Abstract:
The climate change is a global, natural phenomenon which has significant impacts on the ecological system, and through its development, it results in many of the negative effects because of global warming and gas leaks occurring. There is a strong and close relationship between economic development and climate change. However, this relationship is doomed to fall actually due to the current climate changes that cause disequilibrium which threatens economic growth, food, water, and energy security. The climate change is a phenomenon that has increasingly obvious effects all over the world. The more the Earth's temperature continued to increase, the deeper impacts it will have on our fresh water supply, with potentially devastating effects on economic resources. Nowadays, Southeast Asia is seen as one of the most vulnerable regions to climate change. During the next 30-50 years, it is expected that ASEAN countries will face serious effects of global warming. According to recent statistics, increased global warming is expected to significantly impact labor capacity and productivity in Southeast Asian countries by 2045, which will significantly impact vulnerable workers, and have a negative impact on regional economies. The present paper analyses the impacts of climate changes on the economic growth of ASEAN countries, and what significant impacts will result on regional economies and livelihoods of ASEAN countries. Underlying climate change phenomenon, this paper studies how ASEAN countries will work together to mitigate and adapt to climate change.

1. INTRODUCTION:
The problem of climate is regarded as a global environmental issue and an important scientific fact and a problem from which the globe has been suffering for decades. This issue, in fact, involves complex interactions which have political, social, environmental and economic repercussions and changes in the first place. The main reasons for the aforementioned phenomenon are the human activities and exhaustion of the available natural resources, which have led to the disruption of the ecological equilibrium, in addition to natural causes.

Climate changes which are currently occurring in the world are one of the most important concerns of countries, whether developed or developing, because of the global warming and its repercussions and negative effects that affected various areas and human dimensions. Also, the problem of misuse of natural resources and the degradation of the environment has become a critical challenge facing all the governments of the world.
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The climate change is seen as one of the most critical threats and obstacles to the development and progress of the developing countries more than the rich countries in spite of the fact that the poor countries do not contribute with a large proportion of the total gas emissions which cause global warming. In fact, the causes on these countries are related to the fragility of their economies in facing the several repercussions and effects of climate change, in addition to the weak capacity to adapt to these climatic changes.

As climate changes strike many parts in the world, Asia remains as the most vulnerable region to climate change in the globe. In fact, this phenomenon constitutes a threat to both policymakers and governments. Like many developing countries and other poor communities, ASEAN countries are also vulnerable to the effects of climate change. The region is annually affected by climate extremes, particularly floods, droughts, and tropical cyclones.

According to the IPCC 4th Assessment Report, ASEAN countries are expected to be seriously affected by the adverse impacts of climate change since most economies are relying on agriculture and natural resources. Besides, the Asian Development Bank reported, in 2009, that South-East Asia will suffer more from climate change than any other region, or country, in the world, if no measures are taken, and policies are adopted. It is obvious, then, that climate change will affect severely the economic growth the ASEAN countries. So, such climatic impacts will severely threaten the livelihood of poor people living in rural areas with limited adaptive capacity.

The present paper addresses to the following research questions:

- Why ASEAN countries are vulnerable to climate change?
- What economic sectors that are much affected by the impacts of climate changes in ASEAN countries?
- What significant impacts will result on both regional economies and livelihoods of ASEAN countries?
- What policies and reactions that will be taken by ASEAN governments and policymakers to adapt to climate change?

2. The literature review:

The region of South-East Asia is best recognized of its economic and political bond (ASEAN) which contributed to its economic growth since its foundation. However, the vulnerability to and impact of climate change is a major concern to ASEAN countries. Accordingly, many studies and empirical works have been conducted to examine and analyze the impacts of global warming and climate change on the economic growth of ASEAN countries.

Seo, Mendelsohn, and Munasinghe (2005) examined the climate change impacts on Sri Lankan agriculture using the Ricardian method and five AOGCM experimental models. The model analyzed the net revenue per hectare of the four most important crops (rice, coconut, rubber, and tea) in the country. Both the Ricardian method and five AOGCM experimental models showed that the effects of increase in precipitation are predicted to be beneficial to all crops tested and the benefit ranges from 11% to 122% of the current net revenue of the crops in the model.
Mendelshon (2007) examined the impact of climate change on Southeast Asian agriculture for 2100 by using 3 different climate simulation models from AOGCM's: the PCM model, the CCSR model, and the CCC model. According to the results, the mild and wet warming of PCM, will increase agricultural revenues in Southeast Asia by $35 billion per year, a 6% benefit. On the other hand, the CCSR scenario and the CCC scenario would cause net revenues to fall by about $60 billion per year, 11% loss and $219 billion, 39% loss to Southeast Asian agriculture.

Basak (2009) has analyzed the impacts of climate change on rice production in Bangladesh by using simulation model. The latter is specifically focused on Boro rice production, which accounts for 58% of the total rice production during 2008 in Bangladesh, to estimate the effects of future climate change. Soil and hydrologic characteristics of the locations, typical crop management practices, traditional growing period, and climate data in 2008 were used for the analysis and temperature and CO2 levels are controlled in the simulation model called DSSAT (Decision Support System for Agrotechnology Transfer). The simulation results showed that rice production varies in different locations for different climatic conditions and hydrological properties of soil although same Boro rice was used in all areas.

In her report, Braatz (2009) examined the alignment of climate change mitigation and adaptation strategies with ASEAN’s economic integration, social and environmental goals. It highlighted the importance of adopting people- centred and integrated approaches to land use and resource management, in the agriculture, forestry and fisheries sectors, for effective climate change responses. Finally, she suggested some strategic directions to promote integrated approaches and to encourage harmonized partner support for developing and implementing these.

Measey (2010) reviewed the causes of Indonesia’s high greenhouse gas releases, the impacts climate change has on the country, and the effects of climate change. Also, she showed that deforestation, forest fires and the degradation of peat land have been the main causes for Indonesia being the world’s third largest emitter of greenhouse gases. She summarized some of the main impacts climate change has in Indonesia, which include temperature increase, intense rainfall, sea level rise, and a threat to food security. Accordingly, climate affected (1) Indonesia’s economy and poor people, (2) human health, and (3) Indonesia’s environment and biodiversity.

Mahfuz Ahmed (2014) reported that as more extreme weather hits South Asia, the effects of climate change are taking a toll on the economy, with the region at risk of losing up to 8.8 percent of their GDP by 2100. Furthermore, he assessed that the impacts of climate change on the economies of South Asia, and stressed that the countries of the region should work in order to adapt to climate change so as to avoid economies’ hardships.

3. The links between climate change and economic growth:

The problem of climate is regarded as a global environmental issue and an important scientific fact and a problem from which the globe has been suffering for decades. This issue, in fact, involves complex interactions which have political, social, environmental and economic repercussions and changes in the first place. The main reasons for the aforementioned phenomenon are the human activities and exhaustion
The effects of climate change on the economic growth of ASEAN countries

of the available natural resources, which have led to the disruption of the ecological equilibrium, in addition to natural causes.

The issue of climate changes which are currently occurring in the world is one of the most important concerns of countries, whether developed or developing, because of the global warming and its repercussions and negative effects that affected various areas and human dimensions. Also, the problem of misuse of natural resources and the degradation of the environment has become a critical challenge facing all the governments of the world.

The climate change is seen as one of the most critical threats and obstacles to the development and progress of the developing countries more than the rich countries in spite of the fact that the poor countries do not contribute with a large proportion of the total gas emissions which cause global warming. In fact, the causes on these countries are related to the fragility of their economies in facing the several repercussions and effects of climate change, in addition to the weak capacity to adapt to these climatic changes.

4. Why ASEAN countries?

4.1. Definition of ASEAN region:

Geographically, the ASEAN region is located between of the Pacific Ocean, Indian Ocean, Andaman Sea, and South China Sea. It stretches to more than 3,300 kilometers from north to south (latitudes 30° North to 11° South), and 5,600 kilometers from west to east (longitudes 92° West to 142° East) (Letchumanan, n. d. p. 1). The ASEAN region borders China to the north, India and Bangladesh to the northwest, East Timor, Papua New Guinea, and Australia to the southeast, Bay of Bengal and Andaman-Nicobar Islands (India) to the west, and India and Bangladesh to the northwest (Gupta, 2010, p. 1). Also, the region has a long coastline, measuring about 173,000 kilometers, and is surrounded by major seas and gulfs; such as, the South China Sea, the Andaman Sea, and the Gulf of Thailand. ASEAN consists of the ten following countries: Brunei, Cambodia, Indonesia, Lao PDR, Malaysia, Myanmar, Philippines, Singapore, Thailand, and Vietnam (Letchumanan, n. d. p. 1).

Fig. 1: Map of ASEAN countries.

The ASEAN countries have succeeded in developing their economies. Their success had already started with the four countries of Taiwan, Hong Kong, South Korea, and Singapore, which became to be known as Asian Tigers. Accordingly, as these countries began to play an active role in international trade, regional unions have been established in the region, most notably the Association of Southeast Asian
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Nations (ASEAN), which has become one of the most important economic unions in both the world and Asian Continent.

ASEAN emerged in 1967 as a political block against Communism which spread in Southeast Asia, especially Vietnam, Cambodia, Laos, and Burma. The initiative to form ASEAN was started by Malaysia, Indonesia, Singapore, Thailand, and the Philippines. Brunei joined later in 1984. Malaysia is one of the most important enthusiasts of forming this bond which had begun to focus on regional economic cooperation among the member states in the field of unification policies of industrialization, liberalization of intra-trade, and implementation of national import substitution policies and protection of emerging industries.

The five member countries of the Association did not resort to the traditional approach to integration and opted for a cooperative approach. It did not specify a specific date for reaching a certain stage of economic integration.

ASEAN regional economic cooperation succeeded and improved because of the following factors:
- Adopting traditional patterns of substitution-based development, relying on the abundance of natural resources and the development of its human resources,
- Cooperation between the countries regional economies,
- Adopting open industrialization policies through foreign investment agreements (Malaysia and Singapore),
- The success of savings and investment policies.

According to the Bangkok Declaration of 1976, ASEAN aims to achieve a set of goals and important objectives which are as follows:
- Accelerating economic growth, social progress, and cultural development in South-East Asia by joint action based on a spirit of cooperation, equality, and participation to promote the bases of a prosperous and peaceful society;
- Promoting social progress and improving the standard of living of its members and encouraging active cooperation and mutual aid;
- Cooperating more effectively in the use of agricultural and industrial activities and expanding its trade;
- Strengthening studies on the South-East Asia Region;
- Establishing close and beneficial relations with international and regional institutions with similar objectives;
- Promoting peace and regional political and economic stability in the face of major powers; and avoiding conflict between the member countries by respecting the rule of law in the relations between the member countries of the region.
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As seen above from its objectives, ASEAN member countries aim to fully achieve integration of a unified position behind the economic issues at the international scene, and an influence in the world economic issues. Also, ASEAN aims to address to the requirements and challenges of the twenty-first century in regard to both politics and economy.

Actually, South East Asia is annually affected by extreme climate changes, particularly floods, droughts and tropical cyclones, while large areas of the region are highly prone to flooding and influenced by monsoons. These extremes constitute a great threat to both human existence and sustainable development in the most important sectors in ASEAN region. Since the latter is the focus of the present paper, some of the reasons of why ASEAN region is vulnerable to climate change, as the cornerstone of the study, are listed below.

4.2. An emergent, rising, economic agglomeration:

The Association of South-East Asian Nations (ASEAN) is seen as a successful, rising economic agglomeration between the member countries through regional cooperation and integration. ASEAN has achieved significant economic growth, especially in the fields of industry, trade, and services. This economic growth is explained by the strengthening of cooperation between member states, and by the foreign investment in the region, which is facing tax facilities, low wages, large population (567 million), abundant labor and natural resources.

The outcome of the economic and social growth of ASEAN has led to a series of positive results which are cited below:

4.2.1. Economic level:

- The growth of ASEAN economy with an average of 5.5% annually.
- The Evolution of the value of the GDP in ASEAN: 800 billion dollars in 2005.
- The increase in the value of intra-trade exchanges: 80% of the exchanges of each country within the framework of the Association, as well as ASEAN exchanges with the rest of the world.
- The increase of foreign investment into ASEAN ($ 38 billion in 2005).
- The diversity of products exchanged between ASEAN countries, especially electric machines, industrial equipment, hydrocarbons and derivatives, and agricultural products.

4.2.2. Social level:

- The development of adult education index, which exceeds 90% of the total population
- The relative decline in the phenomenon of poverty.
- The improvement of the human development index (0.728 in 2006).
- Low unemployment rate: 5%.
- Improved GDP per capita, which is reflected in improving the standard of living of the population and increasing their consumption capacity: ($ 1569 per capita in 2006; according to the United Nations Development Program).
The economic growth of ASEAN can be explained to the following factors:

- **Natural resources:**
  
  The ASEAN region has important natural qualifications, which are conducive to cooperation and partnership among ASEAN countries:

  - The availability of fertile and arable land, which are exploited intensively and highly efficient, especially in the production of rice, sugar cane and rubber;
  - The abundance of water for irrigation due to seasonal precipitation, and the existence of a large pastoral area dedicated to raising cattle, especially cows;
  - The availability of an important reserve of energy sources: oil and natural gas, especially in Indonesia and Malaysia.

- **Human and organizational resources:**

  - **Population size:** 559 million in 2006, providing a huge consumer market conducive to the development of the economy within the ASEAN region;
  - **A significant percentage of active population:** 65% of the total population, providing a local workforce characterized by high technical standards, discipline and love of work;
  - **Economic regulations:** Economy within ASEAN countries is regulated tightly in the framework of enterprises with the ability to attract foreign investment, and to face international competition, especially in Indonesia, Malaysia, and Thailand;
  - ASEAN is based on expertise and technical assistance from neighboring countries in Asia; such as, Japan, South Korea, and Hong Kong. Japan is a leading economic pole in the region leading neighboring emerging countries;
  - **Adoption of economic development to bring foreign investment:** $ 38 billion annually, especially in the five major economic countries of ASEAN.

4.3. High population size:

ASEAN is considered as the third largest economic bloc in the world after the European Union and the North American Free Trade Group. Since its foundation in 1967, Southeast Asia has achieved significant economic growth especially in the fields of industry, trade and services. Some industries; such as, mechanical, chemical, and electronic ones, have flourished; exports have increased; exchanges have grown; and the region has become increasingly important in tourism. This economic growth can only be explained by the strengthening of cooperation between member states, and by the foreign investment in the region, which is facing tax facilities, low wages, abundant labor, natural resources, and large population size.

As far as population growth is concerned, the current population of South- Eastern Asia is 646,944,571 (‘South- Eastern Asia Population’, 2017), based on the latest United Nations estimates. Accordingly, South- Eastern Asia population makes 8.62% of the total world’s population. It ranks number 3 in Asia among sub regions ranked by Population.
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The population density in South-Eastern Asia is 149 per Km² (386 people per mi²). The total land area is 4,340,239 Km² (1,675,775 sq. miles). 48.8 % of the population is urban (315,797,197 people in 2017). The median age in South-Eastern Asia is 29.1 years.

<table>
<thead>
<tr>
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<tbody>
<tr>
<td>Indonesia</td>
<td>(263,510,146)</td>
</tr>
<tr>
<td>Philippines</td>
<td>(103,796,832)</td>
</tr>
<tr>
<td>Viet Nam</td>
<td>(95,414,640)</td>
</tr>
<tr>
<td>Thailand</td>
<td>(68,297,547)</td>
</tr>
<tr>
<td>Myanmar</td>
<td>(54,836,483)</td>
</tr>
<tr>
<td>Malaysia</td>
<td>(31,164,177)</td>
</tr>
<tr>
<td>Cambodia</td>
<td>(16,076,370)</td>
</tr>
<tr>
<td>Laos</td>
<td>(7,037,521)</td>
</tr>
<tr>
<td>Singapore</td>
<td>(5,784,538)</td>
</tr>
<tr>
<td>Timor-Leste</td>
<td>(1,237,251)</td>
</tr>
<tr>
<td>Brunei Darussalam</td>
<td>(434,448)</td>
</tr>
</tbody>
</table>

Table 1: Population size in ASEAN (By listed countries) Source: Adapted from: worldometers, 2017.

4.4. Vulnerability to climate change:

It is commonly acknowledged that the danger of climate change is serious as it brings harms on various aspects; such as, economic growth, health, poverty, human right, forestry, agriculture, and fisheries. Besides, it affects the most vulnerable groups, for example women, children, and indigenous people.

Climate change affects all regions in the world, and ASEAN is one of the most vulnerable regions to climate change which poses significant challenges to ASEAN countries. The region is highly exposed to extreme weather events; such as, global warming and heavy precipitation are expected to increase in future decades (Salamanca and Nguyen, 2016, p. 1).

In recent years, several ASEAN countries have suffered from natural disasters; such as drought, sea level rise, and typhoon. For instance, Indonesia and Thailand were hit by tsunami in 2004, earthquake happened in Myanmar in 2012, and also Philippines and Vietnam suffered from Taiphoon Haiyan in 2013. In 2009, the Asian Development Bank (ADB) reported that mainly three factors contributed to ASEAN’s vulnerability: (1) growing population, (2) long coastlines, and (3) high concentration of people and economics activities in coastal areas (Astriana, 2014). Because of population size and extreme poverty, ASEAN countries’ vulnerability to climate change impacts and future disasters is seen to be profound. The majority of South-East Asian countries are low- or lower-middle income countries that struggle to support the needs of their growing populations. Since poorer households dedicate more of their budgets to food, they are the most sensitive to weather-related shocks that can make daily staples unaffordable.

5. The Effects of climate change on agriculture:

Both world countries, whether rich or poor, and international institutions and agencies regard the issue of climate change as serious. They call for urgent measures to be taken into account immediately to address the aforementioned issue.

Since the Earth’s climate is changing, the change is far more rapid and dangerous than thought earlier (IPCC, 2007). What indicates the Earth’s climate change is the global mean temperature of the earth which has been rising. It has risen by 0.7° C in the 20th century, and continues to increase at an
upward trend. Accordingly, further temperature increases contain the potential of much larger and even
catastrophic impacts. There is close to a scientific consensus over the potential ways through which
temperature could affect economic activity.

The damaging effect of changes in temperature on growth rate of GDP is informed by both theoretic
and empirical evidences. First, the destruction of ecosystems from erosion, flood and drought, the
extinction of endangered species and deaths resulting from extreme weathers cause permanent damages
to economic growth. Second, the resources required to counter the impact of warming would reduce
investment in economic and physical infrastructures, research and development and human capital thereby
reducing growth (Pindyck, 2011; Ali, 2012).

As far as agriculture is concerned, economic research on climate change revealed that agriculture, as
an economic factor, is vulnerable climate change. Since it makes up about 5 percent of the world’s
economy, agriculture’s contribution to the world’s economy is expected to decrease because of climate
change (Pearce et al., 1996).

It is worth to mention that most of the developing countries in the world rely heavily, for their
economies, on agriculture. However, since they are geographically located in low attitudes, they are mostly
affected by climate change in temperature. This can be explained to the fact that low attitude regions are
too hot for most of agriculture activities; any increase in temperature rates will result in further decrease in
productivity (Mendelshon et al., 2006).

Since climate change has been a central issue for the world economy, the fact of assessing the
economic impacts of climate change has been a fundamental debate between researchers. Yet, the
research literature has demonstrated links between economic (especially agriculture) production and the
climate change. i. e. There are set of mechanisms through which climate change may influence economic
outcomes negatively.

In analyzing the effects of temperature rates on agriculture, Dell, Jones, and Olken (2012) analyzed
evidences from 136 countries in the period 1950- 2003. They found three primary results. First, higher
temperatures substantially reduce economic growth in poor countries. For instance, a 1° C rise in
temperature in a given year reduces economic growth by 1.3 percentage points on average. Second,
higher temperatures appear to reduce growth rates. Third, higher temperatures have wide ranging effects,
reducing agricultural output, industrial output, and political stability.

Using a simple climate- economy simulation model for their analysis, Frankhauser and Tol (2005)
provided theoretical and empirical investigations on the link between climate change and economic growth.
They argued that the capital accumulation effect is important, especially if technological change is
endogenous, and may be larger than the direct impact of climate change. They concluded that in the long
run, for high direct impacts, climate change may indeed reverse economic growth and per capita income
may fall. For global warming of 3° C, the direct damages to the economy are estimated to at least 15
percent of GDP. When the effect of capital accumulation and people’s propensity to save are factored into
the damages, the impact would be higher.
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In this context, Gornall et al. (2010) admitted that higher growing temperature can significantly affect agricultural productivity, farm income and food security. The effect differs from temperate to tropical areas. In mid and high latitudes, the productivity of crops is projected to increase and extend northwards while the opposite holds for most countries in tropical regions. They found that a 2° C rise in temperature in mid and high latitudes could increase wheat production by about 10 percent while in low latitude regions, it could reduce by the same amount.

In summary, climate change has a negative impact in most tropical regions economies both directly and indirectly. This is particularly important because of heavy reliance on rain-fed agriculture which is the main livelihood of the largest segment of the population. To this end, rising trend of temperature could have significant effect on agricultural productivity, farm income and food security as well as indirect effect on labor productivity through impact on public health.

6. Statistics on the effects of climate change on ASEAN countries’ economic growth:

6.1. Temperature averages:

Since the average surface temperature in the world has increased by 0.76°C for the last 150 years, this, in fact, has made global warming cause greater changes in the climate; such as, changes in precipitation patterns and increase of extreme weather events. These changes have affected many regions of the world, including Southeast Asia (IPCC, 2007). The latter has witnessed climatic changes which affected the areas of water resources, agricultural production, forestry, and industry.

To deal with, the ASEAN region has noticed climate changes in the first half of the 20th century. Like other regions in the world, the average temperature in ASEAN countries has been subject to increase by a degree from 0.1 to 0.3°C per decade over the last 50 years (See the table below).

<table>
<thead>
<tr>
<th>ASEAN countries</th>
<th>Temperature changes</th>
</tr>
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<tbody>
<tr>
<td>Indonesia</td>
<td>Increase of 1.04–1.40°C per century</td>
</tr>
<tr>
<td>The Philippines</td>
<td>Increase of 1.4°C per century</td>
</tr>
<tr>
<td>Singapore</td>
<td>Increasing by about 0.3°C per decade</td>
</tr>
<tr>
<td>Thailand</td>
<td>Increase of 1.04–1.80°C per century</td>
</tr>
<tr>
<td>Viet Nam</td>
<td>Increase of 1.0°C per century</td>
</tr>
</tbody>
</table>


From the data in the table above, there is evidence that temperature increases became more pronounced in recent years in the Southeast Asian region. In Indonesia, it is reported that the mean temperature recorded in Jakarta increased about 1.04° C per century in January (the wet season) and 1.40° C per century in July (the dry season). This, in fact, has caused snow, which covers Mount Jayawijaya of Irian Jaya, to disappear, as a clear evidence of the coming of the warming period. Meanwhile, the Philippines has noticed increases in the mean, maximum, and minimum temperatures up to 0.14° C per decade (IPCC, 2007). Also, climate studies have supported this evidence by revealing increases in the average temperatures (from 1961 to 1990) from 0.61° C to 0.34° C and 0.89° C. Accordingly, the frequency of hot days and warm nights has increased, in addition to the fact that the number of cold days and cool nights decreased. In Singapore, temperature increased by 0.6° C from 1987 to 2007 (about 0.3° C per
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decade). In accordance with the global trend, temperature in Thailand increased, ranging between 0.10° C and 0.18° C per decade. The country has experienced an average daytime temperature of up to 40° C, especially in April. In Viet Nam, the annual average temperature increased by 0.1° C (1900 – 2000), and 0.7°C to 0.14°C from 1951 to 2000. So, since temperature rose faster in the latter half of the century, summers have become hotter in recent years, with average monthly temperatures increasing from 0.1 to 0.3°C per decade.

6.2. Annual rainfall average and its impacts on ASEAN countries:

Precipitation in Southeast Asia was subject to decrease downward in the period from 1960 to 2000. Southeast Asia’s precipitation patterns changed inter-seasonally and inter-annually in the second half of the last century, with an overall trend toward decreasing rainfall until 2000 (see the figure below) and a declining number of rainy days. On that basis, researchers reported that Indonesia’s rainfall decreased in recent decades. The extent of the decrease varies among locations. Between 1968 and 1997, a significant decrease of rainfall of 71.79 mm per year was observed in in Sumatra and 29.71 mm/year in Kalimantan (Aldrian, 2007).

Rainfall in Thailand and Singapore also decreased in the past 3–5 decades, compared to the first half of the last century. In most areas of Viet Nam, average monthly rainfall has decreased, particularly between July and August, and has increased between September and November (Cuong, 2008).

In contrast, since 1960 mean annual rainfall and the number of rainy days in the Philippines has increased. However, as in other places the country has experienced similar variability in the onset of the rainy season. The trend has been toward decreasing rainfall over Luzon and parts of Mindanao and increasing rainfall over the central western part of the country (Anglo, 2005).

Fig. 2: Annual precipitation in Southeast Asia. Source: Adapted from IPPC, (2007).

According to the data above, scenarios of precipitation in ASEAN countries are projected to decrease, and, meanwhile, to increase by the end of the century. It is expected that by 2050 Southeast Asia’s precipitation will increase by 1% and 2.25% with the strongest rise in the inter-tropical convergence zone (December– May). On the other hand, precipitation will decrease away from the inter-tropical convergence zone.
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Some findings suggest seasonal rainfall in Indonesia would increase consistently in the period between 2020 and 2080, except in September to November (Boer and Dewi, 2008). Rainfall in the Philippines would continue to be highly variable, as influenced by seasonal changes and climate extremes-for example, El Niño Southern Oscillation (ENSO) of higher intensity (Perez, 2008).

Changes in annual precipitation for Singapore would range from −2% to +15% with a median of +7%. Also, extreme rainfall and winds associated with tropical cyclones are likely to increase (Ho, 2008). In Thailand, there would be a shift in precipitation from north to south (TEI, 1999; Boonyawat and Chiwanamo, 2007). Viet Nam’s rainfall pattern will be greatly affected by the Southwest monsoon. Accordingly, a recent study on Viet Nam’s future rainfall showed that annual rainfall in most areas would increase by 5–10% toward the end of this century (Cuong, 2008).

In another context, sea levels in ASEAN countries are subjected to climate change, too. They have risen on average in the last few decades between 1 and 3 mm per year higher than the global average. Several studies (IPCC, 2007; Arendt et al., 2002; Rignot et al., 2003) reported rises in sea level of 3.1 mm per year over the past decade compared to 1.7–2.4 mm per year averaged over the last century. The Indonesian State Ministry of Environment reported that mean sea level increased by 1–8 mm per year, with the highest increase registered in the area of Belawan (SME, 2007).

In the Philippines, studies on rising sea levels in major coastal cities showed a slight upward trend (Yanagi and Akaki, 1994). The Manila area has exhibited a particularly strong increase in mean sea levels, probably due to a combination of local subsidence as well as a global rise in sea levels (Perez, 1999; Hulme and Sheard, 1999).

In Viet Nam, an upward trend in mean sea level has also been observed, at an average increase of 2–3 mm per year. Sea levels are projected to rise 40 cm in Southeast Asia by 2100, which will likely increase the loss of small islands. IPCC (2007) predicted sea levels will continue to rise 1.3 ± 0.7 mm per year over the next several decades. By the end of the century, the global mean sea level is projected to increase by 0.18–0.59 meters relative to the mean sea level in 1980–1999. It could be even higher than 1 meter, as suggested by some climate experts, if the rapid melting of ice sheets and glaciers is taken into account (Adam, 2009). For Southeast Asia, the most conservative scenario estimate is that sea level will be about 40 cm higher than today by the end of the 21st century (IPCC, 2007).

Fig. 3: Sea level rise in Indonesia and The Philippines. Source: Adapted from Boer and Dewi, (2008) and Perez, (2008).
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6.3. The impacts of climate change on ASEAN agriculture:

The impact of climate change affects several sectors in ASEAN countries, mainly agriculture, forestry, industry sector, water resources. Agriculture is one of the sectors greatly affected by extreme climate change. Physical damage, loss of crop harvest, drop in productivity, vigor and others related to crop potentials are examples of direct and indirect effect of the extreme climate change.

Agriculture remains a major economic sector throughout Southeast Asia. The region has about 115 million ha of agricultural land planted, mainly to rice, maize, oil palm, natural rubber, and coconut. It is a major producer and supplier of grains and the largest producer of palm oil and natural rubber. It also raises a considerable amount of livestock, which in recent years has grown dramatically in importance and at a much faster rate than croplands and pasture. In recent years, due to climate change coupled with growing populations and emerging industries, the agriculture sector in Southeast Asia has been under considerable environmental pressure.

Increasing temperature amplifies the rate of evapotranspiration, which intensifies stress in crops, particularly in those areas with limited water supply. The combined effect of heat stress and drought reduces crop yields.

Erratic precipitation patterns affect land preparation and planting times and alter the life cycle of major pests and diseases affecting agricultural crops. Drought during the El Niño years causes water stress to crops and increases pest and disease infestation. Heavy rains during La Niña years bring severe flooding, massive runoff, and soil erosion, reducing soil fertility and productivity. Rising sea levels amplify soil salinity in many low-lying agricultural areas and even expand the intrusion of seawater into groundwater resources and aquifers. Higher sea levels also cause the loss of arable lands in the region.

Table 3: Agriculture land and land use. Source: Adapted from FAO, (2016).

<table>
<thead>
<tr>
<th>Country</th>
<th>Total area (000 Ha)</th>
<th>Total Land area (000 Ha)</th>
<th>Arable land (000 Ha)</th>
<th>Permanent Crops (000 Ha)</th>
<th>Permanent Pasture (000 Ha)</th>
<th>Total Agrc. area (000 Ha)</th>
<th>% of Agriculture area to land area</th>
<th>Rural Population (000)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brunei</td>
<td>577</td>
<td>577</td>
<td>5</td>
<td>6</td>
<td>3</td>
<td>14</td>
<td>2,7</td>
<td>97</td>
</tr>
<tr>
<td>Cambodia</td>
<td>18,104</td>
<td>17,652</td>
<td>4,145</td>
<td>165</td>
<td>1,500</td>
<td>5,800</td>
<td>30.9</td>
<td>12,423</td>
</tr>
<tr>
<td>Indonesia</td>
<td>190,457</td>
<td>181,157</td>
<td>23,000</td>
<td>22,500</td>
<td>11,000</td>
<td>57,000</td>
<td>31.5</td>
<td>118,309</td>
</tr>
<tr>
<td>Lao PDR</td>
<td>23,080</td>
<td>23,080</td>
<td>1,489</td>
<td>169</td>
<td>877</td>
<td>2,335</td>
<td>10.1</td>
<td>4,306</td>
</tr>
<tr>
<td>Malaysia</td>
<td>33,080</td>
<td>32,805</td>
<td>954</td>
<td>6,600</td>
<td>285</td>
<td>7,839</td>
<td>23.9</td>
<td>7,541</td>
</tr>
<tr>
<td>Myanmar</td>
<td>67,059</td>
<td>66,308</td>
<td>10,772</td>
<td>1,509</td>
<td>300</td>
<td>12,587</td>
<td>19.3</td>
<td>36,245</td>
</tr>
<tr>
<td>Philippines</td>
<td>30,000</td>
<td>29,817</td>
<td>5,590</td>
<td>5,350</td>
<td>1,500</td>
<td>12,440</td>
<td>41.7</td>
<td>51,068</td>
</tr>
<tr>
<td>Singapore</td>
<td>71</td>
<td>71</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>0.9</td>
<td>0</td>
</tr>
<tr>
<td>Thailand</td>
<td>51,312</td>
<td>51,069</td>
<td>16,810</td>
<td>4,500</td>
<td>800</td>
<td>22,110</td>
<td>43.3</td>
<td>43,384</td>
</tr>
<tr>
<td>Viet Nam</td>
<td>33,096</td>
<td>31,007</td>
<td>6,410</td>
<td>3,822</td>
<td>642</td>
<td>10,874</td>
<td>36.1</td>
<td>82,003</td>
</tr>
<tr>
<td>Total</td>
<td>448,036</td>
<td>432,563</td>
<td>69,675</td>
<td>44,611</td>
<td>16,713</td>
<td>131,000</td>
<td>30.3</td>
<td>334,378</td>
</tr>
</tbody>
</table>

Increasing temperature has been undermining the agricultural production potential of Southeast Asia. Temperature and rainfall are the key factors affecting agricultural production in Southeast Asia. The production potential of major crops such as rice and maize has declined in many parts of the region due to the increase in heat stress and water stress. Research in climate change found that rice yield decreases by 10% for every 1°C increase in growing season minimum temperature (The International Rice Research Institute, as cited in Peng et al., 2004).
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In Thailand, it is reported that increasing temperature has led to a reduction in crop yield, particularly in non-irrigated rice. This has been attributed to the effect of drought at critical stages of growth; such as, the flowering period. In a study conducted by the Office of Natural Resources & Environmental Policy and Planning (ONEP, 2008), negative impacts on corn productivity ranged from 5–44%, depending on the location of production.

<table>
<thead>
<tr>
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<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Brunei Darussalam</td>
<td>1.0</td>
<td>1.3</td>
<td>1.4</td>
<td>1.5</td>
<td>1.4</td>
<td>1.4</td>
<td>1.7</td>
<td>2.2</td>
<td>2.3</td>
<td>n.a</td>
<td>n.a</td>
</tr>
<tr>
<td>Cambodia</td>
<td>4,170</td>
<td>5,886</td>
<td>6,284</td>
<td>6,727</td>
<td>7,174</td>
<td>7,586</td>
<td>8,249</td>
<td>8,779</td>
<td>9,000</td>
<td>9,000</td>
<td>8,226</td>
</tr>
<tr>
<td>Indonesia</td>
<td>53,666</td>
<td>53,985</td>
<td>54,455</td>
<td>57,157</td>
<td>60,326</td>
<td>64,399</td>
<td>66,469</td>
<td>65,757</td>
<td>69,060</td>
<td>71,280</td>
<td>69,960</td>
</tr>
<tr>
<td>Lao PDR</td>
<td>2,529</td>
<td>2,568</td>
<td>2,664</td>
<td>2,710</td>
<td>2,927</td>
<td>3,035</td>
<td>3,071</td>
<td>3,066</td>
<td>3,490</td>
<td>3,415</td>
<td>4,002</td>
</tr>
<tr>
<td>Malaysia</td>
<td>2,183</td>
<td>2,312</td>
<td>2,188</td>
<td>2,277</td>
<td>2,383</td>
<td>2,460</td>
<td>2,484</td>
<td>2,685</td>
<td>2,750</td>
<td>2,627</td>
<td>2,381</td>
</tr>
<tr>
<td>Myanmar</td>
<td>24,725</td>
<td>27,694</td>
<td>30,623</td>
<td>31,440</td>
<td>32,572</td>
<td>32,069</td>
<td>32,146</td>
<td>32,064</td>
<td>29,010</td>
<td>27,704</td>
<td>26,285</td>
</tr>
<tr>
<td>Philippines</td>
<td>14,497</td>
<td>14,603</td>
<td>15,537</td>
<td>16,240</td>
<td>16,816</td>
<td>16,269</td>
<td>15,772</td>
<td>16,684</td>
<td>18,033</td>
<td>18,439</td>
<td>18,918</td>
</tr>
<tr>
<td>Singapore</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Viet Nam</td>
<td>36,149</td>
<td>36,791</td>
<td>38,650</td>
<td>36,918</td>
<td>38,730</td>
<td>38,696</td>
<td>40,086</td>
<td>42,324</td>
<td>43,400</td>
<td>44,076</td>
<td>44,975</td>
</tr>
<tr>
<td>ASEAN</td>
<td>167,219</td>
<td>172,317</td>
<td>177,463</td>
<td>182,494</td>
<td>193,018</td>
<td>196,051</td>
<td>200,314</td>
<td>206,925</td>
<td>206,390</td>
<td>214,541</td>
<td>212,560</td>
</tr>
</tbody>
</table>


To sum up, the impacts of climate change can be simplified as follows:

- A reduction in crop yields around tropical and sub-tropical regions;
- Decreased water availability in areas already short of water;
- An increase in the spread of diseases such as malaria, dengue fever, schistosomiasis, and other viral diseases; and
- Increased instances of flooding as intensity of rainfall increases and sea levels increase. But, the positive aspects of a small amount of global warming include:
The effects of climate change on the economic growth of ASEAN countries

- increases in crop yields in some mid-latitude regions with temperature increases up to two to three degrees Celsius;
- potential increase in timber supplies from managed forests;
- increased water availability in regions such as southeast Asia; and,
- reduced winter mortality in high latitude regions.

As for water resources, global warming is likely to worsen water stress in some parts of the ASEAN region, especially in Thailand and Viet Nam. In Indonesia, the most river basin areas are projected to experience no change in water stress by 2050 as indicated in the figure below. In the Philippines, the projection is that some river basins will experience no water stress; some river basins will have the stress weakened; while other basins will have the water stress released. However, river basin areas in Thailand and Viet Nam are projected to experience an increase in water stress due to global warming, as indicated in the figure below.

Fig. 5: Water Stress in River Basin Areas due to Global Warming. Source: Asian Development Bank, (2009).

Water resources in Indonesia, Thailand, and Viet Nam are projected to be most vulnerable to climate change, threatening the lives and livelihoods of millions. Research suggested that 12.2 million people in Viet Nam, 8.6 million in Indonesia, and 3.6 million in Thailand would experience either worsening water stress or new water stress by 2050. This could be explained by the fact that the countries’ population growth (or population distribution) will be matched by increases in water runoff.

In regard to forestry, climate change will also impact forests in Southeast Asia. In 1990, 93% of Southeast Asia’s total forest area was covered by high quality forests, with high carbon sequestration potential. However, because of climate change, this is projected to fall to 92% by 2050, 88% by 2100, 90% by 2050, and 75% by 2100 (without taking into account the impacts of direct human activities of deforestation). Among the ASEAN countries, forests in Thailand and Viet Nam are projected to be most severely affected. Accordingly, the high-quality forest area is projected to decline by 60% by 2100 in Thailand and by 28% in Viet Nam.
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6.4. The Effects of climate change on Industrial sector and labor productivity:

It is commonly agreed that climate change is the outcome of human activity, including industrial production, car exhaust, and logging. These types of activities increase the concentration of carbon dioxide, methane, nitrous oxide, and other greenhouse gases in the atmosphere. So, if the current trend in carbon emissions continues, temperatures will increase by about 1° C in 2030 and 2° C by the end of the next century.

On the other hand, this increase may have mixed effects across regions. For instance, impacts on agriculture will be more damaging in tropical regions than in temperate regions. It is also likely that the developing countries, especially the poorest ones, will be adversely affected for the next 50 to 100 years with a reduction in agricultural lands and their potential of productivity because of their inability to adapt adequately through the provision of the necessary resources, or through increased food imports ("Intergovernmental Panel on Climate Change", 2001).

As far as industrial growth is concerned, the review of literature shed light on the impacts of climate change on industrial production. Accordingly, there exist links between industrial growth, environment and climate change, and some challenges associated with these issues.

In regard to economic growth, the natural environment plays two key roles. From one hand, it provides natural resources as inputs—either direct or indirect, to production of goods and services. On the other hand, it functions as a sink to pollutants which are generated from economic production and consumption. Examples include hazardous air, water and solid pollutants which are dissipated. Also, the natural environment acts as a repository for solid and toxic waste. i.e. the natural environment has some absorption capacity of external pollution (Ekbom and Dahlberg, 2008, p. 2)

In order to protect the environment and reduce the forms of pollution it faces, most of the world's countries are currently working on finding the most important mechanisms and policies as well as legal legislation to address the said challenge. The most important recent studies emphasized on the strong relationship between the need for economic development and environmental protection; based on the fact that the continuity of human well-being is only possible with the survival of the natural environment without distraction, and providing opportunities for future generations to benefit from within the framework of so-called sustainable development. Pollution tax, or namely ‘green taxes’, is the most important tool in the protection of the environment from various forms of pollution, of which the most important economic institutions are responsible. This perspective is accredited to the Economist Arthur Cecil Pigou who set into motion the principle of "Polluter- Pays". Accordingly, environmental tax legislation has proven its environmental effectiveness, even though there are no data on the economic cost of such fees. According to a study published on the effectiveness of environmental taxes in ASEAN countries, data confirmed that environmental taxes proved their effectiveness in combating pollution. As environmental taxes impose obligations on industrial companies to reduce the amount of greenhouse gas emissions to reduce environmental pollution, this factor leads employers to reduce the number of workers in their factories and; thus, results in decrease in total production (Benazza and Benhabib, 2012, p. 1).
The effects of climate change on the economic growth of ASEAN countries

As far as global carbon emissions and their economic cost are concerned, a report of US 'Worldwatch' stated that global economic emissions in the world reached 8.2 billion tons of carbon dioxide in 2007, with an increase of 2.8% over 2006, while the increase is 22% compared to 2000 levels. Organic fuels are responsible for 74% of total carbon emissions in the atmosphere (McKeown, A. and Gary Gardner, 2009, p. 9).

In recent years, China has been the world's most economically growing country. However, although China is far ahead of its population size compared to the US, the latter is the second largest in the population's share of carbon dioxide, with the average US citizen per capita exceeding four times that of China. China was very influential in increasing carbon emissions, contributing with 57% between 2000 and 2007; while India, the US, and Europe accounted for about 15% over the same period. As emissions continue to rise at current rates, global warming intensifies, which calls for the need to reduce the Earth's temperature by 2°C. By 2050, carbon emission levels are required to return to below 50% by 2000 levels and this requires large finance investments from all countries of the world. The United Nations report (2017) predicted the cost of reducing carbon emissions between 0.3% and 2% of global economic output, and it is likely to take 2% for climate change risks to reduce carbon. In the event of a delay in taking measures to achieve this, the ratio will rise between 5% and 20% of the world economic output. In other words, these measures could cost US $ 4.6 trillion, US $ 200 billion a year, to reduce the carbon footprint in 2030 to 2007 levels (Hachem, 2017).

The increase in temperature and humidity in the workplace does not only affect the element of comfort, but health, productivity, and workers' ability to carry out their tasks properly as well. In fact, works safety factors take into account high temperatures and provide preventive measures.

South-East Asia is also the largest contributor to greenhouse gas emissions, accounting for one-third of the world's carbon dioxide emissions and 60% of its coal consumption. The region plays a critical role in advancing the global climate change agenda. In recent decades, the ASEAN region's growth in emissions of carbon dioxide (CO2) has been more rapid than in any other area of the world. Moreover, the region has an array of policies that encourage high levels of emissions and technical inefficiency, such as extensive fossil fuel subsidies. Coupled with some of the world’s most rapidly growing economies, the region is on track for large increases in emissions over the coming decades. Such a rapid rise is incompatible with the established international scientific consensus on the degree of global warming that can be accepted without leading to large catastrophic risks.

Much of Southeast Asia has portions of the year that already exceed this limit, and these portions will grow under climate change, such that labor in physically demanding industries will need to mechanize, investment in cooling will need to rise, or economic output will be sacrificed. The weather factors associated with productivity were collected in the Wet Bulb Globe Temperature (WBGT) which is a measure of the heat stress in direct sunlight, which takes into account: temperature, humidity, wind speed, sun angle and solar radiation, and wind velocity in the workplace (Kjellstrom, T., Gabrysch, S., Lemke, B., and Dear, K., 2014b, p. 3). The latter has been used in several studies aimed at identifying the percentage and impact of worker productivity on climate change. One of these studies, which was published in the 64th issue of the Journal Achieve of Environmental and Occupational Health and addressed various climatic zones across all continents, found that by 2080 with temperatures rising from 2.4° C to 6.4° C and in a scenario that assumes large population growth, medium-speed economic growth, and relatively high emissions, labor productivity in South East Asia will drop by 11% to 27%, since these regions are mostly affected by higher temperatures (Kjellstrom, Kovats, Lloyd, Holt and Tol, 2009a, pp. 9-10). Also, Kjellstrom et al. (2015c) estimated that the Philippines will lose 6% of labor days due to climate change effects on WBGTs by the mid-2050s, and Viet Nam will lose 5%.

The effect is more pronounced in open businesses; such as, roads where workers are significantly affected by the rise in summer temperatures. The same work is affected by increased storms in the winter, which cause some parts to drift or delay the drying of cement. This can be generalized around the world. In any place and to cope with high temperatures, some workers may have to reduce their labor intensity and speed to get them to work, or to take longer breaks or more. If this is not realized, the workers’ productivity will decline. This, in turn, will ultimately affect the speed of completion of work on time, which may pose a significant risk in some projects. Therefore, to compensate for that reduction in productivity, workers will have to work longer hours, or the operator will have to employ more workers, or take preventive measures to reduce temperatures, which means that the cost of doing work will rise.

In other words, the impact of low productivity is not limited only to the speed of completion of work or the exhaustion of workers, but also affects the economy. A recent report by the World Development Assistance Partners (DARA) stated that the decline in productivity caused by climate change costed the world $300 billion in 2010, while it is expected to reach $2.5 trillion annually by 2030 (‘Climate Vulnerability Monitor’, 2012).

7. Conclusion:

The present paper addressed to the effects of climate change in ASEAN countries, with focus on effects on economic growth; such as agriculture, industry, and labor productivity. From the data presented in the paper, it seems clear and evident that climate change in the ASEAN region poses challenges for the economic sectors of economy, particularly in agriculture. Therefore, the relationship between climate change and agriculture is seen as extremely important since the region’s food–production resources are affected by both factors of climate changes and a rapidly increasing population in Southeast Asian countries.
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The reports released by the IPCC and ADB warned of the fact that the ASEAN region will be more vulnerable to climate change, since global average temperatures keep increasing, sea levels rose to 3 millimetres, rainfall trended downward, and widespread melting of snow and ice. Therefore, heat waves, droughts, floods, and tropical cyclones have become more intense and frequent in the region.

The impacts of climate change are of a major concern to ASEAN governments; so, they should address seriously to the issue climate change through different environmental and economic policies over the next years. Accordingly, they should announce voluntary mitigation targets to reduce emission of greenhouse gases to protect the environment, and strengthen their climate change adaptation in development planning.

References:


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