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Examination of Water Use and Social Vulnerability: A Comparison of Four Communities in Alachua County, Florida

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ABSTRACT:
It is projected that about 30% of the world's major cities will face severe water stress and urban drought from 2050 if climate change continues and has the anticipated effects (Florke et al, 2018; www.wrcwebsite.azurewebsites.net). Socio-economic drought, meaning water shortage in urban life, can have significant effects on a city's inhabitants, including health and quality of life. Social and economic factors play an important role in planning and decision making of a society (Zhang et al, 2020). The analysis investigated the relationship between socio-economic factors and the use of potable water, its associated impact on aquifer recharge, and potentially identifying major factors influencing water demand and resource sustainability.

The Centers for Disease Control and Prevention's Social Vulnerability Index (SVI) and other measures were used for evaluating socio-economic factors. However, since SVI showed weak relationship with water use in the county and the neighborhoods, other socio-economic measures were assessed. Past research had found a correlation between water use and population, GDP, per capita income, electricity usage and irrigated land areas (Alacoma et al., 2007, www.usf.uni-kassel.de/watclim). Therefore, socio economic measures such as population density, household size, per capita income, and poverty rate and irrigation (with and without) potable water were analyzed to evaluate the relationship between water use patterns and these factors across the county and in the communities. The western communities had newer development and less parcels compared to the eastern with much older construction, which impacted their water use. Oakmont with separate reclaimed irrigation meter had lesser usage on potable water. Tioga on the other hand irrigated with potable water.

Yearly SVI on a census tract level for the specific years of the study and other socio-economic measures such as population, per capita income, poverty, and household size were used in the analysis. The analysis was performed on four communities in Alachua County, Florida; two at the west and two at the east of the county. Socio-economic measures and physical features were evaluated for communities in the four locations to evaluate whether there is a relationship between water use patterns, spatial characteristics of development such as percent impervious and runoff, and measures of SVI. Spatial and basic statistics was used for this analysis.

The western part of the county has had more intensive development in recent years compared to the eastern part of the county. The eastern communities have a high SVI and low potable water use per capita compared to the western communities. The number of households and population were the primary drivers of potable water use per census block. Percent impervious surface and runoff volume did not show any significant. relationship with a community's SVI. At the parcel level, statistically significant differences were found between communities. For example, potable water use per parcel was lower in communities with high SVI.

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1. Introduction

Historically, growing population can result in resources depletion, ecosystem disturbance, and habitat degradation as the growing population relies heavily on environmental and natural resources. To address this problem, the term sustainability, sustainable construction, or sustainable development have become the new paradigm of development (Brundtland Report, WCED 1987; Du Pisani, 2006; Lele, 1991). This paradigm has been widely accepted by governments and organizations as the much-needed solution to the environmental concerns. However, environmental degradation continuous and has even worse in urban areas as more of the world's population shifted from rural to urban clusters (More than fifty five percent of the global population lived in cities in 2010 and more cities in the world have more than one million inhabitants) (UN, 2011, Steffen et al., 2011; UN, 2014; Vörösmarty et al., 2013; Zhou, 2022).

One of the most critical resources under stress through depletion is freshwater resources. The importance of water to human life and the environment cannot be downplayed (UNESDOC, 2015; MEA, 2005; Revenga, 2005; Abell et al.2008). Water is the source of life (Rippl, 2003) and has a vital role in human and environmental health. Fresh water supports ecosystem functions and helps in food and energy security (Kemper and Sadoff 2003; Falkenmark and Folke, 2003; Folke 2003; Rippl 2003; Vörösmarty, et al., 2005; United Nations, 2015). Despite the importance of water in the environment, sadly, very little emphasis is placed on implementing sustainable water related processes in the built environment (Falkenmark 2003). Usually, sustainable efforts are geared towards reducing energy and carbon due to the assumption that water is in abundance on the earth surface. However, although there is abundance water (eighty percent of the earth's surface is water), only about three percent is available to human and ecosystem as freshwater of which most currently less accessible in ice and deep underground. Efforts towards water sustainability in the built environment are crucial for maintaining healthy water resources (Gleick and Palaniappan, 2010; USGS, 2016; Shiklomanov and Rodda, 2004; Vörösmarty, et al., 2004).

Coupled with water depletion from increased urbanization is the growing increase in imperviousness as natural and more pervious land cover is converted into less pervious or impervious developed land cover which consequently impact the hydrologic cycle and the water balance (Rockström et al., 2014; Blueplanet, nd; Cosgrove & Loucks, 2015). SVI combines a of factors to determine the vulnerability. Since SVI yielded a weak relationship, other socio-economic factors were investigated. Past research investigating water use impact by socio-economic factors found that factors such as income, population, GDP, per capita income, electricity usage and irrigated land areas led to increased water withdrawal and use (Alacoma et al., 2007, Oki et. Al., 2003; Arnell, 2004; www.usf.uni-kassel.de/watclim). Therefore, socio-economic measures such as population density, household size, per capita income, and poverty rate and irrigation (with and without) potable water were analyzed to evaluate the relationship between water use patterns and these factors across the county and in the communities. The western communities had newer development and less parcels compared to the eastern with much older construction, which impacted their water use. Oakmont with separate reclaimed irrigation meter had lesser usage on potable water. Tioga on the other hand irrigated with potable water whereas the eastern communities has only a single serve meter.

Therefore, understanding urban water dynamics, the spatial and temporal variabilities in the urban setting can help create effective systems for ecological, water and socioeconomic sustainability.

2. Description of Area under Study

2.1 Alachua County, Town of Tioga and Oakmont and Duval and Lincoln Case Study Areas

The spatial unit of analysis in the simulation is the parcel. The results were analyzed on the parcel level and on the county, and neighborhood levels by aggregating parcel-level results. Alachua County, Florida contains the four communities analyzed. The Duval and Lincoln neighborhoods were selected from the eastern part of Alachua County and the Tioga and Oakmont neighborhoods are located in the western part of the county.

Alachua County is located in north central Florida. It has a population of 263,291 according to the 2018 population estimate (growth-management.alachuacounty.us, 2019). Fifty percent of the county's population is in Gainesville Florida, ten percent from the remaining towns and cities and the remaining forty percent from unicorporated areas. It has a total land area of 620036.9 acres (FGDL). Alachua County has most of its urban cluster located around the central part of the county and more preservation and agricultural lands at the outskirts (Data and Analysis for CPA-03-19 Adoptation Nov 2019).

Four residential communities, The Town of Tioga, Oakmont, Duval, and Lincoln neighborhoods in Alachua County, Florida were used in this analysis. They are primarily single family residential properties with some supporting commercial facilities. The choice of these four neighborhoods was based on their similarity in terms of planning. For example, the two western neighborhoods exhibit similarities in planning and so does the two eastern neighborhoods. However, the eastern and western neighborhoods are different from each other.

For instance, while Tioga and Oakmont are located in the south western part of the county, Duval is in the north eastern part of the county and Lincoln is in the south eastern part of the county. The four neighborhoods also have unique characteristics with regards to geographical location, socio-economic characteristics, and their water and irrigation use. This gives an opportunity to investigate an interesting perspective of how potable water use, irrigation, geographical location, and socio-ecomonic factors impacts the water balance in a mainly potable water-based residential community and in a potable water and reclaimed water-based residential community. Also, the fact that the eastern neighborhoods are older residential communities when compared to the western communities helps understand model behavior over time due to changes in technology, consumer behavior, and ultimately water efficiency. The western side of Alachua County has seen relatively more development in recent years compared to the eastern side.

The Town of Tioga (see Figure 2A), about 298 acres land area, is an established neighborhood that has seen development over the past thirty years. It has properties dated as far back as 1986. There are 18 different phases with about 23 phases for future development and total of 537 units (Alachua County Property Appraisal; FGDL). Tioga uses potable water for both domestic uses and irrigation.

The Oakmont neighborhood, a 633 acres land, is a relatively new community (see Figure 2B) starting in 2014 and planned to be completed by 2024. It has 999 planned residential units (Oakmontfl.com; FGDL. Oakmont has both portable water, for domestic use and reclaimed water, for irrigation. The use of reclaimed water resulted in less potable water usage in Oakmont.

Duval and Lincoln are neighborhoods (Figure 2C and D) in eastern Alachua County that have seen some major changes in developed land cover in the analysis time span. Duval and Lincoln communities date as far back as the early 1900s. Duval covers an area of 402.73 acres and has over 900 parcels (FGDL). Duval uses potable water for its indoor and irrigation uses. Lincoln has 347.77 acres of land area with about 884 parcels (FGDL). All four communities are primarily serviced by GRU's Murphree Wellfield and Water Treatment plant, which extracts water from the Floridan aquifer

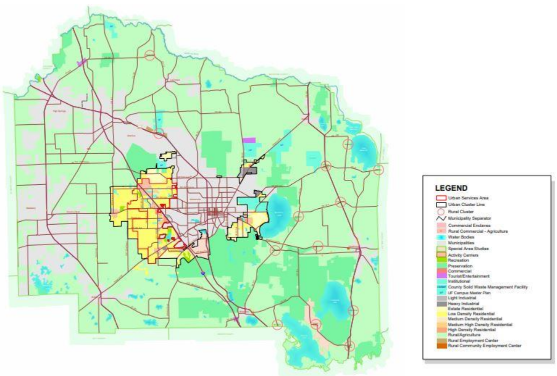
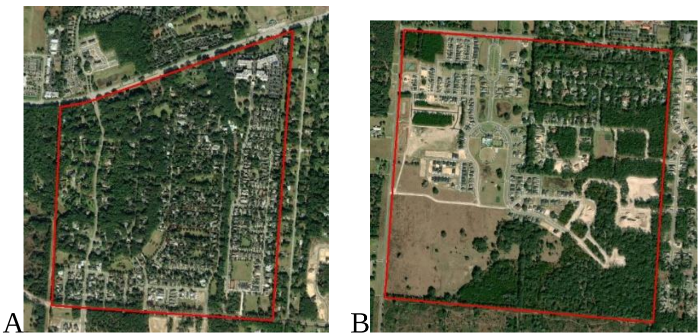


Figure 1: Alachua County Land Use Zoning



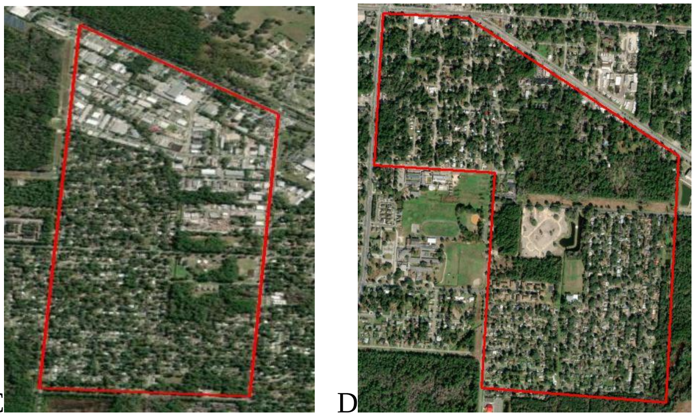


Figure 2: Aerial View with Neighborhood Boundary of A) Tioga Neighborhood, B) Oakmont Neighborhood, C) Duval Neigborhood, and D) Lincoln Neighborhood

3. Methods

This analysis started with creating a scatter plot of potable water and overall SVI (RPL_Themes) and RPL_Theme1 (Socioeconomic), RPL_Theme2 (Housing Composition & Disability), RPL_ Theme 3 (Minority Status & Language) and RPL_ Theme4 (Housing Type & Transportation). This analysis was conducted on a census tract spatial scale because SVI data and other census tract-level variables such as population and employment are census tract-level data. Annual SVI data was available for 2010, 2014, 2016 and 2018.

Scatter plot can be created in ArcGIS and the result is displayed with the corresponding R squared values. The variables tested with the scatter plot can then executed in the OLS geoprocessing toolbox once the dependent and explanatory variables are identified using scatter plots. In this case, the dependent variable was potable water and the explanatory variables were all four SVI themes and overall SVI. Another OLS analysis was conducted for potable water and population, per capita income, poverty, unemployment as explanatory variables. A report and a map are the results of this geospatial process.

3.1 Data Sources and Collection

Alachua County Property Appraisal Data and Florida Geographic Data Library (FGDL)

Parcel data was obtained from both the Alachua County Property Appraisal and FGDL websites. Alachua County Property Appraisal website give data relative to Alachua county only whereas FGDL is a GIS data center for Florida spatial data. Parcel and building information were taken from these sources. Information such as building use type, parcel size, year built, land area and many more were obtained from this source. For example, percent impervious area was calculated parcel size and building footprint. Data cleaning was done to select the right parcel information. For example, extremely small parcels (parcels less than 1,200 square feet). Extremely and extremely large parcels were ignored and not included in the analysis.

Gainesville Regional Utility (GRU)

Water use data was obtained from the county's major utility provider, GRU. Metered potable water use, irrigation and reclaimed water usage as well as wastewater generation on monthly basis were obtained. Data obtained from GRU was in a spreadsheet format. Potable water was categorized under residential regular service (W-RES), general service area regular service (W-GS), residential irrigation service (W-RIR) and general service area irrigation service (W-IR). Wastewater was also grouped under the various categories including wastewater general service area regular service (S-GS), wastewater residential regular service (S-RES), wastewater residential irrigation (S-RES_IR) and waste residential reclaimed water (S-RW).

A house either used potable water or with reclaimed water for irrigation and it is typical to have one potable water meter per parcel. If used for irrigation, reclaimed water is on a separate meter. Potable water for irrigation is estimated as sixty percent of a household's potable water. This was based on past studies and facility's operations.

Weather or Climate data

Daily weather data was collected from the National Weather Service Forecast Office, NOWData or NOAA Online Weather Data. Water balance variables were computed from precipitation, temperatures and relative humidity values. NOAA weather data is available for different location by various spatial scales. Solar radiation was obtained from National Solar Radiation Database (NSRDB) and National Renewable Energy Laboratory (NREL). Data cleaning was done and made consistent and simplified for the analysis.

Social Vulnerability Index (SVI) data

SVI was obtained from the CDC website (CDC SVI 2018 Document, 2020). SVI was obtained in a yearly time step. However, since SVI data is based on a census tract information, it was not available for all years in the analysis period. The years for which SVI data were available within the analysis period were 2010, 2014, 2016 and 2018. At the neighborhood scale, the census block within which a neighborhood is found is used as the SVI for that neighborhood. For interim years SVI remains unchanged i.e., 2010, 2012 and 2013 have the same SVI as 2010

4. Results

The focus of this analysis was to determine if potable water use was related to spatially distributed socio-economic factors. The analysis examines the effect of geographical location and associated socio-economic factors on potable water use. Socio-economic factors are measured using the Social Vulnerability Index (SVI) (CDC SVI 2018, 2020). SVI's spatial unit is the census tract, so this analysis is conducted on the census tract spatial scale. Using a census tract spatial scale also allowed the inclusion of other census variables in the analysis.

An independent sample T test was used to analyze the differences in potable water use for high SVI and low SVI neighborhoods. Tioga and Duval Neighborhoods were used in this analysis due to their low and high SVIs and similarity in total population and housing units (Figure 3). The null hypothesis is that neighborhoods with low SVI do not use more potable water than neighborhoods with high SVI.

The results from the independent sample T test (Table 1) showed that there is a statistically significant difference between potable water use per parcel in Tioga and Duval (p=0.000) for all years from 2010 through 2018. The mean difference in potable water ranges from 11.66 to 19.36. The null hypothesis was rejected, and we conclude that potable water use for Tioga and Duval have a statistically significant difference in the years 2010 to 2018. Potable water use per parcel in Tioga is higher than that of Duval and lower SVI can mean higher potable water use.

An Independent Sample T-Test was also used to examine evapotranspiration, runoff, and infiltration in Tioga and Duval from 2010 to 2018. The results showed a significantly different in evapotranspiration and infiltration for years 2010 through 2018. This can be attributed to the fact that evapotranspiration and infiltration differences are driven by potable water use whereas runoff is driven by precipitation. Runoff from precipitation was statistically significant for 2010 (p=0.001), 2014 (p=0.000), 2015 (0.014), and 2016 (p=0.000). Runoff in Duval was often greater than runoff in Tioga.

Scatter plot analyses were used as a preliminary screening tool for the relationship between potable water use and four SVI themes and overall SVI in 2010 and 2018 in Alachua County. The analysis for overall SVI and potable water yielded an adjusted R squared of negative 0.06 for 2018 and an adjusted R squared of negative 0.01 for 2010. Both adjusted R squared values yielded negative values, meaning as potable water use increases in 2018 and 2010, SVI decreased which is also observed in the graphical analysis (Figure 3). However, the relationship is very weak. Since the adjusted R squared obtained was low, scatter plot analysis was conducted with other SVI themes (RPL_Theme1 (Socioeconomic), RPL_Theme2 (Housing Composition & Disability), RPL_ Theme3 (Minority Status & Language) and RPL_ Theme4 (Housing Type & Transportation)) individually for years 2018 and 2010. The results also yielded low adjusted R values, with the highest R squared value obtained with RPL_Theme 1, Socioeconomic (adjusted R squared value=-0.1 (2018),-0.04 (2010)).

Since the adjusted R squared values are low, scatter plot for individual factors in census data that could impact potable water use were tested. These included total population estimate (E_TOTPOP), poverty estimate (EP_POV), unemployment estimate (EP_UNEMP), housing Unit (HU), per capita income (E_PCI), and crowd/household level estimate (occupied housing unit having more people than rooms (E_CROWD).

Descriptive statistics for 2018 census data (Table 2) showed an average total population per census district in Alachua County of 4,699, mean housing units of 2,076, mean number of households of 1,733, mean poverty of 966, mean unemployment of 144, mean per capita income of $26,892, and a mean potable water use of 11.21 inches. The descriptive statistics for 2010 census data (Table 2) were 4,361 mean total population, 1,982 mean housing units, 1,794 mean number of households, mean poverty of 964, mean unemployment of 146, mean per capita income of $24,446, and mean potable water use of 18.53 inches.

The adjusted R squared for 2018 showed the highest relationship to potable water use in census blocks are the number of households (adjusted R squared=0.39), followed by population (adjusted R squared=0.33). Adjusted R squared in 2010 also showed number of households (adjusted R squared=0.5) followed by population (adjusted R squared=0.29) as the variables with a stronger relationship to potable water. Since the scatter plot comparisons for the number of households (E_HH) and population (E_TOTPOP) census block data had better adjusted R squared values, these variables were used in the spatial statistics analysis.

Instead of potable water use per parcel, an additional variable, potable water use per person, was estimated and tested using a scatter plot. Potable water use per person was calculated by dividing total potable water use in the census block by the estimated total population in the census block. Results from the scatter plot produced adjusted R squared values between 0.0 and 0.07. Scatter plot analysis of runoff and percent impervious against all four SVI themes and total SVI had similar low adjusted R-squared values.

OLS was used to investigate the relationship between potable water use and the number of households and population in 2018 and 2010 since these had stronger relationships in the scatter plot analysis (Figure 4A, B and C) and between potable water use and SVI in 2018. Model residuals were within the expected range. For potable water use and the number of households and population results showed an adjusted R squared=0.37 in 2018 and an adjusted R squared=0.48 in 2010, therefore only about forty percent of potable water use is explained. Results from OLS analysis of the dependent variable potable water and the explanatory variables SVI Themes 1, 2, 3, 4, and total SVI (Figure 5) resulted in an adjusted R squared value of 0.14 for 2018. Only the number of households had a significant p-value. The Jarque-Bera statistics were all significant indicating model bias. Graphical analysis shown in table 3 and a correlation analysis were conducted to see the correlation between potable water and other socio economic factors which were perceived to affect water usage, Total population, number of housing units, per capita income, percentage of people below poverty, percent of people unemployed. The result was a strong relationship between potable water use and the other variables assessed indicating other variable other than the SVI can significantly impact water use.

Another area which was seen to show significant impact on water consumption was irrigated areas. Parcels either had a separate irrigation meter (either reclaimed water or potable water). For example, Oakmont homes had separate irrigation meters for reclaimed water, so water use for irrigation were directly quantified, and their water consumption was lower compared to the other communities. Tioga has very few houses with separate potable water irrigation meters (12 out of 477 cases). Irrigation water use from the separate meters were high compared to the domestic water used, mostly between 55% to over 100%. As stated earlier, an assumption of 60% of metered potable water is assumed for irrigation for parcels without separate irrigation meters. Both eastern neighborhoods had single service meters, as do the majority of parcels in Alachua County and these parcels showed higher water use compared to Oakmont.

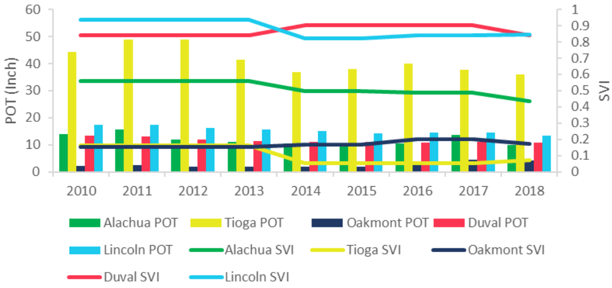


Figure 3: Potable Water and Social Vulnerability Index at County and Neighborhood Scales from 2010 to 2018

Table 1: Mean Difference, T value, P value, and Confidence Interval for Independent Sample T Tests of Annual Potable Water Use per Parcel in the Tioga and Duval Neighborhoods from 2010 Through 2018

	Mean Difference	T value	df	P value	Confidence interval	
					Lower Limit	Upper Limit
POT_2010	18.50	15.554	1316	0.000	16.16	20.83
POT_2011	19.36	16.202	1363	0.000	17.02	21.70
POT_2012	16.25	15.487	1364	0.000	14.20	18.31
POT_2013	13.08	13.244	1399	0.000	11.20	15.01
POT_2014	11.66	12.180	1386	0.000	9.78	13.53
POT_2015	14.61	15.389	1362	0.000	12.75	15.47
POT_2016	16.56	17.534	1367	0.000	14.70	18.41
POT_2017	17.51	17.234	13.80	0.000	15.51	19.50
POT_2018	17.06	16.501	1366	0.000	15.03	19.09

Table 2: Descriptive Statistics for Population, Household, Poverty, Unemployment, Per Capita Income, and Number of People per Room Estimates for Alachua County Census Tracts for 2010 and 2018

	2010			2018		
	Mean	Min	Max	Mean	Min	Max
E_TOTPOP	4416.71	921	9990	4699.07	816	11308
E_HH	1794.93	36	3962	1733	36	3967
E_POV	964.14	12	3886	965.57	10	3568

E_UNEMP	146.45	0	462	143.72	0	405
E_PCI	24446.48	2533	56752	26892.20	2155	50767
E_CROWD	30.91	165	0	31.75	0	213

Table 3: Comparison of Total Population, Housing Units, Percentage of People below Poverty, Percent of People Unemployed (16+ years) and Per Capita Income for Tioga and Duval for Years 2010 and 2018

Community	Year	TotPop	Housing Units	Per Capita Income Estimate	Households with more persons than room	Percentage of people below Poverty	Unemployment rate Estimate
Tioga	2018	6301	2484	45904	0	0.137	0.055
Duval		6655	2448	18756	3	0.863	0.747
Tioga	2010	5452	2361	32817	0	0.0805	0.0470
Duval		5665	2327	16705	56	0.210	0.185

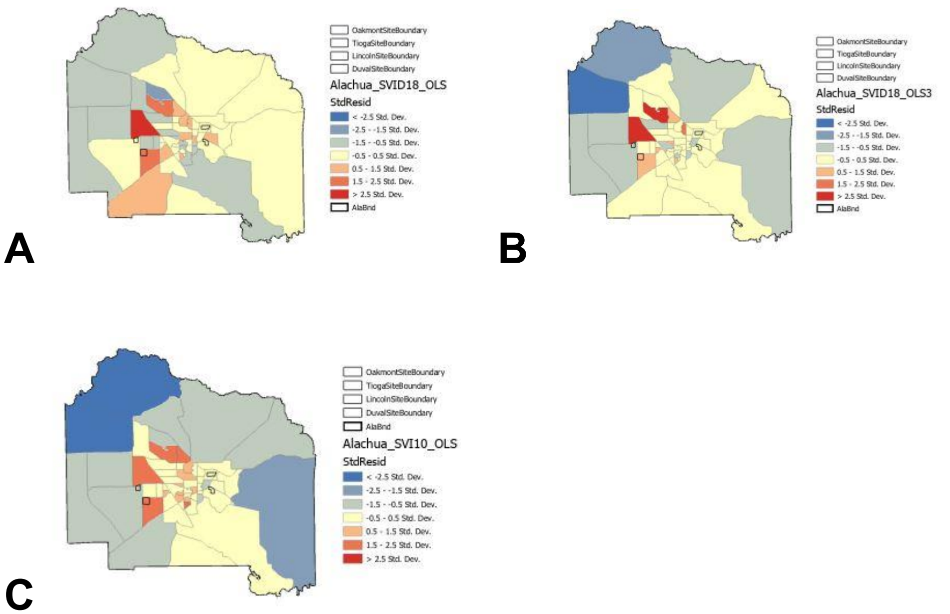


Figure 4: A Ordinary Least Squares Regression Analysis of Social Vulnerability Index and Potable Water in Parcels in Alachua County in 2018; B, Ordinary Least Square Analysis of Total Population and Household Estimates and Potable Water in census blocks in Alachua County in 2018 C, Ordinary

Least Square Analysis of Total Population and Household Estimates and Potable Water in census blocks in Alachua County in 2010

Summary of OLS Results - Model Variables

Variable	Coefficient [a]	StdError	t-Statistic	Probability [b]	Robust_SE	Robust_t	Robust_Pr [b]	VIF [c]
Intercept	12304.416154	15183.240598	0.810395	0.421552	13425.960014	0.916465	0.363820	--------
RPL_THEME1	-27504.20538	26573.655069	-1.035018	0.305639	22112.486110	-1.243831	0.219362	7.630024
RPL_THEME2	11637.434813	21273.678421	0.547034	0.586789	21394.940312	0.543934	0.588905	5.011929
RPL_THEME3	52892.491808	24500.641374	2.158821	0.035689*	23081.446235	2.291559	0.026179*	1.973912
RPL_THEME4	18865.339541	26321.302826	0.716733	0.476872	26613.413489	0.708866	0.481698	6.864603
RPL_THEMES	-34943.97618	58418.220879	-0.598169	0.552427	51958.020461	-0.672542	0.504334	23.833260

Figure 5: Summary of Ordinary Least Square Results Model Variables. Ordinary Least Square Regression of Potable Water, Overall Social Vulnerability Index, Socioeconomic, Housing Composition & Disability, Minority Status & Language, Housing Type & Transportation for Alachua Census Data 2018.

5. Conclusion

There was no difference in the trends in runoff, infiltration, and evapotranspiration when modeled at different spatial scales, i.e., the county, neighborhood, or parcel scale. The analysis did reveal different behavior in different locations. This was attributed to physical differences such as development type, density, and socio-economic differences as measured by social vulnerability and other measures, leading to differences in potable water and irrigation use. There was however difference in potable water used based on location and some socio-economic factors such as household estimate. Also, factors such as whether a parcel irrigated or not and whether the parcel used reclaimed water or potable water for irrigation affected the water use.

6. Limitations and further research

The research focused on ground water since Florida depends mostly on groundwater use, therefore surface water such as river, lakes, springs were not considered and this can give different results. Also, different geographical locations with larger special scale may also influence the results. It is recommended that the research is done on a larger scale such as hydrologic units or river management districts or on a regional scale that covers more than one county with different climate zones and also incorporate the use of surface water in future research.

The use of reclaimed water made a difference in this research. Hence future research should explore low impact development, smart technologies, water and energy efficient measures can be incorporated in the analysis.

Future research should also delve into the interaction of climate change with socio-economic factors, land use and land cover change and hydrologic models and their impact. It is also important to look into policies to address disparities in developmental strategies and how to bridge the gap to achieve better water management strategies for all.

Cost benefit analysis in the form of lifecycle costing and lifecycle analysis could also be incorporated into future research to analyze cost associated with different sustainable scenarios and also an energy analysis on water and wastewater treatment plants to investigate cost efficient options.

References

Abell, R., Thieme, M. L., Revenga, C., Bryer, M., Kottelat, M., Bogutskaya, N., ... & Petry, P. (2008). Freshwater ecoregions of the world: a new map of biogeographic units for freshwater biodiversity conservation. BioScience, 58(5), 403-414.

Alcamo, J., Flörke, M., & Märker, M. (2007). Future long-term changes in global water resources driven by socio-economic and climatic changes. Hydrological Sciences Journal, 52(2), 247–275. https://doi.org/10.1623/hysj.52.2.247

Arnell, N. (2004) Climate change and global water resources: SRES emissions and socio-economic scenarios. GlobalEnviron. Change 14, 31–52.

CDC SVI 2018 (2020) Document https://www.atsdr.cdc.gov/placeandhealth/svi/documentation/pdf/SVI2018Documentation-H.pdf

Cosgrove, W. J., and Loucks, D. P. (2015). Water management: Current and future challenges and research directions. Water Resources Research, 51(6), 4823-4839.

Data and Analysis. Alachua County Comprehensive Plan 2001 – 2020 https://growth-management.alachuacounty.us/formsdocs/Data_and_Analysis_CP_2001_2020.pdf

Du Pisani, J. A. (2006). Sustainable development–historical roots of the concept. Environmental sciences, 3(2), 83-96.

Falkenmark, M., & Folke, C. (2003). Introduction to Freshwater and welfare fragility: syndromes, vulnerabilities, and challenges. a theme issue compiled and edited by M. Falkenmark & C. Folke. Phil. Trans. Roy. Soc. Lond. B Biol. Sci, 358, 1917-1920.

Falkenmark M, Molden D. 2008. Wake up to realities of river basin closure. International Journal of Water Resources Development 24: 201–215.

Flörke, M., Schneider, C., & McDonald, R. I. (2018). Water competition between cities and agriculture driven by climate change and urban growth. Nature Sustainability, 1(1), 51-58.

Folke, C. (2003) Freshwater for resilience: a shift in thinking. Phil.Trans.R.Soc. Lond.B358,2027–2036. (DOI 10.1098/rstb.2003.1385.

Gleick, P.H. and Palaniappan, M. (2010) Peak water: conceptual and practical limits to freshwater withdrawal and use. Proceedings of the National Academy of Sciences of the United States of America 107(25): 11155-11162.

Gwenzi, W., & Nyamadzawo, G. (2014). Hydrological impacts of urbanization and urban roof water harvesting in water-limited catchments: a review. Environ Process 1: 573–593.

Kemper, K. and Sadoff, C. (2003). The global water challenge. World Bank Global Issues Seminar Series (available at http://siteresources.world- bank.org).

Lélé, S. M. (1991). Sustainable development: a critical review. World development, 19(6), 607-621.

Ngigi SN, Savenije HHG, Thome JN, Rockström J, Penning de Vries FWT (2005) Agro-hydrological evaluation of on-farm rainwater storage systems for supplemental irrigation in Laikipia district, Kenya. Agric Water Manag 73(1):21–41

Ngigi SN, Savenije HH, Gichuki FN (2007) Land use changes and hydrological impacts related to up-scaling of rainwater harvesting and management in upper Ewaso Ng'iro river basin, Kenya. Land Use Policy 24(1):129–140

Oki T., Agata, Y., Kanae, S., Saruhashi, T. & Musiake, K. (2003) Global water resources assessment under climaticchange in 2050 using TRIP. In: Water Resources Systems—Water Availability and Global Change (Proc. SapporoSymp., July 2003) (ed. by S. Franks, G. Blöschl, M. Kumagai, K. Musiake & D. Rosbjerg), 124–133. IAHS Publ.280. IAHS Press, Wallingford, UK.

Revenga, C., Campbell, I., Abell, R., De Villiers, P., & Bryer, M. (2005). Prospects for monitoring freshwater ecosystems towards the 2010 targets. Philosophical Transactions of the Royal Society B: Biological Sciences, 360(1454), 397-413.

Ripl, W. 2003 Water: the bloodstream of the biosphere. Phil. Trans.R.Soc.Lond.B358, 1921–1934.(DOI10.1098/ rstb.2003.1378.)

Rockström, J., Falkenmark, M., Allan, T., Folke, C., Gordon, L., Jägerskog, A., ... & Postel, S. (2014). The unfolding water drama in the Anthropocene: towards a resilience-based perspective on water for global sustainability. Ecohydrology, 7(5), 1249-1261.

Shiklomanov, I. A., & Rodda, J. C. (Eds.). (2004). World water resources at the beginning of the twenty-first century. Cambridge University Press.

Steffen, W., Persson, Å., Deutsch, L., Zalasiewicz, J., Williams, M., Richardson, K., ... & Svedin, U. (2011). The Anthropocene: From global change to planetary stewardship. Ambio, 40, 739-761.

United States Census Bureau, 2012. U.S. and World Population Clock. Available from: www.census.gov/popclock

United States Geological Survey (USGS) (2014a). United States, county-level data file. http://water.usgs.gov/watuse/data/2010/ index.html

United States Geological Survey (USGS) (2014b). United States, state-level data file, Table 14. Trends in estimated water use in the United States, 1950–2010. http://water. usgs.gov/watuse/data/2010/index.html

United States Geological Survey (USGS). (2016). How much water is there on, in, and above the Earth? U.S. Geological Survey. Retrieved from http://water.usgs.gov/edu/earthhowmuch.html

United States Geological Survey (USGS) (nd). Fundamentals of the Water Cycle https://www.usgs.gov/special-topic/water-science-school/science/fundamentals-water-cycle?qt-science_center_objects=0#qt-science_center_objects. Accessed June 2018

Vörösmarty, C., Lettenmaier, D., Leveque, C., Meybeck, M., Pahl-Wostl, C., Alcamo, J., & Lansigan, F. (2004). Humans transforming the global water system. Eos, Transactions American Geophysical Union, 85(48), 509-514.

Vörösmarty, C. J., Léveque, C., Revenga, C., Bos, R., Caudill, C., Chilton, J., & Barker, S. (2005). Fresh water. Millennium ecosystem assessment, 1, 165-207.

Vörösmarty, C. J., Pahl-Wostl, C., Bunn, S. E., & Lawford, R. (2013). Global water, the anthropocene and the transformation of a science. Current Opinion in Environmental Sustainability, 5(6), 539-550.

WCED (World Commission on Environment and Development). 1987. Our common future, Oxford: Oxford University Press.

Zhang, D., Sial, M. S., Ahmad, N., Filipe, A. J., Thu, P. A., Zia-Ud-Din, M., & Caleiro, A. B. (2020). Water scarcity and sustainability in an emerging economy: a management perspective for future. Sustainability, 13(1), 144.

Zhou, C., Xie, Y., Zhang, A., Liu, C., & Yang, J. (2022). Spatiotemporal analysis of interactions between seasonal water, climate, land use, policy, and socioeconomic changes: Hulun-Buir Steppe as a Case Study. Water Research, 209, 117937.

www.usf.uni-kassel.de/watclim

https://wrcwebsite.azurewebsites.net/