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Geospatial Application in Ethiopian Energy Sector

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Abstract: Many developing countries like Ethiopia are yet to achieve universal electricity access for their citizens. Access to affordable and reliable electricity plays a critical role in economic development, employment creation and investment. Adequate and sound policies on energy regulation are needed for the achievement of sustainable development goals. To ensure that the citizens are electrified sustainably, efficient, and elective policy frameworks are worth putting into consideration. Although there are different energy sources in Ethiopia which can be used to generate electricity such as solar, wind, hydroelectric, geothermal, biogas only hydroelectric is used to supply to the national as well as regional demands.

Geospatial is widly applicable in the energy sector in resource planning, inspection, maintenance, design and constraction. Geospatial technology improves efficiency in energy sector and brings more efficient design and construct, better stakeholder communication and engagement, beduced outages by identifying critical faults, more efficient maintenance with more detailed asset knowledge, betailed record of easements and lines for maintenance planning, increase transmission capacity by knowing loading on every span, andcorporate GIS provides day-to-day efficiencies to all stakeholders.

Since geographic information systems methodology has proved to be applicable in the energy sector in Ethiopia for informing the electrification strategies in the country, there is a great need for the country to invest heavily on it.As the country is committed to transforming the whole energy sector to provide reliable and adequate electricity to all, then empowering the geospatial technology within the country should be part of the plan.

Keywords: Geospatial technology, Geographic information system (GIS), the energy sector

List of Abbreviations

NSDI- National Spatial Data Infrastructure
IT- Information Technology
EMA- Ethiopian Mapping Agency
GIS- Geographic Information System
SCADA- Supervisory Control and Data Acquisition
DMS- Direct Messaging System
ERP- Enterprise Resource Planning
GPS- Global Positioning Systems
ESMAP- *Energy Sector Management Assistance Program*
NEP- National Electrification Program
GDP – Gross Domestic Product
NSDI - National Spatial Data Infrastructure

1. Introduction

Energy is among an essential aspect of daily life. Most activities done in homesteads rely entirely on electricity. Nevertheless, the majority of workplaces where most of the working hours are spent utilize various forms of energy. Sometimes back, power was only demanded in a few urban areas. However, with the growing population, urbanization and technological advancement, the use of energy has spread out to most parts of any given country (Fettweis and Zimmermann, 2008). Therefore, over the few past decades, the energy market has drastically changed and exponentially expanded. Mostly due to the expanding market, the demand for energy is overgrowing across the globe (Conti et al., 2016). According to IEO (2016), the total consumption of marketed energy was 549 quadrillion Btu as of 2012. This figure is expected to rise by a percentage of 48 to 815 quadrillion Btu in 2048. During the distribution of energy, many losses may occur which are associated with energy theft. As stated by IEO (2016), world distribution losses for electricity were approximated to be 8.61% IN 2013. Therefore, regarding the consumption trends of energy, a country's economy should employ a sustainable infrastructure to help in containing the energy resources. The prominent sources of energy include oil, coal, and gas. However, the rise in the pollution of air as well as climate change due to their use has led leaders to have their focus shifted from those traditional sources to renewables sources of energy. Such sources include Hydro, solar, bioenergy, geothermal and wind. Therefore, to realize a better GDP and economic growth, it is necessary for the government to have energy resources safeguarded and achieved (Pérez-Lombard, Ortiz, and Pout, 2008).

As the energy sector around the world is drastically changing over the last decade, its application and demand increase daily. According to the National Academy of Engineering, development of electric power grid technologies is among the top twenty engineering achievement that has significantly affected the quality of life in the 20th century (Bianco et al., 2007). Such advancements have been witnessed diversely with the recent one being the integration of geospatial technology into the energy sector. As many countries have embraced this technology in enhancing the department of energy, Ethiopia has not been left out. According to Alhamwi et al., (2017), Ethiopia is planning to launch a new connection to the grid which will be based in Geographic Information System (GIS) that applies geospatial data to identify the technology that best suits based on location. Such advancements will see a significant change in the energy sector in Ethiopia. The technology will also have other numerous applications within the energy department. However, this new technique is believed to face several challenges in implementation.

This study aims to identify the diverse application of geospatial application in the Ethiopian energy sector. The study starts by analysing the current energy status in Ethiopia, the literature on geospatial technology, its use, and its state in Ethiopia. The study relies on peer-reviewed articles to establish the applications of this technology. Such forms the basis of the findings and the conclusion is drawn from them.

2. Literature Review

Ethiopian Energy Status

Ethiopia is one of the African counties making a transition to the level of middle-income countries. In such a journey, access to reliable and adequate electricity will be vital. As stated by Mondal et al., (2016), the final consumption of energy in Ethiopia is estimated to be 40,000 GWh. Out of that consumption, 92percent goes to domestic appliances, 3% to industries while 4% to the transportation sector (Mondal et al., 2016). Mostly, the supply of energy is covered by hydro power. Ethiopia as a state has been endowed with sources of renewable energy which include hydro, geothermal, wind, solar and biomass (Khan, and Singh, 2017). However, only a small prospective portion gets harnessed. Notably, Ethiopia's grid is estimated to cover 80% of its entire population (Erbato and Hartkopf, 2012). A few numbers of households standing at 30% have access to electrical energy; this places Ethiopia as the second country among those with the highest access deficit across Sub Saharan Africa (Ebhota and Tabakov, 2019).

Nevertheless, according to Khan and Singh (2017), the demand levels for electricity energy is increasing as most of the daily activities in Ethiopia utilize the latter. As of 2037, energy demand is expected to have risen by a rate of between 10% and 14% (Khan and Singh, 2017). Inadequate access to electricity renders some of the Ethiopian regions backward economically (Erbato and Hartkopf, 2012). Consequently, the country's GDP is adversely affected as the productivity of the available labor is underutilized as a result of less access to electric energy. Therefore, the government of Ethiopia is determined to achieve universal access to power by the year 2025 (Mondal et al., 2016. The approach employed is however focused on the development of infrastructure rather than the delivery of the energy serve. Markedly, new investments are required to back up comprehensive strategies covering the grid as well as the off-grid solutions, the participation of the private sector, and a force to employ the vast sources of renewable energy in the country.

Ethiopia has received notable support in the debut of significant reforms in its energy sector. The changes entail implementation of universal electrification. In 2015, ESMAP supported the government of Ethiopia by financing the Ethiopia Energy Sector Review and Strategy- a study which was to run for three years to provide diagnostics as well as the identify reform actions (Mondal et al., 2016). Consequently, the National Electrification Program (NEP) got developed and launched after the study. The NEP has a plan in place to increase energy connections at a very high rate. It entails a connection program for a fast-paced grid; this will increase connectivity by five-fold of the current one, with more than 14 million homes connected by 2025.

Additionally, a program for off-grid access is being developed with the help of ESMAP; it is targeting the remaining more than five million homes in rural communities with mini-grids and solar systems to ensure coverage of everyone (Khan and Singh, 2017). Another action plan of NEP is to provide access to reliable energy services for health and educational facilities. Moreover, ESMAP also reinforced a prospectus for investment to guide investment in the energy sector.

The achievement of new connections will get founded on the latest Geographic information system (GIS) platform with the aid of ESMAP. GIS utilizes geospatial data to help in identifying a suitable technology based on a given location. The rolling out of this plan will have a significant impact on the life quality of households especially those in rural areas, as well as boost economic growth (Mentis et al., 2016).

Geospatial Technology

The invention of geospatial technology is among the most highly applicable technological advancement over the last decade. This technique comprises a variety of modern tools that aid in geographic mapping as well as earth and human society analysis. The field of geospatial technology has been evolving since the prehistoric times when the first maps were drawn. By 19th Century major transformation where experienced through the establishment of map making and cartography (Nickel, 2001). Consequently, aerial photography was introduced by sending cameras aloft on pigeons and balloons. During the 20th, the aerial photographs were then taken by airplanes.

Photographic interpretation art and science was further advanced during the Second World War and consequently during the cold war (Khudaiberdievna, 2019). During these periods, there was the advent of computers and satellites integrated into the field of photography. Through the satellites, it was now possible to have images of the surface of the earth and also human activities although with limitations. Introduction of computers enabled the sharing and storage of imagery. It further led to the development of digitalized maps, and even software for geographical data analysis on environmental and socioeconomic in general referred to as Geographic information system (GIS) (Chaudhary et al., 2019). An essential aspect of this GIS technique is the ability to arrange geospatial data inform of layers of maps for complex theme analysis. Layering is possible since every single data contains information its particular location on the earth's surface thus known as "geospatial" (Kumar et al., 2019).

According to Chaudhary et al., (2019), during the last decade, this field had considerably advanced into a national security network, commercially operated satellites, and scientific satellites complimented by very powerful GIS desktops. Other advancements include the aerial remote sensing platforms such as crewless aerial vehicles. Some of the technologies under this field include remote sensing, GIS, Global Positioning Systems (GPS), and the Internet mapping technologies (Kumar et al., 2019). These technologies have been utilized in different fields including the energy sector in many countries.

Application of Geospatial in Energy Sector

Geospatial technology has a wide range of applications in most of the utility sectors including that of electricity. In an electricity company, maintaining the most vital assets like distribution and transmission facilities involves a significant cost - Such cost may carry a large amount of the set operating budget for a given year (Calvert,Pearce, and Mabee, 2013). Geospatial technology thus comes in handy as it simplifies the management of records regarding such vital assets in a utility firm. The application of geospatial technology in record management helps in reducing operational costs. Geospatial technology is a powerful tool for decision making; it helps the service providers to focus on the bigger picture by linking the clients as well as the asset formation to a geographical location on a map (Blaschke et al., 2013).

The geographic information systems can be integrated with other software which makes it easy to employ in all utility organizations. Such software includes SCADA and ERP (Harvey, 2011). GIS plays a vital part in the process of generation, transmission as well as the distribution of power. The technology works as a perfect tool in binding together the different pieces making up a distribution system for electricity (Mentis et al., 2017). Therefore, it ensures good management of assets, enhanced client service, more precise data as well as improved management of an outage. According to Back et al., (2014), SCADA, a software which can be integrated with GIS, has a DMS system which provides information regarding the transformer that is off whenever tripping happens. Additionally, SCADA facilitates management for assets which offer a real picture of how things are at the ground level (Back et al., 2014).

Geospatial technology has been significantly applied in powering up of the smart grid. The modern society is at a point where economic, as well as social function, rely on reliable and secure infrastructure in electric power. The roadmap for technology regarding smart grid entails the deployment of increasing numbers of sensing and control intelligent electronic devices (Calvert et al., 2013). The primary challenge encountered is the federating data from such devices, obtaining data from it and disseminating the information to the appropriate control devices. The changes that the energy industry is going through requiring have analysts suggest the application of geospatial technology to act as a foundation for the smart grid. The use of geospatial technology impacts every aspect of utility provision, customers, management as well as the associated operations (Mentis et al., 2017). GIS application provides the foundation for integrating information from intelligent electronic devices.

Challenges Facing Implementation of GeospatialTechnology

In most utility providing companies, the implementation of various types of technology faces diverse challenges. Moreover, even after the application of the geospatial technology by utility companies across the world, multiple problems hinder its usage as well a further growth. Mapping all assets is a big hurdle that needs an intervention (Lu and Liu, 2012); it is among challenges that face the implementation of geospatial technology (Sui and Goodchild, 2011). To get all the assets mapped, they should first be found, correlated with the provided paper records and then assign them effectually in GIS. Moreover, according to Zlatanova and Li (2008), it is difficult to find appropriate land base maps to convert them into vector maps.

Additionally, according to Lu and Liu, (2012), keeping the register for holdings up to date is also a challenge. Some areas have low internet access, lack of well-equipped facilities, and skilled personnel. Besides, sometimes the assets on site may get replaced or taken out to make repairs. Having a close track of every action on site in real time is notably a great challenge. Thus, geospatial data in some cases have been unreliable due to such challenge.

Even though geospatial data has proved valuable in many sectors, the field receives little attention from the government, especially in developing countries. As a result, there is a lack of funds, and sufficient staff for maintenance, running, and updating the systems (Gelagay, 2017).

State of Geospatial Technology in Ethiopia

Ethiopia is one of the developing countries in Africa. Comparing to other developed developing countries within the continent, Ethiopia is among the first in the list of countries that have been utilizing geospatial technology for long. According to Zeleke and his colleagues (2008), Ethio-GIS was launched in the country back in 1999 releasing the first well-organized spatial data for users. The primary purpose of employing geospatial in the country was for natural resource management although it ended up having other several applications (Mentis et al., 2016). Ever since, according to the report, many people have benefited from the database including development groups and academia. A group of experts has been updating the database releasing the second edition in 2008. Over the last decade, several organizations within the country have also been working to develop GIS labs and personal through collecting geospatial data (Zeleke et al., 2008). Therefore, a lot of progress is evident in the field and culture of geospatial data using increasing its capacity within Ethiopia.

Although, geospatial information within the country is increasing, there are some inevitable challenges in the field. Among such limitations include data sharing due to limited internet infrastructure and access experienced (Gelagay, 2017). Also, data quality and standards are also among the challenges in Ethiopia as listed by Gelagay, (2017). Furthermore, the geospatial sector faces data update both within and outside the country problem.

With the growing need for geospatial data in Ethiopia, it has necessitated the construction of National Spatial Data Infrastructure (NSDI) in the country. According to Ethiopian Mapping Agency (EMA) as reported by Zeleke et al., (2008), the demand for this information has risen over the last three decades with the advancement of IT which allowed production, processing, and application of spatial data. As a result, many sectors such as political, economic, and physical environment become primary users of such information. EMA had thus been working tirelessly to maintain the system through; organizing workshops to discuss the issue; identifying main stakeholders and creating awareness of the stakeholders and facilitating working environment. However, EMA experiences challenges in maintaining the NSDI (Gelagay, 2017). The major issues include limited funds for capacity building, the absence of full-time workers, and additional work for the staff since they are volunteers, and value undermining both on the national and institutional level (Zeleke et al., 2008). Consequently, the institution also faces role misunderstanding by most of its stakeholders and global dynamism.

3. Hypothesis

This study hypothesizes that Ethiopia has not yet actualized the full application of geospatial technology in the energy sector.

4. Methods

Finding out the application of specific technology in a given field is quite challenging (Georghiou and Roessner, 2010). To assess the implementation of geospatial technology in the Ethiopian energy sector, the study was based on research for literature over the topic conducted within the last five years. The duration of publication was considered to maintain the relevance of the sources. Also, the duration was considered the geospatial technology is still an advancing field in most developing countries. However, some exceptions were made when selecting sources. The exception caused the inclusion of some articles published more than five years ago. Such was considered to come up with the trend of geospatial application in Ethiopian energy since according to review the technology has been in use since 1999 (Zeleke et al., 2008).

Due to scarcity in literature, getting statistical data was quite challenging, the study thus focused on applications that have been published in a peer-reviewed journal. The established claims were analysed to come up with the conclusion on how advance geospatial is applied in the Ethiopian energy sector. Therefore, the study was based on a descriptive research approach

5. Results

Received outcome

The energy consumption in Ethiopia is close to 40,000 GWh. Most of the energy supply is from bioenergy mainly for domestic use (Korkovelos et al., 2018). Transport sector relies on imported sources of energy in the form of petroleum. Hydropower is primarily generated close to 9000 GWH/a followed by wind energy (Energypedia.info, 2019). The country has a considerable endowment of energy, significant hydro-electric power, geothermal, solar and also fossil fuels. Deployment of grid-connections and mini-grid technologies have changed under diesel price and the electricity demands in the country (Dinku et al., 2014). Movement from the predominantly diesel to hydropower and solar systems have been witnessed in most countries in the sub-Saharan region (Mentis et al., 2017) including Ethiopia. The higher price of diesel can explain this situation. Several factors affect the energy production potential of a country. Such factors include solar radiation intensity, infrastructural developments, topography, and population density. The density and distribution of a population play are crucial in the determination of energy technologies to be implemented.

Application of GIS allows various types of data relating the different energy sources to be integrated into one system for analysis. Such enables a multi-perspective view over a wide geographical area. By using the GIS, solar radiation potential should be considered first in the selection of potential sites for massive energy production in Ethiopia. Solar energy can be derived from high radiation analysis tools.

Electrification in the country

Electrification in Ethiopia heavily relies on the on-grid, mini-grid, and stand-alone energy solutions. An analysis reveals that the grid-based connections are mostly preferred for high consumptions. Over 90 percent of the Ethiopian population is fed with a grid-based connection source of energy (Mentis et al., 2016).Besides, high geo-spatial diversity in the implementation of technology at associated costs. With low electricity access in the rural areas, there is high penetration of stand-alone units and mini-grid connections (Girma, 2016). Considerations for the electrification include diesel costs based on the distribution distance, connection costs, grid, and associated strengthening costs, geo-spatial wind regimes, geo-spatial solar irradiation, and small-scale hydro-electric potential sites.

Two scenarios show the importance of geospatial electrification in the perspective of local energy availability. One scene is considering the investment in stand-alone solar energy by cost. Geospatial technology, in this case, is used in providing data about the best site of location. The other situation is the option of using stand-alone techniques to electrify cells with electricity-free access. Geospatial technology greatly aids in achieving such. Independent technologies have been reported to lower the electrification costs in some households in comparison independent supply of diesel (Hussein et al., 2017). The stand-alone technologies utilizing the geospatial approach would be more viable to get an increased percentage of electrification. The geospatial application aims at higher access targets with the least cost; this involves more utilization of grid and mini-grid options as opposed to stand-alone technologies. The implementation of renewable energy sources instead of independent techniques is seen to provide more economical and sustainable electricity (Mentis et al., 2016).

Hydropower

Hydropower is one of the renewable energy that is economically competitive in the electrification platform. It provides significant efficiency and stability in the energy system space. Ethiopia utilizes a high percentage of hydropower although high potential remains untapped. The possible hydropower production is approximately 45,000 MW (Energypedia.info., 2019). The opportunities for expanding the hydropower in the country are promising and could further enhance energy production in the country (Korkovelos et al., 2018). Hydropower provides a considerably low-level cost, continuous generation and ability to be a standalone source of energy. The exploration of hydropower potential depends on the nature and extent of rivers. Agricultural activities have also taken a sizeable land suitable for the deployment of hydropower (Szabó et al., 2013). Other factors include the impact of the mountains landscape in the western half making the hydropower to be unevenly distributed over the land mass.

Geographic information systems (GIS) in Ethiopia reveals useful information on the enhancement of hydropower (Kougias et al., 2016). Other remote sensing techniques could also be used to ascertain this fact. The integration of hydropower in Ethiopia provides insights for policy making on developments regarding future exploration and distribution of hydropower energy generations. Hydropower assessment reveals a defined capacity range of 0.1-10MW (Kougias et al., 2016).

Solar radiation

The country has a high potential for solar energy. It receives solar radiation of 5000-7000 Wh/m2 (Girma, 2016). The spatial distribution of solar radiation reveals variations throughout the year during different seasons. The suitability for large scale solar farms in the country is based on the criteria such as solar energy potential, slope, land mass cover, distance to the grid, population densities and distance to water sources (Zhou et al., 2015).

The suitable sites for solar radiation implementation in Ethiopia are estimated to be 1.9 TWh/km^2 (Tekle, 2014). The value was obtained by computing the efficiency of different solar cell materials. Total area suitable for the solar implementation accounts for 0.5 % (Kougias et al., 2016) of the entire area in the country as calculated by GIS-based technique.

Geothermal energy

The geothermal resource in Ethiopia is estimated to be about 5 GW. However, 700 MW is suitable for power generation (Korkovelos et al., 2018) The geothermal source is primarily located along the rift valley where the prevailing temperatures range up to 300 degrees (Esmap.org., 2019). Exploration of geothermal power has been done to completion in four prospective geothermal sites including Abaya, and Dofan among other places. A feasibility study is needed to be carried out for expanding the completed stations and for the exploration of other prospects.

Wind energy

The country has good wind resource with a velocity range of 7 to 9m/s. The wind energy potential is estimated to be up to 10,000 MW (REEP, 2019). Seasonal variations of the wind velocity limit the generation of wind power. Changes of the wind speed are recorded during the day with a different rate in the morning, midday and the evening. There are also season variations in speed with high speed from May to August (Krauer, 2008). Commercial wind power plants exist in the country with a power production of 720 MW (Energypedia.info., 2019).

Wind power is considered to be a promising source of energy for the population. Strategies and policies need to be analyzed accordingly to harness the wind energy maximally. Comparison with the hydropower should be a focus in the definition of plan. Hydropower has low production over the dry season while wind power is high during this season (Dinku, 2014). Geospatial application in this sector plays a significant role in determining the energy mix of the optimal energy source for the different seasons.

6. Discussion

Evaluation of results

Energy services in Ethiopia are increasingly delivered in a decentralized manner to ensure electrification in rural areas. Energy planning and research have significantly use the GIS methodology in defining national electrification plans, strategies and policies. The GIS-based tool allows for preparation of renewable energy sources and proper management of the readily available energy sources (Mentis et al., 2017). Several criteria are considered for the identification of the most suitable location for the installation of new energy systems in the country. These criteria may include wind and solar availability, per capita income, closeness to a transmission network and the rural electrification index (Gelagay, 2017) among others. The geospatial application is useful in categorizing zones into areas appropriate for either renewable technologies or conventional sources depending on technology availability and the economic conditions.

The application of GIS approach in Ethiopia has resulted in many significant insights. Solar energy can be a standalone, cost-effective source of energy which will provide primary power in no small part of the population. However, with the increasing population, demands for electrification elevates leading to competition for stand-alone solar and mini-grid based energy sources (Hussein, 2017). Deployment of geospatial technology heavily relies on diesel prices and the growing demand for electricity. The viability of this option is determined by the time, space and the environmental cost. However, grid connections remained the best option in densely populated areas.

The Area solar radiation tool provided by the Geospatial application can be utilized in the calculation of yearly and monthly solar radiation in the country (Tekle, 2014). The solar radiation tool will put into consideration factors such as latitude and elevation, aspect, slope, atmospheric effects, the angle of the sun and the shadows from the surroundings. Quality calculation of the radiations can be achieved depending on resolutions tool used, time interval and sky size resolution (Mentis et al., 2017).

The spatial electrification state currently in Ethiopia is majorly based on the assumptions which are related to the transmission networks and the population densities which have been referenced geographically (Mentis et al., 2016). Relative sizes of the spatial units are the significant constraints for the attempt to relating the electrification distribution in the country. The GIS-based application eliminates this constraint by allowing access to a cost-effective supply of electrical power at any point at any time (Hussein, 2017). This application will further reduce the science-policy gap by providing ease of communication. Achievement of a state where there is universal access to electricity in the country is fundamental for social and economic developments in Ethiopia. Integrating a wide range of technologies in the provision of power to all parts of the country is a vital approach. Implementation of GIS energy planning provides the best way to realizing the objective. The approach eases the identification of areas with the low access to electricity and allows the planners to rationalize the decisions and more so provides an efficient tool for monitoring the electrification.

The geospatial application is useful in the selection of appropriate locations for large-scale sites for solar energy in the country. Other valuable factors to consider in the selection of the sites include topography, economic and environmental factors. The selection of suitable sites for large scale PV installation should consider critical factors. The most appropriate factors to be considered include land cover, distance to road networks, population density, distance to sources of water, transmission lines and the solar radiation potential (Hussein, 2017).

Study limitations

The limitations of this study include inadequacy of improved data sources and lack of incorporated criteria for the application of a GIS-based approach which could have significantly led to the improvement of the reported results. Another constraint in this study was the shortage of the most recent digital spatial data in the study for adequate information. For instance, digital data which use high-resolution tools could have revealed highly reliable results despite increasing calculation time. Moreover, there was the inadequacy of most ground measurements done recently from large meteorological stations which led reliance on incomplete, old radiation values. Due to these limitations, the suitability for geospatial applications in Ethiopia is given in a general overview considering the use in hydropower and solar energies. Despite the constraints present, the study provides a good overview of decision making on the implementation of GIS on the energy potential in the country.

Future study suggestion

Future studies could consider a more in-depth analysis of the application of geospatial technology in the Ethiopian energy sector. Such should include having in-the-field research to come up with data analysis of how the energy sector has changed with time through the employment of this technique. The study should involve collecting data in all the energy production plants within the country to come up with a conclusive overview of the impact of such technology into the energy sector.

7. Conclusion

Social and economic development of a country greatly relies on clean and affordable modern energy. Adequate and sound policies on energy regulation are needed for the achievement of sustainable development goals. To ensure that the citizens are electrified sustainably, efficient, and elective policy frameworks are worth putting into consideration. Such programs are always different from one country to another and largely depends on resource availability, economic and geographical conditions. Although Ethiopia has different energy sources including hydro-electric power, solar energy, geothermal energy, wind energy, and biomass (Girma, 2016), utilizing each of these energy sources demands for careful planning to achieve the maximum energy supply in the country.

The process of electrification must put into consideration the geographical features of the available resources and the spatial dimension of both economic and social sectors to realize the most optimal energy solution (Hussein, 2017). Such is because the geospatial application in the energy sector contributes positively to the optimization of the energy state in Ethiopia. In particular, the application of geographic information Systems (GIS) and geographic theory plays a significant role in the electrification planning. The approaches provide a simplified way of managing required data for decision making since it may assess and integrate all possible energy options.

Since geographic information systems methodology has proved to be applicable in the energy sector in Ethiopia for informing the electrification strategies in the country, there is a great need for the country to invest heavily on the same.As the country is committed to transforming the whole energy sector to provide reliable and adequate electricity to all, then empowering the geospatial technology within the country should be part of the plan. Such would include dealing with the challenges faced by EMA in maintaining the NSDI as highlighted in their 2008 conference report. Since geospatial technology greatly influences the Ethiopian energy sector, its advancement within the country could lead to the fulfilment of their plan on availing reliable and adequate electricity to all as well as eliminating environmental friendly means of energy.

8. References

[1]. Alhamwi, A., Medjroubi, W., Vogt, T. and Agent, C., 2017. GIS-based urban energy systems models and tools: Introducing a model for the optimization of flexibilization technologies in urban areas. *Applied energy*, *191*, pp.1-9.

[2]. Back, S., Kranzer, S.B., Heistracher, T.J. and Lampoltshammer, T.J., 2014, March. Bridging SCADA systems and GI systems. In *2014 IEEE World Forum on the Internet of Things (WF-IoT)* (pp. 41-44). IEEE.

[3]. Bianco, C., Cucchietti, F. and Griffin, G., 2007, September. Energy consumption trends in the next generation access network—a telco perspective. In *INTELEC 07-29th International Telecommunications Energy Conference* (pp. 737-742). IEEE.

[4]. Blaschke, T., Biberacher, M., Gadocha, S. and Schardinger, I., 2013. 'Energy landscapes': Meeting energy demands and human aspirations. *biomass and bioenergy*, *55*, pp.3-16.

[5]. Calvert, K., Pearce, J.M. and Mabee, W.E., 2013. Toward renewable energy geo-information infrastructures: Applications of GIScience and remote sensing that build institutional capacity. *Renewable and sustainable energy reviews*, *18*, pp.416-429.

[6]. Chaudhary, B.S., Sajjad, H., Rani, M., Pandey, P.C. and Kumar, P., 2019. Introduction to Space Technology Challenges: Potential and Future Prospects. In *Applications and Challenges of Geospatial Technology* (pp. 3-6). Springer, Cham.

[7]. Conti, J., Holtberg, P., Diefenderfer, J., LaRose, A., Turner, J.T. and Westfall, L., 2016. *International energy outlook 2016 with projections to 2040* (No. DOE/EIA-0484 (2016)). USDOE Energy Information Administration (EIA), Washington, DC (United States). Office of Energy Analysis.

[8]. Dinku, T., Block, P., Sharoff, J., Hailemariam, K., Osgood, D., del Corral, J., Cousin, R. and Thomson, M. (2014). Bridging critical gaps in climate services and applications in Africa. Earth Perspectives, 1(1), p.15.

[9]. Ebhota, W.S. and Tabakov, P.Y., 2019. Power Supply and the Role Hydropower Plays in Sub-Saharan Africa's Modern Energy System and Socioeconomic Wellbeing. *International Journal of Energy Economics and Policy*, *9*(2), pp.347-363.

[10]. Energypedia.info. (2019). Ethiopia Energy Situation - energypedia.info. [online] Available at: https://energypedia.info/wiki/Ethiopia_Energy_Situation#Wind_Energy [Accessed 25 Feb. 2019].

[11]. Erbato, T.T., and Hartkopf, T., 2012, January. Smarter microgrid for energy solution to rural Ethiopia. In *2012 IEEE PES Innovative Smart Grid Technologies (ISGT)* (pp. 1-7). IEEE.

[12]. Esmap.org. (2019). Spurring Energy Sector Transformation in Ethiopia | ESMAP. [online] Available at: https://www.esmap.org/node/153673 [Accessed 25 Feb. 2019].

[13]. Fettweis, G. and Zimmermann, E., 2008, September. ICT energy consumption-trends and challenges. In *Proceedings of the 11th international symposium on wireless personal multimedia communications* (Vol. 2, No. 4, p. 6). (Lapland.

[14]. Gelagay, H.S., 2017. Geospatial Data Sharing Barriers Across Organizations and the Possible Solution for Ethiopia. *International Journal of Spatial Data Infrastructures Research*, *12*, pp.62-84.

[15]. Gelagay, H.S., 2017. Geospatial Data Sharing Barriers Across Organizations and the Possible Solution for Ethiopia. International Journal of Spatial Data Infrastructures Research, 12, pp.62-84.

[16]. Girma, Z. (2016). Techno-Economic Feasibility of Small Scale Hydropower in Ethiopia: The Case of the Kulfo River, in Southern Ethiopia. Journal of Renewable Energy, 2016, pp.1-12.

[17]. Harvey, F., 2011. Constructing GIS: actor networks of collaboration. *URISA Journal*, *13*(1), pp.29-37.

[18]. Hussein, A. A., Govindu, V., &Nigusse, A. G. M. (2017). Evaluation of groundwater potential using geospatial techniques. Applied Water Science, 7(5), 2447-2461.

[19]. Khan, B. and Singh, P., 2017. The Current and Future States of Ethiopia's Energy Sector and Potential for Green Energy: A Comprehensive Study. In *International Journal of Engineering Research in Africa* (Vol. 33, pp. 115-139). Trans Tech Publications.

[20]. Khudaiberdievna, T.G., 2019. Actual trends in modern creative photography. *World Scientific News*, *119*, pp.85-96.

[21]. Korkovelos, A., Mentis, D., Siyal, S., Arderne, C., Rogner, H., Bazilian, M., Howells, M., Beck, H. and De Roo, A. (2018). A Geospatial Assessment of Small-Scale Hydropower Potential in Sub-Saharan Africa. Energies, 11(11), p.3100.

[22]. Kougias, I., Szabó, S., Monforti-Ferrario, F., Huld, T. and Bódis, K., 2016. A methodology for optimization of the complementarity between small-hydropower plants and solar PV systems. Renewable Energy, 87, pp.1023-1030.

[23]. Krauer, J., 2008. Geospatial Information for Natural Resources Management-EthioGIS: Supporting NSDI in Ethiopia.

[24]. Kumar, P., Rani, M., Pandey, P.C., Sajjad, H. and Chaudhary, B.S., 2019. *Applications and Challenges of Geospatial Technology*. Springer.

[25]. Lu, Y. and Liu, Y., 2012. Pervasive location acquisition technologies: Opportunities and challenges for geospatial studies. *Computers, Environment and Urban Systems*, *36*(2), pp.105-108.

[26]. Mentis, D., Andersson, M., Howells, M., Rogner, H., Siyal, S., Broad, O., Korkovelos, A. and Bazilian, M., 2016. The benefits of geospatial planning in energy access–a case study on Ethiopia. *Applied Geography*, *72*, pp.1-13.

[27]. Mentis, D., Andersson, M., Howells, M., Rogner, H., Siyal, S., Broad, O., Korkovelos, A. and Bazilian, M., 2016. The benefits of geospatial planning in energy access–a case study on Ethiopia. *Applied Geography*, *72*, pp.1-13.

[28]. Mentis, D., Andersson, M., Howells, M., Rogner, H., Siyal, S., Broad, O., Korkovelos, A. and Bazilian, M. (2016). The benefits of geospatial planning in energy access – A case study on Ethiopia. Applied Geography, 72, pp.1-13.

[29]. Mentis, D., Howells, M., Rogner, H., Korkovelos, A., Arderne, C., Zepeda, E., Siyal, S., Taliotis, C., Bazilian, M., de Roo, A. and Tanvez, Y., 2017. Lighting the World: the first application of an open source, spatial electrification tool (OnSSET) on Sub-Saharan Africa. *Environmental Research Letters*, *12*(8), p.085003.

[30]. Mentis, D., Howells, M., Rogner, H., Korkovelos, A., Arderne, C., Zepeda, E., Siyal, S., Taliotis, C., Bazilian, M., de Roo, A., Tanvez, Y., Oudalov, A. and Scholtz, E. (2017). Lighting the World: the first application of an open source, spatial electrification tool (OnSSET) on Sub-Saharan Africa. Environmental Research Letters, 12(8), p.085003.

[31]. Mondal, M.A.H., Bryan, E., Ringler, C. and Rosegrant, M., 2016, January. 100% electrification and renewable based Ethiopian power sector development strategies. In *2016 4th International Conference on the Development in the in Renewable Energy Technology (ICDRET)* (pp. 1-4). IEEE.

[32]. Nickel, D.R., 2001. History of photography: the state of research. *The Art Bulletin*, *83*(3), pp.548-558.

[33]. Pérez-Lombard, L., Ortiz, J. and Pout, C., 2008. A review of buildings energy consumption information. *Energy and buildings*, *40*(3), pp.394-398.

[34]. REEEP. (2019). REEEP - Ethiopia (2014). [online] Available at: https://www.reeep.org/ethiopia-2014 [Accessed 25 Feb. 2019].

[35]. Sui, D. and Goodchild, M., 2011. The convergence of GIS and social media: challenges for GIScience. *International Journal of Geographical Information Science*, *25*(11), pp.1737-1748.

[36]. Szabó, S., Bódis, K., Huld, T. and Moner-Girona, M., 2013. Sustainable energy planning: Leapfrogging the energy poverty gap in Africa. Renewable and Sustainable Energy Reviews, 28, pp.500-509.

[37]. Tekle, F. T. (2014). Assessment of solar energy resources in Ethiopia: modeling solar radiation and GIS-based multi-criteria analysis (Master's thesis, NTNU).

[38]. Zeleke, G., Alemu, B., Hergarten, C. and Krauer, J., 2008. Consultation Workshop on National Spatial Data Infrastructure and Ethio-GIS (2nd Release): Workshop Proceedings.

[39]. Zhou, Y., Hejazi, M., Smith, S., Edmonds, J., Li, H., Clarke, L., Calvin, K. and Thomson, A., 2015. A comprehensive view of the global potential for hydro-generated electricity. Energy & Environmental Science, 8(9), pp.2622-2633.

[40]. Zlatanova, S. and Li, J. eds., 2008. *Geospatial information technology for emergency response* (Vol. 6). CRC Press.