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Analyzing the effects of climate impacts in El Salvador and how they influence pollution, ecosystems and communities

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Analyzing the effects of climate impacts in El Salvador and how they influence pollution, ecosystems and communities

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Abstract

Due to projections of rising temperatures and increased frequency and severity of extreme weather events, the rate at which climate change is impacting nations is devastating. However, developing countries and vulnerable communities are not the primary contributors to climate change, but they are at a greater risk for climate impacts by industrialized nations. As a result of increased human activity, developing nations such as El Salvador are particularly susceptible to climate-related events. Deforestation, water pollution, and human health risks are some activities that have contributed to El Salvador's vulnerability to climate change, drastically affecting rural communities suffering from multidimensional poverty. Gender, housing, health impacts, education, and income are some of the determinants of multidimensional poverty. These factors define the physical, social, and environmental susceptibility of communities and the nation to climate change's effects. Agriculture is the primary source of income for the rural population, but it is also one of the primary contributors to the country's greenhouse gas emissions and water pollution, increasing the environmental risks affecting rural populations. This paper assessed the overall vulnerability of El Salvador and its communities by analyzing agricultural management methods, ecosystem exposure and physical, social, and environmental vulnerability to climate impacts. Based on the research findings, the implementation of alternative agricultural practices, the incorporation of educational programs for community engagement, the expansion of conservation and restoration of mangrove ecosystems, and an analysis of alternative housing locations for vulnerable communities to further augment adaptive capacity.

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List of Acronyms and Definitions

ANDA	*Administración Nacional de Acueductos y Alcantarillados* (National Administration of Aqueducts and Sewers)
AFOLU	*Agricultura, silvicultura y otros usos de tierra* (Agriculture, forestry and other land use)
GVI	Germanwatch Vulnerability Index
GDP	Gross Domestic Product
ITCZ	Intertropical Convergence Zone
ISSS	Salvadorian Institute of Social Security *(Instituto Salvadoreño del Seguro Social)*
MARN	*Ministro de Medio Ambiente y Recursos Naturales* (Department of the Environment and Natural Resources)
	Metodología para el análisis de la Vulnerabilidad (Methodology for vulnerability analysis)
MSPAS	*Ministerio de Salud Pública y Asistencia Social* (Department of public health and social assistance)
PREP	*Programa nacional de restauración de ecosistemas y paisajes* *(*National Program for the Restoration of Ecosystems and Landscapes)
PROGAN	*Programa de desarrollo sustentable de la ganadería* *(*Livestock sustainable development program)
	Programa Nacional de Alfabetizacion (National Literacy Program)
SDG	Sustainable Development Goals
SLR	Sea Level Rise
TRB	Tropical Rain Belt

1. Introduction

The frequency, intensity, and length of extreme weather events, such as heatwaves, storms, and droughts, have grown as a result of anthropogenic activities during the past few decades (Pradyumna & Sankam, 2022). Their effects can have direct or indirect effects on human health via a decline in biodiversity, pollution, and disease vectors, thereby affecting human livelihoods. For instance, the persistent drought that is ravaging El Salvador affects subsistence farmers, resulting in alternative or secondary earnings, lack of water quality and availability, and forced migration (Hallett, 2019). Approximately 60% of El Salvador's land area is devoted to agriculture, the primary source of income for the rural population (MARN, 2018a). 36% of the region consists of arable land, which contains the principal crops consumed and exported by the nation (UNDP, 2021). Nonetheless, El Salvador's placement in the dry corridor, a region of tropical dry forest, makes it very susceptible to climate change (Central America's Dry Corridor, 2020).

Extreme weather events have damaged agriculture lands by leaving them severely degraded to the point that farmers have been forced to relocate to alternate lands by deforesting coastal regions (Herrador-Valencia et al., 2011). Coastal habitats provide coastal protection, climate regulation and economic value (Hernández-Blanco et al., 2022). However, due to their exposure, they are already very sensitive to sea-level rise, pollution, ocean acidification, and extreme weather events, which will have an even bigger impact on these ecosystems in the future (Mercer & Salem, 2012). The deforestation of lands effects disadvantaged people by increasing their food insecurity, illnesses, water availability, and access to healthcare (Hernández-Blanco et al., 2022); hence, transforming coastal regions into agricultural land is not a viable alternative.

Due to El Salvador's history as a mono-export economy, natural disasters have had a negative influence on the country's economy. A mono-export economy is a system that relies on the export of a single primary crop (Hecht et al., 2006). During colonial times, it exported Indigo, whereas coffee is its present export crop. Nonetheless, climate change has damaged the agriculture industry by diminishing crop yields. This is due to the higher temperatures and frequency and severity of extreme weather events, including rainfall and droughts. These effects have left individuals without shelter, food security as both producers and consumers, economic diversity, and clean water. Climate issues lead to a lack of biodiversity, a rise in pollution, environmental degradation, and climate variability, which have a negative impact on food production, availability, and security. These issues are forcing people to migrate to metropolitan regions.

As a result of the migration to the interior of the country, land degradation is intensifying and living conditions are worsening. Communities' health is also a significant factor in this migration, especially for those with low socioeconomic status, as the correlation between health and socioeconomic status is well-known (Tzoulas et al., 2007). This is mostly due to excessive pollution exposure (Hallet, 2019). Approximately 35.2% of the Salvadorian population is compound poor, while 58.5% in rural regions and 22.5% in urban areas suffer from multidimensional poverty as a result of a lack of different income and excessive pollution (Gomes, 2019).

Degradation of the country's land has had a negative impact on vulnerable communities, causing an increase in health issues, lack of money, and poverty. In El Salvador, the agricultural sector is the second largest source of employment in rural areas, ensuring food security, water availability, and water demand (MARN ,2018a). Agriculture contributes for 41.5% of the active population and 52% of water availability and water demand in rural areas (Slotten et al., 2020). The impact of deforestation on natural sources such as forests and mangroves contribute to poor water quality and availability as a result of the agricultural sector's overexploitation. This is due to nonpoint source pollution (NPS) and point source pollution, ultimately affecting the way of life of communities (USGS, 2007). An assessment of possible ecosystem-based adaptations must be addressed so that the country does not experience such detrimental effects on its people and ecosystems. El Salvador must examine strategies to strengthen its adaptive capacity to better handle environmental and social fairness, ecosystem protection, human health, and water scarcity more effectively.

To better comprehend the impact of climate change and its impacts on equality, human health, and mangrove ecosystem functions and services in El Salvador, the last four decades of research on the topic was analyzed. In addition, the evaluation will determine how the ecosystem's current functions and services have changed as a result of human activity and climate change. In developing nations, the implications of climate change exacerbate vulnerability, risk and exposure to extreme weather events. Often, the difficulty lies in assigning priority to the effects of climate impacts and allocating government expenditures to people, infrastructure, and ecosystems impacted by climate change over other sectors (e.g., education, health, etc) (Organ et al., 2012). To protect and avoid further deterioration of ecosystems and their services and functions, adaptation and mitigation actions must be implemented at a faster and equitable rate.

This research aims to better comprehend and recommend appropriate ecosystem-based adaptations in El Salvador to address climate impacts, vulnerability to climate and other impacts and ecosystem conservation. Three sub questions are proposed to better assess the data gathered from the effects of climate change on the aforementioned components and how ecosystem-based responses can play a significant role in minimizing pollution. These questions will aid in comprehending the country's dynamic throughout the past four decades, as well as the expected future effects. The sub questions are as follows:

1. Why is agriculture, forestry, and other land use (AFOLU) sector the largest greenhouse gas emitter and cause of water pollution in El Salvador?
2. What are the impacts of climate change on mangrove ecosystems and how can their conservation help fight climate impacts and human vulnerability?
3. In what ways does vulnerability affect low socioeconomic populations by making them more susceptible to the effects of extreme weather events, pollution, gender inequality, and increased health risks?

Finally, these questions will aid in the formulation of management recommendations to answer the overarching topic of how El Salvador can strengthen its adaptive capacity to handle environmental and social fairness, ecosystem conservation, human health, and water quality more effectively.

2. El Salvador's Background

2.1 *Geography and Climate*

El Salvador, formally known as the Republic of El Salvador, is the smallest country in the Americas. As a result, it has gained the affectionate nickname: "Tom Thumb of the Americas" or "*El pulgarcito de America*." In addition to being one of the smallest countries in the Americas, it is also the most densely populated, with 343 persons per km^2 and an estimated population of approximately 6.3 million, of which 53% are female (United Nations Data Portal, 2022). About 38% of the country's population resides in rural areas, with 20% of that population are women (Gomes, 2019). *El Pulgarcito* consists of 262 municipalities split among 14 departments and four (4) geographic zones: central, paracentral, oriental (east), and occidental (west). In addition, El Salvador is bordered by Guatemala and Honduras and has a 307-kilometer Pacific coastline along the south (Figure 1) (USAID, 2017). As a result of its location inside the Tropical Rain Belt (TRB) and Intertropical Convergence Zone (ITCZ), it has a tropical climate with distinct wet and dry seasons.

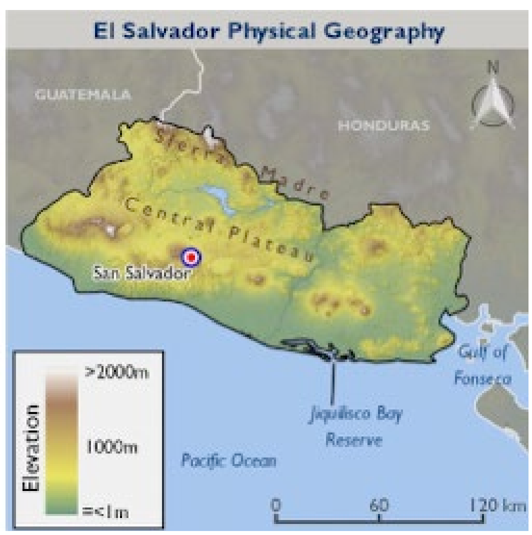

Figure 1. El Salvador's physical geography (USAID,2017)

Its rainy season begins in May and lasts until October, with annual precipitation between 1.200mm and 2.800mm and an average of 1.785mm (MARN, 2018a). Typically, there is a significant drop in rainfall along the shore throughout July and August (MARN,2018a). During these months, the country is hit by precipitation disturbances that frequently produce continuous precipitation with low intensity and large amounts of rain, primarily in the south and east (MARN, 2018a). Consequently, the country faces a rise in tropical storms, hurricanes, heavy rainstorms, and severe droughts, which are exacerbated by El Niño and La Niña.

2.1.1 *Climate Projections*

Since the 1950s, El Salvador has experienced climate changes such as rising average temperatures, more warm days and nights, and fewer cold days and nights. As seen in Figure 2, the frequency and intensity of extreme rainfall events have grown from around one (1) per decade in the mid-19th century to nearly eight (8) per decade in the early 21st century (USAID, 2017). As a result, it endures droughts and dry periods, as well as a decline in precipitation with greater variability. In addition, the sea level has risen 7.8 centimeters since the 1950s (USAID, 2017). There are three climate projections for El Salvador if no mitigation, or adaptation standards are set: Temperature increases between 1.4°C and 2°C, an increase in the frequency and intensity of extreme weather events (such as droughts, tropical storms, and floods), and a sea level rise (SLR) of 18cm are predicted (USAID, 2017).

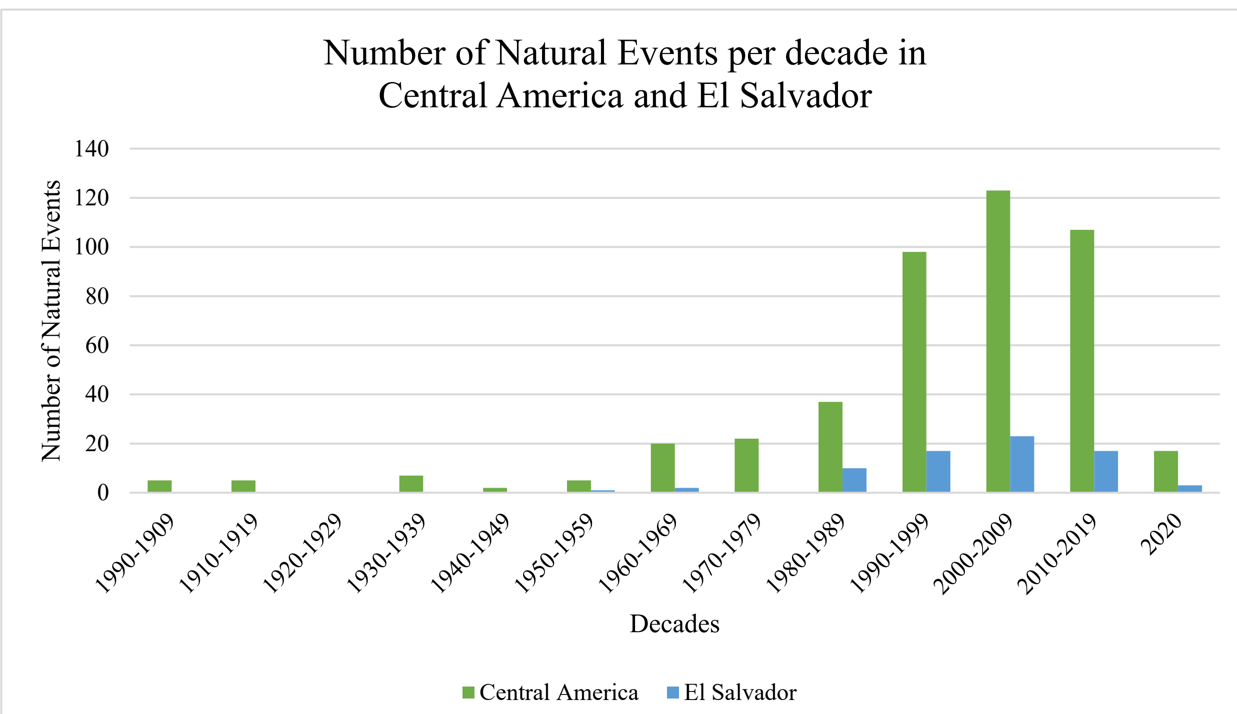

Figure 2 Number of natural events per decade in Central America and El Salvador (Adapted from MARN 2021)

2.2 *Economy*

During the 18th century Spanish conquest, El Salvador's economy consisted of indigo cultivation. However, with the emergence of artificial coloring in the 19th century, it began to decline and subsistence crops began to appear. In the 1930s, El Salvador was the top coffee producer in the world (MARN, 2018a). Due to the move to subsistence crops in the 1970s, the economy became increasingly dependent on agro-export. These exports, which included coffee, cotton, and sugarcane, contributed at least 80 % of foreign revenue causing an economic boom (Artiga-Purcell, 2022).

Beginning the 21st century, the agriculture sector was no longer the primary source of income due to a decline in crop yields caused by climate change. In 2000, agriculture output revenue, which had contributed to an 80% increase in economic growth, plummeted to an astounding 11% (Artiga-Purcell, 2022). This result led to an expansion in non-traditional export industries, such as textile assembly (*maquilas*) and remittances from Salvadorians living abroad. As a result of climatic impacts on the economy, secondary income streams became more prevalent and still are to this day. The shift to secondary incomes is driven by the scarcity of land accessible for crop cultivation. This is due to the reduced income from agricultural output, and consequently the adoption of other adaptation measures to climate unpredictability (Appiah & Guodaar, 2022). Between 2014 and 2015, the agriculture sector had a catastrophic drought that cost the country around $140 million; subsistence farmers and the dairy industry, which lost more than 10% of its production, were hit the worst (Gomes, 2019).

El Salvador's economy entered a new era on January 1st , 2001, when the national currency, *El Colón*, was replaced by the U.S. dollar. At the time, about five *colónes* were equal to 57 U.S. American cents, which later became equal to one U.S. dollar (Times, 2021). The country's capacity for economic growth has been impaired by dollarization, being caught in a loop of low economic growth for the past two decades (MARN, 2018a). El Salvador continues to struggle economically due to its lack of economic growth, the interest rates on the worldwide market, and the pricing of raw materials. El Salvador has experienced average annual economic growth of 2.4% since 1995, compared to 3.9% in Central America, 2.9% in Latin America, and 3% internationally (Bebbington et al., 2019). In the 1990s, the agriculture industry was the greatest contribution to its economy. Today, the largest contribution to the GDP is commerce, hotels, and restaurants, generating 20.6 % compared to agriculture's 10.1% (MARN, 2018b).

However, there are still more individuals employed in the agricultural sector than in any other, and these workers frequently come from poor socioeconomic communities that frequently live in poverty, resulting in high rates of illiteracy (MARN, 2018b).

Education has been shown to improve the social, economic, and health status of individuals and communities (Pullabhotla & Souza, 2022). This illustrates that the greater the education level of a population or community, the lower the poverty rate. The *Programa Nacional de Alfabetizacion* teaches children and adults how to read and write, which has helped reduce the illiteracy rate from 17.97% in 2007 to 10.14% as of today (UNDP, 2021). Access to basic education has grown, which, together with literacy, has been one of the most significant developments in urban areas. In addition, as of 2016, the population with access to potable water climbed from 79% to 89%, and access to better sanitation services increased from 56% to 95% (MARN, 2018). These advancements are a result of the rise in illiteracy and access to higher education. Education is crucial, especially for those in low-income communities because this can help reduce the vulnerability these communities often face, due to lack of opportunities.

Despite socioeconomic advancements, around 35.2% of the Salvadorian population still live in one-dimensional poverty. Furthermore, the rate of multidimensional poverty in rural areas is 58.5% and in urban areas it is only 22.5%. (Gomes, 2019). People who live in poverty, however, refer to it as multidimensional poverty. This includes elements such as poor health, lack of education, inadequate living standards, poor quality work, threat of violence, and living in places with environmental risks (Moreno, 2017). Figure 3 is a map of El Salvador with each of its 14 departments. The map shows the percentage of households in the country that suffer from multidimensional poverty. In 13 of El Salvador's 14 departments, over 50% percent of rural households are multidimensionally poor, making them more susceptible to the impacts of climate change. 83.7% of multidimensionally households lack access to public health care, 37% suffer from food insecurity, and 49% do not have access to potable water (Gomes, 2019). The only exception is the capital, San Salvador, which is also a department. It comprises 3% of the country’s landmass, holds 25.7% of the population, and receives 70% of public and private investment (UNDP, 2022).

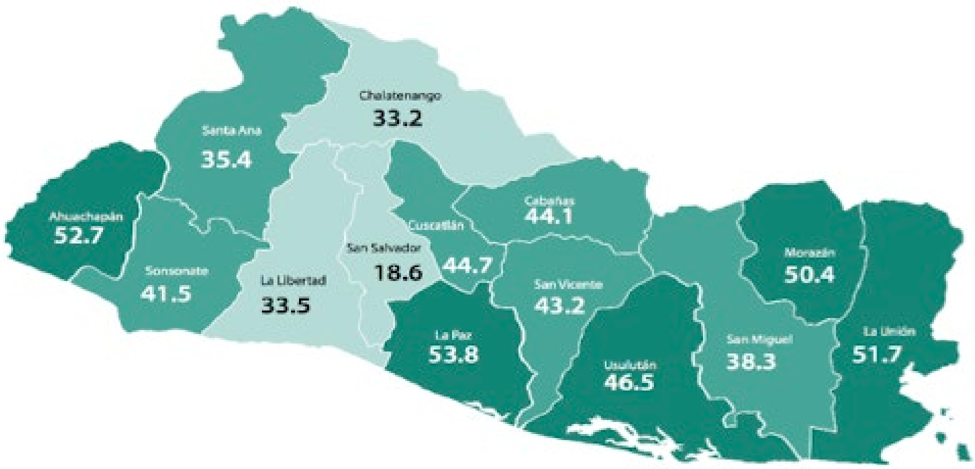

Figure 3.Multidimensional poverty incidence per department in El Salvador (MARN, 2021).

2.3 *Environmental profile*

In 2005, El Salvador ranked 105th on the Germanwatch Vulnerability Index (GVI), which rates countries according to the severity of their exposure to extreme weather-related occurrences, anthropogenic impacts, and economic losses (Global Climate Risk Index, 2021). In 2010, GVI ranked El Salvador as the nation most vulnerable to climate change (Harmeling, 2010). This was attributable to the five catastrophic weather events that struck El Salvador between 2009 and 2011. These were tropical storms Ida (2009), Agatha (2010), Alex (2010), and Matthew (2010), as well as Tropical Depression Twelve-E (12R) in 2011. As of 2018, 88.7% of El Salvador's territory is categorized as a high-risk zone; accordingly, 95.4% of the country's population lives in these areas (Gomes, 2019). Therefore, the implementation of ecosystem-based adaptations to reduce the impacts of extreme weather events can benefit a good portion of the population, especially those that are at higher risk to these weather exposures. This would help reduce the amount of physical damage, health impacts and economic loss the country, communities and people could possibly go through due to a lack of adaptation efforts.

2.3.1 *Droughts*

According to Wilhite & Glantz (1985), there are multiple definitions for what is considered a drought, as they explain that the lack of a definite and objective definition of a drought in a particular context has been a driving factor in determining what a drought is. This lack of comprehension frequently leads to confusion among managers, policymakers, communities, etc. Furthermore, a universal definition of drought cannot (and should not) exist because it is a "complex phenomenon" with significant societal effects (Wilhite & Glantz, 1985). Therefore, Wilhite and Glantz (1985) classified "drought" into four distinct categories: meteorological, hydrological, agricultural, and socioeconomic. Figure 4 depicts the order of drought occurrence as well as the effects of the four recognized drought categories. In this case hydrological drought, agricultural drought and meteorological drought are depicted. It is accepted that all droughts result from a lack of precipitation, a meteorological drought. Nevertheless, a meteorological drought and lack of precipitation can result in many forms of droughts and consequences. Therefore, as duration of the drought increases it results in a socioeconomic drought that impacts the environment, social aspects and the economy.

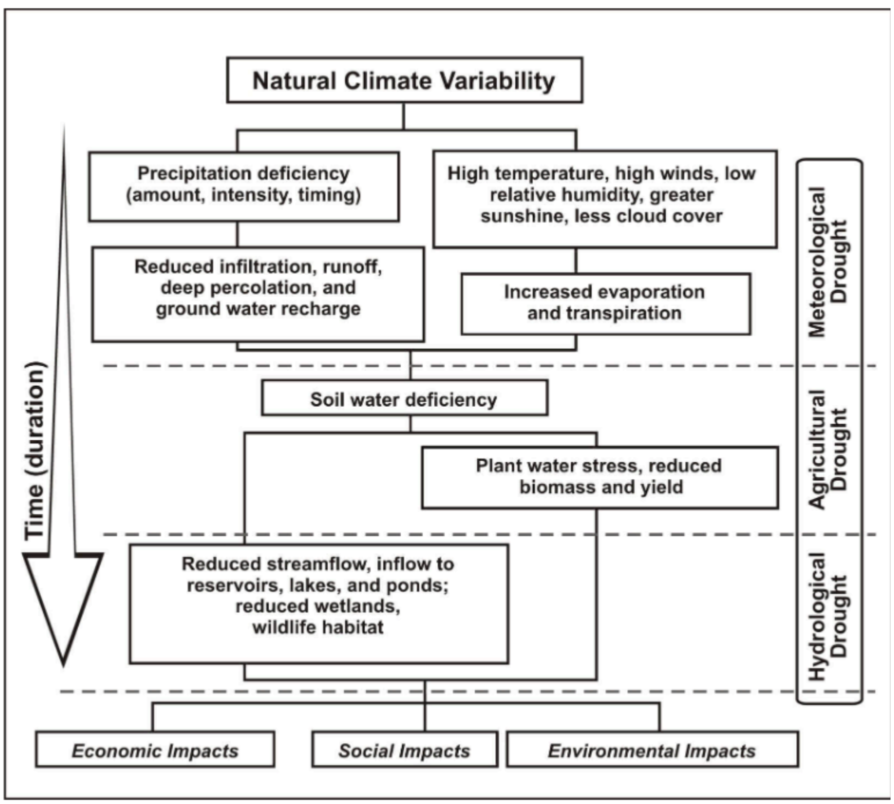

Figure 4. Sequence of drought occurrence. (National Drought Mitigation Center).

El Salvador experienced a meteorological drought from 2012 to 2015, which was eventually reported as the driest trimester (May to July 2015) subsequently affecting the agricultural industry (MARN, 2018a). The drought caused a 90% decline in river flow compared to previous years (MARN, 2018a). In addition, the country has been enduring a water problem for decades due to a lack of water control and political corruption, and the increase in drought intensity and severity is making water availability and quality significantly worse (Artiga-Purcell, 2022b).

2.3.2 *Water pollution*

Flooding has become a more common extreme weather occurrence due to a rise in the frequency and intensity of rainfall events. This is particularly destructive because when rivers flood, the water becomes contaminated with latrine overflow and hazardous waste that adheres to the walls of wells; this water is used for human consumption (Global Future Cities Programme, 2016). The lack of effective water management of latrines, sewers, solid waste, and wastewater supply wells has a profound impact on the housing conditions of rural and urban communities, which are frequently in a fragile state. The wastewater supply wells in homes are evacuated by pipes attached to the wells, which transport the wastewater through city street pipes to landfills. These waste locations are typically streams, rivers, lakes, lagoons, and ponds that are transforming into sewers due to pollution (MARN, 2013a). According to MARN (2018a), approximately 95% of these wastewater supply wells dump untreated water into the environment. Decades of insufficient regulation of water use have paved the way for overexploitation and contamination. This has resulted in a multifaceted issue of water scarcity, quality, and accessibility, affecting over a quarter of the Salvadorian population (Hahn, 2018).

Approximately 590 rivers flow into the Pacific Ocean from El Salvador (UNDP, 2018). The most significant of these rivers is the Lempa (shared with Honduras and Guatemala), a drainage basin noted for water generation, storage, and hydroelectric energy production. Due to inadequate use of territory, erosion, exploitation of water resources, poor solid waste management and deforestation, these factors have all had a significant impact on water availability and water quality.

2.3.3 *Deforestation and Erosion*

Since the 19th century, every single one of El Salvador's ecosystems has been affected by human intervention (Braga-Orillard, 2022). The country lost around 44 million hectares of natural forests in the northeast, center, and southeast regions between 1998 and 2008 (MARN, 2018a). In many protected regions, these trees were turned to land for annual crops (and grasslands) for subsistence farming. In the 1950s, El Salvador had over 100,000 hectares of mangroves, compared to 40,000 hectares in 2010 (Hernández-Blanco et al., 2022). In addition to affecting mangroves, deforestation has also affected the Lempa River which is in a predominantly agricultural region that delivers water to many farmers and people. It faces several environmental issues, including dam development, land usage, population growth, urban construction processes, industrial zones, and deforestation.

Over 50% of the country's surface area has slopes with 15% incline, resulting in extremely erodible soils (Gomes, 2019). The incidence of torrential rain, the exploitation of forest cover, insufficient agricultural methods for subsidence farming on slopes, and land use for vegetation that is inconsistent with its natural use all contribute to soil deterioration (Gomes, 2019). Consequently, impermeable, water-resistant soils tend to proliferate (Hahn, 2018). In addition, erosion results in increased silting in rivers, which affects the hydrology and hydraulic capacity of water bodies. El Salvador's soil degradation is so severe that around 59 million metric tons of soil are lost due to erosion on approximately 75% of the country's land (MARN, 2018a). From the remaining 75%, around 40% of the soil is classified as significant erosion (MARN, 2018a). This degradation of natural ecosystems poses a threat to ecosystem services for local communities, frequently resulting in both long- and short-term consequences.

2.3.4 *Migration*

Increasing global temperatures have encouraged the spread of crop diseases and increased the frequency and intensity of extreme weather events, all of which have contributed to an unreliable harvest, resulting in a migration of the population. Extreme weather occurrences have generated droughts that have resulted in significant losses for El Salvador's small farmers, many of whom are already experiencing food insecurity, which spurs displacement and migration. This movement pattern is prevalent among coffee harvesters, one of El Salvador's primary exports and sources of revenue (Hallet, 2019). Although migration from El Salvador is not new, its cause today is different. Since the 1980s, El Salvador has been a source of emigration due to the Salvadoran civil war (Bebbington et al., 2019). Today, the primary causes of migration are land degradation, lack of job stability, and lack of food security, all of which are prevalent in communities with low socioeconomic status. This has led to climate migration, which occurs when communities are forced to relocate due to environmental problems linked with one (or more) of the three effects of climate change: sea level rise, extreme weather events, or drought (Hallett, 2019).

3. Methodology

Case studies, literature reviews, and government documents spanning nearly four decades were evaluated in order to comprehend the climate changes that the country has experienced and the future climate consequences that the country is expected to encounter. Climate impacts have affected the country's environment and ecosystems, which have in turn affected the population, especially low-income communities. Environmental hazards disproportionately affect areas with low socioeconomic status, according to studies. These environmental repercussions include not only the immediate extreme weather occurrences, but also their aftereffects (i.e: landslides due to heavy rainfall). This project reviews case studies of developed and developing nations to better comprehend the effects of climate change and develop recommendations to assist El Salvador in enhancing its adaptive capacity to address environmental and social fairness, ecosystem conservation, human health, and water scarcity.

This report will analyze the susceptibility of the people of El Salvador to climate change by assessing their physical, social, and environmental vulnerability. Vulnerability is influenced by gender, social status, economic status, environmental exposure, and the distribution of household resources (UNDP, 2014). While everyone is inherently sensitive to adverse conditions and occurrences, some individuals are more susceptible than others. The framework for the assessment of the vulnerability was derived from the report "*Metodología para el análisis de la vulnerabilidad*" (MARN, 2012).

The existing strengths, weaknesses, opportunities, and threats of monoculture versus polyculture were identified and analyzed using the SWOT method. In the research, the SWOT analysis was conducted by collecting qualitative data from both forms of agricultural practices in order to address the agricultural sector's pollution problems. Furthermore, this will help suggest why ecosystem-based adaptation strategies help small farm owners to adjust to the effects of climate change. The optimal objective of the research is to put forth ecosystem-based adaptation strategies to improve the standard of living of low-income communities based on the results of the SWOT analysis.

4. Results

The following sections discuss various aspects that guide the understanding of how climate change affects people and the country by increasing their vulnerability to climate change. This will serve as a foundation for recommending ecosystem-based adaptations to enhance El Salvador's adaptive capability. Section 4.1 examines the AFOLU sector's emissions and water pollution as a result of inadequate management techniques that increase nonpoint source pollution in bodies of water. Section 4.2 examines the anthropogenic and climate impacts on mangrove ecosystems and the ecosystem benefits they provide. The vulnerability of communities to climate impacts due to a lack of protection from extreme weather events is discussed in section 4.3.

4.1 *Emissions due to AFOLU and its subsequent impact on water pollution*

Agricultural practices have a variety of effects on the environment as agriculture contributes to climate change and is impacted by climate change. Agriculture impacts the environment via animal agriculture, water pollution, pesticides, and land use. In developing countries, the agriculture sector tends to be the main source of pollution, as it is the case in El Salvador (MARN, 2018b). To understand how the AFOLU sector is the main source of pollution, an analysis of what, how and why it produces emissions and pollution was analyzed. The analysis will better help understand and recommend management strategies to mitigate impacts from and to the sector, to reduce pollution in El Salvador.

The AFOLU sector amounts for 58% of total GHG emissions that the country emits (Figure 5) (MARN, 2018a). A further break down of that 58% of total GHG emissions as depicted in Figure 6, shows the total GHG emitted by livestock, land, aggregate sources, and sources of non-CO_2 emissions that make up the AFOLU sector. Furthermore, Figure 7 shows the breakdown of the main gasses that are emitted by the livestock, land and aggregate sources. This will help further help understand what actions by the AFOLU sector contribute to the GHG emissions, in order to provide recommendations that will help reduce those emissions.

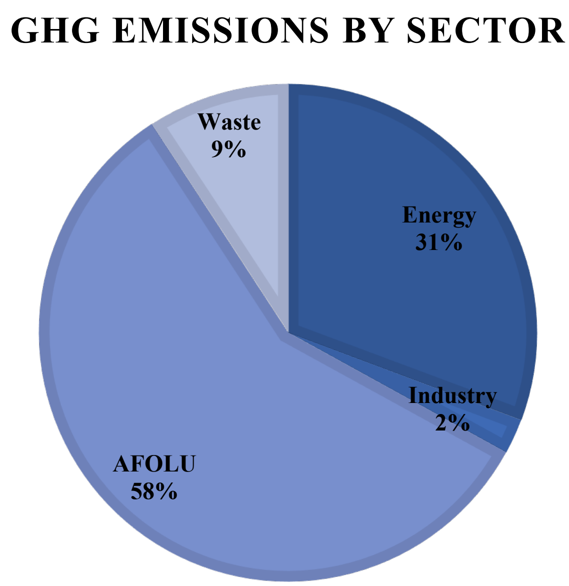

Figure 5 Total Greenhouse Gas Emissions by sectors (kt CO2 eq) Adapted from (MARN, 2018a)

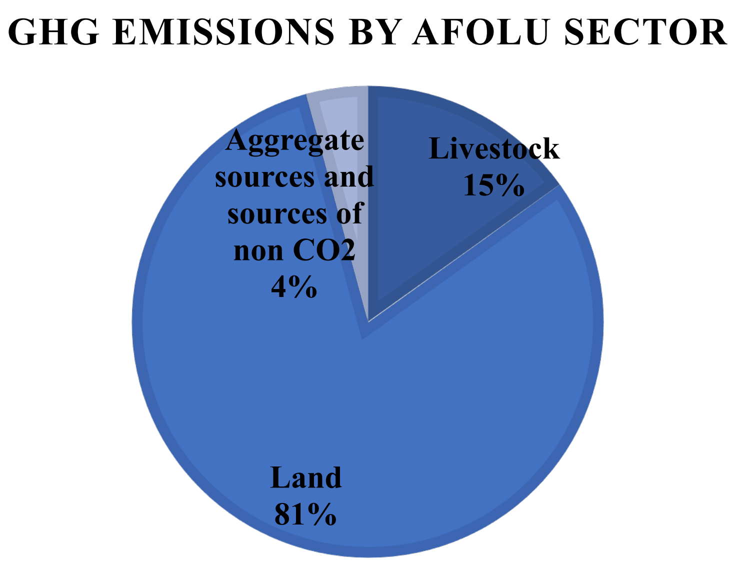

Figure 6 Total GHG emissions by livestock, land, aggregate sources and sources of non CO2 emissions. Adapted from (MARN, 2018a)

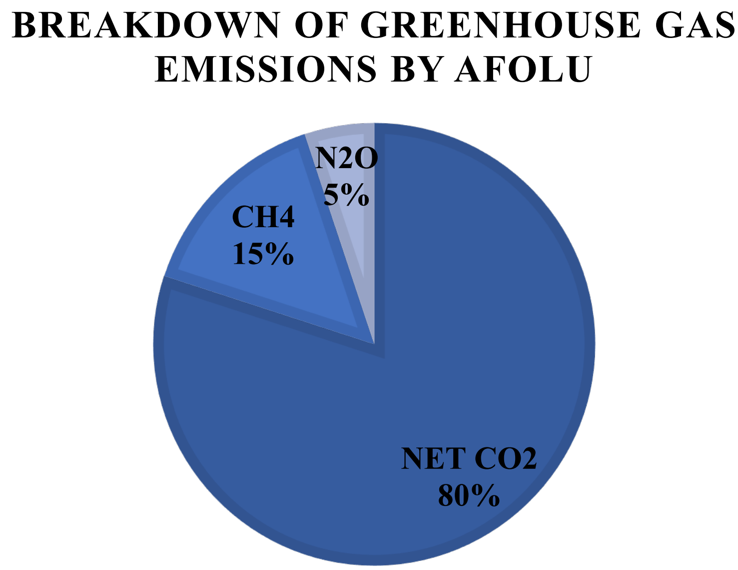

Figure 7 Breakdown of GHG emitted by livestock , land, aggregate sources and sources of non-CO2 emissions. Adapted from (MARN, 2018a).

4.1.1 *Emissions*

Methane emissions due to livestock

Animal agriculture is one of the biggest and well-known environmental contributors associated with pollution via waste management, groundwater pollution and land usage (Xiao et al., 2021). Additionally, meat production by industrial agriculture is one of the main factors that contributes to biodiversity loss and one of the leading sources of water pollution in developing countries. Livestock agriculture is one of the main sources of methane (CH_4) emissions (IPCC, 2018). Figure 8 shows the percentage of animals that make up the livestock industry in El Salvador. Cattle, which is one of the main animals in the beef and dairy industry, are one of the main contributors of CH_4. Cows generate and emit CH_4 via their digestion and through their waste. They undergo enteric fermentation which is a digestive process in which the carbohydrates that are found in ruminant animals (animals with four chambers in their stomach) are broken down by microorganisms resulting in the expulsion of gases like CH_4 and CO_2 and volatile fatty acids (VFA's). Figure 9 shows the percent of CH_4 and N_2O emitted via enteric fermentation and manure management, that contribute to the breakdown of GHG emissions shown in Figure 7.

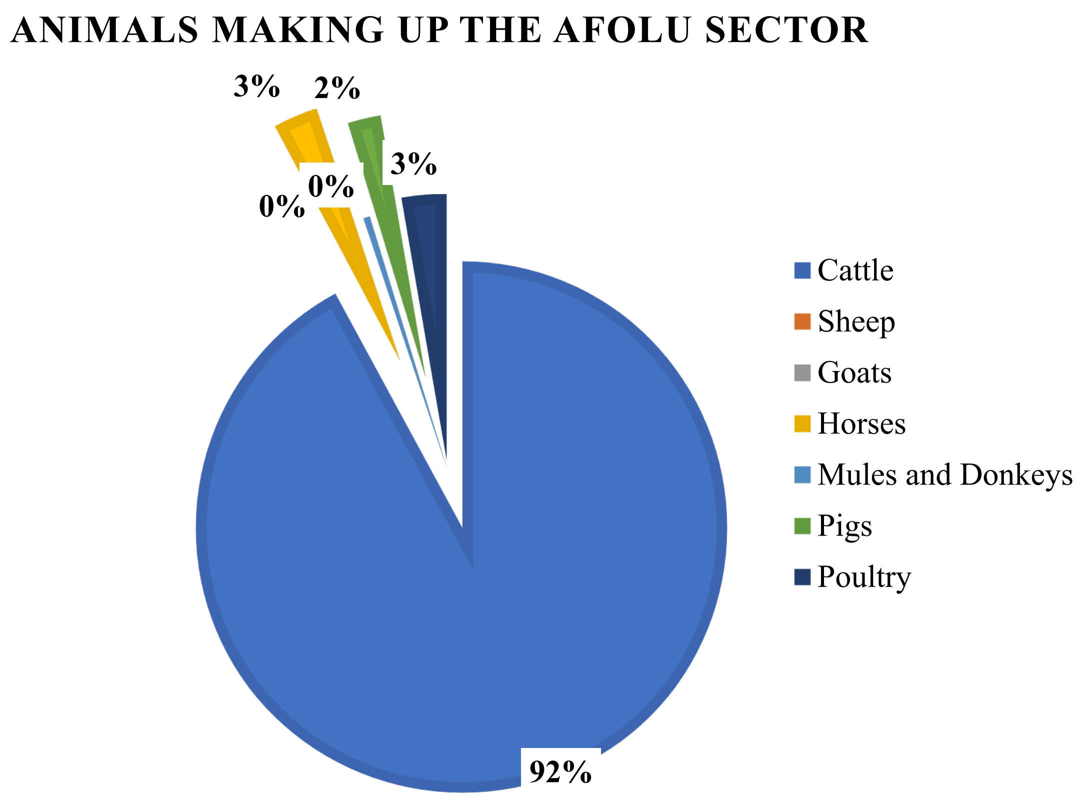

Figure 8 List of other animals that make up the agriculture sector that contribute to GHG emissions. Adapted from (MARN, 2018a)

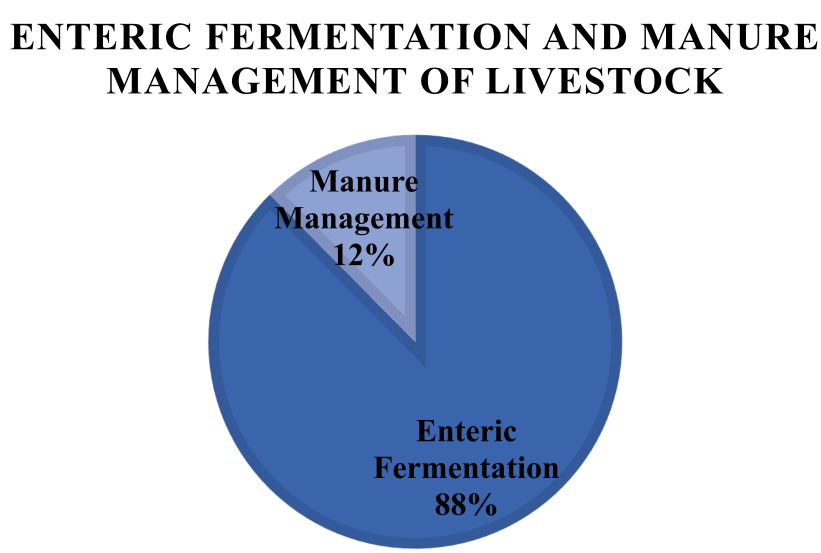

Figure 9 Enteric Fermentation and Manure management in agriculture by livestock. Adapted from (MARN, 2018a)

Manure management involves the emissions of CH_4 and N_2O that result from the decomposition of animal's manure in anaerobic conditions (without O_2). This is because often these animals are being confined to a small poorly managed area (Guan et al., 2022). Therefore, the poorly managed area leads to the manure being stored in large piles or disposed in bodies of water via agricultural runoff. That runoff carries various pathogens like that of bacteria, viruses, nutrients, and oxygen demanding organics and solids that further contaminate bodies of water (USGS, 2007).

Carbon emission due to land usage

Figure 10 breaks down the type of land in El Salvador with its respective contribution to total GHG emissions of the land sector (81%) in Figure 6, to the overall 58% contribution of GHG emissions by the AFOLU (Figure 5) in El Salvador. The largest contributor of emissions to the AFOLU sector, is land usage. Specifically, the forests sector that emits 40% of Carbon emissions.

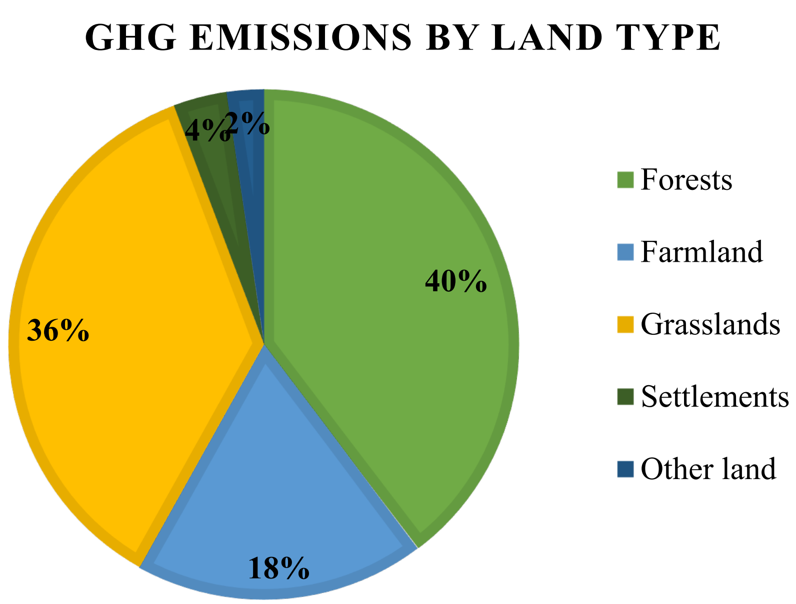

Figure 10 GHG emissions based on land type. Adapted from BUR (2018).

Forests are defined as land with woody vegetation with 0.2 or more hectares of plants that have stems greater than 3m (in height) and who's canopy provides 20% or more of cover in each hectare (PNUD, 2022). Forests are crucial since they are carbon sinks, meaning that they absorb more carbon from the atmosphere than they release. This results in an increase in forest biomass (Livesley et al., 2016). However, the removal of trees causes the release of the stored carbon dioxide (CO_2) into the atmosphere, leaving less trees to absorb CO_2. As seen in Figure 10, forests are the biggest contributors to the carbon emissions that make up the land usage in the AFOLU sector. This is because the lack of trees available leaves soil more vulnerable to drying out, because of the lack of shade and lack of systems to help with the water cycle. It is key to note that even though coffee plantations' purpose is to produce coffee, they are considered forests as per definition. It is also considered a forest due to the difficulty of distinguishing between coffee plantations and secondary forests via satellite imaging (MARN, 2018a).

In addition, El Salvador's emissions contribute very little to the overall global GHG emission scale, as compared to other countries. However, these emissions are not the main cause of climate change impacts even though it may seem that way. That will be further explained in the sections that follow.

4.1.2 *Water pollution due to Agricultural production*

Nonpoint source pollution (NPS) is a type of pollution that comes from many sources as opposed to point source pollution that can be pinpointed to industrial waste from sewage treatment plants (Guan et al., 2022). Runoff is often caused by rainfall, which picks up human made pollutants and natural pollutants resulting in deposits in bodies of waters like lakes, rivers, wetlands, and coastal waters of groundwater. Groundwater is water found in spaces, cracks, and holes between the soil. The leading agricultural activities that cause NPS are poor management of animal feedings, overgrazing, plowing too frequent, lack of proper management of pesticides, water irrigation, and fertilizer use (Guan et al., 2022).That is why agricultural pollution can be classified as biotic (living organisms) or abiotic (non-living organisms) byproducts depending on the farming practices utilized (EPA, 2005). These practices result in the contamination and degradation of ecosystems and impacting humans via direct consumption of this water. Furthermore, when these bodies of water become contaminated, they often result in dead zones, which contain low O_2 due to that agricultural runoff.

In El Salvador, approximately 67% or 11.6 km^3 of the water is considered surface water, with the remainder being groundwater (Taylor, 2005). Surface water is water that is provided by bodies of water usually located above ground. However, groundwater is heavily relied upon for water supply due to surface water being severely polluted by minerals, bacteria, fecal matter, and chemicals. San Salvador, the main metropolitan city in the country is served by the *Acelhuate* River; one of the most important drainage systems (MARN, 2002). However, it is heavily contaminated by heavy metals, insecticides, cyanide, sewage waste, industrial waste, and toxic algae leaving it virtually untreatable (PNUD, 2022). This river flows into the *Cerrón Grande* reservoir known to the locals as *Lago Suchitlán* the largest body of fresh water in the country but also one of the most polluted bodies of water (Hieber, 2010). The reservoir has an outflow to the Lempa River, adding more pollution to the already polluted body of water causing an even greater decline in water quality that provides water for more than half the population. In addition, not only does it receive pollution from within the country, but because the River Lempa originates in Guatemala and runs through Honduras, it also receives pollution from those countries.

To further break down the amount of waste the river gets, roughly 8.8 million lbs. of feces per month gets dumped into the *Cerrón Grande* reservoir, just from the capital (Hieber, 2010). This has caused the lake to turn into a hypertrophic lake, because of the high nutrient concentration causing anoxia (lack of O_2) and poor water quality. The sedimentation that occurs in the reservoir and its outflow is a direct effect of the deforestation of natural lands for the use and conversion to agricultural lands. In 2018, the Ministry of Environment and Natural Resources found that the waste being deposited in the *Cerrón Grande* reservoir was originating from 54 industrial plants, 55 coffee processing plants, seven sugar mills, and 29 sewer systems that where discharging directly into the reservoir (Hieber, 2010).

The problem of NPS pollution isn’t unique to El Salvador, Wang et al. (2022) studied the effects of agricultural nonpoint source pollution on the impact on surface water quality in Chinas second largest reservoir. Rainfall is typically what's assumed to be the primary driver of NPS, however fluctuation of water levels and not rainfall levels, demonstrate the pollution risks to bodies of water. Flooding can result in the dissolution of nitrogen, phosphorus, organic matter, heavy metals, and other pollutants from the soil (Wang et al., 2022). Water fluctuation because of flooding, changes the structure of the soil and accelerates the decomposition of soil organic matter.

Agricultural activities tend to be more common around lakes and reservoirs due to the convenience of water sources availability. Some agricultural lands use insecticides, herbicides, agrochemicals, and fertilizers that have an impact on soil composition and nutrient availability of the ecosystem (Wang et al., 2022). The water quality risks are impacted due to the inundation of bodies of water that then flow onto land, increasing the soil ammonia and nitrate nitrogen contents. The level of contamination due to the deterioration of the pollutant sources tends to vary based on season, water level, rainfall, and fertilization (Wang et al., 2022). The results demonstrated that the primary factor that influenced reservoir ammonia variation was the water level; a high-water level resulted in higher ammonia. Anoxic conditions that occur when the farmland is flooded due to the excess pollutants, cause an increase of ammonia to be released.

Roughly 60% of global agriculture land is at risk for pesticide pollution by more than one type of pesticide (Olalde, 2019). This is due to the excessive use of fertilizer and pesticides that are used to yield more crops but have a greater impact on the water quality. In El Salvador, insecticides like Dichlorodiphenyltrichloroethane (DDT) are the prime culprit especially in cotton cultivations along the coastal plains. There have been concentrations of DDT of 3.15mg/liter found in water in the Rio Grande de San Miguel, in the department of Usulután, which flows into the Pacific Ocean. This amount of DDT is alarming as its triple the lethal limit for fish (Ballestero et al., 2007). This is very alarming as communities obtain water from this river for direct consumption, as well as fish for dietary needs.

Approximately 600,000 people in rural areas lack access to potable water, while many more have restricted or intermittent access (Gomes, 2019). However, around 90% of the country's surface water is contaminated, and not a single major river can be cleansed for drinking water through filtration or chlorination (Hahn, 2018). Because of wastewater supply wells as well as runoff from the industrial and agricultural sectors, untreated wastewater flows directly from sewers into rivers. Large-scale companies are in low-income regions and frequently abuse aquifer water, leaving these vulnerable people without adequate water resources. Due to power asymmetries that influence the decision-making process, industries and sources of economic revenue such as plantations, mining businesses, luxury homes, and bottling companies have been given priority in El Salvador for decades (Hahn, 2018).

In developing countries, it is mostly smallholder farmers that make up the agricultural sector; roughly 90% of them have perceived climate variability (Xiao et al., 2021). This means that they have noticed the impact of climate changes in their farm through own experience and knowledge. Over 85% have made attempts to adapt and shift practice methods by changing sowing dates, different crop usage, soil and water conservation, plant density and a change in irrigation methods (Xiao et al., 2021). However, because these small farmers are often low-income status and without enough government help, there's only so much they can do with the income they obtain from farming.

Bodies of water near agricultural land are often used a source of irrigation that result in outflows for NPS pollution, which results in a constant loop of polluted water utilized in irrigation for crops, streams, or human consumption. Irrigation is a form of delivering water to the soil via sprays, pumps, or tubes in areas where rainfall tends to be irregular or where drought is known to be dominant. Water for irrigation is often obtained via surface water or groundwater sources that because of overirrigation can result in drainage problems (Tulip et al., 2022). Edminster & Reeve (1957) define that the source of the excess water tends to determine the severity of the drainage problem. The problems are often time related to the flooding by overflow from streams or by tidal action in coastal areas, overflow of low-lying flat lands from hillside runoff, return-flow seepage on sloping land, accumulation of water in soils, accumulation of excess water in depressions or low-lying areas, buildup of a high water table from overirrigation, buildup of a high water table from seepage losses from irrigation canals and high water table due to movement of artesian water (Edminster & Reeve, 1957).

Lands are drained primarily to ensure agricultural productivity and increase efficiency of farming operations, but that is not often the case. Coastal plains along the Pacific Ocean in El Salvador have the most irrigation drainage problems as compared to other areas in the country due to mangroves and marshes that saturate the land (Ballestero et al., 2007). Efforts have been made to pump off the excess water that is encountered post rainy season to reduce saturation in the area. However, a shift to higher value crops has risen due to the larger profit obtained which leaves the coastal plains to be neglected. Proper developments of drainage systems need to be administered to help reduce the impacts on coastal plains (and in the agricultural sector overall) by focusing on three basic points: The drainage requirements, the water transmission properties of soils, and physiographic features (Edminster & Reeve, 1957).

4.1.3 *Lack of pollution prevention due to deforestation*

Because of its geography, El Salvador is in the direct path of tropical storms and hurricanes that lead to structural damage, deaths, displacement, major flooding, and mudslides that have only gotten greater in the last decade. Deforestation removes tree cover, leaving the country vulnerable to greater disasters resulting from flash flooding which occur when heavy rainfall occurs in a short period of time. Forests provide protection from flash flooding, via water absorption. However, when flash floods occur, because of deforestation the ground doesn't have enough time to absorb all the water, leading to the rapid rise of water in urban and rural areas, and an overflow in bodies of water. This water then mixes with sewage water, dead animals, debris and can result in sinkholes and the erosion of roads and land.

In 2005, El Salvador was the second most deforested country in Latin America (after Haiti) which subsequently increased their vulnerability to flood disasters (Taylor, 2005). As of 2010, only 45% of El Salvador was considered natural forest cover as opposed to 48% in 2000 (El Salvador Deforestation rates & statistics). However, it has continued to gradually decrease due to deforestation and urbanization by a growing population in a small area. The clearing of forests is becoming more common as little economic growth, lack of income opportunities, and lack of food security, are incentives to use forested land for agricultural land. Deforestation impacts are heavily felt by low-income communities who are dependent on fuelwood, subsistence hunting and agriculture food and income security.

As a result of deforestation, soil degradation has also increased, causing a concern as healthy soils are key for properly functioning ecosystems. Topsoil is very fertile, and it benefits many farmers as this soil causes a positive impact on the ecosystem, down to the microbial level. Microbial communities' impact nutrient cycling, pest and disease control and the chemical components of the soil (Ani & Robson, 2021). Nevertheless, microbial communities are affected by tillage erosion, a frequent agricultural practice that occurs when the soil in cultivated regions is prepared for cultivation (Badrzadeh et al., 2022). Tillage activities make the soil porous, which increase the expanding exchanged area of the soil and water interface, which caused a higher risk of pollution increase (Wang et al., 2022). It is a common practice in areas where coffee is grown, resulting in lower crop yield and lower quality coffee beans, impacting economic outcome of El Salvador including small farmers.

Slash and burn enables deforestation, causing a loss of flora and fauna, increase air pollution, carbon release into the atmosphere, increased soil erosion and sometimes uncontrolled fires (Kearney et al., 2019). However, slash and burn is the main method used in sugarcane farming, which is practiced by some 11 million smallholders in about 65 million hectares across Mexico and Central America (Kearney et al., 2019). The process of slash and burn usually involves forested ecosystems to be cleared with the remainder of the vegetation to be burned. The burning produces ash, subsequently leading to an ash layer that provides a nutrient rich layer enabling the fertilization of the crops. The downside of this method is that the land is only fertile for a couple years due to the absorption of nutrients. This land is often abandoned after all nutrients are used, which results in more deforestation to keep cultivating crops for food and income.

In the recent years, agrarian extractivism or agrarianism has gained attention as it is the idea of improving the economic status of a farmer, via the extraction of agricultural products (Artiga-Purcell, 2022). In El Salvador, agrarianism is most seen in sugarcane production, one of the main pollution drivers by being responsible for the depletion of the water system. Sugarcane production is one of the most important and dynamic industries that make up the agricultural sector of the country. Sugarcane is a monocrop cultivation; the practice of growing the same crop all year round. The most productive harvest for sugarcane occurs in hot weather, which increases water loss even further via evaporation and transpiration. The recurring problem with sugarcane is that it heavily relies on agrochemicals and fertilizers containing nitrogen, phosphorus, and potassium that are used to accelerate the growth and amount of sugarcane plants. Monsanto Roundup products are notorious for being one of the main fertilizers used by farmers in El Salvador (Olson et al., 2012). In addition to the use of chemicals, there is an unregulated overuse of water that is utilized for irrigation that results in bioaccumulation of chemicals and fertilizers in ecosystems that lead to serious problems for direct human consumption and socio-environmental problems.

El Salvador, unlike other Latin American nations, has never been known for its mining industry, which has never contributed significantly to the country's economy (Artiga-Purcell, 2022a). However, Cocos tectonic plate puts El Salvador in a situation highly prone to seismic activity and extreme weather events resulting in pollution of its bodies of water. This is due to the gold mine belt, as seen in Figure 11, that is situated within Cocos plate. The poor management of mines contribute to waste, heavy metals and acidic water that end up in streams and rivers.

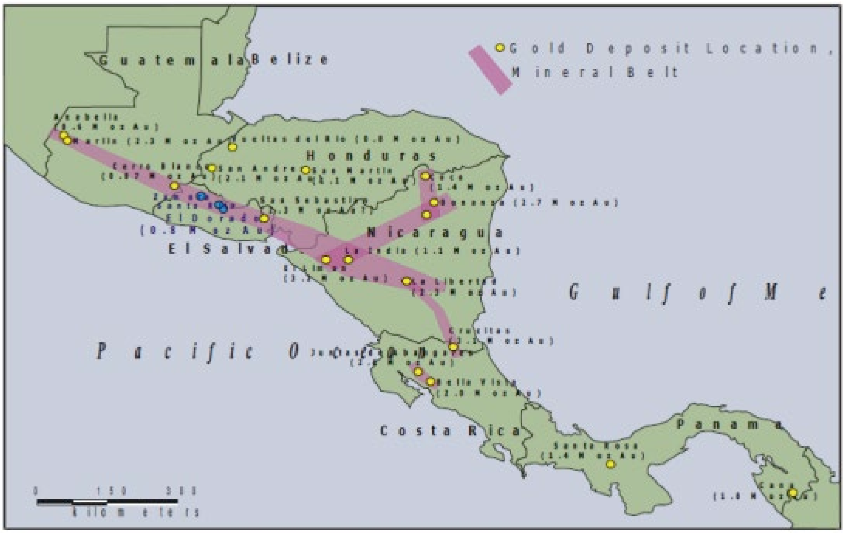

Figure 11 Map of Central America depicting the gold belt.

Cabañas, one of the 14 departments is home to the *El Dorado* mining site, which provides local populations with a path out of poverty through the creation of new jobs and development. On the mining site, however, there are containers filled with cyanide-tainted water that is used to separate gold from the rocks (Artiga-Purcell, 2022a). These containers have been known to easily break by the frequent earthquakes that occur. The local communities noticed that by living near mining excavation areas, environmental problems began to emerge, including restricted availability to water, polluted waters, agricultural impacts, and health concerns (Broad & Cavanagh, 2011). Because job opportunities were being provided, most people saw this as an out of poverty, without knowing the consequences that mining could bring to them. There was that hesitation, because mining could get communities out of poverty but they would be risking their health for a somewhat stable income. However, when they traveled to neighboring nations that are known for mining, they learned about the harm that cyanide and other harmful chemicals can cause to rivers, land, and human health, and they became hostile to mining (Broad & Cavanagh, 2011). This caused an uproar by the local community to urge the shutdown of the mine, due to the devastating impact it had to their environment. The displacement and lack of proper safe job opportunities to low-income communities has an impact on their decisions to their income and health, that needs to be addressed to help reduce poverty and health hazards. Therefore, implementing better job opportunities without risking their health, is a considerable factor to help reduce that health and pollution to these communities.

Regardless of the best practices that are implemented in mining, earthquakes and increased flooding can increase the collapse of mines which can activate acid main drainage; the outflow of highly acidic water due to heavy metal contamination (US EPA, 2015). Agricultural soils can be polluted by heavy metals that further pose a threat to environmental sustainability and the health of the community (Yang et al., 2022). In 2017, El Salvador became the only nation in the world to prohibit metal mining owing to its negative impact on water resources (Artiga-Purcell, 2022a). This prohibition resulted from the extractivism of gold mines located in the Lempa River basin, which is home to around 66% of the country's population (Artiga-Purcell, 2022a). This river is the principal source of hydroelectric power and provides more than 50% of the nation's water supply (MARN,2018a). The Lempa river offers water for the gold mine and sugarcane production, each of which contributes its own socio-ecological impacts to river itself. However, disagreement emerges because the mining prohibition does not extend to nonmetallic mining, such as that of limestone and gravel, which continue to pollute the water resources of the country (Hecht et al., 2006).

In summary, in developing countries agricultural water pollution is becoming a serious problem because the focus of agricultural production is often on the short-term benefits and not the long-term environmental costs. The agricultural sector is very sensitive to climate change impacts as opposed to other sectors. In developing countries, subsidies in agriculture still exist, which in turn exacerbates the water pollution problem (Xiao et al., 2021). Cross sector water pollution from the agricultural sector and others, needs to be examined to come up with universal policies that will incorporate all sectors and not just one. This is because focusing on pollution coming from only one sector and not seeing the multiple sources of diffusion makes mitigation and adaptation quite difficult. For example, pollution from industrial waste affects agricultural pollution and agricultural runoff pollution affects industrial pollution. In developing countries both the agricultural and industrial sector are the main sources of water pollution (Xiao et al., 2021). However, because not enough data was available from the industrial sector in El Salvador as compared to agriculture sector, the focus was solely on the water pollution from the agricultural sector.

The sources of pollution that are mostly generated by agricultural runoff end up in bodies of water or marine ecosystems, ultimately causing harm to these already vulnerable ecosystems. This is the case in Central America, for instance, 16% of mangrove species are threatened with extinction (Polidoro et al., 2010). Mangroves are an important part of El Salvador's ecosystem as they provide economic and social significance to communities. However, because of human activities such as agriculture, aquaculture, forestry, and coastal expansion they have severely destroyed mangrove ecosystems (Valiela et al., 2001). Consequently, the loss of mangroves has an ecological impact on the landscape due to the loss of physical structure and socioeconomic impact owing to the loss of services provided to local populations and the global population (Hernández-Blanco et al., 2022). Furthermore, just because mangrove ecosystems are bodies of water, it doesn't equate to the impacts being felt only in coastal communities. Communities outside of the coastal range, like rural and urban communities are also impacted by the loss of mangrove ecosystems and the services they provide as will be discussed in the next section.

4.2 *Climate change impacts on marine ecosystems: mangrove ecosystems*

Climate change impacts are expected to increase biodiversity loss, coastal degradation, and human-driven deforestation. In El Salvador, the projected climate changes occurring by 2050 include: an increased temperature of 1.4°–2°C, decreased precipitation by 2–15%, longer and drier periods of drought, increased frequency, and intensity of extreme weather events and a SLR of 18 cm by 2050 and 37–44 cm by 2065 (CityAdapt, 2021). All these projected climate changes will have severe impacts on ecosystems. In this case, for coastal and inland communities, marine ecosystems are those that will be most severely and directly affected by the projected and climate impacts.

Currently, sea level rise and increased temperatures are already the lead cause of erosion and the major threats to marine ecosystems (He & Silliman, 2019). Impacts of climate change on marine ecosystems include increased temperature, ocean acidification, changes in ocean currents and sea-level rise which have intensified over the past few decades (He & Silliman, 2019). Climate change is also exacerbating spatiotemporal variability in the physiochemical environment of oceans, resulting in more frequent extreme climate events (e.g., droughts, storms, and heat waves) and spatiotemporal redistributions of climatic conditions (e.g., altered upwelling and ocean circulation). He and Silliman (2019) state that nearly every part of the ocean is affected by human activity. This is because an increase in human density frequently increases the severity of human stressors on marine ecosystems as often, the most densely populated areas are coastal areas, which are more likely to interact with climate change.

The increase of untreated sewage discharge and industrial waste from highly populated densely inhabited cities, as well as fertilizers from agricultural land usage and runoff, increase the nutrient loads and toxic chemical that end up in bodies of water (Cloern et al., 2016). Eroded sediments, nutrients, and pollutants from agricultural and urbanized areas therefore contribute to the contamination of coastal waters (Brodie et al., 2011). For example, over 90% percent of the heat generated by increased GHG emissions due to human activities like that of fossil fuel combustion and land use is absorbed by marine ecosystems (Ani & Robson, 2021). Marine ecosystems are important due to their contribution to regulate climate, the protection of coastal areas providing food for people, a variety of livelihoods and leisure activities (Barbier, 2017). However, temperature and SLR influences the growth, composition, and abundance of fish, the growth and photosynthesis of seagrasses, mangroves, kelp, and the health of corals that provide ecosystems services (He & Silliman, 2019). Therefore, this results in poor ecosystem services and functions provided by marine ecosystems, a decrease in coastal protection, inadequate fisheries management, poor pollution mitigation, and lack of carbon sequestration for climate mitigation.

4.2.1 *The importance of mangrove ecosystems*

Mangrove forests are defined as coastal intertidal areas that are often dominated by woody halophytes like trees or shrubs, occurring mainly in the tropics and subtropics across the world (He & Silliman, 2019). Mangroves provide a vast array of ecosystem services that benefit humanity on a local and global scale, giving them a significant economic value. Salem and Mercer (2012) provide an example of the mean economic values that mangrove ecosystems provide such as recreation and tourism ($37,927: 1 hectare/ year), fisheries ($23,613 1 hectare/ year), coastal conservation ($3,116 :1 hectare/ year), and carbon sequestration ($967: 1 hectare/ year) to countries economic income. However, the economic and social significance of mangroves is frequently overlooked, and as a result, these ecosystems have been severely damaged by climate change and by human activities. These activities often include agriculture, forestry, and coastal development (Valiela et al., 2001). As a result, of climate and anthropogenic impacts, 16% of mangrove species are threatened with extinction, with both Central American coasts being of special concern (Polidoro et al., 2010). It is crucial to protect mangrove ecosystems as the loss of mangroves impacts the physical landscape and socioeconomic structure of populations. This is due to the benefits that are provided to not only local populations but to the world (Ani & Robson, 2021). Mangroves are important for coastal and overall ecosystems as they provide natural infrastructure and protection to nearby populated areas. They are one of the most productive ecosystems because they provide ecosystem functions like income, food, and fuel, as well as nesting and nursery sites for fish and invertebrates. They also aid in stabilizing shorelines, protecting coastal communities and store CO_2 from the atmosphere (Valiela et al., 2001).

Habitat Biodiversity

Numerous species above and below the water rely on mangroves for food and shelter; for example, they serve as essential nurseries for fish and crustaceans, contributing to the local seafood abundance. They also provide habitat for a vast array of birds, mollusks, and insects and many endangered species tend to nest in mangroves (Cloern et al., 2016). Coastal birds' nest among mangroves but also rely on mangroves for a portion of their seasonal migrations, even dead mangroves provide a vital function by providing roosting sites for several bird species. They also provide habitat for as much as 80% of economically and recreationally significant fish species; including more than 3000 fish species (Polidoro et al., 2010).

Resources

Around the world, around 120 million people reside near mangroves (Ward et al., 2016). Mangroves can provide building materials and cooking fuel, which is a positive and a negative factor for local communities. Because of the density of mangrove wood, it is a valuable source of timber and fuel. However, because of the lack of a sustainable retrieving method of said sources, it contributes to the deforestation of the ecosystem. Additionally, several mangrove roots and fruits are employed in traditional medicine, however, as aforementioned there is no sustainable gathering of these sources as they are already running scarcely (Hernández-Blanco et al., 2022).

Coastal Protection and Environmental Benefits

Mangrove forests stabilize the coastline by reducing the erosion that is produced by storm surges, currents, waves, and tides. Additionally, they lessen the influence of waves on the shoreline, even reducing wave heights by up to 66% during storm events (The Nature Conservancy, 2022). Because of their nature of providing coastal protection, they are five (5) times greater at protecting the coastline in a more cost-effective way as opposed to grey infrastructure such as breakwaters (The Nature Conservancy, 2022). During heavy rainfall and storm surge, mangrove peat absorbs water, lessening the likelihood of coastal flooding. Their capacity to filter water by enhancing water quality for communities is one of the main reasons for their conservation that would benefit the communities in El Salvador. They absorb fertilizers and contaminants from stormwater runoff that help increase water quality and reduce the impact of other marine ecosystems.

Climate Regulation and Economic Benefits

By storing Carbon and releasing O_2, mangroves assist in the regulation of global climate. They are beneficial as they produce shade, store and release water vapor and they moderate temperatures and increase rainfall. Carbon is effectively stored in mangroves' leaves, wood, and roots, as well as in the sediments due to their carbon storage being three to five times greater than tropical upland forests (Ward et al., 2016). Because of their effectiveness to store carbon, they ensure the survival of numerous species. The symbiotic relationships they have with species and other ecosystems help provide food and a means of income for local populations by helping to preserve and maintain coastal land. Therefore, in addition to supporting and sustaining fisheries and coastal crops, mangroves also provide ecotourism revenue.

Mangrove forests main climate change stressors are SLR, warming, rising atmospheric CO_2, ocean acidification, and extreme weather events like that of heat, droughts, and storms (Ward et al., 2016). Local human stressors to mangroves include fishing, deforestation, coastal development, freshwater input, sediment input, urbanization, and mining (Ward et al., 2016). The spread of mangroves from North America, Central America and the Caribbean is shown in Figure 12, where mangroves are present in 34 countries. The climate stressors are already being felt in mangroves across El Salvador due to the high incidence of tropical storms, high relative SLR, and steep gradient changes in precipitation and temperature which have a direct effect on the mangroves and their communities.

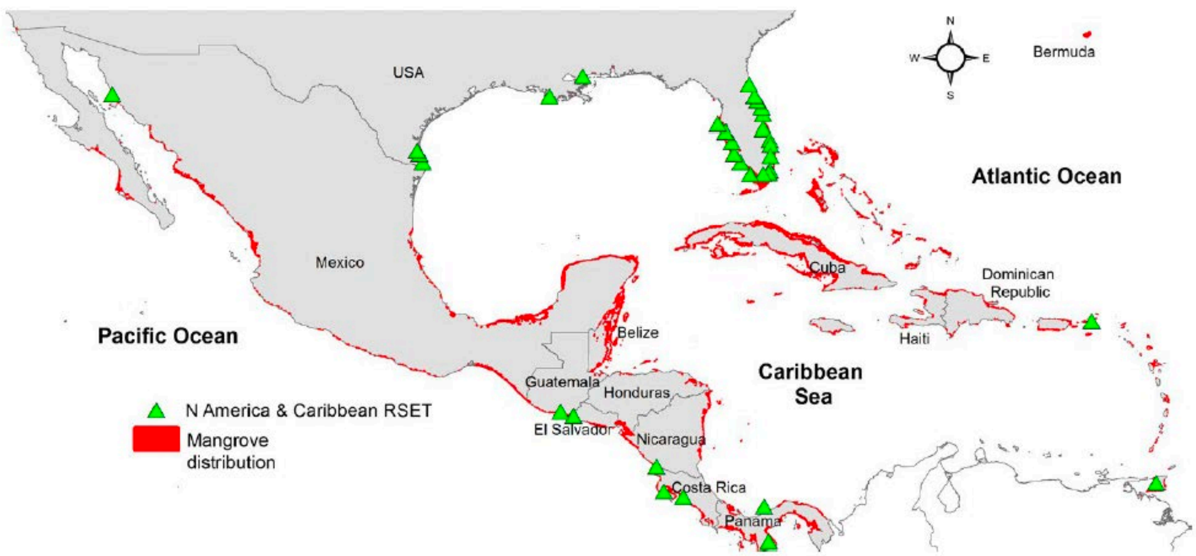

Figure 12 Distribution of mangroves in North America and the Caribbean. Rod Surface Elevation Table (RSET) in mangrove sites. They are used to measure annual sediment accretion. (Ward et al., 2016).

4.2.2 *Climate Impacts on Mangrove Ecosystems*

According to Ellison (2015), SLR, changing ocean currents, increasing storm frequency and intensity, increased temperature, changes in precipitation, and increased CO_2 are anticipated to have a significant influence on mangrove ecosystems as these factors are interconnected (McKee et al., 2012). How vulnerable mangrove regions are to these factors can influence their sensitivity, exposure, and capacity for adaptation.

Sea level rise is a major climate change stressor to mangrove ecosystems due to the sensitivity of mangroves to changes in inundation duration and frequency. This causes an increase in salinity levels that surpass a species-specific physiological threshold of tolerance (Friess et al., 2012). Projected increases in flooding duration can cause plant mortality and shifts in species composition ultimately resulting in a decline in productivity and ecosystem services (Castañeda-Moya et al., 2013). In El Salvador, SLR is anticipated to cause tidal freshwater forested wetland displacement and landward migration of mangrove forests (Ward et al., 2016).

Storms can have a substantial impact on mangrove productivity and health, and it is anticipated that the frequency and intensity of extreme weather events would rise globally (Nguyen & Leisz, 2021). Bender et al. (2010) proposed that the increasing frequency of La Niña events as a direct result of human-caused climate change might double the frequency of Atlantic hurricanes. El Salvador has experienced an increase in hurricanes and extreme weather events since the 1990's that have resulted in significant damage to mangroves as well as communities and the economy. Hurricanes and cyclones have had very significant negative influence on mangroves, due to their destructive nature of uprooting the trees. This causes severe damage to the canopy by leaving it exposed to wind and wave damage. In the worst circumstances, this can result in the complete removal of mangrove forests due to their peats collapsing because of soil elevation.

According to the IPCC (2013), the extreme changes in rainfall will affect the planet, with significant regional variance. This will be heavily felt by mangroves that are on the edge of their tolerances. This is because the changing rainfall patterns are anticipated to have an impact on the distribution, extent, and growth rates of mangrove forests (Barbier, 2017). Extreme variations in precipitation and increased evaporation already have an impact on soil due to the increase of salinity that influences the production and growth of mangroves. In worst case scenarios due to an increase of salinity, mangroves can be lost and converted to mudflats in tidal zones over the course of a couple decades. In Central America climate change models regularly predict higher temperatures and less precipitation during the wet season (Bender et al., 2010). However, because of the anticipated increase of the frequency of extreme El Niño occurrences, El Salvador is most likely to face even more severe droughts (Bender et al., 2010). This will further result in the degradation of mangroves, and an increase in salinity which could potentially lead to the loss of mangrove forests.

By 2081-2100, global temperatures are expected to increase by 4.8° C compared to 1986-2005 (IPCC, 2013). The composition, phenology, productivity, and eventually the latitudinal range of mangrove species' distribution are all expected to be impacted by this rise in temperature. Biochemical responses are influenced by temperature which impacts the ability of mangroves to absorb CO_2 (Ball et al., 1988). For example, mangrove seedlings do not grow in extremely cold temperatures. However, the conversion of mangroves into salt marshes is directly linked to the expansion of temperatures, at the North and South Poles and the rise in sea level (McKee et al., 2012). A slight increase in water temperature of 1.2 °C increased the algal epibiont cover of mangrove roots by 24 % but decreased epibiont diversity by 33 % due to the presence of shorter, weedy algal turfs caused by the increase in temperature (Ani & Robson, 2021). Further demonstrating that although sustained temperature increases would increase the expansion of mangrove forests, the quality of mangrove ecosystems will be altered. This could potentially mean that it could better adapt to the future impacts of climate change but at a cost to ecosystems services.

4.2.3 *Case Study: Mangrove Ecosystem of El Salvador's Paz River*

Conservation and restoration of marine ecosystems for the benefit of local communities has been crucial focus in the lower Paz River basin in El Salvador and Guatemala due to the rich biodiversity this location holds. Due to the importance, the Paz river has been studied by Herandez-Blanco et al. (2022). Agriculture is the primary economic activity in this coastal area which includes communities of low socio-economic status. In the basin, coffee is the primary crop, followed by livestock and grains. However, these agricultural activities have had severe environmental effects on the local ecosystems, most notably the loss of freshwater flows because of unsustainable irrigation practices for sugar cane and cow grazing (Hernández-Blanco et al., 2022). In addition, climate change is anticipated to cut precipitation in the area by more than 15% and increase coastal susceptibility to flooding due to sea level rise and increasing coastal storms (IUCN, 2019). This is further projected to impact the income and food security of these communities in the Paz River Basin.

The potential contribution of mangroves to the emission reduction objectives of Guatemala and El Salvador in order to help low-income communities along the coasts to mitigate the impacts of climate change was analyzed by Hernandez-Blanco et al. (2022). For restoration methods to be successful, the establishment of priority locations needs to be assessed. This is often done based on the possible potential benefits of coastal protection, economic income, and food security. Hernández-Blanco et al.(2022) noted that not all coastal populations will have the same capacity to respond to climate impacts equally due to their vulnerability. Therefore, seeing how mangroves stabilize coastlines and protect significant assets such as heavily traveled highways, , hospitals, and airports needs to be taken into consideration when restoring and conserving mangroves for future climate impacts. That is why it is crucial to maintain these ecosystems to help aid in the adaptation of coastal communities, especially those in developing regions.

The incorporation of local communities is often overlooked when it comes to decisions regarding restoration efforts. That is why Hernández-Blanco et al. (2022) emphasizes that it is crucial that the local communities guide decisions regarding the location and methods of mangrove restoration for it to be successful. These decisions need to encompass environmental and physical elements, as well as social and economic factors, as these are directly impacting local communities. In addition, mangrove restoration can be significantly hindered if land tenure is not recognized and understood (Hernández-Blanco et al., 2022). The participation and support of the community can assure the long-term success of restoration efforts and the equitable distribution of the benefits. This success and restoration efforts can avoid further and future degradation to mangroves that can serve as a model for additional restoration initiatives. For example, the Conservation International and women from the fishing community of Chira Island in the Gulf of Nicoya are replanting mangroves and establishing mangrove nurseries in Costa Rica to increase the habitat area of commercially valuable fish species, while simultaneously restoring other ecosystem services (Hernández-Blanco et al., 2022).

In addition, the income that is generated by the land usage that deforests mangroves can be compared to the social cost of carbon. For instance, converting these mangrove forests into aquaculture ponds would generate more income, but the cost of the climate related damage will then offset the financial gains (Pendleton et al., 2012). Their deforestation can and will result in the release of over 40 % of the carbon already trapped in the atmosphere as CO_2 (Hernández-

Blanco et al., 2022). Therefore, it is beneficial to keep mangroves not only in the Paz River, but elsewhere due to the long-term ecological benefits they provide as opposed to the short-term economic benefits. One of the main ecological benefits that is highly important, is that mangroves are known as blue carbon habitat, which means it's a highly productive, carbon storing coastal ecosystem. Historically, they have been neglected as carbon sequestration solutions, but because climate change devastation is increasing at an alarming rate, their protection and restoration is gaining attention as ecosystem-based solutions to climate adaption efforts.

In summary, the physical processes associated with climate change are predicted to have a significant impact on mangrove communities worldwide. Sea level rise varies widely, but mangroves are likely to be seriously threatened in regions with widespread coastal development, fish populations and wetlands, including saline intrusion in places like RAMSAR site of Jiquilisco Bay Reserve and the habitat-rich Gulf of Fonseca (CityAdapt, 2021). The UN Decade emphasizes both the conservation and restoration of ecosystems in order to achieve the Sustainable Development Goals, but the worldwide restoration of ecosystems and their services will play a critical role (UNEP, 2020). Their capacity to reduce weather extremes and to provide a natural water filtration system benefit vulnerably communities not only those that live on the coast but those that live in urban and rural areas. The importance of restoring and conserving marine ecosystems, especially those of mangroves helps provide several benefits as shown in Figure 13. Mangroves have a larger effect on the vulnerability of communities on the local and regional level by decreasing poverty, inequality, and vulnerability and that is why their conservation is extremely important.

Figure 13 Benefits of Mangroves. Adapted from (Ward et al., 2016)

4.3 *Vulnerability of low socio-economic communities impacted by health risks, extreme weather event and pollution*

Community and individual vulnerability to climate impacts and their capacity to adapt to climate change are influenced by a variety of factors. Vulnerability is defined as a system's susceptibility to the impacts of climate change, such as climate variability and extremes, and its incapacity to withstand these impacts (Gregg & Polgar, 2021). Figure 14 depicts variables that may influence climate change sensitivity and vulnerability. These variables can be living conditions of people, age, location of where they reside, occupation, health, language barrier, racism, and income and often they are not mutually exclusive. These variables are impacted by natural disasters that exacerbate poverty, but also increase people's susceptibility to poverty (Hallegate et al., 2017). These variables can be categorized based on the interaction between underlying causes, societal variables, and biological components, which results in a heightened susceptibility to climate change. Poverty, in its various dimensions, inequality, and vulnerability to natural disasters are concrete examples of how social and environmental imbalances influence one another.

Figure 14 Factors that can increase climate vulnerability. Adapted from Yuen et al., 2017

Hallegate et al. (2017) provides evidence that supports the fact that extreme natural events or disasters have a disproportionately negative impact on the well-being of poor communities, regardless of the frequency or intensity of the event. For example, globally, when the bottom quintile of a population is affected by natural disasters, approximately 11% of total assets and 47% of well-being are lost (Hallegate et al., 2017).

4.3.1 *Vulnerability Assessment (MARN, 2012)*

Families' exposure and vulnerability to extreme events and disasters are influenced by variables other than geography. These factors include urbanization, the dysfunctionality of real estate markets, inadequate transportation systems, the unequal distribution of opportunities and services in the territory, the scarcity of land in urban environments, and housing price disparities (Hallegatte et al., 2017). These are some of the factors that force households in low-income communities, to settle in areas with higher environmental risk. In El Salvador, common examples of the areas where low-income communities reside include slopes, riverbanks, areas prone to mudslides, freeway edges, etc (PNUD, 2022). These areas are at a very high exposure to extreme weather events, that with repeated frequency and increased intensity of the events lead to constant loss of assets.

Due to the absence of proper and adequate planning for home development, insufficient land, and unstable building materials these exacerbate the susceptibility of people to extreme weather events. In 2019, approximately 1.28 million households in El Salvador experienced a housing deficit (DIGESTYC, 2020). The building materials utilized in homes are one of the most important factors in hydrometeorological event protection (i.e: floods, mudslides, droughts, landslides, etc.). The better the material used in the housing construction; the less asset loss occurs as there is less physical structure to repair. However, cheap material often results in a complete loss of the house, which leads to a complete reconstruction in the same at risk area. In 2019, 18.3% of homes had defects in the quality of wall and floor materials (32.5% rural and 10% urban) and 5.2% in the quality of roofs (7.2 % rural and 4% urban) (PNUD, 2022). In households suffering from multidimensional poverty, the frequency with which these deprivations occur increases (Moreno, 2017). In this section, three different vulnerability factors are examined in order to gauge how vulnerable the people of El Salvador are; yet, each one offers a different perspective that is ultimately interconnected.

Physical Vulnerability

Physical vulnerability refers to the location of human settlements in areas at risk for extreme weather events i.e: landslides, flooding, etc., and to the deficiencies of the physical structures to mitigate the effects of these risks (MARN, 2012).Therefore, physical vulnerability can compromise humans or infrastructure. Physical vulnerability brought on by exposure differs from physical vulnerability brought on by flaws in physical structures. The first happens as a result of the location of settlements. The second physical vulnerability is caused by flaws in the infrastructure, building materials, design specifications, and building codes, including whether or not they are intended to withstand the impact of a particular disaster. Because of this, the degree of physical vulnerability brought on by infrastructure flaws varies depending on the type of threat.

Figure 15 depicts the various housing materials used for Salvadorian house walls and the roofs or ceilings. There are a total of 36 possible combinations of these materials, yet only 14 of them account for 97% of the housing in El Salvador, as shown in Figure 16. The 14 combinations depict the most common materials that households in El Salvador are made up of and therefore the remaining 22 are not shown. The order of the 14 combinations does depict the level of vulnerability, with #1 being the most vulnerable to climate impacts. That will be further explained in the sections to come.

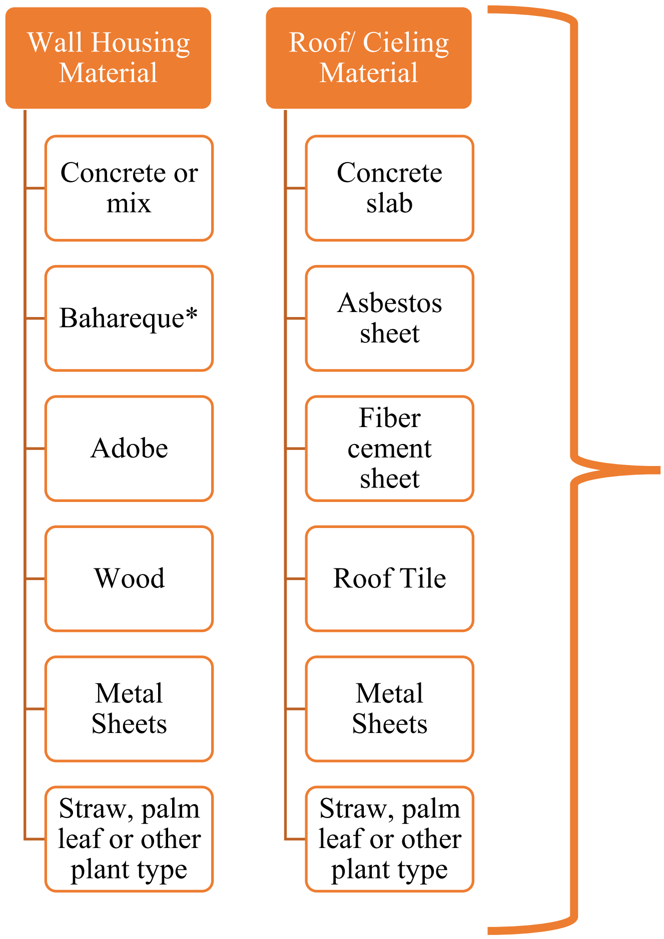

*Figure 16 Wall Housing materials & Roof/Ceiling materials. 36 possible combinations for households can be made from these materials. * Bahareque is similar to adobe, which consists of clay and or mud that is often reinforced with sticks. Adapted by MARN (2012)*

Figure 15 The 14 main combinations of housing materials. Out of 36 different housing combinations that can be formed, these 14 are the most common as they account for 97% of the population. Therefore, the other 22 combinations are not shown. Adapted by MARN (2012

A house's resilience, as determined by the materials used in its construction, varies depending on the event and the severity of the event. For example, certain materials are more susceptible to damage from landslides than from flooding, which can be even more devastating regardless of the material used. Therefore, MARN (2012) assigned values between 0 and 1, to the 14 possible combinations, with 0 denoting the combination that is most resistant and less vulnerable structurally, and 1 denoting the combination that is most weak and, thus, more vulnerable structurally (Table 1; value assessment). By employing a weighted average, a measurement that enables an average result even when not all the components from which it is supposed to be obtained have the same weight, the degree of physical vulnerability was quantified using the following calculation:

$$DPV = \frac{C_a * e_a * V_a + C_b * e_b * V_b + C_c * e_c * V_c + \cdots + C_n * e_n * V_n}{C_a + C_b + C_c + \cdots + C_n}$$

DPV: Degree of Physical Vulnerability
C_n: number of households in a certain area
e_n: coefficient of exposure of the analyzed household
V_n: value assigned to the combination

As an example, susceptibility to landslides was evaluated by MARN (2012). A population of 63 households spread over the various susceptibility bands was evaluated and broken down as follows:

- 10 households with combination number 3; 8 of which are considered extremely high vulnerability and 2 are low vulnerability
- 20 households with combination number 6; 7 of which are considered extremely high vulnerability and 5 are considered moderate vulnerability, 6 are high vulnerability and 2 are low vulnerability
- 30 households with combination number 11; all are considered extremely high vulnerability
- 3 households with combination number 13; all are considered low vulnerability

Table 1 Physical Vulnerability value and Value assessment and Susceptibility coefficients

Combination	Physical Vulnerability Value	Extremely High	High	Moderate	Low
Outside of classification	-	1.00	1.00	1.00	0.00
Combination #1	1.00	1.00	1.00	1.00	0.00
Combination #2	0.92	1.09	1.00	1.00	0.00
Combination #3	0.84	1.19	1.00	1.00	0.00
Combination #4	0.76	1.32	1.00	1.00	0.00
Combination #5	0.70	1.43	1.07	1.00	0.00
Combination #6	0.66	1.52	1.14	1.00	0.00
Combination #7	0.61	1.64	1.23	1.00	0.00
Combination #8	0.57	1.75	1.32	1.00	0.00
Combination #9	0.52	1.92	1.44	1.00	0.00

Combination #10	0.40	2.50	1.88	1.25	0.00
Combination #11	0.28	3.57	2.68	1.79	0.00
Combination #12	0.20	5.00	3.75	2.50	0.00
Combination #13	0.10	10.00	7.50	5.00	0.00
Combination #14	0.01	100.00	75.00	50.00	0.00

Based on the information provided from the example and plugging in data from Table 1, the degree of physical vulnerability can be obtained for the households in that region:

$$DPV = \frac{8*1.19*0.84+2*1*0.84+7*1.52*0.61+5*1*0.61+6*1.14*0.61+2*1*0.61+30*1.79*.28+3*2.5*0.1}{10+20+30+3}$$

$$DPV = \frac{40.3956}{63}$$

$$DPV = 0.64$$

Therefore, comparing the DPV of that region to data from Table 2, its deduced that that region has a high vulnerability to landslides.

Table 2 Vulnerability index. Adapted from MARN (2012).

Vulnerability Index	Value
Extremely High	1.00-0.76
High	0.75-0.51
Moderate	0.50-0.26
Low	0.25-0.00

To further examine how susceptible households in a specific region are, Table 3 presents additional information to the example previously provided.

Table 3 Example data

Population	300
Households	63
Municipality area	20 km^2
Susceptibility Area	2 km^2

Table 4 Calculations

Calculations	
People/ household	300/63=4.76
Population density	300/20= 15 habitats / km^2
Households/ km^2	63/20= 3.15 households/km^2
Households with high susceptibility	$2km^2$ * 3.15 hh/km^2 = 7 households

Therefore, within a $20km^2$ radius the susceptibility results depicted on Table 5 demonstrated the distribution of households in that area. While a region can have an overall specific type of vulnerability (Extremely high, high, moderate, or low), using the DPV formula can better help assess the susceptibility of households in each municipality to better formulate management practices for specific communities within municipalities or certain areas of cities. This can target specific areas and households based on their physical vulnerability, in order to help them decrease that vulnerability that they have to extreme weather events.

Table 5 Susceptibility Results

% Distribution of households	Susceptibility results
Combination #3: 15.87%	7* 0.1587 = 1 household with combo 3
Combination # 6 : 31.75%	7* 0.3175 = 2 households with combo 6
Combination # 11: 47.62%	7* 0.4762 = 3 households with combo 11
Combination #13: 4.76%	7* 0.0476 = 1 household with combo 13

Social Vulnerability

The most economically distressed communities and those with unstable social situations have been demonstrated to have lower levels of resilience on a global scale, which is one of the reasons why they are more susceptible to the effects of natural disasters (Hallegatte et al., 2017). Social vulnerability is the capability to prevent and respond to events that endanger life and property, that is determined by a number of economic, social, and cultural elements (MARN, 2012). These factors include awareness of local hazards, conditions, and the population's ability to recover after the occurrence. Furthermore, the access that humans (based on where they are settled) have to basic services such as education and health has an influence, since these factors largely determine the magnitude of the trauma caused by a disaster. In addition, it is important to note that disasters do not imply the occurrence of new diseases, nor do they produce as many epidemics as is commonly thought. What does happen is that the problems suffered by the community under normal conditions become more acute and more visible during and post disasters, due to the magnitude of disturbance.

MARN (2012) measured social vulnerability in two parts. The first was designed to assess the key socioeconomic factors (using indicators) that contribute to the population's inherent social vulnerability, which is amplified in the case of a disaster. The second seeks to comprehend and examine issues related to an established social structure that is capable of effectively responding to the effects of natural occurrences. Figure 17 demonstrates five main variables that influence social vulnerability. Surveys were conducted in communities based on the five main variables that determined social vulnerability: health, education, housing, employment and income, and population. These variables yielded 17 indicators shown in Figure 17. Each variable and indicator assessed determined just how socially vulnerable a person was to the impacts of climate change. Table 6 demonstrates an example of one of the 17 indicators that were asked in the survey conducted. For example, under health, the first indicator was accessibility to a health facility. Vulnerability was determined by the time that it took a person to get to a health center; giving an idea of the accessibility that a certain person, population or region has to a health care facility. This simple social indicator proves that people who have a shorter travel time to a health center will benefit and use this resource more frequently as opposed to those whom it takes more time to get to the clinic, therefore resulting in a reluctance to visit the health center. Therefore, other indicators followed the same simple format, that helped understand and formulate social vulnerability for people, communities, or populations. This method is easily adaptable and can benefit the Salvadorian people by assessing what indicators are influencing vulnerability the most, in order to help formulate recommendations that will reduce their exposure to climate change.

Health

- 1. Accessibility to health facility
- 2.Prevalence of severe retardation in height of children enrolled in first grade
- 3. Rate of diarrheal diseases reported by the MSPAS
- 4. Rate of acute respiratory infections reported by the MSPAS

Education

- 5. Average schooling
- 6.Illiteracy rate
- 7.Percentage of the population that never attended formal education

Housing

- 8.Percentage of households with water service
- 9. Percentage of households with access to sewage management
- 10.Percentage of households with access to lighting service
- 11.Percentage of households with dirt floors

Employment

- 12.Extreme poverty rate of households
- 13. Percentage of the population whose main activity is agriculture
- 14.Percentage of the PEA that is employed

Population

- 15.Households with overcrowded conditions
- 16.Population density
- 17. Degree of urbanization

Figure 17 The 5 socioeconomic factors that contribute to vulnerability along with the 17 indicators that were used to analyze social vulnerability of a population. Adapted from MARN (2012).

Table 6 Health. Indicator #1 Accessibility to a health facility. Adapted from MARN (2012).

Indicator/ Question	How long does it take to get to a health facility?*	Vulnerability Index	Value assigned
Ranges	1 hour +	Extremely high	1.00
	45 minutes – 60 minutes	High	0.75
	30 minutes- 44 minutes	moderate	0.50
	15 minutes to 29 minutes	Low	0.25
	1 minute to 14 minutes	Extremely low	0

**Denotes a MSPAS hospital, a MSPAS health unit, a MSPAS dispensary or health home, an ISSS hospital or unit, a private hospital or clinic*

Environmental Vulnerability

Environmental vulnerability refers to the environment's sensitivity to sustain harm or lose its natural resources, which can be biological or physical (MARN, 2012). Understanding a region's sensitivity or resistance to the effects of natural disasters is necessary to fully comprehend that region's environmental vulnerability. A region's mitigation and resilience are directly correlated with the range of environmental services it offers (Gregg & Polgar, 2021). This serves as the foundation for managing risk, management recommendations, and identifying high risk areas.

In El Salvador, MARN (2012) emphasized that environmental degradation threatens sustainable development in a variety of ways; the negative impact on the population's health and life expectancy, decreases labor productivity, land and capital productivity, damages economic infrastructure, prevents access to environmentally conscious markets, and lowers quality of life and growth-oriented policies. The degree of conflict between the usage of agricultural land and the presence of trees was evaluated by MARN for the analysis of environmental vulnerability in two ways. The first evaluation was the high conflict indicator of agricultural land use which compares the land's current usage to potential use while taking the soil's geomorphology, slope, and topography, etc. into account. The second evaluation was the tree cover indicator, which helps determine which areas are unprotected from tree coverage which often are areas that are being used for agricultural work, housing, or industrial usage. It also assists to determine which areas will be more susceptible to erosion by taking into account the geomorphology of the soil. To determine the level of environmental vulnerability, three categories were formulated: High, Moderate and Low, as depicted in Table 7 below. This environmental vulnerability can better serve the community by assessing what lands need to be conserved and restored to help mitigate the effects of climate change. Starting off by reducing the amount of deforestation that occurs in these communities by educating the locals to the benefits that certain lands provide to them.

Table 7 Environmental vulnerability categories

Vulnerability Category	Description
High	The land is not used to its full potential; there are issues with erosion and surface runoff in areas with steep slopes or flooding and sedimentation in flat areas.
Moderate	The land is only partially being utilized in accordance with its potential; there have been reports of/a history of runoff, flooding, and sedimentation.
Low	In this category, the category of "null," which denotes that there is no conflict with the use of the land, is also taken into consideration. The land is being used to its almost full potential. Issues of runoff, flooding, and sedimentation are low. “Null” is also a category considered; there is no conflict with the use of the land

Overall, vulnerability demonstrated that climate change and environmental degradation generate challenges that do not affect all individuals in the same way, at the same rate, or with the same degree of severity (Hallegate et al., 2017). This means that just because a person lives in a certain community, they do not have the same level of vulnerability as their neighbor. Their vulnerability can range from their neighbors by simply assessing their physical vulnerability. Meaning that if their housing materials are different, then they will both have different levels of vulnerability exposure. As per social vulnerability, while they might have the same distance to the health clinic, their levels of education might be different which influences their level of vulnerability. However, they both can have the same level of exposure to environmental vulnerability if they live on the same block where there is no tree cover that leaves them highly exposed to the impacts of extreme weather events.

Furthermore, natural disasters tend to disproportionately affect the poor due to several factors. First, the numerous hardships they endure and the locations where they settle make them more susceptible to occurrences such as landslides and repeated damage. This can be assessed via physical and environmental vulnerability. Both of these exposures have a cumulatively negative effect on their well-being (Hallegate et al., 2017). Second, they experience a greater asset loss which makes their recovery more difficult (Hallegate et al., 2017). Due to this, low-income families must make decisions with short-term consequences in mind; yet these actions have uncontrollable long-term implications on their health and education levels that are passed on to future generations. This is evident when conducting a social vulnerability assessment which provides an insight of the specific indicators that create that vulnerability that gets passed down to other generations. This is illustrated in Figure 18, resulting in a never-ending cycle of intergenerational poverty. Furthermore, to maintain equitable chances for all individuals, intragenerational and intergenerationally, is one of the fundamentals of the human development paradigm (Hallegate et al., 2017). If mitigation and resilient strategies are not adapted to aid the poor, they will always be the most affected by disproportionate levels of inequality, their integrity, and their efforts to advance human development.

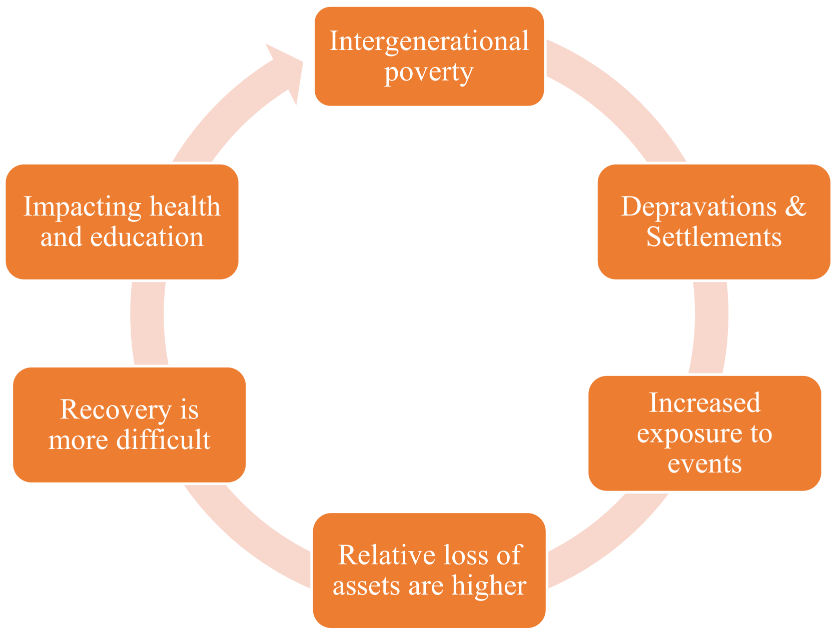

Figure 18 Intergenerational poverty loop. Adapted from Hallegate et al (2017)

4.3.2 *Human development: Gender inequality and unequal opportunities*

One of the most important complementary measurements affecting vulnerability is the Gender Development Index (GDI). However, to understand GDI one must understand the Human Development Index (HDI). HDI is influenced by two factors: an increase in life expectancy and an increase in the number of years spent in school as a result of greater educational access (UNHSP, 2020). The life expectancy in El Salvador rose from 36 to 73.2 years between 1930 and 2017 because of the adoption of preventative health measures, vaccines, and improved treatment against certain diseases (PNUD, 2022). In education, the percentage of 15-year-olds and older who can read and write increased from 27.6% in 1930 to 85.9 % in 2012 (MARN, 2013). Nonetheless, human development does not reach all individuals equally or equitably, particularly the most vulnerable even if a positive increase in development is achieved.

Therefore, GDI estimates gender disparities in three dimensions of human development: health, which is measured by the life expectancy of women and men at birth (UNDP, 2010). Education, which is calculated based on the expected years of schooling of women, men, and children, as well as the average years of schooling of women and men for adults aged 25 and over (UNDP, 2010). Lastly, economic resources, which is measured by the estimated labor earnings of women and men (UNDP, 2010). However, according to the GDI, women's human development is lower than men's, with a ratio close to 1, which is more detrimental to women (UNHSP, 2020). In most developing countries, this gender inequality disparity is present.

Gender inequalities

In El Salvador, households headed by women are more likely to experience moderate or severe food insecurity, necessitating adjustments to their budget and/or the quantity and/or type of food they consume. Quisumbing et al. (1995) call attention to several difficulties associated with the roles of women in agricultural production: access to land ownership (size and quality of land), economic access to food, and the roles associated with household nutrition. For example, often times women's contributions to achieving food security are extensive and include planting or harvesting their own food, or purchasing and preparing food, as well as caring for and feeding others to ensure nutritional and health aspect of the household (Singh et al., 2022).

Women and children frequently transport water for home use, leaving them most likely to be adversely affected by water scarcity that further impacts food security (UN Water, 2022). ANDA, the public water organization that collects water from surrounding rivers, has constructed a system of pipes that is commonly used to provide running water. However, bad management frequently results in water shortages that leave taps dry. About 15% of Salvadorans lack running water in their homes and must collect water from communal pipelines, wells, or the closest river (Brigida, 2021). However, women are more likely than males to participate in the vanguard of the effort to deliver water to their communities (Brigada, 2021). This is due to gender norms, which entail women managing their families, including ensuring there is sufficient water for cooking, cleaning, drinking, and keeping hygiene. Moreover, some regions where women frequently must travel to acquire water are controlled by gangs, putting women and children at an even greater danger of harm, theft, rape, and death (Brigida, 2021).

Roughly 80% of domestic and care work is performed by women, who are also the most devoted to it (DIGESTYC, 2017). According to the National Time Use Survey (2022), approximately 80.8% of women aged 12 and older spend time preparing and serving food, compared to 28.6% of men in the same age range. Compared to men, women devote more than twice as much time (1.97 hours versus 0.92 hours) per day to this activity. Considering the time spent on other primary activities for self-consumption and non-primary activities related to food security, the average time spent increases to 2.46 hours per day for 83.7% of women and 1.80 hours per day for 50.4% of men (DIGESTYC, 2017). Women in rural areas spend an average of 2.89 hours per day, compared to about 2.20 hours for women in urban areas, while men in rural areas spend 2.14 hours and 1.54 hours, respectively (DIGESTYC, 2017). Unequal opportunities have led to the facilitation of these gender roles that are based on beliefs and behaviors that emphasize differences; differences rooted in *machismo,* which is deeply ingrained in Salvadoran culture. *Machismo* and patriarchy are ingrained in the country's history, resulting in power relations and family hierarchies that have facilitated inequality in gender roles and limited the relationships between individuals and the support from institutions (PNUD, 2022).

In 2011, El Salvador enacted the Law of Equality, Equity, and Eradication of Discrimination Against Women and the Special Integral Law for a Violence-Free Life for Women in 2012. Both policies promote gender equality at the national, sectoral, and territorial levels (PNUD, 2022). Thus, resulting in the country's Gender Inequality Index (GII) is 0.384, which placed it 85 out of 159 countries in the 2015 index. About 35% of Salvadoran households are headed by and dependent on women, of which 37 % are living in poverty and 9.2% in extreme poverty (Gomes, 2019). Due to their varied responsibilities, women's food insecurity experiences vary qualitatively among themselves (PNUD, 2022). Objectively and subjectively, the environmental imbalances caused by climate change, productivity losses, lack of economic and political resources, and the decline in the quantity and quality of water will make life more challenging for all Salvadoran households, particularly those headed by women.

Monoculture & Economic inequality

In the 1960s, the first income inequality measurements surfaced. In 1961, the wealthiest 20% of the population accounted for 61.4 % of the national income, while the poorest 20% received only 5.5% (Artiga-Purcell, 2022). El Salvador has experienced a decline in income inequality as measured by the Gini index, which has decreased from 0.54 in 1998 to 0.38 in 2019

(World Bank, 2021). The Gini Coefficient (also known as the Gini Inequality Index) is a statistical measure of dispersion that is designed to represent the economic disparity in a country or among social groups (United States Census Bureau, 2021). Recently, El Salvador has become one of the least unequal countries (not specifically to gender) in Latin America as a result of a 20% gain in income in low socioeconomic status groups (Gomes, 2019). This income inequality is due to the persistence of monoculture that entails negative historical-cultural burdens. The deeply divided and concentrated agrarian structure which the agro-export model rooted in monoculture is based on, was dominated by substantial estates. These estates were owned by family economic groupings that oversaw the various stages of the agro-industrial chain (Artiga-Purcell, 2022). Therefore, influencing the economic inequality that the country is still trying to recover from.

For example, in coffee plantations, this inequality was very noticeable due to these families controlling the product's production, transformation, and internal and external commercialization. In the agro-export model, the land is the main factor of production, and this natural resource was essential to capital accumulation (Artiga-Purcell, 2022). The agrarian elites made its ownership and control a top priority and used the state to take and steal it by displacing low-income and indigenous communities. The distribution of land and the practice of monoculture influence the division of labor. This is due to the shortage of jobs in agriculture, and the hierarchy of agricultural labor of family workers is affected by market conditions and the oversupply of temporary workers (Pérez-Sainz et al., 2018). These effects are visible in the environment as a result of decreased crop yields, soil contamination caused by the use of chemical pesticides and fertilizers, which threaten biodiversity and alter the agricultural practices of indigenous peoples (Kremen et al., 2012).

These agricultural practices resulted in the formation of a dual agricultural structure that was highly concentrated, polarized, and comprised both major producers and small farmers (Slotten et al., 2020). Therefore, economic inequality is exacerbated by the estates used for subsistence farming, which led to a large concentration of wealth and income to those families. This influenced the economic income of low socioeconomic communities by withholding land and income opportunities. Economic inequalities are those that lead to the concentration of power in the hands of a few and distort public policies in ways that reflect inequality patterns (Artiga-Purcell, 2022). This keeps the elite at the top, increasing their economic gain while maintaining the small farmers and poor communities at the bottom of the economic model. Therefore, monopolistic and oligopolistic structures, in addition to the absence of effective market regulations, low wages, and the absence of redistribution mechanisms, have an effect on the current economic model (Artiga-Purcell, 2022).

In El Salvador, due to justifiable gender roles and social hierarchy, there is evidence that socioeconomically disadvantaged groups face more inequality and discrimination than any other group (UNDP, 2013b). Due to a lack of access to education, these groups are often women, the elderly, people living in rural areas, and Salvadorans with darker skin tones from lower socioeconomic communities that face greater inequality and discrimination than other groups (Córdova-Macas et al., 2013). As a result of the Salvadorian civil war, land ownership, distribution, and exploitation are still a major source of conflict between genders and communities in the twenty-first century. However, these tensions have become more complex and now involve pollution, water quality and access, and natural resource conflicts that often determines the level of vulnerability that these communities face.

For example, the pandemic and extreme natural events that occurred in 2020 shed light on the vulnerability of the population's livelihoods, especially for those who rely on agriculture (Lopez et al., 2021). According DIGESTYC (2020), 38 % of corn-growing households and 56 % of bean-growing households lost at least half of their production in 2020. 68% of agricultural households experienced a decrease in income due to a lack of employment and a decline in market sales. In addition, this was exacerbated by the lack of water access, water quality issues, and sanitation systems, which negatively impacted the health of the population. Deficiencies in the provision of water and sanitation services increase the vulnerability of households. Especially, low-income households because they lack the hygiene options necessary to stop the spread of the virus (and other viruses) and prevent infection (UN, 2021). For example, the diseases associated with these deficiencies continue to be among the leading causes of death in children under the age of five (UN, 2021).

Due to the pandemic's severe mobility restrictions and the resulting influx of people combined with natural disasters, numerous facets of life were disrupted, including education. Education is essential for human development, but setbacks are expected due to rising effective rates of primary school dropouts and possibly rising rates of school abandonment. This was and is evident among those who are less affluent and have less access to technology, which often times are low-income communities with high vulnerability risk (PNUD, 2020).

4.3.3 *Multidimensional poverty and its dimension of vulnerability*

Coexistence across dimensions of vulnerability include the exposure to extreme events, polluting practices and depravation of basic services which is more prevalent in rural settings (80.5%), compared to urban settings (26%) (DIGESTYC, 2020). Access to basic services reveal the highest disparities between multidimensionally poor and non-poor households. For example, 82.9 % of multidimensionally poor homes do not have access to a sanitary service connected to a sewer or septic tank, or the service toilet belongs to another household UNHSP (2020). Figure 19 illustrates the interconnections between inequity, vulnerability, and environmental sustainability issues in El Salvador. Deficiencies due to the lack of access to basic services and polluting practices is the most common, followed by simultaneous deprivations in all three dimensions. 32.9% of households do not present any environmental deficiencies, 21% exhibit them only in one dimension and 46.1% exhibit them in two or three dimensions simultaneously. Of that, 27.8% exhibit them in two dimensions and 18.3 % in three dimensions, respectively. This value is nearly 60% higher and three times higher than that of households without multidimensional poverty (25.3%), while the lack of access to potable water is five times more prevalent among poor multidimensional households (DIGESTYC, 2020). Ultimately, these households are also the most vulnerable to severe weather and environmental hazards.

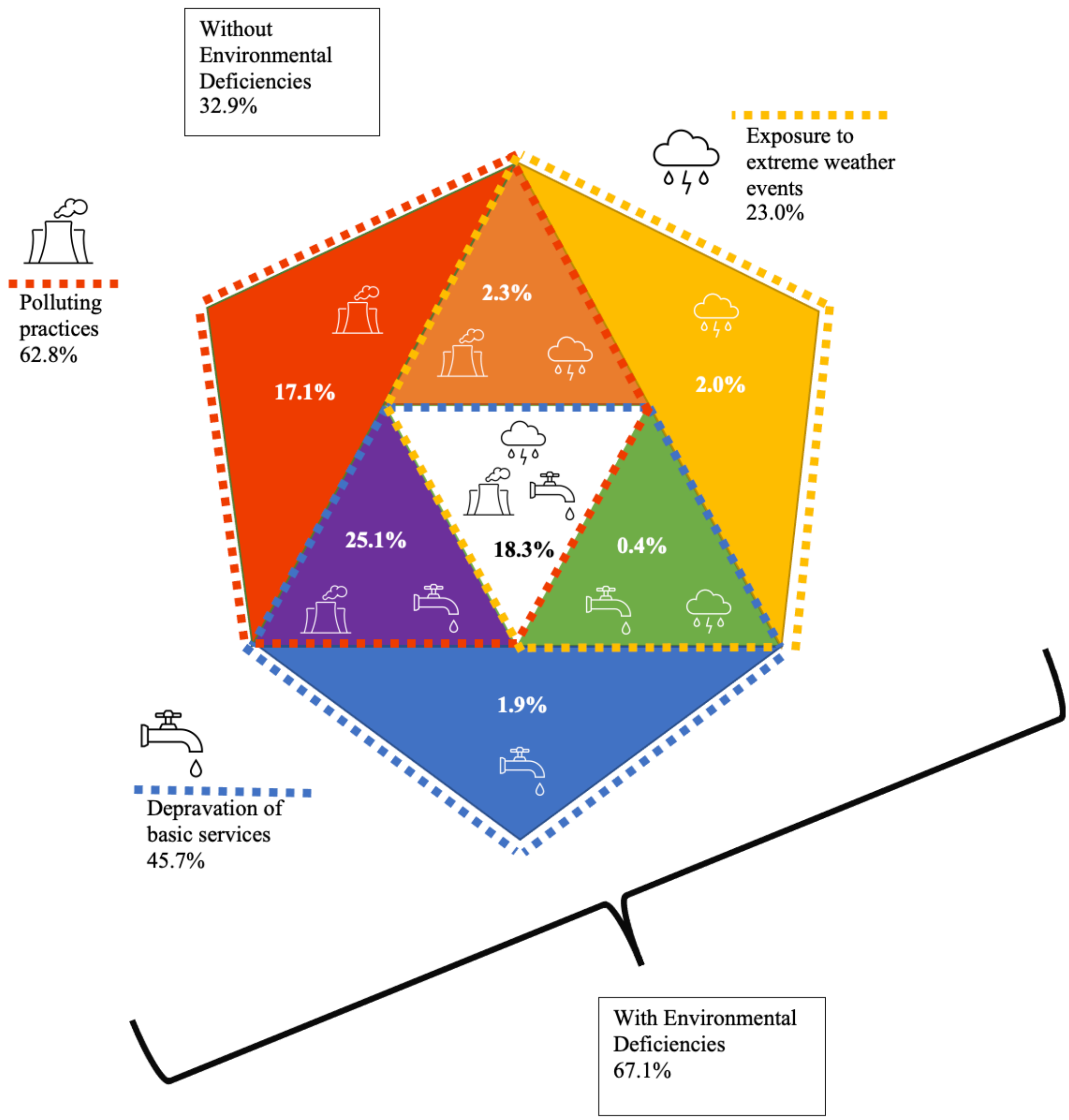

Figure 19 Intersections between dimensions of vulnerability to environmental events and risks (% of households). Adapted from (DIGESTYC, 2020).

Human development and sustainable development are closely related concepts that have similar interests. Both place emphasis on achieving universal and equitable well-being regardless of factors (Age, health, status, education level, etc.). They also emphasize the damaging effects of inequality and the necessity of eradicating severe poverty, end hunger, ensure equitable access to health and education, and lessening gender gaps, etc. (DIGESTYC, 2020). Sustainable development recognizes that environmental degradation has serious effects on people who are poor, marginalized, and vulnerable. In addition, it acknowledges without a doubt, that climate change affects people and countries that contribute the least to it (UNDP, 2016). Which is why sustainable development goes beyond the protection of natural resources and the environment, but the protection of the communities and people from the impacts of extreme weather events.

Sustainable development goals

El Salvador has a set of specific sustainable goals it intends to attain to prevent further climate impacts on the nation. It considers that the concepts of environmental integrity, transparency, transparency, completeness, comparability, and coherence must be encouraged and applied in the process of implementing and accounting for the reduction of emissions and anthropogenic absorption. These SDGs include all objectives set by the United Nations Millennium Development goals except 1, 4, 10, 13, 16 and 17 as depicted in Figure 20. The goals address the needs of people with an emphasis on equity. It tackles the three pillars of sustainable development: social, economic, and environmental, as well as key features of peace, justice, and successful institutions (UN Sustainable goals, 2018)

Figure 20 UN Sustainable development goals. (UN Sustainable goals, 2018)

5. Recommendations

The objective of my paper was to examine the effects that extreme weather events and pollution have on the people and ecosystems in El Salvador, with a particular focus on the most vulnerable population, low-income groups. First, recognizing that communities of low socioeconomic level contribute to and make up much of the agriculture sector; nonetheless, agriculture is the leading cause of water pollution in these communities and across the country. This pollution leads to the deforestation of ecosystems, such as mangroves, so that the land can be used for agricultural profit. This pollution further exacerbates extreme weather events that have a significant impact on the disparity between access to clean water, secure housing, and food. El Salvador can strengthen its ability to adapt to climate change by improving understanding the sources of pollution, particularly from the agriculture sector, and the harm and interconnection that this poses to ecosystems and human health.

Understanding the consequences that the country is currently experiencing and will experience in the future facilitates the development of ecosystem-based adaptation recommendations. These ecosystem-based adaptations contribute to addressing pollution in the agricultural sector, the significance of mangrove ecosystems, and the reduction of vulnerable communities' susceptibility to the effects of climate change. By understanding how these three factors are interconnected, ecosystems-based adaptation is a very green approach to environmental mitigation and adaptation, as ecosystems are a bridge between species and populations. Each of the following management recommendations has the capacity to increase El Salvador's adaptability to the existing and impending effects of extreme weather events.

Recommendation 1: Provide education and learning opportunities about alternative agricultural practices

Lack of management strategies has a substantial effect on the quantity and impact of pollutants. In agricultural practices, management encompasses everything from livestock management and housing to pesticide and fertilizer use. Education regarding agricultural practices and their poor management techniques, such as poorly managed animal feeding operations, overgrazing, plowing, fertilizer use, overirrigation, and incorrect, excessive, or improperly timed pesticide application, could therefore reduce the amount of pollution from the agricultural sector that ends up in bodies of water.

Participation from all farm owners, regardless of size, would generate a more eco-friendly and sustainable approach to pollution sources. Agriculture-related pollution is a well-known global phenomenon; yet a greater understanding of the issue would aid in the implementation of ecosystem-based adaptations to lessen hazardous activities. The promotion of technical assistance to producers in order to achieve sustainable management of natural resources is a primary goal. Specifically, this includes the development of an educational field with an emphasis on sustainable agriculture, livestock and aquaculture for families residing in the most environmentally sensitive regions. Furthermore, this would better help encourage the utilization of crops that are more resilient to the effects of climate change, regenerate soils, enhance ecosystems, and sequester CO_2.

Alternative agricultural practices: A SWOT analysis of Monoculture and Polyculture

Monoculture is a highly dependent farming method in El Salvador. However, this sort of agricultural practice is not suitable for mitigating climate change impacts, unlike polyculture, which is a type of agricultural practice recommended as an ecosystem-based adaptation. Based on the synthesis presented in this study, a SWOT analysis of monoculture and polyculture was conducted. The analysis shown in Table 8 and Table 9, indicates that transitioning to a polyculture technique would be more advantageous for low-income communities and farmers, as well as to help mitigate the countries adaptive capacity. Polyculture provides a lot of strengths and opportunities, which can even incorporate other agricultural practices like that of silvopasture. Silvopasture incorporates livestock to graze the land, as opposed to using heavy machinery for agricultural production. Overall polyculture can help decrease that water pollution that is present in several bodies of water in El Salvador and help decrease the use of fertilizers due to the controlled reduction of pests and diseases from rotating different crops throughout the year.

Table 8 Monoculture SWOT analysis

Strengths	Weakness

• Ease of management due to one crop focus • High revenue due to specialization of crop • Equipment, seeds, and other materials are customized to a single species resulting in cost savings • Farmers and experts also acquire highly specialized knowledge of their crop • Suited to cope with difficulties such as pests and disease, due to focus on one vs various species. • Increase profit	• Deforestation due to utilization of large amounts of acres of land for cultivation • Lack of biodiversity which increases diseases susceptibility • Decreases pollinators due to pesticide use • Pollution due to pesticides that result in algal blooms, hypoxic dead zones, groundwater and watershed pollution • Air pollution • Soil erosion resulting in lack of microbial diversity • Increase H_2O usage
Opportunities	Threats
• Economic advantage • Specific crops that thrive in certain locations • Maximum efficient use of soil • Usage of new technology	• Increase in deforestation results less land available for agricultural usage whenever more land is needed • Diseases due to lack of biodiversity • Climate change • Extreme weather events

Table 9 Polyculture SWOT analysis

Strengths	Weaknesses
• Biodiversity of flora and fauna • Increase crop productivity • Provide habitat and food for species • Increase soil microbial activity & nutrients • Less water pollution • Crop rotations require less water usage • Controlled crop/pest diseases • Resource savings	• Tillage impacts soil biodiversity • Crops that require pesticides during low production season can increase pollution of bodies of water • Increase GHG emissions • Lack of management of crops/ lack of understanding crop knowledge • More investment • Time consuming
Opportunities	Threats

• More tree coverage increases mulch and soil microbes which increases soil nutrient and leads to less usage of fertilizer • Certain crops reduce water loss • Pests and diseases are able to be dealt with; less pesticides due to crop rotations • Better resistance to extreme weather events • Less pollution to bodies of water	• Use of pesticides can decrease pollinators and genetic diversity • Crops with short vs long vegetation period • Can take years to build a proper structure of crop rotation • Lack of knowledge

Recommendation 2: Incorporate community engagement to raise awareness of pollution

Typically, locations that have been degraded are left unprotected from the impacts of extreme weather events and are considered high-risk areas that house low-income communities. As a crucial component of environmental management techniques, local community participation is essential for the improvement, resilience, and mitigation of these high-risk regions. This can be described by the biophilia relationship, which refers to the degree to which nature is a part of human life and to the mutual advantages derived from this relationship. People have a direct impact on the ecosystem in which they live, as well as the ecosystem's functions and health. The AFOLU industry influences everyone in the country, including those who do not live in agriculturally dominant regions. Local communities where AFOLU is prevalent, particularly businesses and corporations that interact with farmers, should be involved in ensuring that this industry transforms to a more resilient and less pollutant producing sector by ensuring their methods are environmentally friendly. The *Programa de desarrollo sustentable de la ganadera* (PROGAN), a particular initiative that is thought to be useful both directly or indirectly for GHG mitigation and adaptation to climate change in the AFOLU sector. Its objective is to promote household food security, diversification, competitiveness, and livestock profitability, it focuses on small-scale farming by means of sustainable methods.

The relationship between people and nature needs to be better understood by the public because of the exposure and occurrence of extreme natural events like that of hurricanes, storms, tropical depressions, floods, droughts, volcanic activity, earthquakes, and landslides. These events are in a direct correlation with urbanization of the natural environment like deforestation, pollution, changes in land use, the expansion of the urban border and the alteration of natural channels and both socio-natural and human variables worsen its effects (UNDP, 2013). The degradation of soils, ecosystems and environmental pollution are a result of a lack of understanding of what pollution is. Understanding that the physical environment and surroundings of a region determine how people develop have a significant impact on human development.

The impacts of climate change demonstrate a feedback loop with many social and economic injustices. However, the pollution and degradation are not brought about by the poor. The dangers and vulnerabilities of populations are jeopardized via their security of food and water. Therefore, in order to achieve that food and water security communities will do anything to achieve that security without realizing the long term effects of their decisions. Understanding that choosing the short-term benefits over the long term benefits, encourages unsafe practices that encourage pollution. This will exacerbate existing exclusionary practices and restrict potential gains in their capabilities, notably those relating to autonomy. Therefore it is crucial to understand and raise awareness as to why non sustainable methods are not beneficial to ecosystems and the communities it sustains. Bringing on awareness of pollution and its aftereffects will better help people understand the damages that practices can have on communities' health and their ecosystems.

Recommendation 3: Expand the conservation and restoration of ecosystems based on adaptation and mitigation influenced by vulnerability

El Salvador is experiencing economic and social impacts from climate change, yet despite contributing very low to the global GHG emissions, the government has established several policies, initiatives, and projects to improve its adaptive capacity. Most are focused on generating positive social and economic benefits while also lowering GHG emissions. One of these projects is the National Biodiversity Strategy (MARN, 2013) which aims to protect, restore and conserve the biodiversity of the country by supporting the social and economic growth of El Salvador through knowledge, evaluation, conservation and sustainable use of ecosystems and their services.

The *programa nacional de restauración de ecosistemas y paisajes* (PREP) with the aim of creating conditions that reduce climatic vulnerabilities and directing mitigation efforts based on adaptation. The initiative focuses on the following elements: Landscape-level sustainable agriculture; restoration and conservation of critical ecosystems; synergistic development of natural and gray infrastructure; and improvement of local governance and management. PREP is crucial in helping the conservations of mangroves in El Salvador due to the importance of the protection this ecosystem provides against storms and erosion control. This program is associated with the Bonn Challenge, which aims to restore 150 million hectares of damaged and deforested land and is regarded as the world's greatest restoration program. As part of the Bonn Latin America Challenge, in 2016 El Salvador pledged to rehabilitate one million hectares, or 50 % of the country's area, of which the majority (almost 70%) is used for agriculture. However, on the Bonn Challenge website no current progress data was provided for El Salvador. This strategy is effective for minimizing deforestation and focusing on ecosystem restoration, but additional support is required. Federal, state, and local entities that may provide employment opportunities, food security, and other success-enhancing resources should boost and support both programs. Incorporating education on pollution by agricultural runoff on bodies of water, marine ecosystems better helps understand why these bodies of water are so crucial to local and urban and rural populations. This aids in comprehending the need of restoration and conservation of mangrove ecosystems.

Recommendation 4: Conduct analysis on current and potential sites in order to provide better housing locations with green infrastructure

Technology such as Geospatial information systems (GIS) and other spatial analysis tools, can be used to undertake site-specific assessments of current environmental hazard sites and potential relocation sites. These evaluations may be useful for determining which places in El Salvador are ideal for relocating or constructing better homes for low-income communities that are extremely susceptible to climatic impacts. In El Salvador, low-income populations reside in places near roads or streams that are especially susceptible to landslides and flooding, a situation that worsens depending on the materials of their homes. Most of the time, when people are affected by such occurrences, they rebuild their complete house or the damaged portion of the house in the same area; an area that with an increase frequency and severity of extreme weather event occurrences make it a constant loop of economic loss. Therefore, utilizing these technologies can benefit low-income communities by locating environmentally low at risk places with the assistance of the government to provide safe housing. Utilizing the risk assessment in specific regions and communities might thereby increase local and regional adaptive capacity.

Through the integration of ecosystem-based adaptations into urban planning, City Adapt aims to strengthen the ability of governments and local populations to adapt to the effects of climate change. Their primary objective is to restore ecosystems in San Salvador to mitigate the effects of climate change. In addition, the incorporation of green infrastructure like that of green roofs, permeable pavements, and rainwater harvesting systems that can also aid in mitigating climate-related problems.

Overall, increasing the agriculture sector's resilience to the effects of climate change with a focus on biodiversity is the goal. This can aid in the recovery of soil and vegetation, the capture CO_2 , the improvement of water regulation, the reduction of agrochemical usage, and the enhancement of ecological diversity. This can be accomplished by expanding agroforestry and implementing sustainable agricultural practices through education. Restoring and preserving marine ecosystems can aid in reducing coastal erosion, strengthening the habitat of flora and animals, enhancing water quality and water storage capacity, and providing flood protection. This can be accomplished through the restoration and preservation of mangrove and other blue carbon ecosystems. Finally, the creation of natural and sustainable infrastructure for vulnerable populations. This can be accomplished by investing in green infrastructure, including old and new residential and industrial buildings, to mitigate climate impacts.

6. Conclusion

Studies on the effects of climate change in El Salvador reveal that biodiversity loss, ecosystem degradation, anthropogenic consequences, human health, and increasing human vulnerability are already being felt. The projected climatic changes of sea level rise, greater frequency and intensity of extreme weather events, longer and drier drought periods, and rising temperatures are expected to exacerbate the aforementioned concerns. Due to improper management, the agricultural sector in El Salvador is the leading cause of water contamination and emitter of greenhouse gases. It is becoming a severe problem owing to the solutions being short-term gains and not the long-term environmental consequences.

Human activities such as agriculture, aquaculture, forestry, and coastal expansion have increased agricultural runoff, which has had a negative effect on marine ecosystems namely mangrove ecosystems in El Salvador. Mangrove ecosystems are significant due to their role in regulating climate, protecting coastal areas, supplying food for populations, acting as natural filtering systems, and storing carbon. Therefore, the loss of mangroves influences socioeconomic status as a result of the loss of benefits offered not just to local populations but also to the global population. In addition, mangrove ecosystems can help reduce vulnerability, particularly in low-income communities that lack protection against harsh weather events. Vulnerability further demonstrates that climate change and environmental degradation cause challenges that do not affect all individuals in the same intensity or frequency. Furthermore, increasing the vulnerability of communities that suffer from multidimensional poverty that are disproportionately affected by natural disasters, resulting in intergenerational poverty.

Due to a lack of proper and adequate planning for residential growth, insufficient land, and unstable building materials, the sensitivity of the population to catastrophic weather occurrences is exacerbated. The environmental imbalances brought on by climate change, productivity losses, a lack of economic and political resources, and the decline in the quantity and quality of water will make life more difficult for all Salvadoran households, especially those headed by women. There is however potential for low-socioeconomic status groups to minimize their exposure to extreme weather occurrences. With the involvement of government agencies, research institutions, environmental organizations, and their own communities, the capacity to mitigate climate change's inequalities and effects on low-income communities, can be increased.

It is crucial that these institutions and organizations keep the community's best interests in mind to prevent future climate effects, inequalities, and health risks caused by improper management.

The proposed recommendations will strengthen El Salvador's adaptive capacity to offset the adverse effects of climate change on agricultural pollution, environmental degradation, and community vulnerability. The SWOT analysis revealed polyculture as a viable alternative to monoculture to reduce greenhouse gas emissions and water pollution. This improves social equity, health, and safety issues for rural agricultural communities by reducing harmful activities. Educating small farmers, large corporations, and the general community about the pollution that ends up impacting bodies of water through education of alternative methods and the significance of mangrove ecosystems because of the benefits they bring to local and rural people, equity can be achieved. The significance of protecting mangrove habitats, particularly because they provide a buffer against extreme weather events, will lower the vulnerability to such occurrences. By providing safer housing places with green infrastructure to mitigate future climate change impacts or by supplying housing materials, the government can break or lessen the severity of the intergenerational cycle of poverty. Consequently, each of the presented recommendations will aid in addressing the health, safety, and environmental issues of the most vulnerable communities.

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