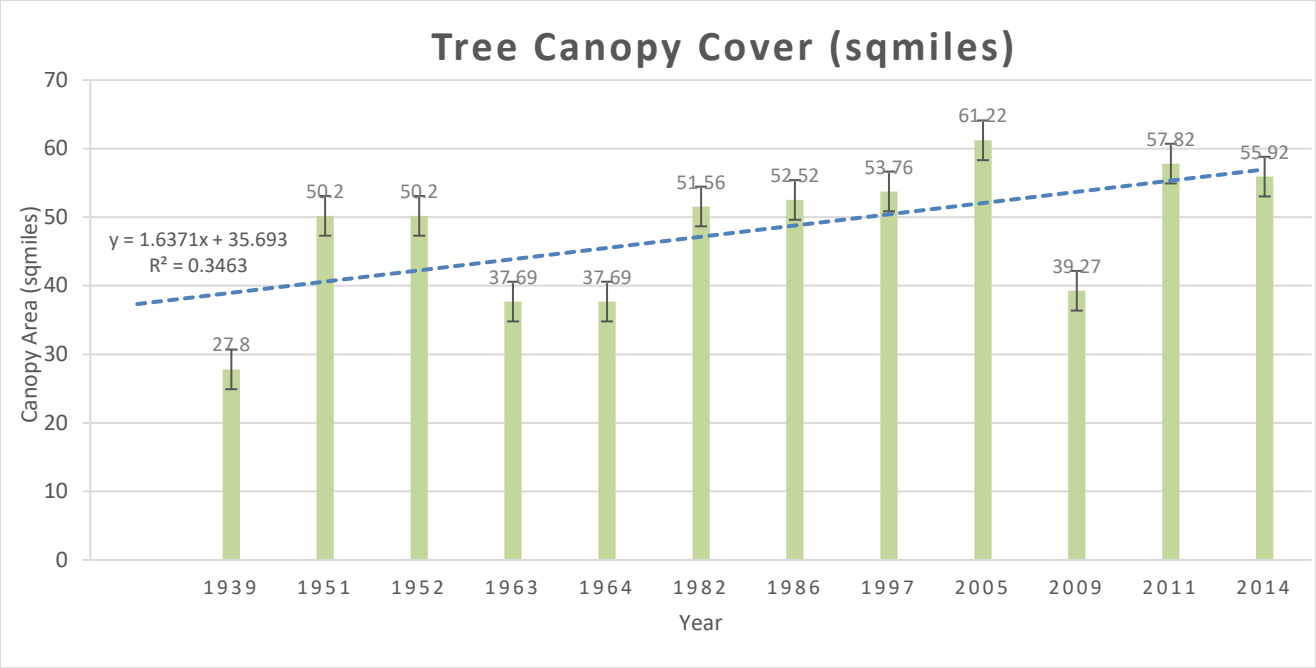


Figure 1. Results of the area of tree canopy cover in upper Gallinas watershed from 1939 to 2014. The chart shows an increasing trend of the tree canopy cover from 1939 to 2014.

The results show an increasing trend of temperature and discharge but a slightly flat trend of precipitation, from 1935 to 2015 (Figures 2, 3 &4). The discharge data indicate a slight increase from below 20cfs to above 20cfs over time (Figure 2).

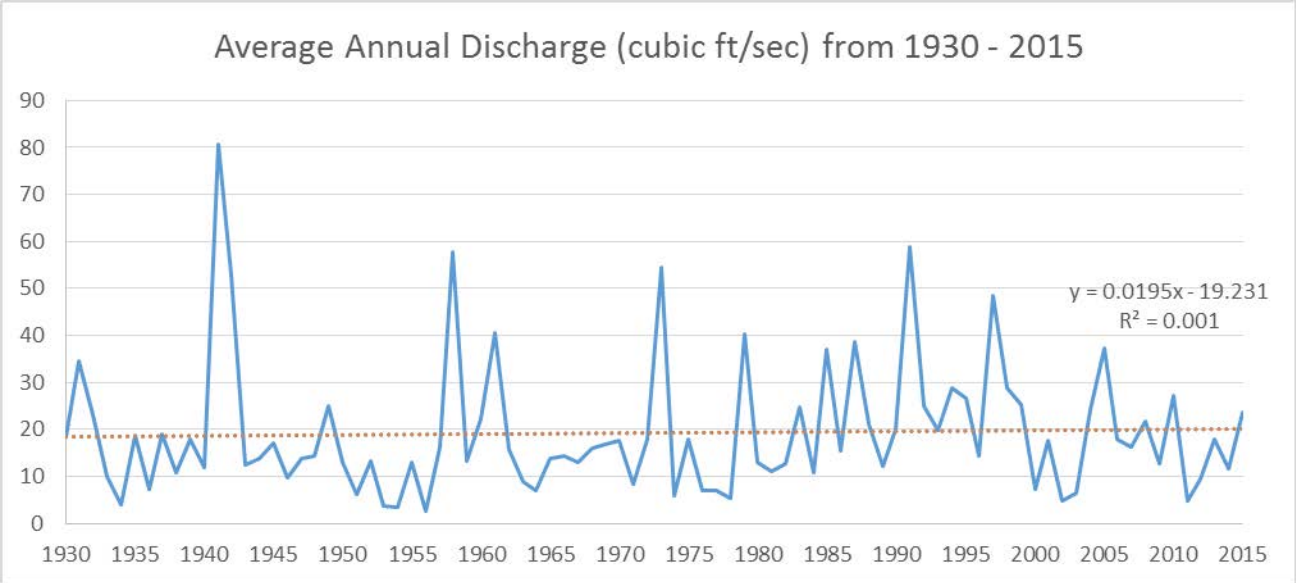


Figure 2. The average annual discharge (ft^3/s) of the Gallinas River from 1930 to 2015. The trend shows a slight increase in the flow of river over the years.

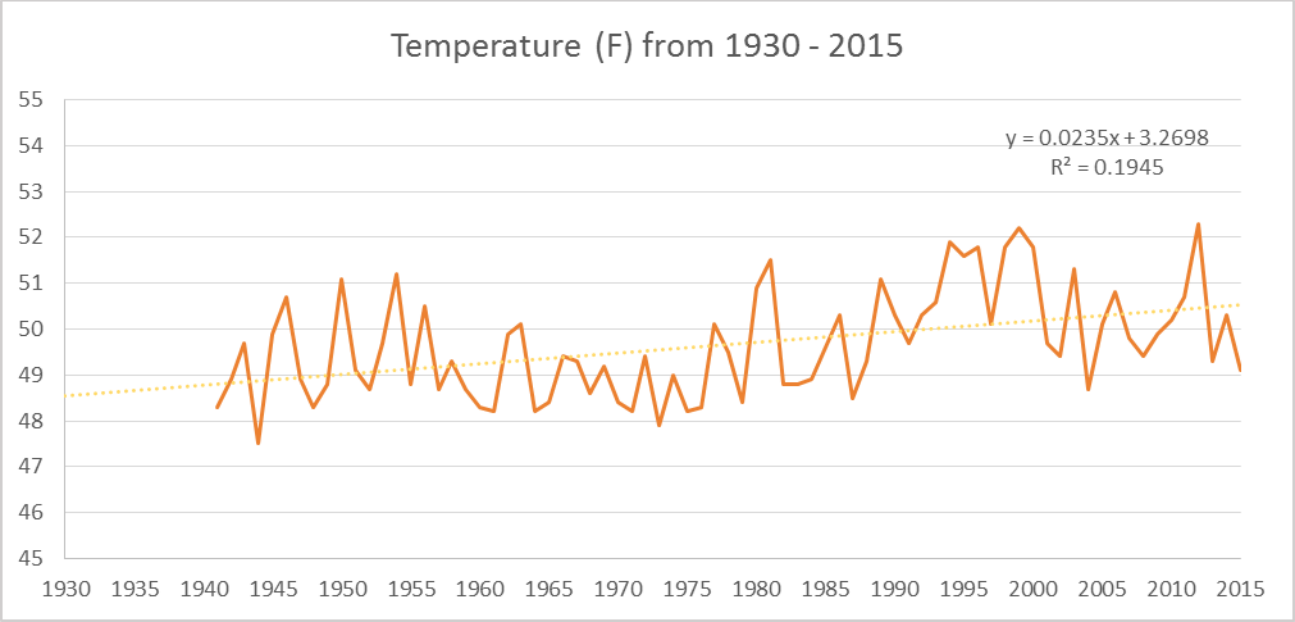


Figure 3. The average annual temperature (°F) in the upper Gallinas watershed from 1930 to 2015. The graph demonstrates that the temperature has continued to increase.

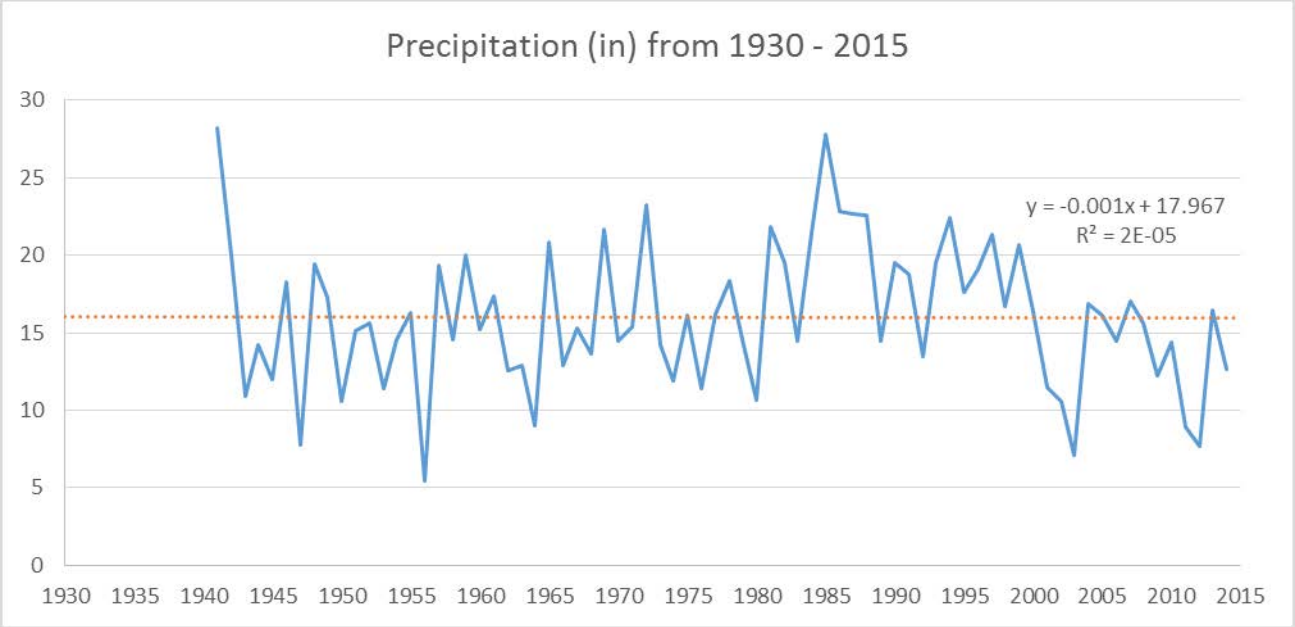


Figure 4. The average annual precipitation (in) in the upper Gallinas watershed from 1930 to 2015. The graph indicates almost a flat trend of precipitation over this period of time.

Table 1. Illustrates the percentage of tree canopy cover, annual mean discharge, temperature and precipitation from 1939 to 2014.

Year	Canopy cover (%)	Aver. Q (cubic ft./sec)	Temperature (F)	Precipitation(in)
1939	36.6	17.8	45	18.03
1951	65.96	6.26	49.1	15.1
1952	65.96	13.34	48.7	15.62
1963	49.55	8.84	50.1	12.93
1964	49.55	6.72	48.2	8.97
1982	67.79	12.69	48.8	19.54
1986	69.05	15.49	50.3	22.85
1997	70.74	48.53	50.1	21.37
2005	80.49	37.38	50.1	16.13
2009	51.63	12.59	49.9	12.27
2011	76.02	4.91	50.7	8.94
2014	73.52	10.07	50.3	12.67

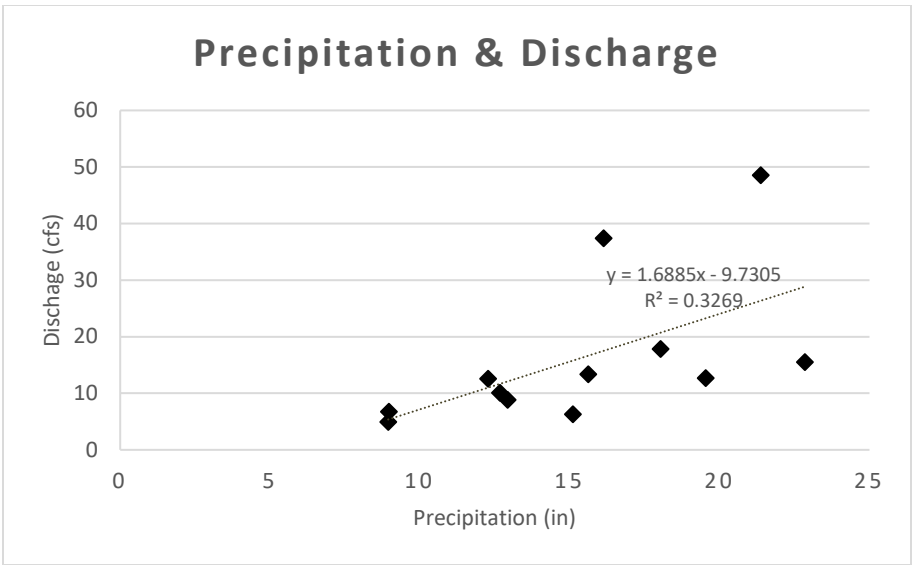


Figure 5. This graph shows a strong correlation between the precipitation (in) and the Gallinas River discharge (CFS) from 1939 to 2014.

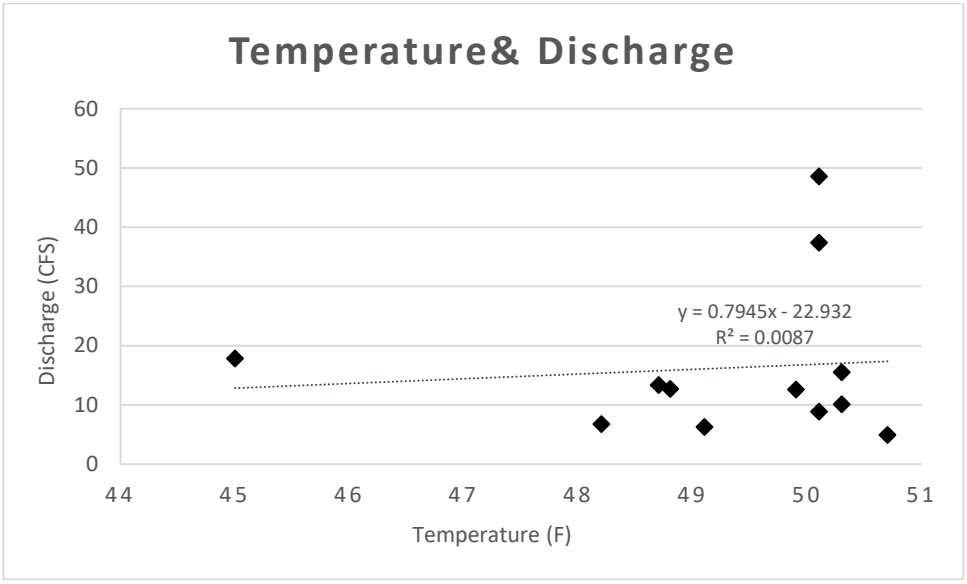


Figure 6. The above graph illustrates the correlation between the temperature and discharge of the Gallinas River from 1939 to 2014. It shows there is not a strong correlation between the temperature (F) and the discharge (CFS) of the river.

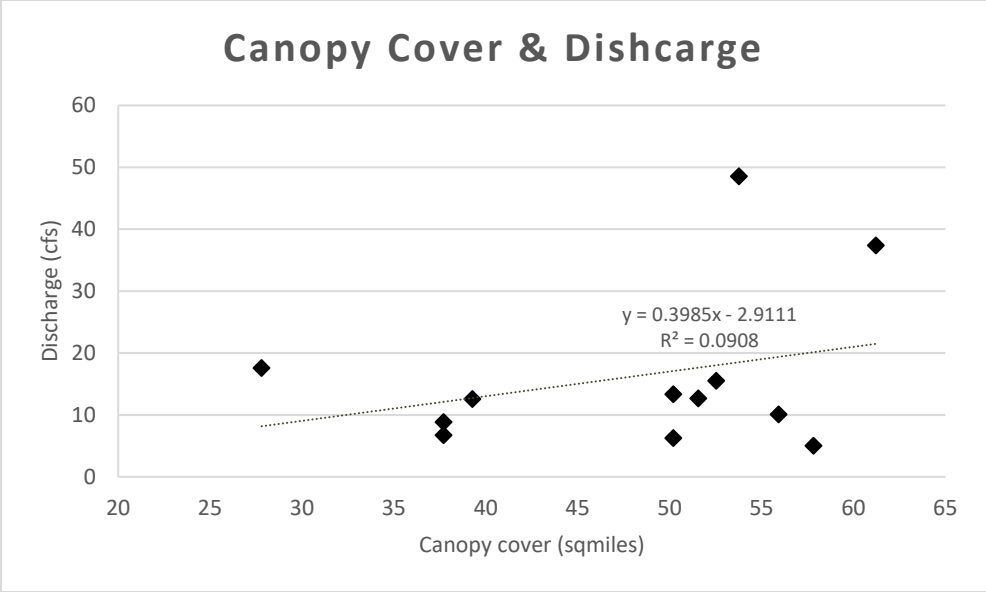


Figure 7. The relation between the area of canopy cover on upper Gallinas watershed and the discharge of the Gallinas River. The graph shows a positive correlation between these two variables.

The results also indicate a strong correlation between the precipitation and discharge. Discharge and canopy cover have a positive correlation, increasing tree canopy cover results in increasing the stream flow (Table 1 & Figure 5, 7).

6. Provide a paragraph on who will benefit from your research results. Include any water agency that could use your results.

The results of this research will be useful for restoration managers and landowners to make environmentally friendly decisions on utilizing the land. As the Gallinas River is the primary source of water for the residents of Las Vegas, the City of Las Vegas who provides drinking water for the residents in Las Vegas will benefit from this research. The other communities who will benefit from this research are, land owners who use the Gallinas River water for their agriculture purposes, US Forest Service as they conduct restoration projects, agriculture and recreation activities and the people using the watershed area for their recreational activities, including hiking, camping, and fishing.

7. Describe how you have spent your grant funds. Also provide your budget balance and how you will use any remaining funds.

I would like to thank the NMWRRI for generously providing me with the Student Water Research Grant.

The majority of the grant was allocated as my salary to continue my research, with $3,600 of the grant going to provide my salary. This salaried period began on October 1, 2016, to June 1, 2017. $1,014 of the grant was used to purchase the aerial photography of the study area for 1986-1987.

$83.48 was used to purchase an external hard drive to store data.

The total amount used from the initial grant is $4697.48 with the balance of $22.52 which has not been used.

8. List presentations you have made related to the project.

I have presented my research project in the conferences/events listed below:

Yekkeh, B., Martinez, E. A., Biggs, J. R., Zebrowski, J. P.& Dappen, P. R. (2017, April). *Relationship between Tree Canopy Cover and Discharge in Upper Gallinas Watershed, NM, 1939 – 2015*. Poster session presented at The 15th Annual NMHU Student Day for Research and Creative Work, Las Vegas, NM

Yekkeh, B., Martinez, E. A., Biggs, J. R., Zebrowski, J. P.& Dappen, P. R. (2017, April). *Relationship between Tree Canopy Cover and Discharge in Upper Gallinas Watershed, NM, 1939 – 2015*. Poster session presented at New Mexico Geological Society Annual Spring Meeting, Socorro, NM

Yekkeh, B., Martinez, E. A., Biggs, J. R., Zebrowski, J. P.& Dappen, P. R. (2017, March). *Relationship between Tree Canopy Cover and Discharge in Upper Gallinas Watershed, NM, 1939 – 2015*. Poster session presented at HAR-CeSER 2017 Conference, '*High Altitude Restoration Science & Practice*', Fort Collins, Colorado

Yekkeh, B., Martinez, E. A., Biggs, J. R., Zebrowski, J. P.& Dappen, P. R. (2016, October). *Relationship between Tree Canopy Cover and Discharge in Upper Gallinas Watershed, NM, 1939 – 2015*. Poster session presented at 61st Annual New Mexico Water Conference, '*Where Does All the Water GO?*', Silver City, NM