Prospectus

Carbon Capture, Utilization and Storage
(Technical Topic)

Analysis of the Effect of Climate Change on Cultivation of Arabica Coffee (*Coffea arabica)*
(STS Topic)

By

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On my honor as a University student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments.

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Introduction

Climate change is almost certainly the defining issue of the current generation, and the leading contributor to climate change is carbon dioxide (CO_2) (NASA, 2014; IPCC 2017). Agriculture is one of the most dramatically effected industries due to climate change. Cultivation of the arabica coffee plant, which is now categorized as an endangered species, is among the most highly threatened agricultural practices. Technologies, such as carbon capture, utilization and storage (CCUS) have the potential to mediate a portion of greenhouse gas (GHG) emissions. Even with the implementation of CCUS technologies, farmers must still consider adaptation techniques to reduce the potential for extinction of *Coffea arabica*.

The International Energy Agency (IEA) reported a 2.3% increase in global energy demand in 2018, resulting in a 1.7% increase in CO_2 emissions from energy-related processes (Jungcurt, 2019). Energy-related CO_2 discharges from the United States alone amounted to 5,268 million metric tons in 2018 (EIA, 2019). Industries such as cement, steel, and chemicals production all release CO_2 during manufacturing, but quite literally lay the foundation for global infrastructure development (IEA, 2019).

While carbon emissions are an inherent part of day-to-day life, CCUS technologies are at the forefront of carbon emission mitigation techniques. CCUS is the process of capturing, transporting, and re-using or storing CO_2 to prevent its release to the atmosphere. A reduction in the concentration of CO_2 in the atmosphere will lower the CO_2 loading rate on Earth that is known as a main cause of climate change.

Changes in the climate caused by GHG emissions are projected by experts to limit, if not fully eliminate, agricultural arabica coffee cultivation, which is a staple to society on a global scale (Davis, Dr. Aaron P, 2017). Coffee consumption was at its highest during the 2017/18 fiscal year, with the global population consuming 161.74 million 60kg bags (ICO, 2019). Investigation of the potential effect of climate change on growth of *Coffea arabica* is vital to not only the global population, but farmers and the livelihoods of their communities. Greater than 90% of coffee production is located in developing countries (Ponte, 2002), and the residents of these areas are found to be extremely vulnerable to climate change.

Carbon Capture, Utilization and Storage

As the world's population continues to grow, energy demands increase proportionally, and although renewable energy sources are becoming more prevalent, "fossil fuels [will] still account for more than three-quarters of world energy consumption through 2040" (Doman, 2017). Thus, while furthering development of renewable fuels positively contributes to lessening reliance on fossil fuel-driven energy sources, action must be taken to reduce carbon dioxide emissions to provide an immediate, viable solution to the world's energy crisis. The technical portion of this analysis pertains to the design of an effective application of carbon capture, utilization and storage (CCUS) technology, a method that has the potential to reverse alarming emissions trends.

CCUS technologies have been around since 1989, when MIT initiated the first Carbon Capture and Sequestration Technologies Program (Lin, A., 2016). CCUS involves removing carbon dioxide from gaseous byproduct streams produced in industrial processes, and either storing or using it to create valuable products, including fuels. While CCUS has been applied to pilot-scale operations, industries have yet to put forth financial resources required to create large-scale systems. The primary challenge preventing this commitment is the drastic energy demand of separating carbon dioxide from other gases, resulting in a high cost. Based on initial CCUS designs, this single step alone "could consume 25 to 40% of the fuel energy of a power plant" (Haszeldine, 2009, p. 1648). In order for CCUS technology to thrive, design of the separation process must be optimized to decrease its associated cost, which is the most pressing challenge and one of the primary objectives associated with the technical project. The design must not only be economically viable, but additionally must operate as efficiently as possible while taking safety and environmental concerns into account. Based on preliminary research, removal of carbon dioxide from emissions streams at coal-fired power plants using monoethanolamine (MEA), a chemical solvent, is a viable approach for the design of CCUS technology.

Power plants that rely on fossil fuels as a source of energy burn the substance at high temperatures, producing flue-gas as a result of combustion, a vapor stream that includes carbon dioxide as well as water vapor, nitrogen, oxygen, and traces of other gases. In order to begin the CCUS process, carbon dioxide must be separated from other species, producing carbon dioxide with the highest possible purity. The overall separation process is represented by the "Separation System" block within *Figure 1*, which outlines the process of CCUS. The first step of separation involves cooling flue-gas and feeding it to an absorption column, where it comes into contact with MEA solvent, which absorbs carbon dioxide, separating it from other gaseous compounds.

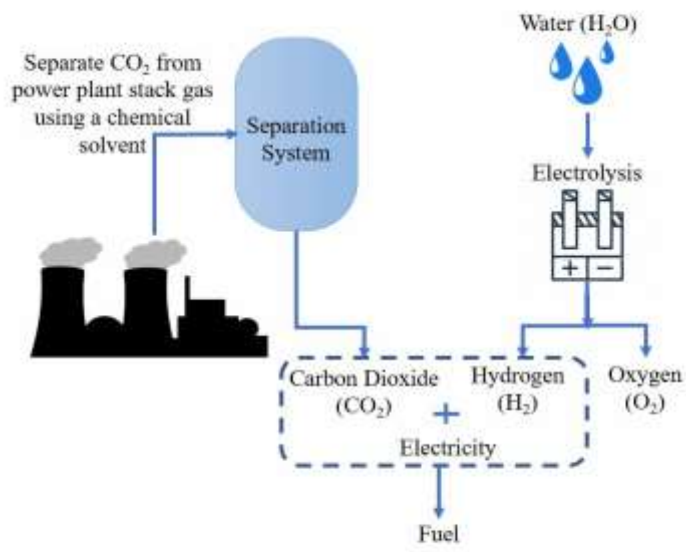

Figure 1. The Pathway of Carbon Capture & Storage: CCUS begins with the separation of CO_2 from an emissions stream such as flue-gas from a power plant, after which it can be combined with hydrogen and electricity to produce renewable fuel. Public Domain. (Magner, 2019)

The resulting solvent stream, which is rich in carbon dioxide, is heated and fed to a stripping column, where additional heating causes chemical bonds to break, allowing carbon dioxide to be released and collected (Liao et al., 2018, p. 528). As shown in *Figure 1*, the CCUS process additionally includes the electrolysis of water, which involves running an electric current through water molecules to break them into their individual elements, hydrogen and oxygen. Separated carbon dioxide and hydrogen can be combined with energy in the form of electricity in order to produce fuel, which provides "a potentially cost-competitive way to make gasoline, diesel, or jet fuel that doesn't add any additional CO_2 to the atmosphere" (Leahy, 2018).

The use of carbon dioxide to produce an alternative fuel source significantly increases economic feasibility of the CCUS process. Although use of MEA to separate carbon dioxide from flue-gas is criticized due to significant energy demands associated with regenerating solvent, combining this separation technique with production of fuel is a novel approach that has the potential to maximize efficiency and economic yield (Luis, P., 2016, p. 94).

By developing a model of this process for a specific industrial power plant, including detailed simulation of process equipment and layout, calculation of heat and material balances to determine properties of inputs and outputs, and an analysis of economic feasibility of the design, the intended outcome is to determine optimal conditions for applying CCUS technology. The ultimate goal of this project is to contribute to the creation of a more sustainable future in the energy sector, meeting the objective of the Paris Agreement, which, according to Zheng et al. (2018), "…is that the global average temperature must be controlled within 2 °C in this century" (p. 1). Through the technical analysis, which will be presented in the form of a scholarly article, the chosen approach to CCUS technology will be evaluated. This evaluation will be based on its viability in both reducing carbon dioxide emissions at their source, and transforming this compound from a pollutant into an economically feasible source of renewable fuel. Creating a successful design for CCUS encourages widespread application of this technology, which has potential to alter the trajectory of the energy industry, preserving the future of Earth's climate.

The Relationship between Climate Change and Coffee

Changing climate conditions have already led to an increase in poor harvests of arabica coffee, and land suitable for coffee growth is expected to deteriorate globally. Wild Arabica Coffee is projected to substantially decline in numbers, if not become fully extinct by 2080, and its survival is paramount to the endurance of the coffee industry as a whole (Davis, 2017). It is necessary to address the social and economic impacts of climate change on socioeconomically vulnerable farmers along as well as gathering technical data addressing the effect of climate change on the cultivation of arabica coffee. The majority of *Coffea arabica* production spans a slim band of lands tracing the equator, see *Figure 2* (Varcho, 2008), and the bulk of these countries are categorized as "developing countries". As conditions continue to change, the potential for families in these locations to lose their livelihoods as the climate becomes too poor for cultivation and harvest increases. It is vital to identify what communities are most vulnerable to climate change deteriorating *Coffea arabica* cultivation conditions.

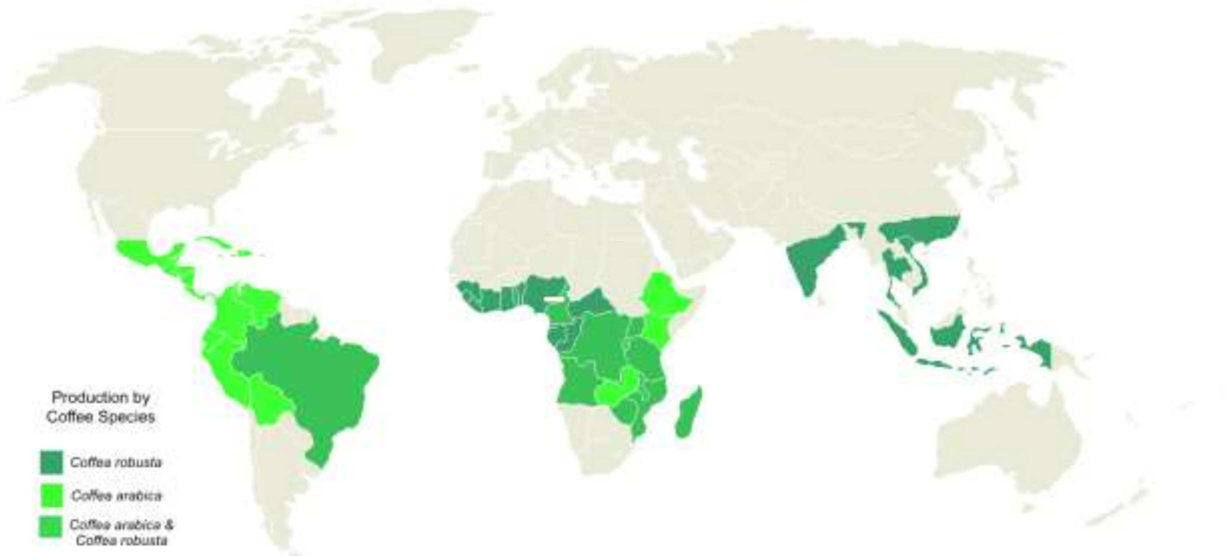

Figure 2. Map of coffee production by country. Diagram by Brhaspati, 2007. Public Domain. Retrieved online from Ohio State Pressbooks (Varcho, 2008)

Nations producing arabica coffee with a Human Development Index (HDI), developed by the United Nations (WPR, 2019), of less than 0.80 and spanning near the equator, such as Vietnam and Costa Rica, are the focus of this study. In 1999/2000, Vietnam was the world's second largest producer of coffee (Ponte, 2002) and has three zones particularly vulnerable to climate change: the Mekong Delta, the central highlands, and Son La (Parker, Bourgoin, Martinez-Valle, & Läderach, 2019). Scientists from the University of Costa Rica stress that coffee production in Costa Rica is an important economic and cultural market that will experience a drastic shift in suitable locations by the year 2070 (Coto-Fonseca, Rojas, & Molina-Murillo, 2017). It is necessary to explore the impact of climate change on the production of Arabica coffee in developing countries that rely on the crop as a staple of their economy due to extensive research providing troubling projections for its production in the future.

Gathering an understanding of the manner in which coffee farmers personally view the impact of climate change is critical to generating a representation of the social impacts of climate change. Research shows that impoverished coffee farmers are of the highest vulnerability to climate change (Mayer, 2013). Ninety-three percent of farmers in the Lawra district of Ghana have perceived climate risk, and the focus is on resources available to the farmers based on socio-economic class. Agriculture adaptations to climate change may cause land-use impacts, and the prospect of moving to a new location to follow suitable land poses social and economic issues, especially for poor farmers (Ndamani & Watanabe, 2017).

The relationship between climate change and coffee farmers will be explored using the technological determinism theory developed by Thorstein Veblen (Papageorgiou & Michaelides, 2016) as interpreted by Oliver Brette. Brette states, "Veblen analyses institutional change as an emergent effect of the dynamics of interactions between instincts, institutions and the infrastructural conditions (Brette, 2010)." This framework emphasizes the deterministic effect of technology on societal norms and cultures of affected areas based upon its interaction with situational circumstance and ideology of localities impacted. It details the idea that technology shapes society, not the other way around. Specifically, descriptive technological determinism is used as a means to focus on the force driving sociotechnical change (Wyatt, 2008).

In this specific case of arabica coffee harvesting in developing nations, farmers are left with virtually no option but to adapt according to the effects of climate change that they experience. Climate change is a direct result of technological utilization of fossil fuels to generate energy, and this technology has a clear impact on coffee farmers in developing nations. It is an issue whose cause began during industrialization, but whose effects are fully impacting future generations and require a response.

Research Question and Methods

The research question that will be explored is as follows: What are the expected repercussions of climate change on the cultivation and harvest of coffee, specifically *Coffea arabica*, and resulting effect on society at a national level?

My research will be focused on major Arabica coffee-producing locations near the equator that have an HDI of less than 0.80 and therefore are more sensitive to economic impacts in the agricultural sector brought on by climate change. Puerto Rico, Costa Rica, South Sudan, Kenya, Nicaragua, Ghana, whose locations can be seen in *Figure 3*, are the main focus of case study research utilized in this prospectus. The relationship between climate change and arabica coffee cultivation is extremely complicated and will require extensive research from many perspectives. For example, Costa Rica is projected to experience geographical shifts in suitable locations for arabica coffee production, but will not experience an overall loss in suitable land area. That being said, economic growth of Costa Rica is leading to the urbanization of suitable coffee cultivation areas to become suburban, which will lead to the country experiencing pressure to move coffee production to higher elevations in more forested areas that have the potential to remain viable for coffee production much longer. This will lead to a loss of important biodiversity and problems related to water quality and quality in metropolitan areas (Coto-Fonseca et al., 2017).

Figure 3. Foundational Thesis Research Countries: A world map highlighting countries of interest explored in-depth in preparation for the Prospectus Proposal. Diagram by Rachel Berry, 2019. Public domain. Retrieved from MapChart.net (Berry, 2019).

To ensure the breadth of research is suitable to tackling such a complex issue at a national level, primary sources will be utilized to gather first-hand perspectives on the effect of climate change on the cultivation of *Coffea arabica*. Farmers are the first to feel the change on the agricultural sector brought on by climate change, and their perception of climate change decides the manner in its effect is felt by consumers when it comes to their cultivated products. Personal accounts such as surveys, interviews, focus groups and other primary sources detailed in academic papers will be utilized to construct a meaningful account describing the effect of climate change on the production of *Coffea arabica*. Outside of academic articles and journals detailing the position of farmers in their local communities, staff at local businesses that source their coffee beans directly from these countries will be interviewed. Shenandoah Joe coffee roasters, Grit Coffee, and MudHouse Café are just three of the local coffee locations from which I will inquire about their sourcing and connections related to coffee beans. Once primary data is collected, these accounts will be grouped based on perceived risk and knowledge of climate change to conclude vulnerability and address any educational needs related to climate change.

Conclusion

Fossil fuel incineration feeds the majority of the world's energy needs, and urbanization and development require the use of materials that release CO_2. That being said, advancements in carbon capture, utilization and storage technologies (CCUS) give the potential to trap CO_2 emissions either directly from the atmosphere, or before they reach the atmosphere to reduce human impact on the ever-changing climate. Though one of the major causes of climate change can potentially be addressed utilizing CCUS technologies, the effects of industrialization and urbanization are already being felt by the global population and are projected to continue. One of the most drastically effected social groups are arabica coffee farmers in developing communities and nations, and it is imperative to the global coffee market to investigate the intensity and nature of impacts of *Coffea arabica* caused by climate change.

My timeline as follows will be adhered to as closely as possible within the next six months. I plan on contacting local businesses and scheduling interviews by the end of December, and having all primary-source evidence compiled by the end of January. This evidence includes, but is not limited to: in-person or virtual interviewing, academic case-study compilation, and survey results. All primary-source evidence must be reviewed, grouped, and analyzed by the end of February. A full comprehensive draft of the thesis must be completed by the middle-to-end of March, so there is plenty of time for revisions, questions, and last-minute further research for clarification if necessary. The final draft will be submitted mid-April to ensure ample time for approval.

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