The impact of climate change on drought and its adaptation strategies: findings from regional climate models and households in Tien Giang Province, Vietnam

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Abstract

Drought is one of the most frequent and widespread natural hazards in Tien Giang province of Vietnam, which is aggravating under the influence of climate change. As agriculture is the primary economy of the province, it is crucial to understand the influence of climate change on drought severity and how the local farmers perceive and adapt to climate change. Therefore, to examine the impacts of climate change on drought in the Tien Giang province in the Mekong Delta, the present study used three General Circulation Models (GCMs) - ACCESS 1.3, CNRM-CM5 and MRI-CGCM3 under two Representative Concentration Pathways (RCPs) 4.5 and 8.5 scenarios. In addition, the study evaluated household-level adaptation strategies based on structured questionnaire-based household survey data and focuses group discussion. This study identifies that the drought will be getting more severe for the future in the province based on using three GCMs and two climate change scenarios. The estimated results of the Standardized Precipitation Index (SPI) showed that there would be many potential extreme drought years between 2020–2050. The results from the questionnaires survey depicted that the household perception of drought is moderate in the Mekong Delta. The current adaptation measures are good enough to adapt to fair drought and can be improved to adapt to more potential extreme drought condition in the future. This study provides important insights for decision-makers to manage future drought situations in the Mekong region.

1 Introduction

Climate change is a global environmental challenge, but its implications are often felt regionally. Several scientific assessments reveal that it is the possible cause of the intensification of extreme climate events, and the situation is getting more severe than ever (e.g. Lindner et al. 2010; Pramanik et al. 2021). In the context of droughts, climate change affects the hydrological cycle owing to increased radiative forcing, which causes an increase in temperature and evaporation (Trenberth 1999). Across many places around the world, climate change has already affected the total annual precipitation and the seasonal dynamics (IPCC 2007; Pramanik et al. 2018), including extreme climate events, such as heavy storms, heat waves, rainfall, flood and droughts, often with increasing intensity and frequency (IPCC 2007). As such, the impacts of climate change can be examined by analyzing observed data (Thanvisitthpon et al. 2018); and from climate projections at the regional level by downscaling General Circulation Models and Regional Climate Models (Aslam et al. 2020; Dash et al. 2019).

In Vietnam, drought is one of the most frequent and widespread natural hazards after the flood, storm, and has become more severe in recent years owing to climate change (Vu et al. 2015). Drought severity varies across various regions of Vietnam in terms of timing, underlying causes, damage and spatial extent (Vu et al. 2015). Several assessments (e.g. Dasgupta et al. 2009) revealed that Vietnam- and in particular the Mekong Delta- is highly susceptible to climate change. According to Global Facility for Disaster Reduction and Recovery Vietnam ranks among the five countries likely to be most affected by climate change (GFDRR 2010). Similarly, according to the climate risk index of Germanwatch Vietnam ranked 6th among the high-risk countries (Eckstein et al. 2019).

The Mekong Delta is a low lying and flat terrain located downstream of the Mekong River, with crisscrossing rivers and canals. The Mekong Delta of Vietnam suffers from sub-optimal agriculture production due to the impacts of climate change (Huynh et al. 2020). As a result, water shortages and drought are most often associated with salt-water intrusion in all cropping seasons in the Mekong region (Vu et al. 2015). Therefore, even with marginal changes in the climate, it will significantly influence agriculture production as well as the economy, ecosystems, and people's livelihoods. Huynh et al. (2020). Ty et al. (2015) and GFDRR (2017) showed that drought has become more severe and persistent in many parts of Vietnam, including the Mekong delta.

The Standardized Precipitation Index (SPI) is both a probabilistic and a standardized drought index. The Standardization of the drought index ensures that the index in question is independent of its geographical consideration concerning average precipitation (Bordi and Sutera 2007; Vu et al. 2015). In Asia, particularly in Vietnam, many researchers have adopted this index as an efficient and useful tool for drought monitoring at the regional as well as the national scale (Huynh et al. 2020; Udmale et al. 2020; Vu et al. 2015). The impact of climate change on drought is complex and challenging to assess because it depends on many climate factors, including land and sea surface temperature, water resources and rainfall pattern (Huynh et al. 2020). Several modelling approaches can be used to estimate future climate; however, the estimation accuracy depends mainly on the quality of hydrogeological and climatic data.

Apart from that, people's perception and adaptive capacity to climate change in general and drought, in particular, varies between the areas. At the management level, assessing and quantifying climate change impacts on drought is one of their greatest concerns because it can support them in preparing mitigation and adaptation strategies to reduce climate change consequences. Till date, there have been various researchers evaluating the impacts of climate change on drought in central Vietnam with considering very limited data and not focused on the detail of its implications. Besides this, there is no such studies were undertaken for the detailed analysis of the local level perception and adaptation strategies with a specific focus on gap analysis of drought management over the region. It is; therefore, the present study intends to fill the research gaps by evaluating the climate change impacts on drought (2020–2050), the perception of local farmers about drought, and the coping and local adaptation strategies by drought-affected rural households in the Mekong region, particularly in Tien Giang province in Vietnam. A stronger focus on the local implications of global climate change models, suitable adaptation strategies will be particularly useful for water and agriculture management agencies and policy-makers to assess practical measures to cope with climate change and drought conditions in future.

2 Materials And Methods

2.1 Data collection

In this study, we have used both climate data and household level primary data to evaluate the climate change impacts and potential drought adaptation strategies. To analyze the climate change impacts on drought, two main climatic indicators (e.g., temperature and precipitation) are evaluated. Observed data of these climatic data is collected from Southern Regional Hydro-meteorological Center and Tien Giang

Hydro-meteorological Station. Historical and future climatic scenarios are generated using three General Circulation Models (GCMs): ACCESS 1.3, CNRM-CM5 and MRI-CGCM3 under RCP4.5 and RCP 8.5 scenarios. These GCMs are chosen because of these following reasons: they are developed by reliable organizations or institutes; they have data for emission scenarios 4.5 and 8.5; the data period from them is suitable with the data period from field collected data; and their dataset includes precipitation and temperature which are 2 main variabilities which are used in this research (Lewis and Karoly 2014; Moss et al. 2010; Pramanik et al. 2018; Voldoire et al. 2013; Wayne 2014; Yukimoto et al. 2012).

For socio-economic data, we have conducted a structured questionnaire-based household survey in the studied province. In the household survey, we have considered one landlocked district (i.e., Cho Gao district) and one coastal district (e.g., Go Cong Dong district) to compare the household level perception and adaptation strategies of drought based on geographical distinction. Random sampling was used to collect 60 households level information from the region. The location of the two selected districts is shown in Fig. 1. Using a socio-economic approach is useful to understand local perception, adaptive capacities and resilience (Lwin et al. 2020).

2.2 Linear downscaling technique

The linear scaling approach operates with monthly scaling values based on the differences between observed and historical runs. This method can correct biases in the mean but not the intensity and wet day frequencies. Precipitation is corrected with a scaling factor, a ratio of monthly mean observed and historical run-in temperature; it is corrected by adding the scaling value that is a difference between long-term monthly observed temperature and climate model's historical run.

For precipitation;

$$P_f^* = P_f\left(d\right)\frac{\mu_m(P_{obs}(d))}{\mu_m(P_{his}(d))}$$ ………………(Eq. 1)

For temperature

$$T_f^* = T_f\left(d\right) + \mu_m\left(T_{obs}\left(d\right)\right) - \mu_m\left(T_{his}\left(d\right)\right)$$ ………………(Eq. 2)

Where, P = precipitation, T = temperature, his = historical run, obs = observation data, f = model future run, μ = average, m = month, d = day, * = bias corrected.

2.3 Standard Precipitation Index (SPI) and drought evaluation

The Standardized Precipitation Index is a tool that was developed primarily for defining and monitoring drought. A drought event occurs when the SPI is continuously negative and reaches an intensity of -1.0 or less. It categorizes as an extreme drought when the SPI value of – 2.0 or less (Svoboda et al. 2012). The event ends when the SPI becomes positive. Therefore, each drought event has a duration defined by its beginning and end, and an intensity for each month that the event continues. The positive sum of the SPI for all the months within a drought event can be termed the drought’s magnitude.

3 Results And Discussion

3.1 Future climatic trends and SPI for 2021–2050 under RCP 4.5 scenario

The trends of the future projected temperature of three climate models under the RCP 4.5 scenario are shown in Fig. 2(a). All three models show an increasing trend. In ACCESS 1.3 model, the average temperature of 2041–2050 is 28.3^{o}C, which is 0.6^{o}C higher than the period of 2021–2030, and 0.3^{o}C higher than the period of 2031–2040. In CNRM-CM5 model, the average temperature for the period of 2041–2050 is 27.6^{o}C, 0.4^{o}C higher than the period of 2021–2030, and 0.2^{o}C higher than the period of 2031–2040. In the MRI-CGCM3 model, the average temperature in 2041–2050 is 27.7^{o}C, which is 0.3^{o}C higher than 2021–2030, and the same as 2031–2040.
There is no general trend for future projected precipitation of three models under the RCP 4.5 scenario, unlike temperature. The values are shown in Fig. 2(b). In the ACCESS 1.3 model, the general trend is decreasing. The period 2021–2030 has the highest average precipitation, 1568.6 mm, while the period 2031–2040 has the lowest amount, 1334.8mm. Same as the ACCESS 1.3 model, the general trend is decreasing in the CNRM-CM5 model. The period 2021–2030 has the highest average precipitation, 1421.1mm and the period 2041–2050 is the lowest, 1364.9 mm. In the MRI-CGCM model, the general trend is increasing. In the period 2021–2030, the amount of precipitation is 1421.1mm. Then, in the period 2031–2040, it is 1395.9 mm, which is the lowest. In the period 2041–2050, it is rapidly increasing to 1519 mm and becomes the highest. Even the trends are not similar; the ranges of average precipitation by the decade are not different in three models under the RCP 4.5 scenario. The range oscillates from 1334.8 mm to 1568.6 mm in ACCESS 1.3, from 1364.9 mm to 1421.1 mm in CNRM-CM5, and 1408.1 mm to 1519 mm in MRI-CGCM.

To know which years may have a high potential of drought, SPI-3 for all three models is calculated. Thereafter, the results of SPI-3 from 3 models will be compared to find out the drought period from 2021 to 2050 under the RCP 4.5 scenario. Figure 3 shows the results of SPI-3 of 3 models. The potential drought years are summarized in Table 1.

Table 1
Potential drought years based on three climate models data in Tien Giang province under RCP 4.5 scenario (predicted years in all model showed in bold)

Model results	Potential drought years
ACCESS 1.3	**2024**, 2025, 2026, 2027, **2031**, 2032, 2036, **2037**, **2041**, 2044, 2046, **2047**, 2050
CNRM-CM5	2023, **2024**, 2025, **2031**, 2032, 2034, **2037**, **2041**, 2046, **2047**, 2050
MRI-CGCM3	**2024**, 2026, 2027, **2031**, **2037**, **2041**, 2043, **2047**, 2048
	2024, 2031, 2037, 2041, 2047

Based on Table 1, the drought years from 2021 to 2050 can be 2024, 2031, 2037, 2041 and 2047. Figure 3 also shows that drought might happen regularly from 2021 to 2050, but severe drought (with SPI value from − 1.5 to -1.99) and extreme drought (with SPI value equal to or less than − 2.0) are not frequent. The extreme drought can happen three times during this period. Although droughts are usually associated with the lack of precipitation in an area over a period, the present study shows that the rising temperature is one of the most important drivers of climate change that will affect droughts in any season over the study area (Shiru et al. 2018). This study has shown that rising global warming-induced temperatures could lead to more droughts with devastating repercussions in Vietnam. More specifically, the increasing severity of drought events estimated in the present research is consistent with the findings of Shiru et al. (2018) and Mohsenipour et al. (2018).

3.2 Future climatic trends and SPI for 2021–2050 under RCP 8.5 scenario

The trends of the future projected temperature of three climate models under the RCP 8.5 scenario are shown in Fig. 4(a). Same as the RCP 4.5 scenario, they all show an increasing trend. In ACCESS 1.3 model, the average temperature in the 2041–2050 period is 29.6^{o}C, which is 0.8^{o}C higher than the period of 2021–2030, and 0.5^{o}C higher than the period between 2031–2040. In the CNRM-CM5 model, the average temperature in the 2041–2050 period is 27.9^{o}C, 0.5^{o}C higher than 2021–2030, and 0.4^{o}C higher than 2031–2040. In the MRI-CGCM3 model, the average temperature in the 2041–2050 period is 28.2^{o}C, 0.6^{o}C higher than 2021–2030, and 0.5^{o}C higher than 2031–2040. Because the RCP 8.5 is extreme, the temperature in this scenario is much higher than the temperature from the RCP 4.5. If the future emission leads to this pathway, it will be hotter and extreme events including drought and will happen more frequently than RCP 4.5 in Tien Giang province. The results of the present study show the conformity with the findings of Betrie et al. (2011) and Van de Giesen et al. (2010), that the drought severity has increased in the study province.

The trends of future projected precipitation of three climate models under the RCP 8.5 scenario is the same as RCP 4.5, which do not have the general trend for these climate models Fig. 4(b). However, the trend of the ACCESS 1.3 model is the same as the CNRM-CM5 model, while both are different from the MRI-CGCM model. In ACCESS 1.3 model, the general trend is decreasing. In the period 2021–2030, the amount of average precipitation is 1452.2 mm. In 2031–2040, the amount of precipitation is 1459.9 mm, which is the highest. In 2041–2050, it is decreasing to 1435.3 mm, which is the lowest precipitation. In the CNRM-CM5 model, the general trend is also decreasing. The trend by decade is the same as ACCESS 1.3 model with a different value. In the period 2021–2030, the amount of average precipitation is 1476.1 mm. In 2031–2040, it is 1530.2 mm, which is the highest amount of precipitation in the region. In 2041–2050, it showed the lowest precipitation (1454.8 mm) with decreasing trend. In the MRI-CGCM model, the general trend is increasing which is quite different from the other two climate models. In the period 2021–2030, the amount of precipitation is 1309.2 mm. In the period between 2031–2040, it is increasing to 1342.6 mm. In 2041–2050, the rate of precipitation is rapidly growing to 1599.4 mm and becomes the highest.

However, the range of decadal average precipitation in all three selected climate models under the RCP 8.5 scenario is similar with the RCP4.5 scenario. In ACCESS 1.3 model, the precipitation ranges between 1435.3–1459.9 mm. The range of the CNRM-CM5 climate model is 1454.8–1530.2 mm, while it ranges between 1309.2–1599.4 mm in the MRI-CGCM model. Moreover, SPI-3 will help to understand the distribution of precipitation and identify the potential drought years in the future under the RCP 8.5 scenario. The results of the present study support the findings of Van de Giesen et al. (2010) and Betrie et al. (2011), that the precipitation pattern can lead to the increase of drought severity in the study province.

In the same way, which is used in 3.1, the potential drought years are identified by summarizing the result of SPI-3 of three models (Fig. 5). Table 2 shows the potential drought years of three climate models in Tien Giang province under the RCP 8.5 scenario.

Table 2
Potential drought years based on three selected climate models in Tien Giang province under RCP 8.5 scenario (predicted years in all models shown in bold)

Model results	Potential drought years
ACCESS 1.3	**2021**, 2022, 2024, 2025, 2026, **2027**, 2028, 2032, 2033, 2034, **2035**, **2036**, 2037, 2040, **2041**, 2046, **2047**, 2050
CNRM-CM5	**2021**, 2022, 2023, 2024, **2027**, 2029, 2030, **2035**, **2036**, 2037, 2038, **2041**, 2044, 2045, 2047, 2050
MRI-CGCM3	**2021**, 2023, **2027**, 2030, 2031, **2035**, **2036**, 2039, **2041**, 2043, **2047**, 2048
	2021, 2027, 2035, 2036, 2041, 2047

From Table 2, it can be seen that the drought years are 2021, 2027, 2035, 2036, 2041 and 2047 in Tien Giang province under the RCP 8.5 scenario. In comparison to each model in the RCP 4.5 scenario, the drought may be more extreme and happen more frequent. The severe drought can happen four times in this period under this scenario. If the future emission is going in this pathway, the extreme scenario, the adaptation strategies need to be more drastic steps and required more investment in the region.

3.4 Local perception analysis

The socio-economic and demographic information of the respondents is shown in Table 3. Of 60 household respondents, 45 respondents are males and 15 are females. The average age of the respondents is about 51 years and they are living more than 43 years in this area. Therefore, the period is long enough to perceive the change of climatic variability. The level of education is relatively low. Most of them are farmers who depend a lot on the weather condition for agriculture. The health care aspect gives a good sign; 90% of respondents have health insurance. The family size of respondents is not big, with the average number of family members being 4.45, but the working-age is the majority.

Table 3
Socio-economic and demographic information of the respondents in the study

Category	Number	Percent
General information		
Number of respondents	60	
Average age of respondents	51	
Average year of living in study area	43	
Total number of members in respondents' families	267	
Age of members in respondents' families		
Below 18	40	14%
18 to 60	166	60%
Above 60	61	22%
Health insurance		
Yes	54	90%
No	6	10%
Gender		
Male	45	75%
Female	15	25%
Education		
Primary	14	23.3%
Secondary	27	45.0%
High School	15	25.0%
Diploma	3	5.0%
Graduate	1	1.7%
Job		
Farmer	43	66.2%
Worker	1	1.5%
Small Business	9	13.8%
Government Officer	6	9.2%

Category	Number	Percent
Others	6	9.2%

From analyzing the questionnaires and comparing them with the reality in the recent drought, it was revealed that the local people had fair bit of understanding about drought. Table 4 shows the perceived reasons for drought, of which, the main reason for drought is the deficit of precipitation (46.7%) followed by water shortage (43.33%) and high temperature (33.33%).

Table 4 also shows the channels in which local people received drought information and early warning. The most popular channels are television accounting for 78.3%, government accounting for 55%, and radio accounting for 48.3%. The information source from the government means the government provided timely information for the local people. The information channels of neighbors and the internet have a small portion of 8.3% and 6.7% respectively. In the rural area of Vietnam, word-of-mouth is an important information channel. The more people are interested; the more information is delivered by word-of-mouth. The low number of respondents who choose neighbor as their information source proved that the drought information is not talked much in daily communication of local people. Internet is the less popular source of information, possibly due to higher age of the respondents.

The responses about level of drought risk and level of preparation show that local people are underestimating the impacts of drought in this study area. Even 60% of respondents thought that drought is getting worse in recent years, 73% respondents thought the level of drought risk was mild, while 55% respondents thought the level of their preparation for drought was high. But, according to the summary report of ‘natural disaster prevention and control of Tien Giang province in 2015–2016, 1475.66 ha rice field was damaged, and 40,000 households lacked to access freshwater. The impacts of drought are higher than the respondents think.

Table 4
Drought perception of the respondents in the study

Category	Frequency	Percent
Reason of drought		
High temperature	20	22.0%
Water shortage	26	28.6%
Lack of rainfall	28	30.8%
Because of God	9	9.9%
Overexploitation of water	3	3.3%
Bad irrigation system and water management	4	4.4%
Others	1	1.1%
Drought information and early warning sources		
TV	47	32.9%
Radio	29	20.3%
Internet	4	2.8%
Newspaper	15	10.5%
Neighbor	5	3.5%
Government	33	23.1%
Head of village	10	7.0%
Level of drought risk		
No risk	2	3.3
Mild	44	73.3
Moderate	9	15.0
Severe	5	8.3
Level of preparation		
Very high	1	1.7
High	33	55.0
Medium	18	30.0
Low	5	8.3
Very low	3	5.0

Although 100% of respondents determined that drought impacted their livelihood, based on their evaluation and the impacts were not high. Table 5 shows ten common impacts of drought, which were evaluated based on 5 levels, i.e., very high, high, medium, low and very low, which the score varies from 5 to 1, respectively. According to the view of respondents, the household level water consumption, reduction in household income, health, unemployment, and conflict for water in society are the major concerns, because these problems affect directly the households and their livelihood when drought occurs. This result is in some way consistent with the study of Keshavarz (2017) which analysed the susceptibility to drought to livelihood. They argued that drought represents the main threat to the security of livelihoods, while the interaction between drought intensity and their duration leads to greater vulnerability, particularly to household revenue, by reducing crop production (Keshavarz et al. 2017). The impact is low to very low indebtedness, food security, entertainment, schooling for children and population migration.

Table 5
Drought impacts on livelihood rated by respondents

Impacts	**Very high**	**High**	**Medium**	**Low**	**Very low**	**Average score**
	5	**4**	**3**	**2**	**1**	
Household water consumption	4	19	14	15	8	2.93
Reduction in household income	3	15	18	15	9	2.8
Health	2	6	21	19	12	2.45
Unemployment	2	9	11	23	15	2.33
Conflict for water in society	2	5	14	21	18	2.2
Indebtedness	1	4	6	26	23	1.9
Food security	2	1	13	11	33	1.8
Entertainment	0	2	14	14	30	1.8
Schooling for children	3	0	0	13	44	1.42
Population migration	1	0	1	15	43	1.35
Average of total						2.01

3.6 Household-level drought adaptation strategies

During the drought period, local people and the government have already applied a lot of adaptation strategies. Figure 6 shows the answers of respondents to some popular drought adaptation methods for local people. Water storage, using less water, saving money, reducing cash expenditure, buy health insurance were widely applied in the study area. These are the basic strategies for drought adaptation; however, these are short-term measures. If in the future, the drought becomes more severely like in RCP 4.5 and RCP 8.5, long-term measures are needed to ensure the livelihood of local people during the drought time. In this survey, no one applied migration and sell assets; this proved the local people could still survive through the drought period in the present time as well as the government had rational actions to adapt to drought. In addition, the respondent has high average age, so they did not want to move out from their current residence.

According to the respondent, they all received support from the government and other organizations. The support they received depended on their geographical location, jobs, and the level of drought impacts to their livelihood. In Fig. 7(a), it can be seen that the support that local people received the most were early warnings and frequently updated drought information, training, and freshwater pipeline extension. The methods such as water point rehabilitation, renovation irrigation system, money support and health support had decent respondents but less than the others mentioned above. It is easy to understand because the target of these methods is narrower; they are more complicated and need more budget to do. Drill wells, relief food, and provide seeds, animal foods, and feed storage assistance had the lowest response. These methods require a lot of budget and technique, so they were applied to the households in an emergency.

Figure 7(b) also showed that the Go Cong Cong district received more support than the Cho Gao District. Especially in water point rehabilitation, drill wells, relief food and health support, the balance tilted towards Go Cong Dong district. This is in line with the actual situation because the Go Cong Dong district was impacted by drought more than the Cho Gao District. Go Cong Dong district is a coastal district; drought combined with saltwater intrusion caused more damage while Cho Gao district is an upper stream district, it had more fresh water and be affected less than Go Cong Dong. In addition, the main crop of the Go Cong Dong district was rice, which needed more freshwater than the main crop of Cho Gao district, which was fruits and vegetables. Finally, Cho Gao district is nearer the center of Tien Giang province, and the economy is more developed than the Go Cong Dong district. These are the reasons why the Gong Cong Dong district received more support than the Cho Gao District.

Overall, many adaptation strategies were applied in the study area by both local people and the government. These strategies cover almost all required aspects, and they are good enough to adapt to fair drought; however, to adapt to severe and extreme drought, some strategies need to be improved to make them better.

4 Drought Management Recommendations Under Climate Change

As discussed above, Tien Giang province had decent adaptation strategies. Still, lack of cooperation between responsible units about climate change adaptation and disaster risk reduction government, low perception and knowledge of local people and authorities, and mistrust between local people and local authorities pulled the effectiveness of these strategies back. If the cooperation was tighter, the perception and knowledge were higher; the impacts were not huge like what happened. The gaps are shown in Fig. 8. To make the adaptation strategies more effective, these gaps need to be closed.

Closing the gaps of cooperation and perception is a complex process that needs good management, the consensus of stakeholders, and time. It is involved in awareness, preparedness, and mitigation more than the response in place. In reality, in the study area, many actions to promote cooperation and increase

perspective have already been done, but the results have not been satisfactory. In this study, to give effective adaptation strategies based on location and climate scenarios, Tien Giang province is divided into 3 areas: landlocked districts in the West of the province, landlocked districts in the middle of the province, and coastal districts in the eastern province. It is shown in Fig. 9.
The adaptation strategies based on location of each area are as following:

Landlocked districts in the West of Tien Giang province: These districts have higher precipitation than other districts, and water resource is more abundant because they are upstream districts.

- Under the RCP 4.5 scenario, the economic structure should be kept the same. Raising awareness is the main adaptation strategy to aware people to use less, save water for downstream districts, and keep their health during the dry season.
- Under the RCP 8.5 scenario, because drought can be getting more severe, some parts of these districts can be impacted by saltwater intrusion; authorities should pay more attention to researching and testing saline tolerant crops to adapt to this problem.

Landlocked districts in the middle of Tien Giang province: Cho Gao district belongs to this category. These districts have a good amount of water; the level of saltwater intrusion is fair during drought.

- Under the RCP 4.5 scenario, these districts should consider planting drought and saline tolerant crops and fruit in some areas. The government should encourage local people to expand the area of dragon fruit, a drought-tolerant plant. Other than plan rice throughout the year, watermelon, groundnut and some typical local fruits can be planted during the dry season. Innovating irrigation systems, water reservoirs and rain reserving systems are the activities that need to be done every year, especially in drought years—considering building new adaptation constructions inappropriate places. Finally, raising awareness is always a required adaptation strategy.
- Under the RCP 8.5 scenario, because drought will worsen in this emission scenario, the preparation needs to be better. The authorities of these districts should put more attention to reactions in play, such as water pumping, freshwater hub rehabilitation, relief, etc., to respond promptly to drought. Applying new technology in natural disaster response is needed.

Coastal districts: This category includes districts in the East of Tien Giang province. Go Cong Dong district is in this category. These districts have less precipitation; water resource is not as good as the other districts. In addition, these districts are very vulnerable to saltwater intrusion. Even though Tien Giang has a good irrigation system if these districts experience drought-like the 2015–2016 period, the system cannot protect them.

- Under 4.5 scenarios, drought and saline tolerant crops and fruits should be planted, especially during the dry season. Raising awareness and a well-prepared reaction plan in place are also needed adaptation strategies. Authorities should focus more and prepare better in these districts to respond as soon as drought occurs because they are the most impacted districts in the province. The mangrove forests should be protected, expanded and improved in quality. The mangrove ecosystem has many services and benefits. It provides food, timber, and aquatic species and reduces impacts of climate change and natural disasters, including drought, sequestering carbon, supporting the nutrient cycle, and research, education, and recreation. Therefore, mangroves reforestation is an activity that can adapt well to drought and bring more benefits to people.

- Under the RCP 8.5 scenario, these districts will be impacted severely; therefore, the adaptation strategies need to be more resolute. During the dry season in drought years, there is a need for policy to prevent and cultivate rain-fed crops because it will make the recovery process from drought consequences more difficult. The economic structure of these districts can be changed to suit climate change in the future, focusing on creating new jobs for residents during the dry season to ensure people livelihood, for example, aquaculture and tourism.

5 Conclusion

This study attempted to determine the impacts of climate change on drought and adaptation strategies in Tien Giang province, Vietnam. Past climate trends and indices were analyzed to determine the past drought events. Three GCMs, i.e., ACCESS 1.3, CNRM-CM5 and MRI-CGCM3, were then used to project future climate change and drought under RCP 4.5 and RCP 8.5 scenarios by the linear downscaling method. Thereafter, 60 respondents were interviewed to understand their perception of drought, including the drought risks, and adaptation strategies. Finally, based on the result from both the physical and socio-economic approaches, adaptation strategies were formulated under two emission scenarios over the three geographical areas in Tien Giang province.

The result shows that under the impacts of climate change, the drought has been getting more severe which would continue in the future. From 1986 to 2016, the temperature increased continuously, and precipitation increased slightly. The general result of future climate projection from the three models illustrate that the temperature will continue to rise and the precipitation would be inconsistent. Therefore, the drought may become more severe; particularly in the RCP 8.5 scenario as compared to RCP 4.5 scenario.

In addition, the analysis accents the importance of cooperating between responsible units to disaster risk reduction and climate change adaptation as well as raising awareness for local people and authorities. High cooperation and awareness will be helpful to close the gaps in the drought management system and elaborate suitable adaptation strategies. The adaptation strategies in this study are given based on the results of climate scenarios and hydrometeorology characteristics of three areas. They focus on awareness raising, plant structure transformation, and irrigation system improvement.

Based on the results of the present study, there are many ways to develop deeper research by fields, areas and methods. Because the Mekong Delta of Vietnam is vulnerable with various hazards of climate change, researching in multi-hazard is a way to cover all the impact of climate change on different climate-related disasters. The results of this study about drought can be utilized in calculating and accessing the impact of climate change in a case of multi-hazard of Tien Giang province and the Mekong Delta of Vietnam.

Declarations

Ethical approval:

This article is from a thesis of Mr. Bui Phan Quoc Nghia in Asian Institute of Technology (AIT). All procedures were monitored by thesis committee and followed AIT rules. More details of ethical approval, please contact Dr. Indrajit Pal, chair of the thesis committee and an author of this manuscript.

Consent to Participate and

The authors agreed to participate in the research.

Consent to Publish:

The authors agreed to publish the research.

Author contribution:

- Bui Phan Quoc Nghia: Conceptualization, Methodology, Formal analysis, Investigation, Writing - Original Draft
- Indrajit Pal: Conceptualization, Methodology, Writing - Review & Editing
- Malay Pramanik: Writing - Review & Editing, Visualization
- Rajarshi Dasgupta: Writing - Review & Editing

Conflict of Interest:

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Figures

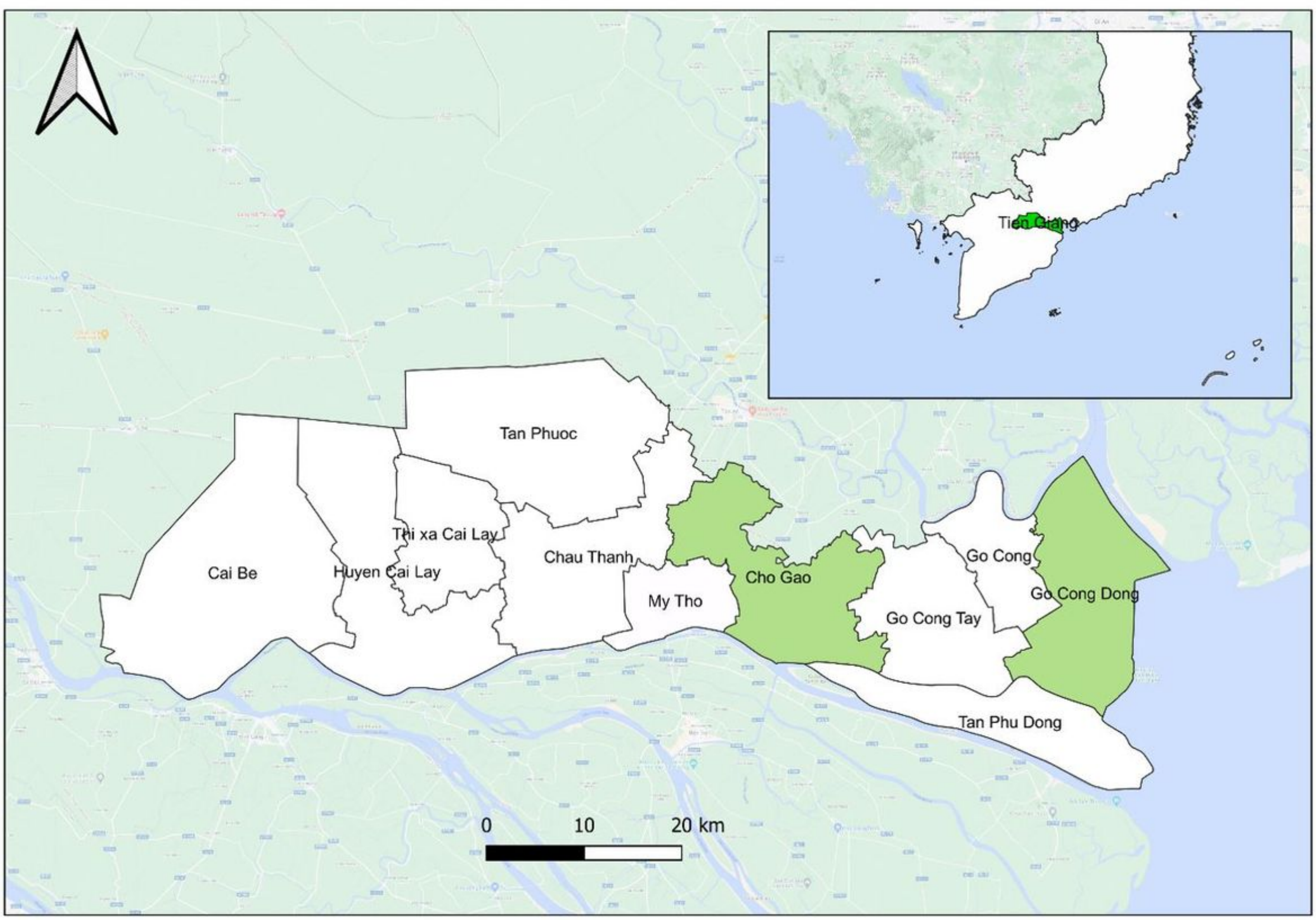

Figure 1

Districts for the household survey

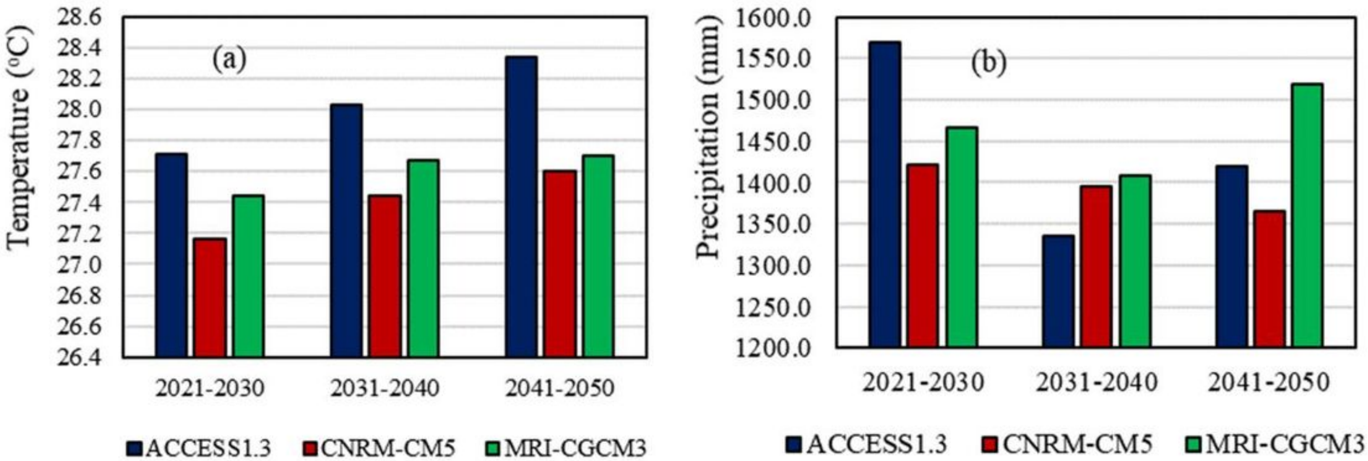

Figure 2

The decadal change of average temperature (a), and average precipitation (b) of 3 GCMs under the RCP 4.5 scenario in Tien Giang province from 2021 to 2050

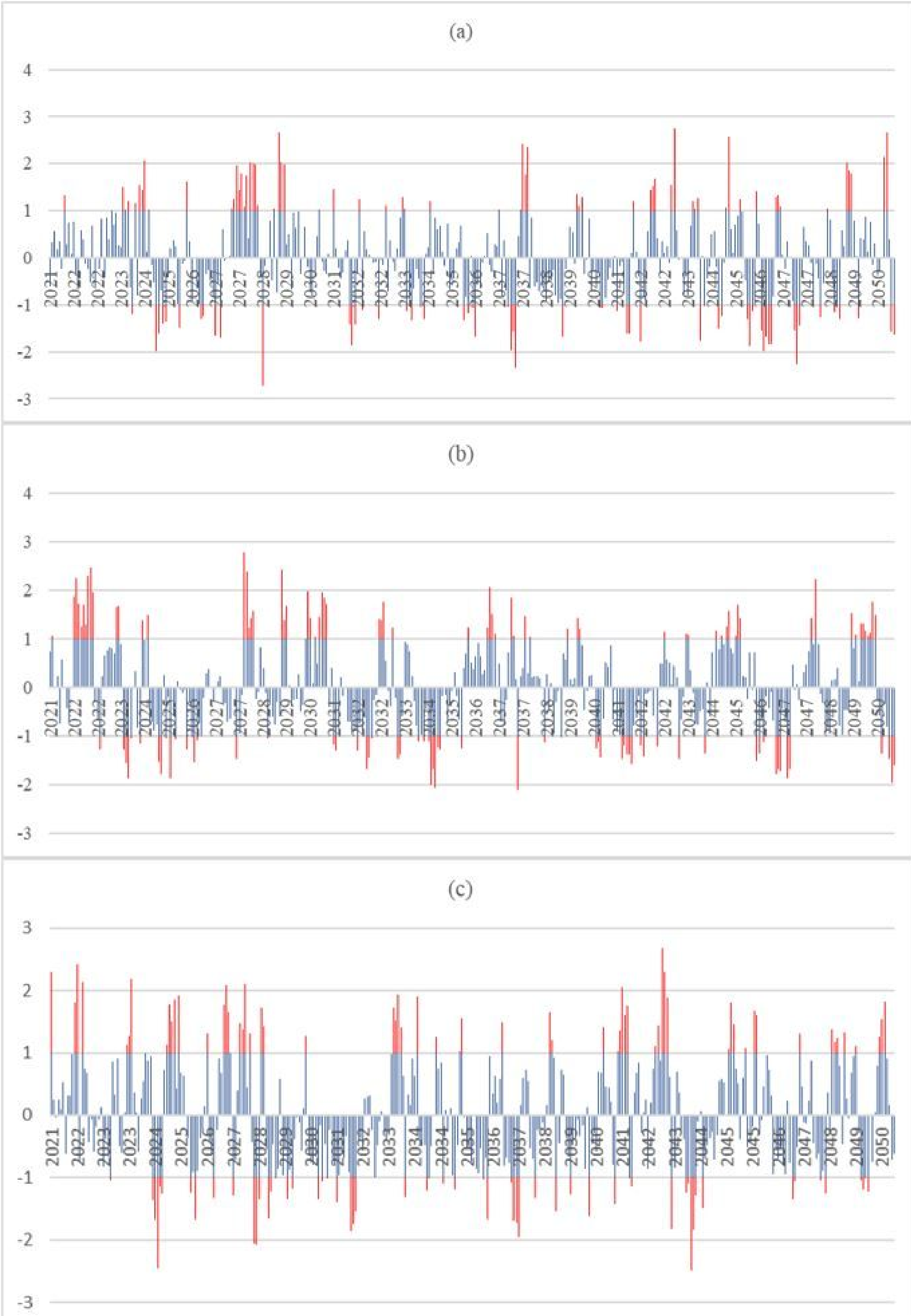

Figure 3

SPI-3 of ACCESS1.3 (a), CNRM-CM5 (b), and MRI-CGCM3 (c) in Tien Giang province for the period of 2021-2050 under RCP 4.5 scenario

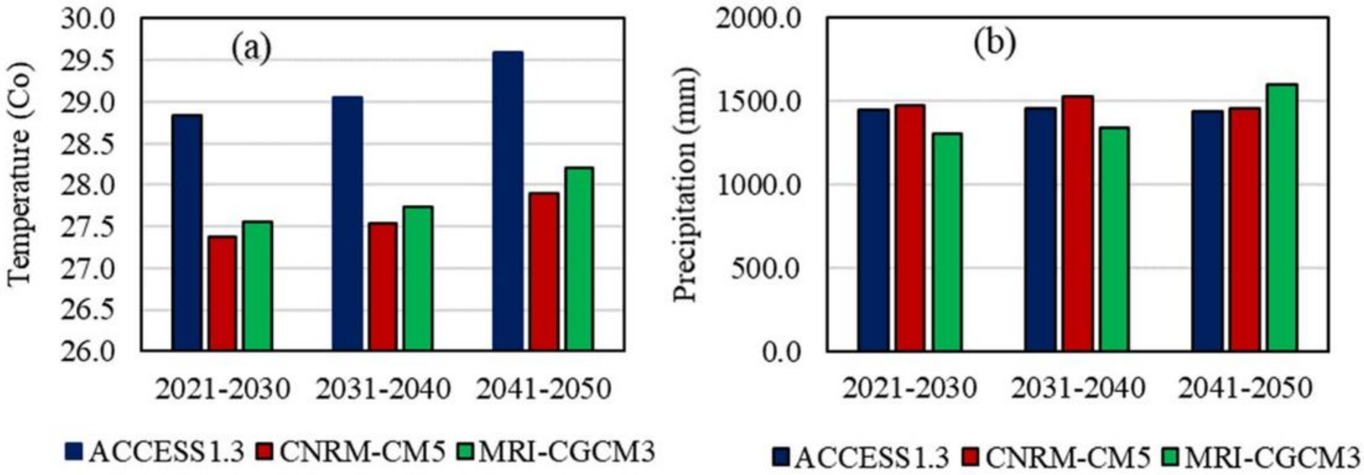

Figure 4

The decadal change of average temperature (a), and average precipitation (b) of 3 GCMs under the RCP 8.5 scenario in Tien Giang province from 2021 to 2050

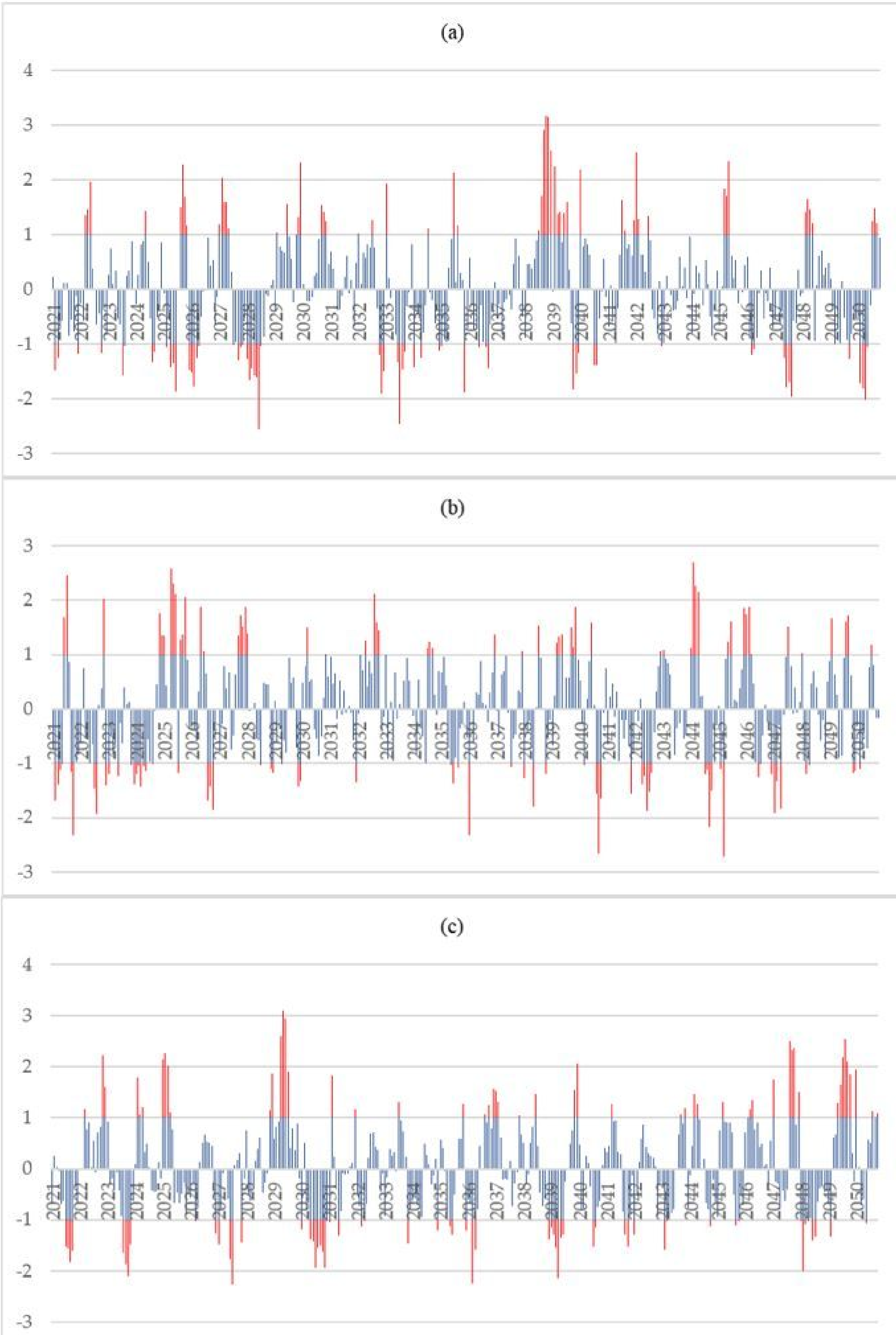

Figure 5

SPI-3 of ACCESS1.3 (a), CNRM-CM5 (b), and MRI-CGCM3 (c) in Tien Giang province for the period of 2021-2050 under RCP 8.5 scenario

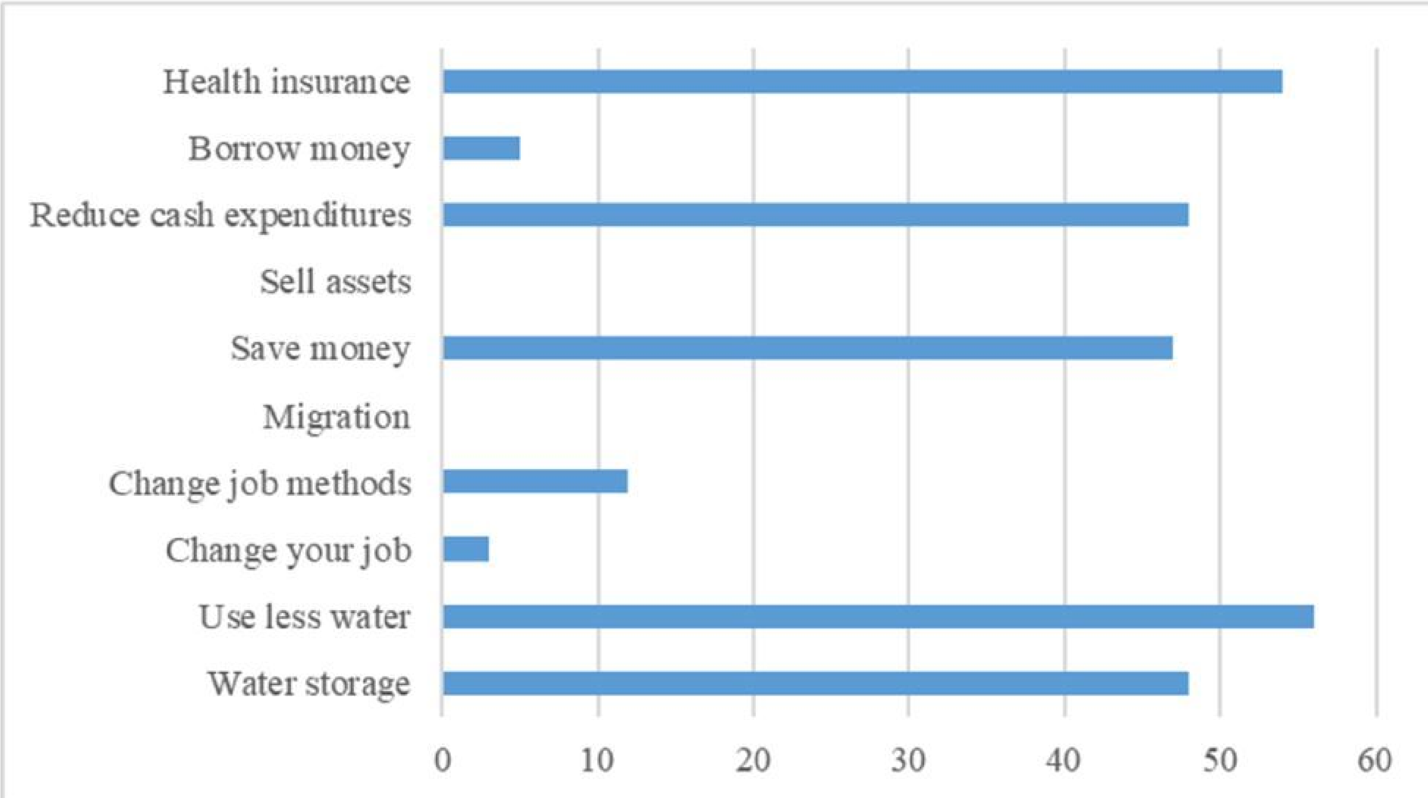

Figure 6

Household-level drought adaptation strategies in the study area

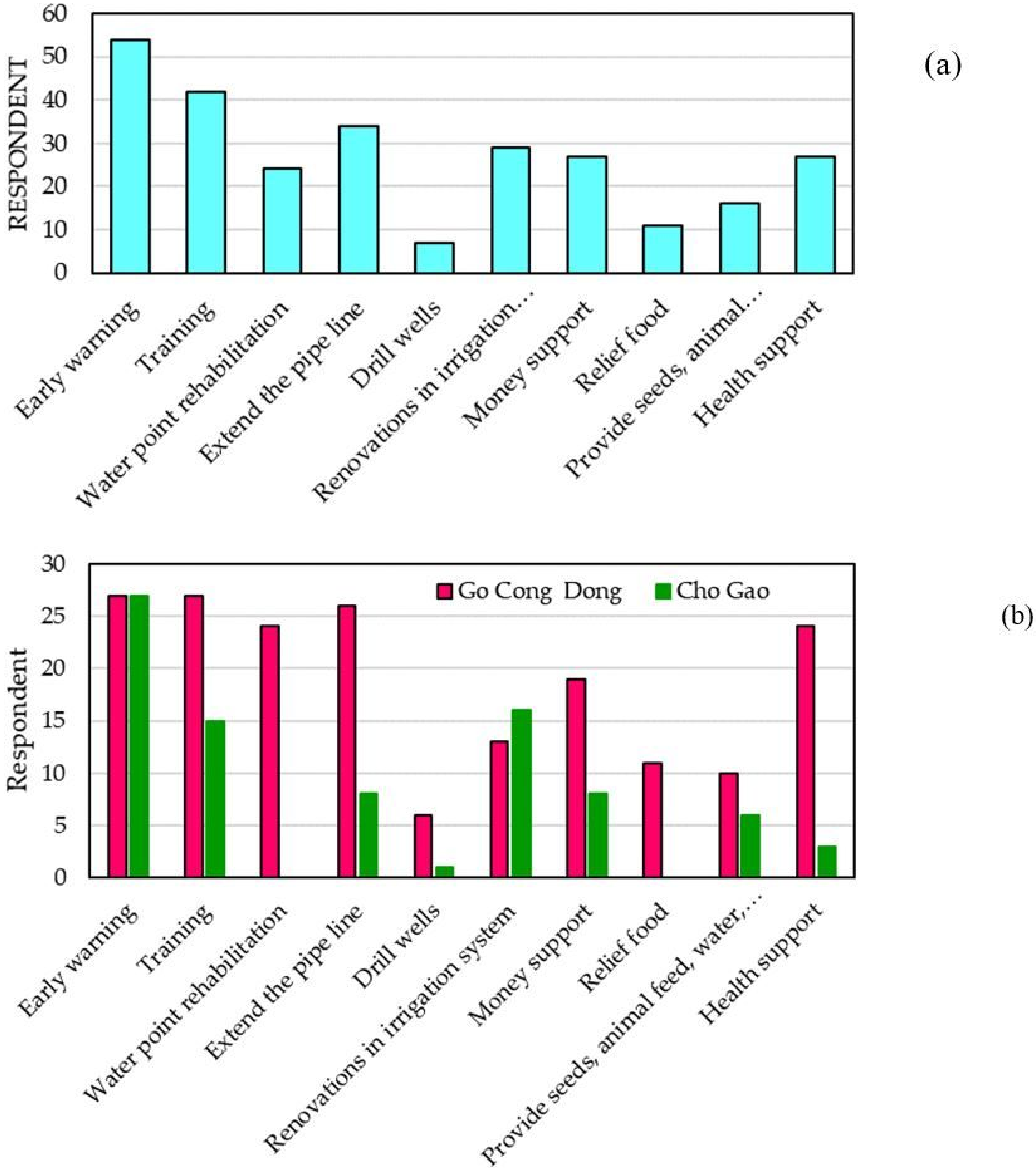

Figure 7

Support from the government and other organizations based on respondents' perception of total support (a), comparative support in the Go Cong Dong district and Cho Gao district (b)

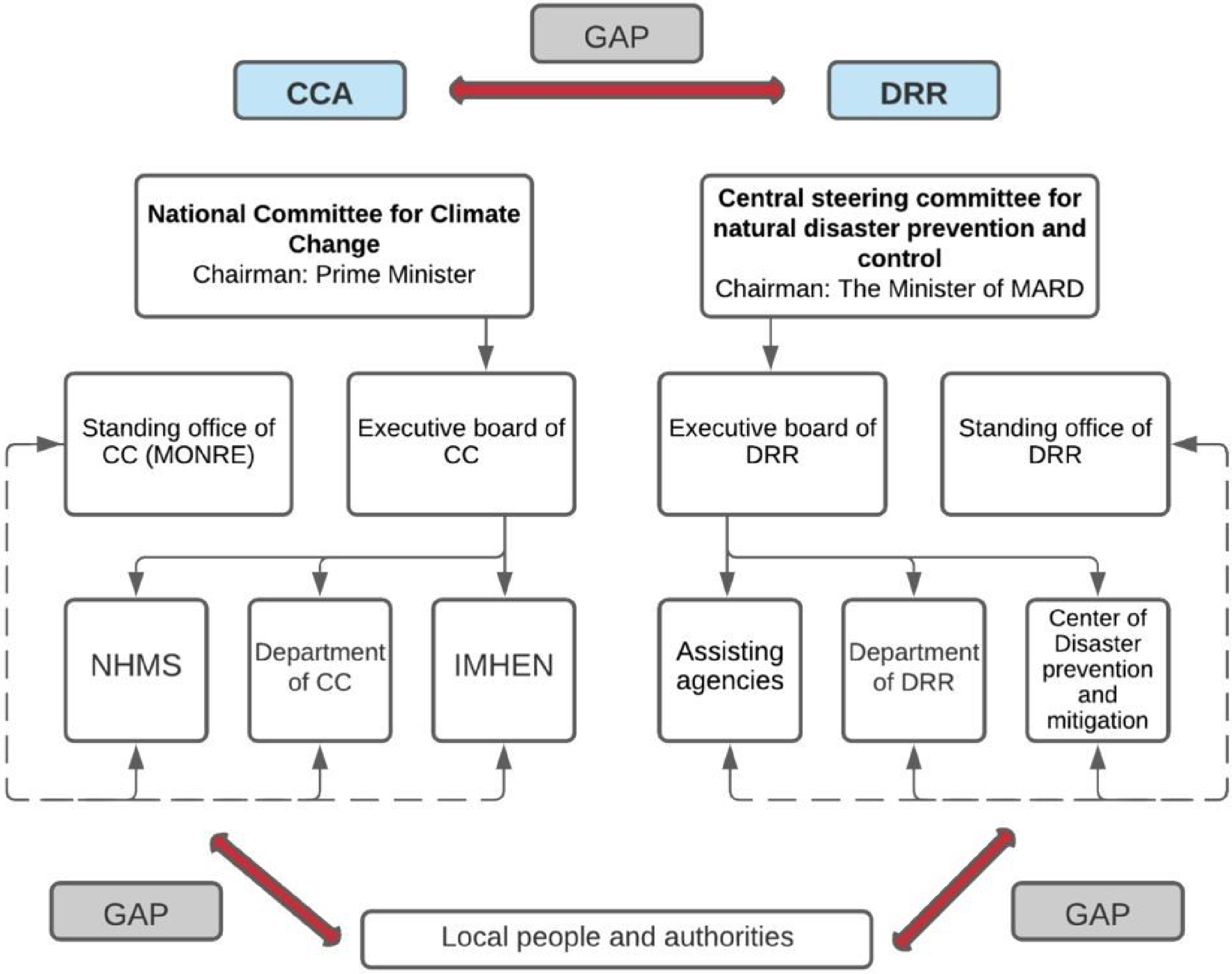

Figure 8

Gaps in the management system of disaster risk reduction and climate change adaptation in Vietnam

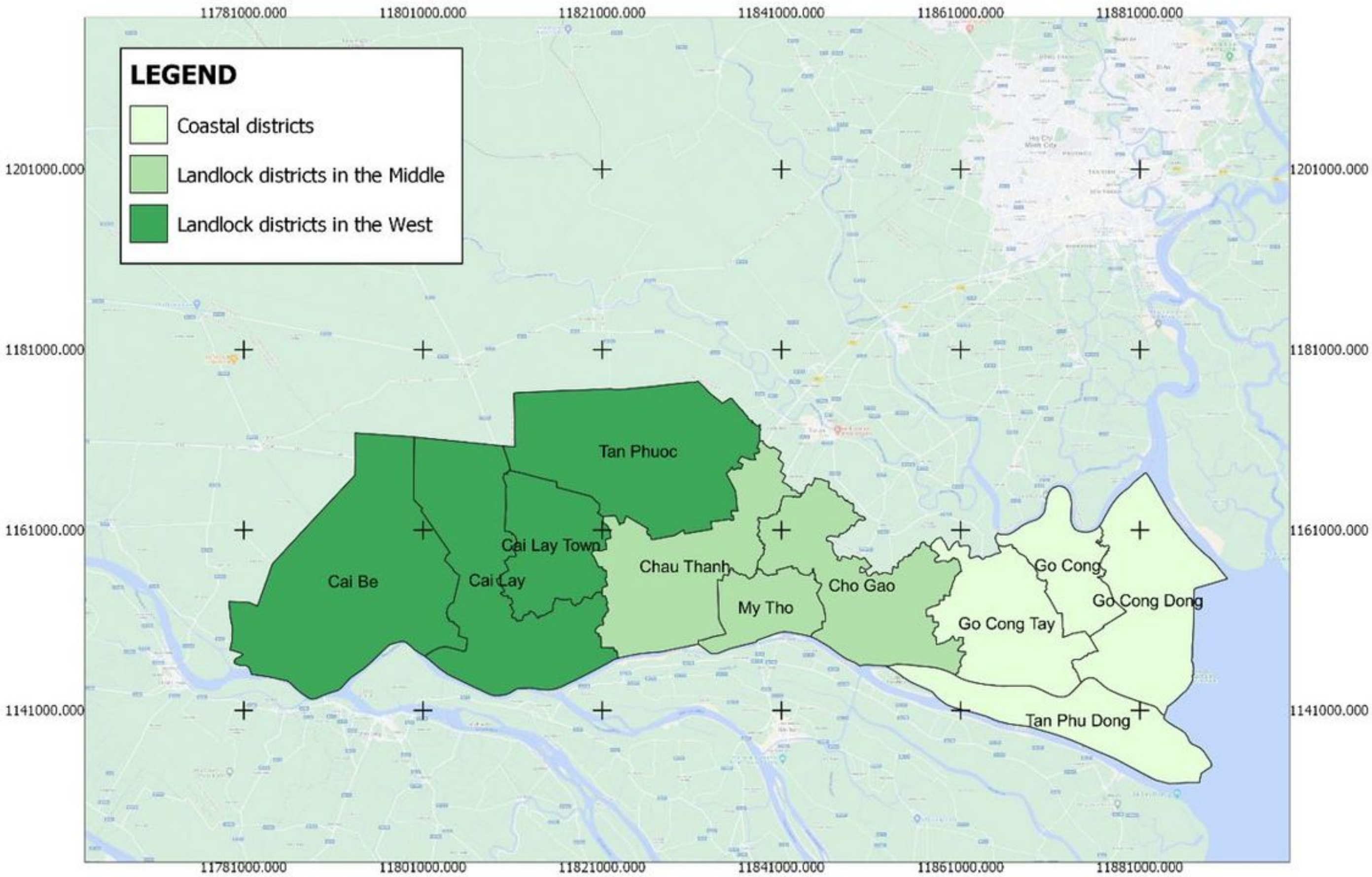

Figure 9

Divided areas for adaptation in Tien Giang province