The Relationship between Gold Mining and the Local Economy: A Case Study from Burkina Faso

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Abstract:

This study looks at the effect international mining corporations have on local economic activity around gold mines in Burkina Faso. It also asks whether the mines have any additional effects, such as changes in poverty or inequality. The study does this by using remote sensing data, particularly nighttime lights, NDVI, and forest loss data to analyze the mine's effect on the surrounding area. In addition, statistics from the World Bank, G-Econ, and a literature review are used to substantiate the findings. This is framed by the theoretical perspectives of world-systems theory, unequal exchange, frontier theory, and environmental history as political economy. Together, they lend credence to the argument that the people of Burkina Faso would be better off if they had control of their own natural resources. The main findings of the study are that based on the rapid expansion of nighttime lights in the areas near gold mines, international mining corporations do have a significant impact on local economic activity in the short-term. The NDVI dataset corroborates this trend as well. However, while it is unclear where most of the profits end up, it is fairly certain they do not provide much benefit to Burkina Faso or its people. Regarding additional effects the international corporations have, the research is inconclusive, but it is very possible they perpetuate an endemic system of poverty and inequality. Overall however, this study does indicate that international mining corporations largely increase local economic activity, and opens up more options within the social sciences for doing research with remote sensing.

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I. Introduction

Background

Burkina Faso is a country in west Africa, lying on the southern boundary of the Sahel region. It achieved independence from France in 1960, and has since had a number of military or populous coups that decide who runs the country (The World Factbook). The most recent one, on October 31, 2014, ousted then-President Blaise Compaore, who had been in power since 1987 (*ibid*). However, Burkina Faso is now in the process of organizing presidential and legislative elections for late 2015 (*ibid*).

The country faces a huge number of economic and social problems. According to poverty rates, "Burkina Faso is the world's third-poorest country…and relies heavily on cotton and gold exports. Approximately 90 percent of the population depends on subsistence agriculture" (2015 Index of Economic Freedom). The rest mainly rely on artisanal mining or working for the government.

Mining has long been a major component of many African economies (Andersson et al. 2014, 2). Regardless of the scale, it has always left a large impact on both the people and the landscape (*ibid*). This is evident by the host of social and environmental issues that have plagued mining operations across the continent. Many say it causes air and water pollution, land use issues, deforestation, and drives social inequality and protests (Hilson and Yakovleva 2007; Andersson et al. 2014, 2). Its proponents claim it provides much needed jobs, development, and is a vital source of rising GDP (Andersson et al. 2014, 2).

While Burkina Faso does not have a long history of commercial mining, gold mining constitutes a significant portion of its economy today (Andersson et al. 2014, 5). During the droughts of the 1980s, people turned from agriculture to artisanal mining to make ends meet (*ibid*, 4; Luning 2008, 390). In 1983, Burkina Faso took action to ensure it maintained tight

control of its gold market, introducing the Burkinabé Precious Metals Counter (Andersson et al. 2014, 4). Since then, gold has overtaken cotton as the country's main export commodity (*ibid*, 5). The first commercial gold mine opened in 2007, and revenues from mining were responsible for a whopping 7% of all Burkina Faso's revenue in 2011 (*ibid*, 5). By 2013, gold accounted for nearly 75% of Burkina Faso's export revenue (The World Factbook). This makes analyzing this incredible growth and its effects all the more important.

Finally, gold in and of itself is an important topic. It is a very special metal in that it is "malleable and ductile, an excellent conductor of heat and electricity, immune to tarnish, and resistant to all but the strongest acids" (Mining, Minerals and Sustainable Development Project 2002, 99). This unique combination of properties is part of what makes it so valuable. Humans have been extracting and processing gold for over 6,000 years now, in which time we have extracted 140,000 tons of it (*ibid*, 100). Up to 80% of it is now used for jewelry, though it is also used in electronics, dentistry, medals, and coins (*ibid*). Furthermore, "until recently, it backed most of the world's principal currencies, and is still held as a reserve asset by many central banks" (*ibid*, 99). Given the historic to modern-day allure, coupled with the aesthetic and practical uses of gold, it is likely to remain an incredibly important metal.

Phenomenon to be Studied

This paper studies the relationship between gold mining and economic activity in Burkina Faso. The World Bank and International Monetary Fund claim that allowing foreign direct investment in developing countries helps stimulate their economies, increasing overall quality of life, life expectancy, income, and education, amongst others. One of the most profitable of these foreign direct investments is gold mining. Using data from case studies, statistics, and nighttime lights, this paper uses Geographic Information Systems (GIS) to analyze the veracity of these claims.

Research Questions

The primary research question is as follows: how do international corporations mining gold in Burkina Faso affect local economic activity? The secondary research question is as such: do international corporations mining gold in Burkina Faso have other notable effects, such as changes in poverty or inequality?

These questions were selected because of the large economic and social impact international corporations have in developing countries. Mining in particular, as noted in the introduction and elaborated on in the literature review, is a particularly lucrative and influential industry in terms of the number of people it employs, and the amount of money it makes (Luning 2008; Mégret 2011; Mining, Minerals and Sustainable Development Project 2002). Furthermore, particularly in west Africa, the gold mining industry is expected to grow considerably (Mining, Minerals and Sustainable Development Project 2002). This makes these effects, and who the industry is benefitting all the more important to analyze.

However, this is very difficult because of the lack of data available. Particularly in Burkina Faso, and other data poor countries, acquiring reliable statistics and data remains problematic (Hall 2015). This is partially addressed by using remote sensing data.

Definitions

Here are a number of terms that need more concrete definitions:

- Local – within 80 kilometers. This is due to the large knock-on effect the mines have by virtue of each miner supporting many other people, as well as the scale of some of the statistical data available (Mining, Minerals and Sustainable Development Project 2002, 101).
- Economic activity – how much money that area is making. In this context, synonymous with wealth. This is measured by the nighttime lights dataset, the MODIS NDVI dataset, data from the World Bank, and statistics from G-Econ. MODIS stands for MODerate Imaging Spectroradiometer, and NDVI stands for Normalized Difference Vegetation Index (Andersson et al. 2014, 10). It is essentially a measure of agricultural output, and will be explained in greater detail in the data section.
- Poverty – percent of the population living under $2.5 per day. This is measured by Poverty and Inequity data from the World Bank.
- Inequality – income share of the wealthiest 10% compared to the income share of the poorest 10%. This is measured by Poverty and Inequity data from the World Bank.
- Remote sensing data – information acquired despite not being physically present; in this instance, images from satellites. Specifically for this research, nighttime lights, MODIS NDVI, and forest loss data.

Expected Outcomes

It is expected that gold mining will have a small positive impact on local economic activity for the duration the mine is open. This is based on previous research at the national and regional levels, as well as the knowledge that these mines do temporarily employ thousands of people who would otherwise be working in somewhat less profitable positions (Andersson et al. 2014; Andersson et al. 2015; Mégret 2011). However, it is expected to have a negligible or negative effect on poverty and inequality. Overall, remote sensing is expected to be the best option for analyzing local economic activity in data poor countries. However, this is mainly because these countries, such as Burkina Faso, have so little accurate statistical information (Hall 2015; World Bank 2015b) . While still the best option, remote sensing data is used only as a proxy for local economic activity.

Purpose

These research questions aim to address two key issues. Firstly, how does the foreign direct investment advocated by the World Bank, in this case manifested by gold mining, affect people at the local level? Previous research in this specific field has addressed the question at the national and regional levels, but never before has there been an investigation into how it affects the local level (Andersson et al. 2014; Andersson et al. 2015). Secondly, analysis of nighttime lights, paired with agricultural vegetation and forest change has been used previously to successfully model GDP and district growth at the national and regional levels (*ibid*). However, it has not yet been used to verify information at the local level, which will be accomplished by comparing it to results from existing case studies and statistics. Thus, the secondary purpose of this research is to ascertain whether this modeling method still works at the local level. If it does, it will have important ramifications for further social science research.

Relevance to Human Ecology: Culture, Power, and Sustainability

These research questions have great applicability to the field of human ecology. The research seeks to understand the relationship between economic, natural, and social systems. These systems are represented by household wealth and GDP, mining for gold, and the social, economic, and political structures that drive it, respectively. Furthermore, this research is interdisciplinary in that it uses knowledge from statistics, geography, economics, and anthropology.

In addition, these questions have strong ties to culture, power, and sustainability. Culture has a solid connection by analyzing exactly how people's lives are affected by the presence of these gold mines. From education, poverty levels, economic impacts, to inequality levels, these mines have a significant impact on local populations (AllAfrica 2012; World Bank 2015). Furthermore, as later case studies will show, these mines force artisanal miners to be partially nomadic, constantly moving in search of the next unoccupied gold site (Mégret 2011). The immigration and movement of people these gold mines encourage leads to a large-scale mixing of different groups of people (*ibid*). This has a large impact on their culture, as discussed in Mégret's frontier theory.

Power is a central theme in this analysis, particularly power the foreign mining companies have over the economic system in Burkina Faso, and how this is perpetuated by the will of the World Bank and IMF. As later analysis will show, foreign mining companies are using money and influence to change people's behaviors to best suit their needs (Mégret 2011; Luning 2008). In the literature review, numerous cases are discussed which show the artisanal miners and local community are not pleased with the way the international mining companies are conducting business. In the theory section, world-systems theory and the theory of unequal exchange in particular are used to explain the very unequal power relations that exist between the artisanal miners and the international mining companies.

Finally, sustainability is important to this investigation for two reasons. First of all, mining is not renowned for being a sustainable enterprise. At the year 2000 level of extraction, the known amount of gold was expected to last until about 2025 (Mining, Minerals and Sustainable Development Project 2002, 105). This is why in 1997, $5.1 billion USD was spent on gold exploration (*ibid*, 100). Furthermore, as the quality of the remaining gold deposits decrease, exponentially higher quantities of energy and water will be needed to produce an equivalent amount of gold (*ibid*, 105). Additionally, there have been a number of very high profile and well-publicized accidents and failures at major gold mines (*ibid*). As the report notes, "ensuring that all who are mining have the capacity for sound environmental management is a challenge for all of industry; clearly not all do" (*ibid*). Finally, the chemicals native to the gold mining industry are very damaging to the environment. The report states, "using cyanide to extract gold is the technology of choice for larger gold companies; mercury is still the agent of choice for a large part of the artisanal sector. Both of these technologies have caused significant environmental concern" (*ibid*). Cyanide is a well-known poison, and mercury is extremely toxic to nearly all living things. Neither of these is a responsible choice for releasing into the environment in any quantity, let alone at an

industrial scale. Thus, sustainability at many different levels is a concern for the gold mining industry.

Secondly, some of the central tenets to remote sensing in this project are nighttime lights, agriculture vegetation, and forest change. All of these have important implications for sustainability including electricity usage, food production, and biodiversity loss.

Also important to mention is the potential importance of remote sensing data to the social sciences. In regions or countries where there is very little data, or the data is of questionable accuracy, remote sensing is a very good proxy for many important indicators used by social scientists.

Spatiotemporal Frame of Phenomena

Nighttime lights data is analyzed from 1992-2012. NDVI data is analyzed from 2004-2012. Forest loss data is analyzed from 2001-2012. However, as most of the mines analyzed only opened between 2008-2010, most of the analysis will be from 2004-2012. This is to give a before, during-construction, and after-opening comparative viewpoint.

The location of this study is limited to Burkina Faso, specifically to areas within 80 kilometers of a gold mine. The population of study are the inhabitants of these regions.

Spatiotemporal Frame of Research Activities

Research and analysis took place between October 2014 and May 2015.

Collaborating Institutions

The Department of Human and Economic Geography at Lund University has been instrumental to this research by providing processed remote sensing datasets. Statistical information from the World Bank and G-Econ have been very useful as well.

II. Research

Methodological Approach

The methodological approach of this research largely adheres to post-positivism. This is mainly apparent from the large-scale use of quantitative data, although significant qualitative data is used as well. The other main contributors to a post-positivist methodological approach include recognition of the value of the scientific method, the utility of taking some

forms of measurement, and having a controlled comparison (Teaching and Learning Research Programme 2009). Furthermore, it progresses under the belief that, "while any knowledge produced is inevitably fallible, this does not mean that all knowledge claims are equally likely to be false" (*ibid*). This means that while any theory or assumption can turn out to be wrong, it does not mean that any theory or assumption is as likely to be proven wrong, or that their correctness is always relative to cultural or theoretical frameworks.

The main advantages of using post-positivism include being able to analyze data accurately over time. It is a good method to use when dealing with a lot of quantitative data, and consequently is able to answer the different parts of the research question fairly well. These ask about concrete numerical data over time – remote sensing, poverty, and inequality data are expressed as numbers. Furthermore, quantitative data is better suited for GIS and mapping phenomena. Thus, the advantages of a post-positivist methodological approach are well-suited for the scope of the study.

Research Methods and Instruments

ArcGIS is the main research tool in this analysis, providing maps that easily and clearly reinforce the analysis. ArcGIS is a powerful computer program designed to analyze spatial data and create maps, amongst others. The 'GIS' stands for Geographic Information Systems. Statistics and a literature review will feature prominently as well.

Limitations

Despite the strengths of post-positivism, it also has its weaknesses. It has most importantly come under fire for failing to accurately describe what people do and why. Numbers can only tell you so much, and explaining the complexities of human behavior from numerical datasets is not a strength. Given how important understanding human behavior is for a study of the social sciences, this is a significant limitation. Furthermore, this approach has been accused of ignoring how easy it is to manipulate numbers with statistics, and cherry pick data to acquire desirable results. There are many ways to use numbers to create fictional narratives, stories that do not exist, and using improper statistics with an incomplete dataset often creates misleading results. Additionally, post-positivism has been criticized for "portraying what currently exists as natural and inevitable and/or that it fosters forms of purported expertise that support the dominant forces in society" (Teaching and Learning Research Programme 2009). Without an explanation from qualitative data of why things are

the way they are, this approach can too easily be used to back up the status quo and business-as-usual as a natural and inevitable next step. Finally, this numerical, scientific approach has been accused of being dehumanizing, in that it often only looks at people as the sum of their parts. Seeing the statistics of a family in rural Burkina Faso with rising household income 'x' and dropping life expectancy 'y' is very different to hearing the story of Kindo and his wife trying to get enough money to feed and educate their three children by working in the ever-changing and hazardous conditions which constitute artisanal mining. It does not hear their stories, does not hear the 'why' in explaining behavior, and does not treat them as humans. This is a major limitation in trying to explain people's behavior using this methodology.

Thus, the research is limited in its scope and what it is able to accomplish. It does not try to provide new narratives, qualitative data, or explain what people are doing and why. Instead, it explains using remote sensing and statistics the effect international gold mining is having on the people of Burkina Faso.

III. Framework of the Study

Concepts Applied in Collecting Data and Interpreting Phenomena

In collecting data methodological triangulation is used, that is, using more than one method to gather data. A literature review, case studies, statistics, and satellite image data are all used to answer the research questions. The literature and case studies are often from participant observation and unstructured interviews. Due to the physical, financial, and current safety issues making it difficult to conduct first-hand research in Burkina Faso, all the participant observation and unstructured interviews were done by other researchers. The statistics are from the World Bank and G-Econ.

While interpreting phenomena theoretical triangulation is used, which is to say using more than one theory to explain why the system behaves the way it does. The theories applied include world-systems theory, unequal exchange, frontier theory, and environmental history as political economy. These theories are used to explain how the international mining companies are affecting local economic growth around gold mines in Burkina Faso. Other theories could be just as valid for explaining this system, particularly critical development theory and postcolonial theory, but the four discussed here are viewed as the most relevant. This is because they applied to and explained the current situation with international mining corporations in Burkina Faso the best.

Theories Applied in Analyzing Data

World Systems Theory

While many theories explain and relate to gold mining in Burkina Faso, world-systems theory is a particularly excellent one to apply to this research. World-systems theory was developed in the 1970s, and a number of prolific sociologists, anthropologists, and other academics have contributed to it, including Immanuel Wallerstein (Wallerstein 1974a). The theory is based on international trade, unequal exchange, and underpaid labor (Lecher 2001). According to the theory, this world-system started developing out of feudal Europe in the 15th century, and was the groundwork for colonialism and capitalism centuries later (Wallerstein 1974b, 15; Wallerstein 1974a, 401). This divided the world's nations into three distinct categories: core, semi-periphery, and periphery (Lecher 2001). The wealthy core extracts raw materials from the periphery (Wallerstein 1974a, 401). Nations have the ability to change categories over time, but this happens very slowly. As one of the poorest countries in the world, Burkina Faso can be regarded as a definite member of the periphery.

In its modern form, world-system theory argues that capitalism is "a system that operates on the primacy of the endless accumulation of capital via the eventual commodification of everything" (Wallerstein 1998, 10). This is readily apparent with gold mining in Burkina Faso. Having exhausted gold supplies elsewhere, particularly South Africa, the international mining companies are now launching enormous exploration activities, spending over $5.1 billion alone in 1997 on searching for gold (Mining, Minerals, and Sustainable Development Project 2002, 100). Furthermore, according to Wallerstein, "core states concentrate on higher-skill, capital-intensive production; they are militarily strong; they appropriate much of the surplus of the whole world-economy (1974a: 401). Peripheral nations focus on low-skill, labor-intensive production and extraction of raw materials; they have weak states" (Lecher 2001). This depicts gold mining very accurately, as it is a low-skill, high-labor process of extracting raw materials. It also describes the relationship between the international mining companies and Burkina Faso. Extracting raw material from Burkina Faso to send to the wealthy core is exactly what appears to be happening, at the explicit direction of the World Bank and IMF, no less. In fact, two companies each hold 90% of the shares in two of the largest gold mines in Burkina Faso: SEMAFO and IAMGOLD (Andersson et al. 2014, 17). Both companies are from Canada, a definite member of the core nations. As stated earlier, this system is also based on the international trade and unequal exchange that allow this world-system to flourish. Since gold is Burkina Faso's single most valuable export, it makes

sense for the core nations to want to extract it (*ibid*, 5). While the government of Burkina Faso certainly benefits from this economic activity and tax base, it is likely that the core nations benefit far more from extracting such a valuable resource at such cheap prices.

One of the other academics contributing to world-systems theory was Andre Gunder Frank. Scholars like himself have noted that "in the 'new' countries, the people already living there…the indigenous populations, were coerced and suffered extreme social living conditions and depletion of natural resources and land" (Oliverio 2015, 187). This illustration of life under world-systems theory in the periphery matches very closely with the reality in Burkina Faso. More importantly though, is what it says about the international mining companies' effect on local economic activity. The exploitation of a periphery's labor and resources that world-systems theory describes paints a dire picture indeed. Not only do locals not benefit much from their hard labor, but all their resources are extracted and exported as well. Thus, world-systems theory implies that international gold mining is a terrible situation for the people of Burkina Faso. This may suggest they would be much better off if they had control over their own resources.

Unequal Exchange

The theory of unequal exchange takes a prominent position in this study as well. Developed by the work of Arghiri Emmanuel in 1972, it states that "low-wage countries have to export more products in exchange for a given volume of imports from high-wage countries than they would have needed to if the wage level had been uniform" (Hornborg 2011, 107). This means the poorer the country, the more they have to work to import the same level of goods as the richer country. As a fellow academic confirms, "there is an unfairness in the terms of trade between two groups of countries in that the labour of the poor is rewarded much less than the comparable labour of the rich in international trade" (Ross 1976, 42). This means Burkina Faso should be very adversely affected by unequal exchange, as one of the poorest countries in the world. The gold mining industry in particular is rife with examples of unequal exchange – from using cheap labor in Burkina Faso, to buying gold on the cheap from artisanal miners and then selling it for extortionate prices in western countries (Mégret 2011; Luning 2008). If the mine was in a western country, the labor for the same amount of work would cost the corporations exponentially more. In this way, Burkina Faso is very much a victim of unequal exchange.

Another argument put forth by unequal exchange is that it is far easier for companies from core nations to make money in periphery nations. Not only because of the drop in cost of labor, but also due to fewer regulations, oversight, and cost of materials. Similar to the academics quoting Marx realize, "the profit rate is generally higher there [in the periphery] on account of the lower degree of development, and so too is the exploitation of labour, through the use of slaves and coolies, etc." (Foster and Holleman 2014, 203). This suggests that through exploiting both the labor and commodity cost in periphery nations, international corporations reap the benefits of unequal exchange.

However, the theory of unequal exchange has also been heavily criticized for many perceived shortcomings. One of the fundamental problems is the lack of a clear definition for it. As Hornborg elaborates though, "our difficulties in conceptualizing it can be seen as part of the conditions for its existence" (2014, 102). He argues this invisibility perpetuates unequal exchange. A second criticism is that unequal does not necessarily mean unfair. For instance, it is their choice to work for the international mining companies, they are not forced to. However, a counter-argument could be that environmental conditions in the country do in fact 'force' them to work for the mining companies as the only possible means of supporting their families. Finally, there is point to the argument that even though Burkina Faso benefits minimally from this exchange, it still benefits. As academics quoting Marx note, "three days' labour of one country can be exchanged against one of another country…. In this case, the richer country exploits the poorer one, even where the latter gains by the exchange" (Foster and Holleman 2014, 202-3). Mégret backs this up with research from the field as well. He understands that "of course, this occasional wage is locally a windfall for the 30 or so young men employed. However, they acknowledge that a few days' work spread out over a year does not make a real, adequate source of income that can meet the needs of a family on a lasting basis" (2011, 394). So while it may be true that despite unequal exchange, the international mining companies do boost local economic activity in the short-term, this is not enough of a benefit when combined with information from the other theoretical perspectives.

Frontier Theory

Another theory that has been applied to gold mining in Burkina Faso is frontier theory. While first advanced by Frederick Jackson Turner in 1893 to explain the westward movement of North American settlers and their subsequent effect on the United States, it has been rethought and adapted many times throughout the years (Turner 1920; Mégret 2011, 389-90).

Turner postulates that the presence of a frontier in the United States forced pioneers to adapt to new challenges by adopting new ways of surviving (Turner 1920). During this process, the European customs and institutions they had known became less and less useful (*ibid*). This led to a rise in individualism, innovation, and eventually, a new society, very different to those of Europe (*ibid*).

Mégret takes this theory and shifts the focus, using it to explain recast cultural history. On this frontier that is gold mining in Burkina Faso, migrant populations are very important (Mégret 2011, 390). Mines are always running out and popping up elsewhere, so it is very much a population on the move (*ibid*). This leads to more frontiers, and more mixing of groups. With 700,000 people directly involved in this industry, from migrant populations all over the continent, one group very easily affects another's culture (*ibid*). This mass migration to rural areas, coupled with rapid economic transformation leads to "hot spots of social change" (*ibid*, 391). Mégret uses an adapted form of frontier theory to explain these centers of social change, seeking to understand how they operate, what their effect is, and when they occur.

Frontier theory as a means of analyzing cultural interaction in this way is very useful. Mégret's take on it looks at the changing frontier of people and cultural groups, not the changing frontier of the physical environment, as initially proposed by Turner. This is possible for two reasons. Firstly, the high rates of immigrants from incredibly diverse ethnic backgrounds to gold mines. Secondly, when gold mines become exhausted, or the artisanal miners get kicked off, or new mining areas are discovered, the population moves. This rapid mixing of different cultural, ethnic, and linguistic groups is why frontier theory in a modified form is applicable to gold mining in Burkina Faso. The people are the frontier.

While not necessarily Mégret's viewpoint, this theory thus makes important claims about international mining companies and local economic activity. As stated previously, pioneers adapt to the new situations by becoming more individualistic, by participating less and less in the traditions and customs they knew before. This trend toward individualism, coupled with the linguistic, cultural, and ethnic barriers suggests that artisanal gold miners are less likely to form groups and alliances across different boundaries, especially if they do not speak the same language. At least in the short term, these tendencies may prevent them from taking coordinated action against the international mining companies, even if they are severely unhappy with them. This effect may allow the mining companies to keep working conditions and salaries low, with minimal effort to appease the artisanal miners. If true, this would

decrease the effect on local economic activity by allowing the international mining companies to spend less on worker's wages, and export more of the profits.

An additional theory that is highly relevant to this study is postcolonial theory. Looking at this arguable form of economic imperialism through a postcolonial lens may reveal the effect colonialism had on native populations and their current predicament. It is easy to argue they are still not in control of their natural resources, rather that international corporations are paying them a pittance to strip them from the ground under the guise of economic growth. However, postcolonial theory is more applicable when looking at least partially at the historical perspective of gold mining in Burkina Faso, and thus will not be discussed in greater detail.

Environmental History as Political Economy

Finally, mining in Burkina Faso is also connected to Anders Burman's lectures on environmental history as political economy. In this theory, the resources of our ecosystems are intertwined with the commodities of our economies (Burman 2014). A tenet of this theory is sequential overexploitation, in which resources from place to place are inevitably exhausted. This leads corporations extracting the resources to eventually move elsewhere, leaving behind a trail of ghost towns, unemployment, and a social void. To lend credence to this argument, Essakane gold mine, one of the largest in Burkina Faso, is expected to run out of gold in 2025 (Andersson et al. 2014, 18). IAMGOLD Corporation, with a 90% share in the mine, is not expected to stick around.

This is supported by historical happenings. In the 1990s, when gold prices fell, "much of the loss affected countries in sub-Saharan Africa. Gold mining employment in South Africa alone is said to have declined by some 300,000, in what is known there as the Gold Crisis" (Mining, Minerals, and Sustainable Development Project 2002, 104). The international corporations mining gold largely left when this happened, resulting in massive unemployment. As the report enumerates, "from more than a half-million in the late 1980s, the number employed fell to 257,000 (including 130,000 non-South Africans) in 1998" (*ibid*, 102). This enormous drop in employment – over 50% – in what was once the most important industry in South Africa, will likely happen in Burkina Faso as well when the gold runs out. Even more importantly, "because of gold mining's links with other sectors…it is estimated that for every three people working in a mine, another person is employed by industries that serve mining. In addition, on average each worker in the gold industry supports 7-10

dependents" (*ibid*). The importance of these two statistics cannot be understated. First of all, it dramatically adds to the impact gold mines have on local economic activity. Secondly, using simple arithmetic and the 700,000 artisanal miners in Burkina Faso as of 2009, this is saying that 233,000 non-miners have jobs that relate to, and depend on mining (Mégret 2011, 390). In the same case, an additional 5.95 million people depend on the income of a gold miner. This combined total of the nearly 6.9 million people who are either artisanal miners, have jobs because of artisanal mining, or are dependent on someone who is an artisanal miner represents around 40% of the total population. Connecting this back to theory, this sequential overexploitation of resources that leaves behind a trail of environmental devastation will also be marked by social devastation if 40%, or even 20% of the population lose the source of income they rely on. This was a problem of massive proportions for South Africa, and according to the theory will be for Burkina Faso as well in the near future. Based on the numbers, it appears that in the short term, international gold mining is beneficial to local economic growth. Based on the theory, it seems that in the medium-long term, it is disastrous.

Literature Review

In order to round out the study and make it less heavily dependent on numbers, statistics, and maps, relevant literature is reviewed. One collection of this is technical research on GIS and remote sensing. These are the studies that first used nighttime lights, Normalized Difference Vegetation Index, and forest loss data to effectively estimate economic activity on the national and regional scale. That is the research that sets the stage for this study, and gives the process, data, and equations to test if estimating economic activity with remote sensing holds true on the local scale as well. As such, it is quite important to discuss in-depth and have a clear understanding of their process. There are many studies present in this section. Many of the processes used in these studies are also used in this one, making them ideal cases to look at. However, since they relate more to data and data collection, they are discussed at the very beginning of the data section.

The second, and much larger collection of literature on gold mining in Burkina Faso consists of anthropological, cultural, and social studies of gold miners in the country. This section ties the research much more closely to human ecology, particularly with regard to culture and power. This is the section that rounds out the study with stories about people, narratives, and cultural analysis. Here, the realities of power dynamics between massive

international corporations and struggling artisanal miners are realized. Additionally, this section adds a human touch to a research on people, making all the statistics and maps that come after it mean something. There are four articles in this section: a note on gold mining's impact on education, an article about IAMGOLD, an article by Quentin Mégret, and a case study by Sabine Luning.

Children Miners

First, an unfortunate byproduct of the mining boom in the last three years is that children as young as six are now skipping school to work in the mines (AllAfrica 2012). A ministry official stated that "many schoolchildren are known to work mainly in artisanal mines where they crush stones, sieve dust, transport water and cook. Others go to the mines during school off-days on Thursdays and Saturdays" (*ibid*). This news has many angry about the use of child labor in the gold mining industry in Burkina Faso. However, with so few reports and so little news coming from the area, it is difficult to elaborate on how widespread the problem is.

IAMGOLD

Next, it is interesting and useful to hear the other side of the story. In 2012, a journalist interviewed a number of employees from IAMGOLD about their progress in Burkina Faso. IAMGOLD is a Canadian mining company that moved into Burkina Faso in 2008, and has since "become the biggest private employer in Burkina Faso with 2,200 employees. It plans to invest a further $600-million over the next three years to expand its mine and double its processing capacity" (York 2012). There appears to be a trend with all the Canadian gold mining companies moving out of South Africa, where gold output is declining, and into west Africa (*ibid*). This seems to be paying off, with IAMGOLD earning about a 16% rate of return at its Essakane mine, which produced 340,000 ounces of gold in 2011 (*ibid*). A rate of return like this is a huge success for IAMGOLD, representing profit of about $240 million 2011 USD after taxes and royalties (*ibid*). Furthermore, the raw production amount is a big leap over previous figures, as Burkina Faso's "gold production rose by 32 per cent last year. The country is now the third-biggest site of new exploration in Africa, and is projected to become Africa's fourth-biggest gold producer soon" (*ibid*). It is important to understand that whatever benefits or problems these large corporations cause, these effects will only intensify for Burkina Faso in the coming years. This is another reason why this research is so critical.

They sometimes highlight in the article the beneficial aspects IAMGOLD brings to the country. A director at the mine "describes how the company had to train more than 1,000 local people in construction skills to get the mine built. The company also spent about $25-million to move 13,000 people away from the site, building more than 2,000 houses for them" (*ibid*). While this may sound like a large sum initially, it represents less than $2,000 per person, or only $12,500 per house. With materials, transportation, and labor costs, fitting on average 6.5 people in a house that costs $12,500 sounds like a terrible deal.

While there are also security concerns for the western personnel at the sites, mainly linked to Islamic extremists, coups in neighboring countries, or drunk soldiers, they dealt with that by building a private airstrip within the perimeter fence surrounding the mine (*ibid*). That, combined with an 18:00 curfew keeps the IAMGOLD employees relatively safe (*ibid*). A far bigger concern to IAMGOLD are changes to how mines are regulated. According to York, "on the economic front, there have been rumblings of tax increases aimed at mining companies, which have required sensitive negotiations with the government. And the high rate of unemployment is another potential trigger for instability. Last month, about 100 people blocked a road near the Essakane mine for several days to demand more job creation" (*ibid*). IAMGOLD's huge profits, this pressure on the government to keep taxes on mining corporations low, combined with the local population demanding more job creation is a sign that the international mining companies are not doing anywhere near enough to fairly distribute the country's mineral wealth. This is a hugely important point that will be referred back to in the data and analysis sections.

Mégret

Next is an article by Quentin Mégret. According to Mégret, the mass gold mining movement started in Burkina Faso in 1974 (2011, 390). This coincided with the sharp rise of the price of gold on the global commodities market, as well as severe droughts in the Sahel region (*ibid*). According to Mégret, "for Burkina Faso, this new way of life spread and extended rapidly to new regions" (*ibid*). By 1998, they had spread across the entire country, and in some cases beyond international borders (*ibid*). In August of 2009, "Burkina Faso's current Minister of Mines, Quarries and Energy advanced the figure of '700,000 people directly involved in this sector' (Ouedraogo 2009). This shows the extent of the phenomenon in a country whose total population in 2010 is probably around 15-16 million" (*ibid*). That is

roughly 5% of the entire population that is directly involved in this one economic activity for their livelihood, a huge percentage by any comparison.

From a social and cultural perspective, this constitutes an enormous change. Speaking in relation to frontier theory, Mégret notes "the frontier is above all a geographical region with specific social, economic, and political characteristics. Grätz very aptly describes the gold-mining camps as isolated points which, though peripheral, are in fact hot spots of social change (Grätz 2004)" (Mégret 2011, 391). This has excellent implications for a country that just last year overthrew their leader of 27 years in a coup (Taoko et al., 2014). Furthermore, it should be noted that "many young people join in this activity, for an often undecided length of time, because they also have a taste for travel and adventure" (Mégret 2011, 391). This is important to be aware of the demographics of the miners, as well as a sense of their motivations for this drastic change of lifestyle.

On the frontier, Mégret noted the following typical features: "the mass translocal migration to rural areas; the rapid economic transformation of the host regions which were only partially integrated into the market economy, and the development of interstitial spaces of social change and political competition" (2011, 391). Most important here is the second point, which ties directly into the research. This shows, using data from the ground, that the host regions to these gold mines are in fact experiencing rapid economic transformations as a result of these gold mines.

However, relating to the topic of sustainability, Mégret points out that "inherent in the notion of a frontier is the idea of cutting vegetation, clearing or deforesting a wild, virgin space unoccupied by people" (2011, 391). This activity by so many miners has brought them into conflict with the farmers who work the land. Interestingly, "the miners recognise to a certain extent that the land they occupy is already socialised and cultivated, but they consider that their arrival contributes to the economic growth of the region and suffices to justify their practices" (*ibid*). This insight reveals that the miners believe that by their actions as miners, they bring in additional income not only to themselves, but to the regions they inhabit. This is a very useful revelation, and one that supports the results of this study.

For international mining corporations, the process of acquiring the right permits, prospecting, and actually excavating the gold is a complicated one (Mégret 2011, 394). They must go through an enormous bureaucratic process, subsidiary companies, and experts on the ground to actually start mining. Coupled with intense competition amongst these companies, "it should be noted that partnerships and other mergers affecting mining companies are also common" (*ibid*). This results in a very haphazard and informal relationship with the artisanal

miners, one fraught with short-term contracts and the constant threat of unemployment. Additionally, these companies make use of the "cheap local labour (from 2,500 to 3,000 CFA francs, the equivalent of €4-5 a day of grueling labour)" (*ibid*). Often, miners are quite bitter about the role of large international companies in gold mining. Mégret states that "artisanal miners are obliged to adapt to organisational criteria imposed and applied with varying degrees of rigour by the mining companies licensed for the purchase and export of gold. As this pioneering miner said, bitterly:

'You go into the bush every day, you suffer, you don't earn enough to eat and when you find the lode and you've cleared the site properly, a boss comes along from Ouagadougou to set up shop" (Mégret 2011, 395).

This arrangement is very detrimental to the livelihoods of many miners, who find themselves forcibly removed from the most profitable sites to make way for the corporations. Understandably, the artisanal miners are quite frustrated with this situation.

Interestingly, the mining code has been reworked several times in the last few decades to allow for this to happen. When Thomas Sankara came to power in 1984, land was considered to be the exclusive property of the state (Mégret 2011, 395). However, according to Article 5 of the 2003 mining code, the most recent major overhaul of the mining code:

"Natural mineral substance deposits in the soil and subsoil of Burkina Faso are, by law, the property of the State. The State shall ensure that they are developed by, *inter alia*, calling on private initiative in accordance with the provisions of the present law" (*ibid*).

This allows mining resources to be developed with private companies, which are often or always international ones. Article 1 of the 2003 mining code is even more explicit in this connection between the government and foreign direct investment:

"The purpose of the present law on the mining code in Burkina Faso is to promote investment in the mining sector in Burkina Faso. It aims to foster and encourage prospecting for and exploiting the mineral resources necessary for the economic and social development of Burkina Faso (LOI No. 031-2003/AN)" (*ibid*).

As a result of these liberalizations, foreign mining companies have taken a much greater interest in Burkina Faso over the last decade. This is supported by the whole host of mines popping up over the country, as well as the exponentially increasing revenue (Andersson et al., 2014, 5). Unfortunately though, "the State lost its exclusive right to prospect for, extract, and market mining resources found in the national territory" (Mégret 2011, 395). As Mégret explains, this has detrimental effects on the development of the country. He states "today, since it is not powerful enough to ensure the opening up and development of the national

territory, the State is forced by the policies of international institutions (World Bank and International Monetary Fund) to open up its territory to foreign investment, delegating responsibility for the economic development of the country to multinationals" (*ibid*). This is an incredibly important piece of information, that Burkina Faso has been forced by the World Bank and IMF to open up its territory and resources to multinational corporations. Unfortunately, these Canadian based mining companies do not appear to be terribly concerned with shouldering the responsibility for the economic development of Burkina Faso. Instead, IAMGOLD's stock jumped nearly seven-fold with the discovery and subsequent development of their new mine (Toronto Stock Exchange, 2015a; Andersson et al., 2014, 18). SEMAFO's stock leapt nearly ten times higher shortly after the development of their Mana Mine. (Toronto Stock Exchange, 2015b; Semafo 2015).

Mégret notes that though Burkina Faso as a state does retain significant power in handing out permits, authorizations, and mediating between the different groups, "the mining community and the local populations who live alongside are quite broadly excluded from these decision-making spheres of power. For instance, the status of land-owners remains insecure and local populations lack the means to exert pressure to ensure that their rights are respected" (Mégret 2011, 396). This appeals to the idea that while the current mining setup is somewhat economically beneficial in the short-term, the artisanal miners will be out of luck once all the gold is gone.

However, it must be pointed out that Burkina Faso is aware of these issues. Ouagadougou held their fourth mining promotion event in December 2009, which focused on the following points:

- "the contribution of mines to combating poverty;
- the consideration of local community interests;
- environmental issues;
- post-mining action" (Mégret 2011, 396).

These are certainly the right issues to be focusing on, and it is promising that the event received wide coverage in Burkina Faso's media (*ibid*). As Mégret aptly states however, "it can only be hoped that what the State preaches at the day events to promote mining is followed by a genuine effort to implement it" (*ibid*).

In Mégret's final notes, it appears this may have already started to happen. He reports that "since 2009, the Minister of Mines, Quarries and Energy of Burkina Faso has on a number of occasions announced a new revision of the Mining Code. In the framework of full

joint operation, this draft revision would aim in particular to give a more important place to local authorities. From a formal point of view, gold-mining at present generates no resources for local budgets" (Mégret 2011, 397). This suggests that Burkina Faso realizes not enough of the profits are benefitting local communities and budgets, and are actively taking steps to remedy that.

Overall, Mégret's work gives a much clearer idea of what is happening on the ground, and why. It shows why migrants are so attracted to artisanal mining opportunities, despite the grueling work and low pay. It tells us what the miners actually think of the multinational corporations, an important indicator. Finally, it generally supports the idea that while gold mining does bring some temporary economic benefits to the local region the mine is in, far too much of the profits go to the multinational corporations charged with developing Burkina Faso.

Luning

In many ways, Sabine Luning supports Mégret's analysis of gold mining in Burkina Faso. However, Luning's work has the advantage of containing interviews with more artisanal miners in Burkina Faso, as well as first-hand accounts of the situation on the ground. She largely agrees with Mégret on the start of large-scale mining activities, citing the droughts in West Africa during the 1980s that triggered interest in artisanal mining (Luning 2008, 390).

One of the most interesting points Luning discusses is the relationship between artisanal miners and multinational corporations. In some ways they have a symbiotic relationship – the miners can benefit from the corporations obtaining permits, and the corporations use the miners as an excellent indicator of gold prospects. Luning quotes a number of companies that show "the presence of artisanal miners is openly presented as an index for promising gold prospects" (Luning 2008, 393). While this system has pros and cons for the miners, it mainly seems to be a negative change. Note that High River is a Canadian gold mining company, listed on the Toronto Stock Exchange. As Luning discovered,

"in the comparisons made by the miners, the rigid organisation of the past was contrasted favourably with the present situation. At least the Sankara period of strict state control provided a clear social situation, whereas the large set of (private) players makes the current situation less transparent. The coming and going of different prospectors and gold buying 'authorities' are perceived as random and unregulated: who will come next, what will be the claims and how will they deal with artisanal miners? The way High River approaches artisanal miners working within their concessions differs from time to time and from place to place. This causes feelings of great insecurity among the miners; how long will they be able

to continue working in a good location, when and how will they be moved, who will be in charge in a new place where they may be tolerated" (Luning 2008, 393-94).

This is saying that with the current situation, it is impossible for artisanal miners to have any sense of job security or permanence. They are constantly a population on the move, searching for the next best location. The constant mergers, acquisitions, and buying of companies makes their source of income, location, and relationships with foreign companies very uncertain.

Whenever artisanal miners find too much gold in an area, foreign companies are sure to enter the picture. For example, "rumours spread that High River was about to clear out the area, and in anticipation of the eviction, the mining crews worked frantically to take out as much ore from their pits as possible…In January 2008, High River hired bulldozers to close all the pits of the artisanal miners" (Luning 2008, 395). This illustrates the delicate balance between the artisanal miners and multinational corporations, and how strained their relationship can be.

Furthermore, a huge number of people are needed for artisanal mining. There are diggers, pit bosses who provide food and medical care, people who separate the gold from the ore, enforcers, security personnel, and gold buyers. All of these parties operate in a complex world of debts and credits that is endemic to artisanal mining (Luning 2008, 397-98). This system enhances the risks and uncertainties facing artisanal miners.

There is a way for artisanal miners to have greater job and location security in the present system, but it also has its drawbacks. As Luning elaborates, "AAM (authorization for artisanal mining) zones are put in place to confine artisanal miners to specific areas where they can have some reassurance that they will not be evicted. This formal acknowledgement, however, has its price; it pins miners down to restricted areas and forces them into a regime of selling their gold to the AAM holder" (2008, 391:398). These AAM zones are the multinational corporation's way of dealing with artisanal miners peacefully. Instead of prohibiting them from mining completely, which would require an incredible amount of policing and enforcement, they relegate them to a less promising mining area. In addition, they ensure the artisanal miners only sell to their buyers, and they dictate the price the buyers are allowed to purchase at. Furthermore, if that mining site happens to be more lucrative than expected, the company has the right to kick the miners off the site and develop a full mine there.

Luning's analysis is very useful because it shows the problematic power relationship between the multinational corporations and the artisanal miners. These companies use the

artisanal miners as an excellent indicator of how much gold is present, then forcibly remove them from the most profitable areas to develop a full-blown mine there. To avoid more problems with the artisanal miners, these companies provide them with just enough to make a living through these AAM sites, while still making a profit from it. This is clearly a system that benefits the multinational corporations, who have the power, money, and influence to enforce their will on the artisanal miners.

Thus, the literature on gold mining in Burkina Faso shows that the artisanal miners preferred the time period before the international mining corporations moved in. While they largely tolerate the corporations, they are often frustrated by the lack of permanence and available jobs. Furthermore, it is clear from the literature that these artisanal miners who do get jobs with the international mining corporations earn a pittance compared to what they would earn in many other countries. This ties in to both world-systems theory and the theory of unequal exchange, which corroborate the information in the literature review.

IV. Data

Correlation between Nighttime Lights and Economic Activity

While remote sensors in satellites are usually designed for a specific purpose, often relating to weather or ground cover, they have turned out to be incredibly useful for viewing nighttime lights (Andersson et al. 2015, 322). One such program, run by the National Oceanic and Atmospheric Association's National Geophysical Data Center (NOAA-NGDC), is the Defense-Meteorological Satellite Program-Optical Line Scanner (DMSP-OLS) (Hall, 4; Andersson et al. 2015, 322). "Launched in the early 1970s, [it] was designed to observe clouds at night for weather forecasting purposes. However, its sensor was soon found to be very good at detecting the presence of light at night on earth (Croft, 1978). The DMSP-OLS sensor is sensitive enough to detect street lights and even saury fishing vessels at sea" (Andersson et al. 2015, 322). At night, this is accomplished by use of a photomultiplier tube (Bustos et al. 2015, 3). Also important to note is that since 1992, "at a minimum, one satellite is operated each year" (*ibid*). However, most years there are two satellites collecting data (*ibid*). These produce a nighttime lights dataset with a resolution of 2.7 km (Hall, 5). In addition, "each sensor collects 14 orbits daily in 3,000 km swaths which provide for complete global coverage four times during the day at dawn, daytime, dusk, and nighttime" (Andersson et al. 2014, 7).

However, this data must be processed to remove other sources of light. These include moonlight, sunlight, glare (mainly from moonlight or hills close to a city), aural activity, areas covered by clouds, gas flares, fires, fishing boats, and swidden agriculture (Hall, 5; Bustos et al. 2015, 3; Andersson et al. 2015, 322). Furthermore, all the data from the six different satellites in the program so far must be calibrated to the same base point, to ensure continuity of accurate results (Bustos et al. 2015, 4). There are a few additional steps to processing the data for nighttime lights as well. However, as they are vastly more complex, and the data for this study was pre-processed by the Human and Economic Geography Department at Lund University, this study will not go into such great detail.

There are many studies that have tested the relationship between nighttime lights and human activity. It has been used as a proxy for understanding economic development, population, urbanization, demographics, epidemiology, war and crime, poverty, electricity usage, and GDP (Bustos et al. 2015, 1; Andersson et al. 2015, 323). Most important to this study however is the relationship between nighttime lights and economic activity. Elvidge et al. were the first to publish research relating lighted area to GDP, in 1997. They found a strong linear relationship between the two, with $R^2 = 0.97$ (Andersson et al. 2014, 12). However, all subsequent publications have focused on the relationship between GDP and light intensity, which is viewed as a more accurate model because it allows for upward growth, instead of just outward (Andersson et al. 2015, 323). Doll, Muller, and Morley were the first to apply this technique, in 2006 (Andersson et al. 2014, 12). There were able to achieve R^2 values between 0.85 and 0.98 (*ibid*). Gosh et al. improved this technique when in 2010, they added the percent contribution of agriculture to their analysis (*ibid*). This was an important step, as GDP derived from agriculture is usually missing from nighttime lights datasets because these areas are not often lit (*ibid*). Next, in 2011 Chen and Nordhaus successfully analyzed the relationship between economic activity and nighttime lights over a period of time. This is an important step, as this study uses that same concept. Finally, it is important to note that "a clear pattern in terms of nightlight is that intensification increases during the years associated with an establishment of a mine. This confirms knowledge from the ground saying that activities omitting nightlight are common during the establishment of a mine" (Andersson et al. 2014, 28). They sum it up best by saying "all in all, the literature confirms that there is a strong relationship between nighttime lights and economic activity" (*ibid*, 13). This is how this study is able to use remote sensing of nighttime lights data to more accurately model regional GDP over time.

Furthermore, many have argued that the nighttime lights dataset is very well-suited for social science research (Andersson et al. 2014; Andersson et al. 2015; Bustos et al. 2015; Hall 2015). Even today, there are many problems with the traditional methods of collecting data. As Andersson et al. reports, "despite continuous revisions of knowledge, methodologies, and techniques for measuring income and economic activity using conventional ground survey-based data, reliable yearly statistics at the national level are often a luxury. Many poor countries lack both the resources and the capacity to acquire such reliable data, despite decades of international statistical support" (2015, 322). This is an enormous problem for the social sciences, particularly in time series and multi-country comparisons. Bustos et al. agree, acknowledging "accuracy, reliability, access, and availability of census and survey data differ widely depending on the source of the data and therefore also on the spatial location" (2015, 4). Contrastingly, with nighttime lights, "the dataset has global coverage. Thus, there is no change in the quality of the data based on spatial location" (Bustos et al. 2015, 4). This is another huge advantage of nighttime lights, in that it treats each city, region, country, and continent equally. Finally, Hall notes that "in addition, several studies have pointed out serious measurement errors in, for example, economic growth figures, even in developed economies" (2015, 1). As one of the poorest countries in the world, it may well be that economic data extrapolated from the nighttime lights dataset is more accurate than statistics from the United Nations, World Bank, or Burkina Faso itself, if they provided any. For all of these reasons, the nighttime lights dataset is ideal for this study.

Notes about NDVI, Forest Loss, and G-Econ Datasets

As stated previously, the Normalized Difference Vegetation Index (NDVI) is used in this research as a measure of agricultural productivity. What it generally measures is "photosynthetic uptake by vegetation", which relates to "the vegetation greenness, leaf area index (LAI), and primary productivity of the vegetation" (Andersson et al. 2014, 10). This dataset was processed by the Department of Human and Economic Geography to show the yearly amplitude value (*ibid*). This means each pixel was assigned a value between -1 and 1, based on the difference between the yearly maximum and minimum values (*ibid*). Next, "a mask was constructed to exclude land covers that are not part of the agricultural economy" (*ibid*, 11). This means they selected only the classifications of croplands and cropland/natural vegetation mosaic (*ibid*). These were selected because they contribute to the agricultural economy. In this way, an estimation of agricultural productivity for one year can

be acquired by summing up all the amplitude values of each pixel in a given region for that year. For example, a higher sum of the amplitude values represents an increase in agricultural productivity. This agricultural estimation is particularly important for Burkina Faso, where over 90% of the population relies on subsistence agriculture to make a living (2015 Index of Economic Freedom). This dataset is an important addition to the nighttime lights dataset as a proxy for economic activity. Nighttime lights do a very poor job of estimating agricultural output due to the lack of nighttime lighting involved in most forms of agriculture (Andersson et al. 2014). However, the NDVI dataset is a much better indicator of agricultural output, and works in tandem with the nighttime lights dataset to model the total economic activity of an area.

Forest loss data from the University of Maryland is also used, with the intent of analyzing environmental degradation around the mines. This dataset measures how much forest has been lost and where. For pre-processing, the separate tiles covering Burkina Faso were merged, creating one raster. This was then reclassified into three different year groupings. The first group shows forest loss from 2001-2004, the second group from 2005-2008, and the third group from 2009-2012. This is to correspond to the timeframe of the nighttime lights and NDVI data showing changes from 2004, 2008, and 2012. As the nighttime lights and NDVI data from 2008, for example, can roughly be considered a sum of their respective activity from 2005-2008, it was decided to calculate the forest loss data by grouping them together in this way as well. The amount of forest lost was then calculated in a similar manner to the previous two datasets. However, instead of summing up the values of the pixels as with the nighttime lights and NDVI datasets, it was only necessary to sum up the number of pixels present in any given area, as each pixel represents a unit of forest lost.

The G-Econ database is fairly straightforward to use and understand, but does require one note of clarification. The Gross Cell Product (GCP) data is normalized by population. This is of particular importance later, when analyzing Purchasing Power Parity (PPP) data, to note that though the gridded areas do have different areas and populations, the PPP data are in fact normalized by population (Nordhaus et al. 2006, 7). This means that though area 1 may have three times the population of area 2, the PPP data for both areas takes into consideration the difference in population, and area 1 will not have a PPP figure three times higher than area 2 if they have a similar income.

Primary Data

The research question asks how international corporations mining gold in Burkina Faso affect local economic activity. By using the spatially calibrated data listed below, this research generates primary data on local economic activity around gold mines in the form of analysis conducted using ArcGIS. It is displayed using maps, charts, and graphs. The following primary data (initial processing for the first two done by the Department of Human and Economic Geography) is used in this analysis:

- Nighttime Lights data from 1992-2012. This is very handy for estimating economic activity. 2012 is the endpoint as it is the most recent year the Department of Human and Economic Geography had processed. It is analyzed for 2004, 2008, and 2012.
- Normalized Difference Vegetation Index (NDVI), which adds to the accuracy of the nighttime lights dataset for modeling economic activity by including agricultural output. It is analyzed for 2004, 2008, and 2012.
- Forest loss data from 2001-2013 from the University of Maryland. This is used for analyzing the environmental consequences of mining. It is also analyzed for 2004, 2008, and 2012.

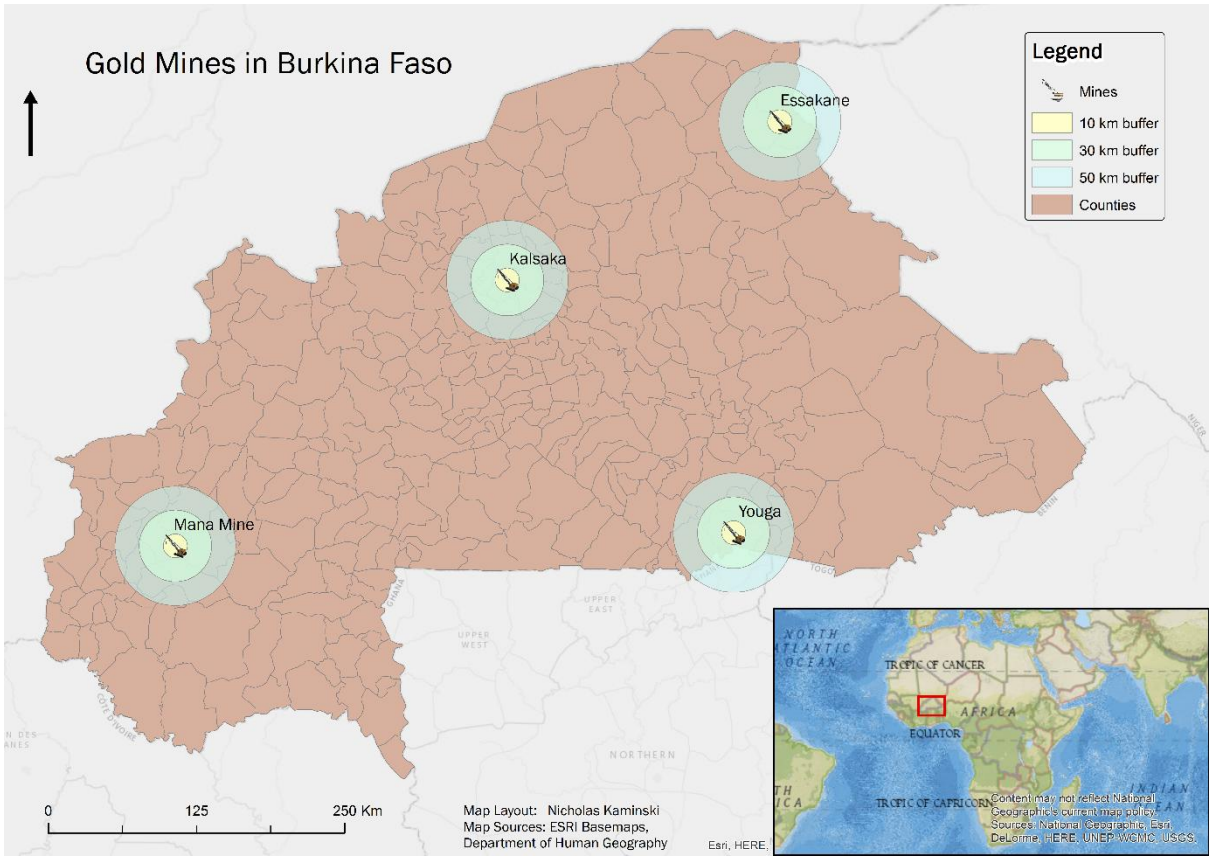

Fig. 1

This map of the gold mines in Burkina Faso show the location of the four mines analyzed, surrounded by buffer areas of 10, 30, and 50 kilometers. The locations of Essakane, Kalsaka, and Mana mine came from the Department of Human Geography. The fourth, Youga, was extrapolated using triangulation based on a description on the company's website (Endeavour Mining 2015).

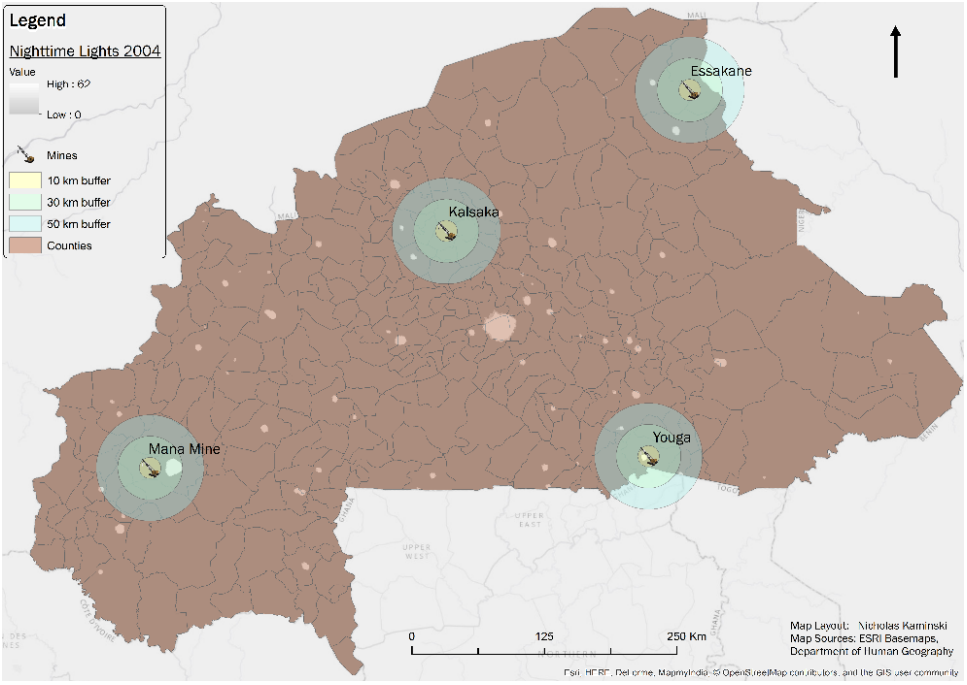

Fig. 2a

Nighttime Lights 2004 (NOAA-NGDC). This map shows the extent and brightness of nighttime lights in 2004. The brighter an area is, the more nighttime light is coming from it. The capital, Ouagadougou, is clearly visible as the largest and brightest patch in the middle of the country.

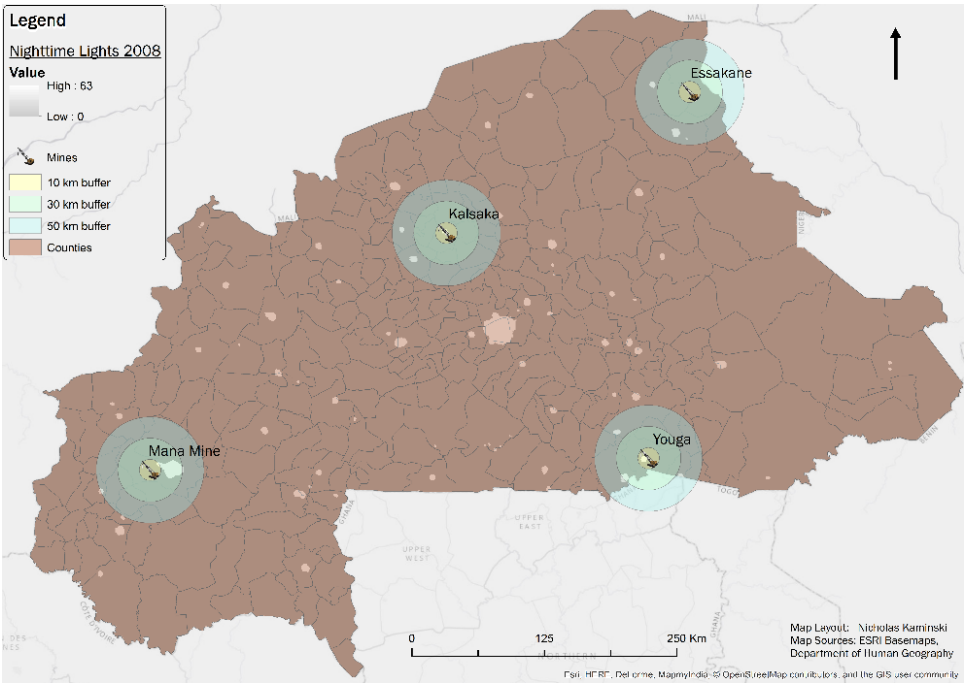

Fig. 2b

Nighttime Lights 2008 (NOAA-NGDC).

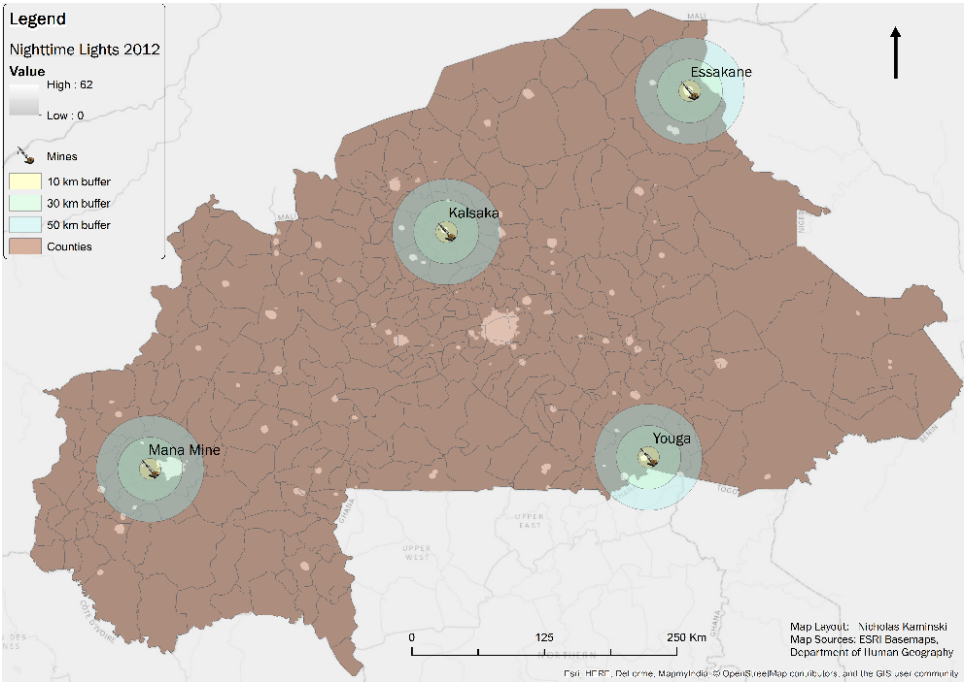

Fig. 2c

Nighttime Lights 2012 (NOAA-NGDC). Note the greatly increased brightness of light coming from within the 10 km buffer from Essakane and Kalsaka mines in particular.

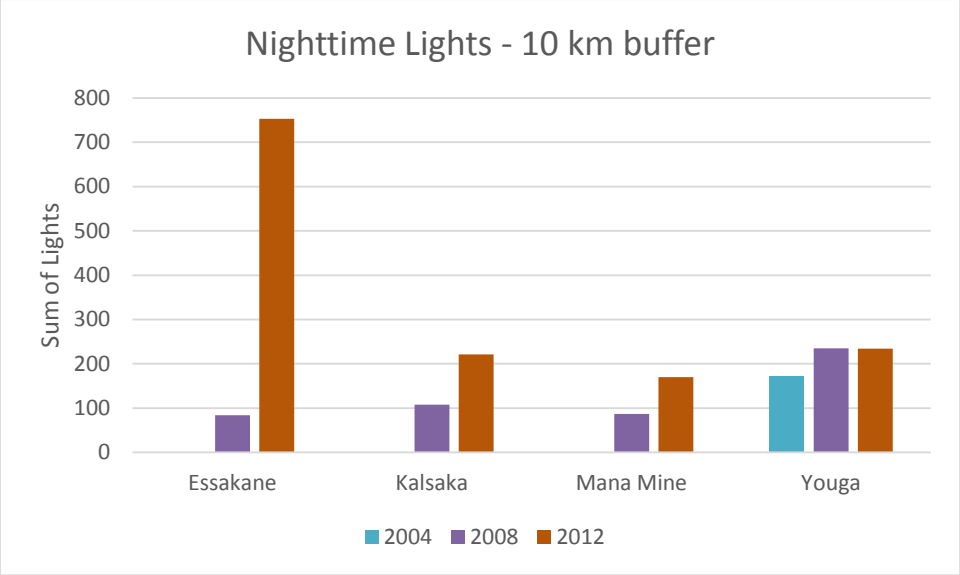

Fig. 3a

Nighttime lights with a 10 km buffer. On the x-axis are the mines, on the y-axis is the sum of the brightness of the lights within 10 km of each mine.

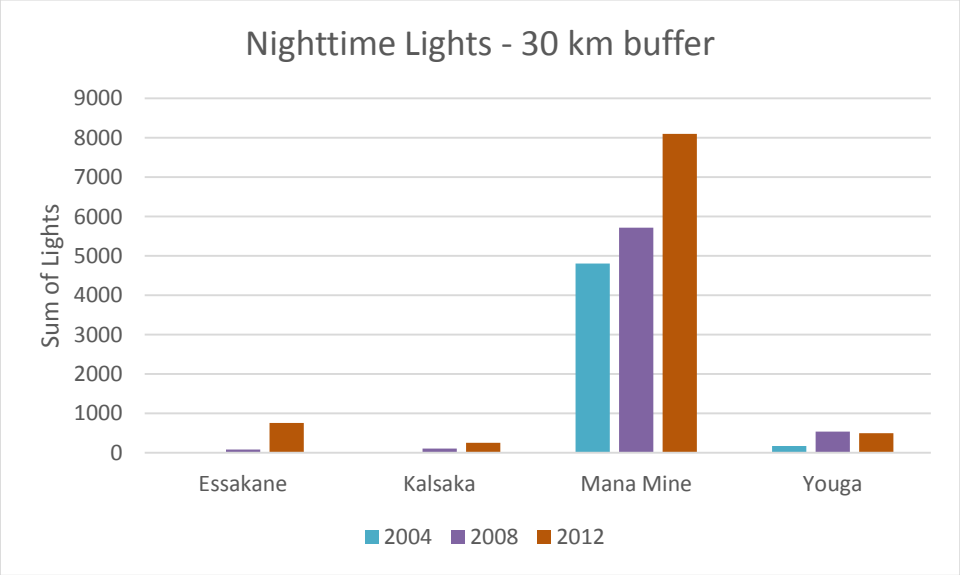

Fig. 3b

Nighttime lights with a 30 km buffer

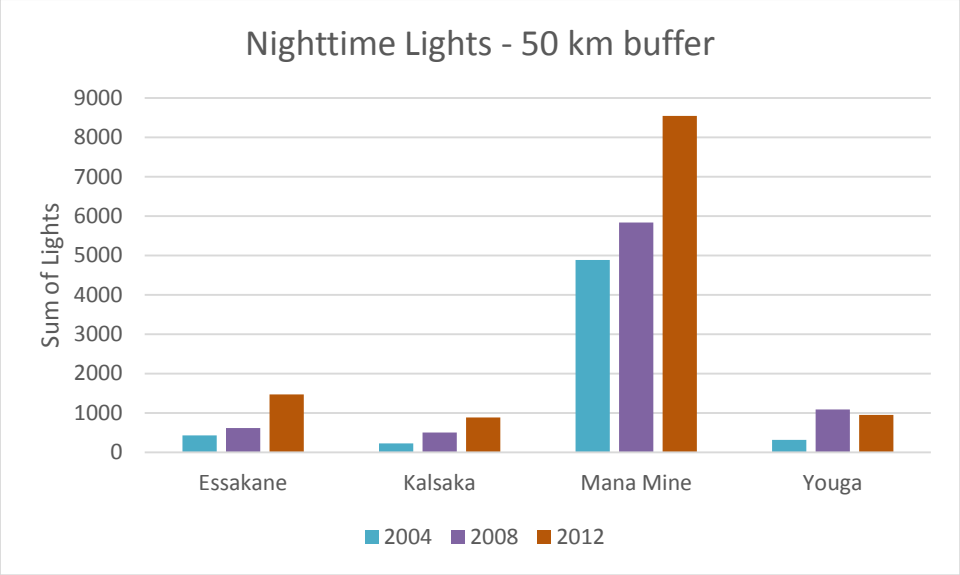

Fig. 3c

Nighttime lights with a 50 km buffer

One special note about the graphs – in most cases, the y-axis on the graphs are different from one another. This is for two reasons. First, with buffer zones of 10, 30, and 50 kilometers, the scale of the data changes dramatically. It would be difficult, and in many cases impossible to properly read the data in the 10 km buffer graphs if there were on the same scale as the 50 km graphs. Secondly, the primary function of the graphs is to illustrate the differences in data over time. 2004 was before the international mining companies arrived, 2008 was when the mines were either in the initial stages of setup or were just opened, and 2012 was when the mines were already operational for 2-4 years. While judging which buffer size represents the data most accurately is an important question as well, particularly for further research on this topic, it was considered less important than showing the difference over time.

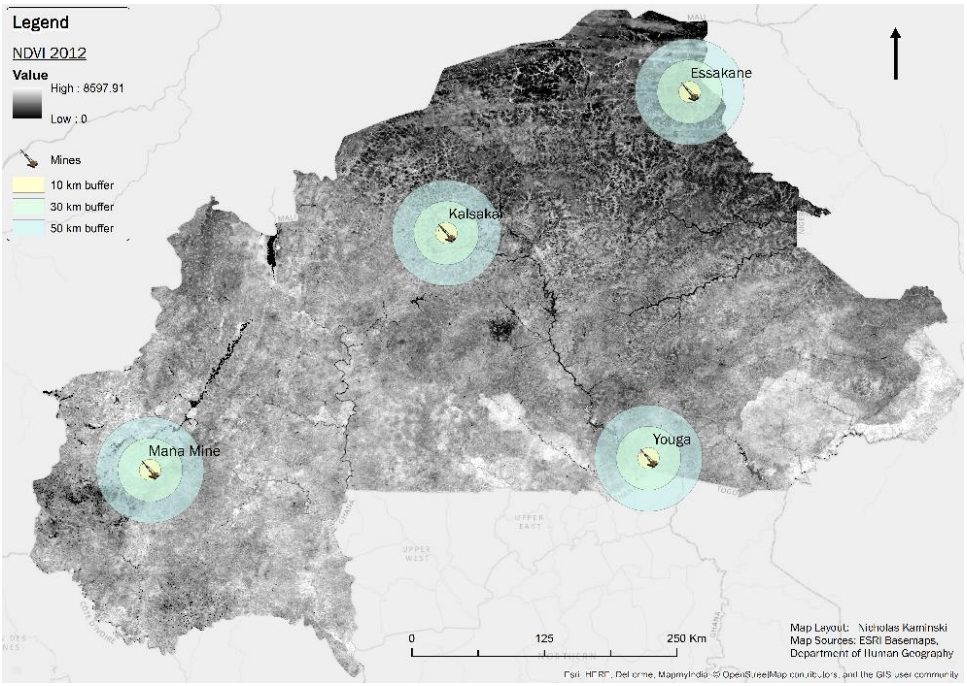

Fig. 4

NDVI 2012 (MODIS NDVI). This map shows what the NDVI dataset looks like on a map. This NDVI dataset has been processed to show agricultural productivity over the course of a year. The darker the area is, the less vegetation it has. Conversely, the lighter an area is, the more vegetation it is growing. Note that the northern region of the country is the southern border of the Sahel region, an arid expanse that gradually brings the Sahara desert to an end (Encyclopedia Britannica). Thus, it does not have much vegetation. Ouagadougou and its surroundings are again visible on this map as the dark circle near the middle of the country. On the other hand, the region south of it following the river appears to be one of the best for vegetation in the country, as it is much lighter there. Since the NDVI dataset is most useful as a sum of the amplitude data expressed in graph form, and is not as easy to analyze with a map, only the map from 2012 is included here.

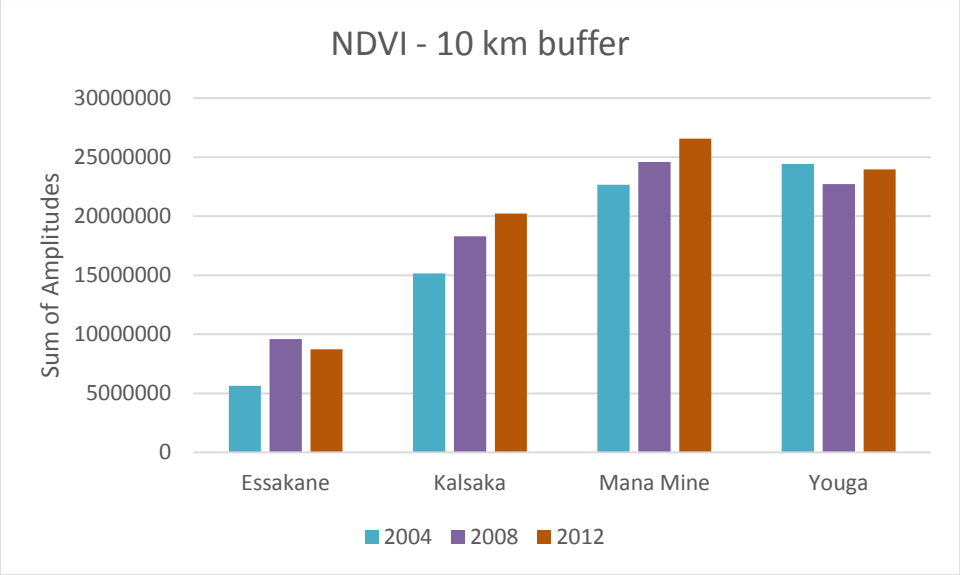

Fig. 5a

NDVI with a 10 km buffer. On the x-axis are the four mines, and on the y-axis is the sum of the amplitude values within 10 km of each mine. The higher the sum of the amplitude values, the more agricultural productivity is expected to come from that region (Andersson et al. 2015).

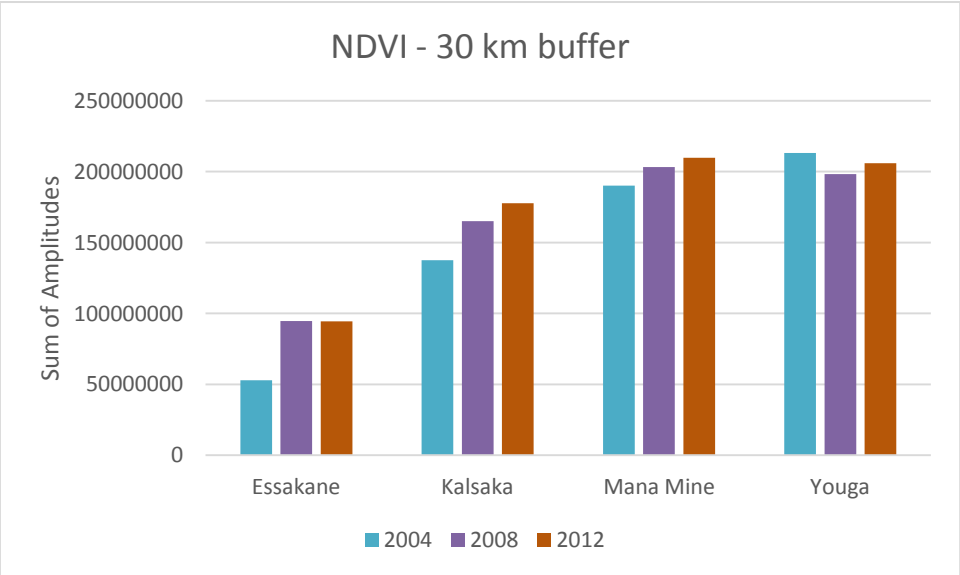

Fig. 5b

NDVI with a 30 km buffer

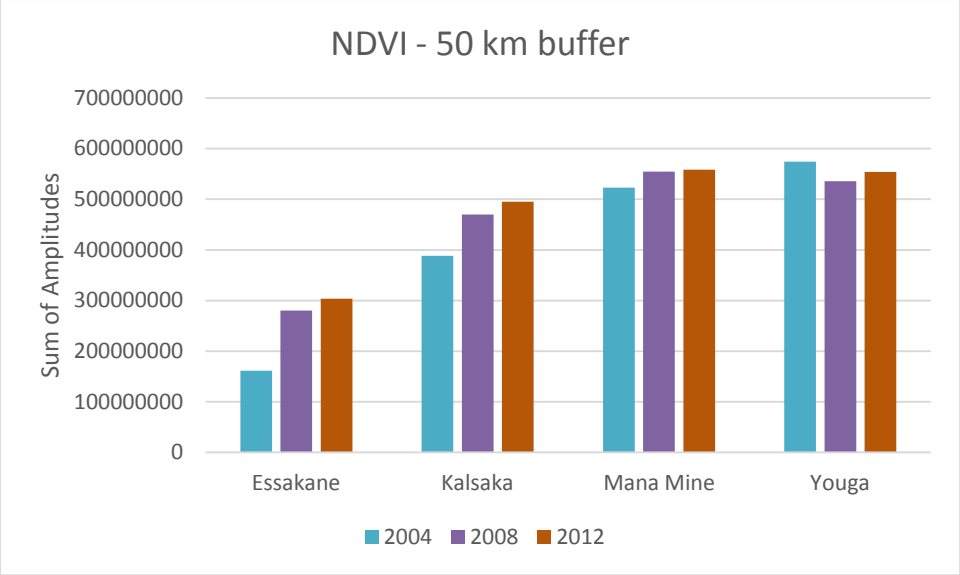

Fig. 5c

NDVI with a 50 km buffer

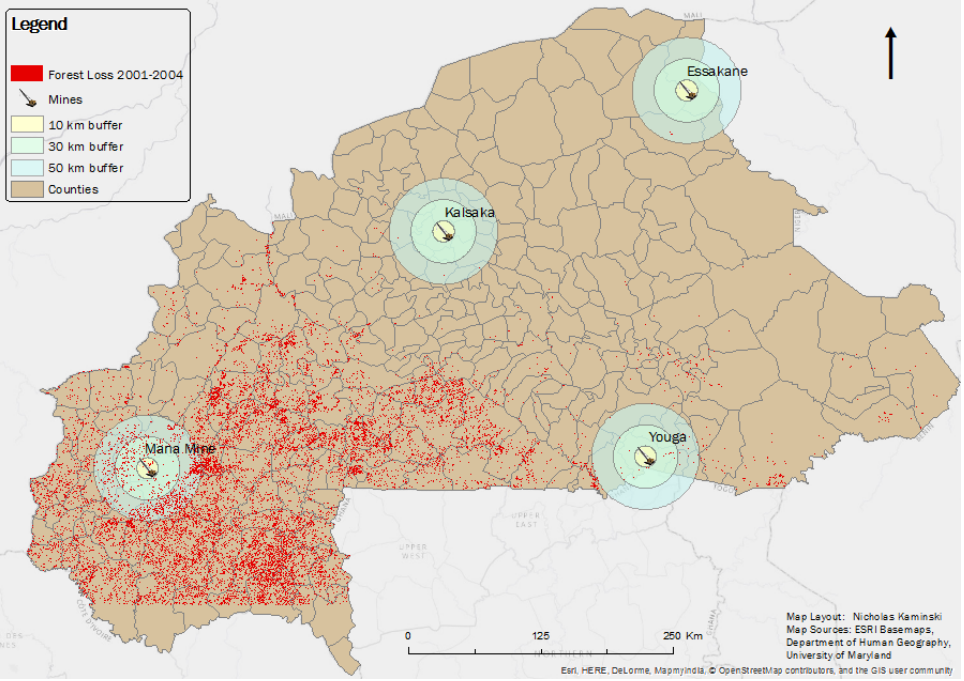

Fig. 6a

Forest Loss 2001-2004 (Hansen et al. 2013). The red dots represent forest that was lost between 2001 and 2004. Data from the far southwest of the country was on a separate tile, hence the sudden horizontal line. It was not included in the merging of tiles because it was not within 80 km of a mine.

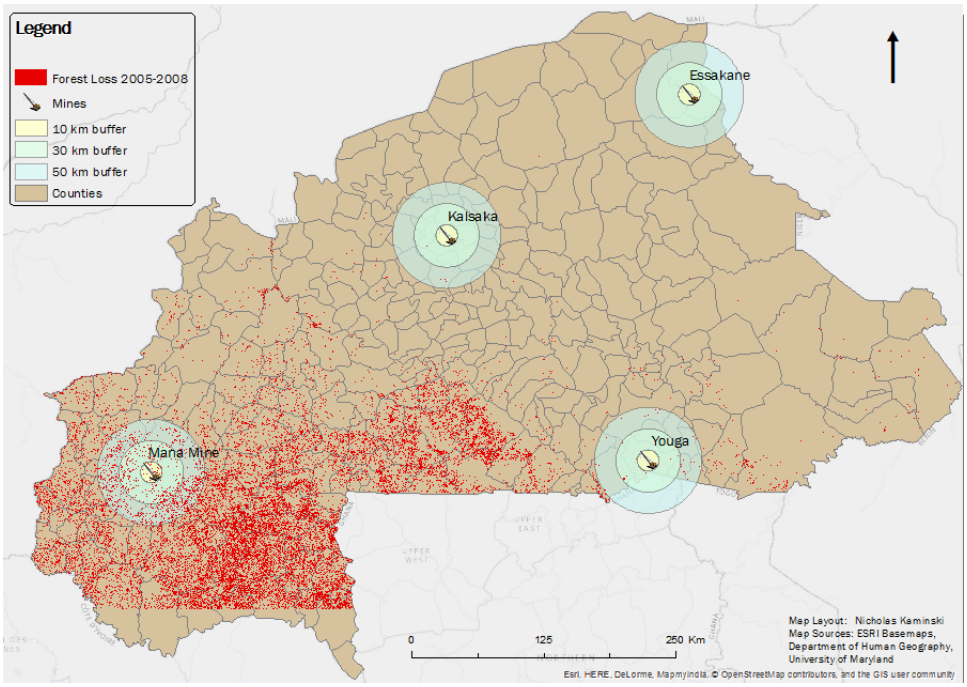

Fig. 6b

Forest Loss 2005-2008 (Hansen et al. 2013).

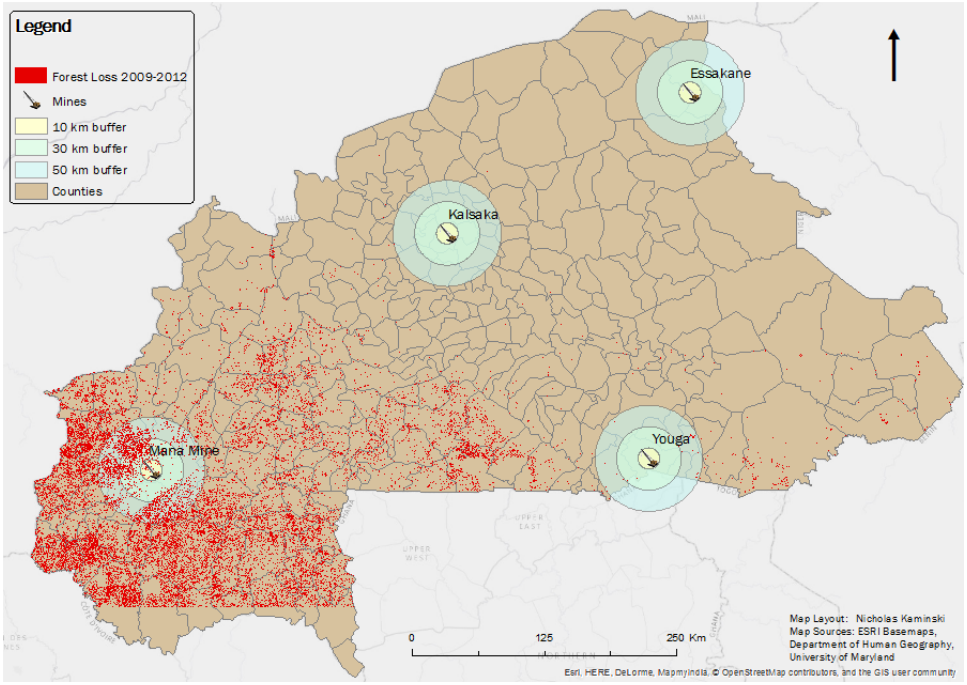

Fig. 6c

Forest Loss 2009-2012 (Hansen et al. 2013).

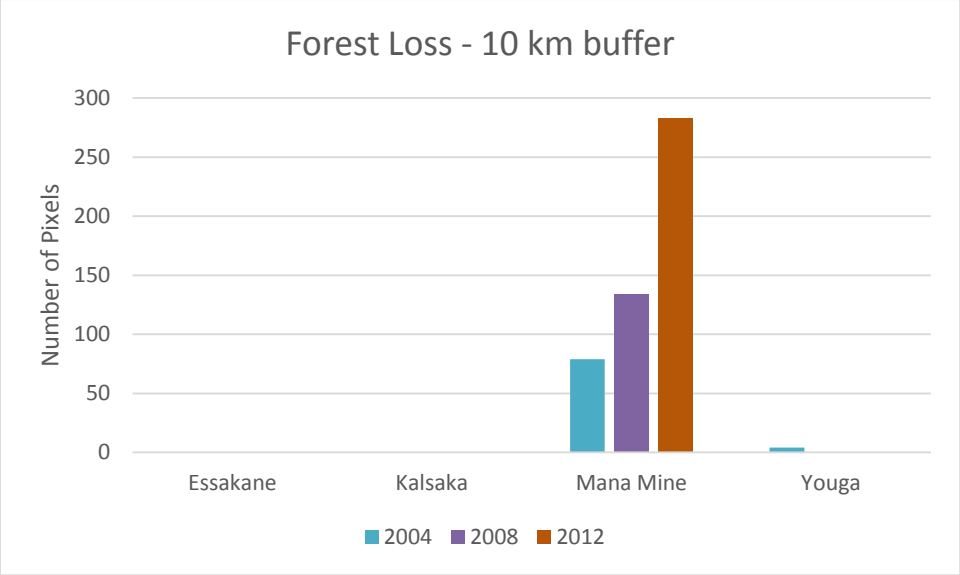

Fig. 7a

Forest loss with a 10 km buffer

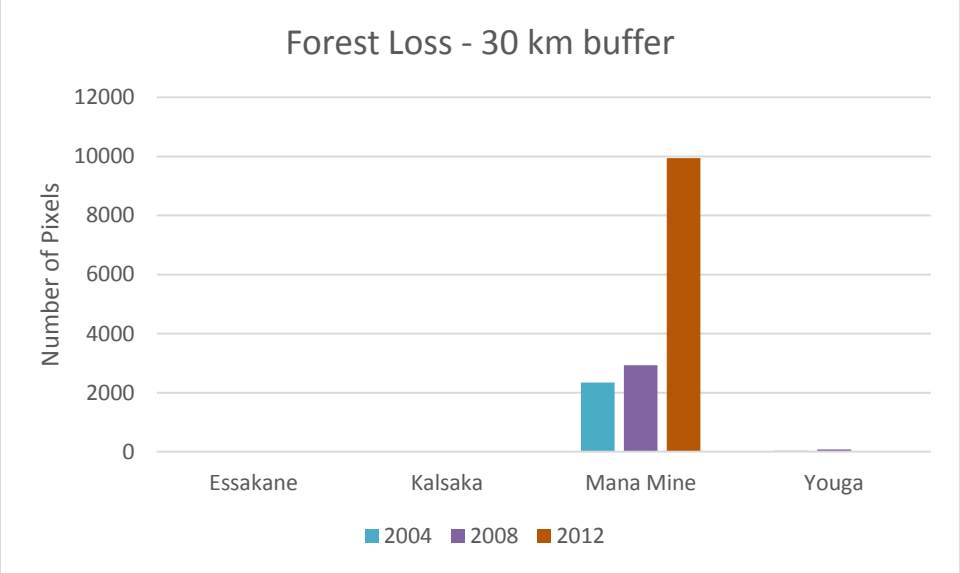

Fig. 7b

Forest loss with a 30 km buffer

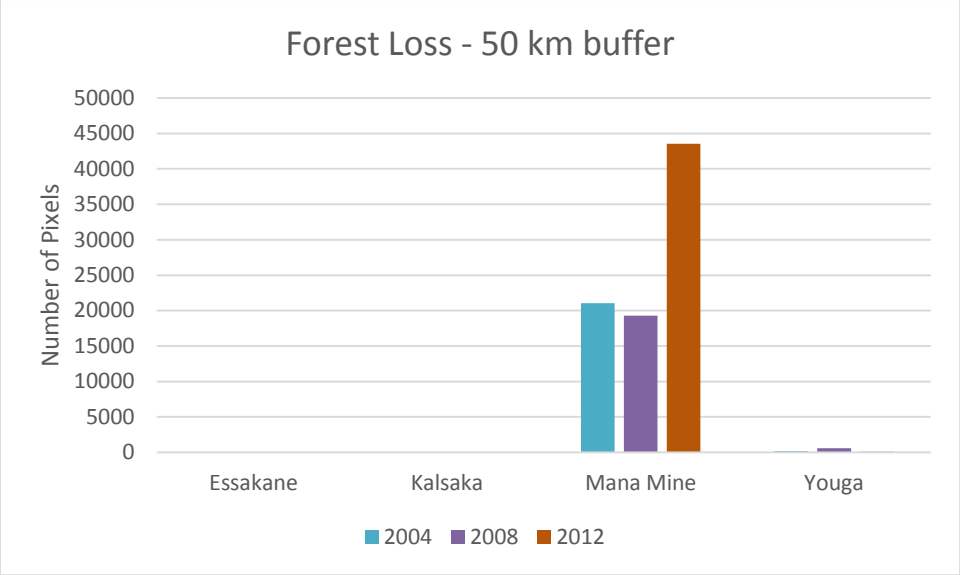

Fig. 7c

Forest loss with a 50 km buffer

In summary of the primary data:

- Fig. 1 is a general map of the gold mines in Burkina Faso, with buffer areas of 10, 30, and 50 km
- Fig. 2a is a map of nighttime lights from 2004
- Fig. 2b is a map of nighttime lights from 2008
- Fig. 2c is a map of nighttime lights from 2012
- Fig. 3a shows nighttime lights with a 10 km buffer
- Fig. 3b shows nighttime lights with a 30 km buffer
- Fig. 3c shows nighttime lights with a 50 km buffer
- Fig. 4 is a map of the NDVI data from 2012
- Fig. 5a shows the NDVI with a 10 km buffer
- Fig. 5b shows the NDVI with a 30 km buffer
- Fig. 5c shows the NDVI with a 50 km buffer
- Fig. 6a is a map of forest loss from 2001-2004
- Fig. 6b is a map of forest loss from 2005-2008
- Fig. 6c is a map of forest loss from 2009-2012
- Fig. 7a shows forest loss with a 10 km buffer
- Fig. 7b shows forest loss with a 30 km buffer
- Fig. 7c shows forest loss with a 50 km buffer

Secondary Data

Due to the physical, financial, and current safety issues making it difficult to conduct more first-hand research in Burkina Faso, this analysis relies on a wealth of secondary data. They are summarized here:

- Official GDP data from the World Bank
- Poverty and Inequity Data from the World Bank
- Spatially calibrated statistical information from G-Econ

Coincidentally, this secondary data is very useful for answering the secondary research question, which asks if international corporations mining gold have other effects, such as poverty and inequality.

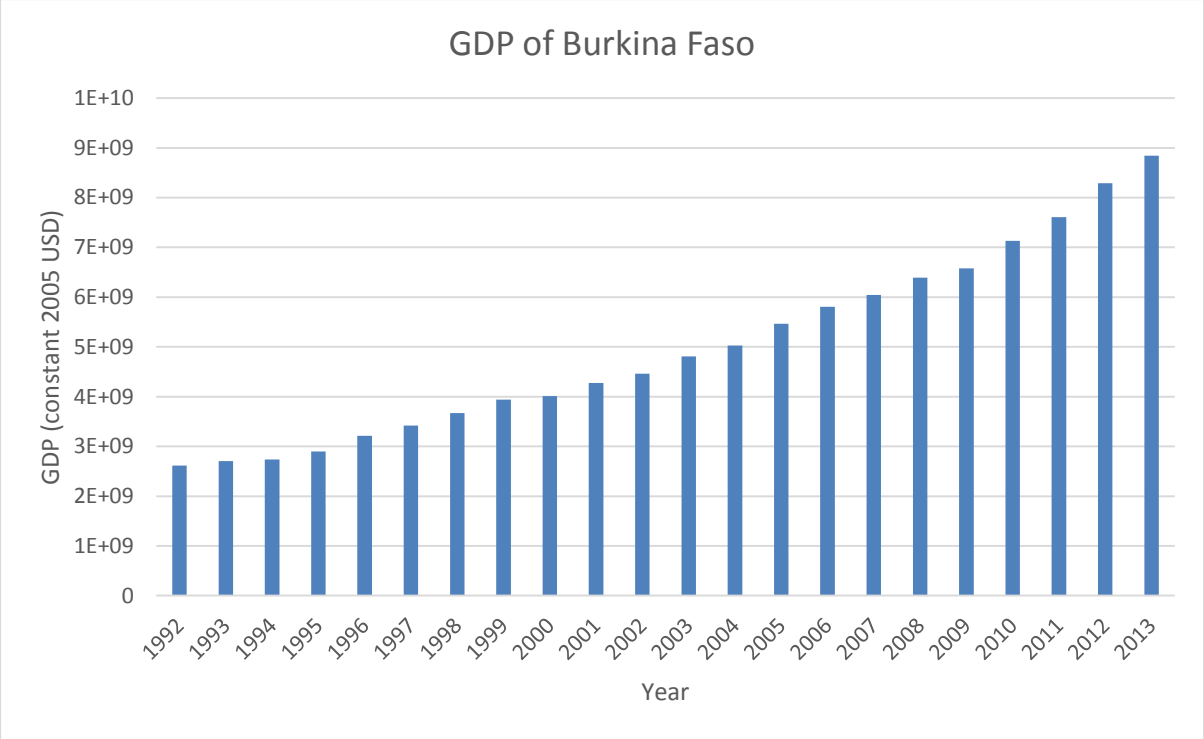

Fig. 8

GDP (in constant 2005 US dollars) of Burkina Faso from 1992–2013 (World Bank 2015b).

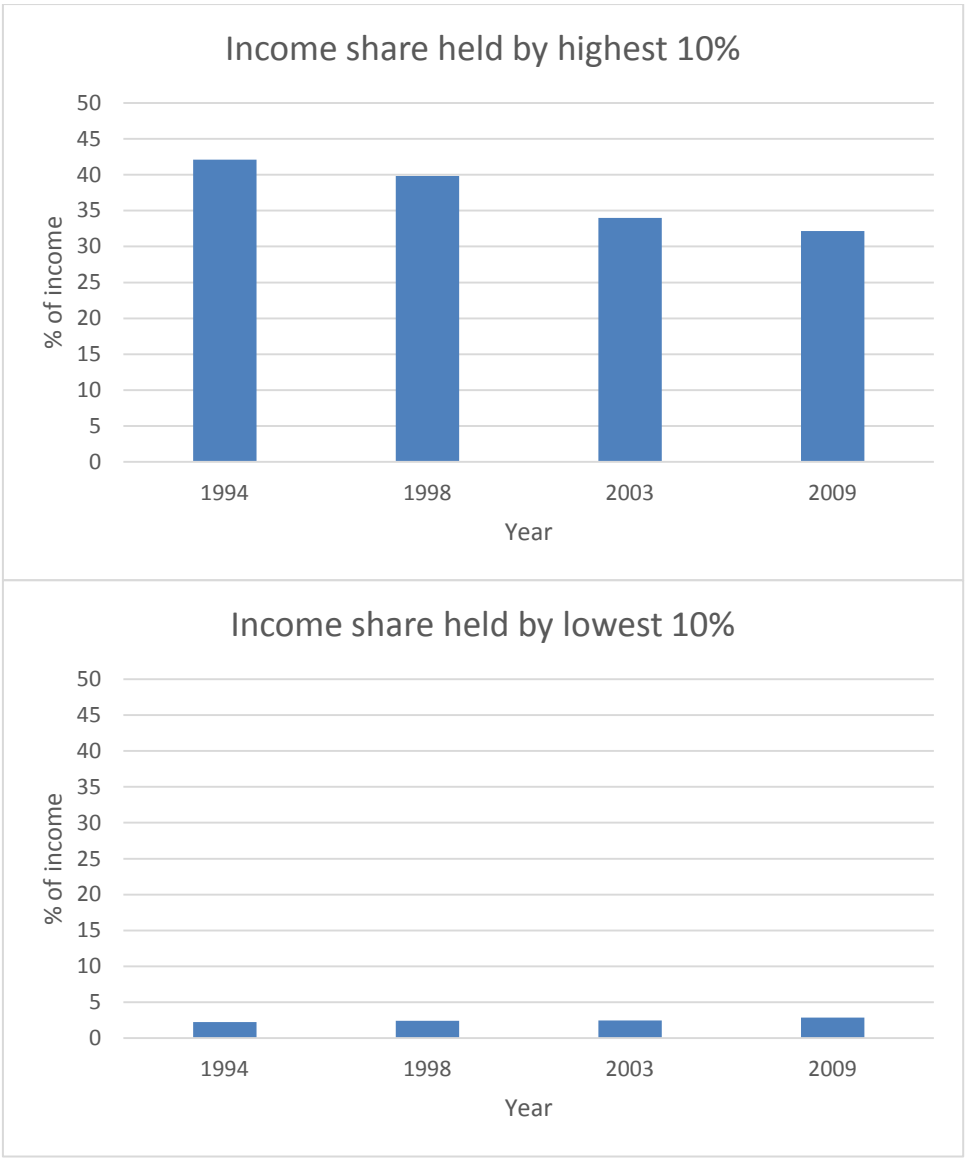

Fig. 9a and 9b

These charts show the income share held by the highest and lowest 10%, respectively, between 1994-2009 (World Bank 2015a). Note that both the x and y-axes on these two graphs are identical.

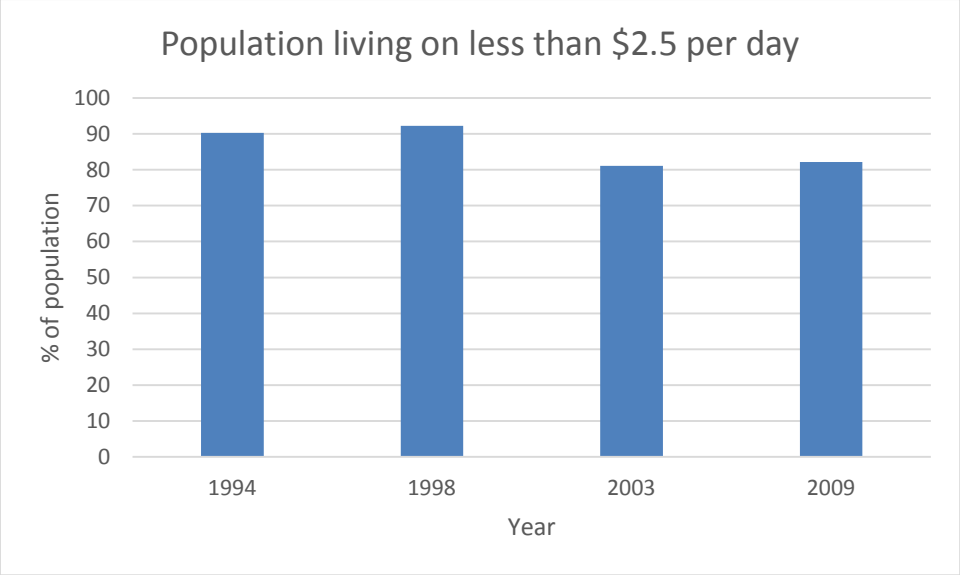

Fig. 10

Percent of population living at less than $2.5 PPP per day, in constant 2005 US dollars (World Bank 2015a).

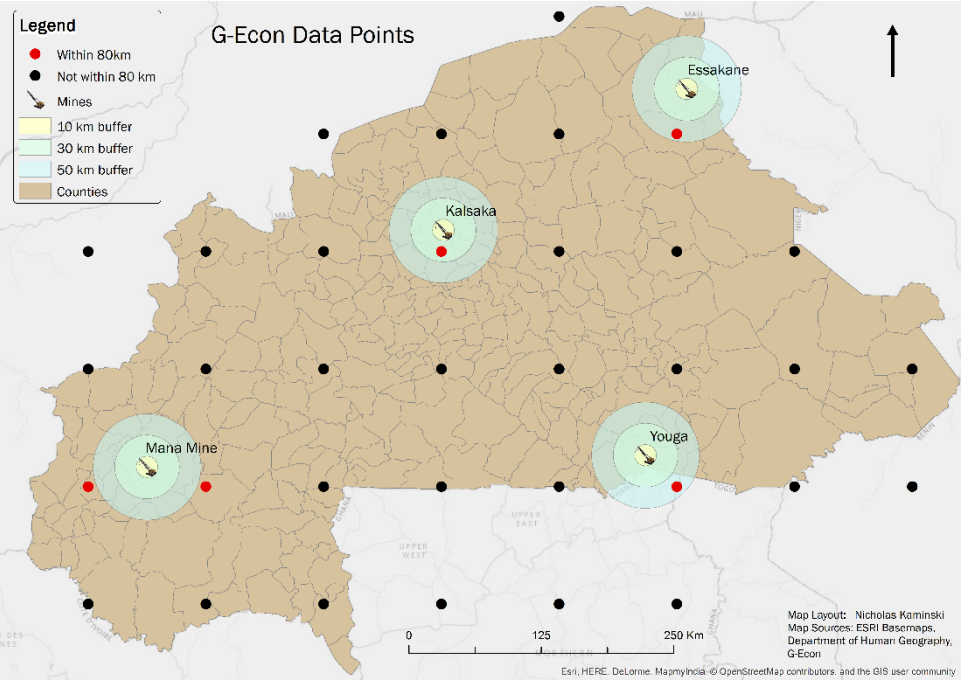

Fig. 11a

Map of the G-Econ data points covering Burkina Faso (G-Econ 2011). The points in red are within 80 km of a mine, the points in black are further than 80 km from a mine. The distance of 80 km was chosen to get a more appropriate sample size – when 50 km was chosen, only 3 of the 39 points were selected, and such a small sample size was judged too likely to be affected by an outlier.

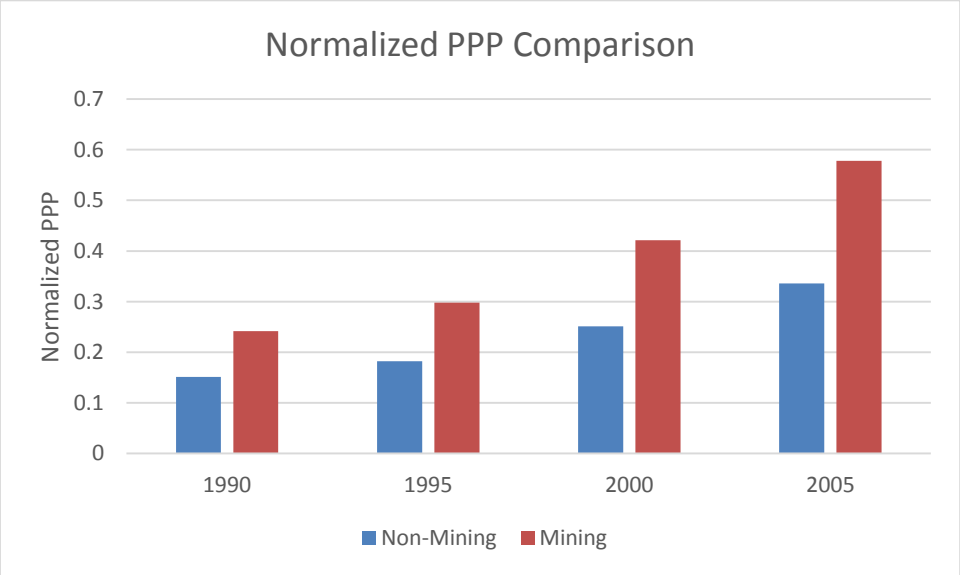

Fig. 11b

Normalized PPP comparison between non-mining and mining areas from 1990-2005 (G-Econ 2011). As noted earlier, this PPP data is normalized by population, meaning it takes into account the differences in population between each data point's surrounding area.

In summary of the secondary data:

- Fig. 8 shows the GDP of Burkina Faso from 1992-2013
- Fig. 9a shows the percentage of income held by the highest 10% from 1994-2009
- Fig. 9b shows the percentage of income held by the lowest 10% from 1994-2009
- Fig. 10 shows the percentage of the population living on less than $2.5 per day from 1994-2009
- Fig. 11a is a map of the G-Econ data points, highlighting those within 80 km of a mine
- Fig. 11b shows the difference in wealth between non-mining areas and mining areas from 1990-2005

V. Analysis

The primary research question in this study is concerned with how international corporations mining gold in Burkina Faso affect local economic activity. The secondary research question looks at how international corporations mining gold in Burkina Faso have

other notable effects, such as changes in poverty or inequality. The primary data included datasets of nighttime lights, NDVI, and forest loss. The secondary data dealt with statistics from the World Bank on GDP, poverty, and inequality, as well as spatially calibrated statistics from G-Econ. Overall, the research finds that international corporations mining gold have a significant effect on local economic activity. However, it is inconclusive whether they have other notable effects, particularly changes in poverty and inequality.

Fig. 1 simply shows the location of the four gold mines in Burkina Faso, and Fig. 2a-c display the nighttime lights from 2004, 2008, and 2012, respectively.

Fig. 3a, however, graphs the nighttime lights with a 10 km buffer. Recall from the beginning of the data section that nighttime lights correlate very well to economic productivity. This 10 km buffer graph is very important for many reasons. First, 10 km is arguably the best distance for analyzing *local* economic activity. It is a limited enough distance that whatever light coming out of that area is either coming directly from the mine, or indirectly from activities associated with the mine. This brings up the next point, which is that all of these mines officially opened between 2008-2010. This explains why only one of the mines shows any nighttime lights within 10 km in 2004 (Youga), which is due to the presence of a nearby town. Furthermore, the massive jumps in nighttime lights from 2008-2012 are hugely important. Essakane (the mine with by far the highest output) in particular jumped 796% between these years. Kalsaka and Mana Mine jumped 105% and 95%, respectively. It is unclear why Youga mine did not grow at all. However, the first three mines experienced jumps in nighttime lights that should correspond to substantial local economic growth. Referring to world-systems theory and the theory of unequal exchange however, it is not possible to tell using nighttime lights alone where or to whom all these economic benefits are going.

In fig. 3b, two things are of particular relevance. First, Mana Mine is a massive outlier here. This is because it is located within 30 km of Burkina Faso's second largest city, Bobo Dioulasso (World Gazetteer 2015). With an estimated population of over 537,000 in 2012, it is unsurprising that it skews the results so much (*ibid*). Secondly, note that the y-axis changes from 800 in the 10 km graph to 9,000 in the 30 and 50 km graphs. Despite making the increases for the first two mines look small, they are still very significant – 796% for Essakane again and 132% for Kalsaka. Again, it is unclear why Youga declined. However, looking at how little Essakane and Kalsaka changed between the 10 and 30 km buffers signifies there were no or limited additional lights in this area. Especially considering the outlier Mana Mine creates when the buffer area is too large, this suggests that a smaller

buffer area is more useful for analyzing local economic activity, or the economic activity of a specific mine.

For fig. 3c at 50 km, the area is big enough to start including towns, villages, and activity that may or may not be related to the presence of a mine. Even in 2004, when there were only artisanal miners, the areas around Essakane and Kalsaka do show some nighttime lights. This suggests 50 km is too large of a buffer area for analyzing local economic activity around gold mining in a country with this population density.

Fig. 5a-c shows NDVI with 10, 30, and 50 km buffers. Interestingly, the size of the buffer seems to matter very little, as the greatest difference between any buffer size for the same mine and year is less than 10%. Also, regardless of buffer size, year, or mine, $^{5}/_{6}$ of the time, the NDVI increased. This could suggest a number of different things. First, it could mean that the increased immigration, and thus population the mines bring with them are planting crops in the local area. This is problematic though. As mentioned by both Mégret and Luning, the mining population is one very much on the move; they are constantly in search of new gold sites, or having the international mining companies kick them off sites (Mégret 2011). Planting crops with such a nomadic, uncertain lifestyle does not fit, at least without additional information. One proposed theory is that "alternatively, mining could create a mini-boom in the local economy – that is, higher employment and higher wages can lead to an increase in local area aggregate demand, including for regional food crops" (Andersson et al. 2014, 2). An interesting proposition, and one that does explain the results. Another factor is that "on average each worker in the gold industry supports 7-10 dependents" (Mining, Minerals and Sustainable Development Project 2002, 102). While it is not specified where these dependents are, if they were in the area it would make sense for them to engage in some form of subsistence agriculture, like the other 90% of the country's population (2015 Index of Economic Freedom). In any case, the data from the NDVI indicates that the presence of a gold mine does increase local agricultural productivity. In such an agrarian economy, this is synonymous with an increase in local economic activity. However, it is not clear why this occurs, and none of the theories reviewed propose a clear answer to this very specific question either.

Regarding fig. 6a-c: as stated previously, since the northern region of the country is part of the Sahel region, there is hardly any forest to cut down there to begin with (Encyclopedia Britannica). This largely explains why there is so little loss in the north of the country. There is, however, a clear trend toward increasing rates of forest loss toward 2012, particularly in the southwest of the country.

In terms of fig. 7a-c, the forest loss data appears fairly useless to this analysis, for a number of reasons. First, and most importantly, the regions most of the mines are in do not have many trees to being with. This explains why the data is virtually nonexistent for Essakane, Kalsaka, and Youga mines, which are not in the southwest of the country. Secondly, the mine that is in that region, Mana Mine, is very close to Burkina Faso's second largest city. This indubitably skews the result. Thus, for a region without many trees, or with a site close to a large urban area, forest loss is not a viable method for determining local economic activity.

Fig. 8 begins the secondary data, and shows the GDP of Burkina Faso from 1992-2013. This is important background knowledge to have about the general trajectory of Burkina Faso's economy. Despite the general upward trend of Burkina Faso's economy, the following graphs show that not everyone has benefitted from this sustained economic growth.

Fig. 9a-b demonstrate that while the wealthiest 10% did experience some wealth redistribution, the poorest 10% experienced virtually no change in their share of income, staying between 2-3% for the whole 15 year period. While this is very revealing and interesting, and ties in well to world-systems theory and unequal exchange, it does not say anything about gold mining in Burkina Faso because the data is not spatially calibrated. These statistics are for the country as a whole. Although gold mining is the most significant industry in Burkina Faso, and gold mining companies are the largest private employers, this does not mean they are solely responsible for the wealth inequality that has been plaguing the country.

While fig. 9b related to only the poorest 10%, fig. 10 shows that at every interval from 1994 – 2009, more than 80% of the population was living on less than $2.5 per day. In fact, between 2003-2009, when the mines were starting to be built and beginning operations, national poverty actually increased from 81% to 82%. Again, though international gold mining companies cannot be held directly responsible for this, it is not a good indication. This graph also relates well to the theory of unequal exchange, in that for periphery nations, it is very difficult to get out of their situation.

The map in fig. 11a shows the information from G-Econ. This dataset is enormously helpful because it offers spatially calibrated statistical information. Unlike the World Bank statistics, which are for the entire country, the G-Econ dataset is able to highlight and separate statistical information within specific regions of a country, such as areas within 80 km of a mine. This dataset is not without its limitations, however. For Burkina Faso, the most recent information is from 2005, three years before the first mine officially opened.

Furthermore, since each point on the map simply represents the center of an area it covers, some of the data will be from places even further than 80 km from a mine. Nevertheless, it is useful because all five of the data points selected do cover the actual area the mines are in, as well as the surrounding area. Additionally, from such a data-poor country, it is still the best information available.

Fig. 11b is an amalgamation of the most important data from G-Econ. In essence, this graph shows the difference in wealth between non-mining areas and mining areas from 1990-2005. In 1990, the mining areas were already 60% wealthier than the non-mining areas. This increased steadily every 5 years, till by 2005 the mining areas were 72% wealthier than the non-mining areas. There are large and steadily increasing differences between the wealth of the mining areas and the non-mining areas. This is a very interesting revelation which has a few possible explanations. According to Luning and Mégret, artisanal mining started becoming popular in the 1970s and 1980s. The presence of artisanal miners for 15 years before the first PPP statistic was recorded may be responsible, or at least partially responsible for the mining areas starting off in 1990 with a 60% lead on the non-mining areas. Another possible explanation has to do with Mana Mine. As stated previously, it is very close to Burkina Faso's second largest city. The fact that two of these five points close to a mine likely included most, if not all of Bobo Dioulasso could skew the results. However, as a counter to that, none of the mining points would have included Ouagadougou, Burkina Faso's capital and by far largest city. There could also be other confounding variables, such as a large economic center within one of the areas. However, given the significant discrepancy between the mining and non-mining areas, it seems to suggest that the mines do in fact have something to do with this difference in wealth. If true, this would imply that the artisanal miners were doing relatively well for themselves before the international mining corporations arrived. Living in a region with 72% more wealth than most other regions in the country is an envious position for most. The implications of this are that the artisanal miners were managing just fine without the World Bank, IMF, and international corporations stepping in to extract and export the resources themselves. This ties in to what Luning said about the miners being happier with the previous system as well, that there was too much uncertainty and worry in dealing with the international mining companies (2008, 393-94). It would be fascinating to see the next two data points in the G-Econ database, for 2010 and 2015, to analyze the effect *after* the international mining companies moved in and set up shop. Unfortunately, despite even contacting Dr. Nordhaus, the creator of the database, 2006 was the most recent year for any data from Burkina Faso.

As listed previously, there were a number of unexpected findings. The uselessness of the forest loss dataset in this context was the biggest one. Granted, it should have been somewhat expected, given the lack of trees. Next, the fairly consistently growing NDVI data was mildly surprising, especially at the 10 km buffer layer. Some would argue that the presence of a mine and its thousands of inhabitants would take up a lot of space, destroying any chance for agriculture in the immediate area, let alone increasing it. Yet the predominant trend was an increase in agricultural productivity. On the other hand, there are reasonable explanations for this, so it is not terribly surprising either.

Given the research question, data, and the results, there are a number of limitations and weaknesses to this study. In general, it is a very complex task to analyze anything with remote sensing data. To answer a question about local economic activity around gold mines, without ever going there, talking to people, or getting statistics straight from the source is a challenging prospect. One of the most significant limitations to this study is a lack of complete data. Only four of the six gold mines currently in Burkina Faso were analyzed, because the location of the other two are unknown. Even the fourth one, Youga, had to be ascertained by triangulation. Burkina Faso does not have a functioning statistics office, and does not conduct a census. This meant relying on the World Bank and G-Econ for statistical information. The World Bank statistics were only at the national level, severely limiting their effectiveness in analyzing anything to do with gold mines in particular. The G-Econ statistics only went up to 2005 in most cases, limiting their effectiveness in analyzing gold mines that were all built after 2007. This is precisely why the remote sensing data is so important – the nighttime lights, NDVI, and forest loss datasets transcend national boundaries, treating every place with electricity, agriculture, and trees equally. Despite this, outliers and skewed data are still a problem. Youga mine presented a weakness to the study, contradicting literally every trend the other three mines exhibited. Mana Mine's close proximity to Bobo Dioulasso presented a problem for all the remote sensing datasets once a buffer area of greater than 10 km was used.

However, despite the weaknesses and limitations of the study, there were many things that worked brilliantly. Most importantly, the nighttime lights data set at a 10 km buffer seemed to capture the local economic activity beautifully. The NDVI did show a fairly consistent rising trend in agricultural productivity, adding to local economic growth. Finally, the statistics from the World Bank and G-Econ suggest that poverty and inequality levels have seen only marginal improvements at best.

VI. Conclusion

Answers to Research Questions

The principal finding of the study is that international mining corporations do have a significant positive effect on local economic activity. Based on the nighttime lights analysis from this study, particularly with a 10 km buffer, nighttime lights increase anywhere from 100-800%. As supported by the large amount of previous studies on the topic, nighttime lights are a very good indicator of economic activity. Less conclusive results came from the NDVI and forest loss datasets, though the NDVI did back up the analysis of increasing economic activity around gold mines. Despite the success of the nighttime lights dataset, it could not tell us where the profits of the increased economic activity were going, and who specifically it was benefitting. However, information from the literature review and theories suggest the vast majority of the profits went to the core nations.

Regarding the secondary research question of international gold mining corporations' effect on other factors, such as poverty and inequality, the results were less decisive. Data from the World Bank did show that poverty and inequality in Burkina Faso are not improving or improving marginally, but this could not be attributed solely to the international gold mining corporations.

The data from G-Econ was limited in that it only went up to 2005, but very powerful in that it could be spatially connected to the mines. The results may suggest that the artisanal miners were doing very well for themselves before the international mining companies came to Burkina Faso. This would corroborate information from the literature review, which suggests that the artisanal miners are not as happy with the international mining corporations as they were with the previous system. Finally, this is supported by the theoretical perspectives, particularly world-systems theory and the theory of unequal exchange, both of which postulate that the people of Burkina Faso would be better off if they had control over their own resources. This is a particularly important issue considering the sheer number of people involved or dependent on someone in the gold mining industry.

Contribution of the Study

This research is beneficial in a few different ways. First, it is beneficial to the social sciences as a whole by adding to existing literature detailing the use of remote sensing to answer social science research questions. This technology is particularly well-suited for data-

poor countries like Burkina Faso, where reliable statistics and information rarely exist. This is because remote sensing gathers data from every country equally, without relying on governmental or non-governmental organizations. Secondly, the research is useful to human ecology. By using an interdisciplinary approach to a research question involving culture, power, and sustainability, it demonstrates that remote sensing can be used to answer these very human questions, while still maintaining a critical perspective. Hopefully, this will increase the use of remote sensing data contributing to the social sciences. Finally, this study adds to existing literature critical of World Bank and IMF policies involving opening up countries to foreign direct investment. By theorizing that these policies in Burkina Faso are not helping the country or its people as much as they should be, this study contributes to a call for significant change to these policies.

Future Research Questions

There are many possibilities for future research questions based on this topic. These include:

- How accurate is the nighttime lights dataset at analyzing local economic activity around gold mines? This could be done by comparing the known output of a mine to the sum of brightness of lights around that mine for each year. Could a direct correlation be established between the sum of lights and the GRP?
- Furthermore, what buffer size is best for analyzing local economic activity around a gold mine? This study concluded that out of 10, 30, and 50 km, 10 was definitely the best. However, perhaps 5, 8, or 15 km would be better.
- Where are the profits going? While the nighttime lights dataset can accurately model economic activity, it cannot tell us where those profits end up, and who benefits. Theories, literature reviews, stock prices, and other data were used to do that in this analysis, but are there other, more concrete ways?
- How do international mining companies affect local economic activity in the long-run? After they leave, is there always an economic crash, or are there viable ways of providing lasting employment for their workers?
- How does gold mining compare to other types of mining? Can the same techniques, methods, and theories be applied to bauxite, copper, or tin mining, for example?

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