5-2018

Mapping Energy Access in Rural Tanzania: 2017 Summer Internship with the World Resources Institute

Naramena McCray
nmccray@clarku.edu

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Nara McCray

Graduation- May 2018

Report submitted to the faculty of Clark University, Worcester,
Massachusetts, in partial fulfillment of the requirements for
the degree of Master of Science in GIS for Development and Environment
Department: International Development, Community, and Environment

Accepted on the recommendation of
Yelena Ogneva-Himmelberger, Academic Advisor

December 2017

Abstract

This report details my 2017 summer internship experience; both the report and the internship being requirements of the GIS for Development and Environment Graduate Degree at Clark University. My internship was hosted by the World Resources Institute, an international non-profit organization in Washington D.C. As implied by my position title, "Energy Access-GIS Intern", I spent the duration of my internship (14 weeks) applying my geospatial expertise to address the topic of energy access which is an issue effecting rural areas of many developing countries. I was given the responsibility of creating an interactive map application of Tanzania accessible by energy practitioners and planners.

Provided the unfamiliar energy sector, the think-tank work environment, and the independent nature of my internship, I gained knowledge and a broadened perspective from this experience. I also benefited greatly from collaboration with internationally diverse experts and by learning to effectively communicate GIS concepts to novice audiences. The final product of this internship has been shared with stakeholders and government officials at two separate conference in Tanzania as of November 2017. The success of the Tanzania Energy Access Maps has led to a collaboration with Facebook to develop a global energy access mapping application, Energy Access Watch.

Academic History

Name: Naramena McCray Report Date: December 2017

Place of Birth: Anchorage, AK **Date of Birth**: 03/19/1991

Baccalaureate School: Alabama Agricultural and Mechanical University

Graduated: May 2013 **Bachelor's Degree**: B.Sc Environmental Science Major, Chemistry Minor

Occupation since date of baccalaureate degree:

Peace Corps Volunteer, Ethiopia, February 2014-April 2016

Dedication

I dedicate this to those who are just as capable but will never be afforded the opportunity to succeed academically. To my siblings, parents and friends who applaud my work ethic, your encouragement and support fuels my ambition. Thank you.

Acknowledgements

I am most appreciative of the World Resources Institute for hosting me and facilitating an exemplary internship experience. The efforts made by the organization to familiarize the interns with their mission are commendable. Lily Odarno, my supervisor who welcomed me warmly and encouraged me to showcase my work at the annual Intern-a-palooza event. Liz Goldman, my mentor who offered her story and advice about navigating the geospatial career field. I also want to thank Sharron Hanna for being a passionate and approachable campus resource, surely her recommendations contributed to me securing this internship and to my overall career development.

WRI Intern-a-Palooza 2017

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Chapter 1: Introduction

My initial exposure to geospatial technology was through formative internships with the National Park Service as an environmental science undergraduate student. These opportunities enabled me to recognize the importance of GIS in assessing the natural environment. I was then introduced to the human component of spatial science through applications to international development as a Peace Corps volunteer in Ethiopia. Knowing the capacity of GIS to improve understanding and inform decision-making, I was inspired to pursue a career addressing topics with which I have moral concern as geospatial scientist.

The Geographic Information Science for Development and Environment (GISDE) Master's program at Clark University has been instrumental in merging my experiences and interests into the ideal career path. The program has provided me with extensive technical and application based skills in spatial analysis. In the summer of 2017, I chose to work for the World Resources Institute (WRI) where I was allowed to utilize my GIS skills in the realm of rural energy access. WRI in an international non-profit with an international development mission focused on human well-being and environmental stewardship. I spend the summer in the Washington DC office working with a diverse team of passionate clean energy practitioners who provided me with the additional expertise necessary to develop a mapping interface to represent energy access in Tanzania.

Energy access is a lacking in rural areas of developing countries around the world. WRI is addressing this huge issue by utilizing geospatial technology to visualize energy access. My summer project was to create the Tanzania Energy Access Maps, to assist energy planners in identifying potential markets for clean energy with the intention of sustainable development. In developing this interface, I used skills in advanced vector and data analysis to transform survey data into spatial representations of energy need. Through this internship, I learned extensively about obstacles to achieving energy access in rural areas of developing countries and the relevance to electrification of sustainable development goals.

Although energy was a sector unfamiliar to me upon starting the internship, I was able to contribute my GIS expertise to addressing a pressing global development issue while learning about an exciting new sector at the nexus of development and environment. I benefited from this opportunity in a variety of ways; by independently applying my education, gaining knowledge on a new sector, networking with inspiring professionals in my aspired career field, gaining exposure to exciting research being done at a impactful organization and honing and acquiring new GIS skills through the development of an interactive mapping application.

Chapter 2: World Resources Institute

The concept of a think-tank was foreign to me prior to coming to my summer internship at the World Resources Institute (WRI). This non-profit organization serves a vital role in cultivating innovative research on sustainable natural resource management. They achieve their mission by harnessing the vast capabilities of the diverse staff from over 50 countries with offices in Brazil, China, Europe, Ethiopia, India, Indonesia, Mexico and in Washington DC. The mission is to mitigate human impact on natural resources at the nexus of between human wellbeing and economic opportunity. Their role as a think tank facilitates the combination of sectors, which operate synergistically to develop and implement innovative solutions to global development issues as they relate to the environment.

WRI started in 1982, has around ~700 employees (2017) worldwide, having doubled in the past five years. The organization has an operating budget near $100 million and was ranked as the number 1 environmental think tank in the world in 2016.

WRI has six main pillars: climate, energy, food, forests, water and sustainable cities. These main goals are strategic points of interest in securing a sustainable future. Four main centers: business, economics, finance, and governance serve as lenses through which to address the six main goals. My internship was with the Energy pillar, although the divisions are intentionally vague, my project mostly aligns with the business center because of the focus on identifying potential energy markets. I found

that the sometimes-murky nature of the pillar and center distinctions creates a collaborative and synergistic work environment through which idea exchange is more easily facilitated.

The staff in the Washington D.C. office where I worked was incredibly diverse in terms of cultural background and high caliber in terms of academic and work experience. It was inspiring to work among graduates from the most prestigious universities in the world and to learn from the eclectic staff in my department. My direct supervisors were from Ghana, South Africa and India, and our meetings were often scheduled to accommodate the WRI India Office who the DC Energy pillar worked closely with. There were around 60 interns at the DC office this summer, only three of which were in the Energy pillar.

Geospatial experts are aware of WRI through their renowned product, Global Forest Watch (GFW). GFW is an interactive web application through which forest gains and losses can be explored spatially. This interface is the product of a collaboration between Dr. Hansen of the University of Maryland and WRI and has been used by government stakeholders to detect illegal logging. Its success can be attributed to its centralized, simple, user-friendly approach to providing technical scientific data to users. WRI understands how maps are essential to understanding global environment problems and has a robust team of GIS experts, majority of which work in the Forest and Climate pillar. I was fortunate to participate in a few working group meetings guided by

Steve Brumby, a research fellow from Descartes Labs, in which the data and spatial experts brainstorm strategies for machine learning techniques for land use classification using Google Earth Engine. Although other sectors of WRI are incredibly advanced in their spatial thinking, there were no GIS working in the Energy pillar; most of the staff were policy and communications focused. The success of GFW has demonstrated the importance of GIS to the other pillars, ultimately resulting in my internship. Recognizing the need for geospatial expertise in the Energy pillar, my seasonal position expanded into a research assistant position to build Energy Access Watch, modeled after Global Forest Watch.

I became aware of the various knowledge products produced by WRI- such as GFW- through the regular brown-bag lunches where speakers would present research they are conducting at WRI. There were also weekly sessions done by leaders from each pillar to acquaint interns with the complex organizational structure and research areas. Through these sessions, I became aware of the dependence on collaboration with corporations and the private sector. I believe one weakness WRI does not fully perceive is that they are straying from their founding mission a bit. They are aware that their rapid growth has led to some incongruences, but to what extent I am unsure. As they have expanded they have catered to corporate interests and currently put a lot of their efforts into communications and branding. These areas are essential to keeping the organization afloat in a world where to effect change you need money. These financial

components are shadowing the more critical, fundamental basis of the non-profit's founding mission. They understand the compromising nature of their relationship with corporate entities and I believe the integrity of the organization will persist through the will of their incredible employees.

They accomplish their mission with excellence. The global network and emphasis on partnerships makes for an incredibly effective strategy. The collaborative environment and variety of experts incorporate all facets necessary to effect change, which allows for WRI's success. With foundations in scientific evidence the organization can then approach their well-established connections with the public sector to effect change in terms of governance. WRI is cognizant of the importance of finance in effecting change and is elegantly maintaining the delicate balance between money, the environment and human-wellbeing.

Chapter 3: Internship Accomplishments

My internship position title was Energy Access GIS Intern. Of the six priority areas, Food, Forest, Energy, Climate, Cities, and Water, I was involved with Energy. Within Energy, I was nested within the Energy Access project which is focused on building capacity to support clean energy investments that alleviate poverty and promote development. People living in India, Indonesia, Tanzania and Kenya represent a third of the global population without electricity (WRI, 2017) and thus are WRI's focus.

Prior to my internship, the energy access project had not yet taken advantage of geospatial methods to understand and address energy issues. Spatial understanding of energy access is imperative to targeting potential energy markets and understanding where the energy poor live. My project for the summer was to develop an interactive web map that can be used by clean energy practitioners, planners and investors to demystify the energy situation in Tanzania in the hopes of accelerating energy access. Rural areas, which are far from the national grid, are the most severely unconnected. Decentralized clean energy solutions such as mini-solar and mini-hydro are key to providing energy to these sparsely populated locations beyond grid extension. Because these areas are rural, it can be hard to obtain information. The big data revolution has made a variety of data available, which can be useful to energy investors and planners in understanding and identifying energy markets.

The interactive maps I created serve as a platform for spatial exploration of various indicators, which can provide insight into electrification rates, and socioeconomic data to inform energy investors of potential markets. Publicly available open source data was utilized to provide a geospatial understanding of the electrification situation in Mainland Tanzania.

These maps display aggregated data with the aim to inform decision-making for the following audiences:

- Social enterprises and impact investors operating in Tanzania Mainland for identifying the markets for renewable energy
- Policy makers to decide on which regions are more conducive to public private participation programs in decentralized renewable energy

Market Criteria

The maps are intended to help energy planners and investors identify new potential markets. A variety of factors can be considered in locating a new area for clean energy investment. The Tanzania Energy Access Market Maps use three different criteria that have been determined as important in determining where potential new decentralized energy markets can be located; they are detailed below.

Population Density

A common characteristic of developing countries such as the United Republic of Tanzania is a large sparsely scattered rural population. Spaciously arranged settlements are advantageous to people who depend on agriculture or subsistence for their livelihood. However, this condition is not optimal for energy distribution. Extending transmission lines to sparsely populated areas can be costly, hence our focus on off-grid energy solutions.

To locate off-grid energy markets we first need to understand where people are. The population map features three levels of sub-national population density visualization.

Zoom Level	Scale	Data
1 (zoomed out)	Region: People per km/sq	2016 Tanzania Energy Access Situation Report
2 (mid-way)	District: People per km/sq	2012 Census: Basic Demographic and Socio-Economic Profile Report, Tanzania Mainland
3 (zoomed in)	Granular: People per 100m/sq	www.worldPop.org.uk

Table 1: Zoom levels for population map

Electrification Rates

We utilized recent 2016 Tanzania Energy Access Situation Report household survey data to provide spatial understanding of the electrification situation in Tanzania. This survey assesses connectivity of electricity to the main dwelling of the household and connection type.

Maps
% Household Unconnected
% Rural Households Unconnected
% of Connected Supplied by Grid
% of Connected Supplied by Solar

Table 2: Types of Maps

The split between Grid and Solar electricity supply is worth examining because of the apparent adoption of off-grid solar energy solutions by rural communities in Tanzania. This is indicative of the success and impact off-grid energy can have on rural communities and the ability/willingness of these populations to invest.

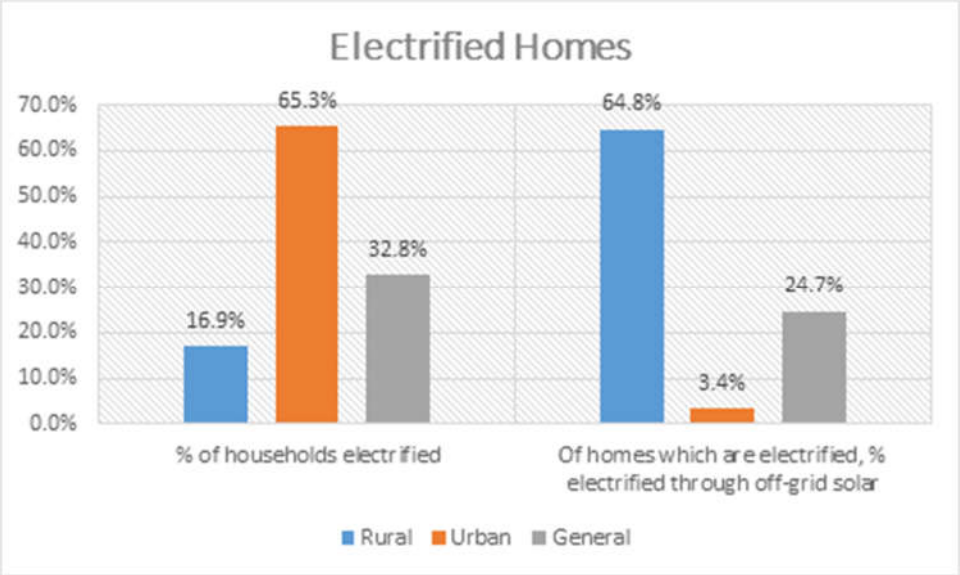

Chart 1: Descriptive Statistics on Electrification Rates

Economic Indicators

Energy access is critical to development; providing light, reducing time used to collect cooking fuel such as wood, new avenues of income generating activity, automating of house-hold tasks, etc. Investment opportunity exists to meet the growing energy demand that is associated with rising economic buoyancy of the Tanzanian population.

In addition to addressing demand produced by growing economies, which are the interest of the private sector, there are also vulnerable populations that are lacking economic buoyancy. The areas most in need of clean energy investment are the economically poor. Considering the capacity of electrification to improve the wellbeing of the vulnerable, we have highlighted economically vulnerable areas of interest to public sector energy investors.

Livestock, Iron Sheet Roofing, and Radio Ownership are household assets that the WRI Energy Access team is using as indicators of economic buoyancy. Each has its own strength in representing a household's wealth or ability to invest in clean energy. Our maps depict regional and district level ownership of these assets according to the 2012 Census.

Priority Filter

The maps are tailored to be useable by private and public sector energy investors, donors, and researchers. To accommodate the different user preferences, our maps feature a filtering interface which allows for the user to select what of the market criteria are most pertinent in the identification of energy markets at both the region and district scale. Filtering a given market criteria limits the regions or districts displayed to only those above or below the threshold. Thresholds are determined by the half-way split of quartile data distribution. The filter will limit the results to the top or bottom two

quartiles of the chosen criteria depending on whether the public or private filter is being used.

Criteria	Relevance to energy consumptions	Quartile Display Threshold	Data source
Energy Need	Locations which are severely energy deficient will be optimal areas for investment for both private and public sector	Region:>75.4% District:>91.4%	Region: 2016 Tanzania Energy Situation Report District: 2012 Census
Ownership of livestock	Rural citizens have assets in the form of livestock as the way of life in rural areas is largely dependent on agriculture and subsistence, this parameter of wealth may not be as strong for urban household's	**Private** Region: >56.5% District: >46.9% **Public** Region:<56.5% District:<46.9%	2012 Census
Radio Ownership	Important indicator of wealth in addition to being indicative of a household's investment in and use of energy	**Private** Region:>61.5% District:>60.9% **Public** Region:<61.5% District:<60.9%	2012 Census
Iron Sheet Roofing Ownership	As economics grow, traditional roofing material such as thatch is being replaced with more durable iron sheet roofing. Those with the economic freedom to invest in iron roofing may also be able to invest in energy.	**Private** Region:>59% District:>58.7% **Public** Region: <59% District: <58.7%	2012 Census
Ownership of cellular phone	Indicator of pay-as-you-go electricity payment viability	Region: >29.5%	Region: 2016 Tanzania Energy Situation Report
Population Density	Higher population density is preferable for energy markets; more customers and less distribution effort required	Region:>45% District:>73%	2012 Census

Table 3: Data Descriptions

Supplemental Data

In addition to the main factors used to target potential markets there are a variety of data that can provide additional insight into the current electrification situation. Existing infrastructure, fuel use, economic buoyancy and rates of electrification can inform planners and investors about electrification trends. These additional data and their relevance are detailed below.

Mini-grid Infrastructure

Locations of existing, proposed and potential mini-grids and transmission lines have been aggregated to reveal a holistic picture of current and potential off-grid electrification. The locations of these sites were collected through a partnership with World Resources Institute, New Ventures and Tanzania Traditional Energy Development Organization and are hosted on the open data platform www.energydata.info.

Data	Source
Existing mini-grids and existing/proposed transmission lines	https://energydata.info/dataset/mini-grid-locations-in-tanzania
Proposed Mini-Grids	In-Country Stakeholders
Potential Hydro Sites	http://documents.worldbank.org/curated/en/811961487769706306/pdf/112945-WP-P145287-PUBLIC-TanzaniaSmallHydroMappingListMostPromisingSitesWBESMAPJan.pdf

Table 4: Energy Infrastructure Data Sources

Electrification Growth

Our Tanzania Energy Access Market Maps are unique in that we have aggregated various data layers to provide the most accurate visualization possible using open-source survey data. Data as recent as 2016 is available at the regional level which details various aspects of the nation's household electrification rates while 2012 Census data has district-level household electrification information in addition to regional-level. The advantage of having electrification data from different years is the ability to assess electrification growth.

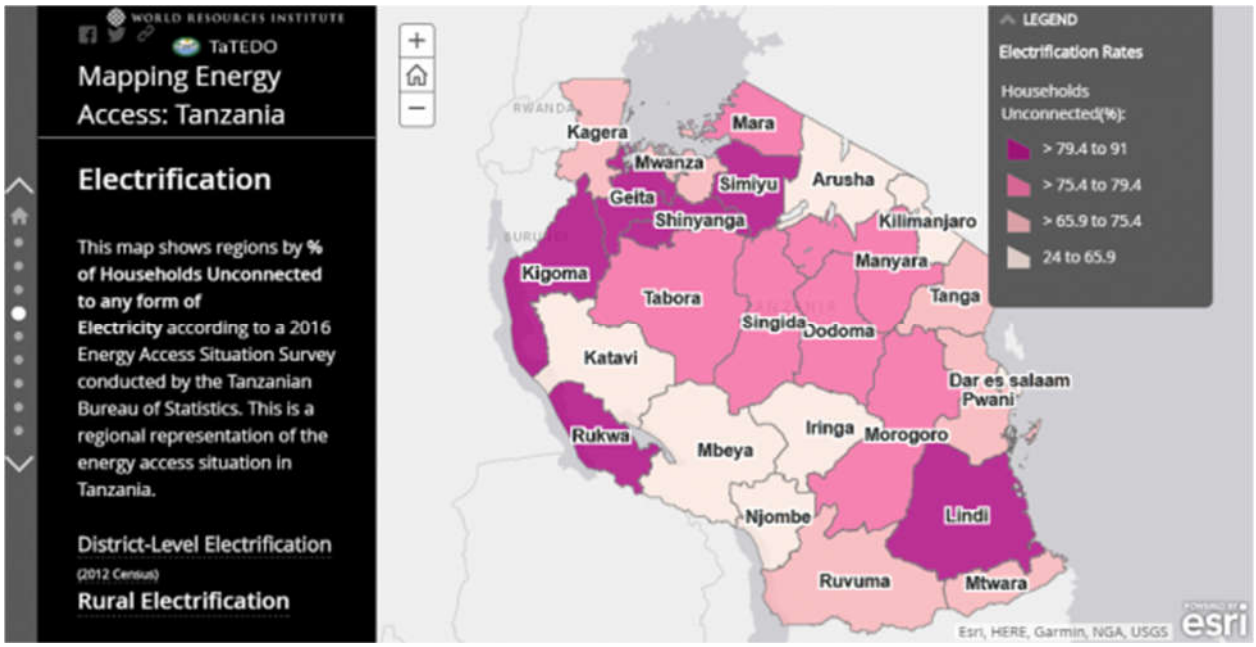

Figure 1: Snapshot of Electrification Map

Decrease in Kerosene Use

Kerosene Use has decreased in Tanzania up to 44% in some regions between 2012 and 2016. This decrease is explained by increasing fuel prices and increases in use of rechargeable lights and solar power. Areas experiencing these dramatic changes are at the forefront of a national transition in fuel use and therefore may be a prospect for energy investors.

Economic Buoyancy

Livestock, Iron Sheet Roofing and Radio Ownership are household assets that are indicators of economic buoyancy. Each has its own strength in representing a household's wealth or ability to invest in clean energy. To create a unit of economic buoyancy, which combines these three asset ownership rates, a weighted aggregation was conducted to account for the varying indicative influence of each asset. This is accomplished by summing the three variables with multiplied weights. Livestock will have a weight of 1, because it is not as indicative of wealth as the other two. Iron roofing will have a weight of 3, and radio, a weight of 3. Each is weighted depending on subjective opinion using evidence detailed below:

Livestock: Fifty-one percent of Tanzanian households are to some extent involved in rearing livestock. "In rural areas, the proportion is higher" (LSMS-ISA, 2012). "The 2012/13 National Panel survey revealed 50% of all households keep livestock (4.6 million households), 62% of which are rural and 23% urban"

(Livestock Modernization, 2014). Because of this inconsistency, livestock has the lowest weight in the aggregation of wealth indicators.

Iron Sheet Roofing: Majority of homes in Tanzania have iron sheet roofing. Those that do not have iron sheet roofing have grass, mud and/or leaves. Those who are economically able to afford iron roofing may also have the economic buoyancy to invest in clean energy.

Radio: "Concerning ownership of assets, results show that a mobile phone was the most commonly owned asset by households (80 percent), followed by house (75 percent), radio (70 percent) and hand hoe (54 percent)" (Tanzania Economic Profile, 2014).

[(% Livestock * 1) + (% Iron Sheet Roofing *3) + (% Radio *3)] / 7 = New Economic Buoyancy Vector

Renewables

Renewable resources are a limitless source of sustainable energy and should be considered in the identification of viable energy markets. Extensive solar and wind mapping efforts have been made in the past few years to promote awareness about and investment in the renewable energy resources in Tanzania.

Data	Resolution	Source
Solar Atlas: Yearly PVOUT – Photovoltaic power potential [kWh/kWp] (2016)	30 arcsec (nominally 1 km)	World Bank Group http://globalsolaratlas.info/downloads/tanzania

Tanzania - Mesoscale Wind Mapping Phase1 (2015)	2 Km resolution	World Bank Group https://energydata.info/dataset/tanzania-mesoscale-wind-mapping-phase1-2015
Existing Solar Sites	Points	Normal: Tanzania Traditional Energy Development Organization (TaTEDO) Mini: https://energydata.info/dataset/mini-grid-locations-in-tanzania
Existing Wind Sites	Points	Tanzania Traditional Energy Development Organization (TaTEDO)

Table 5: Natural Resource Potential Data

Chapter 4: Internship Reflection

My summer internship as a World Resources Energy Access GIS Intern was spent collaborating, learning, and networking. These benefits were an addition to the professional benefits inherently gained through accomplishing my internship responsibilities.

The main responsibility of my internship was to create the Tanzania Energy Access interactive map. Having no previous experience with web mapping, the first major learning opportunity of this internship was learning how to develop an interactive web platform. This was done with a bit of guidance from an experienced but busy research assistant who walked me though the basics of using ArcGIS Online. I independently learned how to upload and host data on the ArcGIS platform. Through research, I identified ArcGIS StoryMaps as the most user-friendly format through which to create the Tanzania Energy Access Maps. The relatively simple interface will accommodate the wide range of energy practitioners and decision makers that will use the tool. Gaining the skill of web map development is useful in that it enables me to share maps through an interactive format in the future rather than the static ones we typically produce through our coursework at Clark.

The Tanzania Energy Access Maps aggregates data from numerous sources (government, open source, survey data) for comparisons and spatial understanding of the electrification situation and economic indicators in Tanzania. This information is

depicted in the format of vector region and district polygons which attributes were derived from census and other household surveys. I was able to develop skills of critical thinking, independence and discernment through the process of identifying data sources and selecting which data would be most useful for understanding the electrification rates and potential energy markets in Tanzania. I had some experience with managing census data from my final project in the Clark Advance Vector GIS course. Material covered in said course also provided me with the knowledge necessary to appropriately break-down the data in quartile data distribution and to combine indicators using weighted linear combination to create a factor of economic buoyancy based on asset ownership.

My understanding of spatial vector analysis certainly equipped me to complete the task of creating the Tanzania Energy Access Maps. But, my experience was lacking in the realm of energy in general. Through the development of this interface, I learned about the intricacies of energy access in developing countries, the public and private sector influence on electricity in rural areas of developing countries, the most promising solutions to this pressing issue and their limitations, as well as how data constraints significantly impact the mission to provide electricity to the energy poor. Although not GIS skills, the insight this background information provided has taught me of the importance of learning more than just the technical components of the work I do as a geospatial scientist. This knowledge reinforced my interest in using GIS to address

development issues because of the obvious lack of spatial maps depicting energy access. These gaps also exist in other realms of international development and I am inspired to pursue a career using geospatial science to improve understanding and effect change.

Energy is not a sector I am particularly interested in, but the international development component which directly relates to electrification rates aligned with my interests. WRI's environmental mission has a heavy focus on developing countries exposed me to the ways in which GIS is being used to address issues such as deforestation (Global Forest Watch) and water risk (Aqueduct). It was enlightening to see such topics that were discussed in the GIS for International Development course being successfully addressed.

The World Resources Institute facilitated numerous brown-bags and information sessions for staff and interns. These frequent and genuine efforts to keep employees informed was an example of the transparency and collaborative nature of the organization. Through these sessions I learned about various facets of cutting-edge environmental and international development work. I participated in Google Earth Engine working groups, which provided a space to learn and ask questions about how the emerging software is used in land-use assessment projects at WRI. Staff provided these learning opportunities with warm, earnest eagerness to share knowledge and to inspire creativity. I would recommend internships at WRI, especially in the Forests and

Cities areas of the organization, as they are using some of the most innovative techniques in remote sensing and data analysis.

Chapter 5: Conclusion

Of the many internships I've had prior, the internship with WRI was pivotal because it was my first professional experience where my contributions were highly valued as I was providing a technical niche skillset to their mission. With the concept of an internship being a training of sorts, I feel this experience has provided me with an exceptional realization that I now possess a valuable skill set which puts me in a position where I can offer an organization just as much as an organization offers me. With this comes with a new-found authority and confidence in that my education has equipped me valuable skills that are in demand. This is due in part to the variety of internships and experiences I have learned from but largely due to the exceptional education provided by the Clark University GISDE program.

I am privileged to learn advanced methods of remote sensing, raster and vector analysis and computer programming in an environment where I am encouraged to experiment and apply these concepts to pressing global issues. The relevant and specialized nature of the coursework have equipped me with a competitive skillset that I successfully exercised during my experience at the World Resources Institute. Though I was assured of my skills through the internship, I also was empowered to gain new ones.

Through this internship I learned new online GIS software and how to develop an interactive web map, how to explain GIS concepts to a novice audience, and about the

procedural workings and workplace environment of an international non-profit think tank. The final product of this internship has been shared with stakeholders and government officials at two conferences in Tanzania as of November 2017. The success of the Tanzania Energy Access Maps has led to a collaboration with Facebook and other entities to develop a global energy access mapping application, Energy Access Watch. Upon the completion of the internship I was hired as a remote-part-time research assistant with the World Resources Institute continuing to scale the energy access mapping efforts. My wish is to remain in the non-profit sector addressing development and environmental issues and I am confident that Clark University and WRI have significantly shaped this goal and will enable me to achieve this goal.

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