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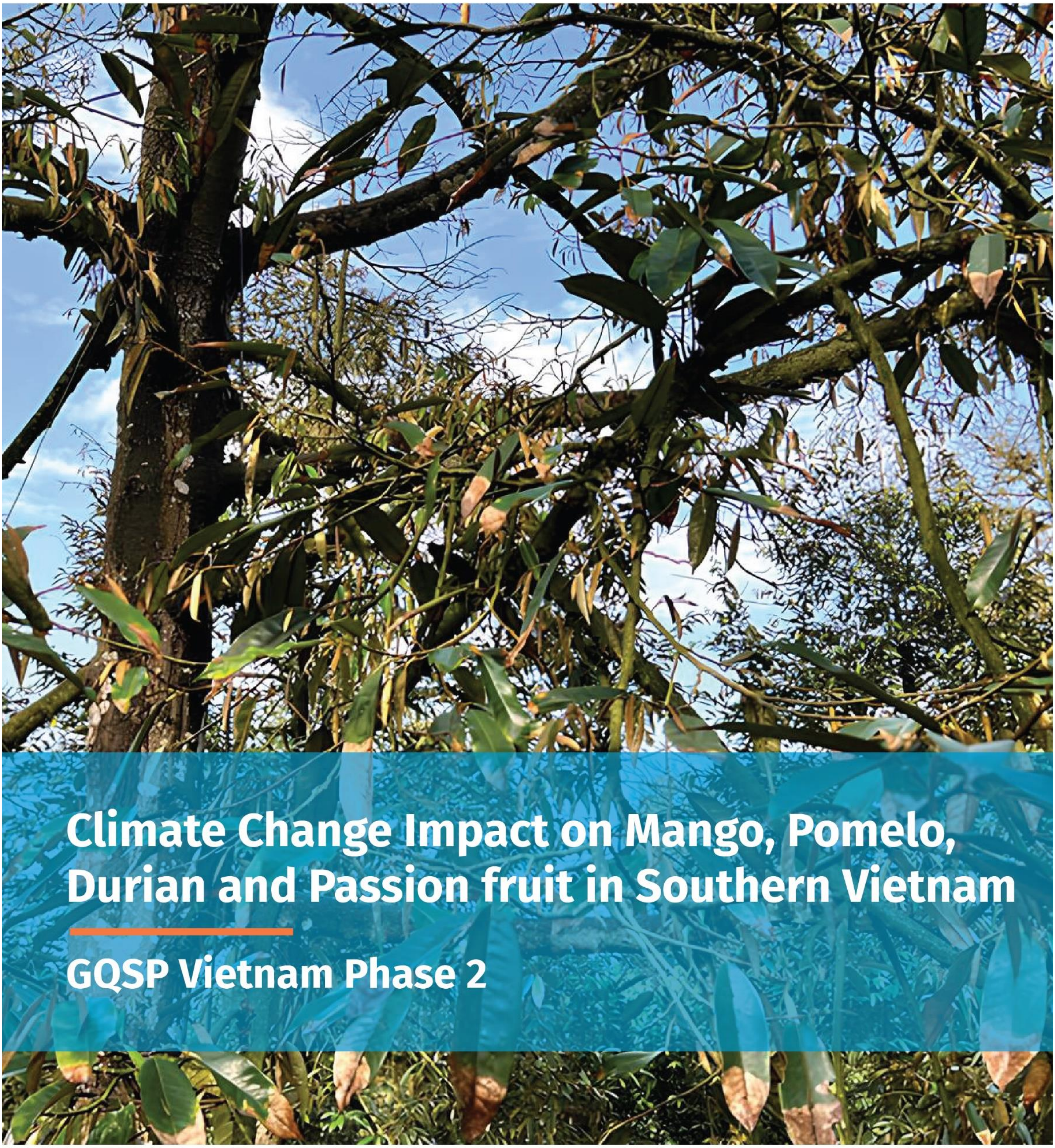

Climate Change Impact on Mango, Pomelo, Durian and Passion fruit in Southern Vietnam

GQSP Vietnam Phase 2

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1. Summary

Vietnam is considered one of the five countries to be most affected by climate change, with increasing temperatures, rising sea levels, increased cyclonic activity and changing rainfall patterns. It will have an impact on agricultural productivity and corresponding negative economic and social impacts. The Mekong River Delta is highly vulnerable to raising sea levels and salinization of farming land, whereas the Central Highlands is prone to temperature rises, flash flooding and drought. For producers, to apply mitigating practices, they need to understand the complexity of change and how it will affect each site differently, awareness must be raised amongst the farming communities so they have the skill to assess the impacts on their businesses and can make informed decisions. As perennial crops such as mango, durian and pomelo are long-term investments farmers will need to look at a short, medium and long-term approach for decision-making. The keys to managing the changes happening are awareness, monitoring and modeling so informed business decisions can be made, and investments at the farm, infrastructure and policy level will support the viability into the future.

2. Introduction

Climate change is the most serious threat facing global food and nutritional security over the next 50 years. As greenhouse gas emissions increase, temperatures are rising due to the greenhouse effect impacting on global weather patterns. The average global temperature is increasing continuously and is predicted by 2100 to rise by 2°C. Due to Viet Nam's long coastline and deltas in coastal areas, the country is one of five countries to be most affected by the negative impacts of climate change (floods, salt intrusions, and drought) (World Bank, 2015; Dasgupta et al 2010). Vietnam's vulnerability score, which measures the country's sensitivity and ability to adapt to climate change, is 0.475, 128 out of all countries and territories (GAIN, 2024[1]). Climate change has the potential to impact every sector of the economy and society but the most vulnerable actors are the low-income rural communities.

Agricultural systems need to learn to adapt to the changing conditions at an unprecedented rate in human civilization. This requires understanding the predicted changes, the impact of these changes on crops and what mitigation practices can be applied to maintain productivity at least in the short to medium term.

3. Climate change impact

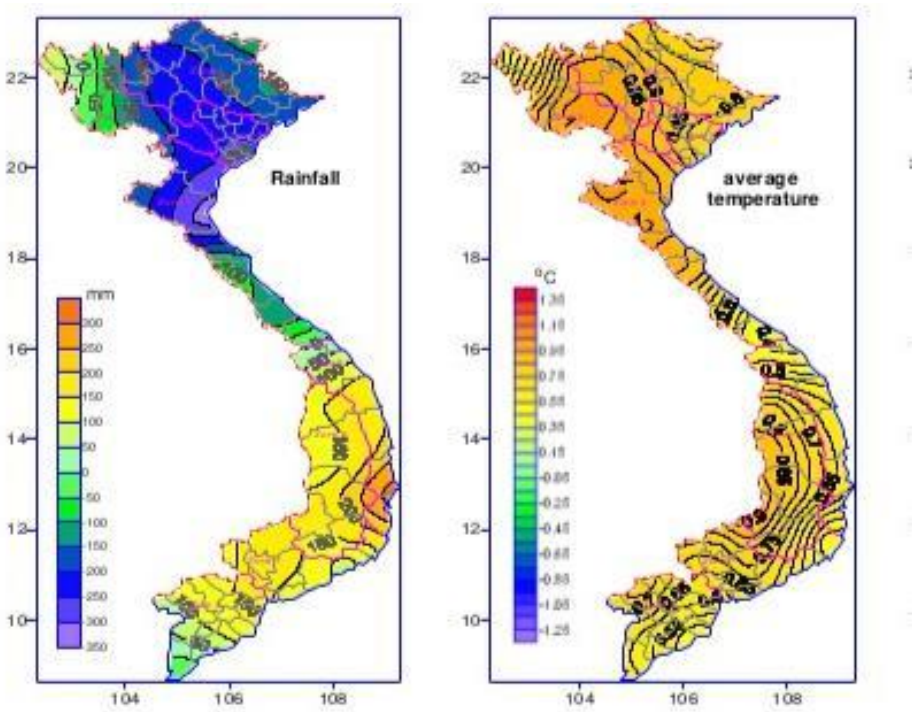
3.1. Current Forecasts

Vietnam is expected to see increasing temperatures, rising sea levels, and increasing variability of rainfall. These combined with increased tropical cyclone activity and intensity as well as drought events are likely to impact all the agricultural regions across the country. Over the past 50 years, the mean temperature in Viet Nam has increased between 0.5°C and 0.7°C (ISPONRE, 2009), and rainfall patterns have changed, increasing in the South and decreasing in the North (Fig 1). Simulation models have the temperature projected to increase by 0.3°C to

[1] The high vulnerability score and high readiness score of Viet Nam place it in the upper-right quadrant of the ND-GAIN Matrix. Viet Nam is the 128th most vulnerable country and the 93rd least ready country

2.5°C by 2070 (Asian Disaster Preparedness Centre, 2023). This increase in temperature alone will decrease agricultural output due to a greater presence of pests and diseases.

Figure 1. Changes in precipitation and temperature 1971-2007



3.2. Mekong River Delta

The Mekong River Delta region is particularly vulnerable as the average height is only 1 to 3m above sea level, data from the Vung Tau monitoring station indicates that an average sea level rise of 3mm per year over the last 30 years (CIGAR 2016), rainfall has increased by 177% during winter in Soc Trang, and 30% annually.

The rainfall pattern has shifted as well with increases at the end of the rainy season and decreases at the beginning of the season (DRAGON)[2] over the past seasons. The intensity and number of tropical cyclones have increased from seven to eight resulting in increased storm and flood damage.

Saltwater intrusion in the Mekong Delta region is occurring 1-1.5 months earlier than in previous years and lasting longer. Salinity at the beginning of the dry season is greater than in the middle of the season. This situation is opposite to the previous pattern of saltwater intrusions. The greatest salinity usually appears mainly in April to May due to tidal influences.

3.3. Central Highlands

Temperatures will rise and there is likely to be less cloud cover so evaporation rates will increase in comparison with past decades, contributing to a rise in the frequency and intensity of droughts. In recent years, the rainy season in the Central Highlands has commenced earlier with higher rainfall of greater intensity. This combined with the effects of storms and tropical depressions increase the risk of flash flooding higher runoff and soil erosion. These changes

[2] The Delta Research and Global Observation Network (DRAGON) Institute at Can Tho University

will directly influence the socio-economic activities in the Central Highlands. In particular, the volume of the annual currents of rivers may decrease in the coming years, and flash floods will continue to be a permanent threat in some areas during the rainy season. However, there may be water shortages due to droughts, leading to reduced productivity and quality of agricultural production.

3.4. Crops

Changing climate will impact each crop differently depending on its location some of the broader impacts are outlined in Table 1, all the crops will be at risk of reduction of productivity and in some cases viability. See Annex 1 for detail analysis of climate change impact on 4 selected tropical fruits.

Rising CO_2 levels will improve plant's photosynthetic capacity and therefore productivity in the short to medium term, but not enough to offset the impact of rising temperature, increased rainfall and salinization. Whilst most crops will be able to cope initially with rising temperatures and changing rainfall patterns it will put them into a declining productivity, which will potentially reach the point of being unviable. Salinity effects are more immediate, most crops will not tolerate high levels of salinity and one inundation event can sometimes be enough to result in tree death. Zones where salinity is increasing such as in some of the coastal provinces of the MRD plantations of susceptible crops are at imminent risk of rapid productivity decline, depending on the specific sites this can occur over several decades, years or even months under certain conditions. Salt also can accumulate in the soil creating irreversible damage such as a break down of soil structure and accumulation of chloride ions. Whilst it is possible to predict with some levels of certainty the impact of rising temperatures, salinity and changing rainfall patterns on tropical fruit crops there is a high level of uncertainty on what these changes will do to insect behavior and subsequent pest pressure on cropping systems. Increases in tropical cyclone frequency and intensity will make perennial crops particularly those within close vicinity to the coastlines more vulnerable to damage and flooding.

These changing trends are likely to have significant social and economic impact on rural communities. It is also noteworthy that some of the current farm practices used by the industry in Vietnam are contributing to greenhouse gas emissions in particular N_2O from nitrogen fertilizers which has a 265 times greater impact (*equivalent weight*) than CO_2 on global warming[3]. A study (ACIAR 2022) on the mango Industry in the Mekong River Delta found that farmers were applying up to 4 times the amount of nitrogen fertilizer than what was necessary for tree productivity this extrapolated across the region and other tropical fruit industries would constitute a significant % of Vietnams total annual greenhouse gas emissions.

[3] United States Environmental Protection Agency Overview of Greenhouse Gases

Table 1. Climate change impact to tropical fruit crops

Crop	Increased Rainfall	Increasing Temperatures	Raising sea levels	Drought events
Mango	• Increase in disease risk • Reduced pollination	• Inconsistent (reduced) flowering • Reduced fruit set (lower yields) • Changes in fruiting patterns	• Salinization (Yield reduction, reduced photosynthetic capacity, dieback and tree death)	• Reduced yields
Durian	• Increase in disease risk • Changes in fruiting pattern	• Reduced pollen viability • Increased tree stress (vulnerability to disease) • Reduce fruit quality (flavor and texture)	• Salinization (Canopy loss reduced photosynthetic capacity, reduced yield, dieback and tree death)	• Reduced yields, canopy damage, increased stress and vulnerability to disease
Passionfruit	• Increase in disease • Reduced fruit set	• Reduced pollen viability	• Not impacting central highlands	• Reduced yields, increased stress and vulnerability to disease
Pomelo	• Increase in disease risk • Reduced skin quality	• Changes in fruiting patterns	• Salinization (Yield reduction, reduced photosynthetic capacity, dieback and tree death)	• Reduced yields and fruit quality
Soils	• Increased runoff (nutrient loss and soil erosion)	• Changes in soil microbiology	• Salinization of soils, breakdown of soil structure.	• Reduced water tables • Acid toxicity in acid sulfate soils
General	• Flooding events inundation of plantations and tree death • Disease risks	• Changes in pest profiles and behavior • Greater pest risk • Impact fruit quality	• Salinization inhibiting the uptake of water and other nutrients	• Increasing Saltwater movement up the Mekong River • Reduced fruit yield

4. Mitigation options

Change is going to be complex and affect each site differently, awareness must be raised amongst the farming communities so they have the skill to assess the impacts on their businesses and can make informed decisions. As perennial crops such as mango, durian and pomelo are long-term investments farmers will need to look at a short, medium and long-term approach to decision-making. For example, whether to replant new trees in a site where salinity is rising and likely to be unproductive in a few years or use different salt-tolerant rootstocks, to make a decision such as this the farmer needs to know what the predictive models are saying and how long will it be before salt levels rise beyond trees tolerance levels.

- ***Short term***: What practices can be implemented now that will maintain current productivity levels? e.g. Monitoring, SOPs
- ***Medium term:*** What practices should the business be starting to invest in that will extend the viability of the business e.g. irrigation systems, environmental modification and new genetics e.g. more tolerant varieties?
- ***Long term:*** What options are there for business should conditions change to the extent that the current cropping system is unviable?
- ***Opportunities***: As with any change new opportunities will arise, which need to be identified and assessed e.g. coconuts, aquaculture

Whilst the impact will vary greatly the two best tools that farmers will need to use are improved genetics i.e. varieties with greater resistance to the conditions and environmental modification which is manipulating the micro environment around the crop to create more favorable production conditions. Both options required resources and time which may not readily be available to the producers. Table 2 shows some of the short medium- and long-term options that can be implemented that will assist in maintaining productivity and profitability during changing conditions. In some cases, these management practices will allow productive cropping to occur for many years. However not all locations will be the same and there are some zones which current cropping or even any crop production will become unviable at some point in the future. The keys to managing these changes that are happening are awareness, monitoring and modeling so informed business decisions can be made, and investments at the farm, infrastructure and policy level will support the viability into the future.

Table 2. Practice changes to help mitigate some of the impact of climate change

Mango, durian, pomelo and passionfruit	Increased Rainfall	Increasing Temperatures	Salinization	Drought events
Short term	• Improved disease management practice SOP • Changes to off-season floral induction timings	• Improved canopy management • Managing floral manipulation to avoid heatwave conditions • Improved irrigation practices • Monitoring for heat events	• Better monitoring of river and groundwater levels. • Irrigation scheduling • Increased irrigation water storage capacity • Potential use of $CaSO_4$ to dislodge chloride ions	• Supplementary irrigation • Increased irrigation water storage capacity
Medium-term	• Improved disease tolerant genetics • Improved earthworks to better manage runoff • Continued improvements in disease management practice SOP	• Micro climate manipulation (artificial/ natural shading) • Improved genetics heat tolerant varieties • Increased pest monitoring	• Salt-tolerant rootstocks • Irrigation scheduling • Change of crop	• Pressurized irrigation systems • Efficient irrigation monitoring and scheduling • Better water storage
Long term	• Disease forecasting based on weather events. • Improved genetics	• Change of crop to more heat-tolerant species • Greater environmental modification such as cover cropping	• Change of crop to salt-tolerant species • Aquaculture in areas that are inundated and no longer useable for cropping	• Water storage infrastructure • Advanced efficient irrigation systems • Advanced irrigation monitoring

5. Recommendations for the project

The following recommendations are identified areas where project investment could have an impact on management:

- Review and refined SOPs that reflect adaptive practices for each of the industries
- Training in SOP adaptive practices
- Provide technical support enabling the adoption of technological solutions in farm practice, monitoring and infrastructure.
- Improve awareness and compliance of local farmers on climate/water monitoring and early warning systems
- GIS mapping of areas inputted into national data base to better asses individual sites vulnerabilities
- Training on business skills to make better decisions on adaptive change
- Develop investment plans for scaling-up existing structural climate-resilient measures
- Strengthen strategic and policy frameworks for climate-smart agriculture and integrated water resources management by supporting through information sharing forums with Industry stakeholders, climate-smart institutions, government and academic institutions

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Annex 1: Specific climate change impacts on the selected tropical fruits

1. Durian

1.1. Temperature

The durian (Durio zibethinus Murray) is a tropical fruit tree that thrives in high temperature and humidity, with an optimal growth range between 24°C to 30°C and air humidity levels around 75-80%. Despite its preference for hot and humid climates, durian cannot withstand extreme temperatures; growth is inhibited below 22°C and above 40°C. Stable humidity levels are crucial, and regions with excessive solar radiation are unsuitable for cultivation[4]. However, recent climate data indicates that average temperatures in the Mekong Delta and Central Highlands have been steadily increasing. Over the past decade, these regions have seen a rise in average annual temperatures by approximately 0.5°C to 1°C, with some areas experiencing peaks exceeding 35°C during the hottest months[5]. This temperature increase has resulted in significant heat stress for durian trees.

Heat stress derisively affects several physiological processes in durian trees. For instance, flowering, a critical stage for fruit production, is highly sensitive to temperature fluctuations. When temperatures exceed the optimal range, the flowering process is hindered, leading to reduced fruit set and lower yields. A study conducted in the Mekong Delta found that durian trees exposed to temperatures above 33°C for extended periods experienced a 20% reduction in fruit set compared to trees in optimal temperature conditions [6].

Figure 2. Drought image in durian orchards in Dak Lak

Additionally, high temperatures can cause sunburn on durian fruits. Sunburn manifests as dark, discolored patches on the fruit's surface, which not only reduces the aesthetic appeal but also the marketable quality of the fruit. In severe cases, sunburned fruits may become unfit for sale, leading to significant economic losses for farmers. Research indicates that during the hottest months, up to 15% of the durian harvest in the Central Highlands may suffer

[4] Teh, C. B. S., Abdullah, M. A., & Lee, C. T. (2018). Effects of temperature extremes on the growth and yield of durian. Journal of Agricultural and Food Chemistry.
[5] Climate Data. (2023). Annual Temperature Trends in Vietnam
[6] Nguyen, T. H., et al. (2022). Effects of Temperature on Durian Flowering in the Mekong Delta. Journal of Tropical Agriculture, 34(2), 125-134.

from sunburn damage, translating to substantial financial losses in a region where durian is a key cash crop.[7]

Figure 3. Sunburn manifests as dark, discolored patches on the fruit's surface

The impact of rising temperatures on durian cultivation underscores the urgent need for adaptation strategies. Without intervention, the continued increase in average temperatures could further exacerbate heat stress and related issues, jeopardizing the sustainability and profitability of durian farming in these critical agricultural regions of Vietnam[8].

Temperature and heatwaves: Climate models predict a further rise in temperatures, which may result in more frequent and severe heatwaves. Such conditions can lead to increased evapotranspiration rates, requiring more efficient irrigation practices to maintain soil moisture levels.

1.2. Rainfall

Durian cultivation requires an annual rainfall of 1,600 to 4,000mm, with an ideal average of around 2,000mm per year, and rainfall should be evenly distributed throughout the year. It is essential to avoid rain during the late fruiting stage and harvesting period. Additionally, the dry season should not exceed three months[9]. Changes in rainfall patterns, such as prolonged dry periods and sudden heavy downpours, can disrupt the water balance necessary for durian growth. Irregular rainfall can cause water stress during critical growth stages and increase the trees' susceptibility to diseases like *Phytophthora*, a soil-borne pathogen that causes root and stem rot[10].

[7] Tran, V. C., & Le, Q. D. (2021). Sunburn Damage in Durian Fruits in the Central Highlands. Vietnam Agricultural Journal, 27(3), 87-95.
[8] Pham, T. M., & Bui, H. T. (2023). Adaptation Strategies for Durian Cultivation under Climate Change. Agricultural Sustainability Review, 19(1), 45-58.
[9] Nguyen, T. H., Tran, Q. T., & Le, M. H. (2018). Climate requirements for durian cultivation in Vietnam. Vietnamese Journal of Agricultural Research.
[10] Phang, S. M., Chin, H. F., & Shamsudin, R. (2020). Phytophthora diseases in tropical fruit crops. Journal of Plant Pathology.

Figure 4. Pathogen in durian orchard in Dak Lak, 2024

Water availability: Future changes in rainfall patterns could exacerbate water scarcity or lead to periods of excessive moisture, both of which are detrimental to durian farming. Efficient water management practices will become increasingly important to mitigate these risks.

Figure 5. Image of installing a water-saving drip irrigation system to combat climate change for durian trees in Dak Lak

In group discussions in the Central Highlands, farmers, scientists, local agricultural managers, and agricultural extension officers analyzed and shared the specific difficulties they have faced in durian cultivation in recent years due to harsh weather conditions. The region has experienced prolonged heat waves with temperatures ranging from 35-37 degrees Celsius, causing many obstacles in tree care. After the heat waves, early season rains led to thermal shock, significantly increasing the rate of fruit drop, averaging about 20-30% compared to the previous year. Furthermore, heavy rains caused the trees to sprout new shoots, but the nutrients were insufficient to support both the shoots and the fruit, resulting in a continued increase in the fruit drop rate, estimated to be up to 40% in some orchards. Farmers are concerned that with these adverse conditions, their durian orchards will experience crop failure, leading to severe economic losses.

1.3. Impact of strong winds

Strong winds can cause significant physical damage to durian trees, leading to broken branches and fruit drops, which negatively impact yield and productivity. In regions prone to strong winds, it is necessary to establish windbreaks to minimize damage. [11]

Figure 6. Tree broken by strong winds

1.4. Salinity

Durian trees are facing the issue of saltwater intrusion in the Mekong Delta. Saltwater intrusion occurs when seawater flows into freshwater areas, increasing the salinity of water and soil, which negatively affects the growth of durian trees. High salinity in the soil and irrigation water causes water imbalance in the trees, reducing their ability to absorb water and nutrients. As a result, durian trees wilt, with leaves turning yellow and falling prematurely, leading to an overall decline in tree health. Saltwater intrusion also impacts the root system, causing root damage, poor development, and making them more susceptible to fungal diseases. Durian trees exposed to saltwater intrusion typically have reduced yields, smaller fruits, and lower quality. The fruits may become hard, lack sweetness, and lose their distinctive aroma. High salinity also affects flowering and fruit setting processes, reducing the number and quality of harvested fruits.

To mitigate these effects, it is essential to manage irrigation by using freshwater sources for watering and minimizing the use of saline water. Digging wells or constructing water filtration systems can help reduce salinity in irrigation water. Implementing drip irrigation systems can conserve water and minimize the impact of saline water on the trees. Improving soil quality by adding organic matter can enhance soil structure and increase the retention of freshwater. Using organic fertilizers, green manure, or bio-fertilizers can help improve soil quality. Planting cover crops or salt-tolerant plants around durian cultivation areas can help reduce the impact of saltwater intrusion. Researching and using durian varieties with better salt tolerance can help mitigate the effects of saltwater intrusion on the trees. These will help reduce the negative impact measures of salinity, thereby improving the yield and quality of durian fruits.

2. Pomelo

2.1. Temperature

Citrus trees in general, and pomelo trees specifically, can be grown in regions with temperatures ranging from 12°C to 39°C, with the optimal range being from 23°C to 29°C.

[11] Wong, S. K., & Yap, H. T. (2019). Climate change impacts on durian cultivation in Southeast Asia. Asian Journal of Environmental Research.

Temperatures below 12.5°C and above 40°C cause the trees to stop growing. The best temperatures for the growth of new shoots in spring are between 12°C and 20°C, in summer from 25°C to 30°C, and for root activity from 17°C to 30°C. During flower bud differentiation, temperatures need to be below 25°C for at least two weeks, or artificial drought conditions are required. The minimum temperature for flower blooming is 9.4°C. Temperature also affects pollination and fruit set rates, with high temperatures from 25°C to 30°C promoting these processes. In winter, low temperatures increase the number of leafless flower branches, leading to lower fruit set rates. The suitable temperature range for fruit development is from 14°C to 40°C, with the best temperature being around 32°C. Temperatures between 29°C and 35°C are optimal for sugar accumulation and achieving the best fruit peel color[12].

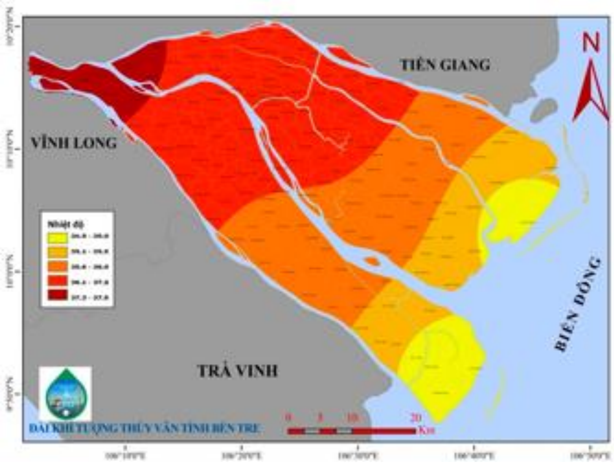

Figure 7. Temperature map of Ben Tre province, 3/2024[13]

Figure 8. Image of pomelo affected by high temperatures in Ben Tre, 4/2024

Based on the temperature map provided by the Ben Tre Hydrometeorology Station, the temperature in the region ranges from 34.5°C to 37.5°C, exceeding the optimal range for the development of pomelo trees. Coastal areas such as Ba Tri and Binh Dai have temperatures ranging from 34.5°C to 35.5°C, which are less negatively affected by high temperatures but still above the optimal range. Districts such as Giong Trom and Chau Thanh have temperatures ranging from 35.5°C to 37.2°C, while Mo Cay Bac and Mo Cay Nam experience the highest temperatures, from 37.3°C to 37.5°C. These temperature levels can cause significant damage to pomelo trees, reducing yield and fruit quality.

Heatwaves and drought: Increasing temperatures and more frequent droughts could stress pomelo trees, reducing yields and fruit quality. Developing drought-tolerant varieties and efficient irrigation practices will be essential.

2.2. Water Availability

Both drought and excessive rainfall can negatively impact pomelo production. Drought conditions lead to water stress, while excessive rainfall can cause waterlogging and root diseases.

[12] Vu Viet Hung et al, 2021, Technical guide for cultivating pomelo trees adapted to climate change, Agricultural Publisher.
[13] Ben Tre provincial hydrometeorological station. (2023). Temperature map of Ben Tre province.

Pomelo trees prefer moist conditions but cannot tolerate waterlogging. Their roots rely on a mycorrhizal system to absorb nutrients, and waterlogged soil deprives the roots of oxygen, leading to poor root function, leaf drop, and fruit loss. This is why citrus trees have a shorter lifespan on flat land compared to sloped land. Critical periods for water needs include bud emergence, flower bud differentiation, flowering, and fruit development. Annually, citrus trees require 9,000 to 12,000 m^3 of water per hectare, equivalent to 900 to 1,200 mm of rainfall. For pomelo trees, the requirement is about 10,000 to 15,000 m^3/ha/year[14].

Water Management: Changes in rainfall patterns will require improved water management practices to ensure sustainable pomelo production. This includes efficient irrigation systems and water conservation techniques.

Figure 9. Silobag storing fresh water in pomelo garden in Ben Tre, 2024

Farmers in Ben Tre, Vietnam, adopted the innovative use of silobags to store fresh water in pomelo gardens. This method addresses the critical need for water management in citrus cultivation, especially for pomelo trees, by ensuring an adequate water supply during crucial growth stages and drought periods. Silobags efficiently store large quantities of water, reduce wastage and evaporation losses, and allow for consistent irrigation, which prevents waterlogging and root damage. This practice helps farmers conserve water, manage irrigation more effectively, and adapt to irregular rainfall patterns and prolonged droughts, thereby enhancing the resilience of their crops to climate change. By using silobags, farmers can maintain healthy trees, leading to high yields and quality of pomelo fruits, demonstrating a sustainable and effective approach to overcoming water management challenges in agriculture.

2.3. Salinity

Saltwater intrusion is a serious issue for pomelo trees in the Mekong Delta, especially in the context of climate change and increasing salinity levels. When saltwater infiltrates pomelo-growing areas, the salt concentration in the soil rises, reducing the trees' ability to absorb water and nutrients. This leads to stunted growth, yellowing leaves, leaf drop, and even tree

[14] Vu Viet Hung et al, 2021, Technical guide for cultivating pomelo trees adapted to climate change, Agricultural Publisher.

death. Pomelo fruits affected by saltwater intrusion are often smaller, lower in quality, and less palatable. Additionally, the root system of pomelo trees, which is sensitive to high salt concentrations, can suffer severe damage, weakening the entire tree. To mitigate the impact of saltwater intrusion, farmers in the Mekong Delta need to implement measures such as regular freshwater irrigation, soil improvement, and using salt-tolerant pomelo varieties. These strategies help maintain the productivity and quality of pomelo fruits under harsh environmental conditions.

Figure 10. Impact of saltwater flooding on pomelo trees in Ben Tre

Climate change poses significant challenges to the production of durian, mango, passion fruit, and pomelo in the Mekong Delta and Central Highlands of Vietnam. Effective adaptation strategies focusing on temperature management, water management, pest and disease control, soil management, and research are essential to mitigate these impacts and ensure the sustainability of these key fruit industries. By adopting these strategies, farmers can improve their resilience to climate change and maintain the productivity and quality of their crops, thereby securing their livelihoods and contributing to the country's agricultural economy.

3. Passion Fruit

3.1. Temperature

Passion fruit vines thrive best in temperatures ranging from 18°C to 25°C. When the temperature exceeds 25°C, the plants encounter difficulties, leading to flower and fruit drop, which reduces yield and fruit quality. High temperatures also cause the passion fruits to become smaller, with thicker skins and less sweet flavor. Conversely, when the temperature falls below 18°C, the growth process slows down, the plants may cease to develop, and their ability to flower and set fruit diminishes. Particularly, temperatures below 10°C can damage the plants, causing branches and leaves to die.

Figure 11. Passion fruit garden in Dak Lak, 2024

Climate change in the Central Highlands exacerbates extreme weather events, causing greater temperature fluctuations, which negatively impact passion fruit vines. The temperature in the Central Highlands varies significantly between the dry and rainy seasons, with prolonged heatwaves or sudden cold spells causing damage to the crops, reducing both yield and fruit quality. To mitigate these effects, farmers can use shading and regular watering during hot days, employ agricultural mulches to maintain stable soil temperatures, and select passion fruit varieties with better heat and cold tolerance. These measures help to minimize the negative impact of temperature fluctuations, improving the yield and quality of passion fruits.

Increased Pest Pressure: Warmer temperatures favor the proliferation of pests such as fruit flies and aphids, which can significantly impact yields and fruit quality. Managing these pests requires more frequent interventions, raising production costs.

Increased temperature extremes: Higher temperatures could reduce the areas suitable for passion fruit cultivation, limiting production. Developing and planting heat-tolerant varieties will be essential to adapt to these changes.

3.2. Rainfall

In Dak Nong and Dak Lak, irregular rainfall patterns are severely affecting passion fruit cultivation. Periods of drought lead to water scarcity, negatively impacting vine growth and reducing yields. A study by Thoa et al. (2019)[15] showed that prolonged dry spells significantly decreased passion fruit yields in Dak Lak, highlighting the urgent need for effective water management strategies. Additionally, Lan et al. (2020)[16] reported that drought conditions in Dak Nong led to a 30% decrease in passion fruit production over three years.

[15] Thoa, N. T., et al. (2019). "Impact of drought on passion fruit yield in Dak Lak." Vietnam Journal of Agricultural Sciences.
[16] Lan, H. P., et al. (2020). "Water scarcity and its impact on passion fruit production in Dak Nong." Agricultural Research Journal

Excessive rainfall also causes significant negative impacts, such as waterlogging and soil erosion, leading to root rot and soil quality degradation. Nguyen et al. (2018)[17] found that heavy rainfall events in Dak Nong caused severe soil erosion, affecting the long-term sustainability of passion fruit farms. Pham et al. (2021)[18] indicated that excessive rainfall and poor drainage systems in Dak Lak increased cases of Phytophthora root rot, severely affecting the health and productivity of passion fruit vines.

Variability in rainfall patterns in Dak Nong and Dak Lak can lead to significant water stress or flooding, both of which have detrimental effects on passion fruit vine health and productivity. Water stress, resulting from prolonged dry spells, can hamper vine growth, reduce flowering, and lead to poor fruit sets, ultimately decreasing yields. Conversely, excessive rainfall can cause waterlogging, leading to root rot and nutrient leaching, which degrades soil quality and weakens the vines. Implementing efficient water management practices, such as drip irrigation systems to optimize water use during dry periods and effective drainage systems to prevent waterlogging during heavy rains, will be crucial in sustaining passion fruit production in these regions. These practices not only help maintain consistent moisture levels but also enhance the resilience of the vines against the adverse effects of irregular rainfall patterns[19][20] [21][22]

4. Mango

4.1. Temperature

Mango trees in the Mekong Delta are highly sensitive to temperature changes, with an optimal range of 24°C to 27°C. Deviations outside this range can disrupt the flowering and fruiting cycles, resulting in reduced yields and lower fruit quality. Recent climate data indicates that the average temperature in the Mekong Delta has increased by approximately 0.5°C to 1°C over the past 50 years (IMHEN, 2020) [23]. This rise in temperature can cause heat stress in mango trees, leading to issues such as flower and fruit drop, which ultimately reduces overall yields (Mukherjee, 1953)[24].

Seasonal temperature variations in the Mekong Delta also significantly impact mango cultivation. During the dry season, temperatures often exceed 30°C, leading to water stress and decreased nutrient absorption, which can harm tree growth and fruit development. In contrast, the rainy season brings lower temperatures and high humidity, increasing the risk of fungal diseases like anthracnose. These conditions necessitate specific agricultural practices to mitigate their adverse effects and ensure the health and productivity of mango trees.

To manage temperature-related risks in mango cultivation, farmers in the Mekong Delta can utilize heat maps and adopt advanced agricultural practices. Heat maps allow farmers to analyze temperature data and make informed decisions regarding planting schedules, irrigation management, and disease control. Effective strategies include using shade nets and

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organic mulches to maintain soil moisture, implementing efficient irrigation systems like drip irrigation, and developing heat-resistant mango varieties. By adopting these practices, farmers can better cope with temperature fluctuations, thereby enhancing yield and fruit quality.

4.2. Salinity

Salinity intrusion in the Mekong Delta has become a major threat to agriculture, particularly affecting mango trees. As saltwater penetrates inland, the increased salinity in soil and water sources creates a harsh environment for mango cultivation. High salinity levels lead to osmotic stress, reducing the trees' ability to absorb water and essential nutrients, resulting in stunted growth, leaf yellowing, and premature leaf drop. During fruit development, salinity stress causes smaller fruit size, lower fruit set, and poor fruit quality, significantly impacting both local consumption and export potential. Chronic exposure weakens overall tree health, making them more susceptible to pests and diseases, ultimately reducing yield and tree longevity.

To mitigate these adverse effects, several strategies have been proposed, including the use of salt-tolerant mango varieties, applying gypsum and organic amendments to improve soil structure, and employing efficient irrigation techniques like drip irrigation. Integrated water management efforts, such as building barriers to prevent saltwater intrusion and implementing water-saving practices, are also crucial. These measures help farmers in the Mekong Delta cope with the challenges posed by salinity intrusion, ensuring the sustainability and productivity of mango cultivation.

Figure 12. Impact of temperature on mango trees

Heat Stress: As temperatures continue to rise, mango trees may experience heat stress, which can shorten the fruit development period and result in smaller, lower-quality mangoes. Developing heat-tolerant mango varieties will be crucial to sustaining production.

Water Management Issues: Projected changes in monsoon patterns will challenge existing water management practices. Farmers will need to adopt more efficient irrigation systems and water conservation techniques to cope with increasingly variable water availability