ABSTRACT

POKHREL, SHILA. Climate Change Impacts and Carbon Related Opportunities in Urban and Community Forestry: Perspectives of Non-Profit Organizations and Public Agencies in California, USA. (Under the direction of Dr. Rajan Parajuli).

Urban and community forests are increasingly acknowledged for their multiple market and non-market benefits, including their recognition as a natural climate solution in urban and developed areas. This study examines the perspectives of Non-Profit Organizations (NPOs) and public agencies involved in California's urban and community forestry (U&CF) toward climate-induced extreme weather events such as wildfires, wind, high heat, drought, flooding, and invasive species. Additionally, this study explores the involvement of these organizations in carbon-related opportunities, such as the Carbon Offset Markets (COM) and California Climate Investment Funding (CCIF) program. Data were collected through a state-wide online survey of NPOs and public agencies in California in 2022-2023. Results suggest that these organizations in California perceived drought, high heat, and wind as the most significant adverse impacts of climate change. The major perceived challenges in U&CF activities due to climate change include higher tree mortality rates and increased operational costs. Both NPOs and public agencies were found to have limited current participation and future likeliness to participate in carbon-related opportunities. The current participation and likeliness to participate in COM and CCIF programs varied significantly according to the size of the organizations, as measured by their annual operational budgets and the number of employees. This study emphasizes the importance of informed decision-making for U&CF stakeholders in developing and promoting climate change mitigation and adaptation plans and advancing carbon-related policies and programs in California.

Climate Change Impacts and Carbon Related Opportunities in Urban and Community Forestry: Perspectives of Non-Profit Organizations and Public Agencies in California, USA

by
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A thesis submitted to the Graduate Faculty of
North Carolina State University
in partial fulfillment of the
requirements for the degree of
Master of Science

Forestry

Raleigh, North Carolina
2024

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DEDICATION

To my late grandfather, in loving memory. I hope I have made you proud.

BIOGRAPHY

Shila Pokhrel was born in Arghakhanchi, a remote district of the middle hill region of Nepal. Her passion for nature and forests led her to obtain her undergraduate degree in Forestry. She started her career in forestry in 2017, working with the Federation of Community Forestry Users Nepal (FECOFUN) for the USAID-funded Hariyo Ban (*Green Forest*) program as a Monitoring and Evaluation Officer. Consequently, she entered Nepal's government service as a Forest Officer under the Ministry of Forest and Environment Nepal. For over five years, she worked closely with community forestry user groups, providing them with technical support for forest management operations and forest ecosystem restoration, including forest fire control, nursery management and plantation, and human-wildlife conflict management. On top of that, she coordinated and collaborated with local government, civil society organizations, politicians, and policymakers, sensitizing them towards environmental issues. Besides that, she actively advocated for gender equality in the forestry sector and the professional rights of government employees in Nepal. She was the youngest central executive member of the Nepal Government Employee's Organization. Meanwhile, she was equally involved in research and authored/coauthored multiple scientific research papers. In parallel, she also completed a master's degree in Natural Resources Management program from Pokhara University Nepal in 2019.

Shila enrolled in the M. Sc Forestry program at NC State University in 2023, with a research focus on urban and community forestry and a minor in Statistics. She plans to return to Nepal to support research, policy development, and implementation related to urban and community forestry, climate change mitigation, and sustainable forest management.

ACKNOWLEDGEMENTS

I sincerely thank my advisor, Dr. Rajan Parajuli, for all his efforts and extraordinary support during my studies. Without his relentless guidance, advice, and encouragement, it would not have been possible. His hard work and dedication to forestry will always be a massive inspiration.

I am grateful to my committee members, Dr. Barbara Fair and Dr. Jonathan Stallrich, for their immense support and contributions to accomplish this project. I am truly indebted to their invaluable time and commitment.

I want to thank the Department of Forestry and Environmental Resources of NC State University, which not only provided this degree and the resources but also offered invaluable personal and professional growth opportunities. This place became a milestone in my career.

I am thankful to Cal ReLeaf for providing this research opportunity and funding and to all the project members: Dr. Eric Wiseman and Brittany Christensen from Virginia Polytechnic Institute and State University, Dr. Natalie Love, Cindy Blain, and Megan Dukett from California ReLeaf, for all their effort and collaboration during the data collection process.

I want to thank my family members, friends, and relatives for their unconditional love and encouragement throughout this period. I am truly blessed to have my supportive and caring spouse, Sandip Khanal, and my adorable son, Saharsha Khanal, for their love, patience, and sacrifice to achieve my dreams.

Finally, I would like to extend my special appreciation to the Government of Nepal for facilitating this in-service professional development opportunity. Their support underscores the importance of continuous learning and growth in our field.

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CHAPTER ONE: INTRODUCTION

1.1. Background of the Study

There is clear research-based evidence that rapidly changing climates are prevalent worldwide, showing differences in atmospheric temperature, annual precipitation, snow cover, and sea level rise, including other extreme weather events (Ontl et al., 2020). Moreover, this climate trend is anticipated to increase, posing significant threats to cities and developed regions (Brandt et al., 2016). Among others, the urban heat island effect, drought/water shortage, extreme storms, and flooding are the highly reported consequences of climate change in the urban landscape, in part due to the disproportionate amount of impervious surface and a high concentration of built structures as compared to green infrastructure (McPherson et al., 2017). As we know, urban regions currently harbor the most world populations, around 55%. Additionally, as anticipated population growth of 70% in urban areas by 2050 is predicted, strategic urban planning and greening have become critical in urban development (Esperon-Rodriguez, et al., 2022).

Urban and community forests (U&CF) have emerged as a promising and cost-effective option in urban planning and management to adapt to climate change impacts and to receive a multitude of ecosystem services and socioeconomic benefits by urban residents (Love et al., 2022; McPherson et al., 2017). U&CF, beyond street trees, comprises trees in city parks and open spaces, vegetation along riparian buffers, and trees in private areas and involves a range of activities associated with the planting, management, and maintenance of trees across the urban landscape (Love et al., 2022). Among others, reducing urban heat island effects, microclimate moderation, pollution reduction, carbon sequestration, wildlife habitat improvement, stormwater mitigation, and water-related services, as well as the enhanced physical and mental health of urban residents, are some highly reported services of U&CF (Brandt et al., 2016; Esperon-Rodriguez et al., 2022; Nowak, 2006). However, great concern has been raised regarding the health and quality of urban trees, as the compounded effects of climate factors such as extreme weather events (drought, warm temperature and heat waves, extreme storm and flooding, hurricanes, etc.), as well as insects, diseases, abiotic stressors, and invasive species potentially exacerbate tree mortality and reduced forest productivity (Brandt et al., 2016). Climate change has altered urban ecosystems' structure, composition, and functioning, requiring additional efforts for management and maintenance and increasing the associated management costs (Esperon-Rodriguez et al., 2022; Love et al., 2022)**.**

Forest management activities, including improved forest management, afforestation, reforestation, and avoided deforestation, have been recognized as cost-effective and viable approaches toward climate change mitigation (D'Amato et al., 2022). Forests reportedly increase the potential for carbon storage in forest biomass and allow landowners to participate in carbon trading schemes, incentivizing them to increase carbon in their forests (Jayasuriya et al., 2020; Moser et al., 2022). In this context, U&CF can offer an additional eligible activity, and its inclusion in urban planning has become an emerging trend worldwide in recent years as an instrument to combat the mounting effects of climate change (Poudyal et al., 2011). U&CF's potential to contribute to the carbon budget by storing 22.8 million tons of CO2 equivalent is significant and is expected to increase with a growing urban forest(Nowak & Crane, 2002). Carbon offset markets, among a diverse array of policy instruments(Graves et al., 2022), are often emphasized as practical and easily accessible tools(Franki, 2023; Marland et al., 2017) specifically designed to assign economic values to the social and environmental costs associated with greenhouse gas emissions. Carbon markets also acknowledge the benefits of activities aimed at reducing greenhouse gas emissions, aiming to counterbalance the release of GHGs from the emitters (Diaz et al., 2009; Moser et al., 2022). California's carbon offset program, launched in 2012, is unique and the first of its kind(Kelly & Schmitz, 2016; Ruseva et al., 2017). As the scope and severity of climate change intensified at the global level and within the state, the California Climate Investment Funding (CCIF) program remains at the center of driving advancements in technologies and practices to accelerate the reduction of GHG emissions and build resilience against climate change. The CCIF program aims to advance the state's climate and resiliency objectives by allocating substantial finance for climate change mitigation and adaptation projects. For example, this program has planted over 200 thousand urban trees, and around 900 thousand hectares of land have been restored in California. Along with general budget appropriations of municipalities, U&CF programs get additional funding from the CCIF and related bonds (Thompson & Reimer; Jeff L., 2018).

The involvement of broad stakeholders, including forest landowners, businesses, and communities, in managing and developing U&CF has emerged in recent years. Apart from private businesses involved in the green industry, public agencies and non-profit organizations (NPOs) are considered key players in provisioning the economic significance of U&CF in regional economies (Parajuli et al., 2022), as well as advocating for proper policies, maintenance, and management of U&CF (Love et al., 2022). Moreover, incorporating these diverse stakeholders and forestry practitioners and evaluating their perceptions of climate change risk is critical to an integrated future risk assessment and its solutions (Soucy et al., 2021).

This study delves into the perspectives of NPOs and public agencies engaged in U&CF activities in California, exploring their perceptions of the impact of climate change on their organizational activities and participation in carbon-related opportunities such as COM and CCIF programs. By understanding the perspectives and knowledge of diverse stakeholders on the opportunities and challenges of forest carbon management, we can inform the discussion, formulation, and implementation of various approaches towards forest carbon sequestration and climate change mitigation (Love et al., 2022). Recognizing the values, norms, and beliefs of different community stakeholders regarding their perception of risk due to climate change is crucial, as they directly influence their willingness to implement sustainable management practices (Feliciano & Sobenes, 2022; Soucy et al., 2021, 2022). This study not only offers strategies for urban and community forestry stakeholders to make informed decisions but also provides hope for the future by guiding the development and implementation of climate change mitigation and adaptation plans, as well as the advancement of carbon-related policies and programs in California and beyond.

1.2. Significance of the Study

California is one of the most populated states in the USA, with around 40 million people, and the trend of urbanization is rising with growing populations across the country (Love et al., 2022; McPherson et al., 2017a). Climate change has exacerbated extreme events yearly with increasing air temperatures, uncertainty in precipitation, and drought, thereby causing increasingly severe threats to urban ecosystems (Thorne et al., 2018). As a result of individual and cumulative effects, the frequency and severity of wildfires have increased, and there are increased incidents of pest issues and more frequent devastating flooding, which is resulting in higher urban tree mortality, thereby reducing the services and goods they provide (Love et al., 2022). California's tree canopy covers 15% of the urban regions, comprising 173.2 million trees, which is recognized as the lowest canopy cover among US states (McPherson et al., 2017b). Even at this low level, it is estimated that ecosystem services provided by urban forests in California are worth $8.3 billion annually, with 103 MMT CO2 stored in 173 million trees (McPherson et al., 2017a). This supports the value of urban tree canopy and the need to maintain and manage that resource as it enhances ecological and economic benefits. Additionally, participation in carbon offset markets and California's climate investment funding could provide new income streams and become a viable option for promoting U&CF activities to alleviate unprecedented climate change impacts.

Understanding how urban forest managers and additional stakeholders perceive climate change is imperative, as it influences their decision-making behavior toward climate change mitigation and adaptation measures. Moreover, understanding the opportunities and limitations allows them to make informed decisions and adopt the best management approaches. Compared to the topic of rural forestry and climate change, there are limited studies in the context of U&CF, particularly understanding the social and cognitive aspects of the adaptation process focusing on urban forests (Živojinović & Wolfslehner, 2015) and examining the perceptions among diverse forestry professionals (Soucy et al., 2022). Hence, this study explores the perceptions of two major stakeholders, NPOs and public agencies, to assess how climate-induced extreme weather events impact their business and management activities and their participation in carbon-related opportunities such as COM and CCIF programs. Specifically, this study addresses the following research questions: i) How do NPOs and public agencies perceive climate change impacts on their organization's involvement in U&CF? ii) Which activities of NPOs and public agencies are highly impacted by climate change events? iii) To what extent have these organizations participated in the current Carbon Offset Markets and California Climate Investment Funding Program? Furthermore, iv) Are these organizations willing to participate in these carbon market opportunities in the future?

CHAPTER TWO: LITERATURE REVIEW

2.1. Climate Change and Extreme Weather Events

Climate change has become a major political issue due to its significant role in environmental challenges. It has consistently been listed among the top five global risks for ten years (Živojinović & Wolfslehner, 2015). Variations in atmospheric temperature, precipitation, snow cover, sea level, and other extreme weather events provide clear evidence of global climate change (Brandt et al., 2016; Zhang & Brack, 2021). These changes have led to ecosystem disruptions, species extinctions, floods, intense rainfall, severe and frequent storms, coastal inundation, and increased wildfire rates, impacting the economy, ecology, and society (Esperon-Rodriguez, Tjoelker, et al., 2022; Pandey, 2002). According to Râmoa et al. (2019), climate change will alter the frequency, intensity, spatial extent, duration, and timing of weather and climate extremes, presenting unprecedented risks due to increased exposure.

Coop et al. (2022) reported that exceptional fire seasons like 2022 are becoming more probable. Under future extreme conditions, such incidents could surpass any previously experienced, heightening concerns about the vulnerability of biota, ecosystem functions, and human populations (Coop et al., 2022). Their study noted that during the 2020 fire season, 4 million hectares were burned in the USA, primarily in the western regions. California alone reported 400,000 hectares burned in August of that year. Climate change drives other extreme weather patterns in California, one of North America's most climate-affected regions, resulting in more frequent and severe heat waves and unpredictable rainfall. Collaborative and integrated efforts are being made to develop sustainable solutions to mitigate the impact of climate change (California's Changing Climate, 2018). Supporting these findings, Parks and Abatzoglou (2020) demonstrated that warmer and drier fire seasons, exacerbated by climate factors, have contributed to increased burned areas in Western US forests from 1985 to 2017 and predicted a trend towards warmer and drier conditions with greater fire severity under future climate scenarios. Table 1 presents various predicted scenarios as reported by the fourth assessment of California (Thorne et al., 2018).

Table 1: Climate Change Trends in California

<table>
<tr><td colspan="2">Climate Impacts</td><td colspan="2">Direction</td><td colspan="2">Scientific Confidence for Future Change</td></tr>
<tr><td colspan="2">Temperature</td><td colspan="2">Warming</td><td colspan="2">Very High</td></tr>
<tr><td colspan="2">Sea Levels</td><td colspan="2">Rising</td><td colspan="2">Very High</td></tr>
<tr><td colspan="2">Snowpack</td><td colspan="2">Declining</td><td colspan="2">Very High</td></tr>
<tr><td colspan="2">Heavy Precipitation Events</td><td colspan="2">Increasing</td><td colspan="2">Medium-High</td></tr>
<tr><td colspan="2">Drought</td><td colspan="2">Increasing</td><td colspan="2">Medium to High</td></tr>
<tr><td colspan="2">Area burned by wildfire</td><td colspan="2">Increasing</td><td colspan="2">Medium to high</td></tr>
<tr><td colspan="6"></td></tr>
<tr><td rowspan="2">If greenhouse gas emissions</td><td>Are reduced at a moderate rate</td><td rowspan="2">Then California will experience average daily high temperatures that are warmer than the historical average by</td><td>2.5˚F
2006-2039</td><td>4.4˚F
2040-2069</td><td>5.6˚F
2070-2100</td></tr>
<tr><td>Continue at current rates.</td><td>2.7˚F
2006-2039</td><td>5.8˚F
2040 to 2069</td><td>8.8˚F
2070-2100</td></tr>
</table>

Source: Adapted from Thorne et al., 2018, page 4&5.

This report indicated that climate change heightens the risk of wildfires due to rising air temperatures, predicting that large wildfires could become 50% more frequent by the century's end, leading to drier conditions and increased insect infestations. Along with the increased risk of wildfires, drought affects nearly all forest ecosystems, depending on soil texture and depth, exposure, life stage, and the drought's frequency, duration, and severity (Dale et al., 2001). Drought can weaken tree vigor, making them more susceptible to insect infestations, diseases, and fires, increasing fuel loads and fire susceptibility (Dale et al., 2001).

Flooding is a rare urban event that complicates the prediction of average recurrence intervals for extreme floods, even under current climate conditions, due to unique hydrological settings and flood-prone structures (Schreider et al., 2000). Evidence shows that climate change-driven disasters have increased in recent years and will continue to rise, posing significant threats to small and large cities and the peri-urban interface (Brandt et al., 2016). Reviewing how each extreme event exacerbated by climate change affects ecosystems and assessing the potential risks provides a foundation for developing strategies to mitigate climate change impacts (Dale et al., 2001).

2.2. Perception of Landowners and Practitioners towards Climate Change Risk

Research supporting the psychology of risk perception offers theoretical expectations of the role of personal experience with extreme weather events in determining climate change views (Zanocco et al., 2018). Climate change perception often works as a necessary antecedent for climate change attitudes and adaptation behaviors, and whether the public is likely to act depends on the hazard and its severity (Gilbert & Lachlan, 2023). Furthermore, it is necessary to understand the diverse social perceptions of climate change by the various stakeholders to identify how decision-makers value the risks and benefits, which also works as a starting point for the creation and comparison of decision options (Živojinović & Wolfslehner, 2015). Feliciano & Sobenes (2022) pointed out that experts depend on statistical analysis and models to make their perception while the public perceives, describes, and acts toward climate change risk management based on their values, norms, and beliefs, which might lead them to underestimate some risks and overestimates others (Lacroix et al., 2020).

Additionally, some studies suggested that integrating traditional knowledge and informal observation of climate variability with exact data is essential to address the uncertainty in data, trends, and projections of impacts, as well as to develop evidence-based climate adaptation plans (Feliciano & Sobenes, 2022). The conceptualization of climate change risk is challenging because of its politicized nature and varying scale and timeline of the threats (Gilbert & Lachlan, 2023). Understanding climate change through personal experiences is also complex, as it is a slow and distant process (Lacroix et al., 2020). In this context, those who believe in significant scientific facts may tend to perceive the mounting risks of climate change, while individuals with cultural worldviews may perceive less climate change risks. Lacroix et al. (2020) further revealed that the climate change risk perception determines the attitude toward climate policy support and is considered a main predictor if compared to demographic factors, political ideology, location, and knowledge about climate change. It is highly considered that the use of adaptation strategies, informing future research, and supporting decision-making are based on the understanding of perceptions towards climate change impacts (Soucy et al., 2021). This study also revealed that although climate change can be experienced personally, it is hard to predict the long-term nature of local climate change, resulting in different perceptions of its risks because people may experience the impacts differently. A similar study also reported an association between personal experiences with extreme weather and climate change risk perception (Gilbert & Lachlan, 2023). For example, Lacroix et al. (2020) concluded that exposure to forest fires influences climate change perceptions, and reversely, those who have strong climate change risk perceptions are more likely to report exposure to forest fires.

The perception and awareness of climate change has also been associated with a person's motivation towards climate change mitigation approaches; for instance, forest owners who are aware of climate change and their knowledge about role of forests towards climate change mitigation were believed to be more interested in enrolling in carbon offset markets(Graves et al., 2022; Kelly et al., 2017; Markowski-Lindsay et al., 2011; Miller et al., 2014; White et al., 2018). Through carbon-focused forest management activities such as plantations, avoiding deforestation, or improved tree management, they can simultaneously achieve sustainable forestry goals and climate change mitigation and benefit through new income streams (Diaz et al., 2009; Dickinson, 2010; Graves et al., 2022).

2.3. Urban and Community Forestry in the face of Climate Change

Urban areas occupy approximately 3% of the Earth's land but house over 55% of the global population, projected to rise to 70% by 2050. This growth will increase societal demands on urban forests, especially in less developed and tropical regions (Esperon-Rodriguez, Tjoelker, et al., 2022; Huang, 2022). Urban landscapes are more vulnerable to environmental challenges, including the urban heat island effect, drought, flood risks, and extreme storms, due to impervious surfaces and densely built structures (Brandt et al., 2016; Esperon-Rodriguez et al., 2022). These interconnected issues pose significant environmental threats to human health and the economy (Livesley et al., 2016). Consequently, cities are adopting strategies to reduce greenhouse gas emissions and adapt to a warming future (Brandt et al., 2016). For instance, a survey of 69 U.S. cities found that 73% have implemented urban forest management practices to mitigate extreme heat (Huang, 2022).

Urban forests play a critical role in climate change adaptation through carbon sequestration and moderating extreme weather events and provide numerous ecosystem services and benefits (Brandt et al., 2016; Esperon-Rodriguez et al., 2022; Hauer et al., 2008; Livesley et al., 2016).

The World Economic Forum's Global Agenda on the Future of Cities in 2015 recognized urban forest programs as a top initiative for climate adaptation (Huang, 2022). Trees and greenery in urban areas are linked to human health, higher property values, community connectivity, and well-being(McPherson et al., 2011). Urban forests include trees in streets, parks, riparian buffers, and private and public areas, expanding the concept from street tree management to the broader urban ecosystem (Nowak, 2006; Poudyal et al., 2011). They also consist of community and urban forests, which include street trees, open spaces, forest patches, institutional properties, municipal parks, playgrounds, yards, and highway

Forests act as carbon sinks by absorbing atmospheric carbon during photosynthesis and storing it in biomass for extended periods, making them crucial for climate change mitigation (Ashton et al., 2012; Marland et al., 2017; Pandey, 2002; Poudyal et al., 2010). They also reduce CO2 indirectly by lowering building energy needs for cooling and heating (Jo & McPherson, 1995). Planting and preserving climate-resilient urban forests can significantly mitigate climate change, including reducing the urban heat island effect through evapotranspiration (Esperon-Rodriguez et al., 2022). Increasing tree cover by 10% can reduce total heating and cooling energy use by 5-10% (McPherson et al., 2017). In the U.S., urban forests store around 800 million tons of carbon, with an annual increase of 6.5 million tons (Yadong & Zhiqiang, 2015). In California, street trees alone store 7.78 MMT CO2 and remove 567,748 tons of CO2 annually, equivalent to removing 120,000 cars from the road (McPherson et al., 2017).

Countries worldwide seek ways to reduce greenhouse gas emissions to avoid severe environmental damage. Forest management for carbon sequestration is cost-effective, technology-friendly, and relatively easy, offering additional ecological and social co-benefits

(Livesley et al., 2016; Ruseva et al., 2017). Forests manage atmospheric carbon by storing it in the biosphere, in forest products, displacing fossil fuels with biofuel, and substituting wood products for fossil-fuel-intensive ones (Marland et al., 2017). Besides carbon sequestration, forests maintain biodiversity, preserve ecosystem services, and improve forest-dependent communities' social and economic well-being (Ashton et al., 2012; Pandey, 2002). Forested lands, including urban and community forests, cover nearly 30% of the Earth's land, representing over 77% of terrestrial above-ground carbon and expected to store additional carbon to offset CO_2 emissions (Ashton et al., 2012; Poudyal et al., 2010). Forest-based carbon sequestration consistently ranks among the most effective natural climate solutions in global, national, and regional studies (Graves et al., 2022). However, declining urban tree canopy cover in California reduces associated ecosystem services and benefits, such as carbon sequestration, energy savings, air pollutant uptake, and rainfall interception (McPherson et al., 2017).

2.4. Climate Change: Management Challenges to Urban and Community Forestry

Urban forests, while mitigating climate impacts, are vulnerable to climate change locally and globally (Brandt et al., 2016; Esperon-Rodriguez et al., 2022). The effectiveness of their mitigation efforts and their ecosystem services are significantly influenced by their size, structure, and species composition (Zhang & Brack, 2021). Climate change threatens urban trees, increasing tree dieback and mortality, thus diminishing the benefits they provide to urban populations (Esperon-Rodriguez et al., 2022). Zhang and Brack (2021) indicated that extreme weather events, especially temperature and drought-related stress, directly contribute to tree mortality and the consequent loss of ecosystem services.

California faces significant challenges in improving air and water quality, addressing water shortages, cooling urban heat islands, and reducing flooding (McPherson et al., 2011). There is often a lack of reliable information on managing urban and community forests (U&CF) to enhance their services and functioning (Dwyer et al., 1992). Strategic and intelligent urban greening plans are necessary to ensure the persistence of urban forests under future climatic conditions. These plans include identifying climate-resilient tree species, diversifying plantings, and providing adequate irrigation and other management actions (Esperon-Rodriguez et al., 2022).

2.5. The Carbon Offset Markets Program

Despite the plethora of challenges and impacts, climate change presents an opportunity in the form of increased forest productivity and associated economic growth (Soucy et al., 2021). Among others, it has created opportunities for forest landowners and managers to participate in emerging carbon markets and contribute to climate change mitigation through carbon-oriented forest management activities, which promote sustainable forestry and provide a new income stream (Chen et al., 2021; Diaz et al., 2009). The offsets from three general categories of forest management, such as afforestation and reforestation, avoided conversion, and improved forest management, are eligible for the carbon offset market in the USA (Diaz et al. (2009) & Jayasuriya et al. (2020))**,** including U&CF as an eligible activity (Poudyal et al., 2011). Among others, planting new trees is a relatively straightforward way to sequester carbon and is the most uncomplicated activity to account for in the forest carbon offset program (Diaz et al., 2009)**.** However, only limited information is available regarding the quality and market possibilities of the carbon offset market in U&CF (Poudyal et al., 2011)**.** Poudyal et al. (2011) revealed that local government agencies in the U.S. have adequate resources to implement the carbon project, ensuring competitiveness and quality criteria. Studies suggested that U&CF plays a critical role in the overall carbon budget by sequestering CO_2 to mitigate climate change (Zheng et al., 2013), storing 22.8 million tons of CO_2e, and it is expected to grow in the future as the rate of urbanization continues to increase (Poudyal et al., 2011).

Atmospheric greenhouse gas emissions reduction markets are generating the production of new, unusual, intangible, and tradeable commodities, called forest carbon offsets, that represent 1 MT of CO2e emission reduction (Kelly & Schmitz, 2016; Marland et al., 2017b; Ruseva et al., 2017). Carbon offsets are often emphasized as practical and easily accessible tools to mitigate the looming threats of climate change (Marland et al., 2017b)**.** Offset can be a helpful mechanism to allow industries with processes that are emission-heavy to purchase carbon reduction elsewhere as a cleaner technological development (Fletcher et al., 2009)**.** However, to ensure California's climate policy's legitimacy and environmental integrity, offsets must be real, additional, quantifiable, permanent, verifiable, and enforceable (Marland et al., 2017; Ruseva et al., 2017). Graves et al. (2022)**,** in a study of non-industrial private forestry owners, highlighted a wide range of policy instruments to incentivize carbon sequestration and storage, such as carbon taxes, carbon subsidies, combined tax-subsidy programs, carbon rental systems, direct incentives programs, and carbon offset markets. Both compliance and voluntary carbon offset markets are common in practice. Compliance markets are based on government regulations that limit emissions from industries or polluters, such as a cap-and-trade system. In contrast, a voluntary carbon market occurs in the absence of government mandates to control emissions, and participation is purely voluntary; Chicago Climate Exchange (CCX) and over-the-counter (OTC) transactions are voluntary carbon markets (Diaz et al., 2009; Dickinson, 2010)**.** Voluntary incentive programs that provide compensation to forest owners either based on the amount of carbon sequestered or based on the adoption of practices aimed at forest carbon management may prove to be the most effective and valuable tool in comparison to potential market-based instruments/compliance systems which encourage carbon sequestration through the sale of offset credits(Charnley et al., 2010; Dickinson, 2010; Graves et al., 2022)**.** However, compliance with carbon markets or market-based approaches can reduce price risk and cover the opportunity cost of lost revenue from timber harvesting (Kerchner & Keeton, 2015). In addition, it prioritizes cost-effective emission reductions to meet the mandatory cap. It allows regulated industries to decide whether to reduce emissions internally or purchase allowances or credits from other market participants (Diaz et al., 2009). California's 2006 Global Warming Solutions Acts (AB 32) provides the use of carbon offsets from forest management as compliance in a statewide GHG cap and trade program, which was launched in 2012 and administered by the California Air Resources Board (CARB) to reduce GHG emissions to 40% below 1990 levels by 2030 (Lambe & Farber, 2012; Ruseva et al., 2017). It is also reported that California's carbon offset program is unique and linked to climate change regulation, the first of its kind in the U.S., and one of the most ambitious policies in North America (Kelly & Schmitz, 2016; Ruseva et al., 2017). Opportunities are emerging for landowners to participate in carbon market trading schemes. Rapidly developing international and domestic carbon markets could increase forest carbon sinks in the U.S. and other parts of the world, rewarding landowners for improved forest management (Diaz et al., 2009). However, it has been reported that using offsets as a primary tool for corporations to meet their emissions reduction goals or for consumers to reduce their carbon footprint will not be enough to meet climate change mitigation goals (Fletcher et al., 2009)**.**

2.6. Limiting Factors for Participation in the Carbon Offset Markets

Participation in the carbon offset program is currently low, though the number of projects has increased over the past few years (Marland et al., 2017). Several studies report that participation in carbon offset markets is primarily determined by variables related to carbon program design and owner characteristics as well as objectives of management(Charnley et al., 2010; Fletcher et al., 2009; Khanal et al., 2019). Some of the factors that deterred landowners from participating in carbon offset programs include limited or uncertain carbon revenues, early withdrawal penalties, long contract length, stringent management plan requirements, and high costs and resources associated with the project development and implementation process (Dickinson, 2010; Kelly & Schmitz, 2016; Markowski-Lindsay et al., 2011; White et al., 2018). Additionally, low familiarity with carbon offset markets has reduced willingness to enroll in the carbon program (Fletcher et al., 2009). A study from Norway by Håbesland et al. (2016) revealed that familiarity with forest management for carbon sequestration and a long-term contract period does not affect their participation; Miller et al. (2012) reported similar findings. The program's characteristics, including the payment amount offered and the management options that landowners are allowed to apply for, may influence the actual level of participation in the carbon program (Håbesland et al., 2016). To increase participation in this program, some potential areas of improvement in the protocol have been suggested, such as reducing the length of the time commitment, the uncompensated and ongoing costs of sampling and verification, and the magnitude of risk reductions (Marland et al., 2017).

Interestingly, regarding climate change, private forest landowners have different perceptions based on the ownership objectives; those with income goals of forest management are found particularly skeptical regarding the threats of climate change, with significantly less interest in participating in or encouraging others to participate in a carbon program. Those with amenity proposes were found to be more interested in climate science and more likely to list reductions of GHG as a motivating factor to join the market (Kelly et al., 2017). Similarly, Håbesland et al. (2016) also reveal that the extent to which landowners believe in anthropogenic influences in climate change and their knowledge of the role of forests towards climate change mitigation motivate them to participate in such programs. Other studies also revealed that attitudes toward climate change are among the strongest predictors of enrollment in the carbon market program. Those who are skeptical about climate change are less interested in carbon markets, and those who are aware of climate change and their belief in the potential for forests to help mitigate climate change are more interested in participating in carbon offset markets (Graves et al., 2022; Kelly et al., 2017b; Markowski-Lindsay et al., 2011; Miller et al., 2012; White et al., 2018)**.**

The carbon offset program could provide significant financial incentives for forest landowners to develop viable projects. However, the associated protocol is complex and requires forest owners to engage in an extensive and lengthy process to list an offset project with a state registry, including an intensive initial inventory, project area verification by third-party experts, time commitment of at least 100 years, ongoing periodic monitoring and reporting obligations, and obtaining certification that their land is being managed sustainably (Diaz et al., 2009; Kelly et al., 2017). However, how these perceived barriers can be resolved and whether additional financial incentives or technical support would motivate landowners more interested in participating in these programs is difficult to know (Håbesland et al., 2016). Most forest offset standards in the U.S. are outcome-oriented, relying on carbon inventories to measure changes in forest carbon over time. However, the interest in emerging carbon markets among landowners and other stakeholders is still growing in the U.S. (Diaz et al., 2009).

2.7. California's Climate Investment Funding Program

As the impact of climate change becomes increasingly widespread, the California Climate Investment funding (CCIF) program remains at the forefront of advancing technologies and practices to expedite greenhouse gas emissions reduction and foster resilience against climate change. CCIF effectively channels billions of dollars from cap-and-trade auction proceeds toward reducing greenhouse gas emissions, economic strengthening, enhancing public health and the environment, and providing meaningful benefits to disadvantaged, low-income communities and households- collectively called priority populations. Hence, it sets a precedent for other national and subnational climate programs, underlining the importance of community engagement and equity in program design and execution (California Climate Investment,2024).

Since 2013, the cap-and-trade program has provided state agencies in California with $6.1 billion to support various climate investment programs primarily oriented to climate mitigation with over 23 million MT CO_2e in emissions reduction (Keenan & Gumber, 2019). In 2017, the cap-and-trade program was extended to allow for investments in both mitigation and adaptation. Keenan and Gumber (2019) also revealed that compared with most other states, California has the comparative advantage of having the experience of making investments through cap-and-trade programs, including some mitigation investments that have co-benefits with adaptation.

The CCIF initiative is dedicated to advancing the state's climate and resiliency objectives through substantial financial allocation through several projects. These endeavors encompass expanding low-carbon transportation alternatives, strategically placing affordable housing, mitigating threats from severe wildfires and waste diversion, improving natural and working lands, clean energy, enhancing water use efficiency, and more. Further, CCIF plays a pivotal role in championing programs that reduce greenhouse gas emissions while supporting other CCIF initiatives such as research, funding comprehensive planning, workforce preparation for a carbon-neutral economic landscape, and facilitation of technical guidance for prospective project applicants (California Climate Investment, 2024).

Following the annual report of California Climate Investment 2024, it becomes evident that as of November 2023, a substantial investment of $11 billion has been realized, with an impressive 76% focus on priority populations and a reduction of 109.2 MMT CO_2e estimated greenhouse gas emission. The program also embraces diverse nature-based solutions to sequester carbon and prevent greenhouse gas emissions, including protecting forests from catastrophic wildfires, supporting sustainable agricultural lands, and expanding urban tree canopies. As revealed in this report, over 200 thousand urban trees have been planted under the CCIF program (California Climate Investment,2024).

As documented by the Intergovernmental Panel on Climate Change (IPCC, 2022), substantial emphasis has been placed on public investments targeting urban green infrastructure to mitigate climate change's impacts and augment overall resilience. This strategic approach is pivotal in expediting urban climate adaptation and bolstering resilience across urban landscapes.

2.8. Stakeholders’ Involvement in Urban and Community Forest Management

The forestry sector comprises diverse stakeholders with various roles, management objectives, and strategies, and they might have different perceptions of environmental and socio-economic changes (Soucy et al., 2021). For example, public agencies are involved in the daily maintenance of trees and the larger management objectives as per the guidelines of government policies and mandates, remarkably increasing tree canopy cover or diversity(Ordóñez et al., 2020). In California, most of the budget for city or county U&CF programs comes through the general tax fund, which has declined over the last three decades(Thompson & Ahern, 2018). However, within the state and federal U&CF programs, there has been a significant expansion of budget and activities, as well as their presence in the U.S. Federal Farm Bill of 1990, due to the reported overall decline in the health of urban forests(Hauer et al., 2008). Poudyal et al. (2010) reported adequate resources in the local government agencies to implement the carbon project. This indicates that stakeholders holding or managing urban forests have opportunities to participate and diversify their additional economic benefits (Poudyal et al., 2010). Thompson & Reimer, Jeff L. (2018) reported that California municipalities spend more than 60% of their U&CF budget on private sector contractors purchasing and planting trees in public spaces. In contrast, municipalities take responsibility for maintaining and managing public properties, including urban trees. Likewise, the NPO sector contributes to U&CF through community education and outreach efforts, funding support and grants to civic groups, collaboration and coordination with stakeholders across all sectors, and community engagement in planning, implementation, and advocacy. The greatest motivation for their involvement is to support environmental programs that benefit human beings and the environment (Martin & Olson, 2023).

CHAPTER THREE: METHODS

3.1. Study Region

This study was conducted in California, USA, in 2022-2023, with a particular interest in evaluating the economic contribution of all U&CF-related businesses and activities to the state economy. California has 58 counties and 482 municipalities and extends 423,970 square kilometers. California is the USA's third most significant and populous state (40 million). Urban tree canopy covers 15% of the urban area in California, which is relatively low in terms of urban tree canopy per capita (90.8 m^2) compared to other states (McPherson et al., 2017a). In this study, some smaller towns have been intentionally omitted because their population was below the threshold of 2,500. Approximately 115 Non-Profit Organizations (NPOs) are involved in U&CF activities in California. In coordination with California ReLeaf, an online Qualtrics survey was conducted among public agencies and NPO professionals to assess their perceptions of climate change-related challenges and opportunities for U&CF in California.

3.2. Study Population

For this study, participants were asked to provide their perceptions of the impacts of climate change events such as wildfire, high heat, winds, drought, flooding, and invasive species based on their perceived effects on their organizational activities. Additionally, they were asked to provide their current participation and likelihood of participation of their organization in carbon-related opportunities such as the Carbon Offset Market (COM) program and California Climate Investment Funding (CCIF) program. This study defined urban and community forestry as all activities supporting trees or tree populations—including producing, planting, maintaining, and removing trees—in cities, towns, suburbs, and other developed areas.

The carbon offset market program encompasses voluntary and compliance markets where offset credits for carbon sequestered in forests are bought and sold. Moreover, the CCIF program was implemented in California to support projects under the U&CF and urban greening umbrella through grants funded by Cap-and-Trade auction proceeds. Survey respondents were recruited through mixed-method approaches, including convenience sampling emails, newsletters, websites, and advertisements targeting U&CF professionals across California.

3.3. Sampling Frame

Cal ReLeaf and their networks helped us obtain a list of email addresses for various CA municipalities and the related NPOs working towards U&CF activities. We updated the email list for each survey iteration by adding and replacing new emails that were unsuccessfully delivered. Email addresses not delivered in the first round were corrected using staff directory pages of the respective city or county website for individuals working within the parks and recreation departments. We selected the most appropriate staff members to participate in the survey based on their job title- manager, superintendent, or director using city and county websites to determine whether urban forestry activities were overseen by them or someone else, potentially in another department. In addition, newsletter advertisements and direct calls from California ReLeaf to network members were also employed for both public agencies and NPOs. Additionally, several recruiting efforts, such as social media campaigns and newsletter advertisements, were conducted through various stakeholder organizations.

3.4. Survey Design and Validation

The survey was conducted through Qualtrics using flow tools and skip logic, where respondents were allowed to choose their specific sector questions. The responses were collected based on 2021, and all the questions were optional. The Institutional Review Board of North Carolina

State University (IRB #25150) reviewed and approved all research protocol and survey process aspects.

Stakeholders were involved in the survey's design and testing prior to its administration among the selected sampling population. These stakeholders represented various U&CF communities, such as the Society of Municipal Arborists, the American Society of Consulting Arborists, the Hispanic Arborist Association, the Plant California Alliance, the Western Chapter ISA, and San Diego Gas and Electric. After obtaining stakeholder input, beta-testing of the survey was conducted with selected representatives from these groups before the survey was fielded in September 2022. In collaboration with California ReLeaf representatives, the researchers involved in this study performed an internal review of the survey to ensure the readability and ease of completion.

3.5. Survey Procedure and Data Collection

Three survey rounds were implemented to ensure the best representation of study populations. The first survey round was administered on Sep 8th, 2022, through a dedicated webpage posted on the Cal ReLeaf website. The webpage with study details and the Qualtrics survey link were shared using social media platforms such as Facebook, Instagram, Twitter, and LinkedIn, as well as through e-newsletters, advertisements, and personal email from Cal ReLeaf.

After the first survey ended with insufficient responses, a second round was launched on Jan 19th, 2023, making some changes in advertisement and recruitment strategies and including a raffle-based incentive ($100 Amazon gift card) for 25 respondents. However, this incentive increased fraudulent responses from suspicious internet bots on Qualtrics. We removed the fraudulent responses applying a 6-step removal process, including responses within bot clusters, Qualtrics flagged responses, duplicate IP addresses and emails, longitude and latitudes outside of the USA, short duration of responses, suspicious free responses, and suspicious email addresses. In this round, two follow-up emails were sent to the same respondents. We replaced the bounced and failed emails with new email addresses by once again searching the organization's working directory.

Consequently, in May 2023, the third round of the survey was conducted to increase the response rate from the public sector. In this round, the survey was deployed to municipalities precisely due to their lower rate of responses in the previous rounds, but it did not include incentives. In this final round, respondents were offered an option to respond by either filling out the survey on the Qualtrics system or filling out a physical copy and sending it to NC State University's mailing address. After three weeks of survey administration, a final reminder email was sent to California municipalities.

The survey ended with a 13% response rate from public agencies and a 32% response rate from NPOs in California. Out of the total sample population of 354 municipalities and county governments, 49 valid responses were collected from public agencies, where only 44 responses were used for data analysis, omitting the partial responses. Similarly, from a sample population of 115 NPOs, 37 valid responses were recorded in Qualtrics, and only 33 complete responses were used in the data analysis. The results from each survey round are presented in Table 2.

Table 2: Survey responses were recorded for each survey round.

Sector	Survey population	Round 1	Round 2	Round 3	Total
NPOs	115	17	20	--	37
Public Agencies	354	2	30	14	46
Total	469	19	50	14	83

3.6. Data Analysis

In this study, there were two major themes for the data analysis: i) the perception of U&CF stakeholders towards climate change events based on the impacts on their organization's U&CF activities, and ii) their participation in carbon-related opportunities such as COM and CCIF, currently and in the future. In terms of statistical methods, simple descriptive statistics were used to describe the results of sociodemographic information of the respondents, including age, education, gender, and race, along with their years of work experience and affiliation with U&CF-related organizations. Similarly, graphs and charts were used to present the proportions of responses in each category of variables, such as those related to the perception of different climate change events (wildfire, high heat, winds, drought, flooding, invasive species) and the impacts on U&CF activities in each sector, and their participation in COM and CCIF programs. The Mann-Whiteny-U Test was performed within and between the organizations to compare the statistical differences between the two groups of interest for the categorical data. As a proxy for the size of the organizations, public agencies were split into two groups based on their total annual operating budgets: less than $750,000 and more than $750,000, and NPOs were split into two groups: less than $50,000 and more than $50,000. Similarly, the number of U&CF employees was also considered a determinant of the size of organizations, and tests were applied to explore its association. In public agencies, the number of employees was categorized into two, such as less than two and more than two, while in NPOs, the number of U&CF employees was categorized into less than one and more than one. These categorizations were done based on the median values in both cases. The organizational characteristics were considered to determine if their perception of climate change events and participation in carbon-related opportunities is related to the size of their organization. The tests were conducted within and between the NPOs and public agencies. Similarly, data with more than three categories were analyzed using the Kruskal-Wallis-U Test to compare any differences among the groups. Notably, for this study, we compared the differences in perception towards climate change events across the three categories of organizations, with different levels of likelihood to participate in carbon-related opportunities (Unlikely, Neutral (neither unlikely nor likely), and Likely). The Mann-Whitney-U and Kruskal-Wallis-Rank-Sum tests were applied to data with small sample sizes and non-normal and ordinal values (Hoffman, 2019; Matthews, n.d.). In these tests, all the data are pooled and ranked from the smallest to largest, followed by adding sums of ranks in each group to calculate the probability. The Mann-Whitney-U test was applied when there were only two groups, and the Kruskal-Wallis Test was employed with more than two groups. Descriptive statistics such as mean values and standard errors were also reported and interpreted to support these tests. The data analysis was performed using R.

CHAPTER FOUR: RESULTS

4.1. Socio-Demographic Characteristics of The Respondents

This study focused on two groups, NPOs and public agencies, involved in managing urban and community forestry in California. After omitting partial responses, 77 valid responses were used in the data analysis, with NPOs comprising 33 and public agencies comprising 44 fully completed responses. The respondents' socio-demographic information includes their position in their organization, number of years of work experience, age, education level, race, gender, and affiliation with professional societies.

4.1.1. Public Agencies

Municipal forester or arborist was the most reported job category, comprising 68% of the agency's respondents, followed by an administrative position, which was 11%. They indicated they were members of the International Society of Arboriculture (59%) and the California Urban Forest Council (18%). Male respondents represented 80%. In terms of education, most of the respondents had bachelor's degrees (38%), followed by high school completion (23%). All the respondents had at least six years of working experience, and 52% were between 35-44 years, followed by 55-74 years (27%). Fifty-nine percent of the respondents were Caucasian, followed by 23% Hispanic, Latino, or Spanish.

4.1.2. Non-Profit Organizations

Most of the respondents from NPOs were administrative personnel (61%). In terms of their affiliation, about 30% were associated with the Utility Arborist Association (30%), followed by the American Public Garden Association (24%), and the Society of American Foresters (21%). Fifty-eight percent were female. Caucasian was the most reported race (76%). Most respondents had fewer than six years (45%) of work experience, and most were between 55-74 years (39%). Regarding education, most respondents had at least a bachelor's degree.

4.2. Perspective On Climate Change Impacts

Responses were collected on participants' perceptions of the following question: *"Climate change is believed to lead to the increased occurrence and intensity of climate change events such as those listed in the table below. Rate how much each of the following has impacted your agency's work in 2021".* Six climatic events were listed: drought, high heat, flooding, winds, wildfire, and invasive species. Respondents were asked to rate their perception of these based on five Likert scale points: very negative, somewhat negative, no impacts, somewhat positive, and very positive, each corresponding to numeric values of 1, 2, 3, 4, and 5, respectively.

Table 3 shows the test results comparing perceptions of climate change events between NPOs and public agencies and suggests a significant difference (α=0.10) in perceptions of high heat events, where NPO participants perceived higher negative impacts than public agencies.

Table 3: Differences in perceptions between NPOs and public agencies towards climate change events.

Climate Change Events	**NPOs (n1=33)**	**Public Agencies (n2=44)**	**Mann-Whitney-U-Test**	
	Mean (S.E)	Mean (S.E)	U	P-Value
Wildfire	2.7(0.12)	2.91(0.1)	613	0.1537
High heat	2.09(0.18)	2.52(0.17)	559	0.06568**
Winds	2.3(0.13)	2.25(0.16)	800.5	0.4012
Drought	1.85(0.18)	2.05(0.19)	696.5	0.749
Flooding	2.97(0.08)	2.82(0.1)	801	0.2894
Invasive Species	2.48((0.16)	2.43(0.14)	765.5	0.6695

Note: The values in parentheses include standard errors. The symbol * indicates $p < .05$ and ** indicates $p < .10$. For each climate change event, responses were collected on a five Likert scale (1= Extremely Negative Impacts, 2= Somewhat Negative Impacts, 3= No Impacts, 4= Somewhat Positive Impacts, and 5= Extremely Positive Impacts). Hence, a smaller mean value indicates higher negative perceived impacts.

4.2.1. Public Agencies

The results show that wind events would potentially have the highest negative impacts (73%) due to climate change in U&CF activities of public agencies, followed by drought (70%) and high heat (61%). (Figure 1). Interestingly, most respondents believed that wildfires (73%) and flooding (70%) had little to no impact.

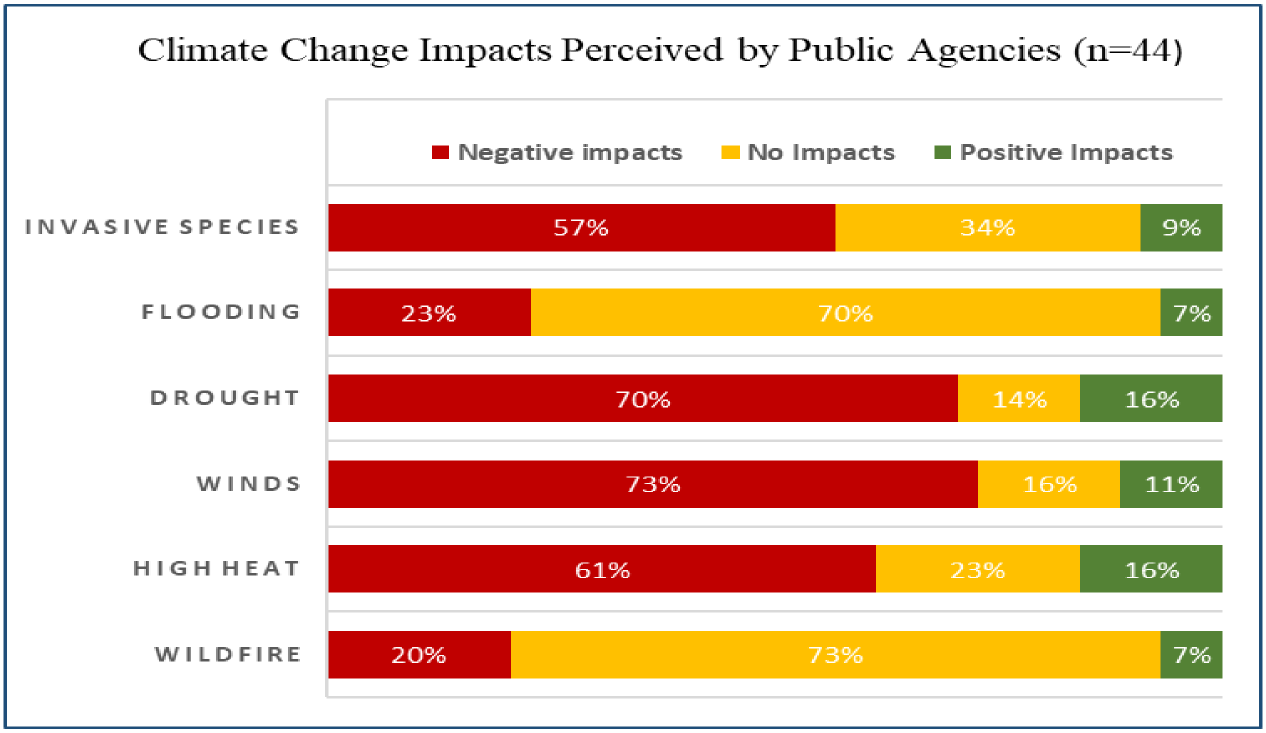

Figure 1: Climate Change Impacts Perceived by Public Agencies**.**

4.2.1.1. Climate Change Perceptions and Sociodemographic Characteristics of Respondents

Table 4 presents the test results regarding respondents' sociodemographic characteristics related to their perceptions of climate change events. The test results suggest that females perceived higher negative impacts of wildfire events than male respondents. Respondents younger than 44 perceived a higher negative impact of flooding events than those over 44, and those with an associate's degree or below perceived higher negative impacts of wind events. However, comparatively, respondents with a lower level of education perceived slightly higher negative impacts of climate change on their U&CF activities. The results suggest no significant differences in perceptions based on their years of employment with their organization.

Table 4: Differences in perceptions towards climate change events based on socio-demographic characteristics of public agencies respondents.

		Climate Change Events					
Sociodemographic Characteristics		Wildfire	High heat	Winds	Drought	Flooding	Invasive Species
Gender							
Male (n1=38)	Mean (S.E)	2.84(0.16)	2.11(0.25)	1.84(0.23)	1.89(0.295)	2.74(0.17)	2.11(0.22)
Female(n2=6)	Mean (S.E)	2(.45)	2(0.68)	1.33(0.33)	2(0.68)	2.33(0.42)	1.67(0.42)
Man-Whitney-U-Test		157.5	119.5	130.5	109.5	134	131
P-Value		0.05904**	0.8438	0.4836	0.8646	0.404	0.522
Age							
<44 years (n1=12)	Mean (S.E)	2.5(0.26)	1.67(0.38)	1.5(0.26)	1.67(0.38)	2.17(0.3)	1.67(0.28)
>45 years (n2=32)	Mean (S.E)	2.81(0.19)	2.25(0.28)	1.88(0.27)	2(0.28)	2.88(0.18)	2.19(0.25)
Man-Whitney-U-Test		166.5	154	178.5	176	131.5	158
P-Value		0.3977	0.255	0.661	0.6108	0.04785*	0.3165
Education							
Associate or Below(n1=18)	Mean (S.E)	2.78(0.22)	1.89(0.33)	1.11(0.11)	1.44(0.26)	2.67(0.24)	2(0.29)
Bachelor or Above(n2=26)	Mean (S.E)	2.69(0.21)	2.23(0.32)	2.23(0.32)	2.23(0.33)	2.69(0.21)	2.08(0.28)
Man-Whitney-U-Test		244	209	145.5	179	232	232.5
P-Value		0.771	0.5005	0.00712*	0.105	0.9643	0.9784
Years of Experiences							
<10 years (n1=21)	Mean (S.E)	2.91(0.2)	1.96(0.3)	1.61(0.23)	1.78(0.3)	2.57(0.25)	1.87(0.28)
>10 years (n2=23)	Mean (S.E)	2.52(0.24)	2.24(0.35)	1.95(0.36)	2.05(0.36)	2.81(.19)	2.24(0.29)
Man-Whitney-U-Test		284	219.5	226.5	222.5	212.5	202
P-Value		0.205	0.5606	0.6627	0.5881	0.402	0.2984

Note: The values in parentheses () indicate standard error. The symbol * indicates $p < .05$, and ** indicates $p < .10$. For each climate change event, responses were collected on five Likert scale (1=extremely negative, 2= somewhat negative, 3= no impact, 4= somewhat positive impacts, and 5= extremely positive impacts). Hence, a lower mean value indicates higher negative perceptions and vice versa.

4.2.1.2. Climate Change Perceptions Varied by the Organizational Size

The size of organizations, as measured by the annual operating budget and the number of employees, was tested to see if this measure impacted respondents' perceptions. The public agencies were categorized into two groups based on annual budgets (<$750,000 and > $750,000). The test results in Table 5 show significant differences in perceptions towards flooding between these two groups, split by their operating budget size. Public agencies with an annual budget of more than $750,000 perceived the impact of flooding on U &CF activities as highly negative (mean=2.57), compared to those with an annual budget of less than $750,000 (mean=3.04).

Moreover, the total number of employees involved in U&CF activities was divided into two categories (fewer than two and more than two) to understand if the size of employees influenced their perceptions of climate change events. The test results show no significant difference in perceptions between the two groups of public agencies by the number of employees. However, the mean negative perception towards most climate change events was higher in public agencies with fewer than two U&CF employees compared to those with employees more than two.

Table 5: Public agencies' Perceived impacts varied by size in terms of the total budget and number of employees.

	Total Annual Budget			
	< 750,000(n1=23)	>$750,000(n2=21)	Mann-Whitney-U-Test	
Climate Change Events	Mean (S.E)	Mean (S.E)	U	P- value
Wildfire	3.04(0.15)	2.76(0.12)	285	0.1947
High heat	2.65(0.23)	2.38(0.26)	291.5	0.214
Winds	2.3(0.2)	2.19(0.25)	265	0.5565
Drought	2.26(0.27)	1.81(0.27)	294.5	0.1876
Flooding	3.04(.13)	2.57(0.15)	314.5	0.03383*
Invasive Species	2.43(0.23)	2.43(0.18)	244	0.96

Table 5: (continued)

	Number of Employees in U&CF			
	<2 (n1=22)	>2(n2=22)	Mann-Whitney-U-Test	
Climate Change Events	Mean (S.E)	Mean (S.E)	U	P- value
Wildfire	2.73(0.2)	2.73(0.24)	243.5	0.976
High heat	2.18(0.31)	2(0.34)	265.5	0.534
Winds	1.73(0.28)	1.82(0.31)	239	0.9401
Drought	1.64(0.28)	2.18(0.36)	204.5	0.2792
Flooding	2.64(0.21)	2.73(0.24)	233.5	0.8142
Invasive Species	1.95(.28)	2.09(0.29)	228	0.7204

Note: The values in parentheses () indicate standard error. The symbol * indicates $p < .05$, and ** indicates $p < .10$. For each climate change event, responses were collected on five Likert scale (1=extremely negative, 2= somewhat negative, 3= no impact, 4= somewhat positive impacts, and 5= extremely positive impacts). Hence, a lower mean value indicates higher negative perceptions and vice versa.

4.2.2. Non-Profit Organizations

Among the climate change events, NPO respondents perceived drought as having the highest negative impact, at 88% (Figure 2). High heat was the second highest response at 79%, followed by winds at 67%. Most NPO respondents also reported that flooding (88%) and wildfires (64%) did not affect their U&CF activities.

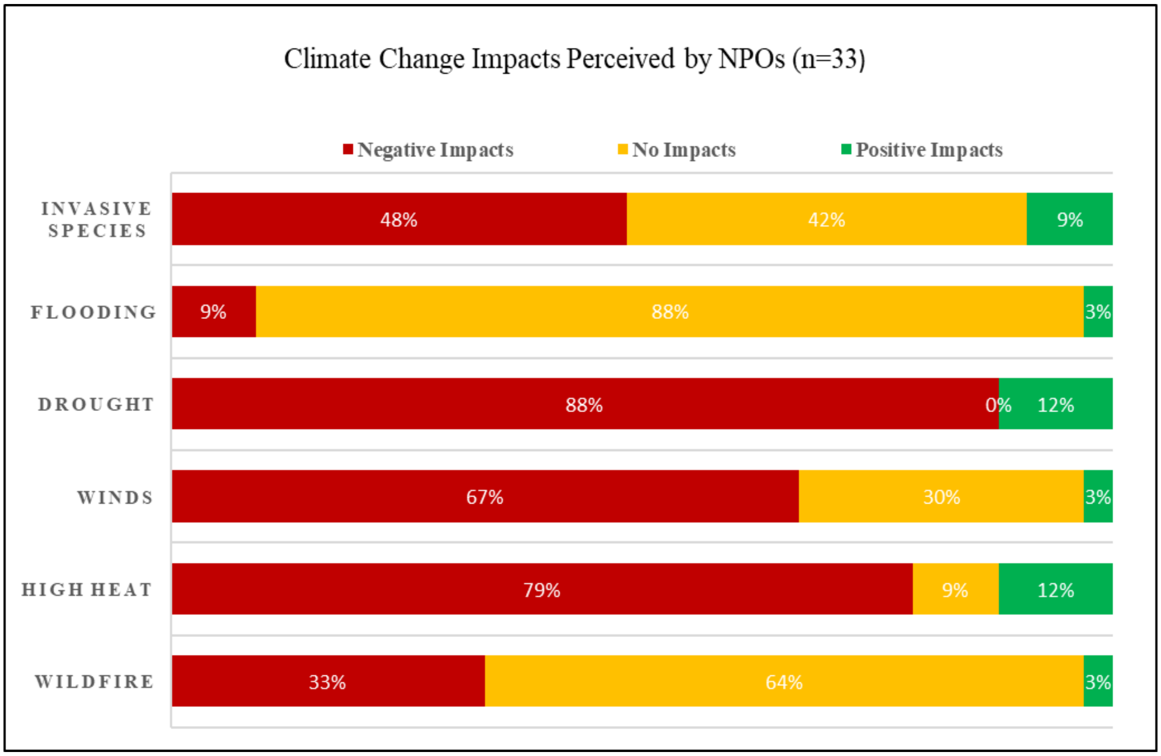

Figure 2: Climate Change Impacts Perceived by NPOs

4.2.2.1.Climate Change Perceptions Varied by Sociodemographic Characteristics

Table 6 demonstrates the test results on how perceptions of NPO respondents varied based on their sociodemographic characteristics. Results suggest that females perceived a significantly higher negative impact of wildfire (p=0.02, α = 0.05), while males perceived significantly higher negative impacts of high heat (p=0.08, α = 0.10) and drought events (p=0.08, α = 0.10).

Additional results suggest no significant differences based on respondents' age and education level. However, respondents who have worked with their organization longer than five years perceived higher negative impacts of wildfire (p=0.02, α = 0.05).

Table 6: Socio-demographic characteristics of NPO respondents and perceptions towards climate change events.

Sociodemographic Characteristics		Climate Change Events					
		Wildfire	High heat	Winds	Drought	Flooding	Invasive Species
Gender							
Male (n=14)	Mean (S.E)	2.86(0.14)	1.14(0.14)	1.57(0.25)	1(0)	2.86(0.14)	2.43(0.33)
Female(n=19)	Mean (S.E)	2.05(0.28)	2.05(0.39)	1.84(0.28)	1.84(0.38)	2.89(0.19)	2.05(0.32)
Mann-Whitney-U-Test		187	98.5	120	105	131	157.5
P-Value		0.0204*	0.0825**	0.579	0.0765**	0.9232	0.3313
Age							
<44 years(n=13)	Mean (S.E)	2.54(0.24)	1.92(0.43)	1.62(0.27)	1.62(0.42)	2.69(.21)	2.23(0.36)
>45 years (n=20)	Mean (S.E)	2.3(0.26)	1.5(0.29)	1.8(0.27)	1.4(0.28)	3(0.15)	2.2(0.3)
Mann-Whitney-U-Test		147	149.5	122.5	137	111	133
P-Value		0.4693	0.3264	0.7538	0.672	0.2289	0.9185
Education							
Bachelor or Below(n=18)	Mean (S.E)	2.44(0.27)	1.44(0.3)	1.89(0.29)	1.44(0.3)	2.89(0.2)	2.11(0.33)
Bachelor or Above(n=15)	Mean (S.E)	2.33(0.25)	1.93(0.38)	1.53(0.24)	1.53(0.36)	2.87(0.13)	2.33(.32)
Mann-Whitney-U-Test		140	108	153.5	132	136	119
P-Value		0.8465	0.1792	0.4288	0.873	0.9745	0.5334
Years of Experiences							
<5 years (n=15)	Mean (S.E)	2.87(0.24)	1.8(0.38)	1.8(0.33)	1.53(0.36)	3(0.2)	2.33(0.32)
>5 years (n=18)	Mean (S.E)	2(0.24)	1.56(0.32)	1.67(0.23)	1.44(0.3)	2.78(0.15)	2.11(0.33)
Mann-Whitney-U-Test		189	147.5	138	138	149	151
P-Value		0.0213*	0.543	0.9125	0.873	0.3889	0.5334

Note: The values in parentheses () indicate standard error. The symbol * indicates $p < .05$, and ** indicates $p < .10$. For each climate change event, responses were collected on five Likert scale (1=extremely negative, 2= somewhat negative, 3= no impact, 4= somewhat positive impacts, and 5= extremely positive impacts). Hence, a lower mean value indicates higher negative perceptions and vice versa.

4.2.2.2.Climate Change Perceptions Varied by Organizational Size

In the case of NPOs, the total annual budget was split into two categories (less than $50,000 and more than $50,000), and the number of employees involved in U&CF activities was divided into two (less than one and more than one) based on the median value. Smaller NPOs with a budget of less than $50,000 perceived higher negative impacts of invasive species than those with a higher budget. Based on the mean value, NPOs with smaller annual budgets and fewer employees perceived high negative impacts of climate change events compared to those larger NPOs in budget and employee size.

Table 7: Perceived Climate Change impacts and organizational size of NPOs.

	Total Budget		Mann-Whitney-U-Test	
	< 50,000(n1=18)	>$50,000(n2=15)		
Climate Change Events	Mean (S.E)	Mean (S.E)	U	P- value
Wildfire	2.56(0.15)	2.87(0.19)	111	0.315
High heat	1.83(0.15)	2.4(0.34)	108	0.2965
Winds	2.28(0.16)	2.33(0.23)	142.5	0.7746
Drought	1.5(0.12)	2.27(0.34)	94.5	0.1124
Flooding	2.94(0.06)	3(0.17)	137	0.9237
Invasive Species	2.11(0.2)	2.93(0.23)	74.5	0.02102*
	Number of Employees in U&CF		Mann-Whitney-U-Test	
	<1 (n1=19)	>1 (n2=14)		
Climate Change Events	Mean (S.E)	Mean (S.E)	U	P- value
Wildfire	2.47(0.26)	2.29(0.27)	143	0.6804
High heat	1.63(0.31)	1.71(0.4)	131.5	0.9593
Winds	1.95(0.28)	1.43(0.23)	162	0.2069
Drought	1.42(0.29)	1.57(0.39)	128	0.7719
Flooding	3(0.15)	2.71(0.19)	151	0.2604
Invasive Species	1.95(0.28)	2.57(0.37)	100	0.1883

Note: The values in parentheses () indicate standard error. The symbol * indicates $p < .05$, and ** indicates $p < .10$. For each climate change event, responses were collected on five Likert scale (1=extremely negative, 2= somewhat negative, 3= no impact, 4= somewhat positive impacts, and 5= extremely positive impacts). Hence, a lower mean value indicates higher negative perceptions and vice versa.

4.3. Perceived Climate Change Challenges in Organizational Activities

Figure 3 presents the perceived challenges in U&CF activities brought about by climate change in California. The responses were recorded on a multiple-choice basis, where the list of activities was as follows: higher demand for U&CF activities, fewer workable hours per day, unfavorable working conditions, higher operational costs, increased mortality of transplanted trees, and increased health problems of established trees.

Findings suggest that NPO participants perceived that there would be increased health problems with established trees as well as higher operational costs due to climate change challenges (21% each), followed by increased mortality of transplanted trees (19%), unfavorable working conditions (16%), and higher demand for UCF activities (14%). Meanwhile, public agencies (20 %) believed that climate change would increase established trees' health problems, increase transplanted trees' mortality, and lead to higher demand for U&CF activities. Higher operational costs (18%) and unfavorable working conditions (14%) were also noted. Neither group felt climate change events would lead to fewer daily workable hours for various U&CF activities.

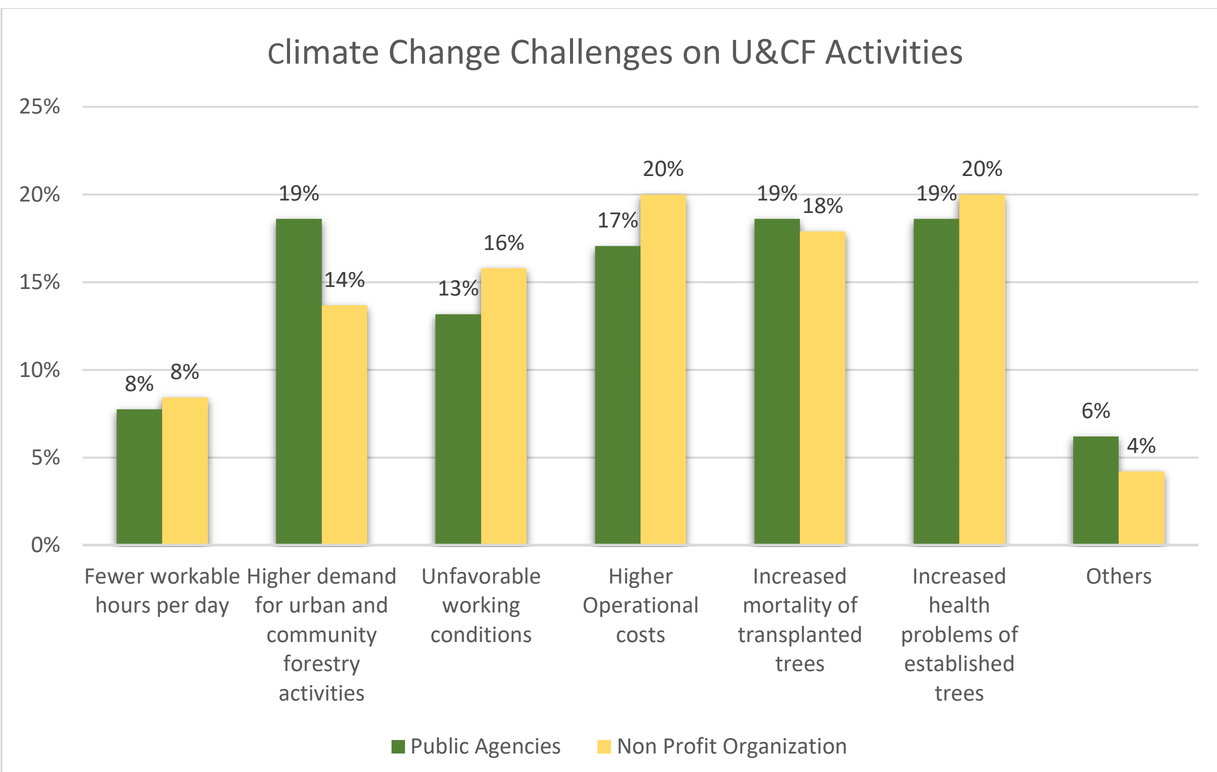

Figure 3: Percentage of the responses on each U&CF activity impacted by climate change events.

4.4. Current participation in carbon-related opportunities

We evaluated the status of the current participation of public agencies and NPOs in the Carbon Offset Markets (COM) and California Climate Investment Funding (CCIF) program. The respondents were asked to answer yes (=1) and no (=2) based on their current participation status in these programs. Figure 4 illustrates the current participation of government agencies in carbon-related programs such as COM and CCIF programs. The analysis shows that around 20% of respondents participated in a carbon offset market program, and about 30 participated in the CCIF program.

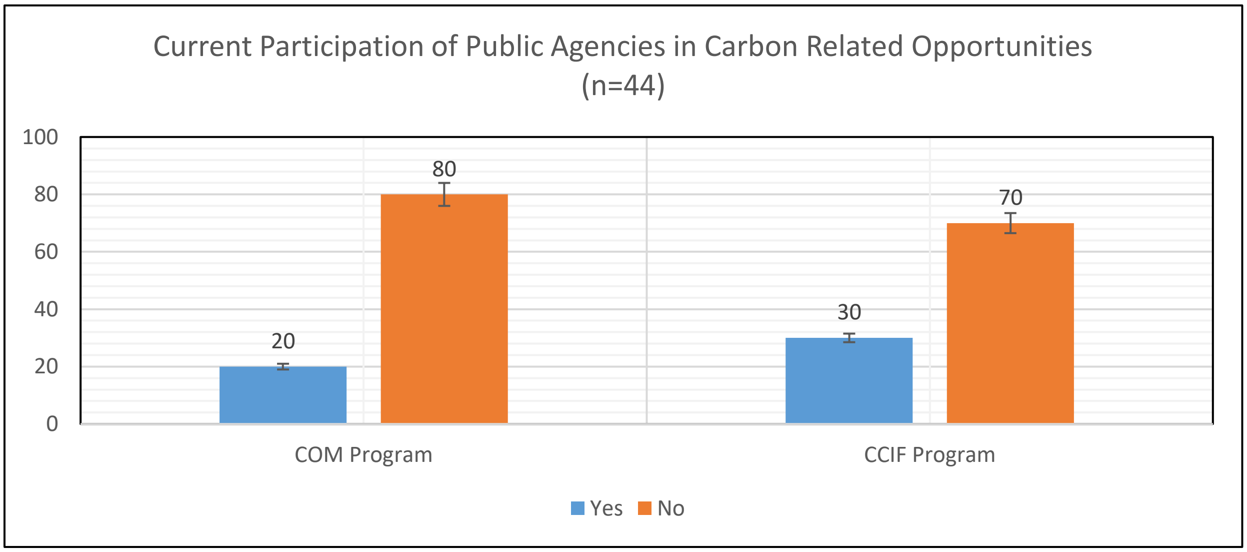

Figure 4: Current participation status of public agencies (%) in carbon-related opportunities.

Figure 5 illustrates the status of NPOs' current participation in carbon-related opportunities, such as COM and CCIF programs. The results found that only 6% of NPOs participated in the COM program, and 42% participated in the CCIF program.

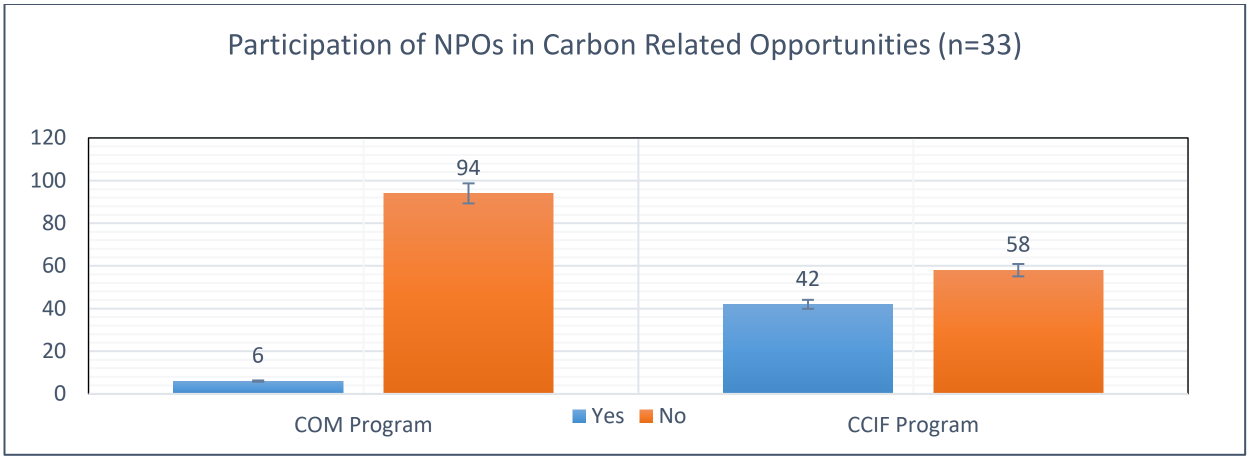

Figure 5: Current participation status of NPOs (%) in carbon-related opportunities.

Table 8 shows the test results comparing the participation status in the COM program and CCIF program between public agencies and NPOs. The result suggests a significant difference (α=0.10) between the two organizations regarding their participation in the COM program. The average mean values suggest that participation of public agencies was higher than that of NPOs. However, there is no significant difference (p-value> 0.10) between the two organizations regarding their participation in CCIF programs. As indicated by the average mean scores, the participation of NPOs was higher in CCIF programs compared to public agencies.

Table 8: Differences in participation in carbon-related opportunities between NPOs and Public Agencies

Carbon Related Opportunities	NPOs (n1=33) Mean (S.E)	Public Agencies (n2=44) Mean (S.E)	Mann-Whitney-U-Test U	P
Participation in the COM program	1.94(0.04)	1.8(0.06)	830.5	0.07738**
Participation in the CCIF program	1.58(0.09)	1.7(0.07)	632.5	0.2468

Note: The values in parentheses () indicate standard error. The symbol * indicates $p < .05$ and ** indicates $p < .10$. Participation in COM and CCIF programs each have two categories, such as yes and no. As we set 2 for no participation, the lower mean value denotes the higher participation and vice versa.

4.4.1. Participation in Carbon-Related Opportunities and Organizational Size

The total budgets of the organizations and the number of employees engaged in U&CF activities were considered to determine whether differences in organization size influenced their participation in the COM and CCIF programs.

4.4.1.1.Public Agencies

The test results reveal no statistically significant differences in participation in carbon-related opportunities based on the total annual budget of the public agencies. Moreover, there were significant differences in participation in CCIF programs based on the number of employees. Public agencies with more than two employees were associated with higher participation in the CCIF program (Table 9). The mean values suggest that public agencies with bigger employee sizes also had slightly higher participation in COM programs.

Table 9: Differences in participation in carbon-related opportunities based on the organizational size of public agencies.

Organizational Characteristics	: Total Budget		Mann-Whitney-U-Test	
	< $750,000 (n1=23)	>$750,000 (n2=21)		
Carbon Related Opportunities	Mean (S.E)	Mean (S.E)	U	P- value
Participation in the COM program	1.78(0.09)	1.81(0.09)	235	0.8401
Participation in the CCIF program	1.65(0.1)	1.76(0.0.1)	215	0.4396
	: Number of Employees in UCF		Mann-Whitney-U-Test	
	<2(n1=22)	>2 (n2=22)		
Carbon Related Opportunities	Mean (S.E)	Mean (S.E)	U	P- value
Participation in the COM program	1.86(0.07)	1.73(0.1)	275	0.275
Participation in the CCIF program	1.95(0.17)	1.59(0.11)	303.5	0.07745**

Note: The values in parentheses () indicate standard error. The symbol * indicates $p < .05$ and ** indicates $p < .10$. Participation in COM and CCIF programs each have two categories, such as yes and no.

4.4.1.2. Non-Profit Organizations

There was no statistically significant difference in NPOs' participation in the COM program by their total annual budget and the number of employees (Table 10). However, NPOs with a higher annual budget and more employees participated significantly more in the CCIF program.

Table 10: Differences in participation in carbon-related opportunities based on the organizational size of NPOs.

Organizational Characteristics: Total Budget			Mann-Whitney-U-Test	
Carbon Related Opportunities	< 50,000(n1=18) Mean (S.E)	>$50,000(n2=15) Mean (S.E)	U	P- value
Participation in the COM program	2(0)	1.87(0.09)	153	0.126
Participation in the CCIF program	1.89(0.08)	1.2(0.11)	228	0.00009421*
	: Number of Employees in U&CF		Mann-Whitney-U-Test	
Carbon Related Opportunities	<1 (n1=19) Mean (S.E)	>1 (n2=14) Mean (S.E)	U	P- value
Participation in the COM program	2(0)	1.86(0.1)	152	0.1031
Participation in the CCIF program	1.84(0.09)	1.21(0.11)	216.5	0.0004*

Note: The values in parentheses () indicate standard error. The symbol * indicates $p < .05$ and ** indicates $p < .10$. Participation in COM and CCIF programs each have two categories, such as yes and no.

4.4.2. Perceived Climate Change Impacts and Participation of Organizations in Carbon-Related Opportunities

4.4.2.1.Public Agencies

Table 11 demonstrates the test result comparing public agencies' perceptions of climate change events based on their current participation status in the COM program. Public agencies not participating in the COM program perceive higher negative impacts of drought events than those currently participating.

Table 11: Differences in perceptions towards climate change events based on current participation status in the COM program by public agencies.

	Participation in the Carbon Offset Market Program			
	Yes (n1=9)	No (n2=35)	Mann-Whitney-U-Test	
Climate Change Events	Mean (S.E)	Mean (S.E)	U	P value
Wildfire	3(0.33)	2.89(0.09)	157.5	1
High heat	2.78(0.46)	2.46(0.18)	175.5	0.5864
Winds	2.33(0.44)	2.23(0.17)	163	0.8742
Drought	2.78(0.46)	1.86(0.2)	221	0.05023**
Flooding	2.78(0.32)	2.83(0.1)	129	0.3102
Invasive Species	2.89(0.45)	2.31(0.13)	192.5	0.2839

Note: The values in parentheses () indicate standard error. The symbol * indicates $p < .05$, and ** indicates $p < .10$. For each climate change event, responses were collected on five Likert scale (1=extremely negative, 2= somewhat negative, 3= no impact, 4= somewhat positive impacts, and 5= extremely positive impacts). Hence, a lower mean value indicates higher negative perceptions and vice versa.

Table 12 shows that public agencies that perceived high heat, winds, and drought as significant climate challenges were more unlikely to participate in the CCIF program than not.

Table 12: Differences in perceptions towards climate change events based on their current participation status in the CCIF program.

	Participation in the CCIF Program			
	Yes (n1=13)	No (n2=31)	Man-Whitney-U-Test	
Climate Change Events	Mean (S.E)	Mean (S.E)	U	P value
Wildfire	3(0.23)	2.87(0.1)	213.5	0.7042
High heat	3.31(0.38)	2.19(0.16)	300	0.007069*
Winds	2.92(0.31)	1.97(0.16)	305.5	0.003768*
Drought	3.08(0.37)	1.61(0.18)	326.5	0.000623*
Flooding	3.08(0.21)	2.71(0.12)	242.5	0.1944
Invasive Species	2.77(0.38)	2.29(0.12)	245	0.2377

Note: The values in parentheses () indicate standard error. The symbol * indicates $p < .05$, and ** indicates $p < .10$. For each climate change event, responses were collected on five Likert scale (1=extremely negative, 2= somewhat negative, 3= no impact, 4= somewhat positive impacts, and 5= extremely positive impacts). Hence, a lower mean value indicates higher negative perceptions and vice versa.

4.4.2.2.Non-Profit Organizations

Table 13 demonstrates the test result to compare the differences in perceptions of NPOs towards climate change events based on their current participation status in the COM program. The test results reveal that only the flooding event was perceived as significantly different (α=0.10) between the two groups (yes and no) of NPOs. The mean values indicate that NPOs currently participating in the COM program believed the higher negative impact of flooding.

Table 13: Differences in perceptions towards climate change events based on their current participation status in the COM program by NPOs.

	Participation in the COM program			
	Yes (n1=2)	No (n2=31)	Mann-Whitney-U-Test	
Climate Change Events	Mean (S.E)	Mean (S.E)	U	P value
Wildfire	2.5(0.5)	2.71(0.12)	25.5	0.6555
High heat	3(1)	2.03(0.18)	46	0.2332
Winds	2(0)	2.32(0.14)	23	0.522
Drought	3(1)	1.77(0.18)	50	0.1254
Flooding	2.5(0.5)	3(0.08)	17	0.07215 **
Invasive Species	3(0)	2.45(0.17)	44	0.3157

Note: The values in parentheses () indicate standard error. The symbol * indicates $p < .05$, and ** indicates $p < .10$. For each climate change event, responses were collected on five Likert scale (1=extremely negative, 2= somewhat negative, 3= no impact, 4= somewhat positive impacts, and 5= extremely positive impacts). Hence, a lower mean value indicates higher negative perceptions and vice versa.

Table 14 shows the test results to compare the differences in perceptions of NPOs towards climate change events based on their current participation in the CCIF program. The test results reveal that only the invasive species was perceived as a significantly different (α=0.05) climate change impact between the two groups (yes=participate in CCIF program and no=do not participate in CCIF program) of NPOs. NPOs who currently do not participate in the CCIF program perceive higher negative impacts of invasive species.

Table 14: Differences in perceptions towards climate change events based on their current participation status in the CCIF program by NPOs.

	Participation in the CCIF Program			
	Yes (n1=14)	No (n2=19)	Mann-Whitney-U-Test	
Climate Change Events	Mean (S.E)	Mean (S.E)	U	P value
Wildfire	2.86(.21)	2.58(0.14)	152	0.4255
High heat	2.29(0.34)	1.95(0.18)	146	0.6198
Winds	2.43(0.25)	2.21(0.14)	144	0.6652
Drought	2.07(0.35)	1.68(0.17)	145	0.6456
Flooding	3(0.18)	2.95(0.05)	130	0.8723
Invasive Species	2.93(0.22)	2.16(0.21)	191.5	0.02461*

Note: The values in parentheses () indicate standard error. The symbol * indicates $p < .05$, and ** indicates $p < .10$. For each climate change event, responses were collected on five Likert scale (1=extremely negative, 2= somewhat negative, 3= no impact, 4= somewhat positive impacts, and 5= extremely positive impacts). Hence, a lower mean value indicates higher negative perceptions and vice versa.

4.5. Likeliness to Participate in Carbon-Related Opportunities

Figure 6 shows how likely public agencies are to participate in carbon-related opportunities. The results reveal that most respondents (39%) were extremely or somewhat likely to participate in the COM program, followed by neutral (36%), and 25% were extremely or somewhat unlikely to participate. Similarly, regarding the CCIF program, many (50%) were extremely or somewhat likely to participate, followed by neutral (30%), and 20% were extremely or somewhat unlikely to participate.

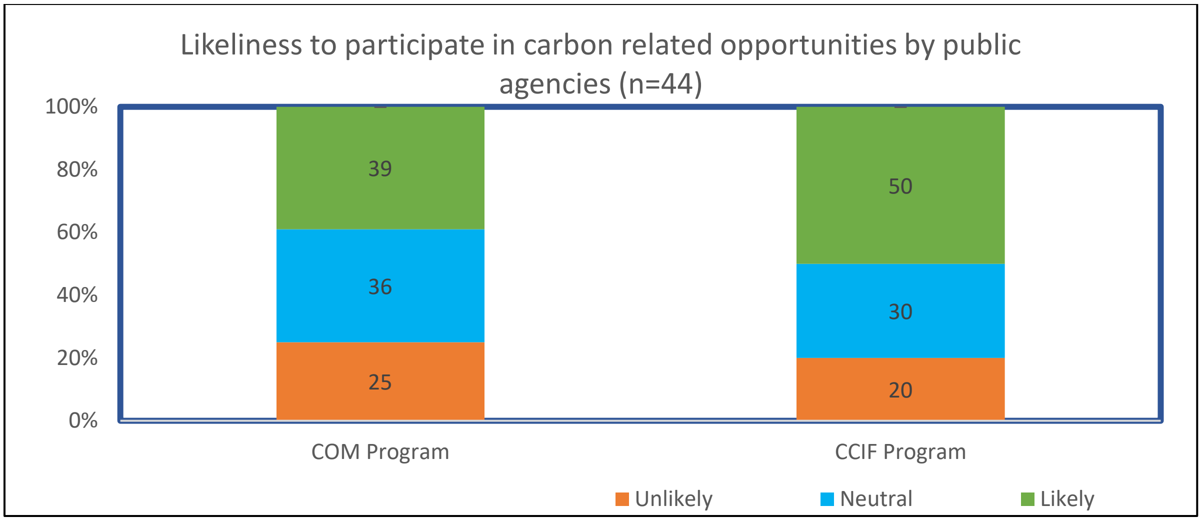

Figure 6: Likeliness to participate in carbon-related opportunities (%) by public agencies

Note: The figure in the bar represents the percentage of responses in each category.

Figure 7 reveals that most NPOs (46%) were extremely or somewhat unlikely to participate in the COM program, and 27% were neutral and highly or somewhat likely to participate. Regarding the CCIF program, about 61% are extremely or somewhat likely to participate, 9% are neutral, and the rest are unlikely to participate.

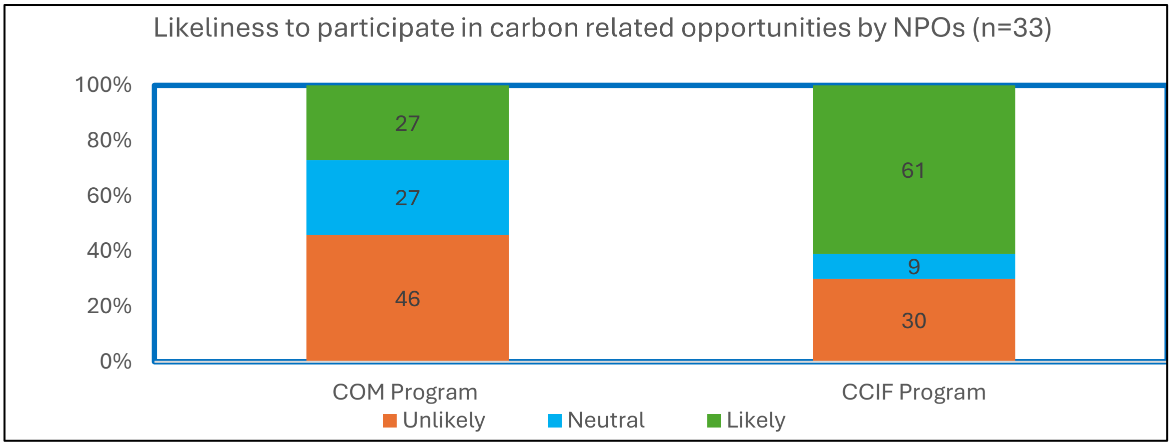

Figure 7: Likeliness to participate in carbon-related opportunities by NPOs.

Table 15 demonstrates the test results comparing the differences in likeliness to participate by NPOs and public agencies in the COM and CCIF programs. The results reveal that the likelihood of future COM program participation was perceived significantly differently (α=0.10) by NPOs (n=33) and public agencies; public agencies show a higher likeliness to participate in the COM program in the future. However, there is no statistically significant difference regarding their likelihood to participate in the CCIF program; the mean scores suggest that the NPOs had slightly higher mean values, indicating their higher likelihood to participate in the CCIF program in the future.

Table 15: Differences in likeliness to participate in carbon-related opportunities between NPOs and Public Agencies.

Likeliness to Participate in Carbon Related Opportunities	NPOs (n1=33)	Public Agencies (n2=44)	Mann-Whitney-U-Test	
	Mean (S.E)	Mean (S.E)	U	P
COM program	2.58(0.21)	3.14(0.18)	550	0.0624*
CCIF program	3.48(0.27)	3.36(0.18)	801.5	0.4274

Note: The values in parentheses () indicate standard error. The symbol * indicates $p < .05$, and ** indicates $p < .10$. For each carbon-related opportunity, responses were collected on five Likert scales (1= very unlikely, 2= somewhat unlikely, 3= neutral, 4= somewhat likely, and 5= very likely). Hence, a higher mean value indicates higher likeliness and vice versa.

4.5.1. Climate Change Perceptions and Likeliness to Participate in Carbon-Related Opportunities

The Kruskal-Wallis-Rank-Sum test explored the association between respondents' attitudes toward climate change events and their likelihood of participating in carbon-related opportunities. The likelihood of participation in these carbon-related opportunities was collected using three Likert scales: unlikely, neutral, and likely. Similarly, the perceptions of climate change impacts were divided into three categories: negative, no, and positive.

***4.5.1.1.*Public Agencies**

Table 16 demonstrates the test results comparing public agencies' perceptions of different climate change events across the different scales of likelihood of participating in the COM program in the future. Based on the Likert scale, we found no significant differences in perceptions of climate change events and the likelihood of future COM program participation.

Table 16: Differences in perceptions towards climate change events among the public agencies having different likeliness scales for participating in the COM program.

	Likeliness to Participate in the COM Program			Kruskal-Wallis-Rank-Test		
	Unlikely (n1=11)	Neutral (n2=16)	Likely (n3=17)			
Climate Change Events	Mean (S.E)	Mean (S.E)	Mean (S.E)	Chi-Sq	Df	P-Value
Wildfire	2.73(.14)	2.88(0.18)	3.06(0.16)	2.0601	2	0.357
High heat	2(0.13)	2.62(0.27)	2.76(0.35)	2.8741	2	0.2376
Winds	1.82(0.18)	2.19(0.23)	2.59(0.32)	2.3978	2	0.3015
Drought	1.36(0.15)	2.19(0.31)	2.35(0.37)	3.5064	2	0.1732
Flooding	2.55(0.25)	2.75(0.14)	3.06(0.16)	2.8104	2	0.2453
Invasive Species	2.09(0.21)	2.38(0.2)	2.71(0.28)	2.1981	2	0.3332

Note: The values in parentheses () indicate standard error. The symbol * indicates $p < .05$, and ** indicates $p < .10$. For each climate change event, responses were collected on five Likert scale (1=extremely negative, 2= somewhat negative, 3= no impact, 4= somewhat positive impacts, and 5= extremely positive impacts). Hence, a lower mean value indicates higher negative perceptions and vice versa.

Table 17 demonstrates the test results to compare the perceptions of public agencies on different climate change events across the different scales of likelihood to participate in the CCIF program in the future. The test results show that public agencies who perceived the high negative impacts of drought are unlikely to participate in the CCIF program. If we refer to the descriptive results, public agencies that perceive the high negative impacts of climate change events are unlikely to participate in the CCIF program.

Table 17: Differences in perceptions towards climate change events among the Public Agencies having different likelihood scales of participating in the CCIF program.

	Likeliness to Participate in the CCIF Program					
	Unlikely (n1=9)	Neutral (n2=13)	Likely (n3=22)	Kruskal-Wallis-Rank-Test		
Climate Change Events	Mean (S.E)	Mean (S.E)	Mean (S.E)	ChiSq	Df	P-Value
Wildfire	2.78(0.15)	2.85(0.22)	3(0.13)	1.3878	2	0.4996
High heat	2.33(0.37)	2.31(0.24)	2.73(0.28)	0.95125	2	0.6215
Winds	1.78(0.22)	2.31(0.31)	2.41(0.24)	2.17	2	0.3379
Drought	1.22(0.15)	1.92(0.31)	2.45(0.31)	6.3271	2	0.04228*
Flooding	2.56(0.24)	2.69(0.24)	3(0.11)	2.8275	2	0.2432
Invasive Species	2.22(0.28)	2.46(0.18)	2.5(0.24)	0.24064	2	0.8866

Note: The values in parentheses () indicate standard error. The symbol * indicates $p < .05$, and ** indicates $p < .10$. For each climate change event, responses were collected on five Likert scale (1=extremely negative, 2= somewhat negative, 3= no impact, 4= somewhat positive impacts, and 5= extremely positive impacts). Hence, a lower mean value indicates higher negative perceptions and vice versa.

4.5.1.2. Non-Profit Organizations

Table 18 demonstrates the test results indicating that there was no significant difference in perceptions towards climate change events between the three categories of NPOs having various levels of likeliness to participate in the COM program in the future

Table 18: Differences in perceptions towards climate change events among the NPOs having different likeliness scales for participating in the COM program.

	Likeliness to Participate in the COM Program					
	Unlikely (n1=10)	Neutral (n2=3)	Likely (n3=20)	Kruskal-Wallis-Rank-Test		
Climate Change Events	Mean (S.E)	Mean (S.E)	Mean (S.E)	Chi-Sq	Df	P-Value
Wildfire	2.5(0.22)	2.67(0.33)	2.8(0.16)	0.7016	2	0.7041
High heat	2.3(0.21)	2(0.58)	2(0.26)	2.0743	2	0.3545
Winds	2.2(0.2)	2.33(0.33)	2.35(0.2)	0.12264	2	0.9405
Drought	1.9(0.28)	1.67(0.33)	1.85(0.26)	0.47576	2	0.7883
Flooding	3(0)	3(0)	2.95(0.14)	0.715	2	0.6994
Invasive Species	2.3(0.3)	2.67(0.33)	2.55(0.22)	0.66304	2	0.7178

Note: The values in parentheses () indicate standard error. The symbol * indicates $p < .05$, and ** indicates $p < .10$. For each climate change event, responses were collected on five Likert scale (1=extremely negative, 2= somewhat negative, 3= no impact, 4= somewhat positive impacts, and 5= extremely positive impacts). Hence, a lower mean value indicates higher negative perceptions and vice versa.

Table 19 demonstrates the test results, showing no statistically significant differences in perceptions of climate change events between the three categories of NPOs having various levels of likeliness to participate in the CCIF program. The mean scores suggest that NPOs who perceive higher negative impacts of climate change events are more likely to participate in the CCIF program in the future.

Table 19: Differences in perceptions towards climate change events among the NPOs having different likeliness scales to participate in the CCIF program.

	Likeliness to Participate in the CCIF Program					
	Unlikely (n1=15)	Neutral (n2=9)	Likely (n3=9)	Kruskal-Wallis-Rank-Test		
Climate Change Events	Mean (S.E)	Mean (S.E)	Mean (S.E)	ChiSq	Df	P-Value
Wildfire	2.8(0.22)	2.56(0.18)	2.67(0.17)	0.82528	2	0.6619
High heat	2.33(0.27)	1.89(0.31)	1.89(0.35)	2.1311	2	0.3445
Winds	2.47(0.26)	2.33(0.17)	2(0.17)	2.2626	2	0.3226
Drought	2.07(0.28)	1.56(0.34)	1.78(0.32)	2.7591	2	0.2517
Flooding	3.07(0.15)	2.89(0.11)	2.89(0.11)	0.79852	2	0.6708
Invasive Species	2.6(0.27)	2.44(0.34)	2.33(0.24)	0.30069	2	0.8604

Note: The values in parentheses () indicate standard error. The symbol * indicates $p < .05$ and ** indicates $p < .10$. For each climate change event, responses were collected on five Likert scale (1=extremely negative, 2= somewhat negative, 3= no impact, 4= somewhat positive impacts, and 5= extremely positive impacts). Hence, a lower mean value indicates higher negative perceptions and vice versa.

4.5.2. Likeliness to Participate in Carbon-Related Opportunities Based on Organizational Size.

4.5.2.1.Public Agencies

Table 20 shows the test results, showing that public agencies with more than two U&CF employees were significantly more likely to participate in both carbon-related opportunities. However, budget size did not significantly influence their likelihood of participating in these opportunities.

Table 20: Likeliness to participate in carbon-related opportunities based on the organizational size of public agencies.

Organizational Characteristics: Total Budget				
	<$750,000 (n1=23)	>$750,000 (n2=21)	Mann-Whitney-Test	
Carbon Related Opportunities	Mean (S.E)	Mean (S.E)	U	P- value
COM program	3.17(0.27)	3.1(0.25)	261.5	0.6347
CCIF program	3.48(0.26)	3.24(0.27)	277.5	0.3881

Organizational Characteristics: Number of Employees in UCF				
	<2 (n1=22)	>2 (n2=22)	Mann-Whitney-Test	
Carbon Related Opportunities	Mean (S.E)	Mean (S.E)	U	P- value
COM program	2.73(0.36)	3.82(0.28)	153.5	0.02759*
CCIF program	3.05(0.34)	4(0.32)	161	0.04128*

Note: The values in parentheses () indicate standard error. The symbol * indicates $p < .05$, and ** indicates $p < .10$. For each carbon-related opportunity, responses were collected on five Likert scales (1= very unlikely, 2= somewhat unlikely, 3= neutral, 4= somewhat likely, and 5= very likely). Hence, the higher mean value indicates a higher likeliness to participate and vice versa.

4.5.2.2. Non-Profit Organizations

The test results reveal that the larger size of NPOs with higher total annual budgets and more employees are more likely to participate in both carbon-related opportunities (Table 21).

Table 21: Likeliness to participate in carbon-related opportunities and organizational size of NPOs.

Organizational Characteristics: Total Budget				
	< 50,000 (n1=18)	>$50,000 (n2=15)	Mann-Whitney-U-Test	
Carbon Related Opportunities	Mean (S.E)	Mean (S.E)	U	P- value
COM Program	2.22(0.27)	3(0.31)	87	0.07651**
CCIF Program	2.78(0.36)	4.33(0.29)	51	0.001745*
	: Number of Employees in UCF		Mann-Whitney-U-Test	
	<1 (n1=19)	>1 (n2=14)		
	Mean (S.E)	Mean (S.E)	U	P- value
COM Program	2.05(0.35)	3.43(0.43)	73	0.01988*
CCIF Program	3.11(0.45)	4.29(0.4)	89.5	0.07042**

Note: The values in parentheses () indicate standard error. The symbol * indicates $p < .05$, and ** indicates $p < .10$. For each carbon-related opportunity, responses were collected on five Likert scales (1= very unlikely, 2= somewhat unlikely, 3= neutral, 4= somewhat likely, and 5= very likely). Hence, a higher mean value indicates higher likeliness and vice versa.

4.5.3. Current Participation and Likeliness to Participate in Carbon-Related Opportunities in the Future

Table 22 shows the test results on the likelihood of participating in carbon-related opportunities based on their current participation status.

The test results reveal no significant differences in the likelihood of public agencies participating in both carbon-related opportunities; NPOs currently participating in these programs are more likely to participate in both programs in the future. However, the descriptive result indicates that public agencies currently participating are more likely to participate in both carbon-related opportunities, such as the COM and CCIF programs.

Table 22: Differences in likelihood of participation in carbon-related opportunities based on their status of participation in these opportunities.

Public Agencies:	Current Participation in the COM Program			
	Yes (n1=9) Mean (S.E)	No (n2=35) Mean (S.E)	Mann-Whitney-U-Test U	 P value
Likeliness to participate in COM	3.44(0.41)	3.06(0.2)	185.5	0.4068
Public Agencies:	**Current Participation in the CCIF Program**			
	Yes (n1=13) Mean (S.E)	No (n2=31) Mean (S.E)	Mann-Whitney-U-Test U	 P value
Likeliness to participate in CCIF	3.69(0.35)	3.23(0.22)	247.5	0.2259
NPOs:	**Current Participation in the COM Program**			
Climate Change Events	Yes (n1=2) Mean (S.E)	No (n2=31) Mean (S.E)	Mann-Whitney-U-Test U	 P value
Likeliness to participate in COM	4(0)	2.48(0.22)	54	0.07996**
NPOs:	**Current Participation in the CCIF Program**			
Climate Change Events	Yes (n1=14) Mean (S.E)	No (n2=19) Mean (S.E)	Mann-Whitney-U-Test U	 P value
Likeliness to participate in CCIF	4.79(0.11)	2.53(0.31)	250	0.0000108*

Note: The values in parentheses () indicate standard error. The symbol * indicates $p < .05$, and ** indicates $p < .10$. For each carbon-related opportunity, responses were collected on five Likert scales (1= very unlikely, 2= somewhat unlikely, 3= neutral, 4= somewhat likely, and 5= very likely). Hence, a higher mean value indicates higher likeliness and vice versa.

CHAPTER FIVE: DISCUSSION

5.1. Climate Change Perceptions

Results suggest that drought, high heat, and winds were the most significant negatively perceived impacts, and these organizations had no differences in climate change perception. Consistent with our findings, most previous studies revealed that drought is one of the most significant challenges in urban forestry (Love et al., 2022; McPherson et al., 2017). California recently encountered the most prolonged driest period (2014-2018) in recorded history; urban forests in this region ultimately faced drought challenges accompanied by unfavorable site conditions. Aligning with our study, the increased frequency and duration of wind and heat waves were also reported as adverse effects of climate change, causing damage and health problems for urban trees in California (Milanes et al., 2022). Respondents reported no significant perceived impact of wildfires on business activities related to U&CF in California. Generally, wildfires are commonly reported in rural areas where inadequate resources and inaccessibility make it difficult for fire management. However, Urban and developed areas are usually equipped with readily accessible fire emergency services. Since our targeted respondents were from urban regions, it seems relevant that wildfires may have no impact on U&CF business activities. Furthermore, supporting our result, Schreider et al. (2000) revealed that there are only rare damaging floods in the urban regions, primarily exhibiting uncertainties for the recurrence interval for extreme floods, even under the present climate change scenario. Similarly, some authors argued that climate change might positively impact forestry, which complies with this study. For example, Soucy et al. (2021) claimed that drought and high heat could accelerate photosynthesis and increase tree biomass. Moreover, Brandt et al. (2016) mentioned in their study that climate change may reduce the viability of some invasive plants and pests, thus facilitating their control and allowing new plantations of climate-adaptive species.

The survey results show that the increased health problems of established trees, the higher mortality rate of transplanted trees, and higher operational costs are the significant challenges posed by climate change in U&CF activities in California. In a study of urban forestry in Chicago, Brandt et al. (2016) had also identified similar impacts of climate change on urban forests, such as i) unusual precipitation and flooding causing stress and mortality of trees and decreasing habitat suitability for existing species, ii) spread of invasive species, insect pests, and diseases, iii) added workload for staffs, and iv) unpredictable climatic conditions. Additionally, McPherson et al. (2017) and Esperon-Rodriguez et al. (2022) in a study of California's urban forests came to a similar conclusion that trees in urban regions face many threats from drought, high heat, and pest infestations, reducing the environmental and socio-economic benefits of urban forests and adding management costs to the urban residents and government. Comparing these facts, it can be generalized that NPOs and public agencies in California are also concerned with and affected by the impacts of climate change as they perceive the increased health risk and mortality of trees in U&CF.

Based on the socio-demographic characteristics of the respondents, we found mixed perceptions towards climate change events between the organizations. Female respondents perceived significantly higher negative impacts of wildfire in both organizations; however, male respondents of NPOs perceived higher negative impacts of drought and high heat. Overall, female respondents perceived higher negative impacts of climate change. Similarly, mostly younger respondents perceived higher negative impacts of climate change. Ballew et al. (2020) also revealed that females had stronger beliefs about the impacts of climate change and the associated threats. Similarly, Whitmarsh and Capstick (2018) revealed that men and older people were more skeptical and less concerned about climate change than females and younger people. Again, a lower level of education and more years of working experience were associated with higher negative perceptions towards climate change. This scenario indicates that even with a lower level of education, several years of professional engagement provides them with a detailed understanding of climate change impacts. Ballew et al. (2020) also state that education and proper experiences positively predict the scientific understanding of climate change and its existence. However, Whitmarsh and Capstick (2018) indicated that personal values, worldview, and ideology are stronger predictors of climate change perceptions than demographic knowledge and other factors.

Though there were no differences in climate change perceptions between the two organizations, they held different perceptions within the organization based on the size of their organizations measured by the annual operating budget and the number of employees involved in U&CF activities. Public agencies with fewer employees perceived higher negative impacts of climate change events; however, NPOs with lower annual budgets and fewer employees perceived higher negative impacts of climate change events. Prior studies also revealed that perceived climate change impacts could vary by organizational attributes such as goals, institutional context, and resource availability (Berkhout, 2012). For instance, public agencies or government organizations usually have a dedicated budget and personnel (Ordóñez et al., 2019). Similarly, consistent with our results, Barona et al. (2023) pointed out in their study that non-governmental actors usually suffer from limited budgets and human resources, limiting their choice of management actions and policy implementation. However, a study of Belgrade city, Serbia, on the perception of urban forestry stakeholders towards climate change adaptation reported that organizations with limited human and financial resources showed a more positive attitude towards climate change, considering it as a pressing issue (Živojinović & Wolfslehner, 2015).

5.2. Participation in Carbon-Related Opportunities

The study investigated the current participation and future willingness of public agencies and NPOs in California's COM and CCIF programs. Participation in both programs was low, with significantly higher non-participation rates. However, there was a positive trend in future willingness to participate, particularly in the CCIF program. The result indicates that both organizations were reluctant towards the COM program. Supporting our findings, Marland et al. (2017) also reported that participation in the carbon offset program was low in California, with a significant dropout rate. The COM program is a complex protocol requiring additional policy documents, financial investments, time commitment, and technically sound personnel to operate this system (Moser et al., 2022).However, the CCIF program offers flexibility regarding commitments to GHG emission reductions without requiring financial investment or a complex policy protocol. Participating in the CCIF program is less risky and less complex, which could be why both organizations prefer the CCIF program over COM.

Similarly, the annual budget had no significant differences in public agencies' participation, while larger agencies with more employees had a positive association with their current and future participation. Likewise, larger-sized NPOs with higher annual budgets and more employees had higher participation, currently and in the future, in both carbon-related opportunities. This scenario indicates that financial resources are not the primary barrier for public agencies; having more personnel can foster innovation and adopt new opportunities, including carbon programs. In contrast, limited financial and human resources may hinder NPOs' participation. In a study from Minnesota, USA, Moser et al. (2022) also reported that budget, area of forestland, and technical resources of organizations are important determinants of participation in the forest carbon offset program. Aligning with our result, Poudyal et al. (2010) also highlighted that public agencies had adequate financial and human resources to participate in the U&CF carbon trading program.

The study also revealed that perceptions of climate change did not significantly influence participation in carbon programs. Despite negative perceptions of climate events such as drought and high heat among public agencies, this did not lead to increased participation in carbon programs. Previous studies corroborate these findings, showing that public land managers often prioritize other issues over climate change mitigation through carbon management (Dilling et al., 2013). Conversely, other studies identified that attitudes toward climate change strongly predicted enrollment in carbon market programs. For example, private forest landowners who were skeptical towards climate change were less interested in carbon markets, and those who were aware of climate change and their belief in forests towards mitigating climate change were more interested in participating in carbon offset markets(Graves et al., 2022; Miller et al., 2012; White et al., 2018).

Though we did not explore the potential reasons for lower participation and less willingness to participate in COM programs, several underlying factors might deter them from participation. In general, common barriers in forestry projects include but are not limited to the complexity of the forest carbon offset protocol requiring intensive inventory, project area verification by third-party experts, time commitment of at least 100 years, monitoring and reporting, and certification for sustainability (Diaz et al., 2009; Kelly et al., 2017). Meanwhile, U&CF might face additional challenges to enter the carbon market. For example, urban forests are primarily considered for their aesthetic and associated socio-ecological benefits rather than direct economic benefits. Moreover, the site conditions and urban tree canopy cover in the urban regions could be questionable regarding the fulfillment of quality criteria such as additionality, permanence, and verification. On the other hand, most of the U&CF is operated and owned by public agencies; unlike private sectors, they are less influenced by market forces and economic incentives (Poudyal et al., 2011). Instead, developing new or revising existing urban forestry extension programs and policies could be beneficial in involving more public agencies in carbon trading schemes and climate change mitigation approaches.

CHAPTER SIX: CONCLUSION

In recent years, while urban and community forests have been recognized worldwide for their socio-economic and environmental benefits, they face significant threats due to climate-induced extreme weather events. This situation necessitates the incorporation of diverse stakeholder perspectives to address the climate change challenges and adopt potential mitigation and adaptation measures in U&CF.

Our findings indicate that extreme weather events, such as drought, high heat, and winds, may negatively affect U&CF activities in California. These extreme weather events reportedly result in increased health risks to urban trees and higher mortality of newly transplanted trees, raising the operational costs of U&CF management.

NPOs and public agencies exhibit limited current and potential future participation in carbon-related opportunities in California. Our findings suggest that an organization's perception of climate change does not strongly determine its participation in carbon-related opportunities. Even organizations with high negative perceptions of climate change events demonstrated a low preference to engage in these programs, currently and in the future. However, NPOs expressed more concern about the challenges of climate change and were more supportive of climate mitigation and adaptation policies.

There are some caveats worth noting. First, despite extensive efforts in survey fielding in California, the survey response rate was low, hindering the application of advanced statistical analyses. Second, in this exploratory study, the selected survey respondents were recruited through convenience sampling, by recruiting respondents' emails, and by choosing their affiliation with U&CF. This technique might result in biased responses; respondents with strong beliefs about climate change and carbon programs might be interested in responding to the survey. Furthermore, this study only covered the perception of public agencies and NPOs, although multiple stakeholders(Parajuli et al., 2022) are actively involved in managing U&CF. Moreover, this study tested multiple hypotheses to explore the interlinkage between perceptions rather than directly asking and understanding respondent's thoughts. We did not explore the reasons or factors behind their perceptions of climate change events or participation in the carbon program, which could provide detailed insights and feedback for U&CF stakeholders in designing future climate change mitigation and adaptation programs. Future studies should assess the understanding and perceptions of various urban and community forestry stakeholders regarding climate change impacts and explore the barriers and solutions to enhance their participation in carbon-related activities.

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