Thesis Portfolio

Quantifying the Economic Impact of the Grand Ethiopian Renaissance Dam on the Nile River Basin

(Technical Report)

A Word of Caution: Advocating for Human-Centered Design in the Further Development of Social Media Technology

(STS Research Paper)

An Undergraduate Thesis

Presented to the Faculty of the School of Engineering and Applied Science

University of Virginia • Charlottesville, Virginia

In Fulfillment of the Requirements for the Degree

Bachelor of Science, School of Engineering

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Spring, 2022

Department of Engineering Systems and Environment

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Sociotechnical Synthesis

Throughout my thesis portfolio I investigate the complex relationship between the development of technology and the development of society. Sociotechnical issues are particularly challenging to investigate thoroughly because there are various analytical frameworks through which a problem can be confronted, and each framework may result in a completely different, but valid, problem statement and solution. Therefore it is important to perform a genuine analysis that is not only focused on the parameters and specifications of one analytical method, but also acknowledges the inherent limitations of the study and denotes further directions of study that would help to further elucidate the subject.

My STS paper considers human-centered design (HCD) as a viable design philosophy to address the widespread consequences of social media addiction. My capstone paper considers the economic effects of the Grand Ethiopian Renaissance Dam (GERD) on the Nile River basin. Although the two papers varied greatly in scope and content, striking similarities in the challenges I faced while completing both projects provided a unique learning experience that allowed me to complete both projects with an increased appreciation for the task at hand. The unifying factor between the two projects was how difficult it was to form a comprehensive problem statement. The wide web of psychological, physiological, societal, and technical factors that contribute to social media addiction mirrors the intricate interactions between hydrology, agriculture, climate, economics, and politics in the Nile River basin.

In both the individual STS project and the group capstone project, either I or my group restated the problem multiple times over the course of several months. In order to address the underlying problem, and not just a symptom of the deeper condition, it is necessary to continually refine the problem statement as understanding of the situation grows. Although this

process is frustrating, because it may feel like starting from scratch over and over again, the situation becomes less murky, and the iterative process occurs quicker as minds begin to fully grasp the situation. A concern about social media addiction leads to a deepdive into social media legislation, leads to thoughts on behavioral design, leads to the concern of ethics in addictive technology, leads to a desire to advocate for human-centered design in social media technology. Similarly, a concern of water scarcity for Egyptian farmers leads to questions about how land use and land cover has changed in the Nile basin, leads to questions about hydropower production and rural electrification in Ethiopia, leads to questions about how the economies of countries in the Nile basin will be impacted by the GERD.

Exploring these two topics simultaneously created an environment that was not only conducive to learning, but also incredibly impactful as a climactic ending to my undergraduate engineering career. By applying a range of technical skills and analytical problem solving methods to the two problems at hand, I was afforded an opportunity to demonstrate the skills that I have gained during my time at UVA.

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A Technical Report submitted to the Department of Engineering Systems and Environment

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Bachelor of Science, School of Engineering

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Spring, 2022

Technical Project Team Members
Charles Bass
Matthew Fitzsimmons
Stuart Keith
Thomas Lam
Adam O'Neill

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

Venkataraman Lakshmi, Department of Engineering Systems and Environment

Quantifying the Economic Impact of the Grand Ethiopian Renaissance Dam on the Nile River Basin

Charles Bass, Matthew Fitzsimmons, Stuart Keith, Thomas Lam, Adam O'Neill, and Venkataraman Lakshmi

***Abstract*— Tensions between Egypt, Sudan, and Ethiopia have grown as a result of concerns regarding water security. These tensions have been magnified by the construction of the Grand Ethiopian Renaissance Dam along the Nile River. The dam has potential to increase power production of the region while also creating risk for downstream countries. Therefore, this research will focus on quantifying the economic impact of the Grand Ethiopian Renaissance Dam to understand its implications for the Nile River basin. This will be accomplished by utilizing historical data and case studies to identify factors which may significantly change as a result of the dam construction for the countries of Egypt, Sudan, and Ethiopia. Cases of interest include the High Aswan Dam in Egypt as well as the Merowe Dam located in Sudan. Ultimately, the results of this research take the form of analysis conducted on water security, land use, agriculture, hydropower and the broader economic considerations for the Nile River basin. Additionally, despite the uncertainty of future management strategies, revenue generation was projected using two filling timelines. By quantifying the economic impact of the dam, the results of this research will provide an understanding of how the Grand Ethiopian Renaissance Dam will influence the future of the Nile River region.**

I. Introduction

The Nile River Basin contains numerous reservoirs that serve the purpose of irrigation, hydroelectricity, domestic and industrial use as well as to buffer flooding and droughts. Currently, the Nile River contains 30 large dams that encompass over 200 billion cubic meters of water, accounting for over 25% of Africa's storage capacity [1]. Many of these reservoirs operate independently, often focused towards benefiting their respective regions rather than pursuing a larger basin-scale approach [2].

In 2011, Ethiopia announced the construction of the Grand Ethiopian Renaissance Dam (GERD), located on the Blue Nile River in western Ethiopia. When completed, the GERD is expected to generate 6,000 megawatts of power for both domestic use and export, becoming the largest dam in Africa [3]. The dam is expected to create access to hydropower for over 65 million rural Ethiopian citizens [4]. Both Egypt and Sudan are heavily dependent on the Nile for agriculture and domestic water use, accounting for 80% and 17% of the Nile's water withdrawals [5]. In general, the region has also experienced an increase in urbanization and creating greater stress on agricultural and water resources [6]. Additionally, with 85% of the main Nile's water originating in Ethiopia and almost all water consumption from the Nile occurring in Sudan and Egypt, major concerns have arisen over the construction of the GERD [2].

Figure 1. Nile River Basin. [15].

II. Data

Agricultural, water use, and land use information was collected from World Bank datasets AQUASTAT [7] and FAOSTAT [8]. Data used to model the filling process of the dam and subsequent hydropower production was collected from Zaroug et al. [9], Samra, et al. [10], and Kansara et al. [11]. Economic data including energy consumption, gross domestic product, and net imports was collected from the World Bank datasets [14].

III. Methods

Analysis of the Nile River region was conducted in five main sections: water security, land use changes, agriculture, hydropower, and broader economic implications for the region.

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A. Water Security

Egyptian water use, economic, and population data were analyzed to better understand the potential for volatilization of the Nile system that filling GERD poses. Water stress defined by SDG 6.4.2 [12] is calculated as total water withdrawals divided by total freshwater resources less environmental flow requirements. Correlation was calculated through linear regression between water stress and population for 1977-2018. GDP and water stress were then compared for similarities in trends.

B. Land Use

Land use consists typically of three categories: agriculture, forest, and urban land areas. For this study, focus was given to agriculture and urban land use as these land areas are dependent on water. Agricultural land use and urbanization data was imported into Microsoft Excel to examine trends for each respective country. Both crop index and hydroelectricity data were used to analyze agricultural production and hydroelectricity generation trends relative to agricultural land use.

C. Agriculture

Agricultural data for Egypt, Sudan, and Ethiopia was analyzed in order to determine potential effects from implementation of the GERD. Variables used to accomplish this included fertilizer consumption per hectare of arable land, at-risk crops (sugar cane and rice), and international trade for agricultural products across the three countries. Summary statistics were calculated in Microsoft Excel.

D. Hydropower

GERD filling and hydropower projections required data collection from available sources. Data regarding the dam filling regime is scarce, therefore data was aggregated from multiple sources to make a sufficiently robust model. Literature was consulted regarding GERD design specifications in order to determine constants for the model.

TABLE I. HYDROPOWER MODEL PARAMETERS

Parameter	Symbol	Value	Source
Hydropower Potential	P	Variable	[16]
Turbine Efficiency	n	87.50%	[17]
Density of Water	ρ	1,000 kg / m^3	-
Volumetric Flow Rate	Q	Variable	[9]
Hydraulic Head	h	Derived from Fig.	[10],[11]
Capacity Factor	Cf	0.3	[18]
Electricity Price	π	$0.50 / kWh	[19]
Gravity Constant	g	9.81 m / s^2	-

Two distinct time periods are referenced in this analysis: filling and maintenance. Filling coincides with peak Blue Nile flow, when reservoir volume increases rapidly from June to August [9]. Maintenance occurs during months of decreased Blue Nile flow (August to June), during which water levels in the dam are constant or decreasing [10].

Linear regression was performed on datasets acquired from remote sensing publications in order to acquire parameters for a projection model of reservoir levels. The output from reservoir projection will be the input for the hydropower model, resulting in a projection of hydropower production for both 6 and 12-year filling regimes. This will be forecasted until the reservoir maximum capacity of 74 billion cubic meters (BCM) has been reached. The model used for forecasting was adapted from Mays [16] and can be seen in (1) where the parameters are described in Table 1.

$$P = (n \cdot \rho \cdot g)(Q)(h)(Cf) \quad (1)$$

$$\text{Value Created} = P \times t \times \pi \quad (2)$$

To convert from hydropower potential to value of hydropower produced, hydropower potential in watts was multiplied by the number of hours in each month (Jan-Dec). The monetary conversion follows with the listed electricity value, shown in Table 1. This calculation can be seen in (2) where the output of (1) is multiplied by the number of hours and the price per kilowatt hour.

E. Economics

In the broader economic environment, the GERD has influenced flow of the Nile and the resiliency of economies in times of drought. Additionally, although Ethiopia will benefit from hydropower directly, the additional supply of energy in the region will change how energy is traded in the region. However, due to the uncertainty regarding the management practices which will be employed at the dam, the implications of the GERD on the resilience of the economies in the region and the change in trade are also uncertain.

Therefore, to understand how the GERD could potentially influence the broader regional economy, historical data is used to assess how resilient the economies for Egypt, Sudan, and Ethiopia have been to drought in the past as well as assess how previous hydropower infrastructure has influence the dynamics of energy trade. To accomplish this, rainfall amounts are binned according to percentile and the mean agricultural productions are compared according to country. Additionally, the impact of additional energy supply in the region is assessed by using historical data on energy imports, particularly in the context of changes following the construction of both the High Aswan Dam of Egypt and the Merowe Dam of Sudan.

IV. Results

A. Water Security

The GERD is interfering with an already water scarce system in the Nile River Basin; Egypt is independently suffering from water stress. The only variable currently changing is total water withdrawals, as total resources are reported as a steady 55.5 billion cubic meters per year (BCM/yr) [7], which may be explained by population growth. Water stress in Egypt correlates strongly with population growth, as highlighted by the correlation coefficient which was calculated to be 0.98. As GDP rises, according to Fig. 2, so does water stress. These factors suggest that Egypt's growing population and subsequent need for food and water are the principal strain on their Nile resources. 11.3% of Egypt's GDP comes from agricultural production, and nearly 30% of jobs are agricultural [13]. Accordingly, a significant portion of GDP increases are related to agriculture. The water-intensive nature of agriculture thus supports why GDP increases as water stress increases. The High Aswan Dam's reservoir, Lake Nasser, provides a buffer from normal hydrologic variability such that Egypt's water security is not currently tied to upstream hydrology under normal flow conditions, but rather is primarily tied to downstream intensity of water stress. The total freshwater available from the Nile to Egypt has not changed, yet water stress has consistently increased.

B. Land Use

Over the past 40 years, the percentage of agricultural land has remained relatively constant for Egypt, Ethiopia, and Sudan, with marginal increases for Ethiopia. Additionally, there has been increases in the percentage of urban populations for Ethiopia and Sudan with a plateau in Egypt. Crop Index, a measure of agricultural production relative to the baseline average set from 2014-2016 has increased for both Egypt and Ethiopia since the 1990's. However, as shown in Fig. 3 there has been no significant increase in agricultural land.

In addition to producing hydroelectricity, dams can store water which can be used for irrigation practices. Therefore, hydroelectricity produced by dams can be used as a proxy for water available for irrigation. Shown in Fig. 4 is variation in hydroelectricity generation and agricultural land percentage for each respective country. As seen, there is relatively no increase in agricultural land for an increase in hydroelectricity for Ethiopia and Sudan. Meanwhile, hydroelectricity and agricultural land remain relatively constant for Egypt.

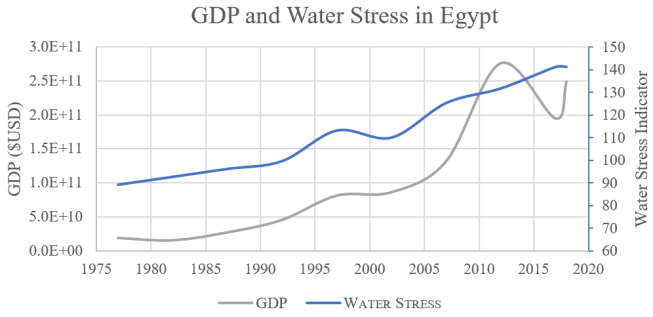

Figure 2. GDP and Water Stress in Egypt over Time.

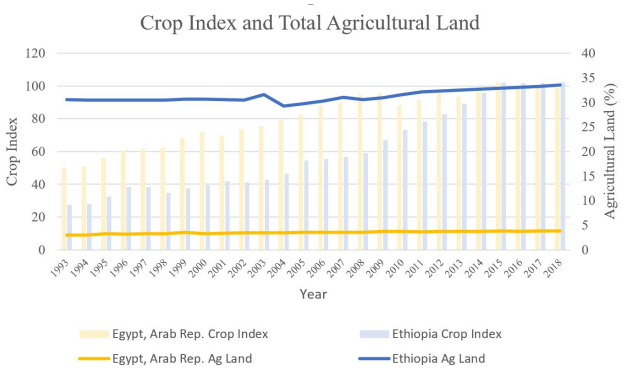

Figure 3. Crop Index and Agricultural Land in Egypt and Ethiopia over Time.

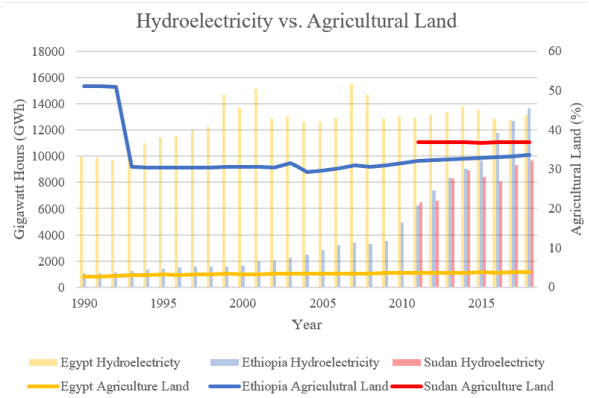

Figure 4. Hydroelectricity Generation versus Agricultural Land in Nile Basin over Time.

C. Agriculture

With the prevalence of moderate or severe food insecurity in the total population of Egypt at 27.8%, there is a need to address agriculture production at a basin-wide scale [8]. Furthermore, assessing the GERD's potential influence over certain agricultural variables will be essential to increase the resilience and economic gains associated with agricultural development in Egypt, Sudan, and Ethiopia.

Fertilizer use in Sudan and Ethiopia is minimal and has not changed a significant amount over time, thus Egypt will be the primary country of study for this variable. From 1990-2018 there was a 5.33% increase in the amount of fertilizer used and with fertilizer consumption amounting to 569.12 kilograms per hectare of arable land in 2018 [14]. However, there is a

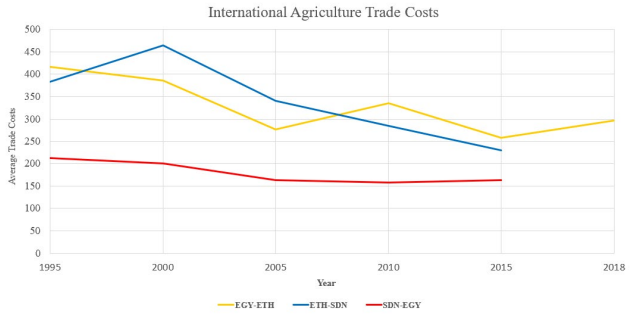

Figure 5. Bilateral Trade Costs for Basin Countries

plateauing effect for fertilizer consumption in Egypt, confirming that the amount of arable land in the country is stable.

Two major Egyptian crops that are most at-risk from changes in water availability are sugar cane and rice. Sugar cane and rice use the most amount of water per hectare, indicating that these crops are of the most risk as the GERD is implemented upstream. Furthermore, sugar cane is the highest produced crop by volume in Egypt, where in 2019 16.32 million tons of the crop were generated [8].

International trade between Egypt, Sudan, and Ethiopia from 1995-2018 can be seen in Fig. 5 [14]. The reported values are an index value that shows the rate at which trade costs have evolved over time. This figure shows the bilateral trade costs across the three countries under analysis, where the costs involved in trading goods internationally with another country relative to trading goods domestically has decreased for all three scenarios. With Egypt and Ethiopia having the highest bilateral trade costs for agriculture, it can be determined that trading the same goods with other countries may prove more beneficial as water flows change in the Nile.

D. Hydropower

Using the model adapted from Mays [16], the results from the linear regression are seen in Tables 2 and 3. If the GERD water management regime continues as it has for the past two years, it can be expected that the dam will reach its maximum capacity of 74 BCM by 2032, approximately 12 years. Seeing as how Ethiopia desires to have the reservoir filled in 4-6 years so that they can receive the full benefits of Africa's largest hydroelectric dam, it is possible that the dam operators may begin taking a more aggressive approach in filling the reservoir of the GERD, thus limiting the amount of water released downstream. The reservoir volume and area projections are seen in Fig. 6.

By doubling the amount of water that is stored in the dam each year, a 6-year filling period is derived and set to conclude by 2026.

TABLE II. LINEAR REGRESSION OUTPUT

Time	Variable	Period	Value	Unit
12 Years	Volume	Filling	0.1038	BCM/day
12 Years	Volume	Maintenance	-0.0012	BCM/day
12 Years	Area	Filling	2.8917	km^2/day
12 Years	Area	Maintenance	-0.1242	km^2/day
6 Years	Volume	Filling	0.2076	BCM/day
6 Years	Volume	Maintenance	-0.0012	BCM/day
6 Years	Area	Filling	5.7834	km^2/day
6 Years	Area	Maintenance	-0.1242	km^2/day

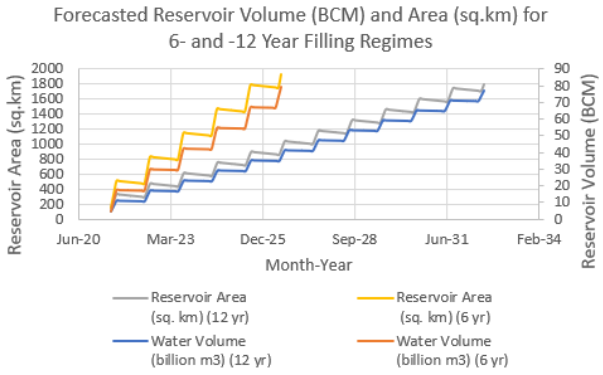

Figure 6. 6- and 12-Year Reservoir Filling Scenarios.

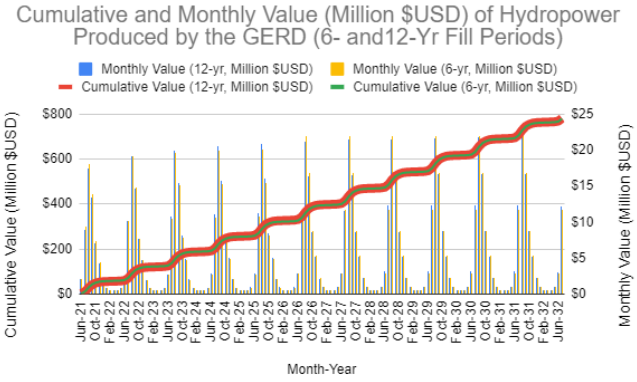

Figure 7. Revenue Generation via Hydropower Production in 6- and 12-Year Filling Scenarios.

After the models for 6- and 12-year filling regimes were created, the average reservoir head data was calculated by dividing the reservoir volume by the area, then entered into the hydropower model. The model displays the monthly and cumulative values of hydropower produced by the GERD in millions of $USD. Output from the model is plotted in Fig. 7. Under both 6- and 12-year filling regimes, the dam will be producing approximately $22 million USD worth of hydropower during the peak flow month of August each year,

and down to a low of around $1 million USD worth of hydropower per month during low flow (Jan-May).

Under a 6-year filling regime, the cumulative value of hydropower produced after 12 years will be approximately the same as the projected value for the 12-year filling regime. This indicates that the dominating factor in this hydropower model is the volumetric flow rate, because peak power production and value generation both correspond with the maximum Blue Nile Flow period from June to August, as indicated by Zaroug et al. [9].

E. Economics

Droughts influence water availability which directly affects agriculture in the region. The presence of the GERD creates a risk which may magnify the impact of droughts within the region. Plotting agricultural growth over precipitation in the year, as shown in Fig. 8, demonstrates the significant variability found in the production of each country. However, when means for growth were compared in drought versus non-drought years, there was not statistically significant evidence at the 5% level to suggest that drought years had lower agricultural growth. This is explained by the fact that improvements to agricultural technology and other factors such as temperature and the presence of natural disasters also play a crucial role in determining agricultural production. Additionally, as economies rely less on agriculture, the change in agriculture value added will decrease as fewer resources are dedicated to the sector so the variability will be less than that of countries whose increased reliance on the sector magnified variability from year to year.

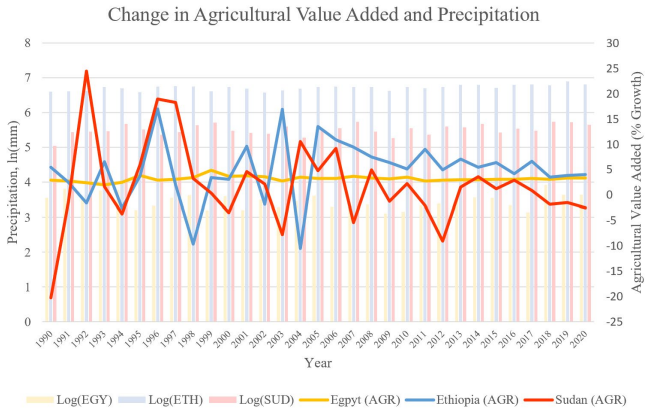

Figure 8. Change in Agriculture's Value Added versus Precipitation over Time.

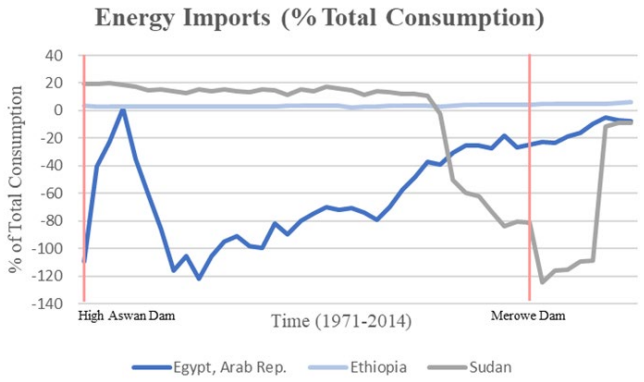

Figure 9. Energy Imports over Time for Nile Basin Countries.

When analyzing the trends of energy imports within the region, Ethiopia is the only country of the three which is a net importer. Fig. 9 shows that in the most recent decade, both Egypt and Sudan are net exporters of energy. While data from the EIA suggest both of these countries rely on fossil fuels to contribute to this, it is important to note that following the construction of large hydropower facilities within the country, the country remained an exporter even as demand for energy increased.

V. Conclusion

In regards to the water security of downstream nations such as Egypt, it can be seen that if the availability of freshwater does decrease upstream due to the filling of the GERD, then Egypt will have abnormally low flow conditions into Lake Nasser, meaning Egypt will have increased water stress from the numerator (total withdrawals) and denominator (total inflow) of the water stress equation.

From a land-use viewpoint, it was hard to correlate agricultural land percentage to both crop index and hydroelectric generation. However, after analyzing the data, it can be noted that Egypt and Ethiopia are contributing more to the agricultural markets without increasing agricultural land. Additionally, hydroelectricity generation was seen to have little to no impact on agricultural land for Ethiopia and Sudan, although data for Sudan was sparse. Egypt remained relatively constant with respect to agricultural land and hydroelectricity. Therefore, similar results may be seen upon completion and filling of the GERD.

The dominating factor in the hydropower model for this study was the monthly discharge in the Blue Nile River, as opposed to the filling regime of the dam. In spite of a six-year difference in filling periods, by the end of the first twelve years, both of the filling regimes were projected to produce roughly the same value of electricity for Ethiopia. This finding may be useful for international dam management

conversations, as it is possible that the dam could be filled slower, resulting in less water strain on Sudan and Egypt and minimal loss in hydroelectric generation capacity for Ethiopia.

With regards to the broader economic implications of the GERD, the conclusions which can be drawn are limited. While findings were not statistically significant, the GERD is a part of a much larger system whose relationships and dependencies which were not completely discussed in this research. On main example of this is translating energy availability to future economic growth. While energy itself is a source of revenue for the country of Ethiopia, the question remains whether this will spark greater economic innovation and investment into the countries of the Nile River Basin.

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In Partial Fulfillment of the Requirements for the Degree

Bachelor of Science, School of Engineering

Matthew Fitzsimmons

Spring 2022

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

Dr. Hannah Rogers, Department of Engineering and Society

STS Research Paper

Abstract

Social media addiction (SMA) is a complex sociotechnical issue that impacts millions of people around the world in the 21st century. A combination of psychological, physiological, and technical factors lie at the root of SMA, creating an increasingly challenging system to thoroughly study and understand. In order to simplify the analysis, this paper will only consider technical factors that may be contributing to SMA, specifically features that are intended to increase engagement with or time spent on a platform. I will consider human-centered design (HCD) as a viable method for further development of social media features, and provide examples of how HCD could be implemented into social media with the intention of increasing user autonomy. I will briefly consider economic and technical factors that serve as obstacles to the implementation of HCD, and fields of interest for future study.

Note: Each section begins with a quote taken from the Netflix Documentary *The Social Dilemma*, except for "Human-Centered Design", which comes from Don Norman's book, *The Design of Everyday Things*.

Introduction

"When you look around you, it feels like the world is going crazy. You have to ask yourself, like, is this normal? Or have we fallen under some kind of spell?" - Tristan Harris, former Design Ethicist at Google

The average social media user spends two and a half hours combined across platforms every day (DataReportal, 2022). Over the course of a year, that's the equivalent of watching the Bee Movie 600 times. In a decade, 6000 times. Although most users of social media do not meet the criteria for a clinical addiction, 94% of college students still feel anxious if they don't have their phone with them at all times (Psychology Today, 2015), and Americans at large launch social media applications a combined 17 times per day (digitaltrends, 2015). The exponential growth of social media engagement would suggest that these figures, even from 2015, underestimate societal conditions in 2022.

Social media adaptation has increased drastically over the past decade. In the period from 2012 to 2022, the number of social media users across all platforms has increased by an average of over 12 percent per year (DataReportal, 2022). The most astounding aspect of this growth is that the percentage change per year has remained relatively constant, indicating that progressively more people have joined every year. For example, the total number of social media users increased by 1.2 billion in the period from 2012 to 2017, while the total number of social media users increased by 1 billion from 2020 to 2022 (DataReportal, 2022). A combination of societal and psychological factors have contributed to the increased adaptation of social media, and technical features that are intended to "hook" users have played an equally critical role (Purohit, et al, 2020).

The design motivation behind these features quickly comes into question when we consider the negative effects that social media is observed to have on users. If young adults who use social media are at increased odds for depression (Lin et al., 2016), and body image, self-esteem, or eating disorder concerns (Santarossa and Woodruff, 2017), then why do

corporations continually implement features that are designed to sustain or increase screen time and engagement?

Behavioral Design

"Exploiting a vulnerability in human psychology - we understood this, consciously. And we did it anyway." - Sean Parker, former President of Facebook

Behavioral design is a design principle that utilizes understanding of human behavior and decision making in order to make a product that *influences* human behavior. As defined by Astrid Groenewegen, founder of the SUE Behavioral Design Academy, behavioral design is a combination of "psychology, design, technology, and creative methods to find out why people do the things they do and to figure out through experimentation how to activate them to change their behavior" (Groenewegen, 2022). The behavioral change can be beneficial, in the case of a journal that helps people keep track of and pursue their goals, or exploitative, in the case of a grocery store that continually changes product layout in order to increase the amount of wandering that customers do in the hopes that they find more products and spend more money.

Social media companies have employed behavioral design into their platforms for years, and voices are starting to rise against the practice. A bill recently proposed in the 117th Congress, the *Kids Online Safety Act* (2022), explicitly calls out social media platforms as having "a duty to act in the best interests of a minor that uses the platform's products or services." Section 3b of the bill, Prevention of Harm to Minors, specifically notes the threat of "patterns of use that indicate or encourage addiction-like behavior." Section 4a, Safeguards for Minors, notes that platforms would be required to "limit features that increase, sustain, or extend use of the

covered platform by a minor, such as automatic playing of media, rewards for time spent on the platform, and notifications" (KOSA, 2022).

Features that Increase Social Media Engagement and Use Time

"How much time can we get you to spend? How much of your life can we get you to give to us?" - Tim Kendall, former Director of Monetization at Facebook

The like button was a seemingly innocuous addition to social media technology that started out as a method of simplifying interactions. Rather than commenting "I like this picture," there was a simpler method of conveying the same sentiment (Tsotsis, 2010), or so it was thought. The like button was the first in a line of features that would seek to increase user engagement and time spent on social media. As later put by Adam Alter, "The like button, simple as it was, tapped into a bottomless font of social feedback" (Alter, 2017).

Notifications help individuals stay up to date with everything that is happening online. Whether it is new content being posted or another user interacting with old content, notifications serve as reminders that the recipient is already falling behind on online happenings. Notifications also play a key role in the development of social media addiction, as they fiercely target a user's dopamine system (Nasti et al., 2021). Dopamine is a neurotransmitter that largely governs the human experience, influencing what we want, crave, and seek out. Dopamine aids the formation of reward-seeking loops, in which people will repeatedly perform behavior that led to past experiences of pleasure (Psychology Today, 2022). Nasti, et al. discovered that severe social media addiction was correlated with a high number of notifications received, and also elevated dopamine levels (Nasti et al., 2021).

Infinite scrolling is a feature that allows users to view more content without having to redirect to another page. After the end of a web page or article has been reached, more content will automatically be generated and appear at the bottom of the page as the user continues to scroll. This affords the possibility of scrolling indefinitely, long after the content that originally attracted a click has passed. In the words of the *creator* of infinite scrolling, Aza Raskin, "It's as if they're taking behavioral cocaine and just sprinkling it all over your interface and that's the thing that keeps you coming back and back and back" (MakeUseOf, 2007). Infinite scrolling enables excessive use, as the user is able to enter into a kind of flow-state that never receives the implicit reminder to stop from a bottomed out page.

Personalized content, such as that which appears in TikTok's "For You" page or Youtube's recommended section, is a feature supported by artificial intelligence that presents content an individual might like based on their previous interactions. The system is able to become increasingly accurate with repeated engagement, as further interactions with the content teaches the AI what type of posts are most likely to keep the user's attention. Although this feature may seem well-intentioned, its inherent purpose is to increase the amount of time users spend on the platform by pandering to their fancies. Such personalized content recommendations increase a platform's capacity to foster addictive behavioral patterns (Brown Undergraduate Journal of Public Health, 2021).

Consequences of Social Media Addiction

"There has been a gigantic increase in depression and anxiety for American teenagers, which began right around, between 2011 and 2013." - Jonathan Haidt, PhD, NYU Stern School of Business, Social Psychologist

Social media addiction is a prolific phenomenon that has been associated with diminished mental health and academic performance among students (Hou et al., 2019) and lower wellbeing and workplace productivity among adult employees (Priyadarshini et al., 2020). Social media taps into the same neural pathways as other potentially addiction-inducing activities such as gambling and hard drug use, and can be described as “a syringe of dopamine being injected straight into the system” (Addiction Center, 2022). That is, social media addiction is no joke.

Youth and teenagers have been hit particularly hard by the wave of social media addiction. The adolescent brain, which will not be fully developed until the mid-20's, is keen to be rewired by dopamine inducing behaviors. The brain will train itself to seek out more of that destructive behavior, causing a positive feedback loop that will make the individual more prone to addiction later in life as well (Get Smart About Drugs, 2022). Teen years are already challenging enough because of increased responsibility in school and extracurriculars, the confusing and hormone-filled period of puberty, and the pressure to find out one’s identity in a sea of faces. By targeting these individuals with platforms that produce a powerful blast of dopamine at arm’s reach, there is significant potential for crisis. Parents and educators alike express concerns about the habits and tendencies of teens regarding their social media use. Students are using their phones in school more than ever, and the phone use is strongly correlated with decreased test scores regardless of gender or GPA (Bjornsen and Archer, 2015; Duncan et al., 2012). Parents witness the behavior at home more than ever, attributing a decline in quality of household interactions to excessive phone use (HPRC, 2017).

Teens are not alone in their susceptibility to addiction, nor is this a phenomenon that exists solely in the United States. Children, middle-aged, and eldery people all over the world are

all just as susceptible to the allure of social media use as teens are. Children are exhibiting symptoms of anxiety and low self-esteem (Cleveland Clinic, 2021), parents who exhibit excessive phone usage are more likely to have children with the same issue (Matthes et al., 2021), and people over 65 are spending over 10 hours per day on screens (The Economist, 2019).

Psychologists and tech experts alike warn of a pandemic-like situation, in which the instance of obsessive phone use continues to increase among all user demographics (Salon, 2021). There exists great potential for societal harm if the trends in social media use continue as they have over the past decade. Worker productivity and quality of students - creative thinking, language command, motivation - all threaten to decrease drastically, and have already begun to, as a result of increased social media use in and outside of school and the workplace (Munene, 2013; Akram and Kumar, 2017).

Additionally, there has been a death, of sorts, of the practice of well-spent leisure time. Leisure is an important aspect of life that is correlated with physical health and mental well-being (Paggi et al., 2016). Athletic, artistic, and outdoor pursuits, all of which are incredibly beneficial to the overall health and well-being of individuals have been in significant decline, as an increasing proportion of free time is spent online (National Review, 2018).

How are the negative consequences of excessive social media use to be addressed? More than just retroactive legislation and regulation, a forward-thinking solution is necessary. A solution to this issue must not only address historical harm, but also ensure that future harm is avoided through design that is well thought out, and considers the extent of human physiological and psychological needs. Design must serve the humans that use it, not exploit them for profit. Design must cultivate an enriching and thought-provoking experience that leaves the user better off for having interacted with it.

Design must be human-centered.

Human-Centered Design

"The solution is human-centered design (HCD), an approach that puts human needs, capabilities, and behavior first, then designs to accommodate those needs, capabilities, and ways of behaving." - Don Norman, *The Design of Everyday Things* (Page 8)

Human-centered design is a philosophy that emphasizes, well, humans. A basic definition of HCD is design that intentionally addresses the psychological and physiological needs of humans, in addition to accounting for their strengths and weaknesses (Norman, 2013). HCD seeks to sustain or increase the well-being of the user through participation in the designed artifact. Abiding by these principles, autonomy is an essential aspect of human-centered design.

Autonomy, as defined by the Merriam-Webster dictionary, is a self-directing freedom, or independence from external influence (Merriam-Webster, 2022). As it applies to decision making and self-determination, autonomy involves self-reflection and a "sense of volition and choice about what one is doing," as opposed to "control, which means being pressured to experience or behave in particular ways" (Deci and Ryan, 2013). Autonomy is essential for human development and well-being, and has been associated with "greater persistence, more satisfying relationships, and enhanced psychological wellness" (Deci and Ryan, 2013).

From a HCD standpoint, the aforementioned applications of behavioral design within social media are antithetical to human well-being, because they either explicitly or implicitly decrease the amount of autonomy that the user has while interacting with the platform. The

implementations seek to influence the decisions of users and reduce their ability to control their own behavior. These features are not human-centered in principle, they are profit-centered.

The business model of most major social media platforms is attention driven, wherein more money is made when users spend more time on the platforms. Developers have incentive to release features that objectively exploit users, cause mental and bodily harm, and render them addicted to their creation- as long as it increases their bottom line (Bhargava and Velasquez, 2020; Scales, 2020). A redirection toward human-centered design in social media is not only advisable, but necessary in order to preserve human wellbeing and ethical design practice.

Human-Centered Design in Social Media

"These technology products were not designed by child psychologists who are trying to protect and nurture children. They were just designing to make these algorithms that are really good at recommending the next video to you." - Tristan Harris, former Design Ethicist at Google

The successful implementation of human-centered design in social media would increase user autonomy. The increased autonomy would result in increased user wellbeing, increased user satisfaction, and decreased user exploitation. Platform customization and a nudge system are two applications of human-centered design that can be incorporated into social media.

One method of increasing user autonomy is by increasing the ability of the social media platform to be customized to user specifications and likings. Similar to how the iPhone allows users to turn off notifications, remove color, and add screen time limits, social media apps could add a toggle feature for some of the most problematic features. As noted by Cheng and See (2016), the ability to customize user experience is linked to higher degree of user satisfaction,

which is beneficial to both the user and the platform that hosts the user. The user would be able to toggle features on and off, such as likes, comments, recommended content, autoplay, or infinite scrolling. The capacity to turn these features on and off already exists in some capacity for most platforms. For example, Instagram allows users to turn off comments on their posts (Meta, 2022), and Youtube offers users the opportunity to turn off the autoplay feature with the flip of a button (Youtube Help, 2020). These features should, however, exist across all platforms and for every aspect of the technology.

The nudge is a feature that has already been implemented on several platforms. After three episodes or 90 minutes of uninterrupted viewing have passed, Netflix will ask, much to your chagrin, if you're still watching (Netflix Help Center, 2022). Nudges have already proven to be useful on their own, increasing mindfulness of platform engagement, decreasing time spent online, and generally making the user experience more pleasant (Purohit et al., 2020). Adding the element of customization will only increase user autonomy and satisfaction. For example, a Netflix user could indicate that they would not like nudges while watching House of Cards, but that they should receive a nudge after every episode of the Great British Bake off, because otherwise they would watch the whole season in one sitting. Similarly, an Instagram user could create a nudge that relates to the number of times the app has been opened. The first time Instagram is opened in a day would have no nudge, but every occasion thereafter would elicit a nudge reminding them that they have already checked the app that day. Personalized nudges place authority of regulation back into the hands of the individual, and allow them to regain a sense of ownership over their viewing experience.

Obstacles to Human-Centered Design in Social Media

"What I see is a bunch of people that are trapped by a business model, an economic incentive, and shareholder pressure that makes it almost impossible to do something else." - Tristan Harris, former Design Ethicist at Google

Unfortunately, human-centered design in social media conflicts with the primary monetization mechanism of most social media platforms, which is to sell personalized ads to users. If users are spending less time on the app, then they are viewing fewer ads, and the platform is making less money. This business model is distinctly different from subscription-based services such as Netflix, and provides further incentive for implementation of behaviorally manipulative design. Netflix only cares that you stay subscribed, but Instagram and Facebook need you to spend more time in the app so that you see more ads (Bhargava and Velaquez, 2020). Granting users more autonomy would most likely require major social media platforms to compromise on their revenue, which is an unlikely occurrence.

Another obstacle to the implementation of HCD in social media is that the autonomy that users would obtain may pose a technical challenge to the developers of social media sites. While not outside of their capability, it would certainly pose a novel challenge to navigate how 5 billion personalized accounts with different variations of software features would all interact with one another.

Future Outlook

"I mean it seems kinda crazy, right? The fundamental way that this stuff is designed isn't going in a good direction. Like, the entire thing. It sounds crazy to say we need to change all that, but that's what we need to do." - Tristan Harris, former Design Ethicist at Google

Human-centered design is a viable route for the establishment of user autonomy within the world of social media. By implementing customization into the social media experience, users would not only be empowered with the agency to address their own perceived frustrations within the platform, but they will actually be afforded the capability to do away with those nagging features that trouble them the most. Higher levels of autonomy in social media result in increased user well being and satisfaction with the platform, both of which are good for the company. Happy and healthy customers are good customers.

Certainly, HCD design does not hold all of the answers to the problem of social media addiction. This paper was not comprehensive, in that it did not consider the sociological or psychological factors that are perceived to play a role in social media addiction. Further study would be necessary in those fields in order to prescribe a more accurate solution to the perceived problem, but HCD is compatible with each of those fields of study, because they are all inherently concerned with humans.

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Assessing the Environmental and Economic Effects of the Grand Ethiopian Renaissance Dam (GERD) on the Nile River Basin
(Technical Project)

Climate Change and Water Related Disasters: A Comparison of Flooding Vulnerability Factors on the Coasts of Virginia, USA and Gujarat, India
(STS Project)

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

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Introduction

I love water. For most of my life, I have been a swimmer, lifeguard, and avid hydrater; my 32oz Gatorade squeeze bottle has been by my side through thick and thin. The pool is my canvas: a medium for athletic expression, a safe retreat when stress looms, and a source of knowledge for controlling my body and mind. My formative years were fruitfully influenced by water, and so it may not come as a surprise that I decided to pursue environmental and water resources engineering in college. This newfound knowledge, however, opened my eyes to the destructive potential of water that lurks just beneath the surface.

For some, water means flooding - drowning, death, and the inundation of cities. For others, it is a medium for parasitic disease vectors and waterborne pathogens. For some two billion people around the globe, lack of water means no access to sanitation or drinking water. As long as there are humans on Earth, we will be forced to negotiate with this disembodied personality, who is given to whim and not often open to compromise. Without it, life would not exist, but with it, we are subject to its beauty and destructive force. Though we may try, water cannot be tamed.

As I have grown in both my education and personal life, my fascination with water has collided with a desire to obtain a broader world view: one that surpasses the US-centric perspective that has been purveyed to me by the media and education systems. My thesis and capstone research projects pursue both my affinity for water and my goal to grow as a global citizen, investigating water resources engineering and management on a multi-national basis.

My STS thesis presents a comparison between social and physical factors that affect flooding vulnerability on the coasts of Gujarat and Virginia, states in India and the United States, respectively. My capstone research team is partnering with Professor Venkataraman Lakshmi to

investigate the environmental and economic effects of the Grand Ethiopian Renaissance Dam (GERD) on the lower Nile River basin. These projects are structured to achieve learning objectives that will serve me as both an engineer and individual: gaining a global perspective on human/water interaction and the effects of climate change, and learning how to perform a broad scale analysis for methodological reference in future projects.

STS Topic: Comparing Flooding Vulnerability Factors in Coastal Virginia and Gujarat

As climate change progresses around the world, it is important to understand what factors make some communities more or less vulnerable to subsequent weather extremification, and to identify what actions can be taken to mitigate such factors. These factors comprise a wide range of social and physical conditions that have the potential to make the effects of a flood more or less severe (Mavhura, 2019). Poor communities in particular are disproportionately impacted by extreme weather events, as they are more likely to lack the resources necessary to function in the wake of a natural disaster than wealthy communities (Huq and Reid, 2007).

Although the effects of climate change are manifested in a variety of weather phenomena, the focus of this study will be flooding and the relevant social and physical factors that contribute to its severity. Due to the complex nature of flooding and its myriad causes, this study will attempt to simplify the analysis by selecting two regions that exhibit similar geographical features- coastal Gujarat and Virginia. Both states have sections of shoreline that are fully exposed to the water, and sections on the inlet of a large body of water: the Arabian Sea for Gujarat and the Atlantic Ocean for Virginia (**Appendix A**). Each region has already documented increased incidence of flooding (Kleinosky et al. 2006 and Lodhia, 2012), therefore a

comparison between the two cities provides an opportunity to compare and contrast disaster effects under varying social and physical circumstances.

The results of this research will lend to future study in the fields of legislation and policy. The factors which are deemed to be most impactful on the extent of flooding damage can be considered while implementing policy that aims to serve communities that have been ravaged by floods.

Technical Topic: The Grand Ethiopian Renaissance Dam (GERD)

As the global population continues to increase, demand for food, water, and electricity will place a burden on society. By harnessing the energy that is contained within flowing water, countries will be able to reduce their reliance on fossil fuels in favor of a more sustainable alternative; the construction of dams is only expected to increase in coming years (Elagib and Basheer, 2021). The study of the GERD investigates water insecurity in northern Africa and the effects of hydroelectric dams as an energy source.

Located on the Blue Nile, the GERD will provide reliable hydropower for over 65 million Ethiopians (Yuki, 2021), but the reservoir filling process will restrict access to water for a combined 150 million people in Egypt and Sudan (**Appendix B**). Additionally, the possibility for detrimental environmental effects leaves the net effect of the Gerd somewhat ambiguous. The purpose of our project is to weigh both the technical and environmental benefits of the GERD with its respective drawbacks, and perform an objective analysis of the situation that could be used to advise political actors in their future decisions. My area of specialty within the project is the environmental impact of dams and the logistics of hydropower production as a means for sustainable energy production.

Eldardiry and Hossain (2021) recently investigated the hydropower potential of the GERD, finding that 5,150 megawatts/hr would be a reasonable expectation for its electrical production: a utilization of only 30% of the dam's hydropower potential. Although an amazing result for the people of Ethiopia, the low capacity factor draws criticism because it indicates the dam may be over-engineered, holding far more water in its reservoir than is necessary. This fact may lead to a variety of negative downstream effects, as detailed by Karim Morsy et al. in a 2021 study on the potential downstream environmental effects of the GERD. Its conclusions drew from knowledge of the effects of the Itaipu dam, which is located on the Panará river on the border of Paraguay and Brazil. Downstream effects of the Itaipu included increased turbidity, suspended solids, oxygen demand, and potential increase of nitrogen depending on human activities. A run-of-the-river dam may have produced fewer effects than a gravity dam, because they do not require reservoirs, but that is no longer an option. Morsy et al. noted how difficult it is to estimate the impact of the GERD, because several variables are subject to change at any time: rainfall, reservoir fill-time, electrical grid capacity, population, and societal conditions, to draw from an extensive list. In addition to the aforementioned, Elagib and Basheer (2021) note the possible negative effects on downstream flora and fauna, specifically as a result of changes in water temperature, salinity, and oxygen content. These changes would harm the downstream ecosystem and biodiversity in the river.

Prakrut Kansara et al. (2021) used remote sensing data to investigate effects of the GERD specifically during reservoir filling. Immediate ecological effects were noted, such as the unusually high amount of rainfall and runoff in the area surrounding the upstream basin. This could be a result of the large reservoir of water that has been accumulating, creating more potential for evaporation, and thereby more rainfall. A significant increase in water upstream

from the dam, and a corresponding decrease downstream, indicates that downstream Nile flow may be limited as the dam fills.

Methodologies

The method of the STS thesis is based on a study by Emmanuel Mavhura (2019) that analyzes the social and physical factors that drive flooding vulnerability in southern Africa (**Appendix C**). I will be creating a similar web of vulnerability factors for both Gujarat and Virginia. My research will differ from that of Mavuhra because I will then take those two webs and compare them between the two cities using Latour's Actor-Network-Theory framework (Crawford, 2020).

The method of the capstone study is based on a concept from Professor Leidy Klotz's CE 4040 lecture: *Sustainability and Systems in the Built Environment*. An idea map is a visual representation of the analysis that will take place throughout the course of the project, and is a useful organizational tool for the synthesis of broad subjects (**Appendix D**).

Research Questions

For the STS thesis, I am considering how the social and physical factors that dictate flooding vulnerability differ in coastal Gujarat and Virginia, in order to discern what policy implementations might help vulnerable communities around the world cope with the effects of climate change. For the Capstone project, my group is considering how the Grand Ethiopian Renaissance Dam is impacting the Nile River Basin in order to determine to what extent Sudan, Ethiopia, and the larger Nile ecosystem will have to adapt, and what technical solutions might be applied to the situation.

Conclusion

By working on the technical and STS research projects simultaneously, I am able to learn what works well or poorly in one project (brainstorming, research, argument development, etc.) and apply that knowledge to the other, ultimately increasing the quality of both deliverables. The projects will provide me with a foundation of practical engineering knowledge within water resources engineering, and the contrasted team and individual environments will grant me a perspective on the differing dynamics of those two styles of professional work. I will use research that I do to assess my areas of interest for work in the future, as I'm considering graduate school and a career in the non-profit space, specifically in the field of increasing access to water in developing countries, which has been a passion of mine for several years now. Ultimately, I would like to use my engineering career to increase access to water in developing countries around the world, and the abundance of work and study within the field of water resources engineering I have done throughout my undergraduate career has helped me to realize that passion of mine.

In future work, I am interested in applying Mavhura's web methodology to the social and physical factors that impact vulnerability to water accessibility, and potentially using the Actor-Network-Theory framework to compare factors of vulnerability in different communities in order to understand the variety of considerations that must be taken into account when working toward universal access to clean water.

Appendices

Appendix A

Clockwise from top left (all images taken by author using Google Earth):

The location of Virginia in the United States

The location of Gujarat in India

A closeup of Gujarat

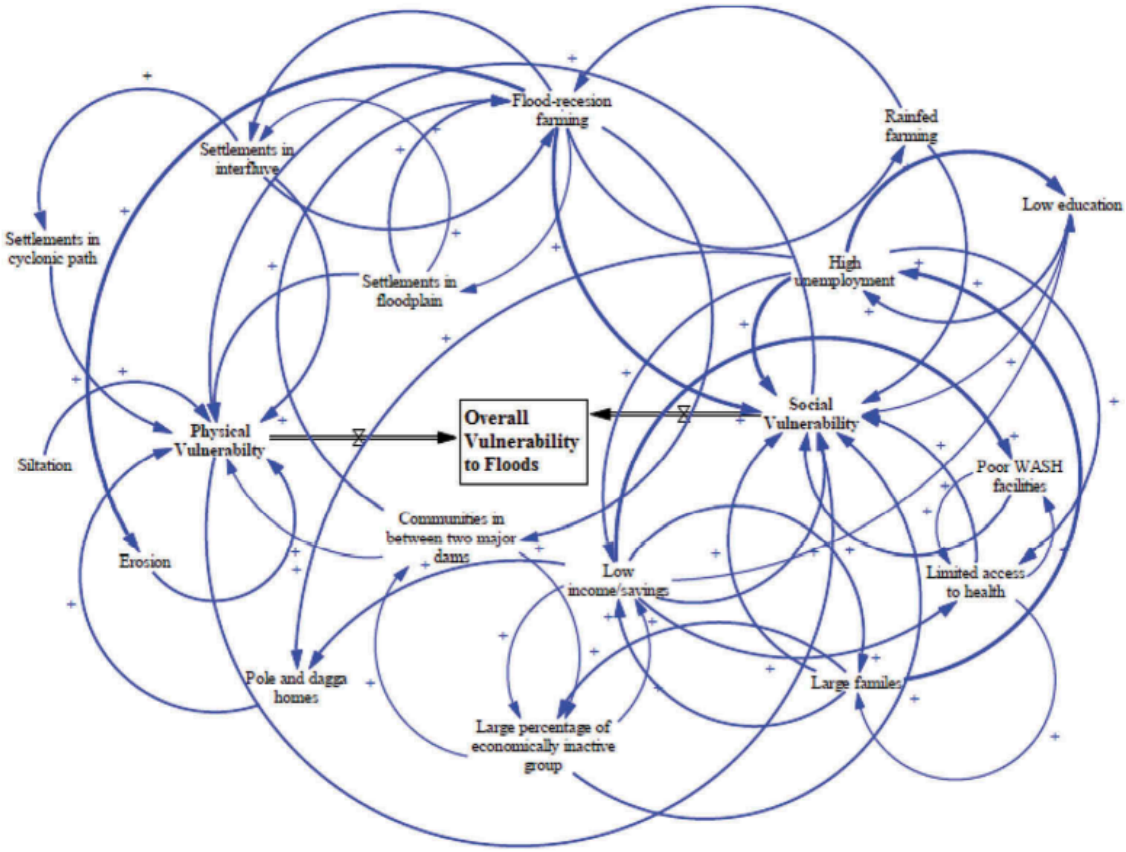
A closeup of Virginia

Appendix B

Satellite image of the Grand Ethiopian Renaissance dam. The dam is so new that satellite imagery has not fully updated in the region, resulting in this half-rendered image. Image taken by Author using Google Earth.

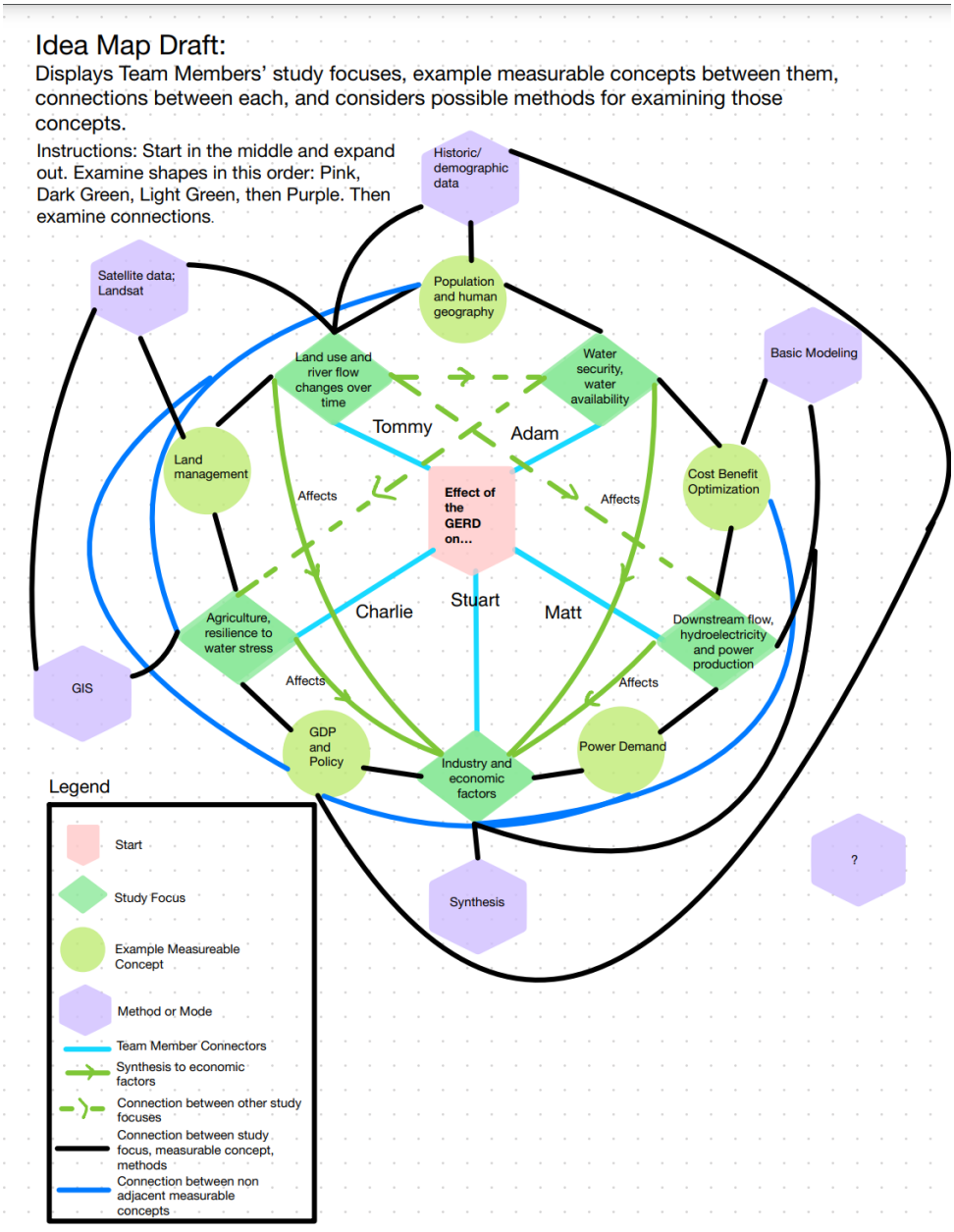
Appendix C

Mavhura's model for visualizing the interaction between various physical and social effects in relation to flood vulnerability in the Muzarabani District of Zimbabwe. I will be creating a similar diagram for each of Virginia and Gujarat, and then comparing the models in order to determine differences in flooding vulnerability between the two regions.



Appendix D

The idea map that serves as the methodological reference for our group capstone project, as was taught in Professor Leidy Klotz's *Sustainability and Systems in the Built Environment*, taught at the University of Virginia. The map indicates the role of each individual group member, and how all of the parts will come together into one coherent project.



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