Factors Influencing Climate Change Adaptation Decision Making among Farmers: Case Studies and Lessons Learnt in Trinidad and Tobago

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Abstract: The agriculture sector is integral to fulfilling the human biological need to consume nutritious food. The industry depends significantly on climate-sensitive assets. Because of this dependency, the need to implement climate change adaptation measures has become increasingly necessary for the sector's survival, growth, and development. Farmers are engaged in the most fundamental steps to safeguard healthy food production. This typically involves activities necessary to grow crops and rear livestock. They make critical decisions on the use of various agricultural resources, such as land, labour, capital, water, and chemicals, that impact food production and security. This study aims to determine the measures that farmers are implementing to adapt to climate change and identify the drivers of these measures. This chapter describes a qualitative study examining the climate adaptation measures in Trinidad and Tobago's farming community. It examines factors influencing adaptation choices and the extent to which desired outcomes are achieved. Climate and food production data are used to contextualise critical issues. The study revealed that most farmers implemented measures to adapt to extreme weather conditions, specifically periods of low rainfall and flooding. It was reported that the implemented measures were successful and that their choices were driven by the availability of resources. Based upon empirical findings, the chapter sheds light on lessons and discusses cases of adaptation that would inform policy decisions and provide farmers with knowledge of various adaptation measures. Moreover, a combination of policy and improved agricultural knowledge would guide farmers in building resilience to climate change.

1. Introduction

The twin-island state of Trinidad and Tobago is a highly industrialised nation in the Caribbean archipelago (Mohammed et al. 2019). The utilisation of hydrocarbon resources has resulted in the country having one of the region's highest Gross Domestic Products (GDPs) (World Bank 2020). Although the agriculture sector is responsible for only 0.5% of the GDP, it provides employment (4%) (Shik et al. 2018) for citizens who depend on the sector for their livelihoods. The relatively low agricultural activity in the country, however, contributes to the country's dependency on food imports (Eitzinger et al. 2015). Securing the stability of the agriculture sector is therefore essential for ensuring food security and protecting vulnerable members of society, regardless of overall economic contribution. The ability of the agriculture sector to contribute towards local food security and socioeconomic stability is becoming increasingly threatened by climate risks.

Understanding the potential impacts of climate hazards on farming practices requires understanding the local climate state and the extent to which location-specific farming practices can be affected. The primary activities in the crop cultivation process include soil preparation, sowing, adding manure and fertilisers, irrigation, weeding, harvesting and storage (Ministry of Planning and Development 2022). By utilising these activities, farmers can produce various crops to fulfil the human biological need to consume nutritious food. The total annual quantity of food crops grown in Trinidad and Tobago over the last few years have remained relatively consistent, with a noticeable decrease between 2017 and 2019, followed by an increase in 2020 and a subsequent decline in 2021 (Figure 1). The primary type of crop grown (based on weight) in Trinidad and Tobago in 2021 was green vegetables (113,211 kg), followed by root crops (28,919 kg), and then other pulses, such as corn and pigeon peas (11,091 kg) (Central Statistical Office 2022).

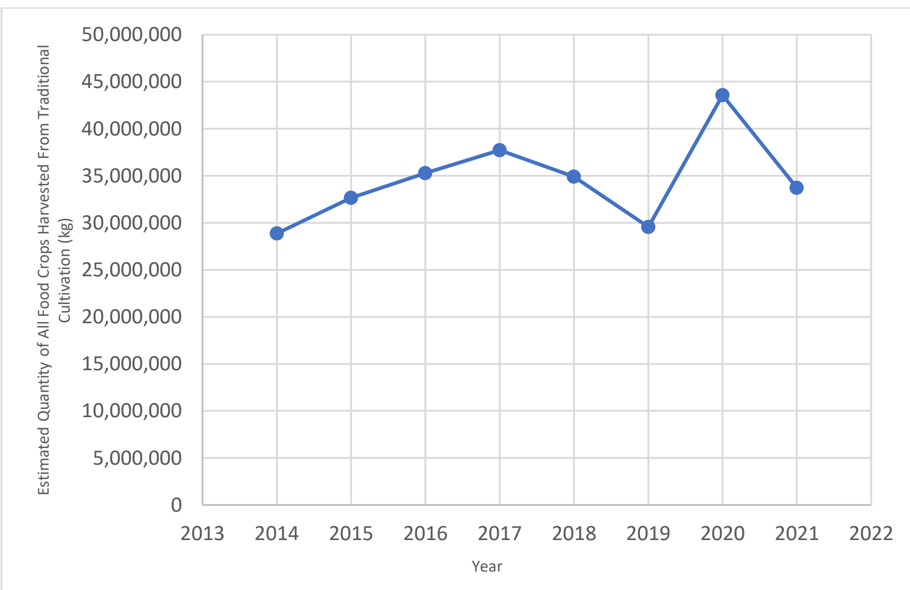

Figure 1. Estimated Quantity of All Food Crops Harvested from Traditional Cultivation in Trinidad between 2014 and 2022. Source: Authors' compilation based on data from Central Statistical Office (2022).

The agriculture sector is highly dependent on climate-sensitive assets (Linnenluecke et al. 2013) and would therefore be sensitive to climate change. The burden of climate change is disproportionately borne by low-income earners and the most vulnerable in society (Dodman and Mitlin 2013), including farmers. Climate change is expected to disproportionately affect farmers' livelihoods, especially in rural areas (Hutchinson 2011). Farmers are susceptible to climate risks because of exposure to various climate hazards, limited adaptive capacity, and multiple vulnerabilities.

Increased ambient temperatures and droughts are climate hazards that can directly reduce crop yield. Changes in these meteorological conditions can impact crop yield by disrupting the environmental conditions needed for survivability and growth. For example, lower rainfall and higher temperatures are expected to disproportionately affect Trinidad and Tobago's root crops (Ministry of Planning and Development 2019). This effect can have far-reaching consequences, given that root crops were the second most cultivated crop (by weight) in Tobago (Central Statistical Office 2022).

Meteorological conditions can also lead to other changes that can affect crop yield. For example, changes in rainfall and temperature patterns can increase the proliferation of pests and crop-related diseases. Climate change is not only expected to affect crop yield but also the areas where certain crops can grow (Eitzinger et al. 2015). Farmers will be forced to abandon or relocate farms if existing areas become unsuitable for growing crops. This adaptation to climate change can have socioeconomic consequences that far exceed those associated with disruptions to crop yield. Generally, climate change is expected to disproportionately affect the livelihoods of farmers, especially in more rural areas (Hutchinson 2011).

It is also essential to consider the impact of climate change on farmers. Temperature increases can lead to health and safety issues among farmers. For example, high ambient temperatures are linked to chronic disease among agricultural workers in tropical regions (Nerbass et al. 2017). Moreover, high ambient temperatures are known to lead to increased physical injuries (Tawatsupa et al. 2013) mental health issues, chronic diseases, and acute heat-related illnesses such as heat exhaustion and heat stroke (Levy and Roelofs 2019). Vector-borne diseases are also expected to increase as ambient temperature rises (Moore et al. 2017). The increased use of pesticides to combat these vectors also increases the risk of farmers being exposed to pesticides (Gatto et al. 2016). Long-term pesticide exposure increases the risk of chronic diseases (Abdollahzadeh and Sharifzadeh 2021). Moreover, high ambient temperatures can increase the extent to which xenobiotics such as pesticides are absorbed via skin and lung exposure (Gatto et al. 2016).

The health and safety issues affecting farmers have direct social consequences, reduce farm productivity, and diminish income. The negative effects of poor workplace health and safety practices on productivity have been observed in several industries (Shikdar and Sawaqed 2003).

Because of the direct or indirect consequences of climate change, a reduction in crop yield can lead to reduced income, affecting the quality of life of farmers and their households (Cammarano et al. 2020). However, this cascading impact of climate change on crop yield and the resultant social impact on the livelihood of farmers and their dependents is not inevitable. As defined by IPCC (2014), implementing adaptation measures is the "the process of adjustment to actual or expected climate and its effects, in order to moderate harm or exploit beneficial opportunities". This can help farmers mitigate or exploit opportunities related to climate change. Farmers possessing the necessary resources would have better adaptive capacity that enables them to maintain or improve their livelihoods by adjusting to the impacts of these climate risks and reducing vulnerabilities that climate hazards can exploit. Adaptation measures are barriers that prevent the impact of climate change and resultant effects on farmers from being inevitable.

Several studies have examined climate adaptation among farmers. For example, Belay et al. (2017) investigated the determinants of adaptation decisions made by farmers in Ethiopia. Studies by Ghanian et al. (2020) and Zobeidi et al. (2022) examined determinants of adaptation decisions among farmers in Iran.

Arising out of many studies, typical adaptation measures can be organised into general categories. However, there is room for innovation within this arena. Means of adapting to climate change can arise from cultural practices that are unique to the Caribbean. Determining unique measures can provide a means of expanding the adaptation tools available for farmers to meet the prevailing threat of climate change. However, to the best of the authors' knowledge, no study has been reported to examine adaptation decision making in Trinidad and Tobago.

Agricultural activity is concentrated mainly in the western Trinidad areas vulnerable to coastal erosion, coastal flooding, and sea level rises. These coastal issues can exacerbate the adverse effects of meteorological conditions on crop yield.

Building adaptive capacity requires accessing and utilising various resources needed for adaptation. For farmers, these resources include land, labour, capital and knowledge. However, understanding the complex impact of climate change on farmers is necessary before developing appropriate measures to use these and other resources to improve adaptive capacity.

A qualitative approach was used to examine adaptation challenges among farmers in Trinidad and Tobago. A qualitative approach is ideal for exploring the experiences, perceptions and behaviours associated with responding to real-world problems (Tenny et al. 2021). This approach allows for the deep exploration of the nature and ensuing challenges of the adaptation activities that farmers in Trinidad and Tobago were implementing. Questionnaires mainly comprising open-ended questions were distributed to 31 farmers in Trinidad and Tobago to assess adaptation activities. Questionnaires were distributed to farmers conducting farming activities mainly in the eastern areas of Tobago and the northern area of Trinidad. The study was mainly conducted in the Tunapuna–Piarco area of Trinidad and in the Roxborough area of Tobago (Figure 2).

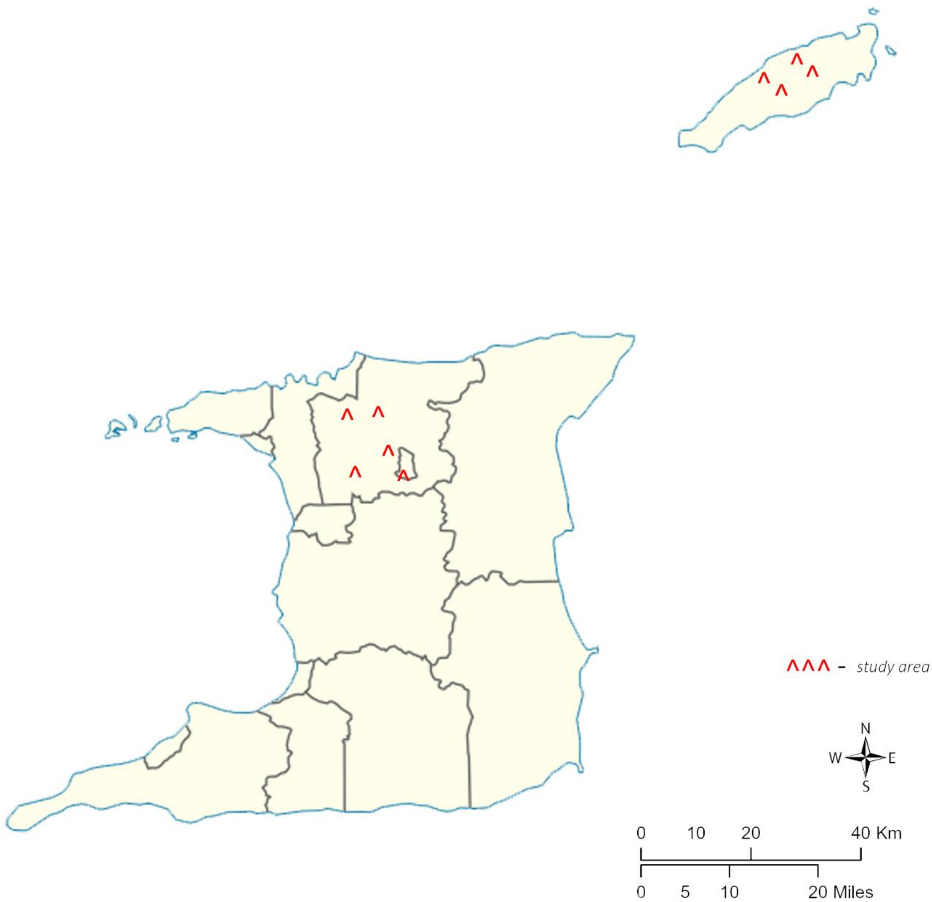

Figure 2. Study Area. Source: Adapted from Google Maps (2023).

2. Climate Change Impacts on Farming in Trinidad and Tobago

Approximately 18,951 farms (covering a total land space of 84,990 hectares) in Trinidad and Tobago grow various crops, with more than half being managed by individuals, households, and sole proprietors (Ministry of Planning and Development 2022). Therefore, reducing the impact of climate risk on farming activity in the country primarily depends on the decisions and adaptive capacity of individuals and social units rather than large-scale organisations. However, these small-scale operations often have limited resources, making adjusting to climate impact more difficult.

Farmers in this study earned approximately between 3000 and 7000 United States Dollars (USD) in annual revenue. The average farmer spent 5.6 h per day farming (or approximately, 5 days per week), resulting in an hourly income range of roughly USD 2 to USD 5. These values place the income range just below and above the country's national minimum wage, which changed from USD 2 to USD 2.60 in 2019 (Ministry of Labour 2021). Some farmers may be more capable of living on a minimum wage than others, depending on their living situation, the number of dependents, household size, and other factors. However, living on a minimum wage can be difficult because it may not cover the costs of acquiring basic needs such as food, transportation, and medical care. Additionally, farmers who earn a minimum wage may have difficulty saving money, investing, or planning for their future. Certainly, disruptions to income-earning capacity because of climate risks can push some farmers below the poverty line. It is, therefore, essential to characterise local climate risks to safeguard the livelihood of farmers. Understanding climate risks is necessary for developing appropriate measures to improve the adaptive capacity of farmers.

As reported by the Ministry of Planning and Development (2019), the twin-island state of Trinidad and Tobago is vulnerable to climate changes, such as rises in temperature, changes in rainfall, increases in atmospheric carbon dioxide, saltwater intrusion, extreme weather events and sea level rise. According to Mohammed et al. (2019), the mean annual temperature in Trinidad and Tobago has increased by approximately 0.6 °C since 1960, and the total yearly rainfall has increased by 37% over the past four decades. However, annual rainfall data do not provide insight into rainfall distribution throughout the year, particularly during dry seasons when precipitation levels are lower than in the wet season. The dry season is when farming activities are most likely to be compromised by water scarcity. Another study by Stone (2021) determined that precipitation levels during the dry seasons in Trinidad and Tobago have been statistically consistent.

Given that overall precipitation levels are increasing and dry seasons remain unchanged, it is expected that prevalent water scarcity issues in Trinidad and Tobago should be consistent or reduced over the years. Indirectly, however, other non-climate-related factors (such as poor land development and drainage) can exacerbate the effects of rainfall, leading to flooding events. The far-reaching effects of flooding events in Trinidad include damage to infrastructure, farm equipment, and machinery (Dixon 2018). Farmer demotivation, productivity reduction, and crop destruction were also identified as negative effects of flooding events in Trinidad. Flood-related issues can affect the profitability of farming operations.

Recent studies found that the farmers' choice of crop grown has been impacted by climate change. For example, certain species of corn and beans are more tolerant to drought than other crops (Peyster 2016). Whenever access to water is limited, farmers who choose to grow these drought-tolerant species of crops would be more capable of maintaining crop yield and profitability. Several crops are monitored by the Ministry of Planning and Development (2022) (Table 1). Data are unavailable on the extent to which a crop species is vulnerable to climate change. This information can inform farmers on alternative crop options that would be more resilient to future climate states.

Table 1. Food Crops Grown and Monitored in Trinidad and Tobago (Ministry of Planning and Development 2022).

Green Vegetables	Root Crops	Other Pulses
Tomato	Cassava	Green Corn
Cabbage	Dasheen	Pigeon Peas
Cucumber	Yam	
Melongene	Tannia	
Bodi	Ginger	
String Beans	Sweet Potato	
Okra		
Lettuce		
Pak Choi		
Watermelon		
Sweet Pepper		
Celery		
Pumkin		
Dasheen Bush		
Squash		
Cauliflower		
Pimento		
Chive		
Thyme		
Hot Pepper		
Herbs		
Sorrel		

Source: Authors' compilation based on data from Ministry of Planning and Development (2022).

3. Climate Change Adaptation

It is recognised that adaptation activities can be specific to locations and context because of variability in the social and natural environment, climatic impacts, and socioeconomic and cultural conditions (Füssel and Klein 2006). For example, the spatial heterogeneity of climate change vulnerability and effects (IPCC 2022) is expected to lead to variation in adaptation activities. Different regions will have to adapt to the specific climate vulnerabilities and challenges that exist in that area. Climate change is expected to lead to varying degrees of precipitation across the African continent, with some areas projected to have more intense rainfall and others, less rainfall (Dunning et al. 2018). Additionally, within a specific geographical location, there may be variations in adaptation activity owing to differences in perception (Berkhout 2012). Farmers are sometimes challenged to develop novel means of adaptation. Moreover, non-traditional cultural measures may have been developed to adapt to climate change. The type and extent to which various adaptation measures are implemented, the underlying factors driving adaptation decision making, the lessons learnt, and the success achieved can provide policymakers with information on the practical experiences of the farming community.

The Ministry of Planning and Development (2019) recommends farmers in Trinidad and Tobago implement adaptation measures such as water management, land distribution and management, research and development, climate-sensitive farming systems, increased awareness, and communication. Based on the cost–benefit ratio, suggested high-priority adaptation measures include on-farm water storage, mainstreaming climate change issues into agricultural management and drip irrigation. In addition, crop diversification was recognised as a suitable adaptation measure (Hutchinson 2011). Eitzinger et al. (2015) also identified cassava, sweet potato, and yam as alternative crops that might be more resilient to the changing environmental conditions in Trinidad and Tobago. Climate monitoring was also suggested as a suitable adaptation measure. Climate monitoring can inform farmers of optimal planting times to maximise the possibility of having the best possible crop yield. Climate monitoring can also ensure farmers are not overexposed to harmful weather conditions that threaten their health and safety.

4. Methodology—Data Collation and Analysis

A convenience sampling approach was used to distribute questionnaires to farmers selling crops at agricultural markets in Trinidad and Tobago. Questionnaires were distributed to farmers attending meetings held by agricultural organisations. Referrals from farmers who participated in the study were contacted and invited to fill out the questionnaire over the phone or using an online version of the questionnaire. In addition, discussions were held with farmers based on their responses to the questions included in the questionnaire. Overall, 31 farmers participated in the study. Responses from the farmers were analysed for themes and descriptions of farming adaptation activities and challenges.

5. Findings on Farmer Experiences and Adaptation Considerations

Most farmers were not members of agricultural societies (77.4%) or registered with the Ministry of Agriculture, Land and Fisheries (58.1%). In addition, most (76%) farmers indicated that they grew crops for domestic and commercial purposes. However, these factors did not appear to influence the adaptation decisions made by farmers.

Farmers in the study grew a wide variety of vegetable and fruit crops of which the most widely grown crop was plantain (Table 2). Most of the crops grown by farmers were short-term crops (crops with a harvesting time less than 365 days). The long-term crops (harvest times greater than 365 days) grown by farmers include avocado, lime, orange and mango. Short-term crops such can be harvested in as little as 4 to 5 weeks (lettuce, pak choi, chive, and celery), and as long as 10 weeks (melongene, tomatoes, and hot peppers) (Ministry of Agriculture, Land and Fisheries n.d.).

Table 2. Frequency of Crops Grown by Farmers.

Crops	Frequency	Crops	Frequency
Plantain	12	Paw Paw	3
Dasheen	10	Pumpkin	3
Bananas	9	Shadow Beni	3
Pimento	9	Cashew	2
Cassava	8	Cucumbers	2
Coconut	7	Ginger	2
Pak choi	6	Grapefruit	2
Tomatoes	6	Sapodilla	2
Avocado	5	Yam	2
Lemon	5	Bhagi	1
Lime	5	Broccoli	1
Orange	5	Cane	1
Corn	4	Cauliflower	1
Hot Pepper	4	Celery	1
Lettuce	4	Chive	1
Mango	4	French Thyme	1
Melon	3	Kale	1
Tanaya	1	Melongene	1

Source: Authors' compilation based on data from Ministry of Agriculture, Land and Fisheries (n.d.).

The main climate concern expressed by farmers in the study was related to precipitation patterns. However, there was no consensus on the overall trend. Some farmers perceived that the dry seasons were becoming dryer and the rainy seasons wetter. Others reported that the rainy season appeared to be dryer. Farmers stated they would adapt to rainy seasons and flooding by changing farming operations. These changes include land development and changing the location where crops are planted. Farmers stated they would plant crops on hillsides to facilitate drainage by gravity. This measure can be easily implemented if the land utilised by the farmer has slopes. Although less costly than alternatives, planting on hillsides is more labour-intensive. Other farmers stated they would opt to implement more expensive measures, such as constructing drainage systems alongside growing crops on hillsides. The combination of drainage construction and planting on slopes appears to be successful, as one respondent indicated that excess water is drained from the land because of proper drainage, land development, and topography when there is heavy rainfall during the rainy season.

Some farmers opted to grow plants in pots instead of in the ground. This is an economical option and should be successful, provided that farmers place the pots at elevations above flood waters.

In circumstances where farmers had challenges obtaining water, installing systems to provide water during prolonged periods of little rainfall was a common adaptation approach. Farmers installed drip irrigation equipment, rainwater harvesting, and storage systems and used artificial ponds to ensure timely water delivery to crops. Many indicated that they unsuccessfully sought government assistance to provide equipment and improve the water supply. In addition, some farmers utilised innovative methods to reduce the costs associated with preventing crops from suffering from water stress. This method involved a farmer attempting to incorporate water conservation, capturing, and storage practices to create a self-contained farming system that mimicked the conditions of a tropical rainforest. The approach involved the farmer covering coconut and fruit trees with bags and placing coconut mulch at the tree's roots to reduce water loss by evaporation and evapotranspiration. Rainwater was also harvested and used to provide water to the crops. This approach reduced the demands on the irrigation systems that deliver stored rainwater to crops, thereby enabling the system to be self-sustainable.

Coupling water conservation practices with water collection and storage methods is effective for managing prolonged periods of low rainfall. The efficient use of limited water resources would increase the probability that crop yield can be maintained under extreme circumstances. The ability to provide and conserve the water needed by crops will become more important if precipitation levels continue to fall and other means of sourcing water are not readily available. Water conservation measures (such as using mulching or other low methods) could reduce the evaporation of water from soils and covering plants and create a microclimate environment. The effectiveness of these measures facilitates the recycling of water that crops use for evapotranspiration.

There appear to be significant consequences of changing weather patterns. A respondent indicated that the quality of the plants has changed since the climate has started to change. Changes include low crop yield and the need to introduce several types of chemicals to improve crop quality.

5.1. Farming Cycle and Workday

The time spent working on the farm can affect the frequency and duration of exposure to environmental conditions. However, on average, most farmers spend 5.6 ± 3.2 h working on their farms. Many factors were responsible for the variability in the average length of time on farming, including the availability of personnel (family and employees), the stage of the farming cycle (i.e., planting, growing, and harvesting), weather conditions, farming technique, and crop selection. Generally, most farmers worked alone. However, some reported that family members or temporary employees assisted them during the more strenuous phases of farming (planting and harvesting). Having assistance reduced the overall time farmers would spend on the farm. The choice of crop, however, was also a primary factor determining the length of time farming, with some crops requiring more attention than others. Long-term crops such as citrus (e.g., lemon, lime, and orange) require less maintenance than short-term crops such as lettuce. Generally, citrus crops are sold at a higher price than others; however, the price is less stable (Figure 3).

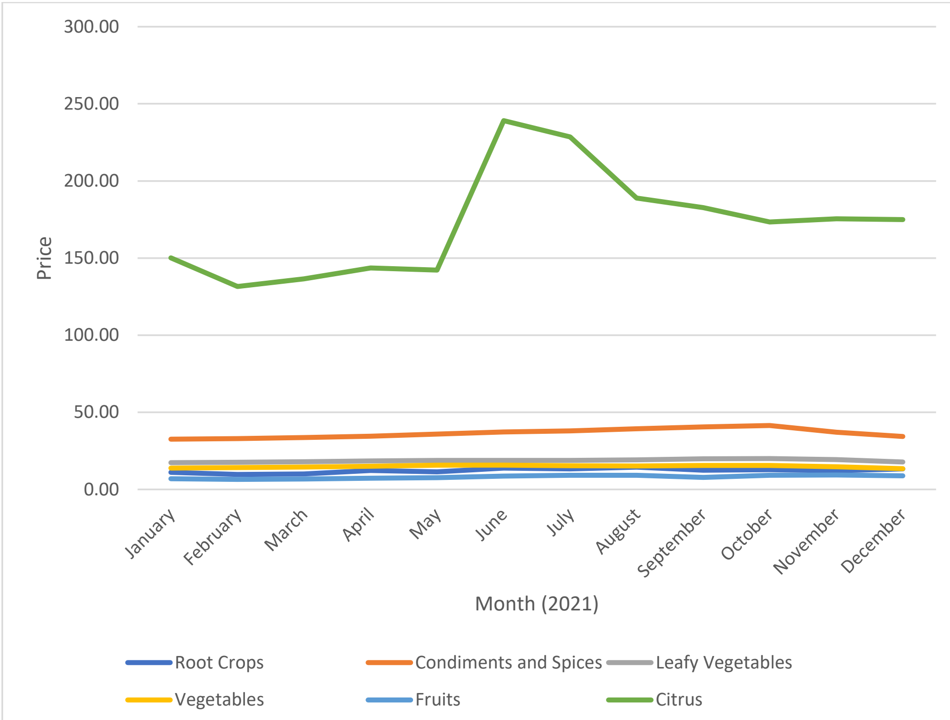

Figure 3. Price of Crops in Trinidad in the Year 2021. Prices: root crops (per kg) include carrots, cassava, yam, dasheen, eddoes, sweet potatoes, and ginger; condiments and spices (per 100) include hot peppers, shadon beni, and pimento; leafy vegetables (per kg) include cabbage and cauliflower; vegetables (per kg) include seim beans, pigeon peas, cucumber, melongene, plantain, pumpkin, sweet pepper, tomato, caraille, squash, and christophene; fruits (per kg) include banana, paw paw, pineapple, watermelon, sorrel and sorrel; citrus (per 100) include lime, grapefruit, oranges, and Portugal. Source: Authors' compilation based on data from National Agricultural Marketing and Development Corporation (2022).

5.2. Adaptation Measures by Farmers

Table 3 shows the categories of adaptation measures utilised by farmers in this study. As the climate continues to change, there may be hotter days. Adjusting the time spent working outdoors is among the measures that farmers should utilise to safeguard against heat-related illnesses. Overall, the techniques used by farmers to reduce time spent working outdoors include selecting low-maintenance crops, hiring workers (or seeking the assistance of family members), and adjusting farming practices to minimise the need for extensive manual operations. Farmers sometimes avoid working during mid-day when ambient temperatures are usually the highest. Although the health and safety of farmers are essential, it is equally critical that they can adjust working practices in a manner that has minimal to no impact on profitability. This balance is given importance when the socioeconomic vulnerability of some farming community members is considered.

Table 3. Emerging Themes and Summary of Practices.

Themes	**Summary of Practices**
Crop Selection and Diversification	• Farmers opted to grow crops, such as citrus, that require less water.
Land Use Management and Infrastructural Adaptation	• Crops were planted on hillsides to avoid floodwaters. • Drainage systems were constructed to prevent lands from being flooded. • Farmers grew crops in pots to avoid floodwaters.
Disease and Pest Management	• Farmers increased the use of pesticides.
Human Resource and Labour Management	• Farmers conducted farming activities during the times of the day when the environment was cooler. • Additional workers were hired during labour-intensive phases of the crop production cycle to reduce the overall time farmers were exposed to a hot environment.
Water Management and Irrigation	• Farmers covered crops with plastic bags to recycle water lost by evapotranspiration processes. • Farmers developed rainwater harvesting systems. • Farmers utilised mulching to reduce rate at which water evaporates from soil.
Business Model Transformation	• Farmers chose to rear animals instead of growing crops.

Source: Table by authors.

Hiring workers or selecting low-maintenance crops can potentially disrupt the profitability of farming operations. For example, hiring workers can be costly, and cultivating low-maintenance crops such as leafy vegetables may not be the most profitable choice. Adjusting farming practices to minimise exposure may be the most economical option to reduce exposure to hot ambient temperatures. However, a farmer reported that they could reduce the time spent on farming by using chickens and mulching to reduce the frequency of clearing weeds from the land. Another farmer developed a job schedule to avoid working on the farm during the hottest times of the day. He opted to start working before the sun rises, take a break in the middle of the day, and resume working in the evening.

Under extreme circumstances, some farmers chose to grow different crops or switch to livestock, most switching to long-term crops. While growing these crops requires less water and maintenance and they can be sold at high prices, they often create cash-flow issues as the crops require a long period before they can be sold. However, such an approach is not desirable for vulnerable farmers who depend on a more consistent income.

Some farmers reported using more chemicals to treat pests and improve crop yield. In some instances, farmers have changed the crops that they are growing, specifically switching from short-term to long-term crops. Some farmers have shifted from crops to solely rearing livestock. These farmers reported that switching to raising livestock was a profitable decision.

Generally, respondents indicated that the adaptation measures they implemented achieved the desired result. Most respondents (90%) reported that their adaptations were successful because there was less crop loss or an increase in yield. All the farmers who installed drainage and irrigation systems reported that the measure was successful. Adaptation co-benefits were also reported. For example, farmers reported that farm management is less stressful and mental health was improved when they switched to long-term crops.

Although some adaptation measures were successful, there were notable challenges. For example, farmers who reported changing to long-term crops as an adaptation measure indicated that although the yield is good, the timeframe to make a return on investment is much longer. Another farmer stated that the increased use of chemicals did not help much because of increased rainfall. Farmers reported effects on production delivery times when the chemicals were effective against the pests. However, there were delays in ensuring that no chemical residues remained on the crops before selling to customers.

Low-cost solutions to climate change challenges are required if vulnerable farmers are to be self-empowered to adapt to climate change, and policymakers must consider the adaptive capacity of farmers. The study identified potential low-cost water conservation measures, but farmers still utilised typical cost-prohibitive water storage and distribution measures. However, some level of government intervention may still be required to equip farmers with irrigation systems.

6. Discussion

Building Adaptive Capacity

Agricultural adaptations to climate change depend on local conditions including socioeconomic status (Reidsma et al. 2010). Generally, agricultural adaptation involves adjusting farm production activities, managing finances, and introducing new technology or government assistance (Smit and Skinner 2002). Diversifying crops and altering planting dates were also identified as important adaptation strategies (Fosu-Mensah et al. 2012).

Fundamentally, the adaption of farmers to climate change initially depends on the perception of the changes and associated risks and then on the availability of resources to adapt (Tripathi and Mishra 2017). The age of the farmer, length of time farming, and education level may have affected their perception of climate change but not the choice of adaptation measures for many reasons, including the unavailability of resources to pursue high-cost or innovative measures. In this regard, a lack of financial resources may have been the main factor limiting adaptation diversity.

Maddison (2007) determined that education and access to financial services are factors that affect adaptation measures implemented by farmers. Farmers willing to implement high-cost measures may be restricted by a lack of finances. One respondent indicated that they required government intervention to implement a complex and potentially costly adaptation system. If most farmers had access to financial resources, the implementation of high-cost measures might have been more prevalent. However, most measures were low-cost measures involving minor changes to current agricultural practices.

It is also possible that the choice of adaptation measures was limited to those that were proven to be effective, and there was no further need to innovate or implement alternatives. Most of the respondents indicated that the implemented measure was effective. There is no stimulus for adaptation diversity if easily implemented, and common types of adaptation measures are effective. However, farmers had perceptions of climate change that can potentially affect adaptation effectiveness.

There were differences between the actual changes in climate and changes perceived by farmers in this study. This aligned with a study by Banerjee (2015) that determined that a farmer's perception of climate change tends to be different from actual climate change. This disparity exists because most farmers equate normal weather variability with long-term changes in weather patterns (Mertz et al. 2009). The difference between real and perceived climate change has led some farmers to mischaracterise adaptation to weather patterns as adaptations to climate change. It is important that farmers fully grasp the principles and risks associated with climate change. This will ensure that they are adequately prepared to meet the real challenges of climate change.

Therefore, there is an urgent need to improve climate change awareness among farmers. There is room for associations and government services to provide this service to farmers. Only 23% and 42% of the respondents in this study are members of agricultural societies and registered with the Ministry of Agriculture, respectively. Both entities are ideal for disseminating climate change information. Climate change issues can be discussed at society meetings, and registration with government agencies can facilitate outreach from extension officers to discuss climate-related matters. These agencies should take steps to actively improve membership (and registration).

The objective of adapting to climate change is to maintain or exceed a predefined or standard state. For farmers and organisations in general, this predefined state is often defined by income and profitability metrics rather than characteristics of organisational operations and the services or products provided. That is, normal is not defined by the operations of the company and the product or services offered but by performance metrics such as income and profitability. Adaptation can include all measures a farmer implements to secure an income sufficient to maintain their livelihoods. This includes abandoning farming to obtain income from other ventures if necessary. Building adaptive capacity would therefore include providing and utilising resources to support farming operations or transition farmers to other economic opportunities needed to secure their livelihood. This may also include the consideration of non-climate-related factors, given that the impact of climate is one of the factors that affects the capacity of farming households to secure a livelihood (Eakin 2003).

The President of the Agricultural Society of Trinidad and Tobago indicated in an article written by Mahase (2022) that there has been a quadrupling of the cost of essential farming commodities, including seeds and fertilisers (including locally produced urea). These non-climate factors also affect the operations of farms and can exacerbate the effects of climate change. The study, however, identified low-cost solutions to climate-related challenges. However, the combination of climate and non-climate stressors can overwhelm the financial resources of the farming community regardless of the implementation of suitable adaptation measures. However, reducing climate risk can be part of an overall strategy for maintaining the financial stability of farmers. In this regard, there is a need to improve the extent to which farmers join and participate in farming organisations. These social groups are necessary for establishing knowledge networks to share and disseminate information on adaptation and exploiting opportunities that can lead to more efficient and profitable farming operations. Most of the farms in Trinidad and Tobago are small-scale individual farms. Farmers can utilise these groups to collaborate and purchase farming material at a lower cost to maximise profits. Improving or maintaining profitability will provide farmers with the capacity to finance adaptation measures if conditions continue to deteriorate or at least build up financial reserves to buffer against market changes.

There is also a need to develop government–farmer partnerships to build adaptive capacity. Government agencies can provide the resources and training needed to adapt or improve productivity. Additionally, social programs can be delivered to members of farming households to facilitate an overall improvement in the adaptive capacity of the home rather than just the individual farmer. These social programs can incentivise education and training in non-agricultural disciplines. In instances where income from farming operations is reduced, the household will be stable if members can secure employment in other industries.

It is important to note that the relatively small number of participants interviewed in this study limits the extent to which broad generalisations can be made regarding the interpretation of the findings. However, the findings provide a foundation for future in-depth studies on the adaptation practices among farmers in Trinidad and Tobago.

7. Chapter Reflection Exercises

The social dimension of climate change often goes understated in many examinations of the impact of the phenomenon. This chapter explores adaptation measures implemented by the farming community in Trinidad and Tobago to maintain a livelihood in an increasingly threatening economic and biophysical environment. As a chapter reflection exercise, readers are asked to consider the systemic impact of climate-related reduced income from the social perspective. Consider how a reduction in household income can lead to other social consequences. This reflection will help further emphasise the impact of developing the adaptive capacity of vulnerable groups to avoid systemic social implications. Utilise the following questions as a starting point for reflection:

1. What are the social dimensions and critical factors affecting farmers' food production operations in Tobago?
2. What are the main considerations and decision areas among farmers in safeguarding farmers' food production and operations in Tobago?
3. How would farmers respond to climate change and associated threats impacting their food production in Tobago?

8. Recommendations

It appears a pressing need for government agencies to develop a policy that encourages farmers to grow climate-resistant crops. This holistic policy should provide support for acquiring, growing, and selling these crops. Acquiring and distributing climate-resilient species of crops to famers is crucial. It is important that farmers are educated on the types and species of crops that are less vulnerable to the local effects of climate change as part of this policy. However, in instances where farmers switch to crops, such as citrus, that are naturally resilient to climate change but have long growth periods, government agencies can provide support to assist in crop sales. Other mechanisms for supporting farmer growing long-term crops should also be considered. The revenue obtained from selling long term crops would have to sustain farming activities and general expenditure for a long period. Government agencies can assist farmers in acquiring larger farms that can help generate income that is more sustainable.

Moreover, it is recommended that the government and/or authorities could initiate launching adaptation measures and associated programmes to educate and enforce climate-sensitive farming practices. An expansion of this study should be carried out to examine various adaptation techniques currently used by farmers. Useful information and relevant publications on adaptation techniques should be distributed to farmers.

Author Contributions: Conceptualisation, C.C.-L.V.; Methodology, C.C.-L.V., Writing—Original Draft Preparation, C.C.-L.V.; Writing—Review and Editing, K.F.P.; Supervision, K.F.P.

Funding: This research received no external funding.

Acknowledgments: I acknowledge the administrative assistance from Oneica Virgil-Solomon, Dyanne Virgil and Carlton Seaforth.

Conflicts of Interest: The authors declare no conflict of interest.

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