2023 Annual Conference & Exposition
Baltimore Convention Center, MD | June 25 - 28, 2023
The Harbor of Engineering Education for 130 Years
ASEE
Paper ID #40161

How Active Rainwater Harvesting May Help Reduce Nuisance Flooding: Flood Analysis and Social Barriers to Adoption

Isabel Lopez, University of Texas at El Paso

Isabel Lopez is a Graduate Research Assistant at the University of Texas at El Paso pursuing a master's degree in Environmental Engineering. She obtained her undergraduate degree in Civil Engineering from the University of Texas in 2020. She completes training and research development in environmental sciences, remote sensing technology, and electric vehicle adoption. Her current research explores alternatives to reduce socioeconomic disparities in nuisance flooding in urban neighborhoods.

Dr. Ivonne Santiago, University of Texas at El Paso

Dr. Ivonne Santiago is a Clinical Professor of the Civil Engineering (CE) Department at the University of Texas at El Paso (UTEP). Dr. Santiago has a combined experience of over 20 years in the areas of water quality, water treatment and wastewater treatm

How Active Rainwater Harvesting may help Reduce Nuisance Flooding: Flood Analysis and Social Barriers to Adoption

Introduction/Background

Rainwater harvesting allows for the collection and storage of rain instead of allowing the rain to become runoff and accumulate in streets. In a residential setting, the water can be collected on a roof, also known as a "catchment area," and then can be redirected for storage in a tank, cistern, or reservoir. This method is classified as active rainwater harvesting (RWH) and is one of two methods available to help capture some or most of the rainfall in a targeted area. The second category is passive, which relies on native plants and trees that flourish based on the area's climate conditions and allows some ground infiltration. Although presented as separate options, active and passive can be used together. The opportunity to use one or the other depends on the landscape and the user's time and financial capabilities. Still, if allowed, both strategies can be implemented to spread the harvested water over the entire landscape. This will enable the water not captured in a cistern/tank to be scattered throughout and permit maximum infiltration. Each RWH technique provides its benefit alone and together, but in active RWH, using a cistern/tank allows the use of the water collected during dry times. Depending on the characteristic we want to address, either method can be favorable. For this study, the main points of consideration are RWH's impacts on urban infrastructure and flooding, locations, and longevity of use.

Rainwater collection is a traditional and straightforward method that dates back hundreds, even thousands of years; archeological evidence attests to the capture of rainwater as far back as 4000 years, and in China, it dates back even further [21]. Historically, the community's needs prompted RWH due to the lack of potable and non-potable water and an absence of a large-scale water distribution system. At the start, rainwater harvesting catchment and storage was much simpler, and the usage of collected water was direct and without treatment [22]. In places where there is still an absence of a reliable water system, a more complex rainwater harvesting system is needed.

Most notably, rainwater harvesting is the preferred method to address water scarcity or lack of clean water [3]. However, its benefits to reducing flooding in residential areas have yet to be readily evaluated. The degree of implementation of RWH varies by location and available resources. The true potential of RWH systems has remained untapped because the benefits have yet to be quantified. Extreme climate events like drought and flood presently occur because of global weather change [22]. Not only areas that experience heavy amounts of yearly rainfall and homes that fall in a designated flood zone are affected by some of these rain events. However, anyone, no matter their location, can be at risk of flooding. If the rain falls fast enough and accumulates in low-lying areas, it is enough to create hazardous conditions, known as Nuisance flooding. Nuisance flooding is also known as "sunny day flooding/clear-sky flooding," which refers to quick-to-form flooding scenarios that cause a public inconvenience by overwhelming existing storm infrastructure, such as storm drains, coincidently causing road closures. In contrast to extreme flood events, sunny-day flooding disrupts routine daily activities and, in some cases, produces minor property damage.

The quantifiable effects of sunny-day flooding have yet to be thoroughly investigated; however, it is essential to review existing literature and work that can aid in understanding and measuring the consequences of urbanization. In urbanized areas, residential neighborhoods primarily comprise large areas of impermeable surfaces that do not allow water infiltration. Impervious surfaces include rooftops, driveways, and sidewalks, generating runoff volumes that accumulate and can cause flooding conditions.

If rainwater harvesting is a practice that has been around for many years, why has it yet to be widely implemented and accepted to reduce sunny-day flooding? Rainwater harvesting can be adapted after a home is built. Still, it could be beneficial to incentivize the inclusion of rainwater harvesting in building design and have regulations that monitor and allow for the large-scale use of the practice. Fundamentally, lack of education and knowledge is the primary inhibitor to developing the Rainwater Harvesting System and its adoption [25].

In places such as Costa Rica, Mexico, and Peru, considered semi-arid regions, which are dry with some precipitation, communities collect road rainwater and implement the collected water for irrigation. Another location with advanced rainwater harvesting collection is Australia, where the collection is used as a supplemental or primary water source to capture some runoff to manage urban stormwater management. The benefit of rainwater harvesting in Australia is evident. For this reason, the Australian state and local governments adopted a wide range of policies, including subsidies and grants, to provide the installation of rainwater tanks in houses [23].

The community's needs determine how rainwater harvesting may benefit them the most. Rainwater harvesting is a technology that can be adapted to tailor the requirements and provide a sustainable method to address water shortage or flooding conditions. However, a significant push to extend this technique is required. Specifically, considerable efforts are still needed in research, investments, information, public education on the importance of rainwater harvesting, economic incentives (subsidies and tax exemptions), suitable legislation, and regulations [23]. Public education can provide the foundation for understanding the importance of rainwater harvesting and give us context on the barriers preventing people from participating.

Perception of Climate Change and Willingness to Modify Lifestyle

Rainwater harvesting has been deemed a viable option to help mitigate sunny-day flooding, as presented by research in the literature [6],[7],[19]. However, it is essential to consider how views on climate change can affect the population's willingness to participate in a community effort to alleviate flooding conditions that were once not the norm.

Climate change in recent years has been more evident, most notable through temperature shifts since it is the most apparent change that communities can detect. It is crucial to understand the community's perceptions and understanding of climate change to know their disposition to make personal changes that can help decrease the effects of climate change. To do so, we must understand what they consider normal or abnormal, which can be affected by age and cognitive biases. Age represents how long an individual has been around to observe and notice climate changes. Personal characteristics such as relationship status, socio-economic status, and culture can increase an individual's vulnerability, in addition to their gender. Climate change acts as a health threat multiplier through a multifactorial framework of direct and indirect mechanisms while increasing health inequalities [20].

Often climate change is thought of as extreme weather events and or increased frequency of such events. However, "smaller-scale events" such as heavy rainfall, resulting flood events, and increased temperatures can create the same climate change effects as "extreme weather events." Overall, the impacts of climate change can fluctuate, affecting the population's health by causing heat stress or even death in extreme cases.

Misconceptions about climate change can act as a barrier to action. For example, if people believe they are not at risk or will not see the effects of climate change in their lifetime, they will not act. To further understand these misconceptions, it is necessary to consider the type of public understanding of climate change and the sources they use to keep informed. If misinformation spreads, it may delay any action to mitigate climate change. Scientists constantly present new findings that correspond to how harmful the effects of climate change are and how they will only worsen if they are not addressed. However, despite the results that explain the causes and hazards of climate change, most of the public seems unwilling to participate in actions that could help reduce the consequences of climate change. When dealing with climate change, there is a wait-and-see preference where many prefer to, in a sense, wait till it becomes what they consider a "real problem" where it is evident that there is an issue. However, as pointed out by multiple authors, it can be problematic due to the long delays between detecting a problem and implementing corrective actions [8]. In the end, disciplinary action might not be enough if implemented when climate change has progressed past the mitigation point.

As all barriers and misconceptions are identified, a proper strategy using education and outreach activities is needed to address them and help reduce the effects of climate change. Milovanic and Shealy surveyed engineering students and determined that only 30 percent understood climate change's specific causes and methods [13]. Early implementation in education could be the key to increasing understanding and spreading information to future generations who will likely have to deal with the consequences of the current lack of action. Current and future engineers are the basis to help solve the effects of climate change on the current population and the answer to developing solutions that can become the basis for the prevention of consequences of climate change. Suppose engineering students, or students in general, are provided with an education where they are presented with all the information and studies on climate change; it will become a foundation that can be built on. In that case, misconceptions can be eliminated or, at the very least, minimized to prevent misinformation from continuing to spread.

Additionally, the sources of information, such as social media and family/friends' opinions, were found to negatively impact the understanding of climate change compared to literature, courses, and information presented by scientists [13]. Compared to the older generation, young people often consume all their news from social media, which shapes who they are, what they believe, and how they identify themselves. Introducing a climate change curriculum early on can help provide them with additional credited sources that help shape their knowledge and understanding. As engineers, if they choose to focus on addressing the effects of climate change, they must fully understand and get rid of misconceptions to develop solutions and present their findings to the community. To teach and provide information that will allow community members to become adequately educated to take preventive actions to address the effects of climate change. To obtain a picture of the needs and wants of a community, we need to hear from the community. This can be achieved through survey distribution, one-on-one communication, or focus groups. A survey for this study allowed for the investigation of perceptions, knowledge, and possible willingness to participate.

Survey Deployment and Results in El Paso, Texas

The area of interest is in a northeast El Paso, Texas, neighborhood. El Paso is considered a high desert with high temperatures and receives, on average, 9 inches of rain annually. Summer monsoons bring heavy rains from June through September. The inundation caused by rains during and outside monsoon season can put communities at risk of flooding, especially in highly urbanized sections where large amounts of runoff are generated. The impacts of unexpected heavy rains can be alleviated through preventative methods, such as passive and active rainwater harvesting (RWH). A 37-question survey was designed to help understand the perceptions, opinions, and understanding of RWH and climate change and what are the barriers to the adoption of RWH practices. The IRB-approved survey was deployed in English and Spanish due to the predominantly Hispanic (81%) and Spanish-speaking population of the survey area in Northeast El Paso. The participation rate was 66.9%, with 105 responses received. Operating under the assumption that not everyone will know RWH practices, each section was prefaced with a brief introduction about what RWH meant and the two methods, active and passive. Method 1 (active) is above the ground by installing rainwater barrels on the side of the home. Method 2 (passive) is adding plants and trees to retain some water.

Section 1: Demographic Information

It is essential to understand the demographic of the survey pool, as well as their socio-economic status. About half of the participants made an annual income of about $30,000-$40,000, while about 25% of the applicants made about $40,000-$50,000. The level of education observed among the participants was "Highschool diploma or higher," (34.5%), and about 28.6% had some college education with no diploma. In terms of upper-level education completion, about 18% fell into that category. Another critical factor was the age breakdown of the participants. This parameter will help us understand how different age groups feel about climate change and RWH. The preliminary analysis of ages showed that 46% fell in the 30-39 age group while 30% were in the youngest age bracket of 20-29. Only 9% of the participants were 50 and older, while 15% were in the 40-49 category. Therefore, the majority demographic of the participants ranged from 20-39 years of age.

El Paso, Texas, has a prominent Hispanic population, so it was predicted that it would be the majority in the breakdown of the ethnicity of those who participated. About 42% of the participants identified as Hispanic, Latino, or Spanish, 36% were white, and 22% identified as other minorities such as Black, Asian, or American Indian.

According to the census, $51,325 is the median annual income in El Paso; the categories of revenues of participants ranging from $0-$10,000, $20,000-30,000, and $30,000- $40,000 were grouped to observe how their responses defer from those participants with higher income. About 62 participants out of a total of 105 (59%) fell into the lowest-income group of ($0-$40,000).

Section 2: Perceptions, Opinions, and Knowledge about Rainwater Harvesting

To the question: "Have you ever had any experiences with rainwater harvesting at your home, either at your home, apartment complex, or with relatives or friends," approximately half of the participants (29%) have yet to gain experience with RWH in their home or their parent's home, with only 19% having experienced it first-hand in the house of relatives or friends (Figure 1a). A primary difference was the increase in the number of people who have seen RWH. In the high-income group ($40,000-$60,000), 33% of participants have visited an RWH system installed in someone else's home (Figure 1b). Consequently, for all participants that had observed RWH in real life, 12 participants from the low-income category and 14 from the high-income group were all willing to participate in RWH initiatives.

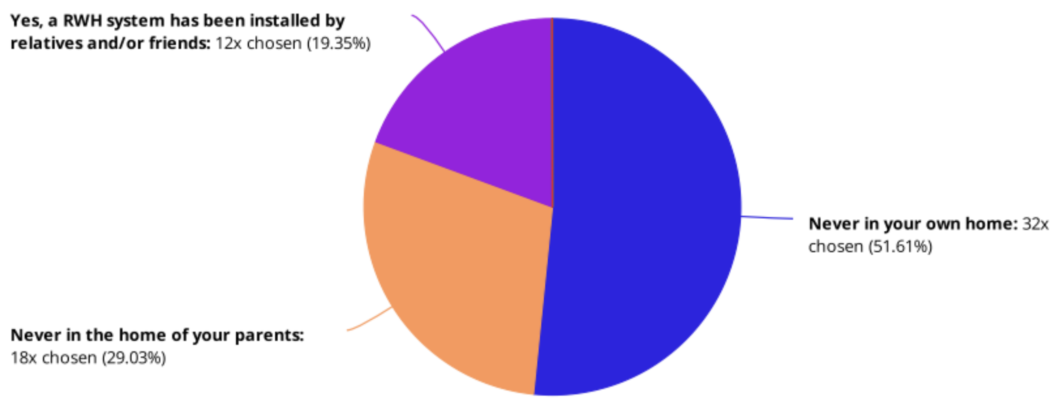

Figure 1a. Low-Income ($0-$40,000) RWH Prior Exposure.

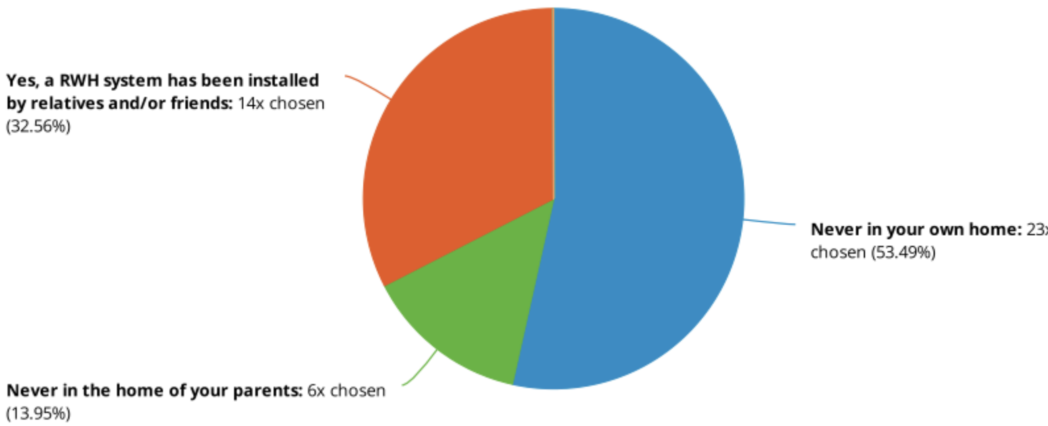

Figure 1b. High-Income ($40,000-$60,000) RWH Prior Experience.

To the question: "What method would you be interested in having at your home," 19 out of 43 participants (44%) of the high-income group would prefer to put a barrel down compared to 34 out of 62 participants (55%) of the low-income groups (Figure 2a-2b). Method 1 refers to using a tank or rain barrel on their property where the water captured is conveyed from an impervious surface. In contrast, Method 2 uses "below the ground" methods, such as planting local vegetation and modifying the landscape to help capture some of the water from a rainfall event. There was a difference in the type of methods of RWH- each income group would be inclined to implement. Higher-income groups seem to slightly prefer Method 2 over Method 1, while the opposite is true for the lower-income category (Figure 2a-2b).

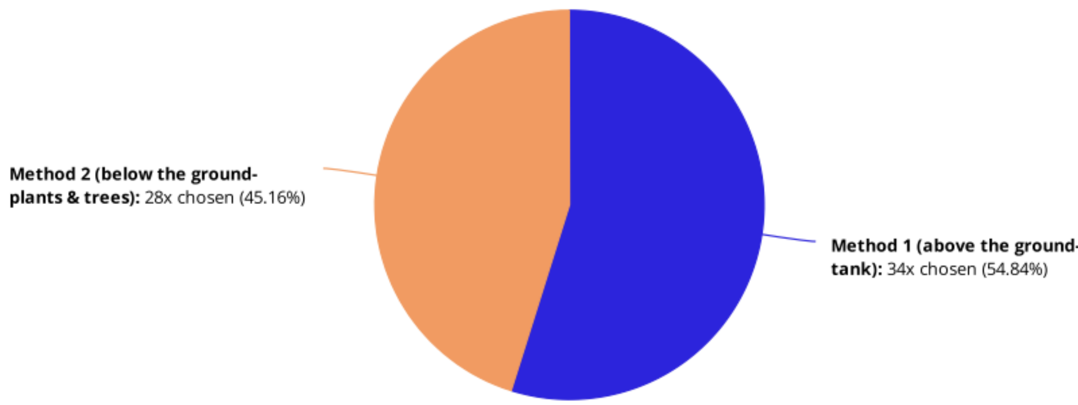

Figure 2a. Low-income Bracket ($0-$40,000) preferred RWH method 1

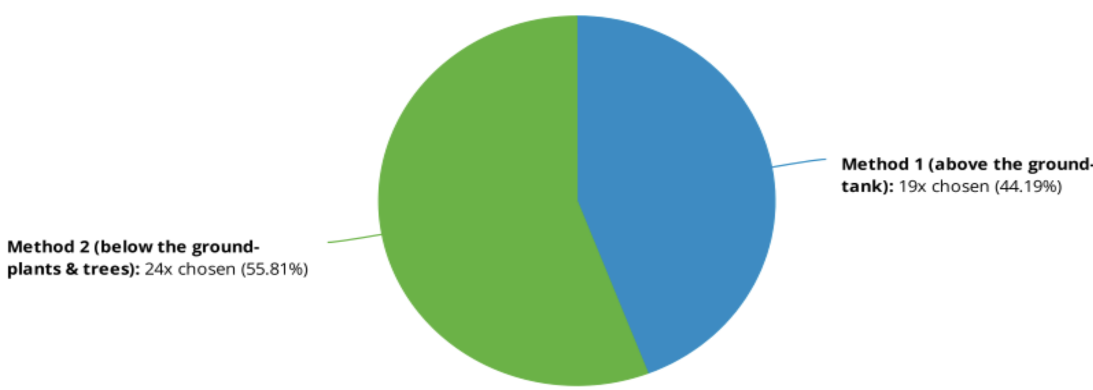

Figure 2b. High-income interest ($40,000-$60,000) preferred RWH method 2.

As we continued to investigate the differences, we wanted to understand the reasons for a change in preference among both groups. For the lower-income groups, 97% experienced flooding conditions. Of the higher-income groups, 88% have experienced flooding. Since lower-income groups have experienced flooding, this makes them much more likely to look for some type of resolution, such as RWH using a barrel.

The amount of money the participants are willing to spend differs among the low-income and high-income groups. In the low-income group ($0-$40,000), the most they are willing to pay is $0-$50 to participate in implementing RWH, with 30% not willing to pay. The high-income group has a more comprehensive range of variance; about the same percentage (10-15%) are willing to pay either $0-$50, $50-$100, $100-$150, or $150-200, while about 32% are not willing to pay at all.

These results from the survey will help us understand the willingness to adopt RWH and pay for water harvesting of participants. Combined with technical information on areas more likely to experience sunny day flooding, the results will help us identify the areas where adopting RWH practices would be successful. In other words, when the willingness to pay and implement RWH and the need to control sunny-day flooding are aligned, we can prioritize areas of likely successful implementation of RWH practices.

Section 3: Climate Change

There are no comprehensive studies about the perceptions, opinions, and knowledge of climate change of residents of El Paso. Our study targeted the population in Northeast El Paso, a typical middle-class, predominantly Hispanic neighborhood of El Paso. The questions in the survey allowed us to find the relationship between climate change opinions and their willingness to partake in RWH.

An initial analysis was completed to compare how different income groups perceive climate change. The exact breakdown of high and low-income groups was conducted in Section 2, where the low-income bracket was from 0- $40,000, and the high-income bracket was from $40,000-60,000. Although both groups in the majority believe that climate change is “Caused mostly or entirely by humans,” there is a higher percentage of participants in the low-income bracket, 35 out of 61 (57%) that selected this option (Figure 3a). The second most preferred option was the “caused equally by humans and natural causes”, while there are 7 out of 61 participants (11%) in the high-income bracket and 7 out of 43 (21%) in the low-income bracket who believe that “natural causes” entirely cause climate change (Figure 3a-3b). The perceptions of this sample showcase a population that does attribute human actions, their own included, to climate change; those that believe their actions do not contribute to climate change are the minority.

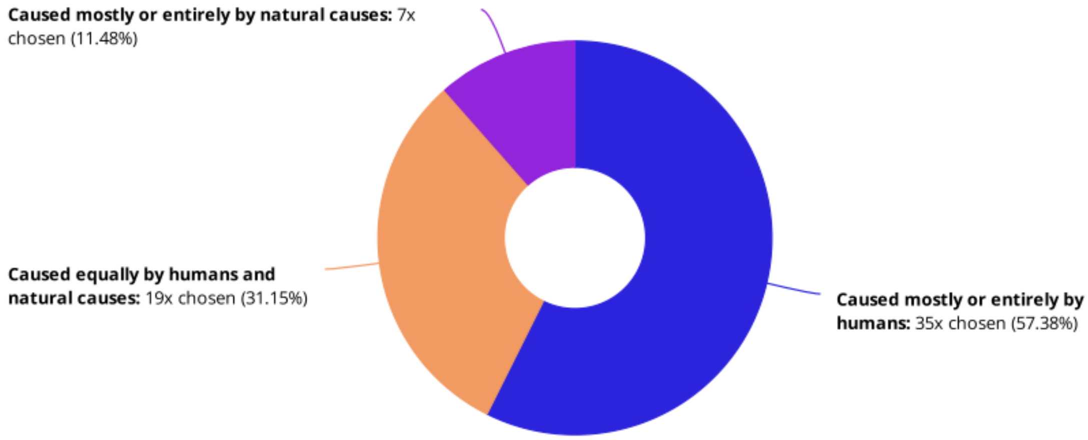

Figure 3a. Low-income Bracket ($0-$40,000)belief of cause of climate change.

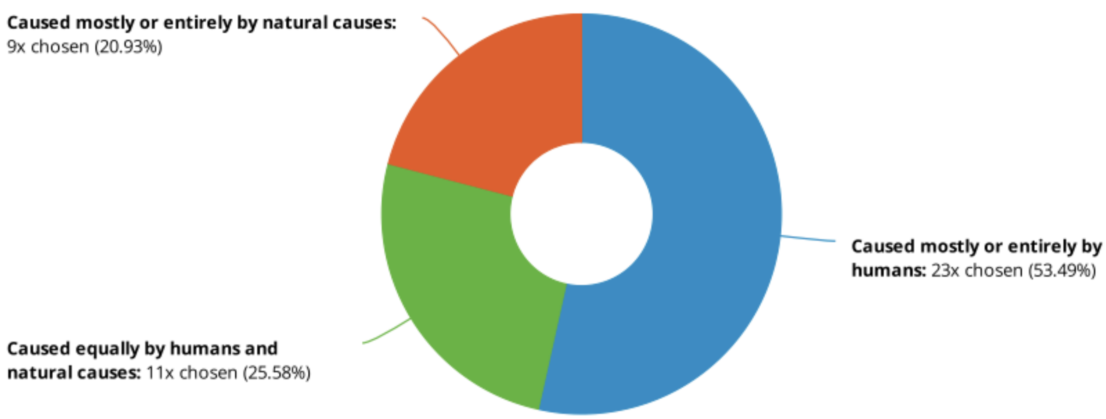

Figure3b. High-income interest ($40,000-$60,000) belief of cause of climate change.

To the question: “Have you personally noticed the following changes in the environment (climate) in the past ten years in your region?” 70 % of participants said they had noticed a change in temperature. Approximately 44% responded that they had seen a difference in the rain, 39% noticed floods, 35% noticed season shifts, and 18% noticed an increase in droughts. Most participants have noticed a regional change, and 11% have not seen any climate changes (Figure

4). Based on these responses, it can be determined that the community is aware of changes in the climate that are not the norm, and any changes are severe enough to be noticed.

Based on these responses, participants have noticed an increase or decrease in weather events enough to be aware that the climate is changing. The community is the most knowledgeable of temperature as a sign of climate change and rain.

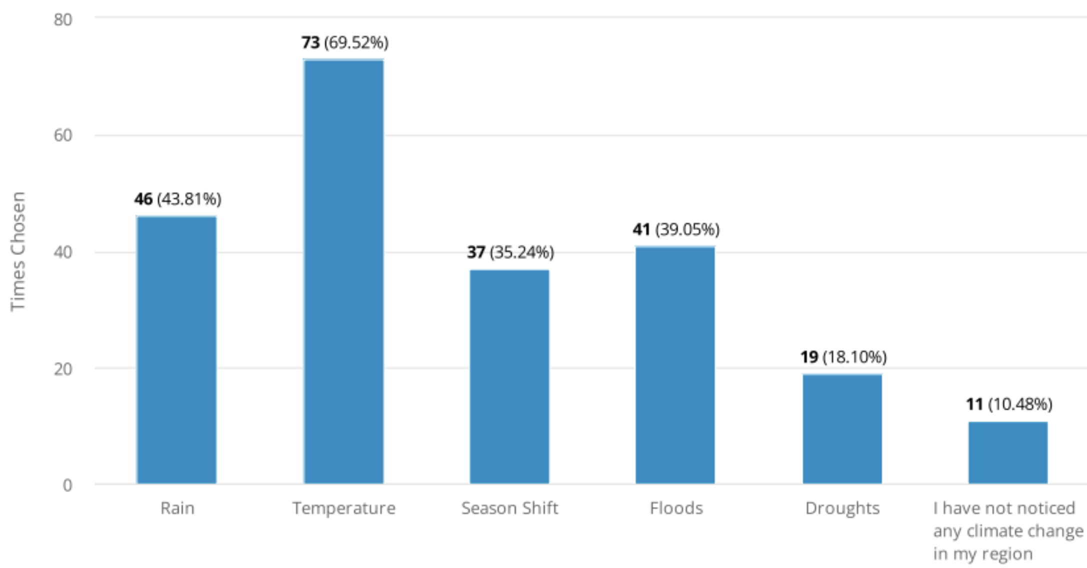

Figure 4. Climate changes observed in the community.

Although most participants have observed some change in climate change, we also wanted to observe if participants actively followed that type of information. To the question: "Do you follow climate change-related activities or policies?", 39 out of 105 participants (37%) followed climate change-related activities or policies, 48 participants (46%) selected no, and 18 (17%) chose not to specify. The low-income bracket does not follow climate change policies only 17 out of 62 (27%), as much as the high-income bracket 22 out of 43 (52%) (Figure 5a-5b.).

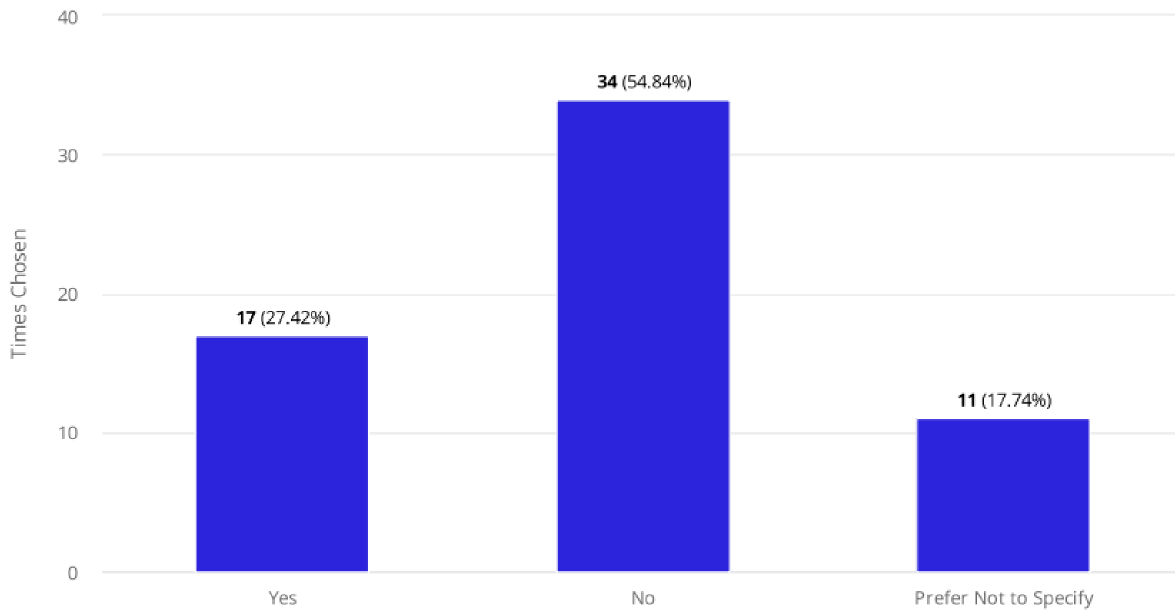

Figure 5a. Participants in low-income bracket ($0-$40,000) who follow climate change.

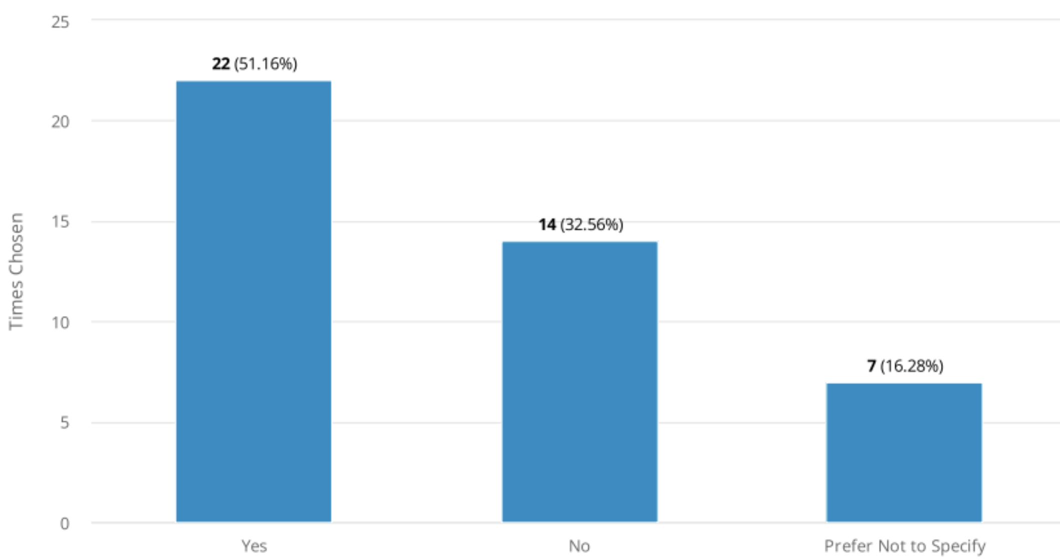

Figure 5b. Participants in high-income bracket ($40,000-$60,000) who follow climate change.

We wanted to determine if the participants considered climate change when making decisions about their household, such as reducing energy and water consumption, waste recycling, choosing alternative transportation methods to reduce air emissions, or insulating their homes.

The question allowed users to select multiple options. To the question: “Do you consider the environment and subsequent climate change when making decisions of….”, the most popular choice was waste recycling, with 64% of participants implementing recycling. Residents of the city of El Paso are provided with a blue receptacle for recycling. Other options like reduction in water consumption (55%) and energy consumption (43%) were also selected by most participants (Figure 6). Options that require additional expenses were not chosen as often, such as “buying environmentally friendly products (31%)”, “buying a car that consumes less fuel and is eco-friendly (17%)”, “alternative transport (11%)”, and “insulating a home (36%)” as observed in Figure 6.

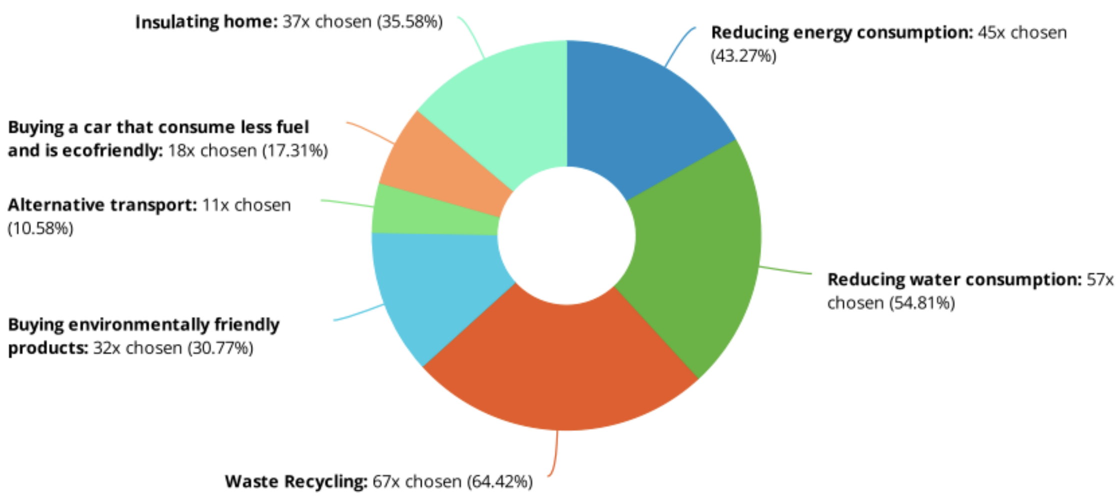

Figure 6. Household modification because of climate change.

To the question: “How worried are you about climate change?”, approximately half of the participants expressed concern about climate change. We wanted to observe how that concern manifested in the rest of their responses regarding other information about climate change and other considerations. As previously mentioned, the questions included perceptions of climate change, sources of information, and knowledge of existing policies.

To the question: “How worried are you about climate change?”, both the low-income group and high-income group consensus is that there is some concern about climate change. About 70% of participants in each category, 43 out of 61 participants, and 29 out of 42 participants for the low-income and high-income groups, respectively, express some worry. However, only 7 out of 61 (11%) and 12 out of 61 (20%) say they are “very worried (Figure 7a-7b).”

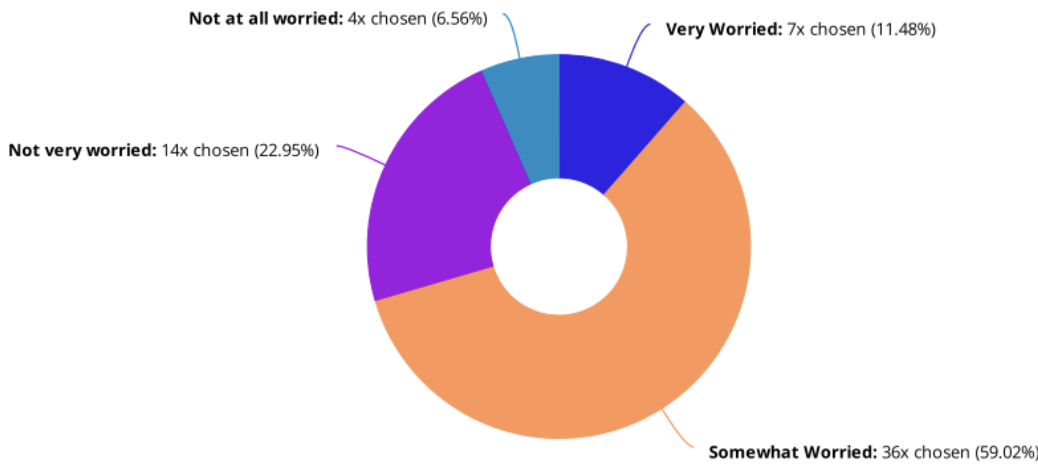

Figure 7a. Low-income bracket ($0-$40,000) concern regarding climate change.

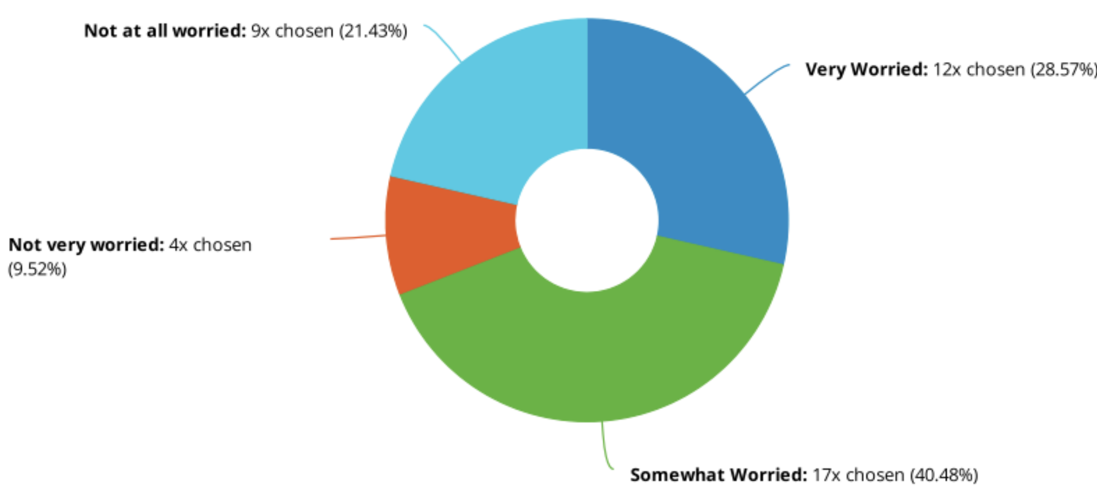

Figure 7b. High-income bracket ($40,000-$60,000) concern regarding climate change.

To the question: “Which is the primary source of information that helps you understand climate change?”, of the participants who expressed concern over climate change, 64% obtained information from the internet, and 49% received information from television (Figure 8a). The same is true of the total survey sample, where most participants obtained information from the

Internet (47%) and television (51%). A significant difference is that of those participants that expressed some degree of concern, only 3% did not use any source of information to help them in their knowledge/understanding of climate change compared to 14% of the total survey pool who did not use any external sources of information (Figure 8b).

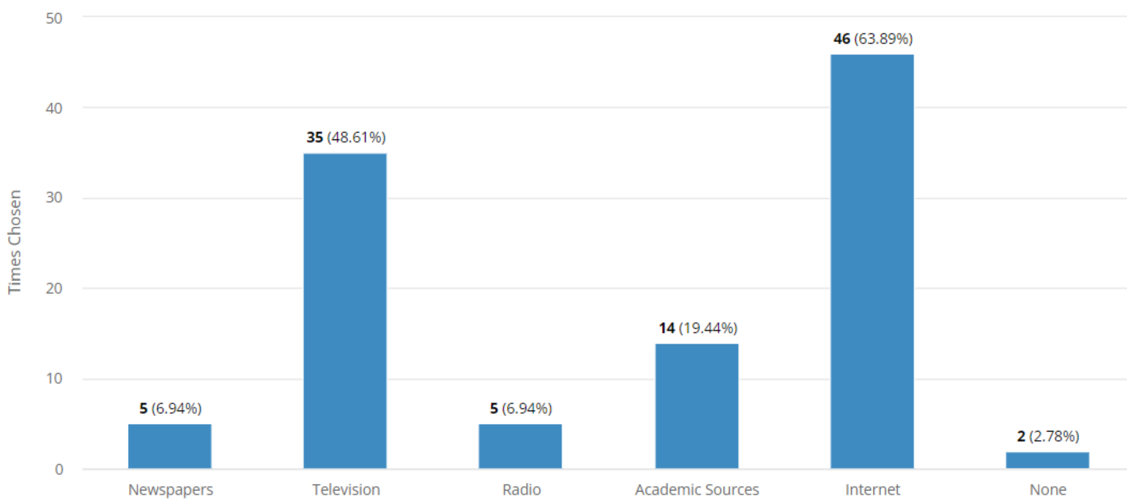

Figure 8a. Sources of Information about climate change used by participants who expressed concern over climate change.

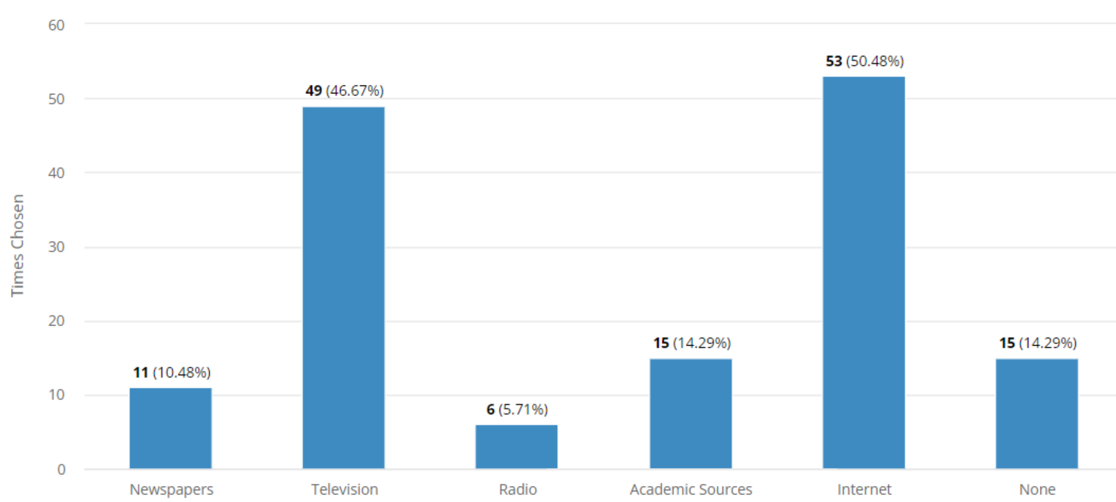

Figure 8b. Sources of Information about climate change used by all participants.

Relationship between Perceptions of Climate Change and Willingness to Participate in Rainwater Harvesting

A closer look was taken at the willingness of the participants to partake in RWH based on their opinions about climate change. Specifically, if someone is concerned with the effects of climate change on the environment, will the individual be more likely to participate in alternatives that can alleviate some of the concerns posed by flooding?

The cross-tabulation of the participant's responses to the question "How worried are you about climate change", was completed along with people who were interested in RWH and selected Yes to the question "In this case, are you interested in participating in RWH?", 65 out of 76 participants (86%) expressed some worry about climate change (Figure 9a). For participants not interested in RWH, 20 out of 26 (77%) were not worried about climate change (Figure 9b). A statistical analysis was performed to determine how much correlation exists between the interest in participation in RWH to climate change concerns. The correlation was evaluated using the Pearson correlation (r), measuring the strength and direction between two variables. An r-value of 0.60 was calculated, signifying that the strength of the association is moderate and strong. A positive correlation is indicated when one variable, in this case, the worry about climate change, changes the other variable, willingness to participate, will change in the same direction.

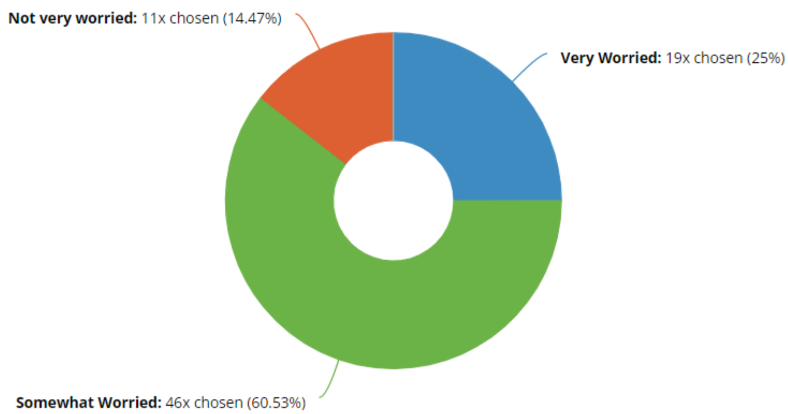

Figure 9a. Concern about climate change by participants interested in partaking in RWH.

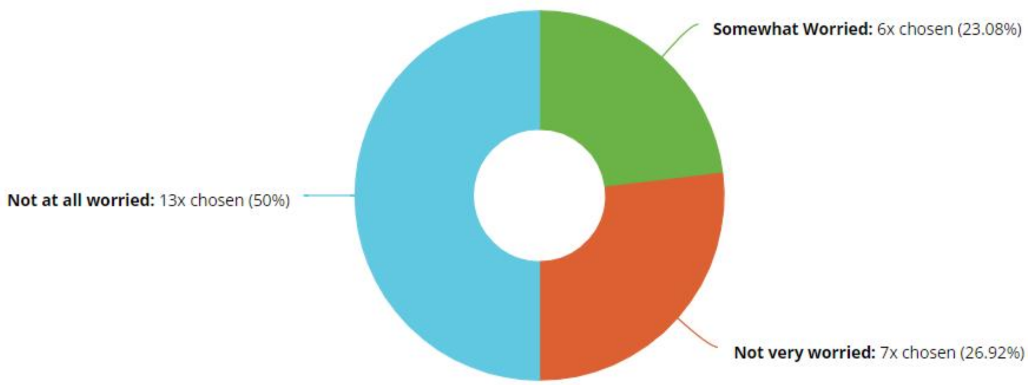

Figure 9b. Concern about climate change by participants not interested in partaking in RWH.

The cross-tabulation of the participant's responses to the questions: "How much do you know about collecting rainwater for future use?", and "How worried are you about climate change?", was completed and shown in Figure 10. Most participants worried about climate change also had some knowledge about RWH, 58 out of 72 (81%).

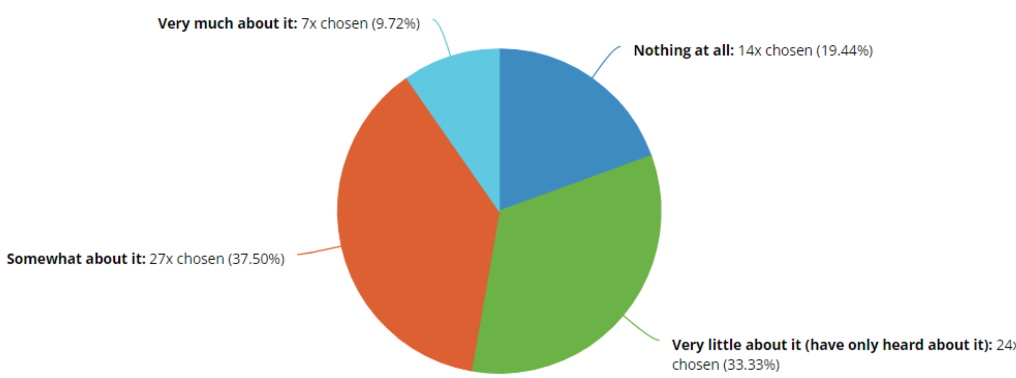

Figure 10. Rainwater harvesting degree of knowledge of participants who expressed concern over climate change.

The cross-tabulation of participants' responses regarding the questions: "What issue in your community do you believe rainwater harvesting can help minimize?", and "How worried are you about climate change?", was completed and shown in Figure 11. Of most participants, 67 out of 105 (64%) are concerned about flash floods, and 48 out of those 72 (67%) are concerned about climate change (Figure 11). Pertaining to other issues, such as global warming and the water crisis, the people most concerned are the participants worried about climate change.

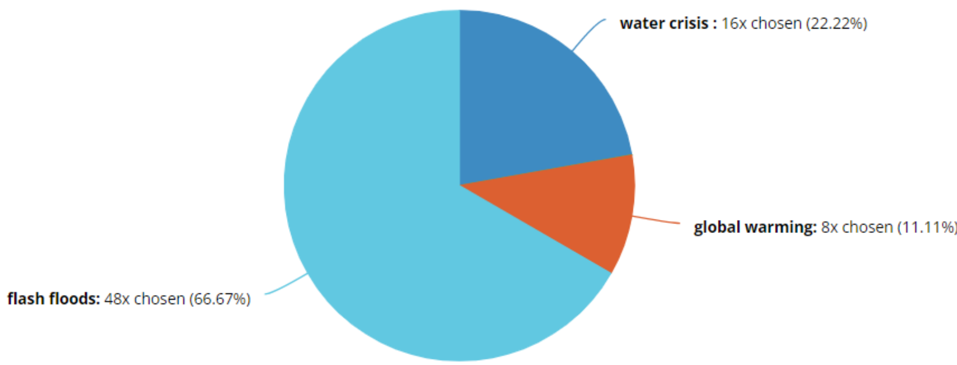

Figure 11. Climate change issues believed to be reduced by RWH of participants who expressed concern over climate change.

The final analysis was completed to gauge the importance of using RWH to meet gardening needs or flood reduction. The cross-tabulation of "How important would it be for you to collect rainwater in your house for your garden or other uses in your home?", and "How worried are you about climate change?", was completed in Figure 12a. The range of importance from "Only a bit" to "very important" has the most responses from participants worried about climate change, with 62 out of 72 participants (87%) finding the importance of RWH to meet gardening needs.

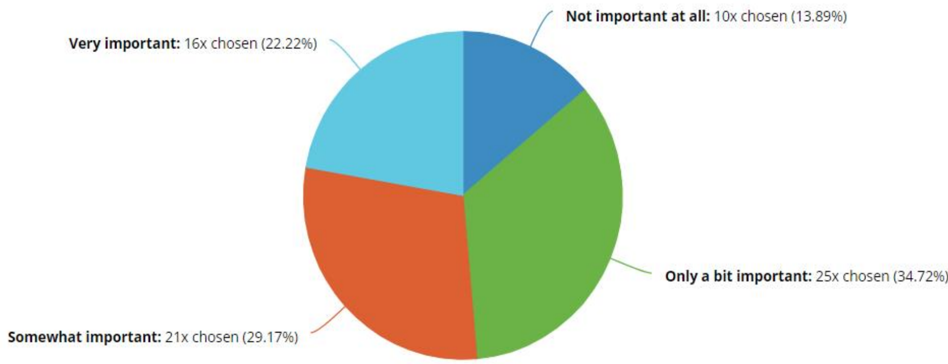

Figure 12a. Importance of RWH to meet gardening needs for participants who expressed concern over climate change.

To the question: "How important would it be to collect rainwater in your home to prevent flooding on the streets you drive, and your children play?", 67 out of 72 participants (93%) who worry about climate change think using RWH to keep water off the streets is important to some degree (Figure 12b).

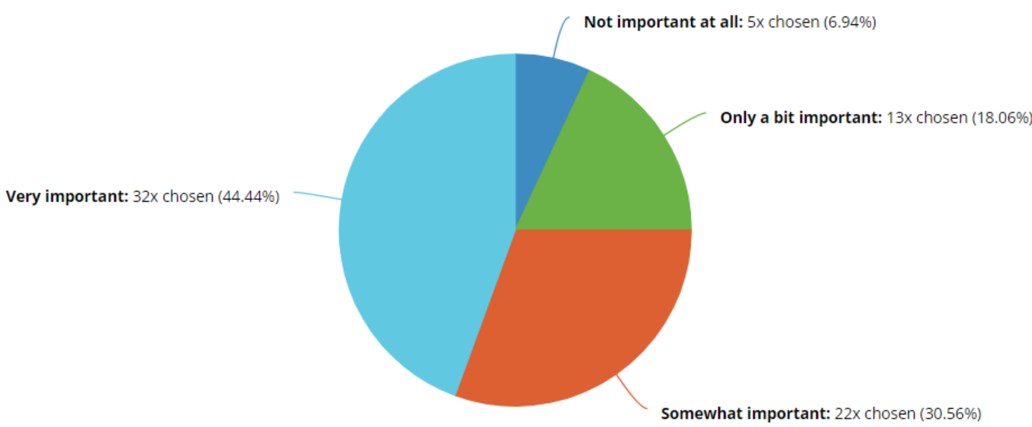

Figure 12b. The importance of RWH to prevent flooding for participants who expressed concern over climate change.

Conclusions

The research and literature on RWH to reduce sunny-day flooding are promising, but they require willing participants to get on board at an urban scale. The survey results provide an initial snapshot of the perception, knowledge, and opinions of a sample of residents of a low-income Hispanic neighborhood in El Paso. Therefore, it may not represent the large metropolitan city and county of El Paso as different areas have different breakdowns of ethnicities and income ranges. However, the average income of residents of this area is lower than other areas of east or west of El Paso. The results from this study helped us understand what can be done to influence the willingness to participate in RWH initiatives for a low-income Hispanic neighborhood and what can be done to increase the adoption of RWH practices to reduce sunny-day flooding in their neighborhoods. Adoption of RWH requires technical competence and an understanding of perceptions, opinions, and knowledge to recognize the barriers to adoption. Barriers can cause social and economic implications to advance RWH; all factors must be considered to develop outreach education programs.

Engaging a Hispanic community is important not just in El Paso but at a national level as the Hispanic population is the nation's second-largest racial or ethnic group behind white American and ahead of Black Americans, according to the US Census Bureau [24].

The willingness to participate in an RWH initiative was investigated by analyzing not only the socio-economic information of the participants but also their preconceived notions on the topic of RWH and climate change. Our results show that these can influence their willingness to participate in RWH practices:

1. In general, participants showed a genuine interest in learning about RWH practices that can help provide water for gardening purposes, and keep water off the streets, to ensure the safety of drivers and pedestrians.
2. The most appealing reason for engaging in RWH practices was water availability for gardening. It is common knowledge that rainwater benefits plant life and creates better-growing conditions for trees and plants. However, if proven, people who do not own a garden may be willing to participate in RWH to mitigate sunny-day flooding. This emphasizes the need to articulate to the public the benefits of RWH, not only to reduce flooding risks.
3. The high-income groups ($40,000-$60,000) were more likely to have witnessed RWH firsthand and had some initial knowledge about RWH practices. Of those, 100% were likely to adopt RHW. Based on the survey results, an introductory understanding of RWH is necessary for some participants to be willing to engage in RWH practices. Those who had witnessed active RWH using a tank at someone's house or firsthand were almost always willing to participate. Educational workshops at a more significant level can help bridge the knowledge gap of many participants. In addition, community events that allow for the demonstration of water catchment and its path to a tank can educate a community and encourage them to partake in such initiatives. This emphasizes the need to

provide pilot and hands-on demonstrations to engage and increase the adoption of RWH practices. Misconceptions or lack of knowledge are the leading cause of apprehension in active participation in RWH.

4. Participants indicated they would be willing to pay $50 for an RWH project in their homes. This can present an opportunity to incentivize participation in RWH initiatives.
5. The differing opinions on climate change, such as the belief that humans do not affect climate change, decrease the desire to participate in RWH practices. If someone believes that climate change effects cannot be attributed to human actions, then they will not see any benefit to RWH. Dissemination of accurate climate information through reliable sources is needed to sway opinions. Early in education, in grade school, and throughout the curriculum, along with visual demonstrations of the effects, can help diminish the misconceptions about climate change. Understanding climate change is the first step to helping connect people to available options to help reduce or prevent the results of climate events, such as sunny-day flooding.

Our results suggest that barriers to adopting RHW can be reduced through education and outreach activities that include hands-on demonstrations. Additionally, RWH workshops can provide a venue for participants to eliminate misconceptions, by demonstrating how RWH works and how it can benefit them by reducing water use for gardening and helping reduce sunny-day flooding in their own communities. Thus, educational workshops that display the basic elements and functions of the RWH system and costs are needed.

Furthermore, our findings show that opinions, knowledge, and perception of RWH may be influenced by social and economic considerations. Thus, this is an example of how social science must be incorporated into the deployment of technology and engineering practices if the adoption of these technologies is to be successfully accepted and embraced by communities. As Engineers, these are considerations that must be part of any design criteria that involve the deployment of technologies within communities. If we do not understand the desires and concerns of the communities that will decide whether they partake in RWH initiatives, we cannot be successful as Engineers with the technical skills to provide an alternative solution to alleviate sunny-day flooding.

Future work

Perceptions, opinions, and knowledge of RWH practices and climate change were evaluated in a northeast neighborhood of El Paso. The same analysis will be conducted for the city, including a much fuller picture of the sociodemographic breakdown, including a hydrologic/hydraulic analysis that will identify the areas prone to sunny-day flooding.

ACKNOWLEDGEMENT:
This study is supported and monitored by The National Oceanic and Atmospheric Administration – Cooperative Science Center for Earth System Sciences and Remote Sensing Technologies under the Cooperative Agreement Grant #: NA16SEC4810008.

The authors would like to thank The City College of New York, NOAA Center for Earth System Sciences and Remote Sensing Technologies, and NOAA Office of Education, Educational Partnership Program for full fellowship support for Isabel Lopez.

References

[1] A. Adham *et al.*, "A GIS-based approach for identifying potential sites for harvesting rainwater in the Western Desert of Iraq," *International Soil and Water Conservation Research,* vol. 6, *(4),* pp. 297-304, 2018.
Available: https://www.sciencedirect.com/science/article/pii/S209563391830114X. DOI: https://doi.org/10.1016/j.iswcr.2018.07.003.

[2] K. S. Balkhair and K. Ur Rahman, "Development and assessment of rainwater harvesting suitability map using analytical hierarchy process, GIS and RS techniques," *Geocarto Int.,* vol. 36, *(4),* pp. 421-448, 2021.
Available: https://utep.idm.oclc.org/login?url=https://search.ebscohost.com/login.aspx?direct=true&db=a9h&AN=148626975&site=ehost-live&scope=site. DOI: 10.1080/10106049.2019.1608591.

[3] T. M. Boers and J. Ben-Asher, "A review of rainwater harvesting," *Agric. Water Manage.,* vol. 5, *(2),* pp. 145-158, 1982.

[4] A. G. Burgos *et al.*, "Future Nuisance Flooding in Norfolk, VA, From Astronomical Tides and Annual to Decadal Internal Climate Variability," *Geophys. Res. Lett.,* vol. 45, *(22),* pp. 12,432-12,439, 2018. Available: https://doi.org/10.1029/2018GL079572. DOI: 10.1029/2018GL079572.

[5] M. Burns et al., The Stormwater Retention Performance of Rainwater Tanks at the Land-Parcel Scale. 2012.

[6] A. Campisano *et al.*, "Urban rainwater harvesting systems: Research, implementation, and future perspectives," *Water Res.,* vol. 115, pp. 195-209, 2017.
Available: https://www.sciencedirect.com/science/article/pii/S0043135417301483. DOI: 10.1016/j.watres.2017.02.056.

[7] M. J. Deitch and S. T. Feirer, "Cumulative impacts of residential rainwater harvesting on stormwater discharge through a peri-urban drainage network," *J. Environ. Manage.,* vol. 243, pp. 127-136, 2019.
Available: https://www.sciencedirect.com/science/article/pii/S0301479719306164. DOI: https://doi.org/10.1016/j.jenvman.2019.05.018.

[8] V. Dutt and C. Gonzalez, "Decisions from experience reduce misconceptions about climate change," *J. Environ. Psychol.,* vol. 32, *(1),* pp. 19-29, 2012.
Available: https://www.sciencedirect.com/science/article/pii/S0272494411000764. DOI: 10.1016/j.jenvp.2011.10.003.

[9] D. K. Dwivedi and P. K. Shrivastava, "Assessment of roof water harvesting potential of Navsari city of Gujarat State, India by Remote sensing and Geographic information system (GIS)," *Journal of Applied & Natural Science,* vol. 13, *(3),* pp. 1143-1150, 2021.
Available: https://utep.idm.oclc.org/login?url=https://search.ebscohost.com/login.aspx?direct=true&db=a9h&AN=152590716&site=ehost-live&scope=site. DOI: 10.31018/jans.v13i3.2798.

[10] K. K. Garg *et al.*, "Identifying potential zones for rainwater harvesting interventions for sustainable intensification in the semi-arid tropics," *Scientific Reports,* vol. 12, *(1),* pp. 1-18, 2022.
Available: https://utep.idm.oclc.org/login?url=https://search.ebscohost.com/login.aspx?direct=true&db=a9h&AN=156296573&site=ehost-live&scope=site. DOI: 10.1038/s41598-022-07847-4.

[11] B. Gavit *et al.*, "Rainwater harvesting structure site suitability using remote sensing and GIS," in Anonymous 2018, . DOI: 10.1007/978-981-10-5801-1_23.

[12] H. Karimi and H. Zeinivand, "Integrating runoff map of a spatially distributed model and thematic layers for identifying potential rainwater harvesting suitability sites using GIS techniques," *Geocarto Int.,* vol. 36, *(3),* pp. 320-339, 2021.
Available: https://utep.idm.oclc.org/login?url=https://search.ebscohost.com/login.aspx?direct=true&db=a9h&AN=148480827&site=ehost-live&scope=site. DOI: 10.1080/10106049.2019.1608590.

[13] J. Milovanovic, T. Shealy, and A. Godwin, "Senior engineering students in the USA carry misconceptions about climate change: Implications for engineering education," *J. Clean. Prod.,* vol. 345, pp. 131129, 2022.
Available: https://www.sciencedirect.com/science/article/pii/S0959652622007612. DOI: 10.1016/j.jclepro.2022.131129.

[14] H. R. Moftakhari *et al.*, "Cumulative hazard: The case of nuisance flooding," *Earth's Future,* vol. 5, *(2),* pp. 214-223, 2017. Available: https://doi.org/10.1002/2016EF000494. DOI: 10.1002/2016EF000494.

[15] D. N. Pandey, A. K. Gupta, and D. M. Anderson, "Rainwater harvesting as an adaptation to climate change," *Curr. Sci.,* pp. 46-59, 2003.

[16] P. Preeti and A. Rahman, "Application of GIS in Rainwater Harvesting Research: A Scoping Review," *Asian Journal of Water, Environment and Pollution,* vol. 18, pp. 29–35, 2021. . DOI: 10.3233/AJW210040.

[17] S. Samouei and M. Özger, "Evaluating the performance of low impact development practices in urban runoff mitigation through distributed and combined implementation," *Journal of Hydroinformatics,* vol. 22, *(6),* pp. 1506-1520, 2020.
Available: https://doi.org/10.2166/hydro.2020.054. DOI: 10.2166/hydro.2020.054.

[18] Q. Zhong *et al.*, "A GIS-based approach to assessing the capacity of rainwater harvesting for addressing outdoor irrigation," *Landscape Urban Plann.,* vol. 223, pp. 104416, 2022.
Available: https://www.sciencedirect.com/science/article/pii/S0169204622000652. DOI: https://doi.org/10.1016/j.landurbplan.2022.104416.

[19] A. Palla, I. Gnecco and P. La Barbera, "The impact of domestic rainwater harvesting systems in stormwater runoff mitigation at the urban block scale," *J. Environ. Manage.,* vol. 191, pp. 297-305, 2017.

Available: https://www.sciencedirect.com/science/article/pii/S0301479717300439. DOI: 10.1016/j.jenvman.2017.01.025.

[20] K. van Daalen *et al.*, "Climate change and gender-based health disparities," *The Lancet Planetary Health,* vol. 4, *(2),* pp. e44-e45, 2020.
Available: https://doi.org/10.1016/S2542-5196(20)30001-2. DOI: 10.1016/S2542-5196(20)30001-2.

[21] Texas Water Development Board (2005a). The Texas Manual on Rainwater Harvesting. Third Edition. Published by: Texas Water Development Board

[22] A. Che-Ani, S. N and A. Sairi, "Rainwater Harvesting as an Alternative Water Supply in the Future," *European Journal of Scientific Research,* vol. 34, 2009.

[23] S. Yannopoulos, I. Giannopoulou, and M. Kaiafa-Saropoulou, "Investigation of the Current Situation and Prospects for the Development of Rainwater Harvesting as a Tool to Confront Water Scarcity Worldwide," *Water,* vol. 11, *(10),* 2019. DOI: 10.3390/w11102168.

[24] C. Funk and M. H. Lopez, “A brief statistical portrait of U.S. Hispanics.” https://www.pewresearch.org/science/2022/06/14/a-brief-statistical-portrait-of-u-s-hispanics/.

[25] N. Ramya, M. M. Reddy, and P. B. T. Kamath, “Household ‘rain water harvesting’ - Who are practicing? Why are they practicing? A mixed methods study from rural area of Kolar district, South India,” vol. 8, no. 7, pp. 2528–2532, Jul. 2019, doi: 10.4103/jfmpc.jfmpc_417_19.