

# **The Impact of Climate Change on Coffee Production in Colombia and Ethiopia**

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## **Abstract**

*This article seeks to address the ways that climate change impacts Colombia and Ethiopia. It directly focuses on the effect of climate change on coffee production, a major part of each nation's economy. This article comments on the differences and similarities for the two countries in how climate change affects their coffee production. It looks at the issues that arise for coffee production because of changes to the global climate. Specifically, it focuses on the increase of coffee leaf rust and the drastic population increase of the coffee berry borer, an insect that feeds on the berries of coffee plants and negatively impacts worldwide coffee production. This article also examines several possible steps Colombia and Ethiopia could take to limit the damage of climate change on coffee production. It also analyzes what steps Colombia and Ethiopia are currently taking and what other possible solutions the nations could consider.*

## **I. Introduction**

After oil, coffee is the most internationally traded commodity in the world; consumers from all around purchase and enjoy coffee on a regular basis. The economies of many countries depend upon coffee production for stability and growth. New studies have found that *Coffea arabica*—the plant that almost all coffee is made from—may go extinct by the year 2080. Climate change already had (and will continue to have) a severe and negative effect on coffee production throughout the world.

In Colombia, an increase in rainfall threatens the health of these coffee plants. In Ethiopia, rapidly increasing temperatures kill the plants at an alarming rate. In both of these nations, pests and disease that target coffee plants have risen in prevalence. Unless action is taken to slow down climate change or find alternative ways to keep coffee plants alive, these two countries will be in danger due to the importance of coffee production for their economies. Some possible actions that would limit the negative impact of climate change include the migration of coffee plants to cooler altitudes, increased funding to protect the plants, and the implementation of shade trees to block the sun.

## II. Brief Literature Review

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. Ethiopia and Colombia depend on coffee production as a major part of their economies, but climate change will cause many problems for them. What follows are some selected works that discuss elements of this issue.

- Deressa (2007) of the World Bank completed an extensive study of Ethiopian agriculture. The study concluded that increasing temperatures and decreased precipitation, due to climate change, will have a long-lasting negative effect on Ethiopian agriculture. Agriculture is the most important part of Ethiopia's economy because about 85 percent of Ethiopians depend on agriculture for employment. It has diverse agriculture with a mix of crops and the largest population of livestock in Africa. Stimulants such as coffee are major cash crops in Ethiopia. Some problems that hurt Ethiopian agriculture include drought, insects, disease, and low levels of technology. Climate change will lead to higher temperatures; developed countries can benefit from the higher temperatures for their agriculture. Developing countries like Ethiopia will suffer because their agricultural technology cannot deal with the changes.
- Jaramillo et al. (2009) discussed that the coffee berry borer, *Hypothenemus hampei*, is one of the main insects that feed on coffee berries. It is one of very few herbivores that feed on coffee because it has tolerance for caffeine. Their research discovered that population growth of *H. hampei* has an exponential relationship with temperature increases. As temperatures rise, the population of coffee's main predator drastically increases. Colombia will face severe consequences from this because its wet climate leads to coffee berries being around yearlong. Ethiopia has a dryer climate, so its coffee berries are only seasonal. This gives *H. hampei* less food and a lower chance of survival.
- Davis et al. (2012) published their research on the effect of climate change on the *Coffea 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.

### III. Empirical Background

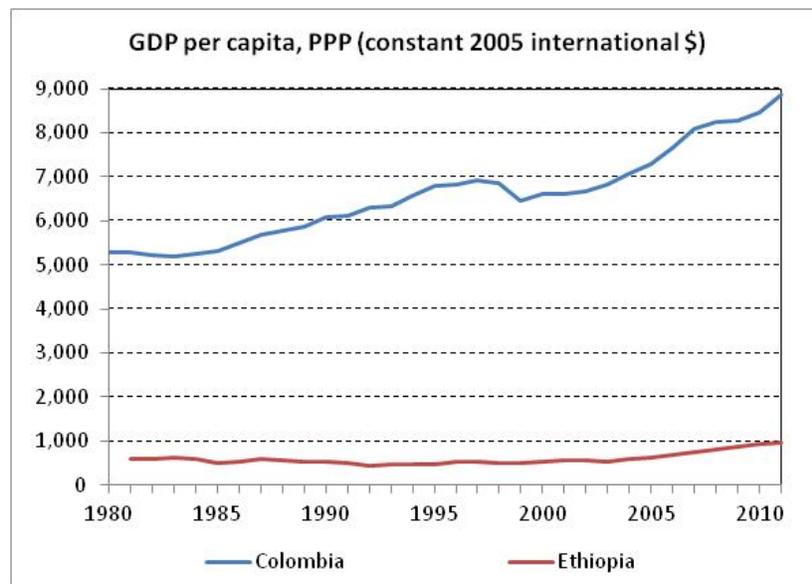
#### III.1. Socio-economic Background of Colombia and Ethiopia

Colombia is an upper middle-income country located in northwest of South America. In 2012, the country had a population of 48 million people, and its gross domestic product (GDP) in current US\$ was \$370 billion. In 2011, 34.1 percent of the population lived below the national poverty line. Life expectancy at birth was 74 years in 2011.<sup>1</sup>

Ethiopia is a low-income country located in the east of Sub-Saharan Africa. In 2012, the population of the nation was 92 million people; and its GDP in current US\$ was \$30.2 billion. As of 2011, 29.6 percent of the citizens of Ethiopia lived below the national poverty line. Life expectancy at birth was 62 years in 2011.<sup>2</sup>

Figure 1 shows GDP per capita of Colombia and Ethiopia in constant 2005 international \$. With exception of the early 1980s and a sharp decline 1998 and 1999 and some stagnation during 2000-2002, Colombia's GDP per capita grew continuously, increasing from \$5,297 in 1980 to \$8,860 in 2011. Ethiopia's GDP per capita grew far less. Most of the 1980s saw actually a gradual decline, reaching a minimum of \$432 in 1992 (which is a nearly 30 percent drop compared to the \$599 in 1981). Over the subsequent 10 years, GDP per capita grew by about \$120 (or an average annual growth rate of 2.6 percent). Only since 2004 saw Ethiopia substantial growth rates, reaching a GDP per capita of \$979 in 2011.

**Figure 1: GDP per capita (constant international \$), 1980-2011**



Source: Created by author based on World Bank (2013).

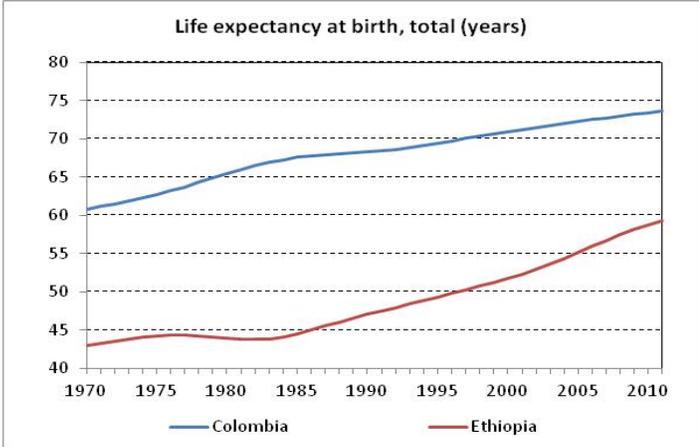
<sup>1</sup> World Bank (2013).

<sup>2</sup> World Bank (2013).

Both Colombia and Ethiopia are similar size countries in terms of land area. Despite their similar land size, Ethiopia has almost twice the population of Colombia (World Bank, 2013). Furthermore, while the percentages living below the national poverty lines (29.6 percent in Ethiopia, compared to Colombia's 34.1 percent) seem to indicate that poverty is more severe in Colombia, the level of these national poverty lines are very different. Ethiopia is obviously much poorer than Colombia.

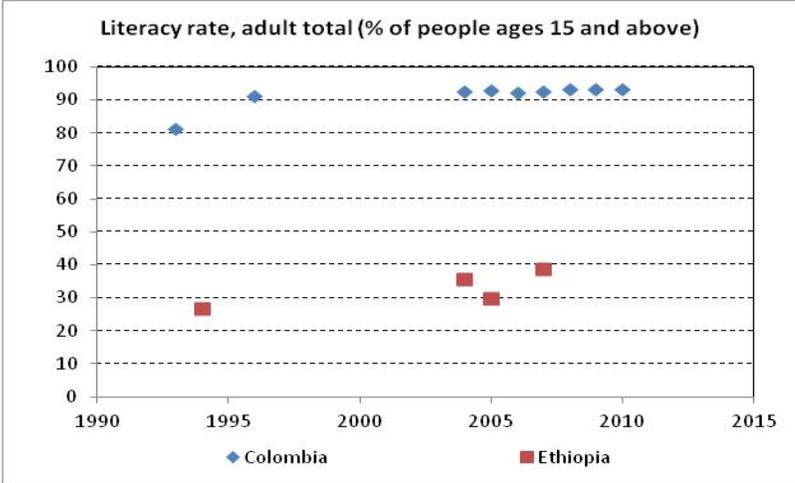
Consistent with the huge difference in income per capita, Figure 2 shows how life expectancy at birth has been and remained much higher in Colombia than in Ethiopia. Figure 3 shows that the adult literacy rate is also higher in Colombia than Ethiopia. Obviously, since these two nations are from different economic brackets, the health and education opportunities are drastically different.

**Figure 2: Life expectancy in Colombia and Ethiopia 1970-2011**



Source: Created by author based on World Bank (2013).

**Figure 3: Literacy rate in Colombia and Ethiopia, available years**



Source: Created by author based on World Bank (2013).

### III.2. 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. In fact, a 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 (Paramaguru, 2012). Over 100 million people depend upon coffee production for their livelihood (Paramaguru, 2012).

Davis et al. (2012) point out that two main species of coffee make up the majority of coffee trade. *Coffea arabica* and *Coffea 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 (Koebler, 2013). 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 (Paramaguru, 2012). Current climate change predictions say the wild form of Arabica coffee could go extinct by 2080 (Paramaguru, 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.

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. Jaramillo et al. (2009) state 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. Most coffee is grown in the tropics, which face severe threats of extreme climate change (Jaramillo et al., 2009). 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 (Jaramillo et al., 2011). Many factors contributed to the skyrocketing of prices worldwide. Productivity decreased in East Africa and Latin America, the main locations of coffee production. Jaramillo et al. (2011) explain that 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.

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 (Jaramillo et al., 2011). They predict this will affect coffee prices and force them to rise even more. 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 management (Ramirez-Villegas et al., 2012).

## **IV. Discussion**

### **IV.1. Colombia: Agriculture and Climate Change**

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 (Ramirez-Villegas et al, 2012). 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. Ramirez-Villegas et al. (2012) say that in 2007, coffee accounted for 17 percent of Colombia's total crop production. Coffee is the highest value crop in the nation. The majority of coffee production occurs on small, family-run farm plots (Martinez, 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 (Ramirez-Villegas et al., 2012). More than 60 percent of the farmable land would be negatively impacted by climate change, according to Ramirez-Villegas et al. (2012). Predictions say 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 the predictions of Ramirez-Villegas et al. (2012) 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 (Ramirez-Villegas et al., 2012). 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.

The 2007 report from the Intergovernmental Panel on Climate Change (IPCC) says climate change will lead to a loss of suitable environments for coffee growth in Latin America and the Caribbean (Ramirez-Villegas et al., 2012). It says climate change will lead to an increase in the coffee berry borer, the main insect threat to coffee. Ramirez-Villegas et al. (2012) reveal that in addition to the increased insect threat, diseases also could hurt coffee production in Colombia. Coffee leaf rust, known as *Hemileia vastatrix*, would hurt a large portion of coffee plants in South America.

### **IV.2. Ethiopia: Agriculture and Climate Change**

Ethiopia strongly depends on the success of agriculture. Deressa (2007) found that 85 percent of the population in Ethiopia gets their job or livelihood from agriculture. Agriculture makes up around 50 percent of Ethiopia's GDP. Of its diverse range of crops, stimulants such as coffee, tea, and tobacco are the major cash crops (Deressa, 2007). 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). Deressa (2007) also lists other dangerous stresses to Ethiopia's agriculture. Biotic constraints in Ethiopia include weeds, insects, and disease. Abiotic constraints include drought, low soil fertility, water logging, and low levels of technology throughout the nation.

Specifically, Ethiopia depends on coffee production. The only type of coffee produced in Ethiopia is Arabica coffee (Davis et al., 2012). Davis et al. (2012) 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 5<sup>th</sup> 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. Deressa (2007) said Ethiopia will experience an increase in temperatures but a decrease in precipitation. This will strongly damage Ethiopia's agriculture. Jaramillo et al. (2011) predict 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 (Davis et al., 2012). As temperatures increase, Arabica coffee production will decrease. This will negatively impact Ethiopia's coffee industry. Davis et al. (2012) forecast that climate change will lead to increased threats to coffee production in southwest Ethiopia.

### **IV.3. Resulting Threats to Coffee: Coffee Leaf Rust and Coffee Berry Borer**

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). The fungus has particularly damaging effects. In the 1860s, coffee leaf rust led to the obliteration of the entire population of coffee in Sri Lanka (Koebler, 2013). 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 than it used to (Koebler, 2013). Coffee leaf rust has attacked Arabica coffee throughout South America and Africa.

Yet, another main threat to coffee has drastically increased in recent years directly resulting from climate change. The insect known as the coffee berry borer, *Hypothenemus hampei* or *H. hampei*, is the biggest pest to coffee plants (Jaramillo et al., 2009). *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. (2011) explain that the exact origin of the *H. hampei* is unknown. The bugs first came to Colombia in 1988 (Jaramillo et al., 2009). 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.

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 performed by Jaramillo et al. (2009) determined 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*.

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 (Jaramillo et al., 2011). At best, Jaramillo et al. (2011) 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.

Jaramillo et al. (2009) calculate 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 (Jaramillo et al., 2009).

#### **IV.4. Moving Forward: Possible Stall Tactics and Robusta Coffee**

Climate change has different effects on developed countries versus developing countries. Deressa (2007) writes 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 (Deressa, 2007).

Both Colombia and Ethiopia 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. In order to limit the damaging effects of the *H. hampei* and other diseases that target Arabica coffee, farmers need to monitor their crops more closely; they need to implement some form of an early-warning system, which will allow coffee to remain sustainable (Ramirez-Villegas et al., 2012). Ramirez-Villegas et al. (2012) also advocate that the governments of Colombia and Ethiopia must increase funding for research that could prevent the extinction of Arabica coffee.

In order to fight rising temperatures, several researchers argue that coffee plants should be moved to higher elevations where temperatures are usually a few degrees cooler (Jaramillo et al., 2011; Davis et al, 2012; Ramirez-Villegas et al., 2012). Unfortunately, this is not a highly feasible accomplishment. Jaramillo et al. (2011) say that in Colombia, Arabica coffee would need to move 167 meters higher in elevation for every 1 degree Celsius increase. However, higher ground is

limited in Colombia (Ramirez-Villegas et al., 2012) and Ethiopia does not have much adequate high-altitude land for farming (Jaramillo et al., 2011). Davis et al. (2012) say that re-colonizing Arabica coffee plants in Ethiopia is not necessarily a good idea because it will take many years for the plants to become productive again, causing the coffee industry to take a severe hit.

Scientists seem to agree that the best way to preserve Arabica coffee is through the use of shade trees (Jaramillo et al., 2009; Jaramillo et al., 2011; Ramirez-Villegas et al., 2012). Shade trees planted near coffee plants have the ability to block out the sun's impact on the plants. They create lower temperatures better suited for Arabica coffee plants. Jaramillo et al. (2011) say shade trees can cause a reduction in temperature by up to 4 degrees Celsius. With the widespread implementation of shade trees in Colombia and Ethiopia, the increase in the population of *H. hampei* could be about 34 percent lower than expected (Jaramillo et al., 2011). These relatively small steps could provide protection and stability to the struggling Arabica coffee plants.

Colombia and Ethiopia have responded to climate change issues in drastically different ways. Economically, Colombia is much better off than Ethiopia. It has significantly more resources to combat climate change. Colombia's National Coffee Growers Federation is a group that works to develop new varieties of coffee plants that have increased disease resistance and are more adaptable to changes in temperature or rainfall (Martinez, 2012). Additional groups to protect Colombia's coffee industry include: Climate and Development Knowledge Network; National Institute of Coffee Research; Universidad del Cauca; Universidad del Valle; Instituto de Hidrologia, Meteorologia y Estudios Ambientales (Martinez, 2012). The most prominent organization in Colombia to protect its coffee industry is Colombia's Cenicafe research center (Koebler, 2013). This organization has created two strands of coffee rust-resistant beans, called Colombia Variety and Castillo (Koebler, 2013). For the past five years, the Colombian government has spent \$1.4 billion to develop rust-resistant Arabica coffee plants. The government assists rural farmers and provides loans due to the high expense and difficulty of redoing farms so they are growing rust-resistant plants (Koebler, 2013).

Ethiopia has extremely limited resources and has no access to resources such as Colombia. Therefore, the nation will fall behind further-developed nations since it has no ability to protect its coffee industry. Colombia far surpasses other nations in terms of protecting coffee production.

Due to the increasingly bleak predictions of the future of Arabica coffee, some have suggested a new focus on the second-best brand of coffee: *Coffea canephora*, commonly called Robusta coffee. Robusta has higher caffeine content than Arabica; it mostly is used for freeze-dried coffee (Paramaguru, 2012). Unfortunately, Robusta does not taste as good as Arabica so coffee producers are hesitant to switch to Robusta (Koebler, 2013). Despite its lower quality, Robusta is more tolerant of climate change and heat; it does not depend as much on rainfall. Researchers are searching for ways to improve the taste of Robusta, but have been unsuccessful so far (Koebler, 2013).

## V. Conclusion

Colombia and Ethiopia are exceedingly different countries experiencing the same dilemma. Both countries face the danger that climate change will permanently destroy one of the most crucial aspects of their economies: coffee production. Due to Arabica coffee's specific requirements for growth, even slight changes to temperature and precipitation could kill the plant. As a result of climate change's impact so far, new threats have arisen in both Colombia and Ethiopia. Coffee

leaf rust and the coffee berry borer are now a much more significant threat to coffee production than they ever were before.

Colombia has significantly more resources than Ethiopia. Colombia has already begun several initiatives to develop new types of coffee that will not face as dire consequences due to climate change. Ethiopia lacks the money and ability to do so. While both nations will struggle because of climate change's attack on their coffee industries, it appears that Colombia will not be in as much trouble as Ethiopia. Colombia has the ability to take the necessary precautions to limit the damage of climate change, but Ethiopia cannot take these same steps. Currently, Colombia and Ethiopia are world suppliers for Arabica coffee. In a number of decades, Colombia may prevail over Ethiopia because of its potential to overcome climate change.

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