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Review on the Impact of Climate Change on Global and Regional Coffee Production

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Abstract

This review is conducted in Debre Berhan Univesity College of Agriculture and Natural Resource Scienceto assess the impact of climate change on global and regional coffee production. It includes the impact of climate change on coffee production, coffee worldwide trade, coffee diseases infestation, and its effect on Colombia, Uganda and Ethiopia coffee production systems. Accordingly in the coming decades the production areas as well as the coffee crop shows decline. This is also more severe in case of coffee Arabica, since it requires specific agroecological growing conditions. Ethiopia is the major coffee producer of Arabica coffee throughout the world but climatic change coming to affect the production power of this leading country.

Keywords: Climate change; Coffee Arabica; Coffee canephora

Introduction

The history of coffee goes at least as far back as the 10th century, with a number of reports and legends surrounding its first use. The native (undomesticated) origin of coffee is thought to have been Ethiopia. The earliest substantiated evidence of either coffee drinking or knowledge of the coffee tree is from the 15th century, in the Sufi monasteries of Yemen (Weinberg et al., 2001). By the 16th century, it had reached the rest of the Middle East, Persia, Turkey, Horn of Africa, and northern Africa. Coffee then spread to the Balkans, Italy and to the rest of Europe, to Indonesia and then to America (Meyers, 2005). Coffee is one of the world's most popular beverages. Some claim it is the most widely consumed liquid in the world aside from water. Coffee is more than a beverage, it is a memory, anticipation, a lifetime of consoling moments of modest pleasure woven into our lives. Coffee's success as a beverage undoubtedly owes both to the caffeine it harbors and to its sensory pleasure. Coffee lovers come to associate the energizing lift of the caffeine with the richness and aroma of the beverage that delivers it [1].

The global climate has changed over the past century and is predicted to continue changing throughout the twenty-first century. Global circulation models all point in the direction of higher mean temperatures and changes in precipitation regimes [2]. Both indicate that there will be a drastic shift in current land use and crop suitability, in addition to general increases vulnerability to climate variability. Climate change, including changes in the baseline and increased variability and frequency of extreme events, will affect agricultural productivity, farm incomes and food security (Fischer et al., 2002). The predicted changes in future climates have the potential to expose agricultural systems to conditions and extremes not experienced before. The impacts are likely to vary across geographical regions and between different agricultural systems. Some of the climate changes could have beneficial effects while others are likely to be detrimental [3].

According to Laderach et al (2008) the climate change will shift the altitude range for coffee to higher elevations over time, with the optimal altitude shifting from 1200m at present to 1400m in 2020 and 1600m in 2050 in Central America. This scenario generates different impacts at different altitudes, with the winners being smallholders at altitudes currently too high for the production of specialty-grade coffees and the losers those farmers currently at the lower viable bounds for production of specialty coffee. As part of this process, the viability of some of the most celebrated origins in the specialty coffee market today, including Antigua, Guatemala, and Las Segovias, Nicaragua, will be put at risk [4].

He also explains it is essential for vulnerable smallholder farmers, whose livelihoods will be most affected by climate change, to understand its likely impacts and develop strategies to adapt. Understanding the implications of these changes is also critically important to all stakeholders in the value chain. To ensure the livelihoods of millions of smallholder farmers and related rural industries, it is crucial to identify adaptation pathways for these production systems or identify opportunities for diversification into other high-value crops. Therefore this work is aimed to assess some reviews on impact of climate change on global and regional coffee production [5].

Major Reviews

Climate change and coffee production

As climate change becomes a more spotlighted issue in the international community, research about its impact rapidly increases. Climate change is predicted to have a variety of negative effects; one negative impact is that it can drastically hurt crop productions. Researchers say coffee plants are especially vulnerable to climate change because the majority of coffee is grown in developing countries. Coffee producing countries like Brazil, Vietnam, Ethiopia and Colombia depend on coffee production as a major part of their economies, but climate change will cause many problems for them. According to Haggar and Schepp (2012) temperature and rainfall conditions are considered to be important factors in defining potential coffee yield. Both factors interfere in the crop phenology, and consequently in productivity and quality. The Arabica coffee plant responds

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sensitively to increasing temperatures, specifically during blossoming and fructification. Robusta coffee is better adapted to slightly higher temperatures, but is much less adaptable to lower temperatures than Arabica [6,7].

Climate change has different effects on developed countries versus developing countries. In this case Deressa (2007) wrote that if temperatures increase by 3 degrees Celsius over the coming years and precipitation increases by 10 percent, developed countries could see an increase in cultivatable land of up to 25 percent. On the other hand, these same changes would cause developing countries to lose an average of 11 percent of their cultivatable land. This has a great influence in coffee producing developing countries including Ethiopia. Both developing and developed countries must take several steps in order to prevent the damage on their coffee production. If no action is taken, worldwide coffee production will encounter enormous harm and the economies of both nations would greatly suffer due to their dependence on coffee exports. Climate change also facilitates the damaging effects of the H. hampei and other diseases that target Arabica coffee and farmers need to monitor their crops more closely (Ramirez-Villegas et al., 2012) [8].

Davis et al. (2012) published their research on the effect of climate change on the Coffee arabica plant. Their research proved that the plant's growing success is directly linked to accelerated climate change, but there is a profoundly negative trend in this relationship. At best, they predict there will be a 65 percent decrease in Arabica production by the year 2080. At worst, they say there will be a 100 percent decrease by 2080. Ethiopia, which is the main African coffee producer, will face serious consequences since coffee exports account for about 33 percent of Ethiopia's export revenue.

Ramirez-Villegas et al. (2012) studied the way climate change will impact Colombia. They say if Colombia does nothing to stop the impact of climate change, it will impact 80 percent of crops and 60 percent of cultivated land. Flooding, increased temperatures, reduction in land fertility, new pests, and diseases threaten crops as a result of climate change. Their research cites coffee as the highest value crop in the nation. Possible solutions to lower the impact of climate change on coffee is to shade the areas where coffee is produced and moving coffee production to higher elevation where there are cooler temperatures.

Climate change and worldwide coffee trade

Coffee has proven to be one of the most important crops in the world due to the sheer magnitude of its trade. Study from the Royal Botanic Gardens performed by Davis et al (2012) explains that coffee is the second most traded good in the world. The most traded good is oil. From 2009 to 2010, coffee exports totaled about US$15.4 billion. During those years, 93.4 million bags of coffee were shipped throughout the world. Over 100 million people depend upon coffee production for their livelihood [9].

According to Davis et al (2012) that two main species of coffee make up the majority of coffee trade. Coffea arabica and Coffee canephora contribute the largest to worldwide coffee production. However, 70 percent of all coffee produced commercially comes from Arabica coffee. Arabica originated in Ethiopia and its wild variety currently only grows in Ethiopia, Uganda, and Kenya. Its cultivated form is grown throughout Africa and South America (Koebler, 2013). The cultivated, commercial form of Arabica coffee lacks genetic diversity, which makes it especially prone to diseases. Current climate change predictions say the wild form of Arabica coffee could go extinct by 2080 (Davis et al., 2012). Without the wild form of Arabica coffee which accounts for over 98 percent of the coffee gene pool no adaptations to the commercial form can be made. This could be disastrous if commercial Arabica experiences as many problems as researchers say it will [10].

For optimum growth and taste, Arabica coffee needs to be in an environment of about 18 to 21 degrees Celsius. Being exposed to temperatures of about 23 degrees or higher can cause the coffee plants to ripen, which negatively affects the taste and quality. Arabica coffee is a unique species because of its climate sensitivity (Davis et al., 2012).

Since Arabica coffee has such picky temperature requirements, climate change could lead to disastrous impacts on the worldwide coffee industry. In this case Jaramillo et al. (2009) states that even the smallest increases in temperature could cause extensive damage to coffee production. They estimate that if climate change continues on its current trend, the suitable land for growing coffee could face a reduction by up to 95 percent. Accordingly he explains that most coffee is grown in the tropics, which face severe threats of extreme climate change. Coffee production already is feeling the impact of climate change.

Between the years 2009 and 2011, the prices of Arabica coffee increased by 160 percent. Many factors contributed to the skyrocketing of prices worldwide. Productivity decreased in East Africa and Latin America, the main locations of coffee production. Colombia in particular faced a decrease between these years due to extreme weather disasters that hurt coffee plants, as well as outbreaks of pests and diseases that attack Arabica plants (Jaramillo et al., 2011).

If climate change continues as predicted, coffee production and trade will face difficult situations. The International Coffee Organization says climate change will lead to large reductions in coffee production. They predict that the biggest declines will occur in Africa and South America This will affect coffee prices and force them to rise even more. (Jaramillo et al., 2011). Ramirez-Villegas et al (2012) say that to protect coffee and coffee prices, greenhouse gases must be limited and reduced. Possible ways to limit greenhouse gases include a reduction in deforestation and better crop managements.

Climate change and diseases infestation

Climate change in South America and East Africa has had many negative effects on agriculture, specifically coffee production. One unforeseen result from climate change is the increase in predators for coffee plants. Arabica coffee does not have many natural predators. Coffee leaf rust is one danger to coffee growth that has emerged as a result of climate change. Coffee leaf rust is a fungus that originated in Africa and Asia, but it now can be found in almost all coffee-producing regions (Koebler, 2013). As Koeber explanation farmers learned that moving to cooler regions at higher elevations could eliminate the presence of this fungus. However, the increasing temperatures and rainfall resulting from climate change has led to coffee leaf rust becoming prevalent at higher altitudes. Coffee leaf rust has attacked Arabica coffee throughout South America and Africa.

The other main threat to coffee has drastically increased in recent years directly resulting from climate change is that the insect known as the coffee berry borer (Hypothenemus hampei / H. hampei). The insect is the biggest pest to coffee plants. H. hampei is one of only a few herbivores that have the ability to detoxify caffeine. Therefore, the insect has no problem feeding on the berries on Arabica coffee plants and remains as the unopposed foe to coffee (Jaramillo et al., 2009).

Jaramillo et al (2009) found that the population growth of H. hampei is directly and exponentially related to increases in temperatures. As temperatures rise, generations of the insect multiply. A study shows

that a 1 to 2 degree Celsius increase in temperature would cause the H. hampei to develop faster; this would lead to more generations per fruiting season. They found that increases of over 2 degrees Celsius would force the H. hampei to migrate to higher altitudes. This explains the bugs' shift from lower elevation where Coffea canephora grows to the higher altitudes of Coffea arabica.

As Jaramillo explains that the exact origin of the H. hampei is unknown. The bugs first came to Colombia in. In Africa, research shows the insect probably originated as a predator to Coffea canephora, a lesser-used coffee plant that grows at lower altitudes and warmer temperatures than Coffea arabica (Jaramillo et al., 2011). With rising temperatures, the coffee berry borer could be forced to migrate to higher altitudes where Arabica grows, giving it a new diet on which it can thrive. Recently, populations of the coffee berry borer have increased throughout southwestern Ethiopia. Studies have determined that while climate change has had many negative impacts on nature, the coffee berry borer has thrived with the rise in temperatures.

Two years later, Jaramillo et al (2011) looked back at their predictions. They found that their predictions were holding true. Over the coming years, they predict the climate of southwest Ethiopia will become more suitable for the coffee berry borer. Southwest Ethiopia is the main location of Arabica coffee production in Africa. Another prediction about the future of the coffee berry borer claims that the population increases will become drastic. Currently, about 1 to 4 generations are born each fruiting season, which refers to the time of year when Arabica coffee thrives. At best, predict this will increase to somewhere between 5 and 10 generations per fruiting season. At worst, they say the numbers could increase from 10 to 16 generations. This drastic increase in the population of coffee's main insect predator will not help the already struggling coffee industry.

Moreover according to Jaramillo et al (2009) calculation that Colombia will experience a devastating impact because of its precipitation. Colombia experiences yearlong precipitation and climate change is expected to increase this. This leads to more flowerings of Arabica coffee, thus creating more food for H. hampei. Ethiopia will face problems as well, but not as much as Colombia because Ethiopia's dry season will limit the flowerings per year.

Impact of climate change on colombia coffee production

Colombia depends highly on agriculture. In this South American nation, at least 3.7 million people depend solely upon agriculture for their jobs and livelihoods. Over a fifth of the nation works in the agriculture sector and a large share of its GDP comes from agriculture production. Of its many crops, coffee is one of Colombia's most prominent. In 2007, coffee accounted for 17 percent of Colombia's total crop production. Coffee is the highest value crop in the nation (Ramirez-Villegas et al., 2012).

Colombia is at high risk for unprecedented climate change. If Colombia does not take any action to impede the rising temperatures, up to 80 percent of its crops will be in danger and more than 60 percent of the farmable land would be negatively impacted by climate change (Ramirez-Villegas et al., 2012).According to this prediction that at best, temperatures in Colombia will rise between 0.5 and 1 degree Celsius. At worst, temperatures could rise from 3 to 6 degrees. The average estimate is that temperatures will rise by about 2.5 degrees Celsius by the year 2050. If his predictions come to reality, it would have a disastrous impact on Colombian coffee production. In addition to increased temperatures, the precipitation in Colombia will experience drastic changes. Annual precipitation will increase by 2.5 percent by the year 2050. High precipitation will lead to increased flooding, risk of salinization, and a reduction in the fertility of land. Ramirez-Villegas et al (2012) calculate that Colombia will experience much dryer dry seasons and much wetter wet seasons each year. These changes would have a profoundly negative effect on crop production.

Impact of climate change on Uganda coffee production

Climate change has an impact on the suitability of Arabica coffee growing areas in Uganda, including the Ruwenzori Mountain and most areas become less suitable, and particularly those at lower altitudes (1500m) will be severely affected. Lower areas that are currently still suitable for Arabica coffee require adaptation strategies in order to sustain the livelihood of farmers depending on Arabica coffee. The lowest Arabica growing areas (<1300m) are likely to become completely unsuitable and farmers may have to switch crops. On the other hand, areas that are currently often considered too cool (>2100m) will see suitability improvements in the decades to come. Broadly, for coffee, if temperatures increase, areas suitable for coffee will be higher up in the landscape. This means that due to climate change, some areas will become more suitable for coffee; others will undergo a reduction of suitability; while much of the area becomes unsuitable (Laderach et al., 2011). Unfortunately, the areas that will become more suitable for coffee will compete with other crops or national nature reserves. In areas where the suitability for coffee will reduce, adaptation strategies will need to be undertaken in order to sustain its production. But, this area is limited in size, soils are often stony, and a substantial part of the area is under nature conservation (Figure 1).

Climate change will affect the crop physiology. The unpredictable rains will cause coffee to flower at various times throughout the year, causing the farmers to harvest small quantities continuously. This is opposed to distinct wet and dry seasons that lead to the preferred

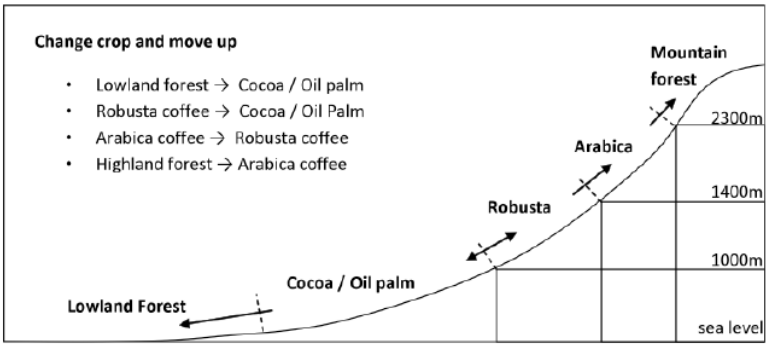

Figure 1: Possible changes in land use and crops induced by climate change.

harvest of large quantities during a short (± 2 months) harvest season. Prolonged droughts can cause flower abortion. Increased temperatures and sunshine can cause premature ripening of the beans, which will have a direct negative impact on the quality of the coffee and yield quantities. Climate change is anticipated to have a strong impact on the incidence and severity of certain pests and diseases. For example, farmers explained that the incidence of leaf miners has increased over recent years. They associate their increased incidence with drought. Coffee berry borer is another pest that appeared recently and is expanding fast. Likewise, coffee leaf rust is associated with warmer temperatures and is recorded to be moving up the mountain slopes (Laderach and van Asten, 2012).

Impact of climate change on Ethiopia coffee production

Ethiopia strongly depends on the success of agriculture and 85% of the population in Ethiopia gets their job or livelihood from agriculture. Agriculture makes up around 50 percent of Ethiopia's gross domestic product. Of its diverse range of crops, stimulants such as coffee, tea, and tobacco are the major cash crops. However, Ethiopian agriculture is prone to significant threats. Ethiopia's agriculture depends on rain, so droughts cause considerable damage and often lead to famine (Deressa, 2007). Also lists other dangerous stresses to Ethiopia's agriculture like biotic constraints in Ethiopia include (weeds, insects, and disease) and abiotic constraints including drought, low soil fertility, water logging, and low levels of technology throughout the nation.

Specifically, Ethiopia depends on coffee production and the only type of coffee produced in Ethiopia is Arabica coffee. It is that found that coffee makes up 33 percent of Ethiopia's exports. Additionally, Ethiopia is the main producer of coffee in all of Africa. It is the 5th largest exporter of Arabica coffee globally (Davis et al., 2012).

Several studies have determined Ethiopia to be especially prone to the impacts of climate change over the coming years. According to Deressa (2007) that Ethiopia will experience an increase in temperatures but a decrease in precipitation. This will strongly damage Ethiopia's agriculture. Jaramillo et al (2011) also predicts that the changes in precipitation will be highly variable. From December through February, Eastern Africa could see a 5-20 percent increase by 2050. However, during the important farming months of June through August, rainfall will decrease by 5-10 percent by 2050. In addition, Africa will lose 60-90 million hectares of suitable land for agriculture by the year 2080 (Jaramillo et al., 2011), which is about 2 to 3 times the land area of Arizona.

Davis et al (2012) predict that climate change will lead to a 65 percent reduction in suitable land for Arabica coffee growth. This is their best-case scenario prediction. At worst, they found that 100 percent of suitable land for Arabica coffee production will disappear due to climate change. They determined a negative trend between the increase in global temperatures and the growth of Arabica coffee. He also explains that as the temperatures increase, Arabica coffee production will decrease. This will negatively impact Ethiopia's coffee industry. More over Davis et al (2012) forecast that climate change will lead to increased threats to coffee production in southwest Ethiopia [11].

Conclusion

Coffee is important and high value crop throughout the world. It the second most traded crop next to petroleum. However, the global climate has change over the past century and is predicted to continue changing throughout the twenty-first century brings high negative effect on its production. Global climatic changes like of higher mean temperatures, change in baseline and changes in precipitation regimes have serious impact on coffee yield and quality. More over there is a claim that Arabica coffee is more sensitive to climate change and as a result it will decrease in production or might lost in next decades. The reduction of greenhouse gases by reducing deforestation and effective crop management; shifting of Arabica coffee production to elevated high land areas and production of coffee under shade condtions may reduce the impact of climate change on coffee production.

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