CHAPTER 7 - EXPECTED CLIMATE CHANGE IMPACTS ON QUANG BINH

7.1 INTRODUCTION

While Chapter 6 provided an overview of the climate of Quang Binh and the history of climate-related disasters in the province, this chapter now looks at likely future climate changes and their potential impact on Quang Binh at the province-wide level. It starts off by firstly explaining the rationale for focusing on a certain set of parameters as measures of climate change, when looking at it from a vulnerability assessment and ecosystem-based adaptation perspective, and then presents possible scenarios for Quang Binh. The bulk of the chapter discusses the likely impacts and implications of those changes, with a main focus on the natural resource related sector of agriculture, forestry, fisheries and aquaculture, as well as on the natural ecosystems that are the source of important ecosystem services. More superficial treatment is generally given to climate change impacts on urban and rural settlements and infrastructure. The original scenario-related work undertaken by the project team is provided as Annex I and Annex II.

The chapter draws heavily from 4 key publications:

- Asian Development Bank (2014) *Urban Environment and Climate Change Adaptation Project IE131001410-06-RP-103C;*
- MONRE (2012) ***Climate Change and Sea Level Rise Scenarios for Vietnam.*** MONRE, Hanoi;
- Nguyen, T.T., Coulier, M., Nhu, O.L., Wilderspin, I (2012) ***A preliminary analysis of disaster and poverty data in Quang Binh Province***, Vietnam, UNDP;
- Southern Natural Resources and Environment Company (2010), *Action plan in response to climate change in Quang Binh Province in 2011-2015, and vision to 2020*.

as well as a number of other important references, and adds the original work and analysis of the vulnerability assessment team to this.

7.1.1. Selection of Climate Change Parameters for Quang Binh

Vietnam is likely to be one of the several countries most adversely affected by climate change. During the last 50 years, Vietnam's annual average surface temperature has increased by approximately 0.5 to 0.7°C, while the sea level along the coastline has risen by approximately 20cm. Climate change has resulted in more severe and/or frequent occurrences of natural disasters, especially cyclonic storms, floods and droughts becoming more extreme (ADB, 2014). Due to climate change, the intensity and geographical scope of the multiple hazards hazards Quang Binh is already facing (described in detail above) will increase (UNDP, 2009).

Overall climate is expected to change and to become more variable, in a number of different ways. In the dry season, there will be less rainfall and longer periods of time without any rain. Maximum and average temperatures will increase and the

number of very hot days will also increase. During the hot dry period, night-time temperatures will not cool down as much as they used to. Conversely during the cold season, intense cold spells may also increase.

In the rainy season, rainfall will increase overall but will be concentrated in a shorter period. There will be more days with very heavy rain. Storms will be more unpredictable, and may happen more often and with greater intensity. Sea level rise will continue to increase.

There are a large number of different parameters that can be used to measure different aspects of climate variability and climate change. For example, considering only one factor - temperature, one could consider:

- Changes in annual mean temperature
- Changes in annual mean maximum temperature
- Changes in annual mean minimum temperature
- Changes in annual mean day-time temperature
- Changes in annual maximum and minimum day-time temperature
- Changes in annual mean night-time temperature
- Changes in annual maximum and minimum night-time temperature
- Changes in number of very hot days
- Changes in number of very cold days

A similarly large number of possibilities exist when we look at precipitation. In addition, all of the above parameters could also be measured as changes on a month by month, or a seasonal basis. Give this vast range of possibilities, it is necessary to pick a few parameters that are important and relevant to our objectives - conducting a vulnerability assessment to identify Ecosystem-based Adaptation (EbA) options - and for which we have the capacity to assess changes and interpret the likely consequences of those changes.

When looking at the species of plants and animals that make up natural ecosystems, we can think in terms of "**comfort zones**" - the range of climate conditions to which each species is best suited, and in which they will thrive. Similarly, with agricultural crops and tree plantations of both native and exotic species, there are climate conditions that are most appropriate to growing each of these species. In this context, measures of average annual changes in temperature and rainfall are not so useful. They tend to even out changes in different directions that happen in different seasons, and don't lead to any real understanding of how living things will be affected.

Changes in extremes and the duration of time over which those extremes persist are more informative, as they may relate to **thresholds** beyond which agricultural and plantation forestry productivity may be affected, and key species in natural ecosystems may be impacted. For example, in coral reefs, if sea water temperature

exceeds a certain threshold, the symbiotic algae in the coral polyps start to produce more toxic by-products. To protect themselves, coral polyps then expel the algae. If the high temperature only lasts for a few days, the algae can return, and the coral can recover. However, if the elevated water temperature persists for a longer period, the algae do not return and such a long-term coral bleaching event can lead to mass mortality of the corals.

Similarly, considering growing of rice and other crops, it is generally understood that higher levels of atmospheric carbon dioxide should stimulate more efficient photosynthesis, leading to increased plant growth. However, theoretical, experimental and real world studies have shown that increased carbon dioxide concentration, combined with increased temperature actually reduces rice yield.

Simulated yield potential in the major rice-growing regions of Asia with present atmospheric CO2 concentration decreased by 7% for every 1°C rise above current mean temperature (Mathews et al 1997). Nevertheless, it is unlikely that rice plants are responding to mean temperature. Further research using actual real world rice yields and temperature records from the International Rice Research Institute (IRRI) in the Philippines over a 23 year period from 1979 to 2002 has showed that the strongest correlation was between increasing night time temperature during the growing season, and reduced rice grain yield. It appears that plants are indeed producing more in the day time as photosynthesis is indeed increased. However, they are also burning up more energy at night time as respiration is also increased with higher temperature. The extra photosynthesis in the day time may produce less than the extra respiration burns up during the night, with the net result of lower yield (Peng et.al 2004). Similar negative effects of increased night temperature on grain yield have also been reported for maize, wheat, and soybeans (Peters et.al. 1971).

Considering the above types of issues, the project selected the following climate change-related parameters to focus on:

Table 7.1: Important Climate Change Parameters

Factor	Type of Change	Rationale/importance
Temperature	Hot season hotter and longer	Reduced soil moisture and increased evaporation, can cause crop wilting and increased risk of agricultural drought. Forest fire risk may be increased. Frequency of some pest and disease outbreaks may increase
	# days > 35°C increasing	Heat stress impacts on humans, crops, and livestock as well as wild species. Forest fire risk may be increased
	Temperature increasing faster and earlier in Spring	May cause changes in phenology of crops and wild plant species, and changes in timing of life-cycle stages of wild insect, animal and bird species
Precipitation	Dry season drier, more dry days	Both hydrological and agricultural drought risk increased, significant issue for crop production.
	More rainfall in rainy season	Waterlogging may reduce productivity of certain crops and trees. Inundation of lowlands may be more common; infrastructure may be damaged. Reservoir capacity may be exceeded with a danger of dam failure
	# days >50mm rain increasing	Increases chance of destructive flash floods, erosion and landslides
Storms	Storms with increasing speed(intensity)/stronger winds	Significant physical damage to crops, infrastructure, property and life, huge economic cost
	Storms more unpredictable and happening at different times	More difficult to plan response, and e.g. to adjust cropping calendar to avoid storm damage
Sea Level Rise	3mm/year in last 20 years, 1m rise predicted by year 2100	Erosion, submergence of coastal land and saline intrusion

The selected parameters combine those that are highly relevant to existing climate-related disasters in Quang Binh - particularly storms and rainfall changes (relating to both floods and droughts), as well as sea-level rise that is likely to become of increasing concern as time goes by.

7.1.2. Climate Change Scenarios

The climate change and sea level rise scenarios developed and published for Vietnam in 2009 were based on the low (B1), medium (B2) and high (A2, A1Fi)

scenarios. The average B2 scenario was recommended for all Ministries, sectors and localities to initially assess the impact of climate change and sea level rise and to build action plans to respond to climate change. Scenarios were updated and developed for each province in 2012. (MONRE, 2012). The below description of the scenarios for temperature and rainfall changes as well as sea level rise, are all taken from MONRE, 2012.

Scenarios for temperature change

Low emission scenario (B1): by the end of the 21st century, annual mean temperature in most of areas of Vietnam north of Hua Thien - Hue (Including Quang Binh) would increase by 1.6 to 2.2°C relative to the baseline period (1980 - 1999).

Medium emission scenarios (B2): by the middle of the 21st century, areas from Ha Tinh to Quang Tri, including Quang Binh would increase by 1.6 to 1.8°C. By the end of the century temperatures in areas from Ha Tinh to Quang Tri, including Quang Binh are forecasted to increase by 3.1 to 3.3°C. In addition, the number of days with maximum temperature higher than 35°C would increase by about 15 to 30 days.

High emission scenario (A2): by the end of the century, annual mean temperature in most of the country would increase by between 2.5 to more than 3.7°C.

Scenarios for rainfall change

Rainfall in the dry season is expected to decrease in most regions of Vietnam, particularly in the southern region. Rainfall during the rainy season and the total annual rainfall are forecasted to increase in all zones.

Low emission scenario (B1): By the end of the 21st century, annual rainfall would increase in most of the country by about 6% relatively to the reference period 1980-1999. In the Central Highlands, the increase could be lower, less than 2%.

Medium emission scenarios (B2): By the end of the century, annual rainfall would increase by about 2 to 7% in most of the country. In general, the dry season rainfall would decrease and rainy season rainfall would increase. Maximum daily rainfall would increase in the North Central zones (including in Quang Binh). Extraordinary daily rainfall may occur anywhere with rainfall about 2 times higher than present maximum daily rainfall.

High emission scenario (A2): By the end of the century, annual rainfall would increase by about 2 to 10 % in most of the country.

Scenarios for sea level rise

Low emission scenario (B1): By the end of 21st century, average sea level rise in most of the coastal zones of Vietnam is anticipated to be about 49 to 64cm.

Medium emission scenarios (B2): By the end of the century, in Quang Binh, the rise is forecasted to be 60 to 71cm.

High emission scenario (A2): the sea level will rise by 100cm.

According to reports on the implementation of CCA plan in Quang Binh in the period of 2000 - 2015, the weather situation has been more complicated and extreme weather phenomena have been happening more frequently. Reported climate trends in Quang Binh are presented in Table 7.2. And predicted impacts of these continued climate changes are shown in Table 7.3.

Table 7.2: Trends in Climate Factors

Climate Trend	Trend
Irregular Rainfall in Rainy season	↗
Annual rainfall	↘
Average annual temperature	↗
Heat waves/ hot-dry days	↑
Meteorological Droughts	↗
Cold spells	↗
Tropical hurricanes/ depressions	↗
Unusual strong wind (cyclone)	↗
Lightning	→

↗ Increasing
↑ Highly increasing
↘ Decreasing
↓ Highly decreasing
→ Unchanged

Table 7.3: Trends in climate-related impacts

Climate Trend	Trend
Upstream floods/ flash flood	↑
River bank erosion and landslides	↑
Downstream widespread inundation	↑
Sedimentation of reservoirs and river mouths	↗
Agricultural Droughts	↗
Water Shortages for domestic and industrial use	↗
Forest fires caused by hot dry weather	↗
Loss of forests and agricultural land by sea level rise	↗
Increasing salinization of coastal plains	↗
Storm damage to infrastructure	↑

↗ Increasing
↑ Highly increasing
↘ Decreasing
↓ Highly decreasing
→ Unchanged

The Vulnerability Assessment team used the official IMHEN/MONRE data used in generating the official 2012 scenarios and produced more detailed maps of the expected changes for Quang Binh (and Ha Tinh) provinces. These changes and their likely implications are discussed in the different sections below. Full details are provided in Annex 7.I.

7.1.3. Likely Climate Change Impacts for Quang Binh

7.1.3.1. IMPACTS OF STORMS

Under climate change projections, the intensity and frequency of storms is expected to change and storms may become more unpredictable. In Quang Binh, storms normally occur from July to September every year. However, in recent years, it seems storms have already started to become more unpredictable and have happened even in March and April, or alternatively in October. Storm intensity has apparently also increased. With increased frequency, intensity and unpredictability, the damages caused by storms are likely to increase with climate change.

7.1.3.1.1. Impacts on Agriculture Forestry and Fisheries

Storms may cause direct physical damage to aquaculture operations in the coastal areas and to crop fields especially in the lowland plains. Strong winds associated with severe storms that penetrate further inland can also cause physical damage to rubber plantations, snapping or uprooting trees, but are still less of a threat to acacia plantations even further inland and at higher elevations.

Increasing storms (and other strong winds) will cause sand blows to occur more frequently and more severely in areas along the coast in two districts - Quang Ninh and Le Thuy, increasingly affecting daily life and agricultural production of local residents. Although there are extensive dune systems in these areas, their natural vegetation cover has been removed. The sparse coverage of casuarina coastal protection plantation forests are incapable of sufficiently protecting the area from wind and blowing sand. Casuarinas nearer to the sea are exposed to strong wind and sea waves and are left with bare roots. Further inland many have a creeping form rather than growing as an upright tree. With climate change, increasingly stronger winds will blow more sand into houses and fields will also be increasingly covered with sand. The effort required to dig up the sand to reclaim arable land area after the storm season will increase over time with climate change.

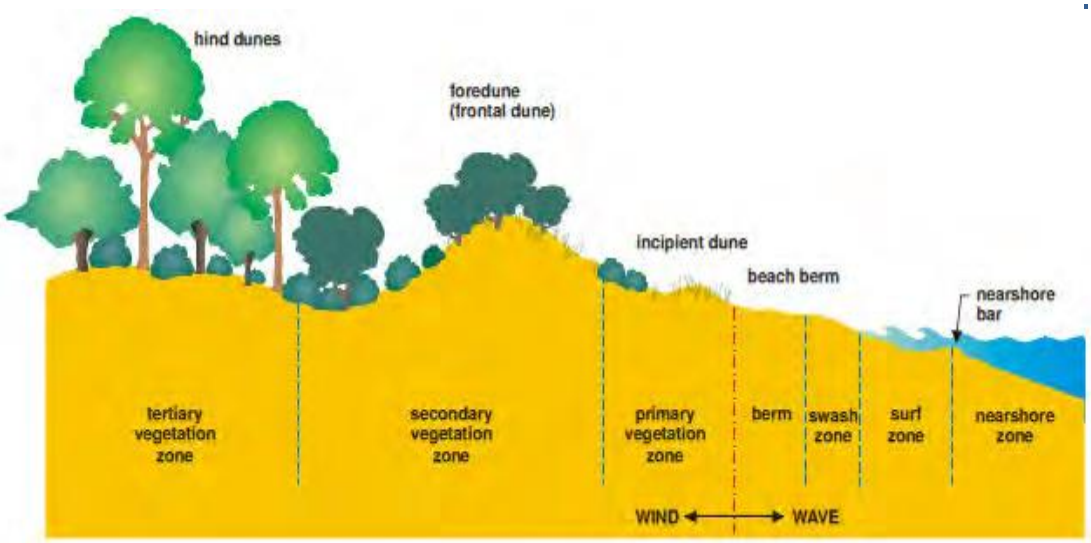
7.1.3.1.2. Impacts on natural ecosystems

Storms create highly turbid conditions which limit light availability for sea-grasses and have caused declines of sea-grass populations in other tropical regions (Shaffelke et al., 2005; Waycott et al., 2007). Sea-grasses are particularly vulnerable to these changes and physical disturbance to sea-grasses resulting from sediment movement (erosion and deposition), turbulent water motion and storm surges (Waycott et al., 2007). Flooding associated with severe storm also reduces salinity and increases turbidity, creating difficult and often fatal conditions for sea-grasses to grow in (Waycott et al., 2007).

Coral reefs are also impacted by turbid conditions reducing sunlight penetration. They can also suffer physical damage from very strong storm surges, but are not as sensitive to this as sea-grass. Mangrove trees can also be physically damaged by strong storms.

More than half of the reported climate impacts on natural ecosystems synthesized by Poloczanska et al. (2013) came from coastal systems. However, sandy beach systems have largely been overlooked in studies of the ecological (and socio-economic) impacts of climate change (Dugan et al., 2010; Barbier et al., 2011, Schoeman et. al., 2014). A typical beach system is depicted in Figure 7.1.

Figure 7.1: A typical beach dune systems



Source: Coastal Dune Management. Land & Water Conservation Department. NSW. 2001

Coastal dunes are accumulations of wind-blown sand located behind the beach. Typically, an undisturbed beach will be backed by a fore-dune (also known as a frontal dune) and hind dunes. Vegetation cover is a crucial element of dune landscapes. Wind velocity is generally reduced by plant cover, encouraging deposition and trapping of wind borne sand. The presence of a stable dune system provides a natural defense mechanism against coastal storm hazards. However, in much of the coastal dune systems of Le Thuy and Quang Ninh Districts, natural vegetation has been extensively removed or degraded. Despite ongoing efforts to stabilize the dunes through planting of casuarina and acacia, the problem of blowing sand that impacts infrastructure and settlements inland of the dunes is likely to continue and may get worse with climate change.

Changes in storm intensity and frequency are likely to have less significant impacts on inland ecosystems, especially those at higher elevation.

7.1.3.1.3. Impacts on Urban and rural settlements and infrastructure

As identified in the previous chapter, the greatest impact of storms is in the coastal and lowland areas of central and southern Quang Binh. As identified in Chapter 2, this is also where most of the population is concentrated, and as identified in

Chapter 4, it is also where much of the infrastructure supporting the economy is located. All types of natural coastal ecosystems - including coral reefs, sea-grass beds, mangrove forests and sand dune ecosystems provide some degree of physical protection against storms, and the erosive forces of high tides and storm surges.

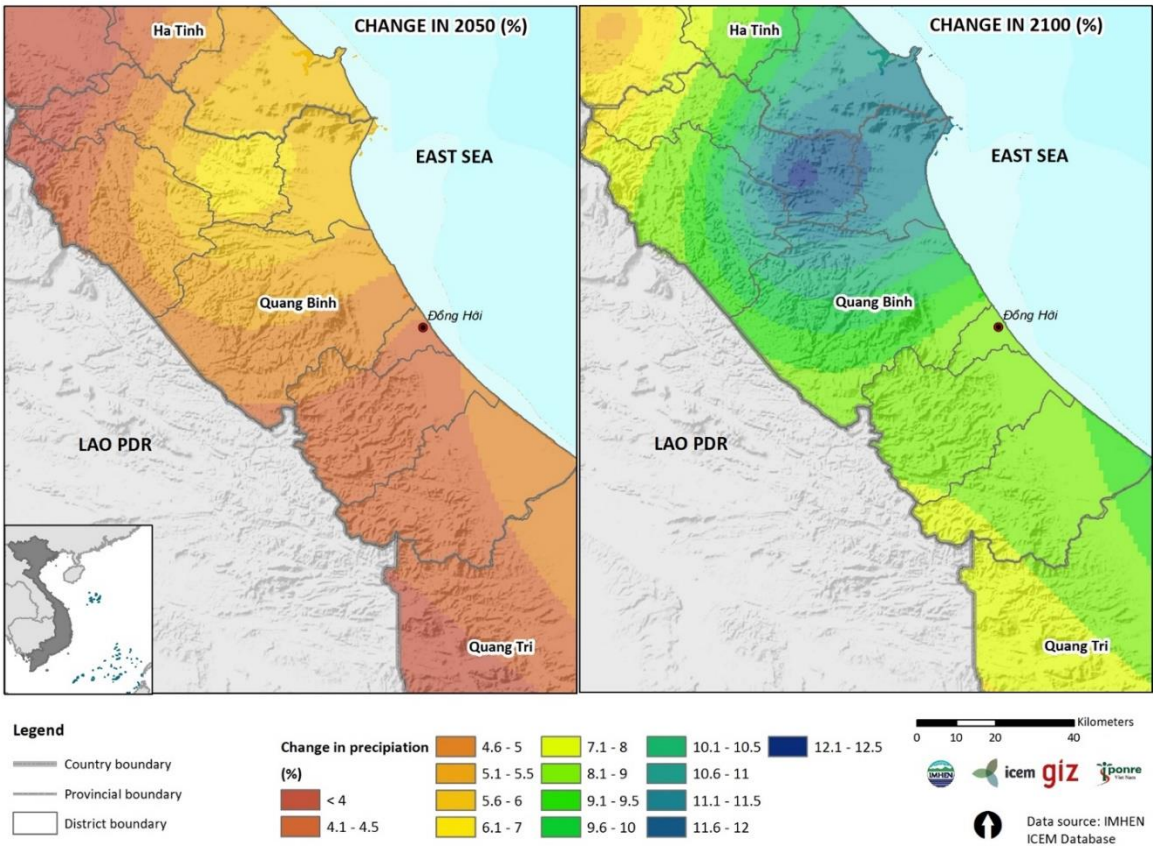
At the moment there is no information on coral reefs and sea-grass in Quang Binh on which to base a discussion of their role in protecting coastal infrastructure. The remaining areas of mangroves are also rather limited and degraded and will only provide very localized protection in some small areas. Sandy shorelines make up the largest proportion of coastal central and southern Quang Binh that is the most affected by storms. On these sandy shorelines, coastal dunes represent the last line of defense against erosion as well as limiting the landward intrusion of waves, oceanic inundations and wind and salt spray associated with storms. Where there is an inadequate dune, properties and facilities near the back of the beach may be subject to inundation from the ocean, and to structural damage from wave attack, undermining by foreshore erosion, and to sand drift, which is already a major problem in Le Thuy District and other places.

Climate change may increasingly create abnormal and hard to predict storm conditions which will affect passenger and cargo flights through Quang Binh province, increasing the flight operating cost and creating impacts on flight safety.

7.1.3.2. IMPACT OF ADDITIONAL AND MORE INTENSE RAINFALL IN THE RAINY SEASON, AND MORE DAYS WITH >50MM RAINFALL

With the changes in weather in the future, overall rainfall will increase in the rainy season and will be more intensely concentrated in a shorter period, with the number of heavy rainfall days also increasing. By 2050 there may be 4-8% more rain in the period of June-August and by 2100 this could rise to 10-12%. The increase will not be evenly distributed across the province (see Figure 7.2).

Figure 7.2: Changes in Precipitation (June-August) in Quang Binh 2050 and 2100



7.1.3.3. IMPACTS ON AGRICULTURE, FORESTRY AND FISHERIES

Periods of prolonged drought followed by sudden heavy rainfall are already a commonly experienced weather pattern in Quang Binh. The resulting sudden influx of rainwater into estuaries can cause a sudden drop in salinity with severe impacts on the brackish and salt water aquaculture sector of the province as shrimps and other aquatic species cannot tolerate the sudden shock, which can cause mass die-offs. This pattern is normally more pronounced when an El Nino period is rapidly followed by a La Nina period, and there have been suggestions that the El Nino-La Nina cycle may happen more frequently even more intensely under climate change scenarios.

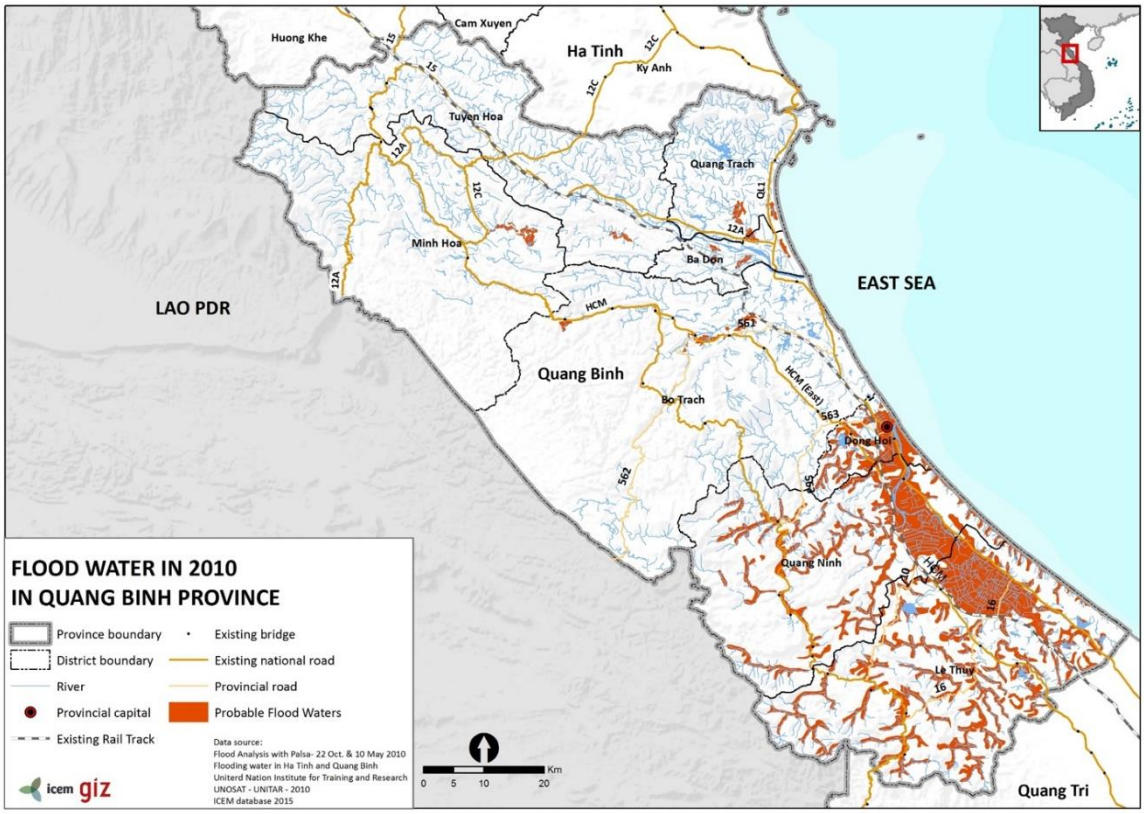
Some drought-stressed crops then exposed to sudden large amounts of rain that leads to rapid growth have a tendency to accumulate hydrogen cyanide (or prussic acid). This can be particularly true for cassava and also for maize, and can be very harmful to people. Cases of people dying after consuming cassava with high levels of prussic acid have been reported from Kenya and the Philippines (UNEP, 2016).

Aflotoxins, molds that can affect plant crops and can cause liver damage and blindness in humans, are also spreading to more areas as climate changes causes these kinds of shifts in weather patterns (UNEP 2016).

Heavy rains can cause devastating flooding of late-summer rice as it is approaching harvest time.

Acacia plantations cover large area of Quang Binh. Short term harvesting cycles (as well as conversion of natural forest to plantations or agriculture, together with illegal logging), contributes more rapid run-off and greater erosion in sloping upland areas, causing flash-flooding in upland areas to happen even more rapidly and more frequently, and shallow landslides to become even worse as watershed forests do not have enough trees to retain soil and slow down run-off. In the 2010 floods, the volume of soil and dirt swept away reached 1,689,000m^3. Without changes to plantation management practices, we could see even larger amounts being swept away by heavier rains in the future.

Figure 7.3: Partial mapping of 2010 floods



7.1.3.3.1. Impacts on natural ecosystems

The natural terrestrial forest of Quang Binh are moist evergreen formations. Additional heavy rainfall in the rainy season is not likely to have a major impact - especially when the forest is over limestone areas where the water drains very quickly. In some low-lying areas some species may not tolerate extended waterlogging, and may slightly shift their preferred area, but this will not have a noticeable effect on the forest as a whole.

Extensive long-duration floods can cause death of mangrove trees if they are submerged for too long. The remaining mangrove areas are very small, so this could be a significant impact on the remaining mangroves.

Heavy rainfall causes increased inflow of freshwater into estuaries changing the salinity profile which will change distribution of brackish water species. But this will most likely only be a temporary change each time a heavy rainfall event occurs.

7.1.3.3.2. Impact on rural and urban settlements and infrastructure

The topography of Quang Binh means that flash floods in upland areas and widespread inundation in lower lying areas, with all the associated impacts that go along with these, will also be increased with heavier rains resulting from climate change. Areas expected to suffer from flash floods and floods are listed in Box 1.

According to Quang Binh's Climate Change response and Action Plan 2011-2015, the residential areas and infrastructure in rural areas will continue to suffer from heavy rainfall and flash floods, particularly Tan Hoa, Hoa Tien, and Yen Hoa (Minh Hoa district); Van Hoa, Tien Hoa, Mai Hoa, Chau Hoa, Duc Hoa, Thach Hoa, Phong Hoa, Dong Hoa, Thuan Hoa, and Kim Hoa commune (Tuyen Hoa district); communes near the Gianh River in Quang Trach district (Quang Tien, Quang Trung, Quang Hoa, Quang Loc, Quang Van, Quang Hai, Quang Tân, Quang Thuy, Quang Minh, Quang Son, Canh Hoa, Phu Hoa); Bo Trach district (Son Trach, Hung Trach, Lien Trach communes); Dong Hoi City (Duc Ninh Dong district, Duc Ninh commune); Quang Ninh district (Tan Ninh, Hien Ninh, Duy Ninh, and Ham Ninh commune) as well as central communes in Le Thuy district.

In addition, Thuong Hoa, Trong Hoa, Minh Hoa, and Hoa Hop communes (Minh Hoa district); Kim Hoa, Thach Hoa, Duc Hoa, Phong Hoa, Chau Hoa, and Van Hoa communes (Tuyen Hoa district); Canh Hoa, Phu Hoa, Quang and Hop communes (Quang Trach district); Phuc Trach, Son Trach, and Hung Trach communes (Bo Trach district); Truong Son and Truong Xuan communes (Quang Ninh district) and Lam Thuy, Kim Thuy, and Truong Thuy commune (Le Thuy district) will have increasingly high risks of flash foods.

Text Box 1: Areas suffering from heavy rainfall and flash floods

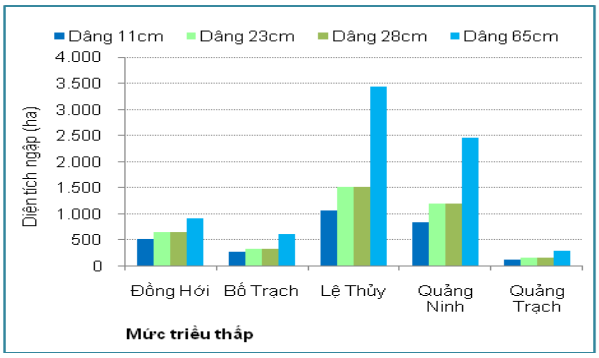
Quang Binh has over 140 reservoirs of various sizes. With increasingly concentrated rainfall in the rainy season, many may not be able to store the full volume of water flowing into them and may be at risk of failure. This could be the case for Vuc Tron, and Tien Lang reservoirs (QuangTrach), Cam Ly and An Ma (Le Thuy), Be (Tuyen Hoa), Vuc Noi and Da Mai (Bo Trach), Phu Vinh (Dong Hoi city), posing significant threats to areas downstream of these reservoirs.

Increased heavy rainfall will threaten to damage many parts of the railway line running through Nam Ly district, Duc Ninh commune (Dong Hoi city), and Mai Thuy commune (Le Thuy district) are at risk of flooding. Landslide risks on roads in mountainous areas will also be increased.

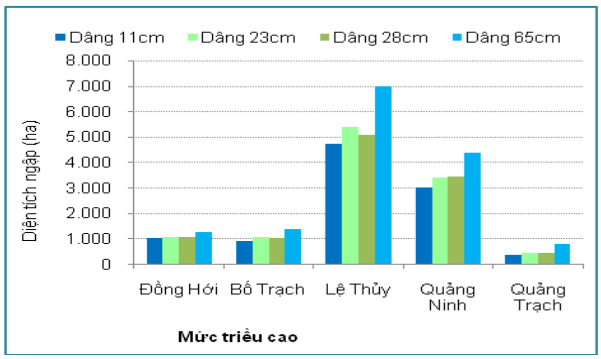
7.1.3.4. IMPACTS OF SEA LEVEL RISE, SALINIZATION AND COASTAL EROSION

According to different climate change and sea level rise scenarios for Quang Binh, inundated areas will evolve as follows during 2020-2100:

Figure 7.4: Inundation caused by sea level rise in Quang Binh - Scenario B1

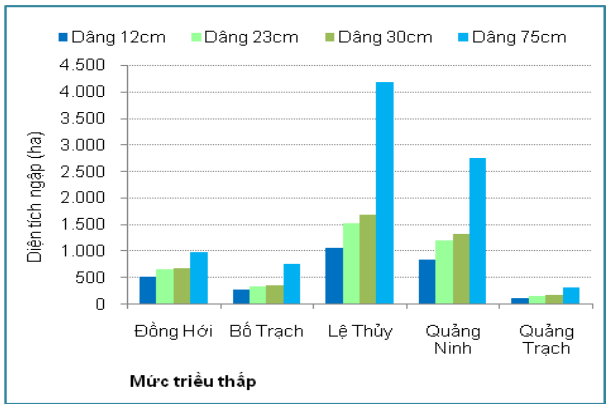


At low tide

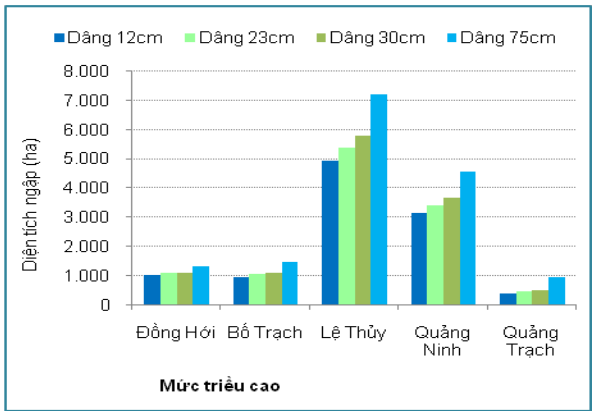


At high tide

Figure 7.5: Inundation caused by sea level rise in Quang Binh Scenario B2

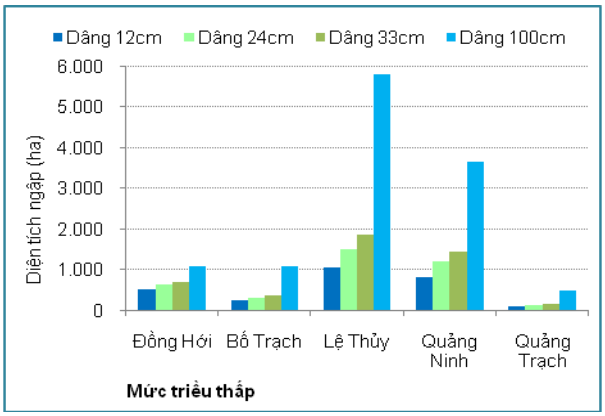


At low tide

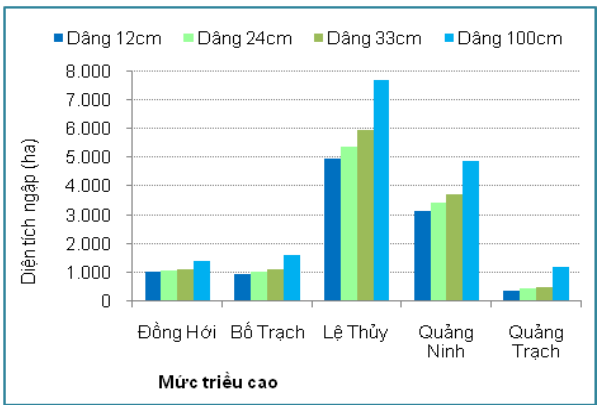


At high tide

Figure 7.6: Inundation caused by sea level rise in Quang Binh - Scenario A1FI



At low tide



At high tide

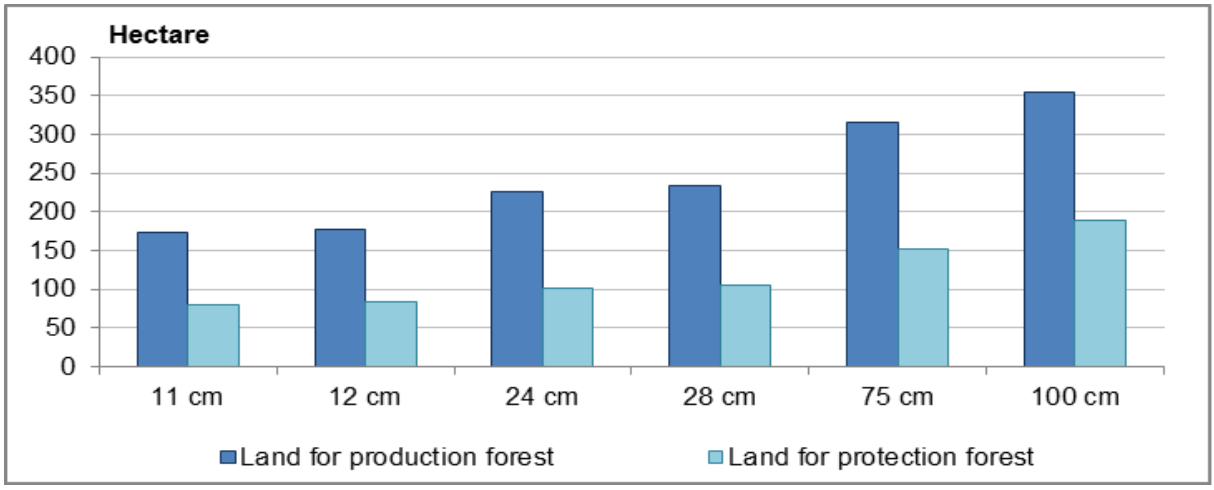
Under the low emissions scenario (B1): inundated area will cover 0.34 - 1.23% of the province area by 2020; 0.47 - 1.41% by 2040; 0.47 - 1.36% by 2050 and 0.95 - 1.83% by 2100. Under the medium emissions scenario (B2) inundated area will increase from Scenario B1 but not significantly: inundated area will account for 0.34 - 1.29% by

2020; 0.47 - 1.41% by 2040; 0.52 - 1.50% by 2050 and 1.11 - 1.91% by 2100. Under the high emissions scenario (A1FI): inundated area at high tide levels will account for up to 1.29% of the province by 2020 and 2.07% by 2100. The majority of the inundated areas will occur in rice cultivation land, urban land and residential areas, as well as in aquaculture land. Inundated areas in Dong Hoi will be the lowest in terms of volume share, but highest in terms of value share.

7.1.3.4.1. Impacts on Agriculture Fisheries and Forestry

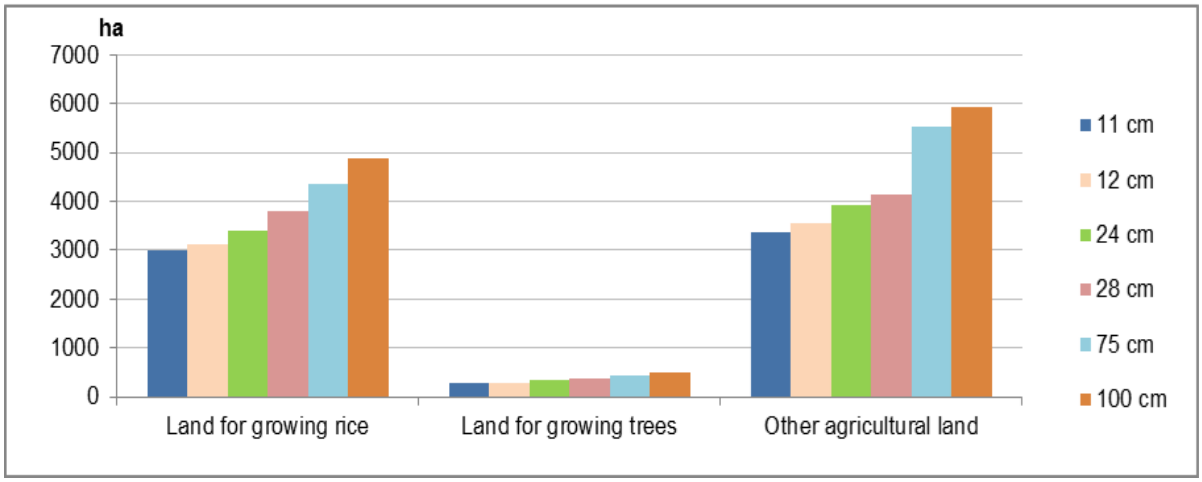
It is forecasted that the most seriously affected area will be the major lowland plain along both banks of the Nhat Le River. This area has many small river branches and the East Sea direction is blocked by high sand dunes along the Nhat Le River. As sea level rises, many coastal fishing villages will disappear, as will some of the Casuarina protection forest ecosystems in Le Thuy and Quang Ninh.

Figure 7.7: Area of forestry land to be submerged by sea level rise



Inundation caused by sea level rise will cause paddy fields along river basins to be seriously salinized, affecting agricultural production.

Figure 7.8: Inundated agricultural land under different scenarios of sea level rise



Sea level rise will foster increased saline intrusion, freshwater and saltwater boundaries will be changed, and saline areas will widen to Chau Hoa, Mai Hoa, and Tuyen Hoa districts. The areas available for fresh water aquaculture in Le Thuy, Quang Ninh and Quang Trach will be reduced. At the same time, sea level rise will facilitate the increased development of brackish and salt-water aquaculture, while the farming area could move deeper into the mainland. Some communes such as Ham Ninh and Duy Ninh (Quang Ninh District); as well as Lien Thuy and Xuan Thuy (Le Thuy district) could change their major land use patterns from cultivation to aquaculture.

7.1.3.4.2. Impacts on Natural Ecosystems

In estuarine and coastal areas, sea level rise will alter the dynamic balance between river and ocean. The inter-tidal area will change, as will the balance of sediment erosion and deposition processes in river-mouths and along the banks of estuaries. The exact amount of inter-tidal habitat lost due to sea level rise in any areas will be determined by a complex combination of local geomorphology and tidal amplitude (Lovelock and Ellison, 2007). Sea level rise will also influence meso-scale habitat connectivity between adjacent estuaries and estuarine mangroves (Munday et al., 2007). Mangroves near Gianh and Nhat Le estuaries will die off in their present locations and will tend to retreat further inland in response to increased salinity and sea level rise. However, they may be impeded by physical barriers including dykes, saline intrusion barriers and other infrastructure.

Coral reefs and sea-grass beds both exist at specific depths appropriate to the level of sunlight penetration they require in the waters they are living in. Sea level rise reduces the amount of sunlight reaching them and therefore reduces their ability to photosynthesize. However, sea-grasses can respond more quickly and grow-up slope to regain their n their "comfort zone" of preferred depth at a rate that exceeds the rate of sea-level rise. For slower-growing corals regaining their comfort zone will take much longer, and will not be able to keep pace with climate change (Bezuijen et.al. 2011). For the already degraded corals of Quang Binh, a combination of sea-level rise and increasing water temperature will likely lead to their complete disappearance.

Changes in inter-tidal habitat areas, changes in connectivity between estuaries and changes in mangrove distribution will in turn affect many important near-shore species dependant on these habitats.

For example, juvenile mackerel inhabit mangrove and intertidal wetlands (FAO, 2011) and they will be particularly vulnerable to the effects of sea level rise on these habitats, particularly as these mangroves are already degraded. Reduced connectivity of habitats between estuaries may also threaten the connectivity of populations of wild mackerel, also reducing their resilience. Blue swimmer crabs - an important species in estuarine and near-shore waters of Quang Binh migrate between estuaries and the open ocean during their adult, larval, and juvenile stages (Kangas, 2000). Their dependence on intertidal habitats during different stages of their life cycles therefore makes them vulnerable to sea level rise. Mussel and cockle

species depend on a specific set of depth conditions in which to grow, and they are therefore also vulnerable to changes in sea-level rise.

7.1.3.4.3. Impacts on urban and rural human settlements and infrastructure

When sea level rises by 12cm, most of the inundated areas will be in Duy Ninh and Gia Ninh (Quang Ninh district), Xuan Thuy and Kien Giang (Le Thuy district), Dong Phu and Duc Ninh (Dong Hoi city) and parts of Quang Trach and Bo Trach district, spreading to Ham Ninh, An Ninh, Tan Ninh (Quang Ninh district), Hoa Thuy, Hong Thuy, Loc Thuy, Phong Thuy, and Lien Thuy (Le Thuy district), Hoan Lao town (Bo Trach district) with high tides.

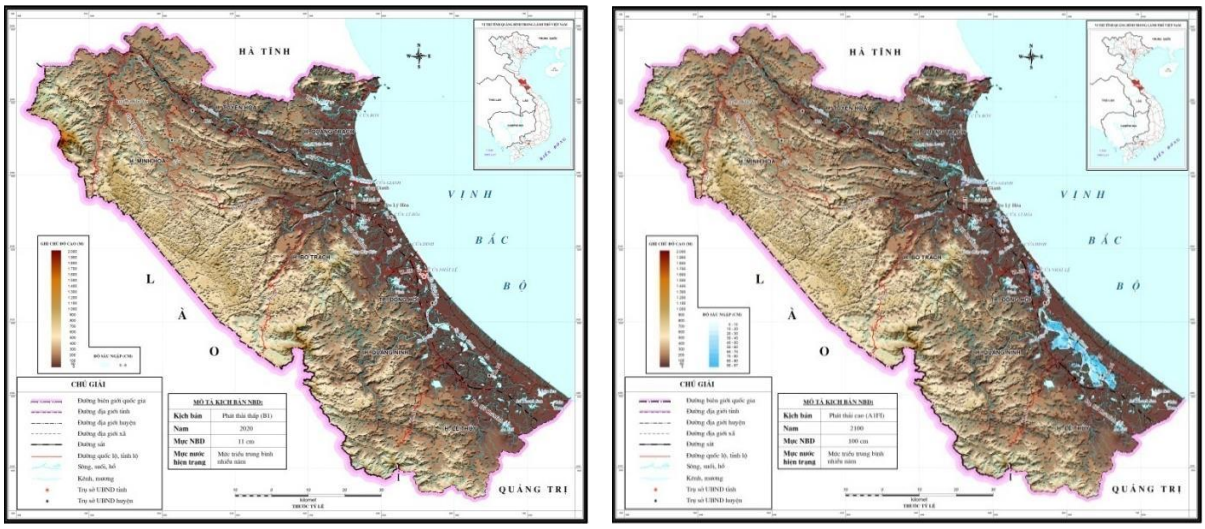
When sea level rises by 24cm inundation will occur in the same places, but covering larger areas, mainly focused on communes along the Kien Giang River in Quang Ninh and Le Thuy districts. Hoan Lao town will only be inundated during high tides in 2020, but by 2040 it will be inundated on an on- going basis even during medium tidal level.

When sea level rises by 33cm: Le Thuy and Quang Ninh districts will be most affected, with the most extensive inundated areas amongst all districts. Most of this inundation will happen in Duy Ninh, Ham Ninh, Tan Ninh, Hien Ninh, An Ninh, Xuan Ninh, Hoa Thuy, An Ninh, Phong Thuy, Lien Thuy, Loc Thuy, and Kien Giang town.

When sea level rises by 100cm, Quang Ninh and Le Thuy districts will still have the highest amount of inundated areas in the province. Compared to the 33cm scenario, inundated areas of Le Thuy will be 3 times greater. Inundated areas in Dong Hoi City, Bo Trach and Quang Trach districts will also increase. Additional inundation will happen mainly in Duong Thuy, Phu Thuy, Vo Ninh and Gia Ninh. Duc Pho and My Chuong rivers will rise and inundate Duc Ninh, Phu Hai, Nam Ly, Dong Phu, and Hai Dinh in Dong Hoi city. By 2100, about one fifth of the area of Dong Hoi city will be inundated.

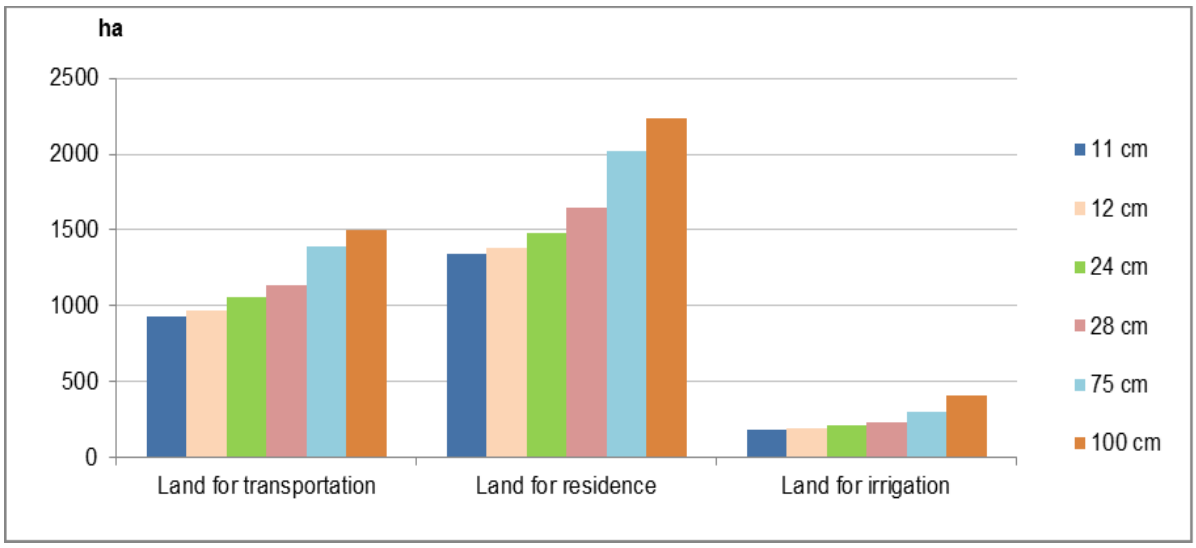
Along large parts of the coastline, thanks to the physical protection provided by high sand dunes, most of this area will not be subject to floods caused by sea level rise with only three exceptions: a small section in the southwest of Su Mountain in Quang Dong commune in Quang Trach district, Canh Duong and Quang Phu communes along the 2 sides of the Roon estuary, and the center of Ngu Thuy Trung commune in Le Thuy district.

Figure 7.9: Maps of inundation caused by sea level rise - by 75cm and 100cm corresponding to 2050 and 2100 under scenario A1F1



Under sea level rise scenario A1FI, by 2100 some major transport routes will be inundated such as: provincial road 2 passing Bo Trach district, and the part of national road 1A passing Dong Hoi city, Bo Trach district, Quang Ninh, and Le Thuy. The concrete and steel bridges along national roads 1A, 12A, and provincial roads passing Quang Trach district, Bo Trach, and Le Thuy, including Gianh Bridge, Quang Hai Bridge, An Hoa and Nhat Le Bridge will all be severely affected.

Figure 7.10: Infrastructure land flooded under different sea level rise scenarios



Hon La seaport is strategically and economically important, receiving over 1 million tons of imports from China, and also responsible for transferring over 1.4 million tomes of products to Lao PDR. At present, at high tide period the water level has already reached the port edge, this means that under scenario sea level rise A1F1 by the year 2100, the port and its associated economic cluster will be flooded.

Developing seaside tourism is important for Quang Binh. According to future orientation by 2020, the province will develop luxury entertainment, resort and

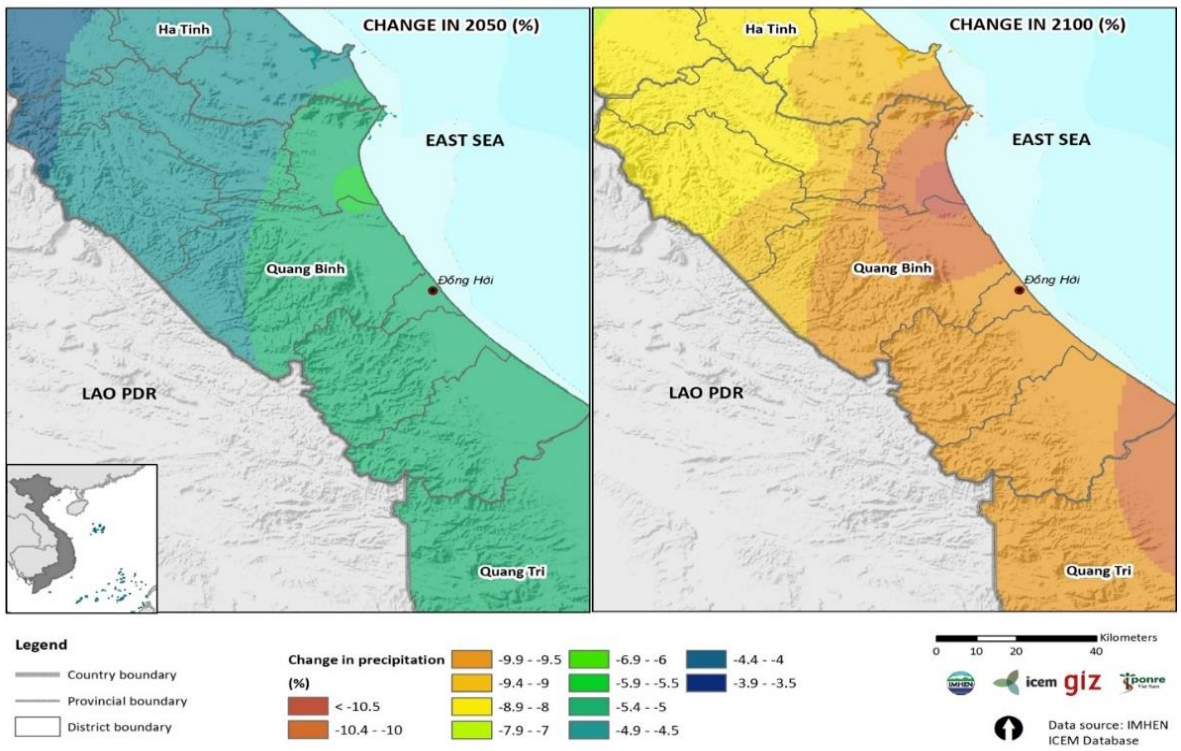
seaside tourism complexes in Da Nhay, Nhat Le - Quang Phu, Bao Ninh and Hai Ninh in order to attract domestic and international tourists. The first 18 holes of several planned golf courses are intended to be completed in 2016. However, due to the effect of climate change, the tourism sector will have to face the major challenge of sea level rise, as well as other climate change related impacts.

7.1.3.5. IMPACTS OF LONGER AND DRIER DRY SEASONS

By 2050, dry season rainfall during Mar-May may be reduced by 5-7%, and by 2100 there could be as much as an 8-10% reduction (Figure 7.11). The number of dry days will also increase (Figure 7.12). Reduced upstream rain, together with increased temperature that increases evaporation, results in water levels in reservoirs dropping to significantly low levels.

Extended droughts together with sea level rise and increasing salinization plus increased environmental pollution after storms and floods, will make provision of sufficient clean freshwater to meet daily consumption and production needs even more challenging. This will in turn affect production, socio-economic development and people's lives.

Figure 7.11: Changes in precipitation (March-May) in Quang Binh, 2050 and 2100



7.1.3.5.1. Impacts on Agriculture Forestry and Fisheries

The interaction between droughts and sea level rise will be an important factor that will result in salinization of surface and ground water across the whole province becoming an even more serious problem. Places already heavily affected by salinization include the Kien Giang river from Nhat Le estuary to Xuan Thuy commune

(Le Thuy district), and the estuaries of Ly Hoa, Roon, Dinh, and Gianh rivers. Salinization results in further freshwater shortages for agricultural production. High levels of evaporation (960- 1,200mm p.a.) coupled with poor ability of coastal sandy land to retain water causes the many coastal areas to already have difficulty in securing sufficient water supply when faced with extended droughts and salinization in estuaries progressively moving deeper inland. Such situations may be experienced more frequently under future climate change scenarios.

In addition, there is a growing annual water demand for sand-based aquaculture. On average, each hectare of aquaculture land would need 30,000m^3 freshwater every year. Thus, some 9,000,000m^3 would be needed for 300ha by 2020. The main water sources for sand- based shrimp farming come from local ground water. Although quite rich, ground water sources in Quang Binh are not evenly distributed at different depth levels. The coastal plain area has narrow but rich ground water sources, but these are usually salinized causing challenges for production and daily life. The midland area has deep ground water sources which are subject to exhaustion during the dry season.

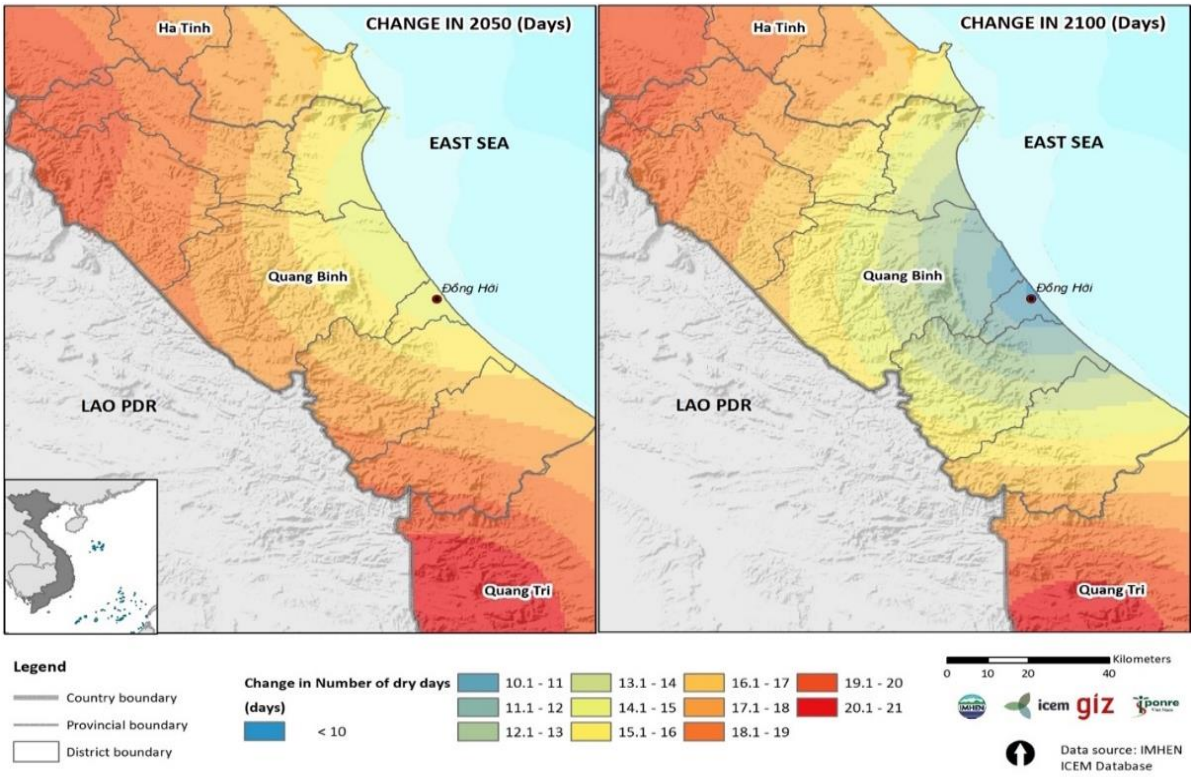
More frequent, intense and prolonged droughts will affect crop production, particularly for spring and early summer rice and other crops.

A longer and drier dry season (together with increased temperature number of very hot days - see next section) will increase the risk of fire in tree plantations. Over a 10 - year period (2000 - 2010), 310ha of plantation forests in Quang Binh were damaged by forest fire (although these were mostly in plantation forests not natural forests). From 2005 - 2010 alone, 45 fires happened with almost 170ha damaged, including pine, acacia, rubber, Dalbergia tonkinensis and Melaleuca quinquenervia, with a total damage of over VND 1 billion. As an example, in the dry season of 2010, at Quang Thuy commune, Quang Trach district, the temperature reached 42 degrees, and in conjunction with the dry and hot wind coming from the west, this sparked a forest fire destroying 5 hectares of ready-to- harvest pine forest. At the same time, at Son Trach commune, Bo Trach district, 2 serious forest fires also occurred. Greater precautions will have to be taken in management of tree plantations to prevent economic losses caused by increased fire risk.

7.1.3.5.2. Impacts on Natural Ecosystems

A longer and drier dry season (together with increased temperature number of very hot days - see next section) will increase the risk of forest fire. Despite this, forest fires are not presently considered as a major problem in Quang Binh, and are not seen as a threat to natural ecosystems. But with climate change bringing prolonged dry periods as well as higher temperatures and more very hot days, combined with the likelihood of more frequent and intense El Nino cycles in the future, thousands of hectares may be at much higher risk, and forest fires will become a matter that warrants increased care and attention.

Figure 7.12: Changes in number of dry days in Quang Binh, 2050 and 2100



7.1.3.5.3. Impacts on Rural and Urban Settlements and Infrastructure

In recent years, drought has appeared unexpectedly and in more extreme forms, and already most reservoirs in Quang Binh are not able to supply sufficient water for agricultural production in severe droughts. For example, in 2014 and 2015 rainfall decreased by about 60% and 80% respectively against average amounts, and reservoirs only filled to 30-40% of their capacity in 2014 and 60% in 2015.

According to the "Water resource plan for Quang Binh by 2020", based on water consumption norms by sector and predicted population and economic growth, water demand for residential, industrial and agricultural use the province has been estimated at 1,655,739m^3/day for 2015 and is expected to rise to 2,179,376m^3/day by 2020. When sea level rises by 100cm (by 2100), it is estimated that 100,000 people living in coastal districts will have serious freshwater shortage during the dry season.

7.1.3.6. IMPACT OF INCREASING TEMPERATURE AND INCREASING NUMBER OF VERY HOT DAYS OVER 35 DEGREES

Changes in rainfall patters (more and heavier rain in the rainy season, less rain and longer dry periods and dry days in the dry season) as well as changes in storms and sea level rise cause types of impacts that are mostly seen as disasters (flash floods, floods, costal inundation, droughts). When considering changes in temperature however, sometimes intense heat waves can also be considered as a type of disaster, but more importantly we need to consider the long-term cumulative impacts of temperature increases on the productivity of key species in agriculture forestry and fisheries, as well on natural ecosystems. While these type of changes are

not as sudden or dramatic, and do not appear as crises requiring the immediate attention of authorities, over the long-term they will have very significant impacts on the economy of the province and the well-being of its residents.

Average daily maximum temperature during June-August may increase by almost 2°C by 2050, and by almost 4°C by 2100 (Figure 7.13) and the number of very hot days (>35°C) may increase by up to 40 days by 2050, and up to 75 days by 21000 (Figure 7.14).

Figure 7.13: Change in average daily max temperature (June-August) in Quang Binh

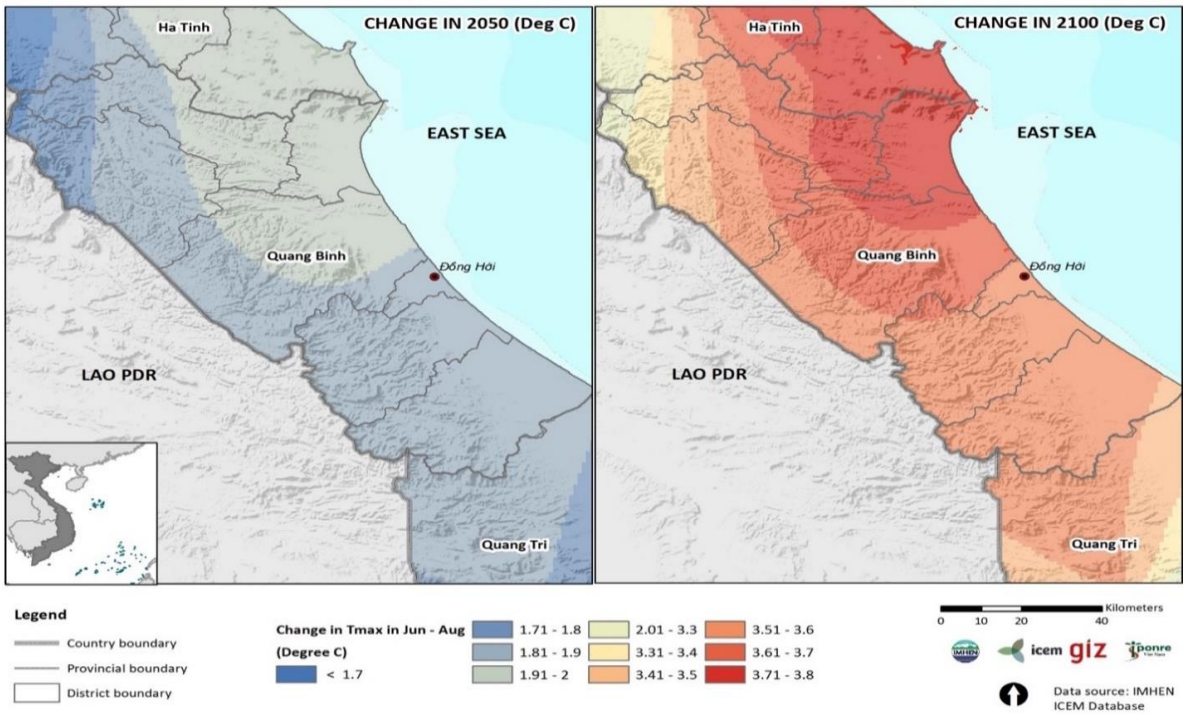
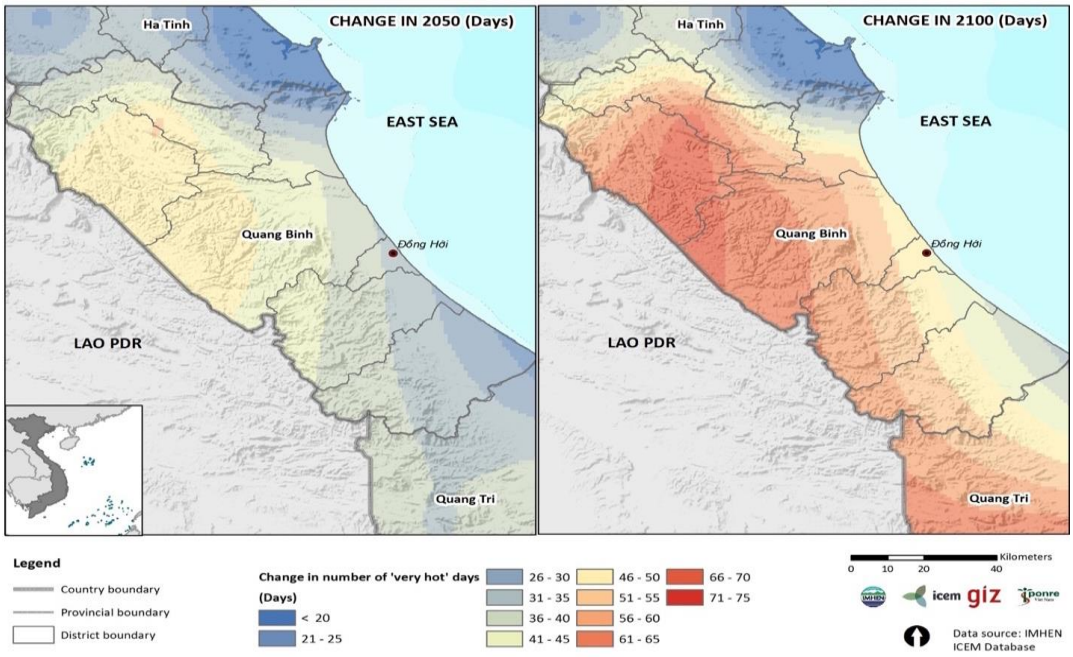


Figure 1.14: Changes in number of hot days in Quang Binh in 2050 and 2100



7.1.3.6.1. Impacts on Agriculture Forestry and Fisheries

Annual mean air temperature increased by 0.4°C from 1961 to 2009 in Quang Binh. According to IPCC, in tropical regions, the increase of average temperature has negative impacts on productivity of most kinds of grain and wet rice. If temperature increases by 1°C, maize productivity will decrease 5 - 20% and it could drop by as much as 60% if temperature rises by 4°C. If the temperature increases by 3°C, crops in all areas will face severe threats (Fisher et al., 2002 and Rosenzweig et al., 2001).

In many places rice is already grown at the upper end of its preferred temperature range (22 - 28°C) and in tropical Southeast Asia it has been clearly demonstrated that increasing temperature reduces rice yields (Feng et al 2004). Yield could decline by 10% for each additional degree rise in temperature. The combination of increased temperature and more frequent droughts is likely to make rice growing less and less successful for Quang Binh's farmers in the future. Meanwhile, tuber crops (such as sweet potato and cassava) may enjoy yield increases, as they tend to develop a higher root tuber/trunk ratio with higher temperatures.

Quang Binh province plantation forestry sector mainly focuses on tree species such as acacia, pine, and rubber. Based on temperature, rainfall and altitude comfort zones, 7.53% of the province is currently rated as very suitable for growing pine, 35.23% as suitable and 57.2% as less suitable. As mean temperature increases over time the area suitable for pine will shrink and will shift towards areas of higher elevation where temperatures are still within its comfort zone.

Acacia is a large genus with over 1,300 species widely distributed throughout the tropics and subtropics. Most species are found in the southern hemisphere and the main centre of diversity is located in Australia and the Pacific. Vietnam has over 400,000 ha of Acacia plantations, including over 220,000 hectares of clonal Acacia

hybrid (*Acacia mangium* × *Acacia auriculiformis*) which is now one of the main species for industrial plantations (Kha 2001). Acacia hybrid is found where mean annual temperatures are 12 - 35°C, annual precipitation is 1,200 - 1,850 mm and elevation is 50 - 350 m (Vozzo 2002). In Quang Binh it is grown well within its comfort zone for temperature and elevation, but in areas where rainfall may be somewhat at the higher end of its preference range.

Climate change induced temperature increases and increases in the number of hot days may not have much impact on acacia directly. However increased temperatures may increase the frequency of pest outbreaks, which are are difficult to control, especially in the remote and mountainous areas such as Tuyen Hoa, Minh Hoa, and Quang Ninh.

Brackish-water aquaculture

The pond and cage aquaculture sector makes an important contribution to the provincial economy, and in recent years the aquaculture area has been expanding - especially for commercial shrimp production on sandy soils. Water temperature in estuaries were cage aquaculture is practiced, and water temperature in shrimp ponds both depend completely on the local weather conditions. In the summer, when the air temperature increases in conjunction with the "Lao wind," and water in the river is at a low level so it heats up more quickly, the scorching heat drives up the ambient temperature to levels which may be beyond the tolerance limits of many commercial cage fish species.

Grouper is the most popular cultured fish in Southeast Asia, largely due to their fast growth, acceptance of dry pellet food, successful spawning in captivity, high feed efficiency and very high market value (Boonyaratpaliin, 1997). Grouper cultured in the South China Sea include orange-spotted grouper (Epinephelus coioides), Malabar grouper (E.malabaricus), giant grouper (E. lanceolatus), tiger or brown-marbled grouper (E. fuscoguttatus) (Kongkeo et al., 2010). Grouper can only be cultivated in cages, with seed mainly collected from the wild, although limited artificial spawning and larva rearing techniques have been developed since 1993 (FAO, 2011).

Seabass (Lates calcarifer) - known as Barramundi in some parts of the Asia-Pacific region, can be cultivated in earthen ponds, cages and pens (FAO, 2011). Seabass are a fast growing fish, tolerant of many coastal conditions such as fluctuating salinity and turbidity, as well as rough handling and the crowded conditions of aquaculture cages (Boonyaratpaliin, 1997) Snapper species (Lutjanus spp.) command a high price similar to both Grouper and seabass species, and are also popular.

Temperature during larval rearing of seabass and grouper have a great effect on health and survival of both of these species (Boonyarat- paliin, 1997). It has been shown that cultured groupers can tolerate temperatures from 22-28 °C, and at temperatures under 15°C they will not feed (Boonyaratpaliin, 1997). There is limited information available on exact upper thermal tolerances on any of the seabass,

grouper or snapper spp. However, according to Katersky and Carter (2005) seabass can be cultured over a wide range of temperatures. Seabass appear to be more tolerant of higher temperature than other cultured species, with an increased survival rate of 66.4% from 11.3% when temperatures were increased from 27-29°C to 34-35°C in experiments by Ruangpanit and Kongkumnerd (1992). In summary there is very little scientific information on which to conduct an assessment of how increased temperatures will impact cage aquaculture, however overall it seems that seabass may be more resilient than other commonly cultures species.

Reduced river flows in the dry season combined with sea level rise will increase salinity further up the estuaries, increasing the area suitable for brackish water cage fish aquaculture.

Theoretically at least, higher temperature means that shrimp can grow faster and to a larger size. However, several other factors associated with increased temperature can counteract this. Firstly, with higher temperatures evaporation of water from shrimp ponds increases, concentrating the salinity and changing the pH and this can have negative impacts on shrimp growth. Secondly higher temperatures encourage algal growth in the ponds and this can deprive shrimp of oxygen. Thirdly, at very high temperatures shrimp stop eating their food. Finally, disease is more prevalent with higher temperatures, and outbreaks of Early Mortality Syndrome (EMS) can be more devastating (Handisyde, et. al., 2006). Prawn farmers will need to manage their ponds more carefully, and should consider planting trees around their ponds to both provide physical protection, and shade to reduce surface water temperature.

Freshwater aquaculture

Fresh water cage fish aquaculture which is mainly concentrated in the upper areas of the Gianh River in Minh Hoa commune, as well as in Le Thuy, Quang Ninh and Quang Trach, will suffer similar impacts of increased temperature. Alternating the raising of fish in rice fields with one crop of paddy rice, is practiced in some areas where rice yields are relatively low. This activity will similarly be impacted by high water temperatures and increased evaporation in the dry hot season. Farmers may shift to do it in the rainy season instead but in this case have to put protective nets around the fields to avoid the fish being flushed out during floods.

Freshwater pond aquaculture involves a number of species, but the snake-head fish is the most abundant in Quang Binh. Snake-head fish are very resilient to poor conditions including high temperature, low water levels and low oxygen supply.

In the last 10 years it has increasingly being grown in simple ponds dug in sandy areas where the water table is very high. While the net balance between annual rainfall and evaporation in the coastal area would not leave enough water in the pond for aquaculture in normal circumstances, the high water table means water simply seeps into the pond. Every couple of months the farmers pump out the waste water from the ponds, and new ground water seeps in to replace it However some reports have suggested that with wide-scale adoption of this approach in the last

decade, the water table is already starting to decline and pond water depth in some places - e.g. in Ton Hai village of Nguy Thu Bach commune - is becoming too shallow to successfully raise the fish

Near-shore fisheries

Small pelagic species including mackerel, squid, sardines and anchovies are important to the near-shore fishing communities of Quang Binh Province. There is evidence that climate trends affect the production of the species that make up some of the major inshore pelagic fisheries of the world, and we should expect to see similar climate change effects on fish production in Quang Binh as well. The type of climate variability or change that affects each species varies depending on the aspect of climate that is important to the life history of the particular species. Although ocean conditions in spawning and first feeding areas play a critical role, unfortunately, the precise mechanisms linking climate trends to production are poorly understood. While we can expect that major fluctuations in the abundances of key species and their fisheries will occur in the future, we still lack an ability to forecast changes in trends that are useful to management (Beamish, 2008)

Analysis of overall trends in proportion of different species making up the catches of inshore fishermen compared with climate changes, are not yet available, either for Vietnam in general of for Quang Binh in particular, but we may expect to see patterns similar to what is happening in other nearby countries. As an example, in Korea, in recent years the portion of small pelagic fish species (anchovy, Japanese sardine, mackerels and common squid) has been increasing, and now makes up 60 to 70% of the total catch. Common squid has been increasing with warming waters since the 1990s, and alone now accounts for 20 to 25% of the total catch (Kim and Kang, 2000).

Sardines and Anchovies

Sardine and anchovy populations are well recognized as responding synchronously and rapidly to changes in their ocean environment (Kawasaki, 1983). In many ecosystems around the world, abundance of anchovy follows trends that are opposite to those of the sardine. In the 1950s and 1960s, anchovy abundance was large when sardine abundance was small. This pattern switched in the late 1970s and 1980s, reversing again in the 1990s (Chavez et.al., 2003). It is expected that similar patterns might be seen in Quang Binh.

The alternating cycles of abundance seem to occur in response to large-scale, climate changes relating to a combination of ENSO events and Pacific Ocean decadal oscillations. Sea surface temperature (SST) effects on early growth rates may be the key factor, with anchovy responding better to increased temperature (Takahashi et al., 2004; Takasuka et al., 2004, 2007). Seasonal and long-term trends of the size of yolk-sac larvae, embryonic mortality, egg production, and spawning stock biomass of anchovy have also been correlated with changes in spring warming, summer cooling, and zooplankton biomass (Kim, 1992; Kim and Lo, 2001).

Variation in oceanographic conditions also affects the adult migration route and the distribution of eggs and larvae.

Mackerel

In general, rapid or dramatic increases in temperature above normal maximum temperatures are expected to have significant effects on overall viability of some pelagic fish populations (Munday et al., 2008). Fish are particularly sensitive to temperature changes during their early life histories. Warming can have either a positive or negative effect on egg production, depending on whether the target fish species is close to its thermal optimum. An increase in temperature of 1-3°C could shorten the incubation period of eggs for pelagic spawning (Munday et al., 2007).

The Indo-Pacific Mackerel (Rastrelliger brachysoma) is a shallow pelagic species of major economic and food security importance. Mackerel spawn offshore however after egg hatching juvenile mackerel travel onshore via currents to develop in mangrove/wetland environments (Venkataraman, 1970). There is very little information about the temperature specific impacts of climate change on this species and their adaptive capacity, however, a study by Pradhan and Reddy (1962) carried out over 50 years ago, shows that mackerel may well be highly vulnerable to changes in temperature. As seas warm, they may be expected to shift their distribution to stay within their temperature comfort zone.

Squid

Squid have a flexible life history which is a result of the highly responsive nature of their growth to temperature changes (Pecl and Jackson, 2008). Tropical squid that grew through periods of warming water temperatures grew 9% faster than squid that grew through periods of cool water temperatures (Jackson and Moltschaniwskyj, 2002). It has been suggested that squid will thrive in the face of a global warming of the seas, with increased growth rates, accelerated life histories and rapid turnover in populations, which could potentially lead to population expansion at the expense of slower growing teleost competitors (Jackson, 2004). However, under continued temperature elevation there will likely come a point where growth rates start to decrease as metabolic costs continue to escalate and growth potential is subsequently reduced (Pecl and Jackson, 2008).

Blue Swimming Crab

The Blue swimmer crab (Portunus pelagicus) also known as sand crabs, are an economically very important species which are widely caught and cultivated across the Indo-Pacific region (FAO, 2011). They are ideal aquaculture species due to their ease and frequency of spawning in captivity (Andres et al., 2010). They are found in estuaries and inshore marine waters in the wild (Kangas, 2000) and constitute an important species in near-shore fisheries in Quang Binh. They are opportunistic, bottom-feeding carnivores and scavengers which means they will be less sensitive to climate related impacts on their food supply than more specialist feeders.

Extremes in water temperature are likely to have significant effects both on survival of larvae and adult blue swimmer crabs as well as affecting growth and reproduction (Hutchings et al., 2007). A sea surface temperature rise would likely increase developmental rate overall, resulting in a net increase in productivity. As with other marine and freshwater species however, these increases would only occur within the thermal tolerance of the individual species. For blue swimmer crabs this has been shown in laboratory settings to be around 39.5°C (Neverauskas and Butler, 1982). Specific thermal tolerances for blue swimmer crab in the wild in Quang Binh are however completely unknown.

7.1.3.6.2. Effects on Natural Ecosystems

Coastal Ecosystems

Coastal systems supply disproportionate ecological services and benefits to human society (Barbier et al., 2011), and coastal waters have warmed faster than those of the open oceans (Lima & Wethey, 2012).

Effects of temperature related effects on coral reefs are highly visible and extensively documented (Veron et al., 2009). Small increases (1-2°C) in sea temperature above the long-term summer maxima destabilizes the relationship between host corals and their symbiotic zooxanthellae algae on which they rely for energy and growth (Veron et al., 2009), resulting in coral bleaching. Increased water temperature also has the potential to affect both the reproductive output of parental colonies, and the success of early coral life stages in corals (Hoegh-Guldberg et al., 2007).

Up to a certain point, higher water temperature may increase the growth rate of sea-grasses. However, sea-grasses have thermal tolerance limits beyond which mortality occurs. Sea-grass species thermal tolerance limits for Quang Binh are unknown. Similarly the different tree species making up mangrove forests, each have their own specific tolerance limits, but these are largely unknown.

Terrestrial Ecosystems

Rich natural forest areas of the province are mainly concentrated in 3 main areas: PNKB National Park, the area from Khe Ve to Mu Gia in Minh Hoa, and parts of Lam Thuy in Le Thuy district next to the border with Laos. The species composition of the different forest types of both tropical and sub-tropical moist evergreen broadleaf forests, as well as coniferous forests, found at different altitudes, and either over limestone or not over limestone is determined by the range of preferred conditions (comfort zones) of each of the individual species that make up the plant community in each forest type. The response of species to increased temperature will be to shift either by altitude or latitude to a place where the climate conditions are still within their comfort zone. In general, for every one degree change in temperature a move of between 100 - 200m to higher altitude (depending on moisture conditions) or a move of 35km towards the poles is required to find a place with the same original temperature conditions.

The large areas of forest remaining in the province provide a good opportunity for the various different types of forest habitat to be able to persist despite future temperature increases, but it will be important to maintain both latitudinal and altitudinal corridors connecting different forest patches across the landscape to facilitate the natural shifts in species distribution in response to temperature change.

7.1.3.6.3. Impacts on urban and rural settlements and infrastructure

Urban centres create well known heat island effects, having temperatures that are already 2 - 3 degrees higher than less urbanized areas. Increased temperature and increased number of hot days resulting from climate change may push temperatures in Dong Hoi and other towns to unbearable levels at certain periods. Heat stress can directly cause sickness and in some cases even death. It can also increase the frequency of other diseases. Very hot days can melt the tarmac on roads.

7.2 SUMMARY AND CONCLUSTIONS

According to plausible climate change scenarios for Quang Binh, we can expect the following major challenges to occur, all of which will become increasingly more pronounced as time progresses:

- Increasingly strong and more unpredictable storms will cause physical damage to aquaculture areas and crop fields as well as to human settlements and infrastructure along the coastline and throughout the lowland plains, but particularly in the central and southern parts of the province.
- Water turbidity caused by storms will impact coral reefs and sea-grass areas, and strong winds associated with storms will increase blowing and flowing sand as well as damaging rubber tree plantations if they are close to the coast.
- Increased rainfall in the rainy season, and increased number of days with very high rainfall will cause increased erosion, shallow landslides and flash floods in the upland areas, especially Minh Hoa and Tuyen Hoa and more widespread, more prolonged and more damaging inundation in the lowlands - particularly along both banks of the Gianh River in a number of communes in Quang Trach, Bo Trach, Quang Ninh and Le Thuy Districts.
- Rapid and massive inflows of water into reservoirs will also raise concerns about reservoir safety.
- Sudden drops in salinity in brackish water areas caused by massive inflows of freshwater will lead to large-scale die-off of brackish water aquaculture species and prolonged freshwater inundation may kill off mangroves - this will be an important challenge in the Gianh and Nhat Le estuaries.
- Sea-level rise will progressively inundate increasingly large areas, as seas continue to rise year after year, and will also result in saline intrusion penetrating further inland. Quang Ninh and Le Thuy will be severely impacted

before other distrits, and will be the most impacted under all SLR scenarios. It is expected that Ham Ninh and Duy Ninh communes in Quang Ninh as well as Lien Thuy and Xuan Thuy communes in Le Thuy will need to start to shift livelihoods from crop growing to brackish-water aquaculture before 2030.

- By 2100 Hon La seaport and its associated economic cluster as well as some major transport routes will be permanently inundated.
- A longer dry season with more dry days and more very hot days will increase risks of fires in both plantations and natural forests - particularly in Quang Trach and Bo Trach Districts.
- It will also result in increasing frequency and severity of droughts which damage crop production (especially spring and early summer rice) and will lead to problems in securing a year round water supply, especially in the coastal sandy areas of Quang Ninh and Le Thuy.
- Increased air temperature will stimulate some species to shift their distribution pattern to regain a temperature regime inside their comfort zone - either by moving further north, moving to higher altitudes or a combination of both.
- Sea water temperature increases will increase coral bleaching events, although sea-grass productivity may increase (up to a point) and temperature change impacts on mangroves are as yet unclear
- Productivity of squid, blue swimming crab, sea-bass and anchovy are likely to increase (up to some unknown threshold), while that of grouper, mackerel and sardine are likely to decrease as the sea gets increasingly warmer.

Without significant, concerted and continuous investments and efforts to address the key issues above, overall climate change is likely to slow down economic growth and negatively affect quality of life in Quang Binh. Natural resources will be more degraded, food production will be reduced, and the impacts of natural disasters will be magnified. The coastal and rural poor (including ethnic minorities in upland areas) with livelihoods most dependent on natural resources, will be the most vulnerable to these changes. In the worst case scenario, recent gains in poverty alleviation may be reversed. Consequently, labour migration, which is already significant may continue to increase, and social problems may become more prevalent. These issues must be given serious attention before it is too late. Key interventions should therefore include:

EbA interventions for sand dunes ecosystems and coastal forests

- An overall provincial management plan should be developed for the sand dune ecosystems of Quang Binh - this should include zoning of the sand dunes for different activities, and should identify core protection zones, as well as restoration zones in order to maintain the physical protection functions the dunes provide.
- Protection Forest planting on the landward side of the dunes should use a multi-species approach, not just casuarina - at the same time all remaining

natural native species coastal forests should be identified and mapped and a plan should be developed for management and restoration of these areas, as well as identifying new areas for planting a more diverse selection of native coastal species. Together these interventions will better control blowing and flowing sand. To support this, nurseries for native species should be established and training provided in propagation and care of a wide range of native coastal species.

- To address the issues of likely future water shortages in coastal areas, an assessment of the actual underground water supply in the sand dune ecosystem should be carried out, and compared with future projected water demand for all planned uses (golf courses, vegetable growing, aquaculture, domestic consumption).

EbA interventions for terrestrial forests and plantations

- For production forest that are acacia plantations, a gradually shift from short term harvesting cycles of around 7 years to longer cycles of around 15 years or more should be promoted, and harvesting at any age should be done in a larger number of smaller patches (rather than a smaller number of larger patches) that are separated from each other by sizeable non-harvested areas. Strips of non-harvested trees should be left every 50m or so on steep slopes and as a riparian buffers along water courses. All these interventions will help reduce erosion and land-slide risk that may become more severe with climate change. This in turn will reduce the severity of flash floods, of downstream inundation and of siltation and shallowing of reservoirs.
- More effort and resources should be focused on fire prevention in both natural forests and plantations, including education of visitors about proper disposal of cigarettes, effective use of fire-breaks, etc.
- Research should be carried out on temperature and rainfall "comfort zones" and thresholds for key natural forest and plantation timber species.
- Forest corridors connecting forest patches in the larger landscape should be identified and maintained along both altitudinal and latitudinal gradients to facilitate the movement of species over time in response to climate change.
- Restoration and improvement of degraded areas (and secondary forest where selective logging had previously taken place), including in the PNKB buffer zone and corridor areas, should use native species that are selected for their suitability to the future climate conditions.

Climate-smart Agriculture

- SRI rice farming should be further promoted in appropriate areas and production shifted from rice to less water intensive crops in areas with no or limited irrigation potential and likely to suffer from future droughts and water shortages.

- Crop calendars should be modified to account for changing climate, and rubber plantations located further inland.
- Studies should be conducted into the temperature and rainfall tolerances of key crop species. If continued production of some species will be unsuitable in the changed climate conditions, plans should be made to promote and support the introduction of alternative species more suited to the new climate conditions.
- Agriculture on steep slopes > 35% should be avoided; where it already takes place, promote soil and water conservation methods to maintain fertility while slowing down run-off and reducing erosion.

Climate-proofing urban and rural settlements and infrastructure

- A number of approaches to climate proofing transport infrastructure are already being implemented in Quang Binh, and these should be continued and expanded:
  - Widening of bridges to take account for increased rainy season river flows;
  - Raising the height of roads to take account of increased depth of future floods;
  - Increasing number and size of culverts under roads to increase transparency of roads to more frequent floods and thereby reduce flood damage to roads;
  - Planting shade trees along roads to reduce road surface temperature and prevent tarmac from melting on hot summer days.
- Employ eco-engineering options for slope erosion control in road construction.
- Ensure the protection of all remaining small lakes/wetlands within Dong Hoi City. They provide valuable flood management, water supply and purification as well as micro-climate regulation services. They should not be filled-in and built upon. Instead they can be developed for recreational, educational and scenic benefits.
- Apply SUDS (sustainable urban drainage) methods in all future urban development planning - maximising natural drainage, to reduce the impact of floods. Apply the 1:4 rule for all construction: for every development each 1m2 of planned concrete surface must be accompanied by 4 m2 of natural surface.
- Plant trees along all streets, increase urban open spaces and create more parks to all provide shade, reduce the heat island effect and reduce heat stress on inhabitants.

In the following chapters, more detailed vulnerability assessments are made of selected priority Socio-Ecological Systems (SESs), and more specific detailed EbA recommendations are made for those priority SESs.

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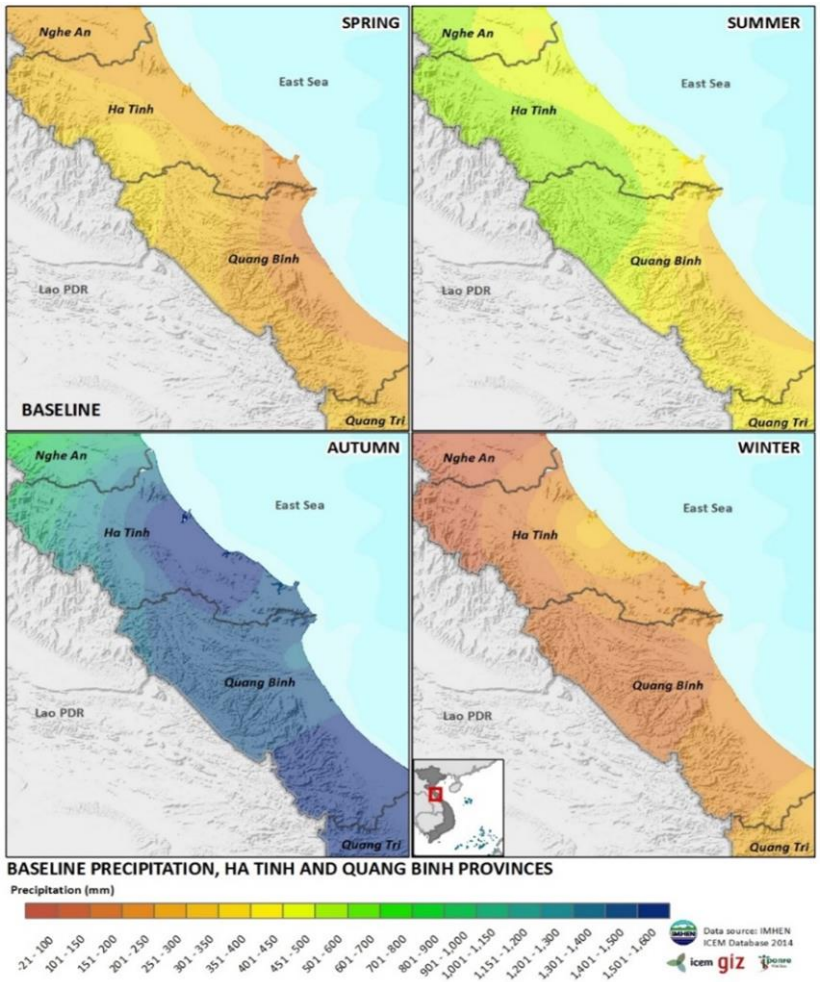
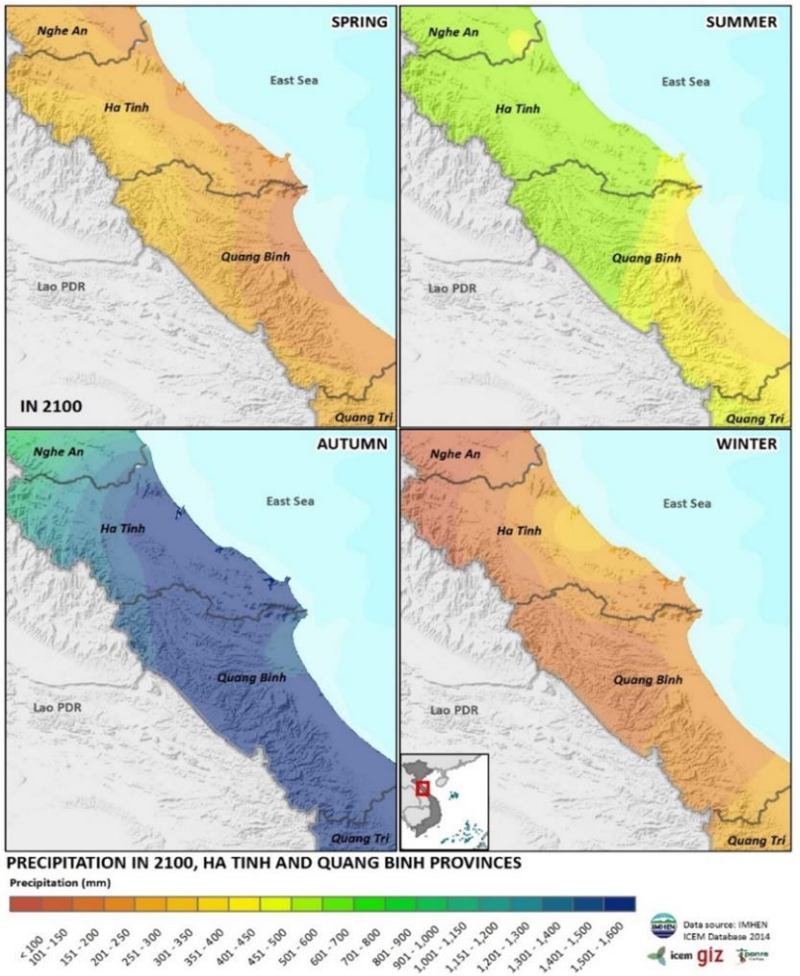
ANNEX 1.I: CLIMATE CHANGE MAPS FOR QUANG BINH UNDER THE MEDIUM EMISSIONS SCENARIO (B2)

1a: Annual Seasonal Maximum Temperature: (i) Baseline and (ii) 2100

(i) Baseline

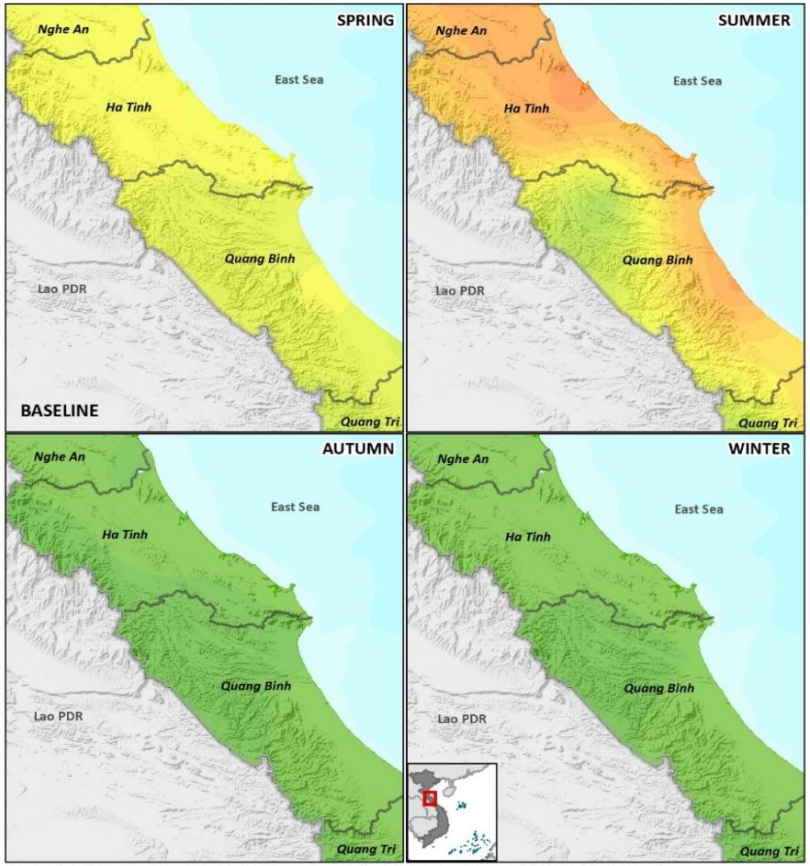


(ii) 2100

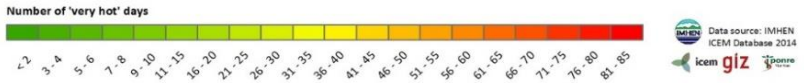


1b: Seasonal Change in Very Hot Days (>35 oC), (i) Baseline and (ii) 2100.

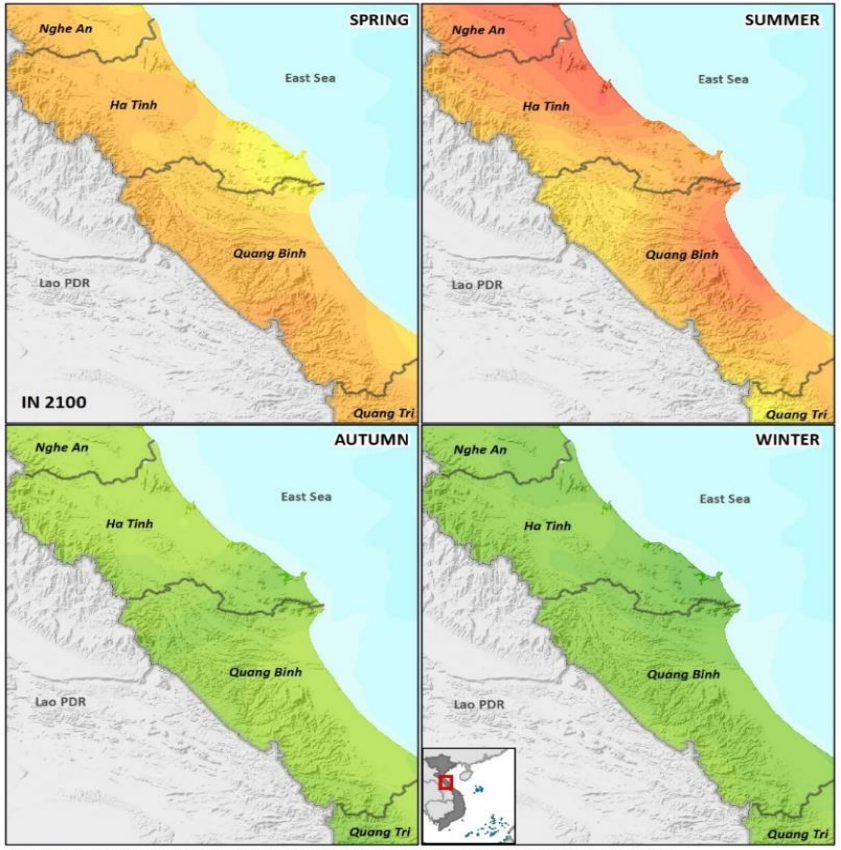
(i) Baseline



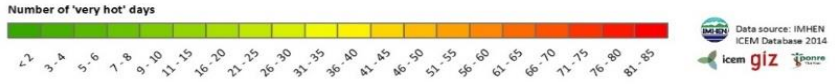
BASELINE NUMBER OF 'VERY HOT' DAYS, HA TINH AND QUANG BINH PROVINCES



(ii) 2100

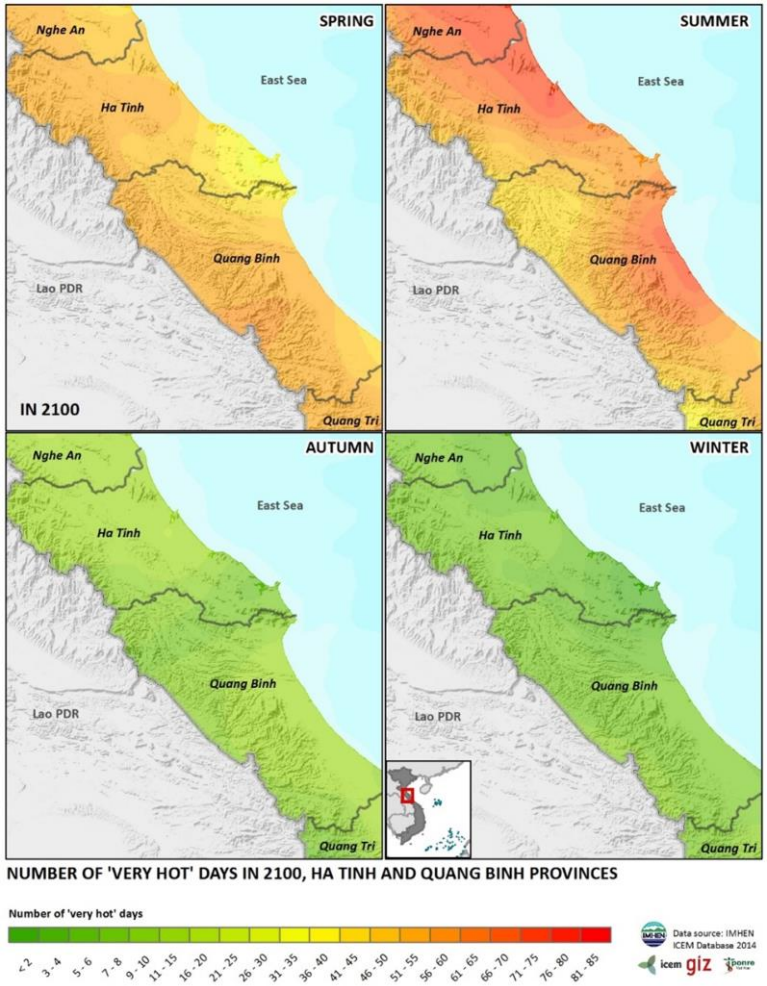


NUMBER OF 'VERY HOT' DAYS IN 2100, HA TINH AND QUANG BINH PROVINCES

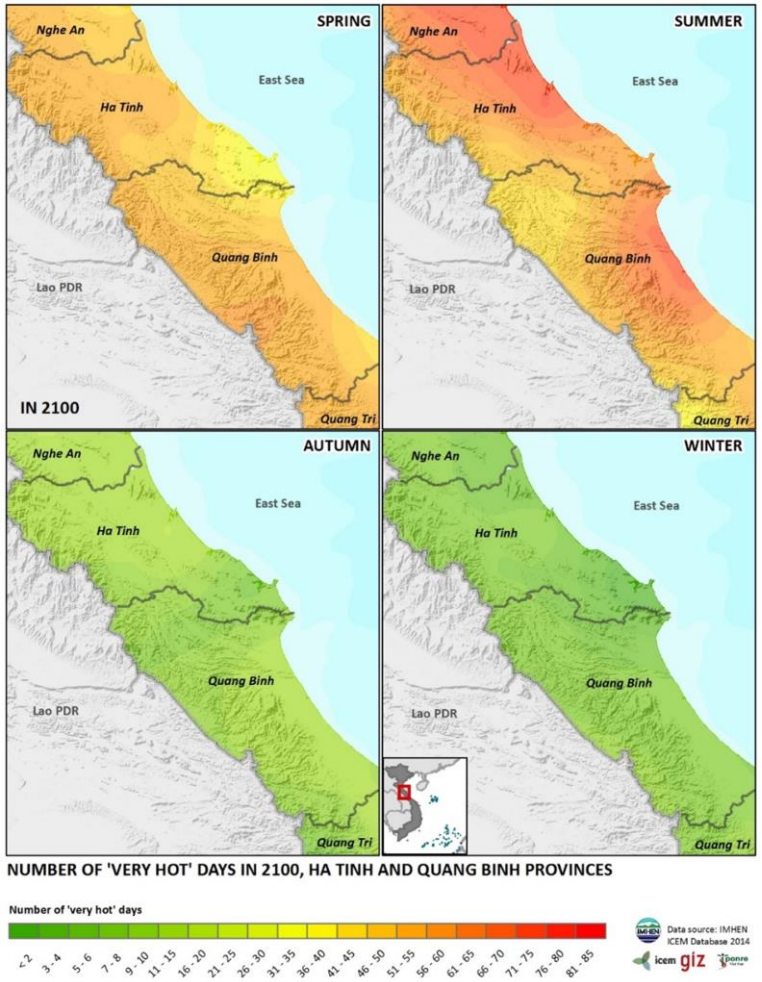


1c: Seasonal Incidence of Very Hot Days, (i) Baseline and (ii) 2100

(i) Baseline

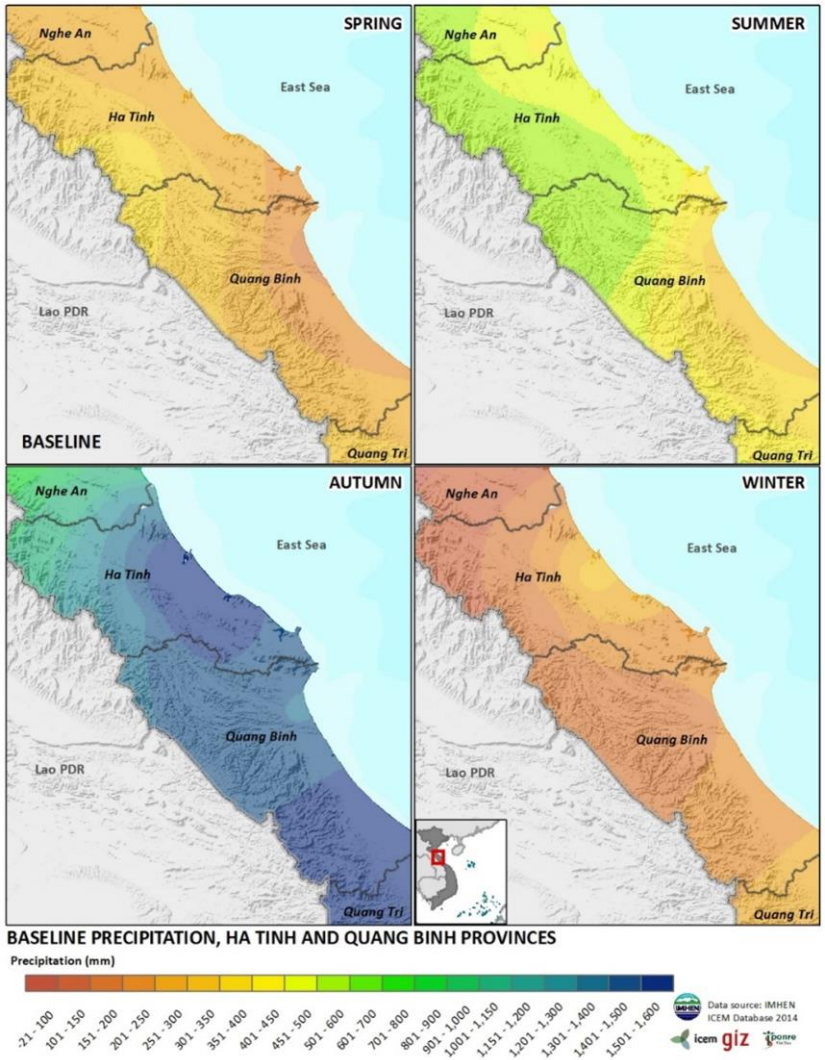


(ii) 2100



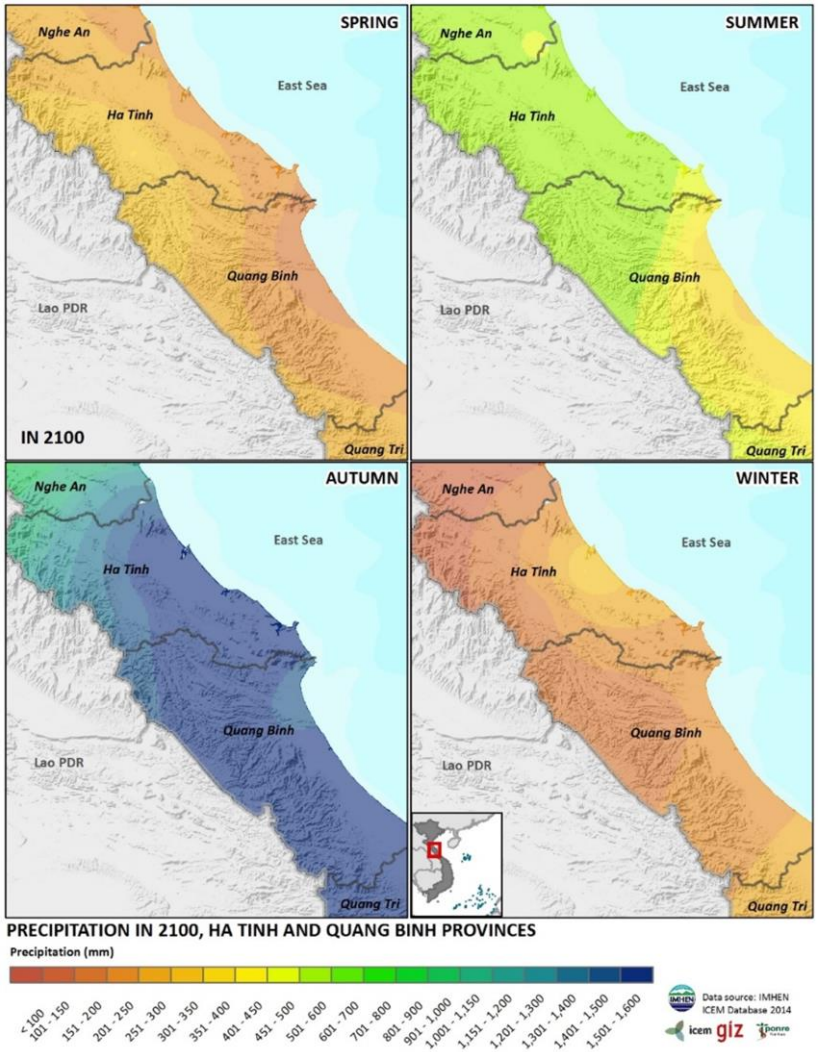
2a: Seasonal Average Precipitation in Ha Tinh and Quang Binh, (i) Baseline (1980-1999) and (ii) 2100

(i) Baseline (1980 - 1999)



BASELINE PRECIPITATION, HA TINH AND QUANG BINH PROVINCES

(ii) 2100



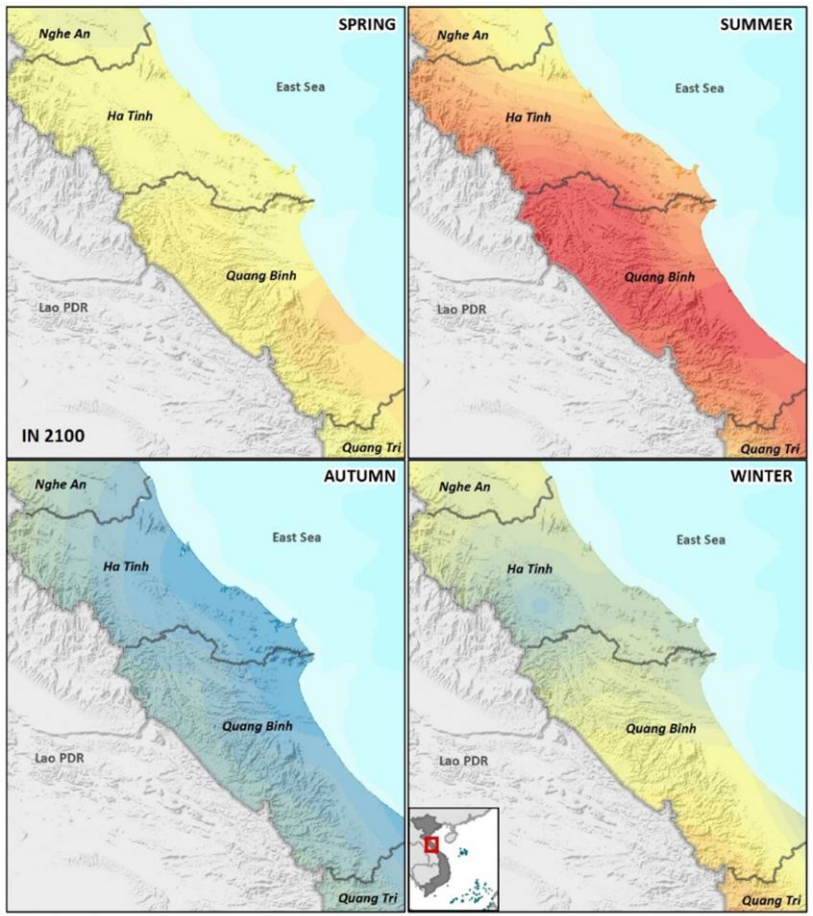
PRECIPITATION IN 2100, HA TINH AND QUANG BINH PROVINCES

2b: Seasonal Number of Dry Days, (i) Baseline (ii) 2100

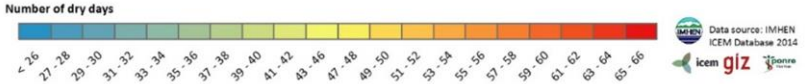
(i) Baseline

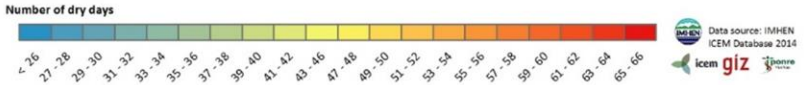
BASELINE NUMBER OF DRY DAYS, HA TINH AND QUANG BINH PROVINCES

(ii) 2100



NUMBER OF DRY DAYS IN 2100, HA TINH AND QUANG BINH PROVINCES





ANNEX 1.II: ALL SEC CC

SES	Avg Tmax Summer change in 2050 (C			Avg Tmax Summer change in 2100 (C			No. hot days (>35C) change in 2050			No. hot days (>35C) change in 2100			Rainfall change (6-8) in 2050 (%)			Rainfall change (6-8) in 2100 (%)			Rainfall change (3-5) in 2050 ((%)			Rainfall change (3-5) in 2100 (%)			Rainfall change (9-11) in 2050			Rainfall change (9-11) in 2100			No. dry days change in 2050			No. dry days change in 2100		
CODE	MIN	MAX	MEAN	MIN	MAX	MEAN	MIN	MAX	MEAN	MIN	MAX	MEAN	MIN	MAX	MEAN	MIN	MAX	MEAN	MIN	MAX	MEAN	MIN	MAX	MEAN	MIN	MAX	MEAN	MIN	MAX	MEAN	MIN	MAX	MEAN	MIN	MAX	MEAN
1a	1.8	1.8	1.8	3.5	3.5	3.5	23	24	23	34	35	34	4.9	5.0	5.0	9.4	9.5	9.5	-5.3	-5.2	-5.3	-10.1	-10.1	-10.1	3.8	4.0	3.9	7.4	7.6	7.5	17	17	17	15	15	15
2a	1.9	1.9	1.9	3.6	3.7	3.6	28	37	33	40	48	44	4.4	5.4	4.7	8.5	10.3	9.0	-5.5	-5.1	-5.2	-10.5	-9.7	-9.9	2.4	3.0	2.6	4.6	5.8	5.1	14	16	15	10	12	11
3a	1.9	1.9	1.9	3.6	3.6	3.6	40	40	40	54	55	55	4.6	4.7	4.7	8.8	9.0	8.9	-5.2	-5.1	-5.1	-9.9	-9.9	-9.9	2.8	2.8	2.8	5.4	5.4	5.4	16	16	16	12	12	12
3c	2.0	2.0	2.0	3.7	3.8	3.7	20	24	21	22	28	24	5.8	5.8	5.8	11.1	11.1	11.1	-5.3	-5.2	-5.2	-10.1	-9.9	-10.0	2.8	2.8	2.8	5.4	5.4	5.4	15	15	15	13	14	14
4a	1.7	1.9	1.8	3.3	3.6	3.5	42	49	47	52	66	64	3.9	5.4	4.8	7.4	10.3	9.2	-5.1	-4.5	-4.8	-9.8	-8.6	-9.2	3.2	3.4	3.4	6.1	6.6	6.5	17	19	18	14	19	17
4b	1.8	1.9	1.9	3.4	3.6	3.6	42	46	44	57	63	60	4.4	5.0	4.8	8.4	9.6	9.2	-5.2	-4.6	-5.0	-9.9	-8.8	-9.7	2.9	3.4	3.1	5.6	6.6	6.0	16	19	17	13	18	14
5a	1.7	1.9	1.8	3.2	3.6	3.5	34	48	41	41	63	56	3.4	4.7	4.2	6.5	9.0	8.0	-5.2	-4.3	-4.9	-9.9	-8.3	-9.4	3.2	4.2	3.5	6.1	8.1	6.7	17	20	19	14	19	17
5b	1.8	1.9	1.9	3.4	3.7	3.6	34	49	47	48	66	63	4.4	5.7	5.0	8.4	10.9	9.7	-5.2	-4.6	-5.0	-10.0	-8.8	-9.5	2.9	3.4	3.2	5.6	6.6	6.2	16	19	17	13	18	15
5c	1.9	2.0	1.9	3.6	3.7	3.6	33	40	36	47	51	49	4.4	6.1	5.3	8.5	11.7	10.1	-5.1	-5.0	-5.1	-9.9	-9.6	-9.7	3.1	3.3	3.2	6.1	6.4	6.2	16	17	17	14	15	14
5d	1.9	1.9	1.9	3.5	3.6	3.6	34	47	43	51	65	60	4.2	4.7	4.5	8.0	9.0	8.6	-5.1	-4.9	-5.0	-9.9	-9.5	-9.7	3.1	4.0	3.4	5.9	7.7	6.5	17	19	18	13	17	15
5f	1.7	2.0	1.9	3.2	3.8	3.6	18	50	39	17	68	53	3.4	6.4	4.8	6.4	12.2	9.2	-5.5	-4.4	-4.9	-10.6	-8.4	-9.5	2.5	4.3	3.3	4.8	8.2	6.2	14	20	18	10	19	16
5g	1.8	2.0	1.9	3.4	3.8	3.6	26	49	35	37	65	48	3.8	6.4	4.9	7.2	12.2	9.5	-5.3	-4.6	-5.0	-10.2	-8.7	-9.6	2.9	3.9	3.4	5.5	7.4	6.5	15	19	17	13	19	15
6a	1.9	1.9	1.9	3.6	3.6	3.6	37	40	39	50	54	52	4.5	4.8	4.6	8.7	9.2	8.9	-5.2	-5.1	-5.2	-10.0	-9.8	-9.9	2.6	2.8	2.7	4.9	5.3	5.2	15	16	15	11	12	12
6b	1.8	1.9	1.9	3.5	3.7	3.6	41	50	48	52	67	63	4.3	6.4	5.2	8.3	12.3	10.0	-4.8	-4.6	-4.6	-9.1	-8.8	-8.9	3.0	3.3	3.2	5.8	6.4	6.2	17	19	19	16	18	17
6c	1.9	1.9	1.9	3.7	3.7	3.7	43	45	44	58	61	60	5.3	5.7	5.5	10.2	10.9	10.5	-5.3	-5.1	-5.2	-10.1	-9.7	-9.9	3.0	3.2	3.1	5.7	6.1	5.9	16	17	16	13	15	14
8a	1.8	2.0	1.9	3.5	3.8	3.6	22	44	33	25	59	44	4.4	6.0	5.0	8.4	11.4	9.7	-5.6	-5.0	-5.2	-10.7	-9.6	-10.0	2.4	3.7	3.0	4.6	7.1	5.7	14	17	15	10	16	13
9a	1.9	2.0	1.9	3.6	3.7	3.7	37	43	40	49	58	54	4.7	5.5	5.1	9.0	10.5	9.8	-5.4	-5.2	-5.3	-10.4	-10.0	-10.2	2.6	3.0	2.8	5.0	5.8	5.3	14	16	15	11	13	12
9b	1.9	2.0	1.9	3.6	3.8	3.7	32	43	37	45	57	49	4.4	5.7	4.9	8.4	11.0	9.4	-5.6	-5.1	-5.3	-10.8	-9.7	-10.1	2.4	3.1	2.7	4.6	6.0	5.1	14	16	15	10	13	11
9c	1.8	2.0	1.9	3.5	3.8	3.6	19	41	29	22	54	39	4.4	5.8	5.1	8.5	11.1	9.8	-5.6	-5.1	-5.3	-10.8	-9.8	-10.1	2.4	3.9	2.9	4.6	7.6	5.6	14	17	15	10	15	12
9d	1.8	2.0	1.9	3.5	3.8	3.6	22	38	29	33	50	40	4.4	5.8	5.0	8.5	11.2	9.6	-5.6	-5.1	-5.3	-10.7	-9.8	-10.1	2.5	3.9	3.2	4.8	7.6	6.2	14	17	16	10	15	13
9e	1.9	2.0	1.9	3.5	3.8	3.6	27	35	31	39	47	43	4.5	5.7	4.8	8.6	10.9	9.2	-5.5	-5.1	-5.2	-10.6	-9.8	-10.0	2.6	3.2	2.8	4.9	6.2	5.5	14	16	15	11	13	12
9f	1.8	1.8	1.8	3.5	3.5	3.5	26	26	26	37	37	37	4.8	4.8	4.8	9.2	9.2	9.2	-5.2	-5.2	-5.2	-10.0	-10.0	-10.0	3.6	3.6	3.6	7.0	7.0	7.0	17	17	17	14	14	14
11a	1.9	1.9	1.9	3.6	3.7	3.6	41	44	42	55	59	57	4.9	5.0	4.9	9.3	9.6	9.5	-5.2	-5.2	-5.2	-10.1	-9.9	-10.0	2.8	3.0	2.9	5.4	5.8	5.6	15	16	16	12	13	13
10c	1.8	1.8	1.8	3.4	3.4	3.4	43	46	44	55	59	57	4.1	4.4	4.3	7.9	8.4	8.2	-4.6	-4.5	-4.5	-8.8	-8.7	-8.7	3.2	3.4	3.3	6.2	6.5	6.3	19	19	19	18	19	18
11d	1.9	1.9	1.9	3.6	3.6	3.6	32	33	32	43	44	44	4.4	4.5	4.4	8.4	8.5	8.5	-5.1	-5.1	-5.1	-9.8	-9.7	-9.8	2.4	2.7	2.6	4.7	5.2	5.0	15	15	15	10	11	11
11h	1.9	1.9	1.9	3.5	3.6	3.6	28	31	30	39	43	41	4.5	4.6	4.6	8.6	8.9	8.7	-5.2	-5.1	-5.1	-9.9	-9.8	-9.9	2.7	3.2	2.9	5.2	6.1	5.6	15	16	15	11	13	12
River-	1.8	2.0	1.9	3.5	3.8	3.7	19	49	35	21	66	47	4.3	6.3	5.1	8.3	12.1	9.8	-5.6	-4.7	-5.2	-10.8	-8.9	-10.0	2.4	4.0	3.0	4.6	7.7	5.8	14	19	16	10	17	13