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Pan African University INSTITUTE OF WATER AND ENERGY SCIENCES (including Climate Change)

– PAUWES –

Pan African University Institute of Water and Energy Sciences

Book of Posters - 2018

Pan African University Institute of Water and Energy Sciences

PAU Nurturing Quality, Exemplifying Excellence

PAUWES Director's word

Prof. Abdellatif Zerga

It is my pleasure to present the 3rd cohort of Pan African University Institute of Water and Energy Sciences (PAUWES) who have weathered through an excellent academic and disciplinary training in the field of Energy and Water (Engineering and Policy tracks).

The 79 graduates coming from countries across Africa have worked zealously over the past two years to gain mastery in the field of Water and Energy Sciences. After successfully completing their coursework requirements, they conducted practice-oriented research for their master thesis based on case studies relevant to continent-wide issues. Their exposure to first class tuition, academic exercise and internship across various private and public sectors have culminated into making them innovative, motivated and entrepreneurial. It is of no wonder that our students keep conceiving and implementing ideas and projects such as the Entrepreneurship and Innovation Club and PAUWES Climate Change and Gender Club which aims at tackling the most burning issues of energy and water security through the creation of climate change awareness across Africa; in addition to taking active roles in managing a student social networking platform - the Community of Practice (CoP).

We, as an institute, pride our self in fostering the academic setting required to ensure the success of our students. I must acknowledge also that our success so far could not have been possible without the unflinching support of the Algerian Ministry of Higher Education and Scientific Research, the German Ministry of Economic Cooperation and Development (BMZ), the German Ministry of Education and Research (BMBF), the German Technical Development Agency (GIZ), the German Development Bank (KfW) and the German Academic Exchange Service (DAAD) as well as the German Higher Education Consortium, and all research partners of PAUWES in Africa such as, WASCAL, 2IE, and the University of Niamey in addition to our host institute—the University of Tlemcen. I also would like to thank the PAU Rectorate, PAUWES staff and lecturers for their support and commitment.

One of the main goals of this institution is to promote the diversity and innovative spirit found within Africa. It is within this mind-set that PAUWES has attracted a larger amount of students from more African nations than ever before. We are proud to announce that we will be welcoming 62students from more than 20countries this coming fall as the incoming Class of 2019. It is with great confidence that we send off the Class of 2018 into their bright futures and look optimistically towards educating the next generation of African leaders in the field of energy and water engineering and policymaking to meet the goals of Agenda 2063.

Pan African University (PAU)

Research and Education for a Peaceful, Prosperous and Integrated Africa

The Pan African University (PAU) is an initiative of the African Heads of State and national governments of the African Union. It is a premier continental university network whose mission is to provide a comprehensive postgraduate education geared towards the development of a prosperous, integrated and peaceful Africa. PAU is part of an African Union Commission (AUC) initiative to revitalize higher education and research in Africa. The PAU strives to foster academic excellence and to enhance the quality of education all the while promoting the attractiveness and global competitiveness of African higher education and research. Five thematic institutes have been established in Algeria, Kenya, Nigeria, Cameroon, and South Africa. The institutes provide Master and PhD programmes and engage in collaborative and development-oriented research. The PAU aims to provide the opportunity for advanced graduate training and postgraduate research to motivated African students. Other objectives also include promoting mobility of students and teachers, as well as harmonizing programs and degrees within the African continent.

Pan African University

Institute of Water and Energy Sciences (including climate change)- PAUWES

The Pan African University Institute of Water and Energy Sciences (including climate change) (PAUWES) is one of the five hub of the Pan African University and is hosted at the University of Tlemcen in Algeria .PAUWES holds a unique position in understanding the Pan-African dimension of scientific problems and is especially suited to find solutions to the challenges faced in different African countries with regards to water, energy and climate change .

PAUWES is committed to educating and shaping the next generation of African leaders who will address the issues critical to Africa's sustainable development, such as water, clean energy, and the challenges associated with climate change. PAUWES offers our graduate students with a diversity of academic perspectives by attracting faculty from across Africa and around the world, as well as providing our students with the tools and training needed to ensure their future success.

PAUWES offers four degree programmes

Master of Science (M.Sc.) in Energy:

- Engineering Track
- Policy Track

Master of Science (M.Sc.) in Water:

- Engineering Track
- Policy Track

Book of Posters

Graduates Class of 2018

This book of graduates is dedicated to the PAUWES graduates class of 2018.

It is a short summary of the works done by the graduates students of 2018 as reseach contribution on different issues and challlenges on the continent non only on the thematic of water and energy, but also on issue addressing water-energy nexus and climat change related issues. These works have been conducted with policy and engineering apporaches according to students' profiles.

The different master thesis projects were conducted with and include case studies in fifteen African countries from the five different regions of continent.

This book is organized around the four courses offered by the institute: Enery Engineering, Energy Policy, Water Egineering and Water Policy.

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Drought Analysis for Water Planning in Agriculture: A Case Study of Gourma Province, Eastern Burkina Faso

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Master of Sciences

Energy Engineering

Design and Analysis of an Off-grid Hybrid Renewable Energy System to Supply Electricity in Small Industries: A Case Of Tanzania

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Abstract

Hybrid power system with various combinations based on renewable sources could be applied simultaneously to cater energy in the form employed in an off-gird supporting with battery storage and diesel generator as backup systems. In this study wind turbine, photovoltaic, battery bank and converter system have been simulated and optimized for the Bellaview Fresh Fruit Processing Industry Ltd in Rombo, Kilimanjaro region in Tanzania. Electric load demand of 1600 kWh/day, peak load of 184 kW was involved during optimization of the power system.

BACKGROUND/CONTEXT

- In the present world, every country is giving important place on energy security and sustainable development.
- The rapid industrialization and growth of Tanzania human population have resulted in the unprecedented increase in the demand for energy and in particular electricity.
- Promoting electricity generation based on non-conventional renewable energy is inevitable.
- Energy security under varying weather conditions and the corresponding system cost are the two major issues in designing hybrid power generation systems.
- The design of hybrid Renewable energy system is an important issue in small industries to increse productivity.

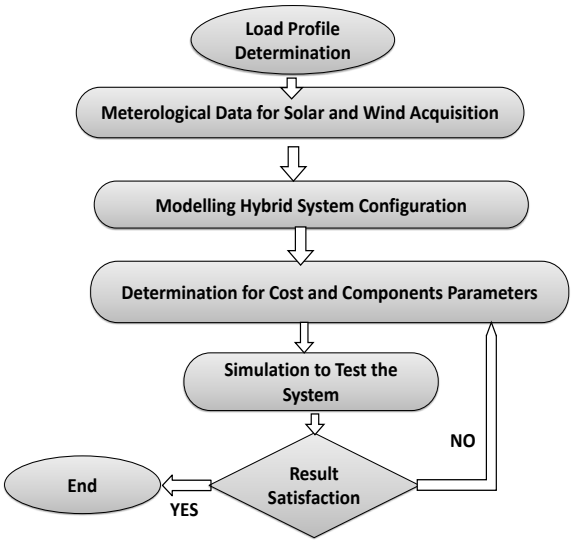
PROBLEM STATEMENT/RESEARCH QUESTION

Despite of the abundant renewable energy resources in Tanzania, many Industries still live and operate under low adequite supply of electricity either from the utility grid or independent renewable energy generated electricity.

OBJECTIVES

Design of an off-grid hybrid renewable energy system that can generate and provide cost effective electricity to the targeted industry

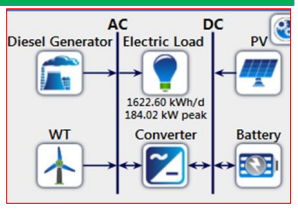
METHODOLOGY



RESULTS AND DISCUSSION

Scenarios considered

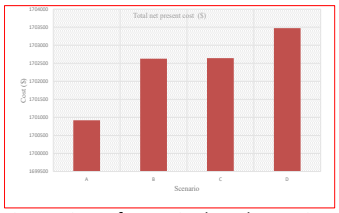
- PV-Wind turbine-battery bank scenario A
- Solar PV-wind turbine-generator-battery bank scenario B
- Wind-battery bank scenario C
- Wind turbine- generator-battery bank scenario D



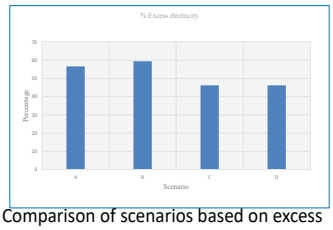
Architecture of the selected technologies

Architecture								Cost			
PV (kW)	WT	Diesel Generator (kW)	Battery	Converter (kW)	NPC ($)	Initial capital ($)	Fuel cost ($/yr)	O&M ($/yr)
189	8		487	142	$1.70M	$1.24M	$0.00	$13,679
258	8	10.0	393	150	$1.76M	$1.34M	$36.09	$14,642
	8		1,186	232	$2.93M	$1.62M	$0.00	$37,860
	8	10.0	1,166	246	$2.94M	$1.63M	$31.26	$33,882

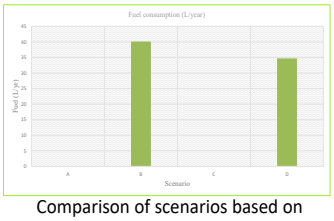
Categorized simulation result system produced by HOMER



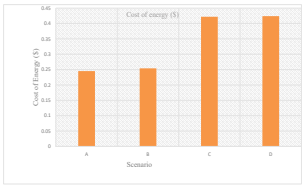
Comparison of scenarios based on NPC



Comparison of scenarios based on excess electricity



Comparison of scenarios based on diesel fuel consumption



Comparison of scenarios based on COE

CONCLUSION

- The selected hybrid system set-up [PV-wind turbine-battery bank *(scenario A)*]which is cost efficient system composed of 8 unit wind turbines with 100 kW each rating power, 189 kW photovoltaic panel, 487 unit batteries, and 142 kW converter.
- To meet the energy requirement of the National, hybridizing renewable energy technologies can cater for sustainable solutions.

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Design of Solar PV-Biogas Hybrid Power System for Rural Electrification in Ghana

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Contact details: flavioodoi@hotmail.com

Abstract

In this study, a solar PV-biogas hybrid power system for electrification is designed for Mankramso community located in the Offinso-North district in Ghana. The findings show that the system configuration which comprises of 18.6 kW of PV panels, 45 kW of biogas generator, 62 kWh of battery storage and 15.7 kW of converter is the most optimal hybrid power system configuration to meet the daily electric load. This optimal hybrid power system has a total net present cost (NPC) of US$ 219,442 and a levilized cost of energy (LCOE) of US$ 0.188/kWh that is only 10.6% higher than current LCOE (US$ 0.17/kWh) for residential tariffs in Ghana. We recommend that rural electrification projects of such nature are combined with innovative energy efficiency practices to increase access to reliable and affordable electricity in rural communities.

BACKGROUND/CONTEXT

- Energy plays a very keen and relevant role in socio-economic and sustainable development of every country.
- Deployment of renewable energy will help to meet Sustainable Development Goals such as clean & affordable energy, no poverty, zero hunger, quality education, good health & well-being, clean water & sanitation, mitigating climate change (IRENA, 2015).
- As at the end of the year 2016, electrification access rate was 89.8% **(Urban areas)** and 66.6% **(Rural areas)** in Ghana (World Bank, 2018).
- Hybrid power systems are cost-effective and more reliable than single source power system (Adaramola et al., 2014).

PROBLEM STATEMENT/RESEARCH QUESTION

- High emissions of Greenhouse gases from the combustion of fossil fuels – need to switch to cleaner power systems.
- Most rural areas in Ghana have no access to electricity due to the lack of grid power system – need to develop off-grid or standalone power systems.
- Depletion of fossil fuels – need to develop alternative and renewable energy systems and increase the penetration of renewable power systems in the energy mix.
- Population growth – The future energy demand will increase due to population growth thus increase the energy production and diversification of the energy systems.

OBJECTIVES

To design and optimize an off-grid solar PV-biogas hybrid power system for rural electrification in Mankramso community in Ghana

METHODOLOGY

Hybrid Optimization Model for Electric Renewable **(HOMER)** software was used to perform **technical, economic** and **greenhouse gas (GHG) emission** analysis of the solar PV-biogas hybrid power System

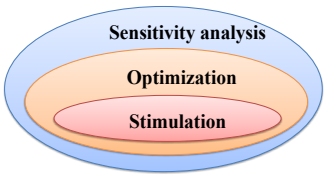


Fig. 3.1: Principal task of HOMER Software

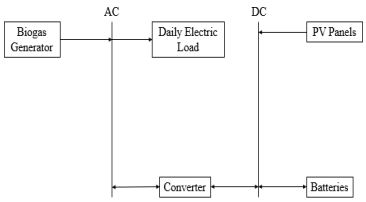


Fig. 3.2: Schematic layout of the Solar PV-biogas hybrid power system

Input data
- Electric load demand
- Renewable resources (solar and biomass)
- Components including cost parameters
- Economic parameters
- System contraints

HOMER Software

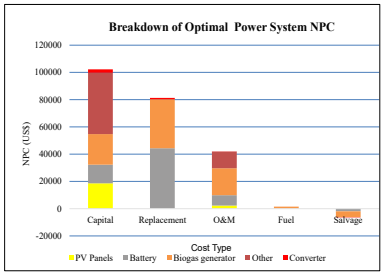
Output
- Optimal system sizing
- Net present cost (NPC)
- Levilized cost of energy (LCOE)
- Capital cost
- Capacity shortage
- Excess energy generation
- Renewable energy fraction
- Fuel consumption

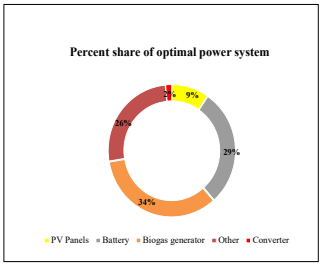
Fig. 3.3: Schematic layout of HOMER software

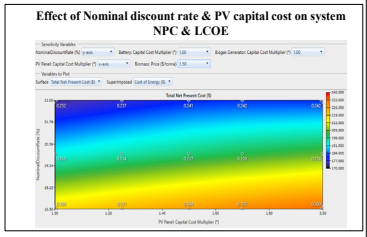
RESULTS AND DISCUSSION

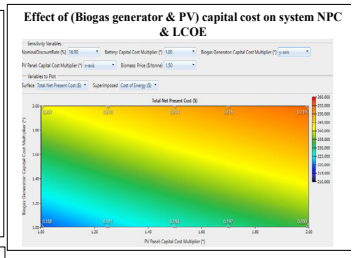
Optimization Results of Most Optimal and Feasible Power System Configuration for Mankramso community

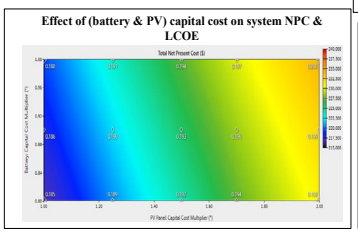
Rank	PV Panels kW	Biogas generator kW	Battery kWh	Converter kW	LCOE US$/kWh	NPC (1000) US$	Operating cost (1000) US$	Initial capital (1000) US$
1	18.6	45.0	62.0	15.7	0.188	220	9.6	103
2	-	45.0	64	15.5	0.205	241	12.8	85
3	257	-	936	108	0.716	838	25.8	523

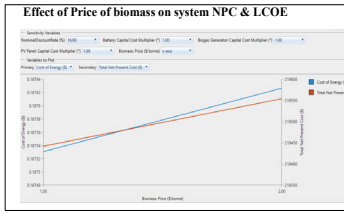












CONCLUSION

- The system will produce 105,479 kWh/yr of electricity and 95,633 kWh wil be consumed by Mankramso community AC loads with an electricity exces of 4,676 kWh/yr.
- Moreover, the system has a NPC of $219,442 with a LCOE of $ 0.188/kWh This LCOE is only 10.6% higher than current residential tariffs (US 0.17/kWh) in Ghana.
- Project lifetime: 25 years; ROI: 12.4%; IRR: 16.5%; Payback time: 5 years
- Furthermore, results from sensitivity analysis shows that, increasing the PV panel capital cost and decreasing the biogas generator capital cost wil decrease the LCOE of the system, thus, making it cost-effective.

REFERENCES

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Design of Home Electricity Supply System using Solar PV and its Integration to the National Grid: A Case Study of Masaka Village

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Abstract

Due to a rapid increase in household biomass energy consumption which has been occurring recently in Rwanda particularly in urban and semi-urban households due to the energy crisis in Rwanda, solar energy is promoted and widely adopted at the domestic level. This work presents a study that examined the possibility of supplying electricity to Masaka village households by using a grid-connected solar PV system. Information gathered have demonstrated that Masaka village receives a monthly average solar insolation of 4.8 kWh/m2/day for the most time of the year. The selected middle-class family has the average peak power of 5.93 kWp while the total daily energy consumption is 8.3 kWh. RETScreen Expert was used to size and simulate the PV system suitable for the selected house. Considering the daily energy consumption for the household and different loses, a 3 kW PV system was sized where the surplus electricity during off-peak demand could be exported to the grid and be imported when there is a low production for the system. The cost-benefit analysis results reveal that solar energy is viable in this selected village with an initial investment of $ 11,489 and a payback period of 8.1years.

BACKGROUND/CONTEXT

The gap between energy demand to meet the needs of the Rwanda energy sectors and the generation capacity and the energy generation capacity is huge: about 70% of the population have no access to electricity and more than 80% have no access to clean modern energy; despite the facts that the country has abundant solar energy potential to support its energy. Only 31% of the population has an access to the national grid with most of them from urban areas. Rwanda conventional energy resources are limited, the best solution is then to develop its renewable energy resources.

PROBLEM STATEMENT/RESEARCH QUESTION

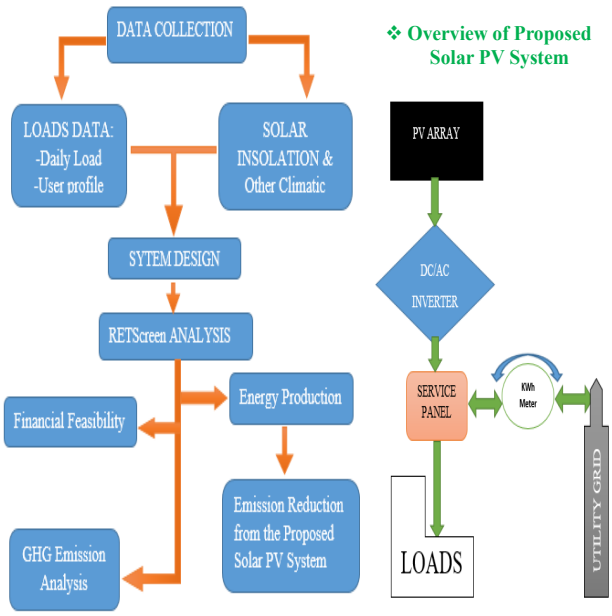
According to MININFRA 2016, Rwanda faces the problem of insufficient energy to meet the needs of the country. Rwanda has the highest electricity prices compared to that of neighboring countries in the region.

With grid-connected consumers paying roughly Rwf182 ($0.22)/kWh)(Livingstone, 2015): due to high cost of imported oil and to poor transmission system(20% of energy is lost).

OBJECTIVES

Design and techno-economic analysis of an electrification system for a remote area. This project address the issues challenging the viable and sustainable provision of electricity to Rwanda

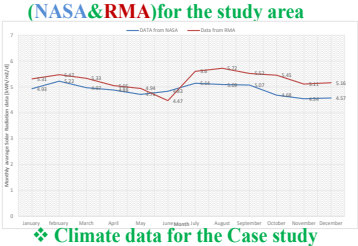
METHODOLOGY



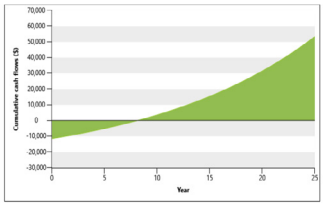
❖ Overview of Proposed Solar PV System

RESULTS AND DISCUSSION

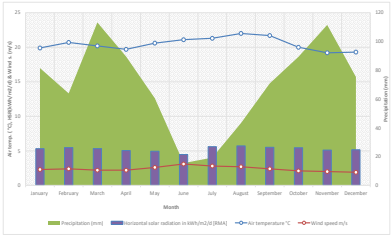
❖ Solar insolation Data (NASA&RMA)for the study area



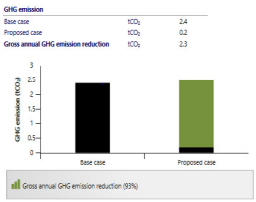
❖ Cumulative cash flow



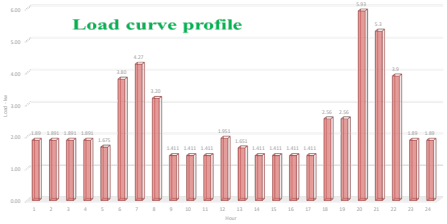
❖ Climate data for the Case study



❖ GHG Emission analysis



For 25-years lifetime for the system will reduce the amount of GHG emission by 57.5 tones.



The max. power consumption demand, for the picked household is roughly equivalent to 5.93kWp.

CONCLUSION

- A **8.36 kWh electricity is needed** for the middle-class households: design of the system with 10 panels of 300Watt capacity each.
- The study has revealed that Masaka receives a monthly average solar insolation of 4.88kWh/m2/day for most time of year.
- In addition, the cost-benefit analysis was performed to determine if the investment would be financially worthwhile. The results reveal that solar energy is viable in this selected village with an initial investment of $ 11,489 and a payback period of 8.1years.

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Feasibility Study of Hybrid Renewable Energy Systems Mini-Grids for Rural Communities in Mali: Case Study Sokolo

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Abstract

Access to energy and electricity remains a challenge in Sub Saharan Africa, particularly in remote rural Mali. In this study various options of hybrid (renewable) energy system were designed for rural electrification perspective. This study assesses the feasibilities of hybrid renewable power systems for the Sokolo community in Mali. The Hybrid Optimization Model for Electric Renewable (HOMER) software was used to run the technical and economic analyses for various scenarios and compared to the system used by AMADER(Malian agency for domestic energy and rural electrification). In addition sensitivity analysis is performed to consider uncertainty in variables: biomass price, PV equipment (modules, batteries, converter, and inverters) and biogas generator price multiplier on the NPC and the LCOE of the selected system.

BACKGROUND/CONTEXT

The supply of clean, reliable and affordable sustainable and environmental friendly energy is a condition for economic, social and industrial development of a nation and the population well-being, RE sources play major role in achieving electricity access in both grid-based and decentralized technologies essential for remote rural areas power generation .

PROBLEM STATEMENT/RESEARCH QUESTION

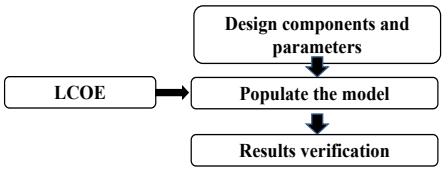
In rural communities, electricity access is a challenge, and grid extension is expensive. Rural areas produce enough biomass and agricultural residues so that their electricity demands can be met by biomass power plants. Apart from providing the rural communities energy self-sufficiency, these plants can also generate enough employment opportunity . Rural employment and wasteland development is possible through this sustainable and renewable source of energy .

OBJECTIVES

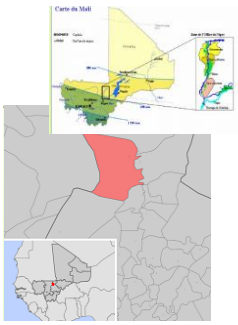
Find a suitable cost-effective, clean and environmentally friendly (HRES) based biomass (locally produced rice straw) for the people of Sokolo

METHODOLOGY

The design of **micro solar-biogas battery hybrid power system**, require inputs such as hourly load profile, available biomass (tonne/day), **cost of biomass**, monthly solar radiation, value for a PV system, the initial costs of each component, cost of diesel fuel, annual real interest rate. **(local RE sources were considered)** Wind and hydropower were not integrated because of the low potential of wind resource in the region and use of water for irrigation.



STUDY AREA



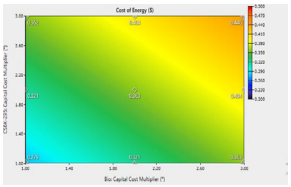
Located in the southern Mali with 22,310 inhabitants in 2017, 2,219 Km² for surface area Sokolo is a major rice growing community in Office du Niger . Office du Niger represents 40% of the total Malian production and close to high voltage transmission line, to allow transport of excess energy.

RESULTS AND DISCUSSION

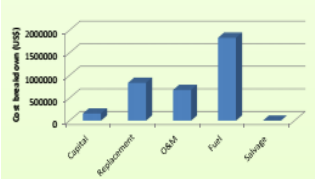
Emission analysis of a HRES (conventional and renewable)

	Scenario B	Scenario C
Carbone dioxide kj/yr	429	72,748
Carbon Monoxide kj/yr	0,728	495
Unburned Hydrocarbons kj/yr	0	20
Particulate Matter kj/yr	0	1,98
Sulphur Dioxide kj/yr	0	178
Nitrogen Oxides kj/yr	0,455	39,6

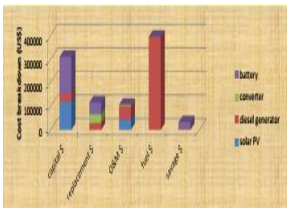
Effects of solar PV and biogas generator cost on LCOE cost of energy



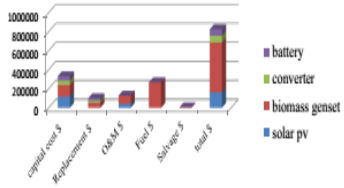
Cost summary of scenario A
NPC $ 3,508,888
LOCE $/kWh 1.21



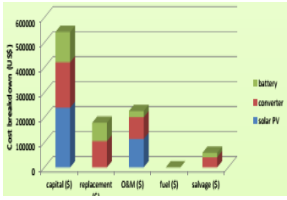
System cost summary C
NPC $ 930,883



Cost summary system B
NPC $ 804,174
LCOE $/kWh 0.279



Scenario D cost summary
NPC $ 888,239.10
LOCE $/kWh 0.238



CONCLUSION

- Optimal system for the to supply Sokolo's load was found to be Scenario B:100 kW PV array, 150 kW biogas genset 144 battery 30kW of converter
- The LCOE US$ 0.279/kWh, NPC US$ 804,174 CO2 emission 490 kg/yr, PT of 8 years and RE fraction 100%.
- The study concludes that agricultural residue can be incorporated in electricity generation and lead to affordable and environmentally friendly and cost competitive supply of electricity and increase electricity access and generate economic activities specially in rural remote areas and can be a better way of disposal for theses agricultural wastes.

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Modelling and Optimization of a Stand-Alone PV-Diesel Hybrid System with Hydrogen Storage: Case of Algeria

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Abstract

The aim of this study is to find the optimum system configuration of a hybrid power system that can supply electricity to a rural community in south of Algeria. A rural village from the region of Adrar containing 15 households is selected with a daily electricity demand of 145.44 kWh and a day-time peak of 39.80 kW. HOMER Pro. (Hybrid Optimization Model for Electrical Renewables) computer modeling software was used to model the power system. The hybrid system configuration has been found to be 21.7kW-PV, three 10kW-diesel genset, 20.0kW-electrolyzer and 380kg-hydrogen tank. The total Net Present Cost NPC of this hybrid power system was found to equal $823.744 and electricity can be supplied at an approximate cost of energy LCOE of 0.60 $/kWh.

BACKGROUND/CONTEXT

According to the REEEP, the Algerian Sahara has an average solar energy of 6.57 kWh/m^2/day. [1]. In order to increase the exploitation of the solar energy potential in Algeria while mitigating the climate changes effect and reducing the toxic pollutants, the installation of hybrid systems represents an excellent option especially in remote areas where the national grid is not available. PV systems and electrolysers can be combined with hydrogen storage and a diesel generator. Unlike batteries, which are considered as flexible and fast response back up storage but very costly, the diesel genset can generate electricity for limitless time to support the PV generator. Hence, combining all of the PV generator, the diesel generator and the hydrogen storage will assure a continuous supply of high quality power generation and an effective storage of energy in form of gas.

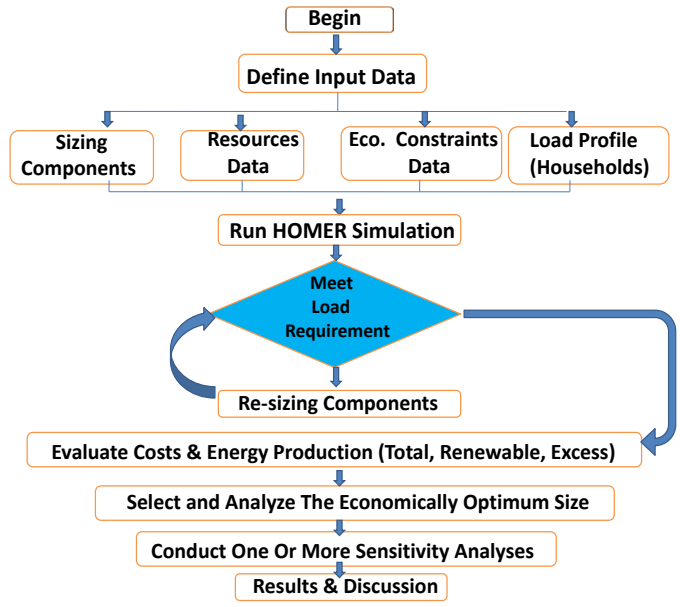
PROBLEM STATEMENT/RESEARCH QUESTION

Algeria relies on fossil fuels to satisfy the national demand of electricity where they account 99% of the electricity generation with the remainder generated by hydropower [2]. This may lead to the depletion of such resources, thus facing a serious national energy shortage crisis.

OBJECTIVES

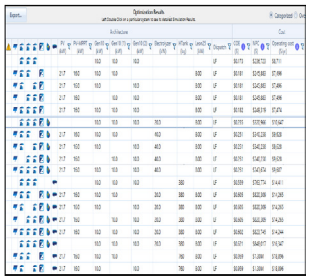
Modelling and designing a PV/diesel hybrid power system associated with hydrogen storage to fulfill the electricity demand of fifteen (15) households in Adrar in affordable, reliable and sustainable way with cost-effective solution.

METHODOLOGY



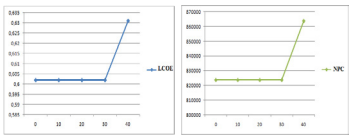
RESULTS AND DISCUSSION

HOMER categorized optimization results



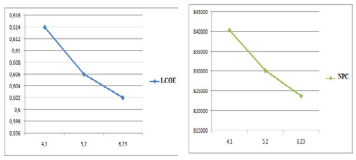
❖ The NPC of the HPS was found to be $823,744 and the LCOE was 0.602$/kWh.

(a) LCOE (b) NPC at different minimum renewable fraction



❖ The increase in both LCOE and the NPC is due to the increase in the solar PV system capacity.

(a) LCOE (b) NPC at different annual average solar radiation



Energy produced by the different energy sources and their shares

Production	kWh/yr	%
PV	37,354	51.24
Genset 1	31,342	43.0
Genset 2	3,437	4.72
Genset 3	759	1.04
Capacity shortage	-	0.188

❖ Solar PV has the highest share however most of it is used to produce hydrogen by the electrolyzer.

CONCLUSION

- At present, hybrid power systems with hydrogen storage are not cost-competitive against both stand-alone conventional fueled system and grid utility power source. However, such storage system type offers the possibility to store safer, cleaner and more efficient energy.
- From the lifetime cost analysis, the estimated levelized cost of electricity LCOE has been found to be 0.602 $/kWh.
- It has been also that this cost increases either with the increase in the minimum renewable fraction of the decrease in the annual average solar radiations.

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Optimization of the Compression Ratio of a Diesel Engine Running on Croton Biodiesel

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Abstract

Over the past few decades, there has been growing concerns over the sustainability of petroleum derived fuels. A number of previous studies have identified croton seed biodiesel as a very promising fuel that can substitute diesel fuel in an internal combustion without any major modifications on the engine. The aim of this study was to analyze the performance, combustion and emission characteristics of a variable compression ratio CI engine running on croton bio-diesel. From the results of the study, croton biodiesel can be used in a diesel engine without any major modifications.

BACKGROUND/CONTEXT

The global energy mix is dominated by fossil fuels, representing over 80% of the total energy supplied in the world today. In the next few years, the world will reach its peak oil production. In addition, the world is faced with issues of environmental pollution and serious global warming. Bio-fuels provide the most promising alternative to the fossil-derived fuels. Croton oil is available in abundance in most regions of Eastern and Southern Africa.

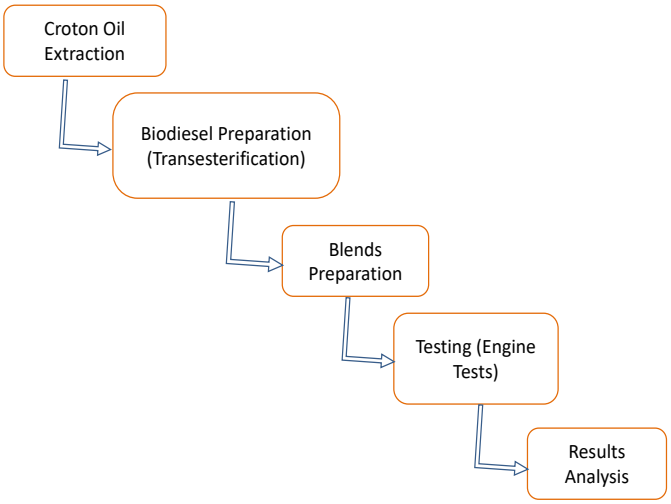
PROBLEM STATEMENT/RESEARCH QUESTION

The world's energy supply will reach its midpoint of depletion and maximum production around the year 2020. Burning of fossil fuels for electricity production, transport and heating contributes the highest percentage of green house gas emissions. The world is getting more concerned about the depletion of oil reserves, the environmental issues as well as the ozone layer depletion caused by combustion of fossil fuels.

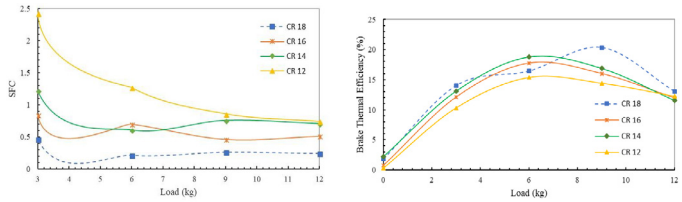
OBJECTIVES

To investigate the effects of varying compression ratios on the performance, combustion characteristics and emissions of a compression ignition engine running on croton biodiesel-diesel blends.

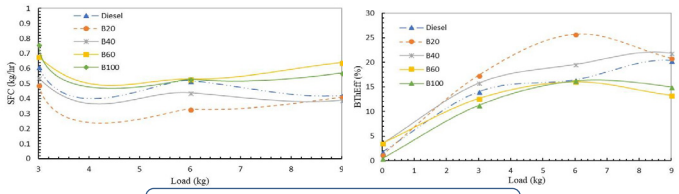
METHODOLOGY



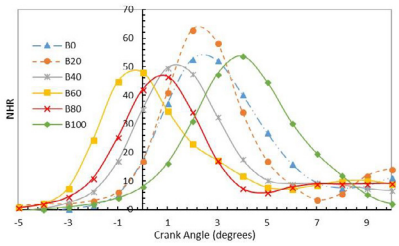
RESULTS AND DISCUSSION



CR 18 has the best performance characteristics



B20 has the best performance characteristics



- B20 produces the optimum NHR curve
- The blend also has the best MGT and MFB characteristics

CONCLUSION

- A higher CR (CR 18) is desirable in a croton biodiesel – diesel fuelled engine
- Blend B20 produces excellent engine characterisitcs. Higher amounts of the biodiesel reduce engine efficiency.
- Blending diesel with croton biodiesel reduces CO emissions
- Croton biodiesel can be used in a diesel engine without any modifications on the engine.

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Sustainable Energy Transitions for Ghana

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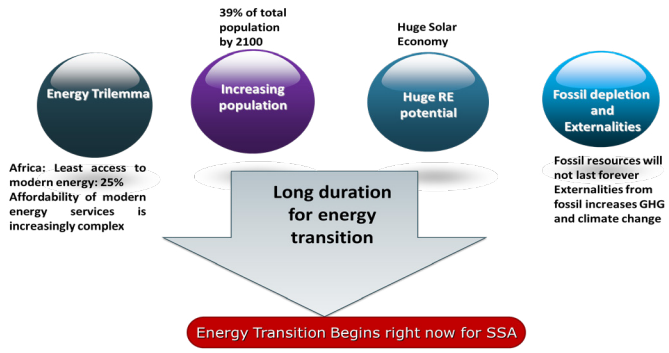
Abstract

The project uses the Energy Return on Energy Invested (ERoEI) to measure the sustainability of fossil and scale unlimited renewable resources (Wind and solar) in Ghana. Considering the dynamic evolution and stochastic behaviour of ERoEI, causal and feedback loops (systems dynamics) are used to model the interactions between the different intervening variables of the two sub systems under investigation: the fossil and the renewable sub system. A timeseries of dynamic evolution of ERoEI is developed for a period of 90 years starting from 2010 to 2100 to characterize and display the sustainability of energy resources available in Ghana.

BACKGROUND/CONTEXT



Sub Sahara Africa Energy Scenario, the challenges, the Opportunities and the need for a transition

PROBLEM STATEMENT/RESEARCH QUESTION

How does ERoEI define a Sustainable transition ?

How can a timeseries of ERoEI be developed using System Dynamics to capture the stochastic and dynamic evolution of the Ghanaian Energy System?

OBJECTIVES

1. Provide information on the technological progression and resource depletion of the different energy resources in Ghana
2. Show how ERoEI metric can be used to assess among different technologies which ones are sustainable and preferential according to the trends of the ERoEI
3. Provide a timeseries information on the annual production and the net energy available for each energy resource to meet the demands of Ghana.

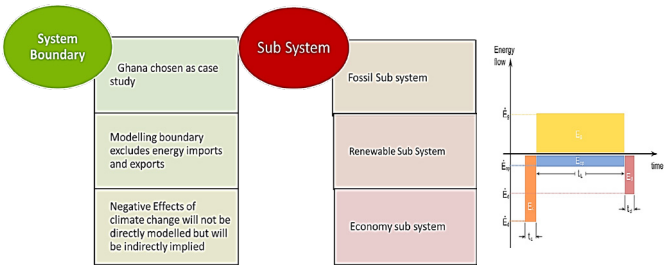
METHODOLOGY

The methodology used in this thesis is a system dynamics approach of modelling the physical component of the resource and the technological progression.

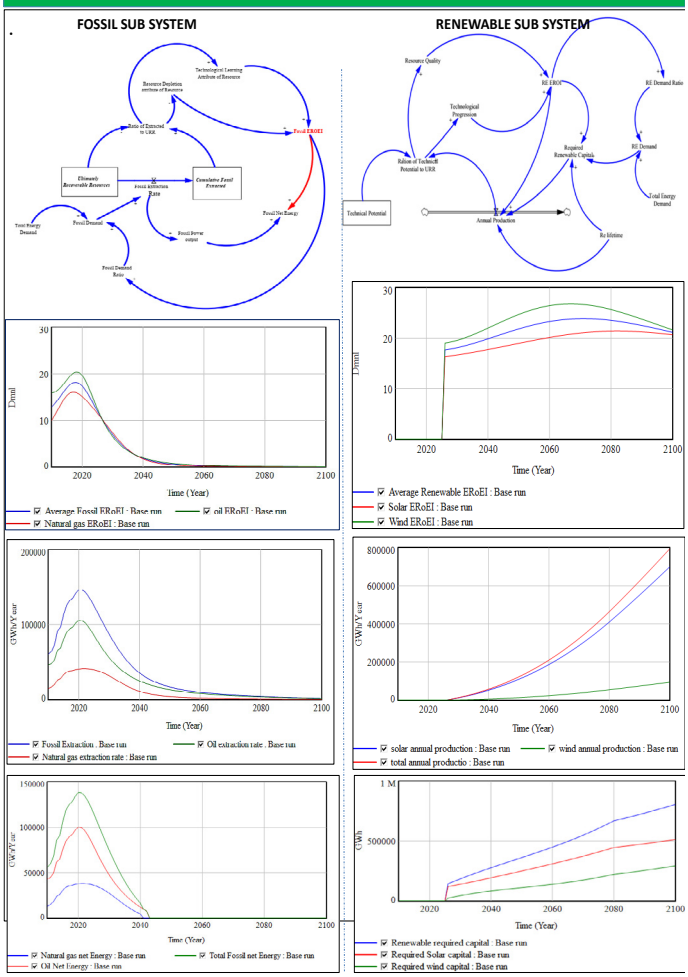
$$EROI_k = \varepsilon_k F(p_k) = \varepsilon_k\, G(p_k) H(p_k)$$

$$G(p_k) = 1 - \gamma e^{-\xi p}$$

$$H(p_k) = \phi e^{\psi p}$$



RESULTS AND DISCUSSION



CONCLUSION

- The significance of this study is to aid energy planning institutes on the priorities of energy infrastructures development owing to the dynamics of the energy return on investments.
- In the case of Ghana with government's plan to expand thermal plants, our results show though this a workable solution for the moment, it won't be a suitable and sustainable as the energy return on investments for natural gas and oil are expected to fall rapidly after 2020 and consequently the fossil resources' depletion is expected to occur by 2040.
- Solar potential in Ghana is very high and solar technology will be the main energy resource for the country for a sustainable transition process.
- Wind too has a considerable potential but with a low resource quality, however, wind technology remains crucial to Ghana.
- We therefore recommend the government of Ghana to quickly implement policies that will accelerate the development of scale unlimited renewables and increase high integration and penetration of renewables.

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Technical Feasibility Study of Biogas Production for Electricity Generation: Case of a Community of Manwi District in Ngaoundere - Cameroon

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Abstract

This study aimed to assess the electrical potential from pig manure produced in a piggery in Manwi district in Ngaoundere (Cameroon). The study consisted firstly to obtain the amount of manure available through census of existing animals. Evaluation of the potential biogas to be produced from manure and electricity consumption in the community around the pig farm followed. Comparison between the electricity potential of biogas and the electricity consumption of the community shows that only 13 % of the electricity need is covered by biogas from pig manure.

BACKGROUND/CONTEXT

- Almost 71.8% of the population in Cameroon in 2014 relies on biomass mostly wood and charcoal for heating and cooking. Hydro is the main resource used for electricity generation.
- Recurring power shortage in the country is now a handicap for business owners and students.
- Main waste streams identified in Cameroon are animal dung, wastewater from slaughter houses, agro-industrial wastes, food waste, municipal solid waste and industrial wastes, all sources of pollution.
- Thus, sustainable distributed electricity generation seems to be an opportunity to increase the rate of rural electrification while solving waste management issue in Cameroonian context.

PROBLEM STATEMENT/RESEARCH QUESTION

- Until now, several case studies in the region are focused on biogas production through anaerobic digestion or co-digestion for cooking with animal manure and/ or agriculture waste as primary resource.
- Electricity generation potential from anaerobic digestion is still unexplored.

OBJECTIVES

This study aims generally :
to assess livestock potential and its potential valorization ways.
Specifically,:

1. Assessment of animal manure potential
2. Assessment of available energy from animal waste;
3. Assessment of energy needs;

METHODOLOGY

1. **Feedstocks assessment**
2. **Waste characterization and estimation of biogas potential of the feedstock**
3. **Energy consumption assessment of the rural community (monthly electricity consumption taken from electricity bill of one household and multiplied by the number of households)**
4. **Volume of biogas necessary to meet the energy demand**

$$B_{igas\ used}) = \frac{P_e * 3.6 * 10^6 MJ/GWh}{CH_4 * H_{vCH_4 * \eta_e}} \quad (1)$$

5. **Determination of biogas proportion used from the total biogas potential**

$$\textit{Estimated biogas to be used} = \frac{Biogas\ used}{total\ biogas\ potential} \quad (2)$$

6. **Computation of the electrical energy production of methane from bioreactor**

$$Electrical\ energy\ production = [volume\ of\ Methane\ (m^3) \times methane\ energy\ content\ (kWh) \times efficiency\ of\ biogas\ engine\ (\%)] \div 100$$

RESULTS AND DISCUSSION

1- Annual electricity consumption of the community (AECC)

AECC = *Annual electricity consumption of one household (1077 kWh) * number of households (7)* **(3)**

$$AECC = 7539\ kWh$$

2- Amount of biogas needed for electricity need in the community (m^3):

$$B_{igas\ used}) = \frac{P_e * 3.6 * 10^6 MJ/GWh}{CH_4 * H_{vCH_4 * \eta_e}} = 3866.15\ m3$$

3- Rate of electricity needs covered by biogas per household

$$(RECBH) = \frac{Electricity\ generation\ potential\ of\ biogas\ yield\ (1024.92\ kWh)}{Annual\ electricity\ consumption\ per\ community\ (1077\ kWh)} = 95\ \%$$

4- Rate of electricity needs covered by biogas per community (RECBC)

$$RECBC = \frac{Electricity\ generation\ potential\ of\ biogas\ yield\ (1024.92\ kWh)}{Annual\ electricity\ consumption\ per\ community\ (7 * 1077\ kWh)} = 13.6\ \%$$

CONCLUSION

- The annual biogas production covers only 14.72% of the electrical consumption of that community (without taking into account energy need for water supply), 103.1 % of electrical consumption of the sample household.
- Impact of quality, quantity of food and season on pig manure characteristics should give exact quantity of manure produced yearly.
- Future studies in order to obtain accurate measured ground data of crop and forest biomass resources out of animal dung especially for electricity generation, cooking and lighting applications.

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2. Jerome Ndam. Improving Access To Modern Energy Services in Rural Areas of Developing Countries. Towards a Comprehensive Access Strategy. PhD thesis in energy and nuclear science technology, 2016

Master of Sciences

Energy Policy

Analysing Feed-in Tariff Policy to Accelerate Renewable Energy Deployment and Electricity Access in Malawi

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Abstract

The purpose of the thesis was to analyse the poor performance of Malawi FIT and redesign the policy to attract investors. Since its inception in 2012, the FIT has neither increased renewable electricity generation capacity nor attracted any Independent Power Producers to connected to the grid or generating and selling power to a particular community as distributed generation. The study also involved modelling FIT rates for Kamuzu International Airport (KIA) solar farm under six scenarios and policy options using RETScreen Expert. To turn the KIA project to profitability, the FIT has to be $ 0.34 kWh and investors will earn a 10 % internal rate of return on equity.

BACKGROUND/CONTEXT

- Feed-in tariff (FIT) is an energy supply policy that attract investments in renewable energy by offering long-term guaranteed purchase agreements to green power producers to sell their electricity into the grid.
- Feed-In Tariff (FIT) policy, the most versatile and widely implemented scheme globally accounting for a greater share of renewable power propagation than any other renewable energy policy support scheme.
- According to the Renewables Global Status Report (GSR 2017), 110 states or countries have FIT policies in place [1].
- FIT account for nearly "75% of worldwide solar photovoltaic (PV) and 45% of global wind energy deployment [2].
- In Europe alone, FIT policy accounted for 93% of all wind onshore capacity and entirely 100% of solar photovoltaics installed by the end of 2010 [3].

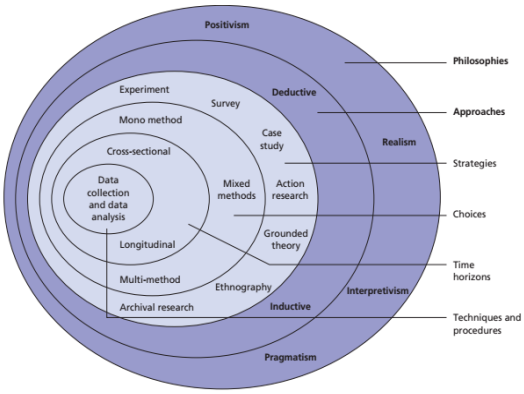
PROBLEM STATEMENT/RESEARCH QUESTION

a) Why the FIT policy in Malawi has actually not increased renewable electricity generation capacity?
b) Why the FIT policy in Malawi has actually not attracted Independent Power Producers (IPPs)?

OBJECTIVES

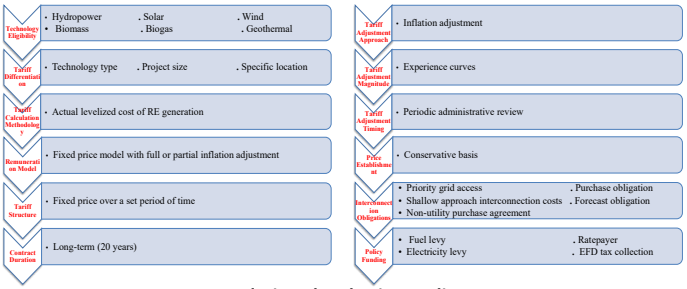
a) Examining feed-in tariff policy design and remuneration model in Malawi.
- Investigating the feed-in tariff policy implementation and the challenges encountered in Malawi.
- Examining the funding for feed-in tariff policy in Malawi.
- Modelling tariff prices using RETScreen Expert.

METHODOLOGY

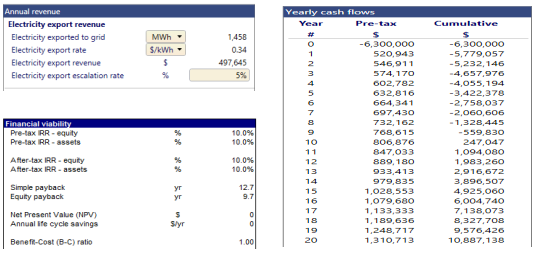


The research onion

RESULTS AND DISCUSSION



Redesigned Malawi FIT policy



Annual revenue

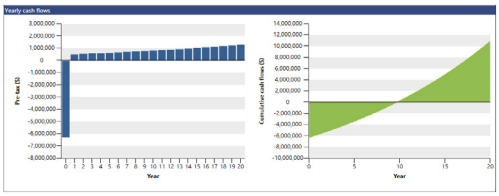
Electricity export revenue		
Electricity exported to grid	MWh	1,458
Electricity export rate	$/kWh	0.34
Electricity export revenue	$	497,645
Electricity export escalation rate	%	5%

Financial viability

Pre-tax IRR - equity	%	10.0%
Pre-tax IRR - assets	%	10.0%
After-tax IRR - equity	%	10.0%
After-tax IRR - assets	%	10.0%
Simple payback	yr	12.7
Equity payback	yr	9.7
Net Present Value (NPV)	$	0
Annual life cycle savings	$/yr	0
Benefit-Cost (B-C) ratio		1.00

Yearly cash flows

Year #	Pre-tax $	Cumulative $
0	-6,300,000	-6,300,000
1	520,943	-5,779,057
2	546,911	-5,232,146
3	574,170	-4,657,976
4	602,782	-4,055,194
5	632,816	-3,422,378
6	664,341	-2,758,037
7	697,430	-2,060,606
8	732,162	-1,328,445
9	768,615	-559,830
10	806,876	247,047
11	847,033	1,094,080
12	889,180	1,983,260
13	933,413	2,916,672
14	979,835	3,896,507
15	1,028,553	4,925,060
16	1,079,680	6,004,740
17	1,133,333	7,138,073
18	1,189,636	8,327,708
19	1,248,717	9,576,426
20	1,310,713	10,887,138



RETScreen results (Financial Modelling)

CONCLUSION

Regulatory policy instruments to promote renewable electricity generation have taken on increasing importance in many countries and states. The widely deployed and successful policy instrument for encouraging generation of electricity from renewables in the world are feed-in tariffs.

Based on the study;
i) The Malawi FIT policy must be gazetted.
ii) Stakeholders should be involved during design and review of the policy.
iii) A stable funding mechanism should be established.

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Assessing Implementation of Energy Efficiency Practices and Industrial Energy Management: A Case Study of Kenyan Industries

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Abstract

The manufacturing industry is facing tougher competition which increases the demand to implement cost-effective energy efficiency measures. However, studies have indicated that obvious cost-efficient measures are not always undertaken. In a country like Kenya where sometimes generated electricity is never enough due to issues like drought which occurs almost on yearly basis and the electricity tariff is very expensive (USD cents 15/KWH), the best solution in this case is for the industries to invest in the adoption of energy efficiency measure in order to reduce the cost of energy use.

BACKGROUND/CONTEXT

- Energy is a fundamental ingredient for economic development as well as for the improvement of social welfare.
- Reports shows that use of energy has been resulting to social problems as well as emissions of harmful pollutants to the environment such as carbon dioxide resulting to disastrous effects such as climate change (IAEA, 2005)
- The judicious use of energy resources and technology in order to reduce their negative impact is strongly related to two concepts namely energy efficiency and energy management (Rosenberg and Winkler, 2011)
- The manufacturing industry accounts for about 75% of the world's yearly coal consumption, 20% of global oil consumption, and 44% of the world's natural gas consumption. Furthermore, the manufacturing industry also uses 42% of all electricity produced (IEA, 2004).

PROBLEM STATEMENT/RESEARCH QUESTION

The demand for energy is increasing at an alarming rate as a result of increased industrialization globally. This has led to some energy related challenges witnessed such as increase in energy prices, rapid depletion of energy resources, climate change due to emissions of CO2 and other pollutants to the environments among others. In order to respond to the increasing concerns related to these challenges, several industries around the globe have already adopted energy efficient and management initiatives in order to reduce their energy intensities. By adopting these initiatives, these industries have contributed in enhancing environmental protection as well as increased their economic competitiveness.

OBJECTIVES

To assess the implementation of energy efficiency practices and industrial energy management adopted by Kenyan industries in the manufacturing sector.

METHODOLOGY

This study was carried out as a case study on Kenyan manufacturing industries situated in Nairobi, Mombasa, Thika and Kisumu.

↓

The data was collected using a questionnaire due to its explorative nature of the study and the multi sites investigated.

↓

The target population of the study consisted of 50 companies from different sectors which are listed in the KAM directory

↓

The research made use of non-probabilistic technique (Etikan and Bala, 2017).

↓

The questionnaires which were returned after being completely filled were edited, coded then entries made into Statistical Package for Social Sciences (SPSS version 25.1).

RESULTS AND DISCUSSION

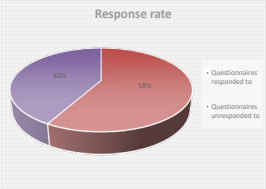

Fig 1. response rate

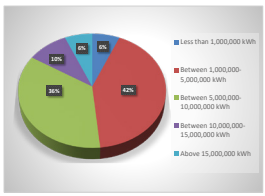

Fig 2. Amount of electricity consumed

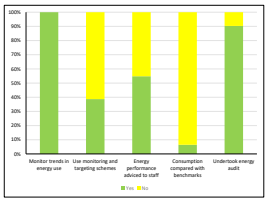

Fig 3. energy management information

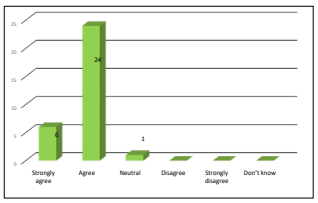

Fig 4. energy efficient opportunities

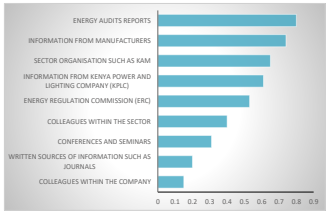

Fig 5. sources of energy efficiency information

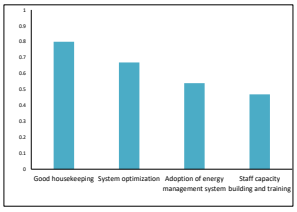

Fig 6. Adopted energy efficient measures

CONCLUSION

- There is existence of energy saving opportunities hence indicating existence of energy efficiency gaps in manufacturing industries.
- Out of the 31 industries surveyed, 27 of them had carried out an energy audit as per the Energy Management Regulation of 2012
- Further research is needed on the in depth analysis of the industries' energy management systems.
- More research is needed to determine how the relevant sectors such as KPLC, ERC and financial institution works to improves on the energy efficiency and management in order to assist Kenya as a nation achieve sustainable energy consumption

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Assessment of the impacts of After Sales Services on Performance of Household Energy Systems in Rwanda: A Case of Ngoma District

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Abstract

This study sought to assess the impacts of after sales services on households' energy systems in Rwanda. Specifically, the study focused on the performance of households' energy systems that have got after sales services and the energy systems that have never had such services. The findings revealed that after sales services are very important in mitigating possible break down of the households' energy systems. The results further showed that many households bought solar home energy systems since provider offered after sales services more frequently than provider of biogas energy systems. The study concluded that household energy systems break down is mainly caused by lack of adequate after sales services from the providers.

BACKGROUND/CONTEXT

Renewable Energy Technology has increased in Rwanda. As of 2017, 10,588 domestic and 86 institutional biogas digester plants have been constructed across the country [1].

According to Rwanda energy group electrification report. 258,670 households have been connected by means of solar systems which has increased off-grid access to 10.7% [2].

PROBLEM STATEMENT/RESEARCH QUESTION

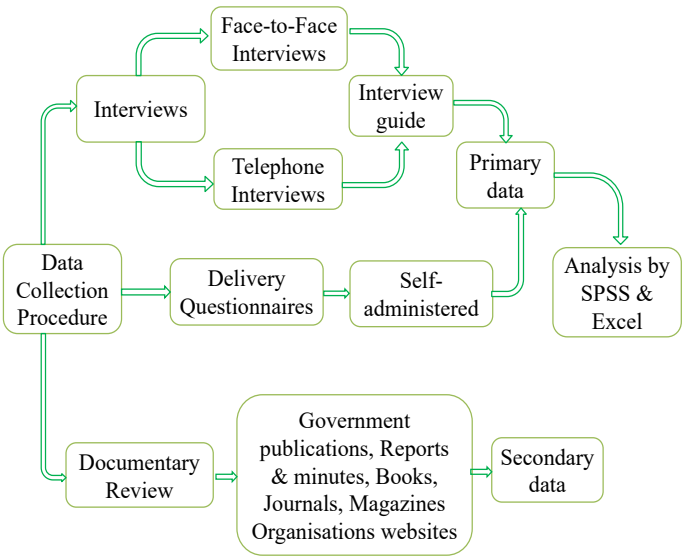
Rwanda biogas program study showed, 65% households satisfied with working of their biogas plants, 25% disappointed, 10% not in operation [3].

The abandonment of the household energy systems is mainly caused by insufficient and inadequate technical maintenance basically due to the lack of regular follow up services / after sales services of the systems.

OBJECTIVES

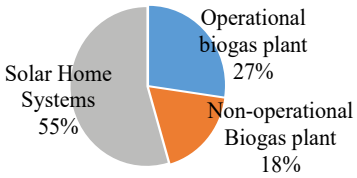
- To assess the impacts of after sales services on performance of household energy systems in Rwanda.
- To determine peoples' perceptions towards after services on household energy systems in Rwanda.

METHODOLOGY



RESULTS AND DISCUSSION

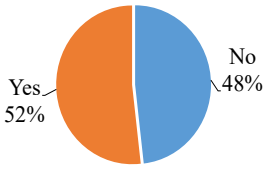
❖ 60% have been receiving after sales services



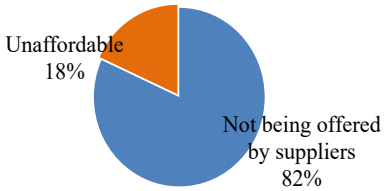
❖ Categories of household energy systems surveyed

		To what extent has your energy systems achieved its intended purpose					
		V.High extent	High extent	Moderate extent	Low extent	V.Low extent	Total
Have been receiving after sales services for the home energy systems	No	0	12	17	12	3	44
	Yes	16	11	13	20	6	66
	Total	16	23	30	32	9	110

❖ All the households that indicated their energy systems had achieved its intended purpose by high extent, received after sales services from the system suppliers.



❖ Energy system run and produce gas/electricity effectively.



❖ The major reason for lack of after sales services.

CONCLUSION

- After sales service improves performance of household energy systems.
- Firms that offer after sales services sell more than those that don't provide.
- There is a need of progressive policies and regulation to manage providers of renewable energy home systems to protect consumers from substandard services from suppliers.

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Assessing Solar Energy Potential over West Africa under Climate Change: The case of Niger

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Abstract

Due to meteorological and environmental conditions, the solar energy potential varies depending on the geographical locations. This study is aimed at assessing the solar energy potential of the cities of Niamey and Agadez in Niger for both present (1979-2005) and future (2019-2100) climates. The study required the collection and analysis of climatic data obtained from the West African Science Service Centre for Climate and Adapted Land Use (WASCAL). The results showed variabilities and trends of direct irradiance (swddir), diffuse irradiance (swddif) and the surface temperature (ts) for both areas. Also, based on the results, both cities are suitable for solar energy applications but Agadez have slightly higher values of direct irradiation compared to Niamey. Additionally, investigations were conducted to determine the existing renewable energy policies and policy recommendations were made for the promotion of solar energy in the Niger.

BACKGROUND/CONTEXT

Many factors can influence power generation from renewable energies. One such factor is without doubt climate change. The main objective of any climate change mitigation strategy is pushing toward lower greenhouse gas (GHGs) emissions. However, the most promising energy generation sources without emissions are renewable energy resources which for most of them are climate dependent.

Like all the regions, Africa must confront some key challenges associated with the use of renewable power sources such as dependency on the weather, intermittency in power and also

the growing concentration of the GHGs in the atmosphere that will likely cause an unstable state of the climate that may affect not only solar power but also hydro and wind power generation performance negatively or positively.

PROBLEM STATEMENT/RESEARCH QUESTION

Niger is endowed with huge potential solar energy resources which if harnessed could contribute to increase the electricity access and the socioeconomic development the country.

Addition to that, given the current trend of changes in climate, it is important to understand the impact of climate variability and change on solar energy resources. Only few studies have analyzed the variability in the diffuse and direct components of solar radiation in the region in general. Understanding the variability of these parameters is critical for the integration of solar energy into the national energy sector. Thus, there is a need for high resolution climate simulations if meaningful studies on the impact of climate variability and change on renewable energy resources such as solar energy resources.

OBJECTIVES

The specific objectives are:

- to determine the trend in the climatic factors such as the surface temperature and the shortwave surface downward irradiance (direct and diffuse) that influence the solar energy potential;
- to explore which locations are currently suitable for solar energy applications and if theses locations will still be suitable under future climate;
- to determine the existing renewable energy policy of Niger;
- to investigate about appropriate policies that could enable the solar energy technologies deployment in Niger.

METHODOLOGY

- A combination of three GCMs (MPI, GFDL, HAD-GEM) with one RCM (WRF) obtained from WASCAL is used in this study.
- The Representative Concentration Pathway Scenario RCP 4.5 (Van Vuuren, et al., 2011).
- From the three-hourly data collected, the monthly and yearly mean of surface temperature, shortwave surface downward direct radiation and shortwave surface downward diffuse radiation were calculated.
- Secondly, an analysis of the trend and variability ts, swddir and swddif over the cities of Niamey and Agadez was done and the future evolution of these parameters explored, using rcp4.5 scenarios for the period of 2019-2050 and 2079-2100.
- The analysis was done using NCAR Command Language (NCL) and Climate Data Operator (CDO) for data manipulation and analysis.
- Additionally, investigation was done to determine the existing renewable energy in Niger and some policy recommendations were made in order to scale up the deployment of solar energy.

RESULTS AND DISCUSSION

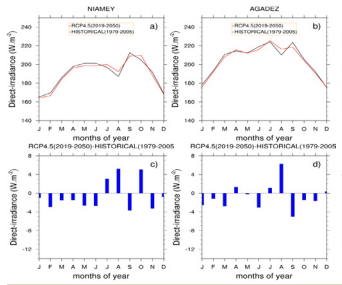

Fig. 1: Evolution of shortwave downward direct irradiance for the reference period to the near future over Niamey and Agadez under RCP4.5 Scenario

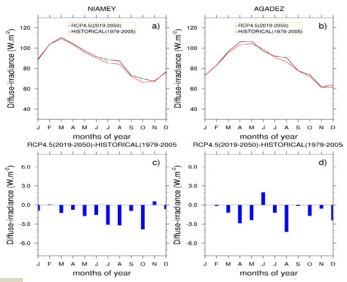

Fig. 2: Evolution of shortwave downward diffuse irradiance for the reference period to the near future over Niamey and Agadez under RCP4.5 Scenario

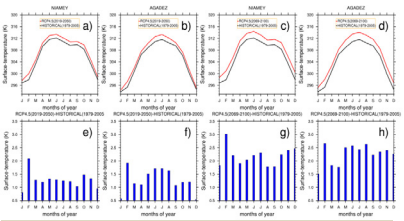

Fig. 3: Evolution of Surface temperature for the reference period to the near future over Niamey and Agadez under RCP4.5 Scenario

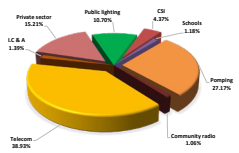

Fig. 4: Solar energy share by different sectors in Niger (CNES, 2015); I.C& A= community and administrative infrastructure; CSI (Lighting, refrigeration, ventilation, Radio)

- An increase of diffuse irradiance up to +2W/m2 is observed in Agadez and around 1W/m2 for Niamey.
- The increase in direct irradiance is almost the same for Niamey and Agadez and is around to 6 W/m2.
- There would be an increase of temperature over both localities in the near future (2019-2050): up to 2.1°C in Niamey and 1.9°C in Agadez.; and in a far future (2069-2100), the increase is up to 3° C for Niamey and 2.6° C for Agadez.

CONCLUSION

Based on the results, both localities are suitable for installation of solar energy panels to satisfy the energy needs in the country. Regarding the siting of the solar panels (or solar farms), additional factors such as topography, land cover, price of the land, proximity to the transmissions lines, and the intended national grid expansion plans, are to be considered to determine the ideal locations to install solar power facilities.

Recommendations to Scaling Up Solar Energy Deployment

The study is also aimed at disseminating the message that countries like Niger could cover large parts of their electricity demands by just developing a fraction of their solar potential, with appropriate policies in place.

Get Around Policy Stagnation, Get Around Political Fragmentation, Support mechanisms, Strengthening the capacities of the National Solar Energy Centre (CNES), Risk insurance, capacity building and Technology transfer.

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Assessing The Impact of Fast Variables on Resilience of Electrical Energy in View of Climate Change and Energy Security in Kenya

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Abstract

Establishing the causes of electricity price fluctuations is essential for making policy decisions that ensure sustainable development. Quantitative analysis of resilience metrics and electricity prices was conducted. Electricity prices in Kenya lack a long run trend owing to high volatility of the prices. Diversity affects electricity prices negatively owing to persistent thermal generation. Electricity importation has been found to increase electricity prices while oil price shocks were found to affect both electricity price and generation.

BACKGROUND/CONTEXT

- Achieving some of the SDGs will not be possible without adequate energy supply and infrastructure. Energy security ensures energy supply that meets demand at an affordable price to consumers.
- Essential dynamics of a given system can be captured by including the key processes with longer and shorter turnover times (slower or faster turnover rates).
- Fast variables (variables that have fast turnover rates e.g. price) of the system show the dynamics of the underlying structural variables.
- Adjusting to adversity can therefore be reflected in electricity price which represents the capacity of the energy system to adjust to change (Molyneaux et al., 2016; GEA, 2012 & Carpenter et al, 2001).
- Therefore, if price can show levels of stability, despite volatility in structural components, then there is evidence of resilience in electricity generation.

PROBLEM STATEMENT/RESEARCH QUESTION

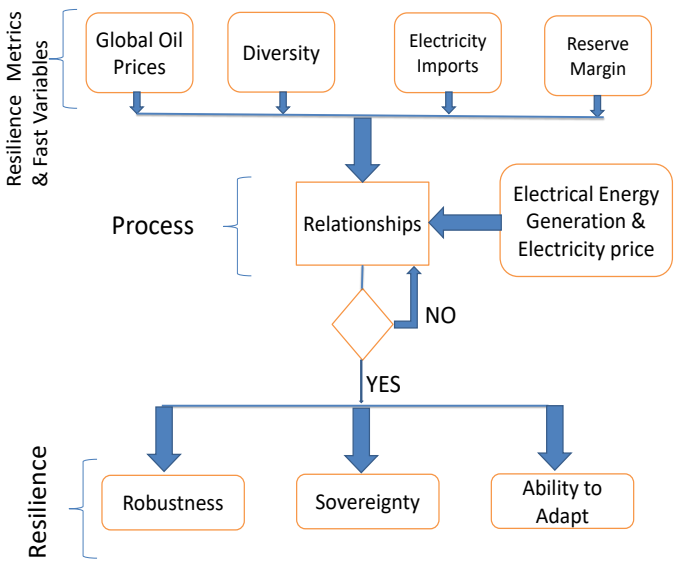
Expensive energy hinders Kenya's competitiveness by raising the cost of doing business.

In this regard, energy accessibility and cost are key priorities of the Ministry of Energy and Petroleum.

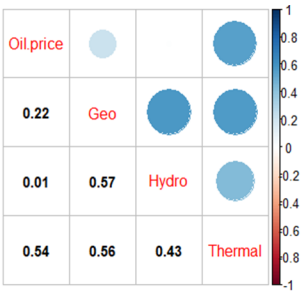
OBJECTIVES

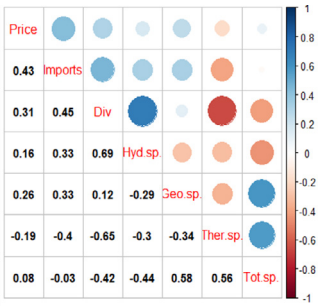
The overall objective of this study was to assess the impact of fast variables on resilience of electrical energy in view of climate change and energy security in Kenya.

METHODOLOGY



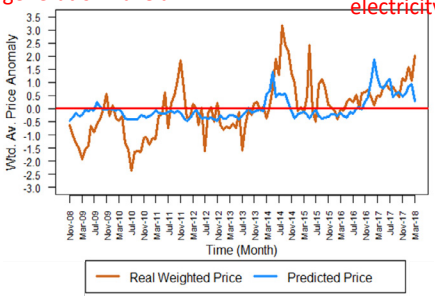
RESULTS AND DISCUSSION





❖ Global Oil Prices and thermal electricity generation have a

❖ Electricity price shows significant correlation with electricity imports and diversity



❖ Empirical statistical model shows a match between the real electricity prices and predicted prices using data from model output

CONCLUSION

- ✓ Increase in electricity imports and thermal generation increases electricity prices.
- ✓ Electricity prices can go down if Kenya decreases thermal generation and reduce electricity imports by putting in place a policy to regulate thermal generation and electricity importation.
- ✓ This study concludes that the energy sector in Kenya is unsecure due to increasing electricity costs, and influence by external factors such as global oil prices.

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Economic and Environmental Comparison of a Natural Gas Plant and Solar PV Systems for Rural Electrification in Nigeria: A Case Study of Iyiora Anam

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Abstract

This study provides an economic and environmental comparison of a Natural gas (NG) plant and Solar PV systems utilizing a mini-grid system to provide electricity access to Iyiora Anam, a rural offgrid community in Nigeria. It adopted the heotretical framework of the Levelized Cost of Energy employing data gotten from literature, survey approach with Off-grid stakeholders; and analysed using HomerPro software. As results, Solar PV has a lower levelized cost but a higher Capital cost 90% higher than the NG plant that has higher levelized cost of electricity. With emission costs, the NG-powered system's levelized cost increased further showing the uncompensated impact of generating electricity with NG. Also, the result of the sensitivity analysis to assess the effects of some parameters (fuel cost, emission charges and annual average solar irradiance) on the cost of electricity generation on the site shows that fuel price and cost of electricity generation have a positive relationship. As well, emission charges and the cost of generating electricity exhibited a positive relationship.

BACKGROUND/CONTEXT

According to British Petroleum (2017), Nigeria has a proven reserve of 186.6 Trillion Cubic Feet (TCF) of natural gas and a proven crude oil reserve of 37.1 Billion barrels. The country holds a significant deposit of coal and renewable energy resources like Solar, Wind, Biomass and Hydro which is capable of delivering enough electricity to Nigerians when harnessed.

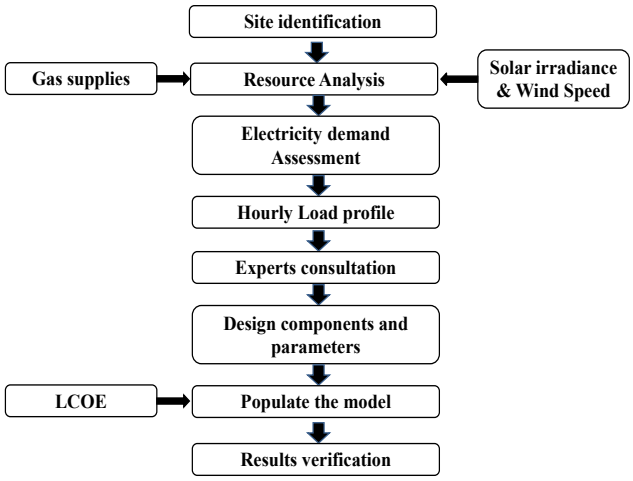
PROBLEM STATEMENT/RESEARCH QUESTION

Despite all these resources, Electricity access rate in Nigeria have been all time low with 70% of rural dwellers lacking access to electricity, despite policies aimed at providing electricity to these off-grid communities.

OBJECTIVES

The main objective of this study is to provide an economic and environmental assessmentof a mini-grid Natural gas fired plant and Solar PV systems for electrification in Iyiora Anam Community

METHODOLOGY

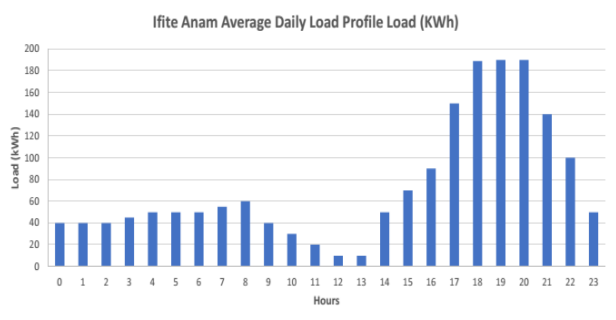


STUDY AREA

Location: Anambra Wset Local Governement Area of Anambra State
Population: 829 Households
Area: 1 sq km
Occupation: Farming and Commerce
Solar Irradiance: Annual averae of 4.83 kWh epr sqm

RESULTS AND DISCUSSION

Electricity Load profile



Cost and the Impacts of emission charges on electricity generation in Iyiora Anam

Cost component	Solar PV (USD)	Natural gas micro turbine (USD) without emission cost	Natural gas micro turbine (USD) with emission cost
Total Net Present cost	3,377,050	4,550,287	4,723,050
Capital cost	2,123,137	214,500	214,500
Operating cost	84,958	237,151	246,600
O&M cost	586,096	1,681,651	1,854,414
Fuel cost	0	1,987,531	1,987,531
LCOE	0.356	0.387	0.402

CONCLUSION

- The results of the analysis show that Solar PV has a lower levelized cost but a higher Capital cost 90% higher than the Natural gas plant which has a lower capital cost but a higher levelized cost of electricity.
- When emission charges were modelled into the Natural gas powered system, its levelized cost increased further to show the uncompensated impact generating electricity with Natural gas.

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Environmental and Economic Cost Analysis of a Solar PV, Diesel and Hybrid PV-Diesel Water Pumping Systems for Agricultural Irrigation in Rwanda: Case Study of Bugesera District

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Abstract

Rwanda agriculture sector has a significant impact on country's economy whereby 80% of population depend on agriculture. Many irrigation projects were proposed with the principal objective of enhancing agricultural production while avoiding dependence on rain-fed agriculture, but the problem of power to pump water is still a major barrier. Therefore, that's why several economic analyses have been conducted in this thesis to identify the most cost effective solution of energy source for irrigation and to evaluate the project profitability toward the country's vision 2020. The HOMER software results show that using PVWP systems for agricultural irrigation is the most profitable when compared to the rest two proposed water pumping systems

BACKGROUND/CONTEXT

The rapid increases of population and climate change will continue to raise the issue of food security (Bhattarai et al., 2002). Agriculture sector has a significant impact on Rwanda's economy whereby 80% of population depend on agriculture (Mbonigaba, 2013). The irrigation system increases crops productivity up to 5 times more than the crops harvested without irrigation's application (MINAGRI, 2016).

In global, agriculture occupies a big portion of freshwater withdrawals and energy consumption where about 70% of freshwater and 30% of energy are utilized in that sector (U.S. Department of Energy, 2014).

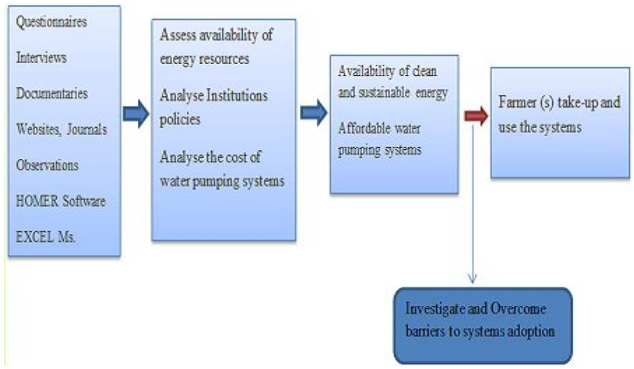
PROBLEM STATEMENT/RESEARCH QUESTION

The food demand in Rwanda is growing dramatically due to the increasing country population while cultivated land is decreasing. Presently, electricity shortage in Rwanda is a major barrier to the national agricultural development because irrigation becomes expensive due to the lack of power for water pumping systems

OBJECTIVES

To analyze Environmentally and Economically the Cost of a Solar PV, Diesel and hybrid PV -Diesel water Pumping Systems for Agricultural Irrigation in Rwanda using HOMER Software

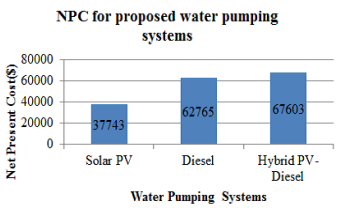
METHODOLOGY

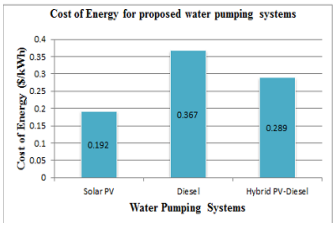


STUDY AREA

- Bugesera district is one of the thirty districts of the Republic Rwanda
- Bugesera climate is dry with temperature varying between 20 and 30°C
- Bugesera district has 3 rivers and 9 lakes.
- Bugesera receives annual average solar radiation of 5.6 kWh/m2/day.
- The average size of land cultivated per householder (HH) is 0.59 ha.
- Precipitation: Below 900 mm per year

RESULTS AND DISCUSSION





The NPC of the PVWP system is the lowest one

COE of PVWP system is lower compared to others pumping systems

Emission (kg/yr)		
Pollutant	Diesel	Hybrid PV/Diesel
Carbon dioxide	14106.50	1218
Carbon monoxide	29.82	2.99
Sulfur dioxide	28.30	2.57
Nitrogen oxides	312.71	28.42
Unburned hydrocarbons	3.66	0.35
Particulate matter	2.83	0.23
Total emission	14483.82	1252.56

Diesel unit is more Pollutant compared to Hybrid system

Barriers and policies suggested for agricultural irrigation development	
Barriers	**Policies suggested**
• Farmers' financial constraints for the purchase of pumping systems even at 50% subsidy.	➢ Improve access to credit and long-term loans especially for small farmers.
• Poor skills about the use of modern irrigation technology	➢ Facilitating training and experience sharing between farmers
• Lack of agro-food processing means and insufficient market information and market networks.	➢ Improving access to timely market information and market networking and Strengthening crop value chain and supply of processing materials
• shortage of agricultural inputs such as improved seeds, fertilizer and pesticides	➢ Improving availability of agricultural inputs at village level.
• The small farm size.	➢ Improving mobilization about land consolidation program

CONCLUSION

- The economic cost analysis showed that Solar PV water pumping systems are more profitable compared to other two pumping systems.
- A replacement of DWP system by PVWP system results in CO2 emissions reduction of about 14.48 tonnes. It was also found that large-scale solar power plants are indirectly CO2 emitters.
- In order to improve and expand irrigation activities, it is necessary to solve all problems raised by respondents include financial constraints through the involvement of all agricultural stakeholders

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Evaluating the Success of Renewable Energy and Energy Efficiency Policies in Ghana: Matching Policy Objectives against Policy Instruments and Outcomes

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Abstract

Energy policy is a strategy for tackling issues related to energy. Policies have been developed in Ghana to improve the uptake of renewable energy for electricity production, ensure efficient use through policy interventions to achieve the objectives set which are yet to be met. A detailed study of the available literature, scientific reports, structured interviews, questionnaires were conducted for different renewable energy stakeholders across Ghana and a comparative analysis on Morocco and South African's renewable energy sectors. The study found out two main issues affecting the renewable energy sector of Ghana. 1) policy implementation affecting grid and off-grid solar PV generators; and 2) barriers to renewable energy development in Ghana, and concluded that, policy incentives such as net metering scheme, feed-in-tariff and the renewable energy funds are poorly implemented in Ghana.

BACKGROUND/CONTEXT

- Access to energy improves human development (Asumadu-Sarkodie and Owusu, 2016).
- Fossil fuel consumption does not necessarily leads to it decrease but have a impact on the environment (Farhad et al., 2008)
- Need for alternative renewable energy sources such as wind, solar, hydro to reduce over dependency on fossil fuel consumption.

PROBLEM STATEMENT

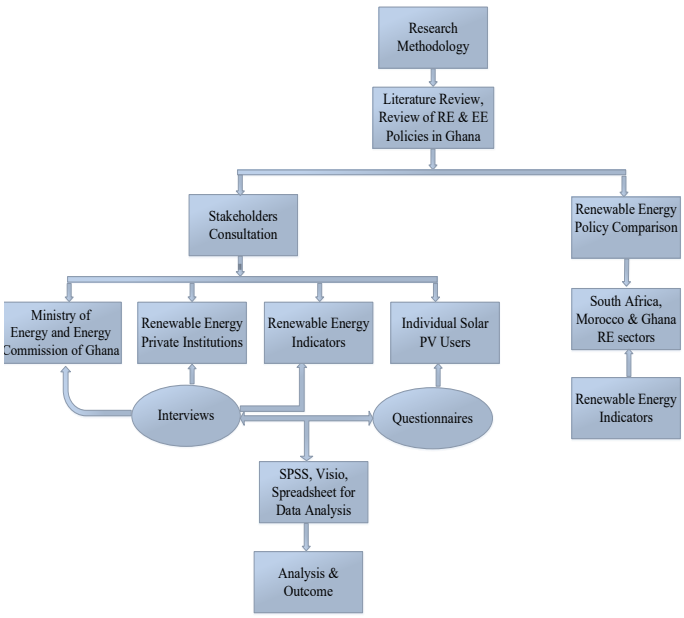
Ghana to generate up to 10% of its electricity from renewable energies by 2020; and later to 2030. Although, there are interventions set thus the policy instruments to achieve the policy objectives, the current renewable energy % share is less than 1.

OBJECTIVES

To evaluate the success of renewable energy and energy efficiency policies in Ghana by matching the policy objectives against the policy outcomes. Specifically,

- To review the existing policies on renewable energy and energy efficiency policies in Ghana;
- To evaluate the success of the policies by matching the policy objectives against the policy outcomes; and
- To analyze challenges/barriers faced by energy institutions in the implementation of renewable energy and energy efficiency policies in Ghana.

METHODOLOGY



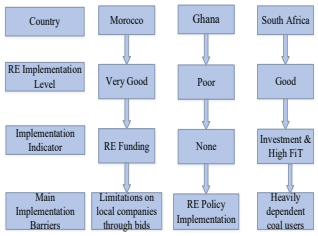
RESULTS AND DISCUSSIONS

Summary Response from the Stakeholders on Policy Regulatory Framework in Ghana

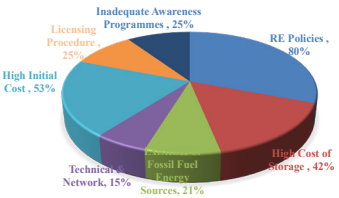
Stakeholders	Policy implementation instruments: Net metering	Feed-in-tariff	RE Funding	RE Purchase Obligation
Lecturers	×	×	×	Quantity unknown
RE Private Companies	×	×	×	Quantity unknown
State	×	✓	×	Small amount
Individual PV Users	×	×	×	Not aware

Note: ×– absent; ✓– present

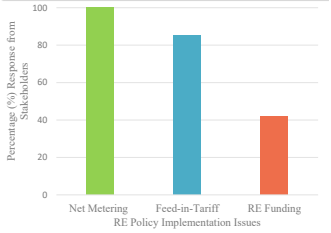
Comparative Analysis of Ghana, South Africa and Moroccan's Renewable Energy Sectors



Graph representing percentage level of Renewable Energy Barriers in Ghana



Graph representing non-Implementation level of Renewable Energy Policy Incentives in Ghana



Evaluation Of Renewable Energy Policies In Ghana

Energy Policies	Targets	Achievements	Analysis
Renewable Energy Act 2011, Act (832)	➢ 10% of power generated from renewables by 2030 in the national energy mix ➢ Implementation of RE policy instruments	0 % of renewables as of 2012	➢ Poor implementation of RE incentives ➢ Unfavourable RE environment to generators
Sustainable Energy for All Action Plan 2012	➢ On and off grid and mini-grids electrification projects ➢ 10% of power generated from renewables by 2030 in the national energy mix	➢ 2.5 MW solar Accounting 0.11 % of renewables as of 2013	➢ Only < 1 % renewables Achieved after a 9-year period of RE polices (2006 – 2015) ➢ Policies unattractive to some energy institutions; unfavourable policies to generators

CONCLUSIONS AND RECOMMENDATIONS

- As a result of failure on the part of some energy institutions to implement the renewable energy incentives in the sector.
  - ✓ Energy Commission of Ghana should invest in renewable energies as well.
  - ✓ Government should implement the incentives to attract renewable energy generators.
  - ✓ A private body should be set up for competitive bidding processors in Ghana like it is the case of South Africa.

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Investigating Factors Affecting Adoption and Scaling Up of Rooftop Solar PV Deployment in Urban Centres: Case Study of Nairobi City

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Abstract

Urban centres in developing countries are growing at unprecedented rate. This is attributed to high population growth being experienced in those nations and more people moving to urban centres and the desire for those nations to industrialize. Energy demand on other side is rapidly increasing as more energy is needed to support urbanization and industrialization. This study was aimed at investigating factors affecting Adoption and Scaling Up of rooftop solar PV in urban centres. It explores on the factors affecting the deployment of the solar PV using Nairobi City in Kenya as the case study. The objective of the study was to establish the reasons why roof mounted Solar PV has not been scaling up in urban centres despite the high energy demand being experienced so far. The study used mixed research design to explore both qualitative and quantitative characteristics of the target population. It was noted that high initial costs, lack of qualified technicians, bureaucracy delay in application and approval process and lack of awareness were among the major challenges affecting adoption and scaling up of rooftop SPV. Most consumers installed rooftop SPV to save on electricity bills.

BACKGROUND/CONTEXT

Urban centres are growing at unprecedented rate in developing nations. This growth is being experienced more in Africa and Asia continents. This is attributed to high population growth being experienced in those nations and more people moving to urban centres and the desire for those nations to industrialize. Urban centres serve as hubs of economic growth as most activities occur there due to presence of supportive environments such as ready market for finished goods and labour availability (UN-Habitat, 2012). These developing countries have abundant and underutilized natural resources that are backbones of economic growth making them attract foreign investments across the world. Energy demand on other side is rapidly increasing as more energy is needed to support urbanization. Electricity generation though remains to be backbone of industrialization is regarded as one among the larger contributors of greenhouse gas emissions associated with climate change.

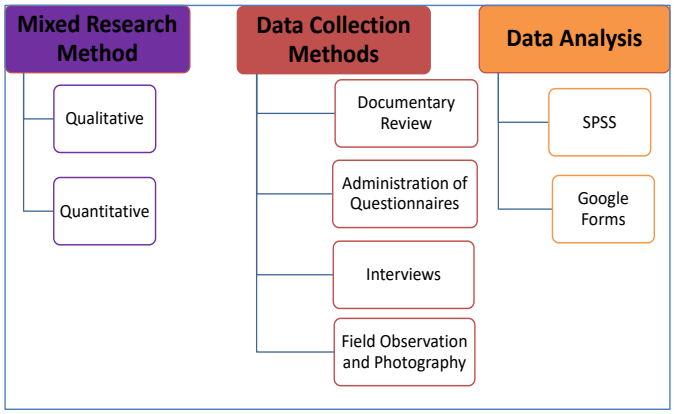
PROBLEM STATEMENT/RESEARCH QUESTION

- Kenya is among the nations facing energy crisis as they aim to get industrialized. Vision 2030 was developed in aim to make Kenya a Middle Income Economy by 2030
- Electricity Access at 56%
- Need for Sustainable Energy Sources in Urban Centres to Mitigate Climate Change Effects

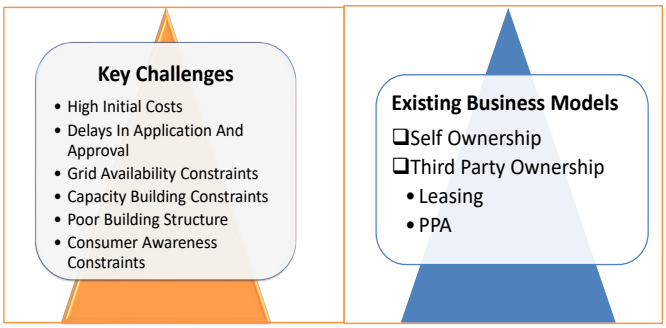
OBJECTIVES

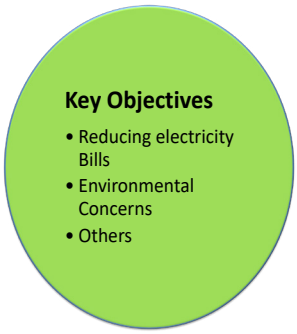
i. To Establish Major Challenges in Adoption and Scaling up of rooftop SPV in Urban Centres
ii. To Identify Key Drivers and Opportunities that can be applied in Adoption and Scaling Up
iii. To Evaluate Existing Business Models that can be Adopted to Scale Up Rooftop SPV Deployment

METHODOLOGY



RESULTS AND DISCUSSION





Policy recommendations

- Introduction of net metering
- Approval of Multiple Buyer Model
- Consumer Awareness Creation
- Capacity Building Programmes
- Replacing FiT Policy with Auction
- Shortening Period in Application and Approval Stage

CONCLUSION

- Despite the Challenges facing Rooftop SPV Technology in Kenya, the technology is playing key Role in Solar PV Deployment in Urban Centres
- Huge Investments in the Sector Underway
- Climate Change Awareness playing key role
- Government Involvement through Legislation Remains Crucial

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Key Factors Influencing Access to Finance for Scaling up Clean Modern Energy in Rural Areas of Rwanda: A Case Study of Ngarama Sector

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Abstract

This study sought to Identify Key factors Influencing Access to Finance for Scaling up Clean Modern Energy in Rural Areas of Rwanda. The study specifically focused on rural population participation in financial institutions; financial literacy of the rural populations; available lending schemes in financial institutions to support the scaling up of clean modern energy and relationship between financial inclusions and local social enterprises

BACKGROUND/CONTEXT

- There is no question that rural financial inclusion can expand access to quality modern energy services for underprivileged people. Access to the finance can help to counterbalance the high upfront cost associated with cleaner technologies, such as biogas, micro hydropower, solar, or liquefied petroleum gas (LPG).
- The rate of diffusion of clean modern energy is very slow in rural areas hence affecting the private sector and investment climate for rural energy services and influence the outreach and impact.
- A deeper understanding of the business opportunities for small-scale lending for energy services, as well as the most effective way financial institutions can respond to these opportunities will facilitate access to appropriate financial services and smooths operations.

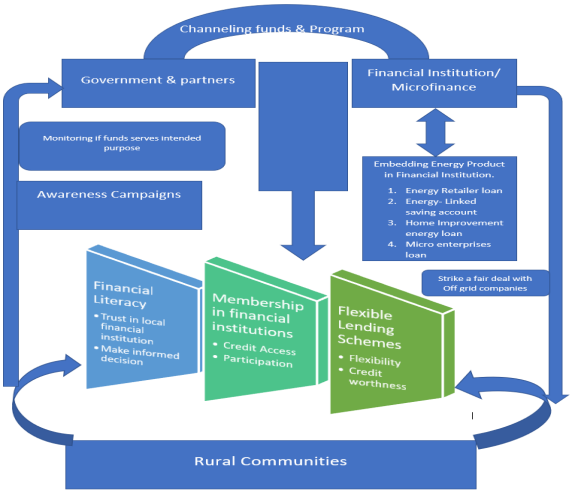
PROBLEM STATEMENT/RESEARCH QUESTION

The main challenges which strongly affects rural underserved communities from acquiring modern energy is inability to raise the needed finance to be able to purchase the modern energy system in sustainable manner. The majority of rural community continue to live without access to affordable, reliable and clean modern energy which results in a number of consequences to the functioning of the society and imposes direct threats to the lives in families.

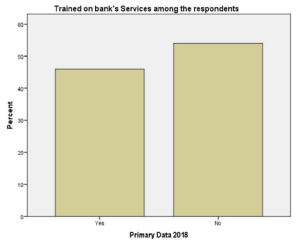
OBJECTIVES

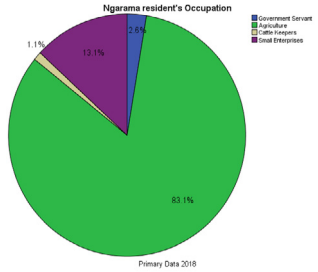
1) To assess the influence of microfinance membership in scaling up access to sustainable clean modern energy in rural areas of Rwanda
2) To examine the influence of financial literacy to the access of finance for clean modern energy in rural areas of Rwanda.
3) To analyze the available lending schemes to support access to finance for scaling up sustainable clean modern energy in rural areas of Rwanda.
4) Evaluate the relationship between rural financial inclusions and local social enterprises working in modern energy sector.

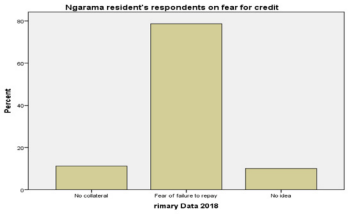
METHODOLOGY

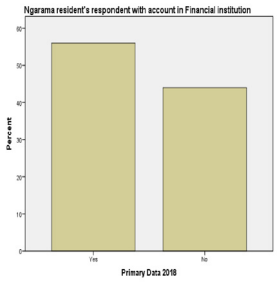


RESULTS AND DISCUSSION

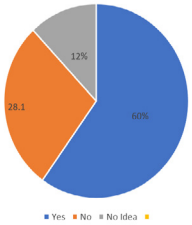








Ngarama resident's response on availability Variety lending schemes



CONCLUSION

- The study concluded that membership in microfinance to rural populations is the crucial step towards drawing closer to the fund
- Financial literacy in rural areas needs to be boosted. The knowledge and understanding of services, operations and opportunities that are channeled through financial institutions by government and its partners
- The study also concluded that lending schemes in place today have got so many obstacles that are not favorable to the rural community customers because of their unique life style. With the high level of illiterate to the rural population who cannot easily be adjusted from their conventional way of doing things,
- Financial inclusions to the local social enterprises has suffered a lot because of rigid system which demands a lot of perseverance and patience to access the financial support from financial institution. Bureaucracy has undermined different programs set by government to boost local entrepreneurs.

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Modelling the Next Energy Transition in Nigeria to Achieve Sustainable Development and Mitigate Climate Change

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Abstract

Projections for future energy demand have time and time again been employed for the planning and sustainable utilization of available energy resources. The findings of this study provide adequate indications that the household sector will continue to lead all other sectors with regards to total annual energy demand regardless of the growth rate of the economy within the period under study (2010-2030). To quicken the rate of energy transition in the household sector to achieve sustainable development, a policy driven energy transition scenario was considered for the household sector. This was done to explore what the future demand could be if LPG becomes the fuel of choice in the household sector.

BACKGROUND/CONTEXT

- Previous energy transitions were driven by a variety of reasons over the past 250 years, the dominant fuel in the global energy mix gradually transitioned from biomass to coal and then to oil, all being carbon-based fuels. Since the beginning of this century, two major factors have played a pivotal role in the need to transition yet the global energy system. The first factor revolves around issues of climate change while the second factor is the shift of the world's centre of gravity towards emerging markets in developing countries.
- With this renewed global focus on the economies of African countries and the increased awareness for the sustainable use of energy, this study details how the energy landscape has changed over time and possible future pathways for the use of energy sustainably.

PROBLEM STATEMENT/RESEARCH QUESTION

Little has been done to explore the role that policies targeted at specific energy demand sectors will play to help developing countries transition yet again their energy system to achieve their sustainable development goals. This study has utilized scenario based modelling to explore what the future energy landscape in Nigeria could look like in the coming years.

OBJECTIVES

To develop and model energy demand scenarios and explore the role policies have to play to consolidate on the gains already achieve in the transition of the Nigerian energy sector.

METHODOLOGY

A bottom-up (End-Use) modelling approach was used for this study due to its in-depth accounting of all sectors, sub-sectors, end-uses and devices that consume energy.

Below are the equations used in the model;

$$E.D_{Industry} = E.D_{Manufacturing} + E.D_{Agriculture} + E.D_{Construction} + E.D_{Mining}$$

$$E.D_{Transport} = E.D_{Intracity} + E.D_{Intercity} + E.D_{Freight}$$

$$E.D_{Household} = E.D_{Space\ heating} + E.D_{Cooking\ \&\ Water\ heating} + E.D_{Lighting} + E.D_{Appliances}$$

$$E.D_{Service} = E.D_{Space\ heating} + E.D_{Cooking\ \&\ Water\ heating} + E.D_{Lighting} + E.D_{Appliances}$$

$$E.D_{Total} = E.D_{Industry} + E.D_{Transport} + E.D_{Household} + E.D_{Service}$$

Where;

E.D = Energy Demand

RESULTS AND DISCUSSION

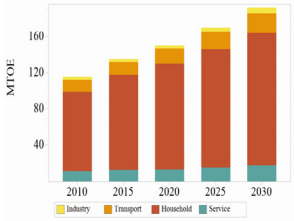

Figure 1: Energy Demand in the Business-as-usual scenario. ***Source: Author***

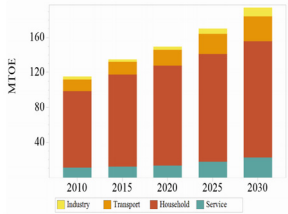

Figure 2: Energy Demand in the Medium growth scenario. ***Source: Author***

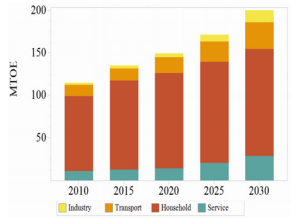

Figure 3: Energy Demand in the High growth scenario. ***Source: Author***

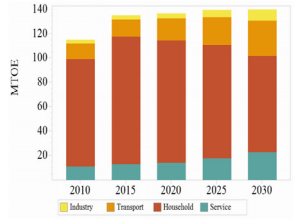

Figure 4: Energy Demand in the LPG substitution policy scenario. ***Source: Author***

Figures 1 to 3 shows how the energy demand in Nigeria is expected to increase in the coming years with respect to different rates of growth of the Nigerian economy. Figure 4 shows a 4th scenario, the LPG substitution policy scenario where policy is used to drive the penetration of LPG into the Nigerian household sector and substitute Fuelwood as the fuel of choice for cooking and water heating.

To achieve this substitution, both market related considerations (inadequate supply and distribution infrastructure, insufficient LPG cylinders and safety) and household related considerations (cost and education) must be decisively addressed to ensure the smooth transition of fuel in the household sector.

CONCLUSION

- Energy transition has rightly been described in this study as the gradual rather than sudden change that unfolds overtime that brings about more diversity to the energy system.
- The transition occurring globally will not leave developing countries behind, hence the need to have an equitable interpretation of energy transition within the context of sustainable development in developing African countries.

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Modeling The Future Energy Scenarios of Bamako City, Mali

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Abstract

Bamako city, the largest city and the fastest growing city in Saharan Africa in 2006, is a mirror of the country. The hybrid model (Bottom-up and Top-up) has been used to project the future energy demand for the key sectors from 2013 to 2033 using LEAP. As inputs of the model, primary data have been collected through surveys, questionnaires, focus group discussions of the key players and stakeholders in the sector. The results show that, under the BAU scenario, the total energy demand in 2033 would reach 51 billion Terajoules, where the household and transport sectors would remain the two main energy consumption sectors, followed by industry, and commercial (formal and informal) sectors. Charcoal and cooking would remain the main fuel and energy service resp. for Households. Under both EST and EFR scenarios, 439,200 tones of charcoal, 229 GWh of electricity could be saved: about 166 millions USD.

BACKGROUND/CONTEXT

Global energy demand is growing continuously and much of this growth is in cities. Over 4 billion of the world's population currently lives in urban areas. As these urban populations continue to grow, there will be a significant impact on global energy demand and the resultant carbon emissions (Bazilian et al., 2012). Research on energy systems at a local or regional level allows to narrow down variations of energy demand, energy supply, to consider local characteristics and dynamics factors, as well as local policy and measures.

Photo: Business in City
Source: author, 2018

The analysis of potential energy future in cities can contribute to the understanding of possible future global and national energy trends, and improve the identification of opportunities for renewables energy, energy efficiency policies, regulations and measures.

PROBLEM STATEMENT/RESEARCH QUESTION

The large cities in such sub Saharan African countries such as Bamako face problems in proper energy management due to unpredicted urbanization and improper energy infrastructure and planning. This situation can have a negative ripple effect on the economic and social growth of the city as well as the whole country, hence the need to thoroughly scrutinize the government's energy expansion plan and provide feasible alternatives.

OBJECTIVES

The main objective is to predict and understand the long term energy future pathway that would response of the Bamako citizen needs and economic development on a sustainable manner.

METHODOLOGY

➢ **Data Collection**

data collection was carried both primary and secondary.

❖**Primary data**

Questionnaires on key sectors:

- 373 Households , 225 Commercial businesses ,9 Industries , and Focused group discussion among stakeholders.

❖**Secondary data**

- Literature review, Annual Bamako city statistics, Directorate of National energy.

➢**Energy Demand development**

A result of total activity times energy intensity for each sector and year (Ouedraogo, 2017b) is used and expressed as follows:

$$ED_{u,s,t} = TA_{u,s,t} \times EI_{u,s,t}.$$

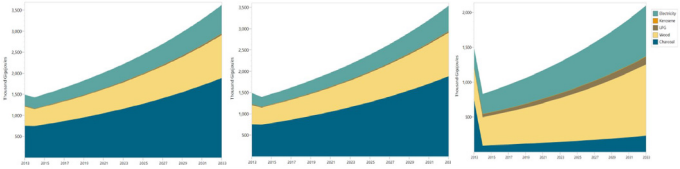
Where: ED is the energy demand in sector u, TA the total activity in sector u EI the energy intensity, s is the scenario and t the time.

Energy intensity will be calculated as a product of energy consumption and total activity:

$$EI_{u,t} = \frac{EC_{u,t}}{TC_{u,t}}$$

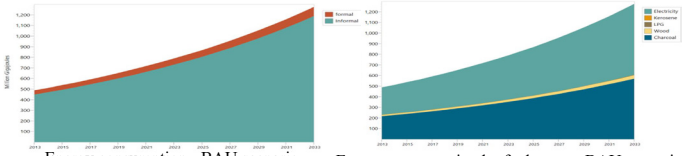
RESULTS AND DISCUSSION

❖**Household sector energy consumption per fuel type**



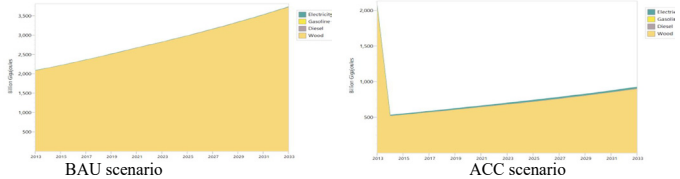
BAU scenario. EFR scenario. ACC scenario.

❖**Commercial sector**



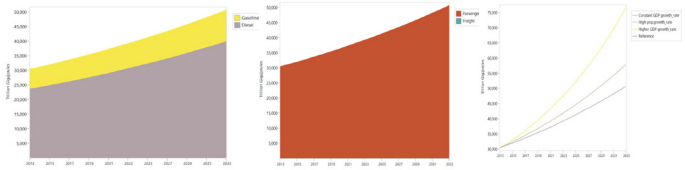
Energy consumption - BAU scenario. Energy consumption by fuel types - BAU scenario.

❖**Industry sector energy consumption by fuel type**



BAU scenario ACC scenario

❖ **Transport sector**



Energy demand by fuel types - BAU scenario. Energy consumption - BAU scenario Fuel consumption - sensitivity scenarios.

CONCLUSION

This study was aims to have a deeply understanding the energy behavior for the Bamako citizens and the next 15 years in purpose to help the decision maker as well in city level as a national level . This dataset has been used to develop an energy systems model that projects long term scenarios of energy use.

➢ **Policies and Recommendations**

- Develop and adopt an energy master plan for the city,
- Promoting and encourage a small scale manufacturing of optima Charcoal cooking stoves;
- Develop and adopt an energy and energy efficiency master plan for each key sector of energy consumption

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Renewable Energy Planning and Regulatory Policy: Tools for Sustainable Electricity Generation and Low Carbon Development: The Case Of Ghana

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Abstract

This study identified and ranked RE obstacles from most notable to least notable to be addressed to develop Ghana's RE sector. Desktop analysis of the literature, survey approach and collected data from RE developers and stakeholders were done; and the Long Range Energy Alternative Planning (LEAP) was used for modelling GHG emissions from electricity generation in Ghana. The average score to obstacles ranged from 4.13 to 2.52 and the overall average score was 3.17 indicating that all the selected barriers are key to the development of RE in Ghana. The study shows that, the most challenging obstacles include cost of financing (high interest rate), lack/insufficient incentives (tax rebate, grants etc), lack/inadequate access to finance and long-term capital, grid connection constraints and lack of grid capacity. Greenhouse Gas emissions from Business as Usual (BAU) of 72,543.8 Mt-CO2eq will decrease by 11.5%, 57.7% and 80.8% by 2030 if fossil fuels are replaced with 10%, 20%, and 40% RE respectively into the current generation mix.

BACKGROUND/CONTEXT

The supply of clean, reliable and affordable sustainable and environmental friendly energy is a condition for economic, social and industrial development of a nation and the population's well-being, RE sources play major role in achieving electricity access in both grid-based and decentralized technologies essential for remote rural areas power generation .

PROBLEM STATEMENT/RESEARCH QUESTION

10% RE mix target in the electricity sector by 2020 is not possible although there are policies and regulations in place in Ghana. Again, attention in the literature within the Ghanaian context about how RE can contribute to the reduction of GHG emission is missing

OBJECTIVES

To identify the obstacles in undertaking RE projects in Ghana from the perspective of investors and stakeholders and to model the amount of GHG emission that can be reduced by RE supply into the current electricity mix in the power sector.

METHODOLOGY

Research Approach

Approach	Activity
Desk study /Review	✓ RE potentials in Ghana, ✓ Obstacles to RE development and deployment, ✓ RE policies and regulations etc.
Survey	✓ For the selected obstacles from developers and stakeholders
Long Range Alternative Energy Planning (LEAP) system	✓ Used for GHG emission strategies (scenarios)

GHG emission in the Electricity sector of Ghana

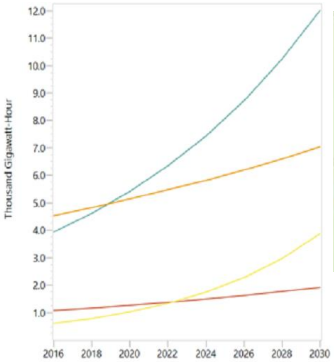
BAU		The time span of this study is 2016-2030. In the BAU, Energy system was modelled without any policy interventions. Energy system of the base year 2016 was modelled using the reported data and then existing energy generation trends projected until 2030
Emission reduction strategy	Scenario 1a	The scenario follows 2010 National Energy Policy target with a target of RE in 2020 by 10% and Ghana INDC plan by 2030.
	Scenario 1b	Scenario with share of RE target in the generation mix to be 20% by 2030.
	Scenario 1c	with share of RE target to be 40% by 2030.

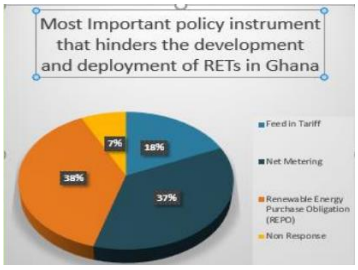
Scenario Assumptions

- The average growth rates of Residential, Non-Residential, Special load tariff and street lighting of 8.31%, 4.27%, 3.17%, 14.25% respectively from 2006-2016 were used for demand (consumption) projections for the scenario years.
- Fossil fuels are replaced with Renewable energies by 10%, 20% and 40% of total installed plants using the base year (2016) figure in different scenarios.

RESULTS AND DISCUSSION

Final Energy Intensity (Demand), TWh





100-YEAR GWP: DIRECT (AT POINT OF EMISSIONS)								
ALL FUELS, ALL GHGS								
BRANCH: TRANSFORMATION\ELECTRICITY GENERATION\PROCESSES								
UNITS: CUMULATIVE THOUSAND METRIC TONNES CO2 EQUIVALENT								
SCENARIOS	2016	2018	2020	2022	2024	2026	2028	2030
BUSINESS AS USUAL	4,838.5	14,510.7	24,182.9	33,855.1	43,527.2	53,199.4	62,871.6	72,543.8
RENEWABLE 10 PERCENT	4,838.5	13,323.5	21,808.5	30,293.5	38,778.5	47,263.5	55,748.5	64,233.5
RENEWABLE 20 PERCENT	4,838.5	8,531.1	12,223.7	15,916.2	19,608.8	23,301.4	26,993.9	30,686.5
RENEWABLE 40 PERCENT	4,838.5	6,117.1	7,395.6	8,674.1	9,952.6	11,231.1	12,509.6	13,921.9

With an introduction of 10%, 20% and 40% renewable to replace fossil-based fuels under various scenarios, total emissions decreased by 11.5%, by 57.7% and 80.8% respectively from the BAU in 2030.

CONCLUSION

Ghana has RE potentials, the sector is only crippled with some challenges and these challenges can be eliminated with pragmatic measures and implementation of already designed policies and regulations in the sector. RE is not just beneficial for electricity generation but also the ability to mitigate GHG emissions to ensure sustainable development and building low carbon economy.

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Master of Sciences

Water Engineering

Analysis of the Effects of Land Use / Land Cover on River Flow Regime: A Case Study of Mkurumudzi River Sub-catchment

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Abstract

The population in Mkurumudzi catchment rely on river water for their livelihood. There is lack of studies on the effects of land use / land cover on river flows for sustainable water management. SWAT modelling of watersheds is important in development and management of water resources. This study involves analysis the river flow discharges based on land use practices in the catchment resulting from human activities. The results obtained indicated that there was effect of land use change that affected the flows for the periods that were examined. Future prediction shows that there would be changes of stream flow as compared with the current flows. Therefore, it is important that the area of forest cover be increased to maintain and land degradation interventions be adopted in order to maintain environmental flows.

BACKGROUND/CONTEXT

Kenya has an area of 582,646 km^2 of which 571,416km^2 is covered by land while 11,230 km^2 is covered by water. Available surface water and ground water is 1,198 and 305 MCM/year respectively (NWMP, 2030: Wrma, 2013). Land Use/ Land Cover change is an environmental problem which impacts ecosystems, agriculture & livelihood thus affecting the hydrological cycle. These effects further slows socio – economic growth.

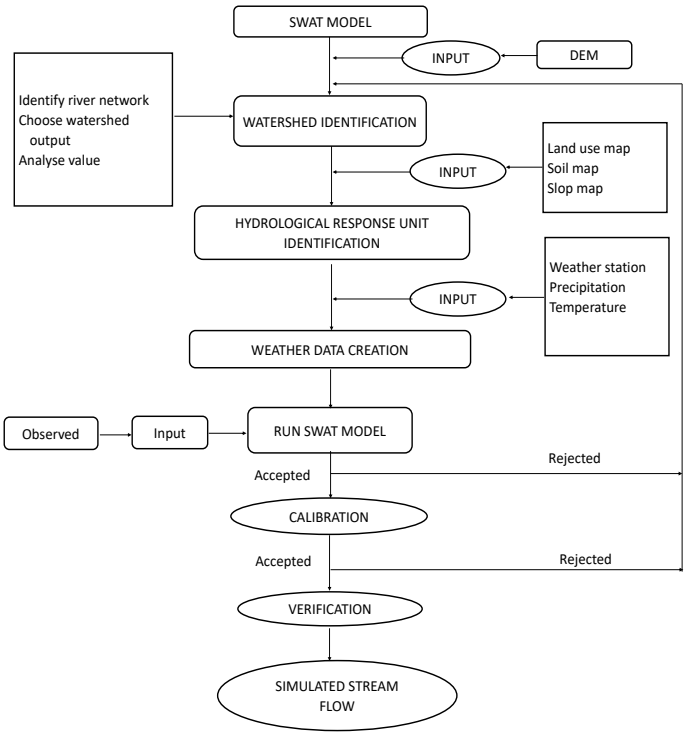
PROBLEM STATEMENT/RESEARCH QUESTION

The catchment has high number of water abstractors (Katuva, 2012). Negative human activities impacts on the catchment poses a great effect to the water resources (Koch et al. 2012). Over the years river discharge has gradually decreased in the area (Katuva, 2012). Therefore, there is need to focus on assessment of land use changes in order to develop strategies to adopt in response to the changed conditions.

OBJECTIVES

To assess land use practices and their effects on Mkurumudzi river flows and formulation of alternative measures to maintain water supply.

METHODOLOGY



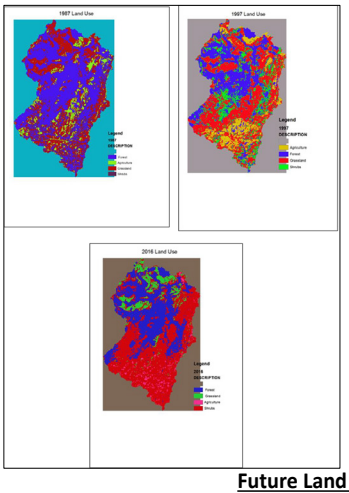
RESULTS AND DISCUSSION

Description	Land Use Area (Ha)		
	1987	1997	2016
Forest	3472.2	2086.2	2419.38
Grassland	2161.26	2892.96	557.1
Agriculture	598.5	741.6	177.21
Shrubs	714.69	1225.89	3792.96

- Forest cover had the largest area in 1987.
- In 1997, grassland occupied the largest part.
- Currently, the catchment has highest shrubs cover

Description	Percentage (%) change In Land Use Based on Preceding Year	
	1997	2016
Forest	-13.86	3.3318
Grassland	7.317	-23.3586
Agriculture	1.431	-5.6439
Shrubs	5.112	25.6707

Classified Satellite Images



- Increase in deforestation is consistent with increase in grassland area that provided potential footprint for agricultural activities.

Description	Year				Percentage Change		
	1987	1997	2016	2030	1997	2016	2030
Minimum	0	0	0	0	0	0	0
Quantile 1	0.0385	0.0429	0.0375	0.0373	11.46	-12.53	-0.6
Median	0.1724	0.1783	0.1694	0.1691	3.42	-4.99	-0.18
Quantile 3	0.52	0.5509	0.511	0.5103	5.95	-7.24	-0.14
Maximum	4.772	4.809	4.788	4.788	0.78	-0.44	0
T-test		0.0543	0.0509	0.068			

- Significant changes in stream flows as a result of land use change.
- Possibility of decreased river discharge in 2030 with increased 10 % land cover.

Future Land Use Conversion

Present Land Use	Future Land Use			
	Forest	Agriculture	Grassland	Shrubs
Forest	+	-	-	-
Agriculture	-	+	+	-
Grassland	+	+	-	+
Shrubs	+	+	-	-

- The + ve means Conversion possible and –ve means conversion not possible

CONCLUSION

The land use and land cover influences the river flow regime of Mkurumudzi River. The major current land use practices in the catchment affecting the river flows is agriculture. From this study, changes in the LULC clearly shows that changes in forest cover was the major LULC change experienced in the catchment. Modelling provided insight into understanding future river flow change and helps formulation of alternative land based intervention measures in response to the changed

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Constructed Wetlands for Treatment of Leachates from a Municipal Landfill in Zimbabwe

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Abstract

Wastewater management presents a great challenge, particularly in Africa where conventional treatment technologies are quite expensive and cannot be properly operated and maintained. Constructed wetlands have been observed to provide a cost-effective, environmentally friendly, affordable, and relatively simple solution that is both sustainable and suitable for the African context. The first-order reaction rate equation was used to model contaminant removal and to design the constructed wetlands for leachates treatment. However, all parameters observed still remained above the maximum allowable concentrations for safe disposal. Therefore, constructed wetlands alone cannot effectively treat landfill leachates to acceptable environmental standards. Coupling the CW system with some aerobic technology such as the Sequencing Batch Reactor (SBR) or an anaerobic technology such as the Anaerobic Filter is highly likely to achieve the required wastewater effluent standards.

BACKGROUND/CONTEXT

- Solid waste management presents a global environmental concern and landfilling remains the most popular solid disposal method
- Mainstream wastewater treatment plants used for most effluents normally cannot treat landfill leachates to acceptable environmental standards

PROBLEM STATEMENT/RESEARCH QUESTION

Richmond sanitary landfill has no treatment system for the leachate produced from the solid waste disposal. Several studies at the site have suggested groundwater pollution due to leachates migrating from the ponds into the shallow unconfined aquifer directly below the site

OBJECTIVES

1. To characterize the effluent from a municipal landfill in Zimbabwe
2. To design a constructed wetland for the treatment of landfill leachates in Zimbabwe
3. To construct and operate a pilot constructed wetland for the treatment of landfill leachates in Zimbabwe
4. To determine the efficiency and effectiveness of the constructed wetland in the treatment of landfill leachates in Zimbabwe
5. To suggest policy recommendations on the application of constructed wetland for the treatment of landfill leachates in Zimbabwe

METHODOLOGY

SAMPLE COLLECTION AND ANALYSIS
↓
DATA ANALYSIS
↓
DESIGN
↓
MESOCOSM CONSTRUCTION
↓
PILOT TESTING & OPERATION
↓
PERFORMANCE EVALUATION

RESULTS AND DISCUSSION

Table 1: Characterization of Richmond Landfill Leachate

Parameter	Mean Influent	ZWS Threshold
T (°C)	18.1	< 25°C
pH	8.81	6.0 – 7.5
EC (mS/m)	5450	NS
DO (mg/L)	1.98	< 7
TDS (mg/L)	27780	1000
TSS (mg/L)	5900	25
BOD5 (mg/L)	641.25	30
COD (mg/L)	2524.40	60
PO4 (mg/L)	2.81	0.5
NO3 (mg/L)	85.12	NS
NH3 (mg/L)	34.30	0.5
Cl (mg/L)	17919	250
FC	16	1000
Cr (mg/L)	0.47	0.05
Cd (mg/L)	0.12	0.01

Table 2: Design Specifications for Constructed Wetlands

Horizontal Subsurface Flow Constructed Wetland
- Surface Area = 2000 m^2 (L:W = 100:20)
- Hydraulic Retention Time = 6 days
- Hydraulic Loading Rate = 3 cm/day

Vertical Subsurface Flow Constructed Wetland
- Surface Area = 1280 m^2 (L:W = 80:16)
- Hydraulic Retention Time = 5 days
- Hydraulic Loading Rate = 5 cm/day

Free Surface Flow Constructed Wetland
- Surface Area = 2200 m^2 (L:W = 100:22)
- Hydraulic Retention Time = 6 days
- Hydraulic Loading Rate = 4 cm/day

Table 3: Efficiency of Hybrid Constructed

Parameter	Mean Influent	Effluent	Removal (%)
TSS (mg/L)	5900	108	98.2
NO3 (mg/L)	85.12	2.11	97.5
COD (mg/L)	2524.40	431.2	82.9
BOD5 (mg/L)	641.25	197	69.3
FC (cfu/100ml)	16	5	68.8
TH (mg of CaCo3)	1313	659	49.8
PO4 (mg/L)	2.81	1.66	40.9
NH3 (mg/L)	34.30	22.96	33.1
Cd (mg/L)	0.12	0.083	28.0
Cr (mg/L)	0.47	0.372	20.3
TDS (mg/L)	27780	24000	13.6
Cl (mg/L)	17919	15600	12.9
EC (mS/m)	5450	4420	2.1
DO (mg/L)	1.98	4.70	-137.4

Figure 1: Construction of Hybrid Constructed Wetlands

CONCLUSION

- Constructed wetlands were evaluated for treatment of leachates from a sanitary landfill.
- The designed system performed better than the operated system. Constructed wetlands alone cannot effectively treat leachates to required effluent standards.
- Recommended systems to be used in conjunction with constructed wetlands are the Sequencing Batch Reactor (SBR) or Anaerobic Filter

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Drought Analysis for Water Planning in Agriculture: A Case Study of Gourma Province, Eastern Burkina Faso

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Abstract

Due to the planning challenges posed by occurrence of drought events to the stakeholders in the Agricultural sector, this master thesis research uses the effective reconnaissance drought index (eRDI) and Pearl millet yield gaps (Yg) to establish the impact of drought in Agriculture. A farmer in Gourma losses up to 775Kg/Ha of grain which translates to 676$/Ha of Pearl millet. This thesis further proposes "Le Guardien de l'espoir" Insurance regime as a drought impact mitigation strategy.

BACKGROUND/CONTEXT

Historically, there are 12 drought events recorded in Burkina Faso between 1900 and 2013 (Masih, Maskey, Mussá, & Trambauer, 2014). These events impacted negatively on agricultural production but the severity has not been accurately quantified. These historical events can be used to inform policy makers and thus mitigate drought impacts in the future.

PROBLEM STATEMENT/RESEARCH QUESTION

Drought is a naturally occurring event that human beings grapple with the question of how to mitigate its impacts. Certainly, Agriculture is one of the biggest casualties of drought events but the extent to which the sector is affected is imperceptible.

OBJECTIVES

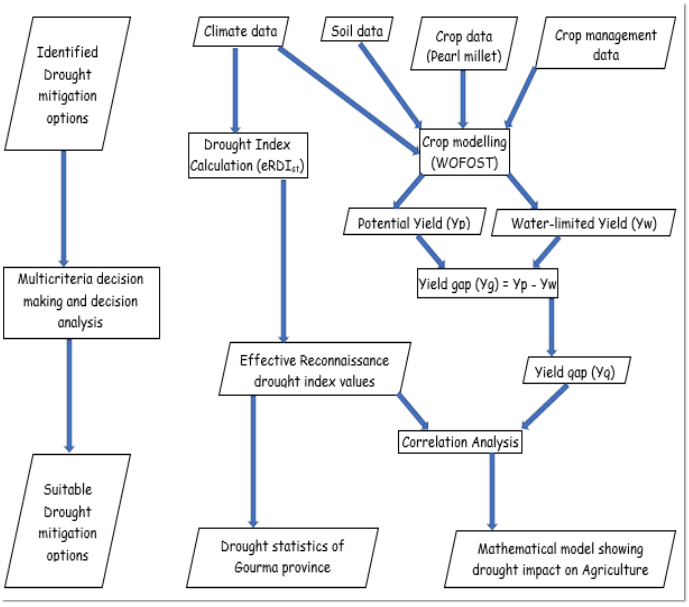
Main Objective

Analysis of Drought for water planning in Agriculture in Gourma province of Burkina Faso.

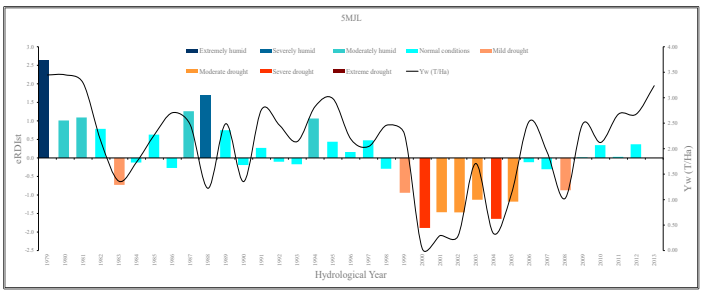
Specific Objectives

1. Characterization of the drought in Gourma Province of Burkina Faso.
2. Demonstrate the implication of the occurrence of drought on agriculture
3. Critically analyze and identify options to mitigate a drought event
4. Make scientific and policy recommendations for the case of Gourma

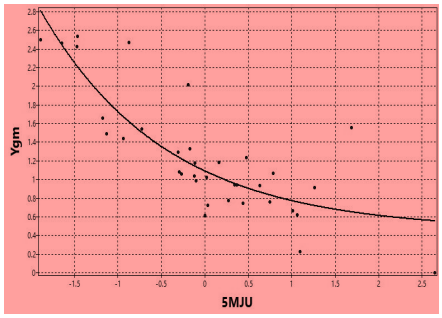
METHODOLOGY



RESULTS AND DISCUSSION



-1983 & 2008 events were least severe
-1999 to 2005 event has highest intensity and longest duration



R^2=0.706266

$$Ygm = 0.46 + (0.63 \times 0.5^{5MJU})$$

	Short-term actions	Long-term actions
Supply increase	Over-exploitation of aquifers	Mulching using crop residues, will enhance the organic matter content also besides reducing the evaporation
Demand reduction	Restriction of the irrigation of some crops (e.g. annual)	Economic incentives for private investments in water conservation
Impact minimization	Temporary reallocation of water resources (on the basis of assigned use priority)	Mitigation of economic and social impacts through voluntary insurance, pricing and economic incentives

CONCLUSION

- ✓ Between 1979 & 2014, there were 3 drought events in Gourma spread over 9 years.
- ✓ Pear millet farmers lose an average of 775Kg/Ha due to drought and this results in economic losses of up to 676$/Ha.
- ✓ Insurance was found to be a suitable long term drought impact mitigation measure.

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Flood Risk Assessment in the Niger River Basin in Support of the Conception of a Flood Risk Management Plan: Case study of the District of Malanville, Benin

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Abstract

This thesis was carried out to evaluate the flood risk in the district of Malanville located along the Niger River. The knowledge produce by this study is useful in the implementation of adaptation and/or mitigation measures to alleviate the impact of the flooding on the populations, the economy and the environment. From the analysis it was found that The townships of Malanville most at risk of flooding are Momkassa and Galiel, located in a high-risk and very high-risk zone, respectively.

BACKGROUND/CONTEXT

With a length of 4,200 km, the Niger River is the third-longest river in Africa. Over the past years, several flooding events have affected the population living along the Niger River. An understanding of the characteristics of the risk will help in effectively managing the flood risk and thus reduce the damage caused by the hazard on the people and their properties. Malanville, a northeastern district of Benin Republic, is one of the areas located along the Niger River, which suffers the impact of its overflow each year. A sound flood risk management plan is needed in the region and must be supported by an accurate assessment of the flood risk. Risk is defined as the product of the flood hazard (probability and magnitude) and the vulnerability (Klijn et al., 2009).

PROBLEM STATEMENT/RESEARCH QUESTION

This research will be guided by the following questions:

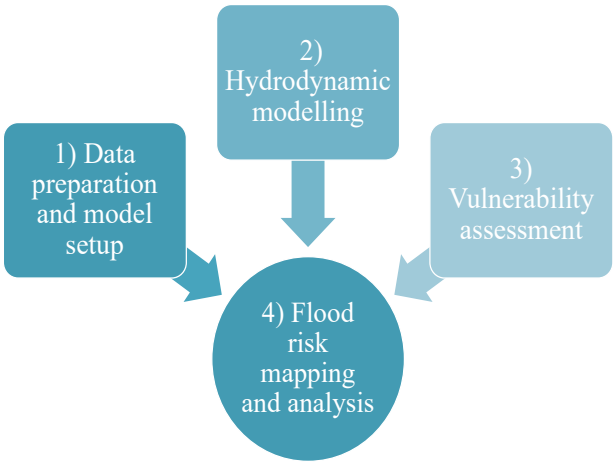
- What is the exposure of the communities at risk to different flood scenarios (low, medium, high)?
- How vulnerable the communities are to the different floods scenario?
- What type of measure (structural and non-structural) would work best to alleviate the flood risk in the study area?

OBJECTIVES

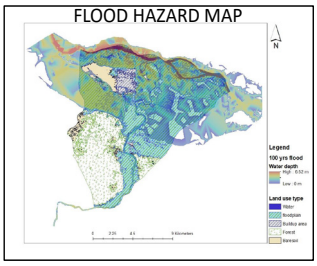
The overall objective of this thesis is to assess the flood risk in the district of Malanville located in the Niger River basin using remotely sensed data, GIS and hydraulic modeling.

METHODOLOGY

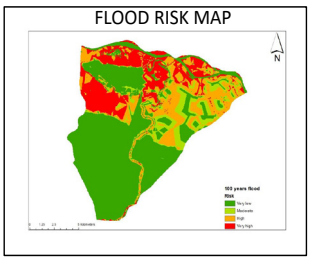
The methodology adopted in this study is comprised of four main tasks:



RESULTS AND DISCUSSION



From the result of the hydrodynamic modelling it was found that between 47% and 50% of the study area will be flooded during the different flood scenarios (10 yrs, 20 yrs, 50 yrs, 80 yrs, and 100 yrs) simulated.



The flood risk assessment revealed that in every flood scenario studied, the townships of Momkassa and Galiel are located in a high-risk zone and in a very high-risk zone of flooding, respectively.
This is related to their high vulnerability and their exposure to high water level during the flooding.

Township/Flood scenario	10yrs	20yrs	50yrs	80yrs	100yrs
MOMKASSA	High risk	High risk	High risk	High risk	High risk
BODJECALI	Very low risk	Very low risk	Very low risk	Very low risk	Very low risk
GALIEL	Very High risk	Very High risk	Very High risk	Very High risk	Very High risk
KOKI	Very low risk	Very low risk	Very low risk	Very low risk	Very low risk
TASSI TEDJI	Very low risk	Very low risk	Very low risk	Very low risk	Very low risk
TASSI ZENON	Very low risk	Very low risk	Very low risk	Very low risk	Very low risk
WOLLO	Very low risk	Very low risk	Very low risk	Very low risk	Very low risk

CONCLUSION

This thesis was carried out to assess the flood risk in the district of Malanville located along the Niger River. In order to analyze the flood hazard a hydrodynamic model (HEC-RAS) was set up for the study area and different flood scenarios were simulated. As for the vulnerability, each of its components were analyzed by using an indicator-based approach.
The results from the flood hazard assessment and the vulnerability analysis were combined to produce a flood risk map of the study area.

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Impact of Climate Change on Groundwater Resources of the Atankwidi Basin in Ghana, West Africa

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Abstract

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Groundwater accounts for about 30% of Earth's total fresh water. It is the primary source of water for over 1.5 billion people worldwide. Groundwater is an essential key parameter to achieving SDG 1 & 6 in Sub-Saharan Africa. The primary source of water for Domestic, Industrial and Agricultural purposes Atankwidi Region is Groundwater. Source: C.P Kumar., 2015; Braune E et al., 2010; Martin N., 2005

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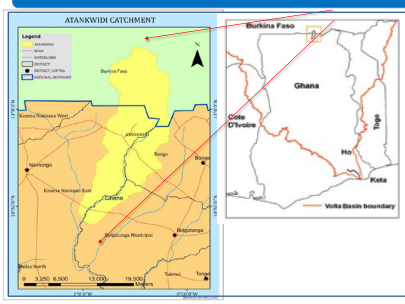

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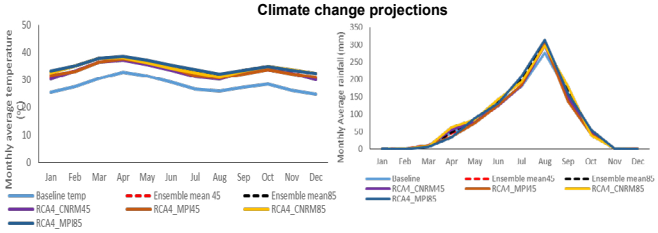

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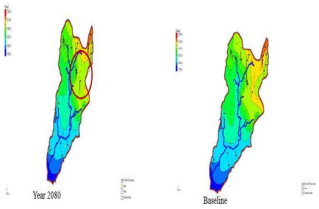
Spatial impact of scenario 1 (changes in recharge only)



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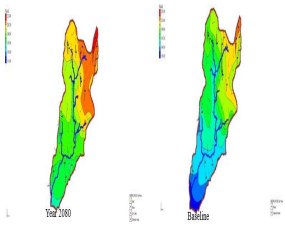

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Gisele Icyimpaye , Dr .Chérifa Abdelbaki [a]

[a]Abou Bakr Belkaid University of Tlemcen, *Tlemcen ,Algeria*

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1.To investigate the causes and impacts of flood in the catchment.

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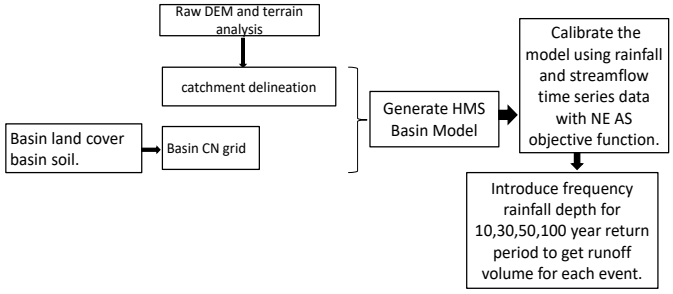

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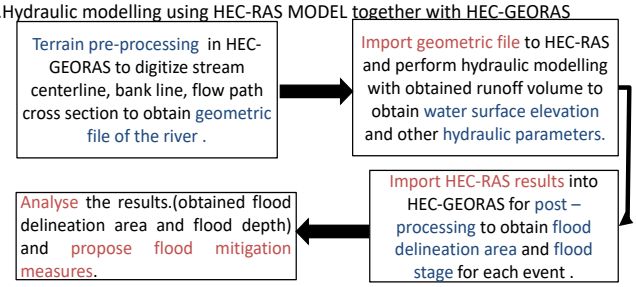

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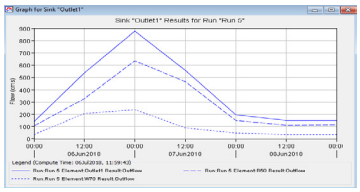

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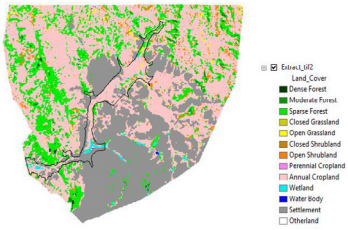

Flood delineation polygon map for 100 year return period

Big area covered with its depth for each event

Return period year	Flood Depth (m)	% Coverage area of the total area
10	0.612- 0.957	33.522
30	0.698 -1.092	33.519
50	0.736-1.152	33.431
100	0.787-1.231	33.442

The high water depth of 3.2 was observed for 100 year return period.

Some proposed mitigation measures included:

- Flood proofing measures,
- Construction of storage reservoir at the upstream the reach,
- Relocation of infrastructures within the flood delineation area,
- Buffer zoning around river,
- Rainwater Harvesting Strategies and Raising public awareness of flood risks

CONCLUSION

HEC-HMS and HEC-RAS models combined with GIS extension demonstrated:

- Expected floodplain area;
- Expected flood depth; and
- Expected vulnerable land use types.

Both engineering and non engineering mitigation measures can be applied. Cost benefit analysis need to be considered before implementation any flood mitigation measure

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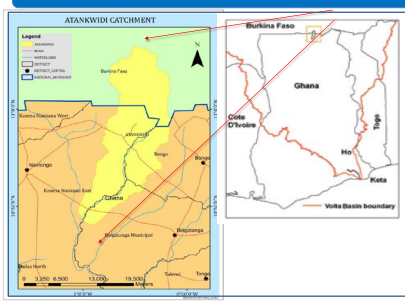

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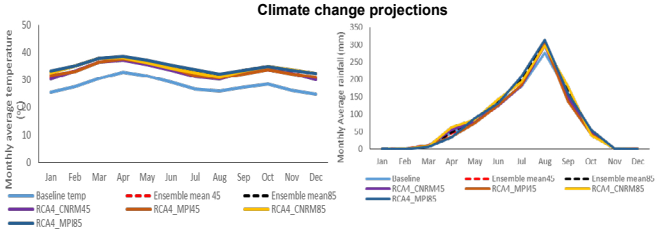

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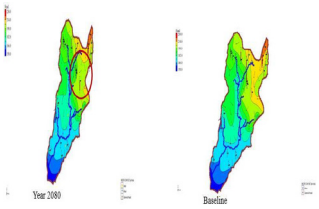

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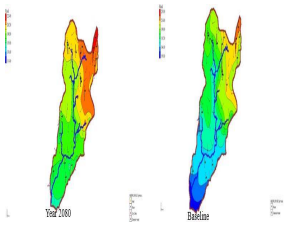

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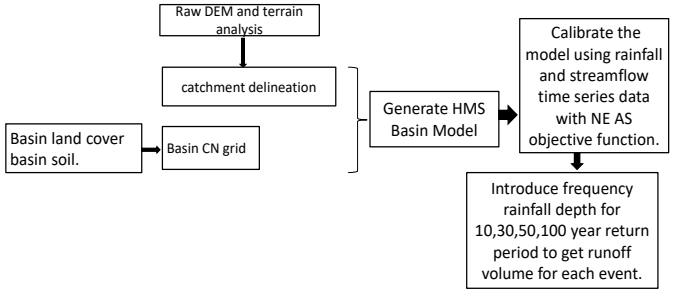

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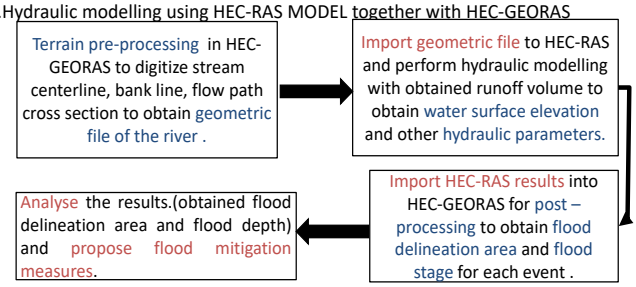

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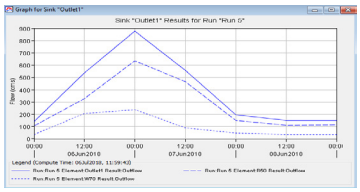

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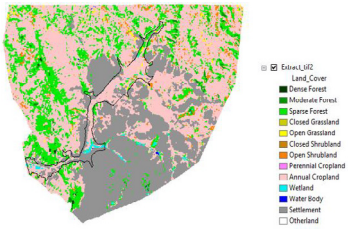

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Big area covered with its depth for each event

Return period year	Flood Depth (m)	% Coverage area of the total area
10	0.612- 0.957	33.522
30	0.698 -1.092	33.519
50	0.736-1.152	33.431
100	0.787-1.231	33.442

The high water depth of 3.2 was observed for 100 year return period.

Some proposed mitigation measures included:

- Flood proofing measures,
- Construction of storage reservoir at the upstream the reach,
- Relocation of infrastructures within the flood delineation area,
- Buffer zoning around river,
- Rainwater Harvesting Strategies and Raising public awareness of flood risks

CONCLUSION

HEC-HMS and HEC-RAS models combined with GIS extension demonstrated:

- Expected floodplain area;
- Expected flood depth; and
- Expected vulnerable land use types.

Both engineering and non engineering mitigation measures can be applied. Cost benefit analysis need to be considered before implementation any flood mitigation measure

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Stormwater Modeling for Improving Floods Resilience, Water Supply, Soil and Ecological Conservation

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Abstract

In this study, the HEC HMS model was used for rainfall-runoff simulation. The computed peak discharge for the 1998 study year was 355.7m^3/s, 402.7m^3/s in 2009 and 437.8m^3/s in 2018 which is an increase of about 23.08% from 1998 to 2018. The peak inflows for all detention basins were observed in the extreme event of 20 December 2011, where reservoir 1 had peak inflow of 123.6 m^3/s, reservoir 2 had 43.5m^3/s, reservoir 3 had 37.5 m^3/s, reservoir 4 had 60.5 m^3/s and reservoir 5 had 19.2 m^3/s.

BACKGROUND/CONTEXT

- Changes in land use usually affect stormwater runoff flow characteristics as the extent of impervious surfaces increases.
- In rapidly urbanizing catchments, increase in stormwater runoff quantity may lead to numerous of serious problems such as flash floods, soil erosion and alteration of an ecosystem.
- Dar es Salaam with a population of 4,4 million in 2012 (NBS, 2013) has become the fastest urbanized city in Africa (AfDB, 2014).
- In this study, the ArcGIS, HEC-Geo HMS and HEC HMS model were used for rainfall-runoff simulation for 1998, 2009 and 2018 years.

PROBLEM STATEMENT/RESEARCH QUESTION

- Dar es Salaam is experiencing significant growth and development (AfDB, 2014).
- With a corresponding increase in the amount of impervious surface covering the landscape from the development activities.
- Resulting to extreme flooding events threatening human lives and their properties as well as leading to soil erosion and ecological destruction.

OBJECTIVES

To assess the impact of land use change on stormwater runoff with respect to the selected rainfall event and land use characteristics for stormwater management engineering solution.

METHODOLOGY

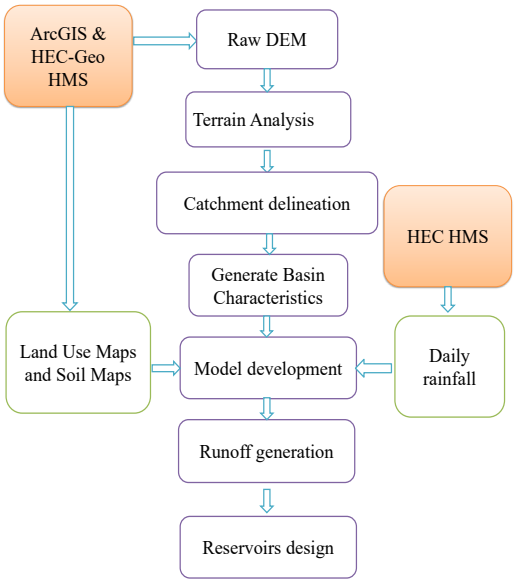
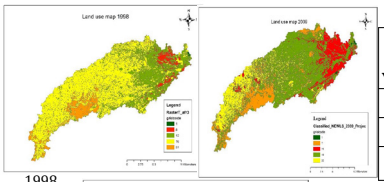


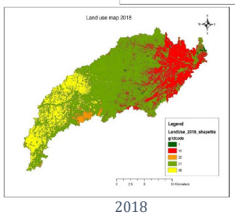
Figure 5. Flow chart

RESULTS AND DISCUSSION

- **Land use change analysis**



1998 2009



2018

Figures 6, 7 & 8: Classified land uses

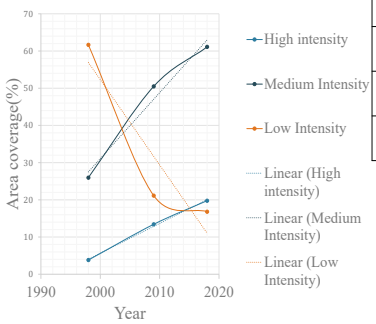


Figure 9. Land use change graph

- **Hydrological model development**

Table 1. Simulated discharges

Year	Simulated Peak Discharge (m^3/s)
1998	355.7
2009	402.7
2018	437.8

- **Reservoirs design**

Table 2. Reservoirs discharge

Sub-basin	Area (km^2)	Coverage (%)	Peak inflow (m^3/s)	Peak discharge(m^3/s)
1	92.7465012	31.343867	123.6	2.3
2	32.2856224	10.910991	43.5	2.1
3	27.6817482	9.3551025	37.5	2.1
4	44.3242012	14.979453	60.5	2.1
5	14.6250142	4.942553	19.2	2

- From figures 6, 7 & 8 of land use change analysis.

Red color: High intensity developed areas, Green color: Medium intensity, Yellow: Low intensity.

- An increase of 23.08% of the runoff generated was observed from 1998 to 2018 due to land use change as shown in table 1.

CONCLUSION

- Efficient storm water runoff management practices can protect one of our most important natural resources, properties and human lives.
- Increased impervious surfaces due to land use changes magnifies the demolishing power of floods as a result of an increase in storm water runoff generation.
- The detention basins are designed to capture and slow stormwater runoff to prevent downstream flooding, reduce the extent of soil erosion, extend water flow period in the river which will also provide water for ecological conservation as well as provide water for none portable uses.

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Study of the Feasibility of Water Reuse for Agriculture as an Adaptation Measure to Climate Change: Case Study of Ain Temouchent, Algeria

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Abstract

This project seeks to study the feasibility of reusing the treated domestic wastewater for agricultural purposes as an adaptation measure to climate change. The research was conducted in the wastewater treatment plant of Ain Temouchent. Analyzes carried out on the physico-chemical and microbiological parameters of the treated wastewater quality have been compared with the World Health Organization (WHO), Food and Agriculture Organization (FAO) and the Algerian standards of water quality for irrigation. The results show that the treated wastewater could be used for the irrigation of fruits trees with specific focus on the olive tree. This choice could be justified by the importance of the olive in the agricultural sector of Algeria. In addition to that, the development of the olive tree is specified by a good efficiency of water use.

BACKGROUND/CONTEXT

- The Middle East and North Africa (MENA) region is the driest and the most water scarce region of the World. With an average of 6.3% of the world's population, the region contains only 1.4% of the world's renewable fresh water (Roudi-Fahimi, Creel, & De Souza, 2002).
- Water shortage in the MENA region will be significant in the next decades and that about 20% can be attributed to climate change and 80% to the increase in demand, population growth and fast economic development (Immerzeel et al., 2011).
- In Algeria, the vulnerability of available water resources is affected by several problems such as climate change, increasing population growth, surface and groundwater pollution, and the over exploitation of fresh water resources.

PROBLEM STATEMENT/RESEARCH QUESTION

The water management situation is characterized by an imbalance between the demand and the available water resources and agriculture is facing more and more serious problems in irrigation. Water intended for this purpose is almost rare and the application of adequate solution is essential adapt to climate change.

OBJECTIVE(S)

- To evaluate the quality of the treated wastewater produced from the wastewater treatment plant (domestic wastewater), of Ain Temouchent, a semi-arid region located in the North-Western part of Algeria.
- To make comparison with the required FAO, WHO and Algerian standards of water quality for irrigation and to assess the possibility of its reuse for agricultural purposes.

METHODOLOGY

Analyze the physico-chemical parameters of the treated wastewater produced from the treatment plant.

↓

Analyze the microbiological parameters of the treated wastewater produced from the treatment plant.

↓

Statistical studies for different parameters to find correlations.

↓

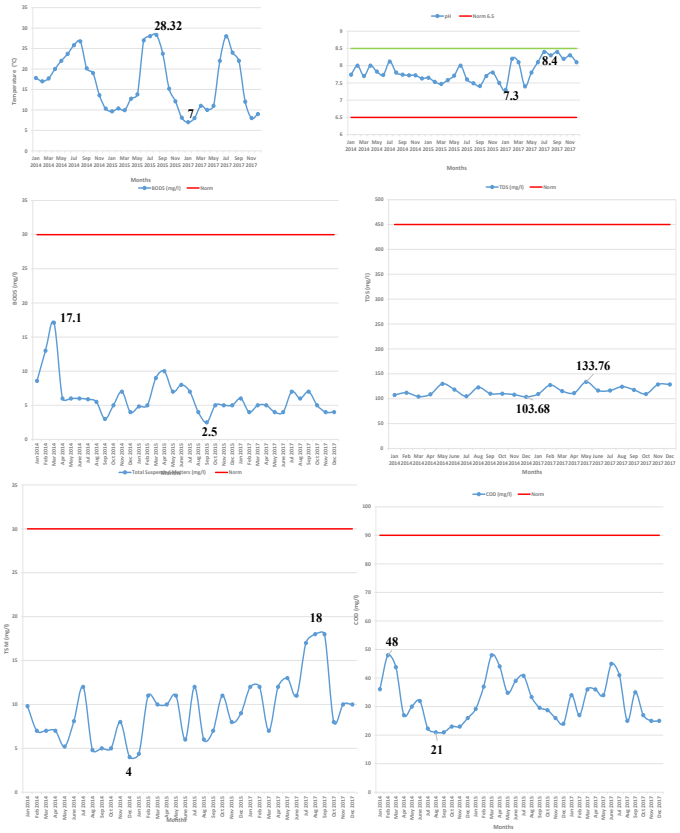
Choose the types of crops that can be irrigated with the treated wastewater.

CASE STUDY

Wastewater Treatment Plant of Ain Temouchent

RESULTS AND DISCUSSION

- In order to assess the quality of the treated wastewater from the wastewater treatment plant of Ain Temouchent, a series of daily analyzes on the water quality parameters were collected from the laboratory of the plant for the time period 2014, 2015 and 2017.



CONCLUSION

- Following the obtained results, we can conclude that the quality of the treated wastewater is satisfactory for the reuse in irrigation.
- The treatment process of the plant is effective to produce a water that meets the reuse standards, since it is equipped with a tertiary treatment units.
- The annual volume of the treated wastewater valued through the irrigation of olive trees will be of great benefit to Ain Temouchent.
- In a context of climate change and in order to preserve the available water resources, the water resources managers of Algeria should promote more wastewater reuse projects in agriculture for a sustainable development.

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Master of Sciences

Water Policy

An Evaluation of Impacts and Sustainability of Humanitarian Organization's Water Projects in Juba, South Sudan

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Abstract

This research work evaluates the humanitarian organizations water projects in water projects in South Sudan. The evaluation water done in three categories namely; the effects on waterborne diseases prevalence in children under the age of five years, girl child school enrolment and women empowerment. The results showed that the water projects had a positive effect on all the three categories.

BACKGROUND/CONTEXT

The civil war in South Sudan has left millions of people living as Internally displaced people. The war led to destruction of water infrastructure and stress to the existing ones. This has led to humanitarina organizations moving into the country to rebuild the water supply systems there by provinding safe water.

PROBLEM STATEMENT/RESEARCH QUESTION

The humanitarian organizations' water projects needs to be evaluated and monitored to ensure that they provide safe water to the vulnerable communities hence preventing the prevalence of waterborne diseases. The study examines the impacts that Oxfam projects have had in Juba in terms of; girl child education, women empowerment and reduction in diseases in children under the age of 5yrs.

OBJECTIVES

To evaluate the impacts of humanitarian organizations' water projects in Juba South Sudan.

METHODOLOGY

Households Survey

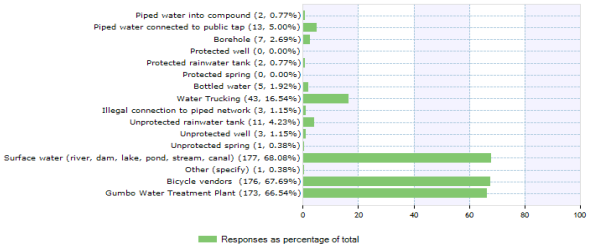
Water Quality testing

Focused group discussion

Key informant Interview

RESULTS AND DISCUSSION

The research found out that most people in South Sudan use the water provided by Oxfam.



Hypothesis testing results showed that the was a positive relation between the Oxfam water projects and waterborne disease, women empowerment and girl child school attendance as shown in the graph below.

Test Hypo	Type Analysis	Results	Decision
Effects on Waterborne Diseases prevalence	Pearson Correlation	r=0.003 and significant of 0.964 implying weak and positive correlation	Accept
Effects on Girls Education	Fisher exact test Pearson Correlation	p=0.025 Oxfam water projects impacted positively and significantly r=0.136	Reject
Effects on Women Empowerment	Fisher exact test Pearson Correlation	P=0.005 R=0.168	Reject

CONCLUSION

- The household survey conducted revealed that there has been a reduction of water related disease among children under the age of five years.
- 92% of the households interviewed also said none of their children had missed school due to water related disease in the last two weeks.
- Data collected from the schools also showed that girl child education has improved. Key informant interview with teachers' revealed that girls were concentrating more on their studies, more punctual and had better test grades.

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Assessing Students' Knowledge, Attitudes and Practices on Water, Sanitation, Hygiene(WASH) and related Diseases in selected Schools in Musanze District - Rwanda

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Abstract

The research assessed students' knowledge, attitudes and practices on water, sanitation, hygiene and related diseases in selected schools in Musanze District, Rwanda.1173 students participated in the research and from the results, it was found that students do not have enough knowledge, have bad practices towards hygiene and sanitation which can endanger their health. Public health education is schools was recommended to upgrade students' knowledge, attitudes and practices on water, sanitation and hygiene related issues.

BACKGROUND/CONTEXT

Global concern on water and sanitation is not of recent existence. The United Nations declared International Drinking Water and Sanitation Decade(1990-1990),and MDGs(2000-2015),SDGs(2015-2030) all which have water and sanitation components.

Despite the efforts, In 2013, globally, it was estimated that 2,000 children under the age of five were dying every day from diarrhoeal diseases (UNICEF 2013). In 2015, only 71% of the global population (5.2 billion people) used improved drinking water source(WHO,2018).

In 2015, only 39 % of the global population (2.9 billion people) used improved sanitation facilities(WHO,2018).In SDG agenda,WASH is to be extended in schools as inadequate WASH can lower school attendance and achievement(WHO,2018)

PROBLEM STATEMENT/RESEARCH QUESTION

According to the World Health Organization, 3.4 million people, mostly children, die annually from water-related diseases. In Rwanda, from 2010 to 2015, fifteen outbreaks were recorded with a total of 285 cases and 3 deaths were recorded (RBC, 2015). In the year 2016 and 2017,Cholera cases were again confirmed to occur in western part of Rwanda.

OBJECTIVES

- To assess students 'knowledge on Water, Sanitation and Hygiene and related diseases
- To Assess students' attitudes on Water, Sanitation and Hygiene
- To Assess students' practices on Water, Sanitation and Hygiene

METHODOLOGY

This research was conducted in six (6) randomly selected schools in Musanze Dsitrict, Northern Province, Rwanda.

Data were collected using questionnaires(Student, school director and teacher's questionnaires) and field observation checklist from.

and analyzed using Statistical Package for the Social Sciences (SPSS,V25).

Sample size of 1,173 students was determined using Krejcie and Morgan (1970) table

Krejcie and Morgan (1970) table is derived from the formula below (Chuan, 2006):

$$n = \frac{X^2 * N * P * (1 - P)}{(ME^2 * (N - 1) + (X^2 * P * (1 - P))}$$

Where

n= Sample size,

X^2=Chi-Square for the specified confidence level at 1 degree of freedom

N=Population size

P=Population proportion

ME=Desired Margin of Error or degree of accuracy (Expressed as proportion at 0.05)

RESULTS AND DISCUSSION

Table 1. Human faeces disposal

			Bush toilet	Latrine	Latrine and bush toilet	Latrine, bush toilet and stream	No answer	Stream	Total
Location of school	Rural	Count	9	500	154	17	6	0	686
		% within Location of school	1.3%	72.9%	22.4%	2.5%	0.9%	0.0%	100.0%
	Urban	Count	24	457	1	1	0	4	487
		% within Location of school	4.9%	93.8%	0.2%	0.2%	0.0%	0.8%	100.0%
Total		Count	33	957	155	18	6	4	1173
		% within Location of school	2.8%	81.6%	13.2%	1.5%	0.5%	0.3%	100.0%

Table 2.Knowledge on diseases related to contact with human faeces.

			Cholera	Diarrhea	Dysentery	Malaria	No answer	Shigellosis	Typhoid	Total
Location of school	Rural	Count	417	161	13	0	84	1	10	686
		% within Location of school	60.8%	23.5%	1.9%	0.0%	12.2%	0.1%	1.5%	100.0%
	Urban	Count	251	150	13	3	35	0	35	487
		% within Location of school	51.5%	30.8%	2.7%	0.6%	7.2%	0.0%	7.2%	100.0%
Total		Count	668	311	26	3	119	1	45	1173
		% within Location of school	56.9%	26.5%	2.2%	0.3%	10.1%	0.1%	3.8%	100.0%

Table 3. Knowledge on prevention of selected WASH related diseases

			Cholera	Diarrheal diseases	Malaria	No knowledge	Shigellosis	Trachoma	Typhoid	Total
Location of school	Rural	Count	86	224	290	74	2	0	10	686
		% within Location of school	12.5%	32.7%	42.3%	10.8%	0.3%	0.0%	1.5%	100.0%
	Urban	Count	99	216	21	127	2	1	21	487
		% within Location of school	20.3%	44.4%	4.3%	26.1%	0.4%	0.2%	4.3%	100.0%
Total		Count	185	440	311	201	4	1	31	1173
		% within Location of school	15.8%	37.5%	26.5%	17.1%	0.3%	0.1%	2.6%	100.0%

CONCLUSION

- There is a need of providing public health education in schools to upgrade students knowledge ,attitudes and practices on WASH.
- Policy on provision of full water supply and sanitation coverage in public places, monitoring of implementation on UNICEF/WHO WASH guidelines in schools, and policy on dissemination of WASH related diseases message in health centers, clinics and hospitals are recommended.

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Assessing the Potential for Water Stewardship Partnership Using Water Risk and Action Framework: The Case of Nzoia Basin, Kenya

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Abstract

There is an increase in water stress and water scarcity. Collective actions among different sectors, institutions and stakeholders are needed to reduce future water risks. Water Risk and Action Framework (WRAF) provides a stepwise guide to water stewardship. Water risks have been quantified using indicators from remote sensing platforms and secondary sources with indicators such as Leaf Area Index (LAI), Rainfall Use Efficiency (RUE), and Soil Water Stress (SWS). The results showed that the Water risks had increased between 2000 and 2014 in different parts of the basin at different magnitude of risk.

BACKGROUND/CONTEXT

Water is the most important substance on earth (Smith et al., 2011). Nearly 80% of the world population is exposed to a high water scarcity threat (Vörösmarty et al., 2010). Globally, Companies are addressing water stewardship as a part of their corporate social responsibility in order to reduce water related risks to their businesses (J. Peter et al., 2015)

PROBLEM STATEMENT/RESEARCH QUESTION

The government and the business sector together share the risks related to water scarcity, poor management or a change in water regulation. Kenya is both a water stressed and a water scarce country. Annual renewable freshwater supplies had decreased from 647 m3 per capita in 1992 to 500 m3 in 2010 and it is projected to drop further to 235 m3 per capita in 2020.

OBJECTIVES

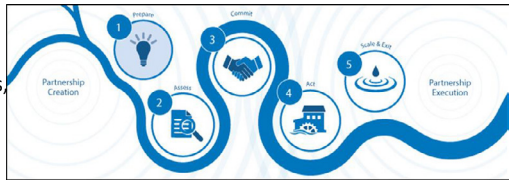
The main objective of this study is to assess the potential for a water stewardship partnership within Nzoia Basin, Kenya.

- To quantify water risks in Nzoia River catchment.
- To map out the potential partnership stakeholders in the Nzoia River basin.
- To assess the potential for stewardship partnership in Nzoia River basin.

METHODOLOGY

1. Water Risk and Action Framework (WRAF)

WRAF stages, (IWaSP, 2018)



2. Quantifying water risks

- **Leaf Area Index (LAI)**
  - **Indicator of degradation Water Risk (WR)=1/LAI**
- **The Priestley-Taylor Alpha Coefficient (PAC)**
  - **Indicator of evapotranspiration rate variation WR=1/PAC**
- **Rain Use Efficiency (RUE)**
  - **Indicator of rainfall variation and land degradation WR= 1/RUE**
- **Soil Water Stress(SWS)**
  - **Indicator of drought and aridity WR=1/SWS**
- **Water Risk Index (WRI)** $= \frac{1}{LAI*RUE*SWS*PAC}$

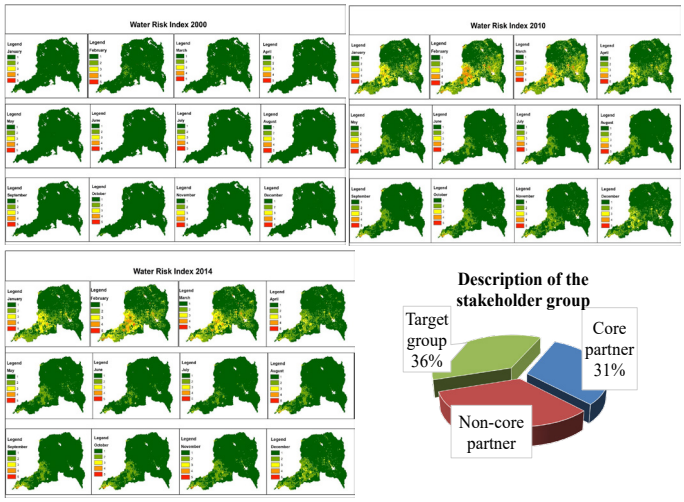
- **Using ArcGIS Raster Calculator**

3. Stakeholder Mapping

- **Use of Stakeholder mapping template by categorizing, prioritizing**
- **Interviewing selected sample**
- **Responses in Descriptive statistics .**

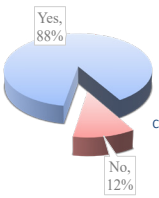
RESULTS AND DISCUSSION

Water Risk Index

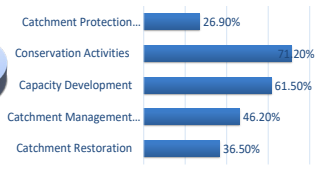


Description of the stakeholder group

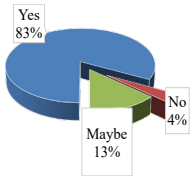
Water stewardship program



Stewardship activities



Monetary Allocation



CONCLUSION

- Evidence of increasing water risks since 2000
- The catchment faces increased deforestation, increased drought, land degradation and land cover changes
- There is a potential for a water stewardship partnership between local, international, Governmental and Non Governmental organization.

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Assessing the Implications of Water Policy on Irrigation Performance in Developing Countries: Case Study From Eastern Province of Rwanda

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Abstract

This study assessed the implications of water policy on irrigation performance in developing countries: case study eastern province of Rwanda. Three dominant irrigation sites (Kagitumba, Nasho/Mpanga, and Gashora) were studied, and a total sample of 563 farmers, five Water Users Association (WUA) and three Key informants were selected. The method used to collect the data included transect walk, focused group, interviews and survey and the data were analysed using SPSS software. The result revealed that the people participation appears in repairing the infrastructure, while public sector help them to strengthen their knowledge through different trainings and financial support while the WUA helps in decentralisation of water management to grassroot level and water use fees payment management.

BACKGROUND/CONTEXT

Area under irrigation have been doubled from 1.4 million km2 1961 to 3.2million km2 in 2012 and 70% of water abstracted worldwide are used in irrigation(USGS, 2017; Mateo-Sagasta et al., 2015). Meantime, the existing water resources management strategies, infrastructures, policies enforcement are not suitable for this high-water demand mainly in developing countries(Georgina, 2017).

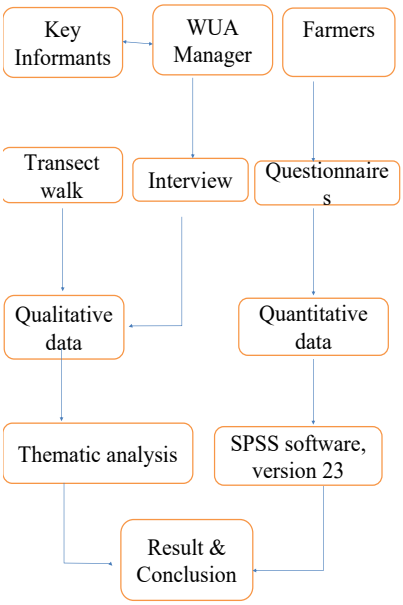
PROBLEM STATEMENT/ RESEARCH QUESTION

Modernisation of irrigation is one of the strategies, adopted by the government of Rwanda, as an adaptation strategy to the impact of climate change to achieve sustainable food security, therefore, there is a need to have effective water policy to control water abstraction rate through proper people participation and functioning WUA.

OBJECTIVES

- Assessing the role of public participation on irrigation performance.
- Evaluating the Impact of Water Users Association on irrigation performance.

METHODOLOGY



RESULTS AND DISCUSSION

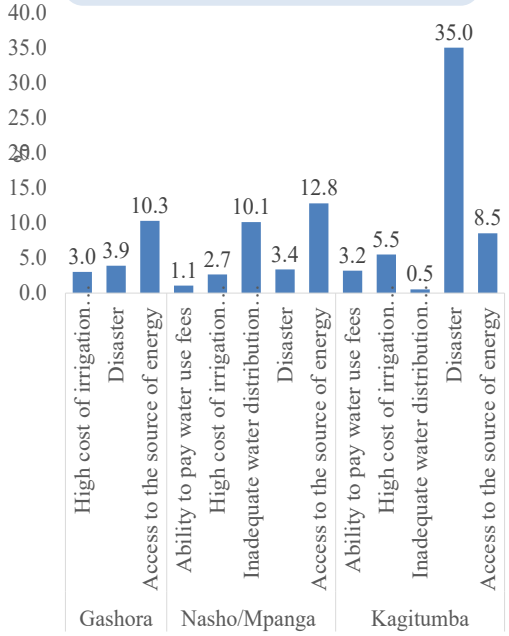
People participation in management of irrigation infrastructures.

Irrigation Site	Technical Problems Repairing Actors	N	%
Gashora	Farmer	78	13.6
	Permanent technicians	19	3.5
Nasho / Mpanga	WUA	60	10.7
	Farmer	21	3.7
	Permanent technicians	88	15.6
Kagitumba	WUA	136	24.2
	Farmer	65	11.5
	Permanent technicians	96	17

Main entry requirements in WUA:
- Plot of land
- Water use fees
- Farming activities in the irrigation scheme

Main Responsibilities of WUA:
- ✓Water allocation.
- ✓management of irrigation infrastructures.
- ✓water use fees collection .
- ✓Water quality monitoring.
- ✓Water related Conflict resolution.

Major irrigation performance challenges



Famers Benefits from WUA	%
Easily getting water subsidy	70%
Farm management training	23.1%
Selling the harvest	4.6%
Credits services from WUA	2%
Others profits	0.2%

CONCLUSION

- The implication of water policy in Rwanda, appears in effective participation of people in the repairing and management of irrigation scheme while the government gives training and irrigation technicians.
- WUA is sole institution which is helping the collection of water use fees and its management.
- Some challenges which are affecting the implementation of water policy in Irrigation includes: Disaster, energy and water allocation calendrer
- This study recommends the volumetric measurement of water resources abstracted as well the encouragement of use of water saving irrigation type.

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Comparative Analysis of Factors that Influence Consistent Use of Household Water Treatment and Storage in Northern Kenya

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Abstract:

Economic, technical, behavioral and contextual factors in an emergency context influence the consistent use of household water filters. Use of household water treatment and storage (HWTS) options improves water quality in emergency contexts and consistent use leads to health benefits. However, HWTS options are often designed for the typical household environment, not taking into account unique challenges faced during emergencies. The study aimed at comparatively analyzing factors that influence consistent use of household ceramic water filters in Northern Kenya which was facing prolonged droughts. The study followed both qualitative and quantitative design using structured observations, questionnaires and a focus group discussion. Spearman's correlation analysis and multivariate regression models were used to understand and explain the predictors of consistency of use of household filters. Findings indicate that consistency of use of filters is affected by different factors. Those filters with a two-bucket interface design were mostly affected by design factors such as functional status indicators while those with one-bucket interface design were mostly affected by psychosocial and economic factors such as peer approval and availability of spare parts. The context, i.e. how well these filters fit in the shelters, was a strong determinant of consistency in filter use for both groups. Regression models showed an increase in percentage of consistency of use by 22 points with agreement to good fit in the house. These findings suggest that, WASH actors should take into account these factors during filter-based interventions in emergency contexts. A tradeoff between space occupied by the filter and filter capacity and how they affect fit in the shelters still exists.

BACKGROUND/CONTEXT

- Protracted droughts, floods and political crisis affect already few sources portable water existing
- Most water sources are contaminated with feacal coliforms which cause diarrhea in children
- HWTS has a role in providing vulnerable people with a tool to improve their own water safety while they continue to wait for reliable water supplies
- Ceramic filters are a viable option to improve water quality but not without consistent use which is related to behavioral and psychosocial factors.

PROBLEM STATEMENT/RESEARCH QUESTION

What factors influence consistent use of household water filters in Northern Kenya?

OBJECTIVES

1) To characterize selected HWTS options in use
2) To analyze and compare how economic and contextual factors in an emergency context support or impede the consistent use of household water filters.
3) To analyze and compare how behavioral and design factors affect consistent use of household water filters

METHODOLOGY

- Diffusion of innovations theory formed the basis of the study
- Qualitative and quantitative approach employing questionnaires, focus group discussions, structured observations and key informant interview.
- SPSS used for descriptive statistics, Correlation analysis and ordinary least regression models.
- Deductive coding used to analyze qualitative data
- ODK and GIS used for data collection and storage

Study context

- Study based on a protracted drought emergency context

Context area: Laisamis, Marsabit County Kenya

RESULTS AND DISCUSSION

One-bucket Two-bucket

Predictors of consistency of use	Nature	Filter Groups	
		Two bucket	One bucket
• It is possible to install this filter anywhere in my house.	Context	✓	✓
• My culture prohibits the use of filters	Context	✓	✓
• I am happy to own this filter	Psychosocial	✓	✓
• The fitting parts can be incorrectly fitted	Design	×	✓
• I would find spare parts to repair the filter easily	Economic	×	✓
• People who are important to me disapprove if I filter my drinking water.	Behavior	×	✓
• Does the product indicate when it is not filtering water properly?	Design	✓	×

CONCLUSION

Filters are not just filters

- The more available the spare parts are perceived to be, the higher the consistency of use for one bucket.
- The more the filter fits spatially in the house & while in use, the more it is consistently used for all.
- Local culture should not prohibit use of the HWTS intervention intended to be administered for all.
- The more the society approves use of filters, the more consistency increases for one bucket filters.
- Consistency of use increases with happy feeling of ownership.
- Understanding of how a filter works for two-bucket improves consistency.
- Users who familiarize with the physical features of filters portray higher consistencies of use for two-bucket filters

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Evaluating Water Security in a Challenging Environment: Case Study of Oti Nord Sub Basin in Togo

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Abstract:

As part of addressing future water shortage impacts on communities, this study aimed at evaluating water security (WS) in the context of the global environmental change taking the Oti Nord sub-basin (ONSB) as a case study. A total of 32 semi-structured interviews with key representatives of various institutions including governmental institutions, civil society, community-based organisations and private operators were conducted to bring out the institutional arena as well as the existing barriers to water security in the sub-basin. Besides, the Improved Fuzzy Comprehensive Evaluation Model (IFCEM) was used for WS level assessment. A basin level WS evaluation system including five subcomponents (external environment security, water resources security, water-society security, water economic security and water-environment security) and 23 indicators related to climate, socio-economy, and water availability and consumption were constructed. The results showed that the overall water level is very insecure in the sub-basin for the assessed years (2010, 2015 and 2025) with the year 2025 being the worse. Finally, this insecurity is found to be the result of many factors including technical, institutional, juridical, environmental, socio-cultural, hydrogeological and demographical factors.

BACKGROUND

River Basins are likely to experience 'low water security' over the coming decades (Gain et al., 2016). As a matter of fact, Volta River Basin is considered to be one of the most affected basins by freshwater shortage in West Africa (Oyebande and Odunuga, 2010).

PROBLEM STATEMENT

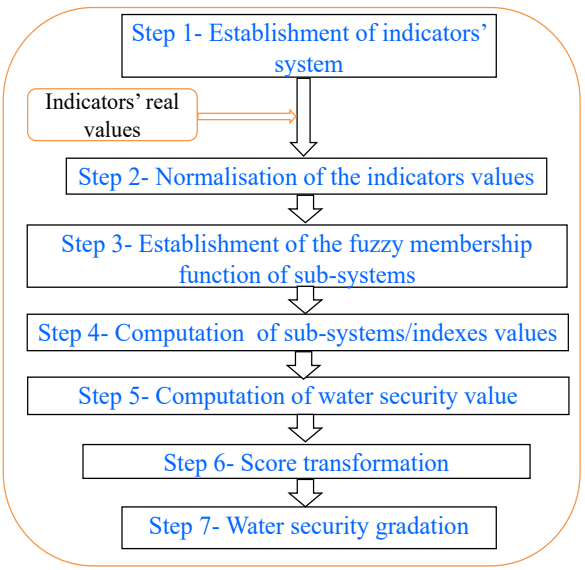
Although its contribution to the national GDP (38% in 2006) and food security, the Oti River Basin in Togo (as integral part of the Volta River Basin) is undergoing changes in its surface water flow, the loss of its surface water, reduction in its groundwater recharge and ground water depletion, mainly attributed to increased population, climate change among other factors. Nevertheless, existing studies have only looked at the potential impacts of climate change on ground water with a focus on administrative boundaries and urban water supply. Therefore, there is a need to assess water security level in the basin under the challenging environment.

OBJECTIVES

- To evaluate water security level over time in the Oti Nord sub-basin in Togo in a challenging environment using the Improved Fuzzy Comprehensive Evaluation Model (IFCEM).
- To Evaluate the potential barriers to water security in the sub-basin

METHODOLOGY

1.



2. Semi-Structured Interview with key representatives of existing institutions in the Oti Nord sub-basin

RESULTS AND DISCUSSION

1. WATER SECURITY LEVEL IN THE SUB-BASIN

Value of Indicators at Different Level

Sub-Components	2010	2015	2025
Water-Resources Security (WRS) (B1)	0.2000	0.3804	0.1780
Water-Society Security (WSS) (B2)	0.5000	0.7579	0.7500
Water-Economic Security (WES) (B3)	0.4000	0.4707	0.6000
Water-Environment Security (WEES) (B4)	0.6991	0.5872	0.6000
External-Environment Security (EES) (B5)	0.7500	0.8452	0.2500
Water security (synthetic values)	0.7841	0.8456	0.7814

Evaluation Results

System	2010	2015	2025
Water security (synthetic values)	0.7841	0.8456	0.7814
Water security (modified values)	0.1592	0.1994	0.1578
Level of water security	Very Insecure	Very Insecure	Very Insecure

Water security Index Value < 0.4 => The sub- basin is under an unsecure state for all the assessed years (past and future).

2. BARRIERS TO WATER SECURITY IN THE SUB-BASIN

JURIDICAL: Non application of juridical texts, non operationalisation of management organs, and political will.

TECHNICAL: Limited investment, lack/limited data, and limited resources (human, expertise and infrastructures).

INSTITUTIONAL: Limited collaboration among water actors, institutional instability, and inadequacies in water and related sector evolution.

ENVIRONMENTAL: Water pollution, disaster/flood, and climate change

HYDROGEOLOGICAL : Natural unavailability of ground water as well as water mobilization difficulty (related to the productivity of existing aquifers).

SOCIO-CULTURAL: Absence of the sense/spirit of paying for water services, cultural taboos, and limited awareness.

DEMOGRAPHIC: Increasing population.

CONCLUSION

- The overall water level is very insecure in the sub-basin for the assessed years (2010, 2015 and 2025) with the year 2025 being the worse.
- Insecurity in the sub-basin is a result of many factors including technical, institutional, juridical, environmental, socio-cultural, hydrogeological and demographical factors.

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Investigating the Role of Water User Associations on Decreased Environmental Flow and Degraded Freshwater Ecosystem in Tanzania

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Abstract

Mkoji sub catchment is the populated and intensified sub catchment while being the uppermost sub catchment in the Rufiji basin the downstream users are critical in water demand. Public participation through water user associations in management of water resources is encouraged but little is known about their role on water resources management and the extent to which the formation of WUAs restored the environmental flows or improved water resources management. The study aimed to assess their role in restoration of the decreased environmental flow and degraded freshwater ecosystem. Both primary and secondary data were used. Results showed decrease in the flows and ecosystem degradation, WUAs use land use management, ecosystem management and water resources management as their strategies in management and restoration while agriculture being the first water user in the sub catchment.

BACKGROUND/CONTEXT

- Environmental flows describe the quantity, timing, and quality of water flows for ecosystems and human (Forslund et al., 2009).
- Pressure on water uses has deteriorated quality and quantity and worsened the environmental flow in worlds rivers, which highlighted the need to a better sustainable management.
- In Tanzania formal and informal community participation are recognized.
- The major water uses in Mkoji sub catchment are irrigation 76%, livestock 6% and 18% for domestic (Lusuva,2009) .
- WUAs have a vital role in management and allocation of water.

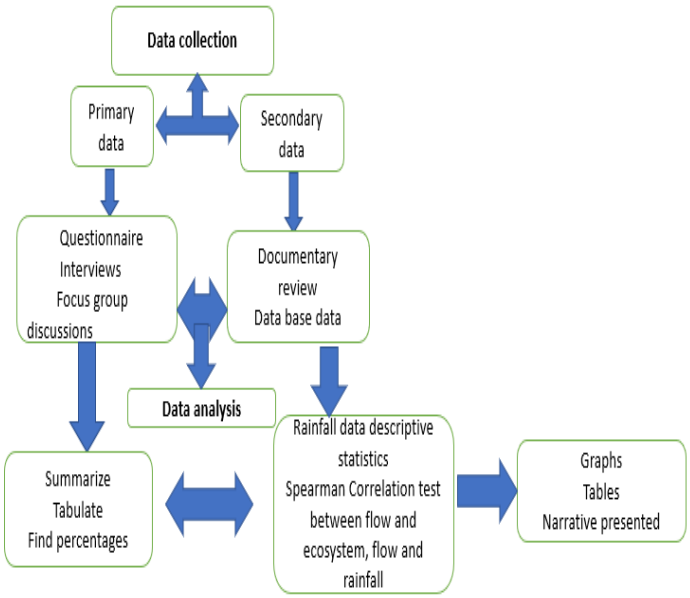
PROBLEM STATEMENT/RESEARCH QUESTION

Mkoji sub catchment is populated and have multiple water users. Over abstraction cause decrease in flow and environmental degradation. WUAs plays a vital role in restoration of both environmental flows and degraded freshwater ecosystem however, their role is not well recognized.
The study investigated the role of WUAs in restoration of decreased environmental flow and degraded freshwater ecosystem

OBJECTIVES

To assess the role of water user associations on the restoration of the reduced environmental flow and the degraded freshwater ecosystems taking Mkoji sub-catchment as case study from Tanzania.

METHODOLOGY

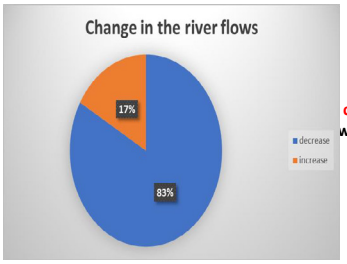


RESULTS AND DISCUSSION

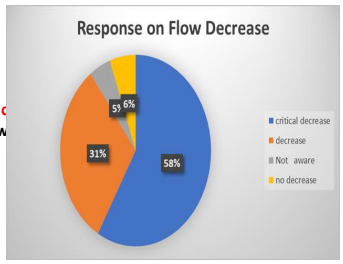
1. Strategies used by WUAS

a. Land use management strategy
b. Ecosystem management strategy
c. Water resource management strategy

2. Status of the flow in sub catchment



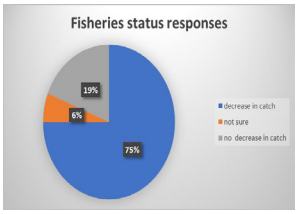
3. Decrease of the flow and gradation of the ecosystem.



There is change of the flows of the rivers and Streams accepted by 83% of the respondents

NO	Scheme name	Mean daily abstractions(m3/s)	Mean daily water right (m3/s)	Average percentage of abstraction to the water rights(m3/s)
1	Ipatagwa	0.268	0.609	44
2	Luanda Majenje	0.097	0.107	90.24
3	Kongolo Mswiswi	0.100	0.213	47.01
4	Mkoji	0.051	0.175	29.05
5	Inyala B	0.043	0.103	41.46
6	Moto Mbaya	0.160	0.730	21.90

The abstarction amount for irrigation is over the permited amount.



There is decrease of about 75% fisheries catch

CONCLUSION

- Water user associations are useful tool in restoration of the Environmental flow and its management.
- Land use influenced the decrease of the flows and degradation of the freshwater ecosystem, agriculture being the main contributor and as climate change and variability effects
- Water user associations are aware of the climate change and variability and its effects, they are using the climate data and hydrological data for mitigation and resilience.

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Optimizing the Benefits of Cooperation on Transboundary Rivers: A Case of Blue Nile River

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Abstract

Transboundary water cooperation leads to the sustainable water resources development, peaceful management and efficient use of freshwater resources. The study finding indicates that there are different type of benefit that can be generated from cooperation and joint actions on the transboundary Blue Nile basin such as hydropower generation and irrigation, environmental sustainability, peace and security in the region, knowledge and information sharing.

BACKGROUND/CONTEXT

- There are about 260 rivers that cross or form international borders
- There are 276 international river basins, of which 60% do not have any framework in place to manage these shared resources cooperatively.
- The data suggest that the challenges of water conflicts are growing, not shrinking
- The increased competition over freshwater resources inevitably entails conflict between riparian states

PROBLEM STATEMENT/RESEARCH QUESTION

- The Nile Basin is classified as one of the most conflict-prone river basins.
- Demand for water in the entire region is constantly increasing due to economic development and population growth.
- Due to the lack of adequate/efficient upstream-downstream water utilization and management, all three riparian countries of the Eastern Nile have been challenged by various complex problems:
- excessive land degradation, flooding and silt accumulation, and excessive water loss through evaporation

OBJECTIVES

- To identify and optimize all the benefit of water cooperation in the Blue Nile River that contributes to the sustainable development and management of the transboundary River basin.

METHODOLOGY

Qualitative Research Design`

Documents Review	Key informant interview

Sampling

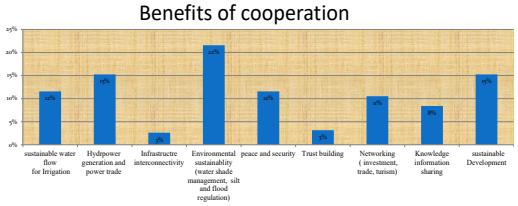
19 Respondent Interviewed	Non probable and snowball sampling technique used

Data process and Analysis

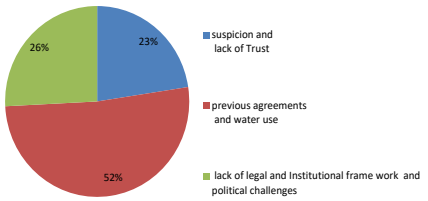
Recorded Data transcribed	Data coding system Developed

RESULTS AND DISCUSSION

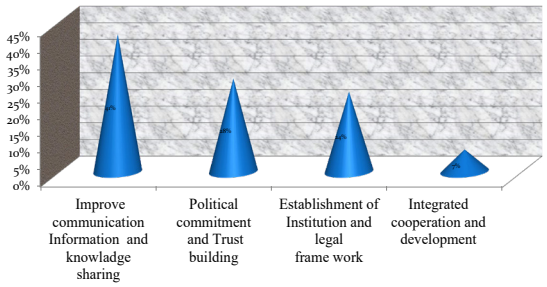
Benefits of cooperation



Challenges of cooperation



Interviewees Recommendations



CONCLUSION

- Win-win cooperation strategy, adaptive-integrated water management approach is vital
- Establish economic integration, which is Africa 2063 agenda of African country integration
- Building trust among the upstream and downstream basin stakeholders
- Establishing a permanent, strong, multilateral institution that is trusted by all Nile countries

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Use of Geographical Information System and Water Quality Index to Assess Groundwater Quality in Naãma, Algeria

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Abstract

The Water Quality Index (WQI) is a great tool which produces effective assessment of water quality. The aim of this study was to assess the suitability of groundwater quality for drinking purpose by using GIS and WQI in Naãma, Algeria. Ten groundwater samples were collected from boreholes in this year 2018 for understanding physico-chemical analysis. The physico-chemical parameters (such as pH, Electrical Conductivity (EC), Total Dissolved Solids (TDS), Bicarbonate, Ammonium, Sulfate, Nitrate, Calcium, Magnesium, Sodium, and Potassium) were selected for the spatial analysis with the help of the Geographical Information System (GIS). Water quality index was compiled using those eleven parameters. The result of WQI showed that 40% of the collected groundwater samples were of excellent quality and 60% were found to be in good quality.

BACKGROUND/CONTEXT

- Groundwater is an important resource in the world. Most of African Country it is highly depending on it.
- It is the only source of drinking water for a majority of the population in Algeria (Zafane.D et al., 2016).
- In Naãma, the groundwater is the only source that is using for domestic household, agriculture and industrial purposes

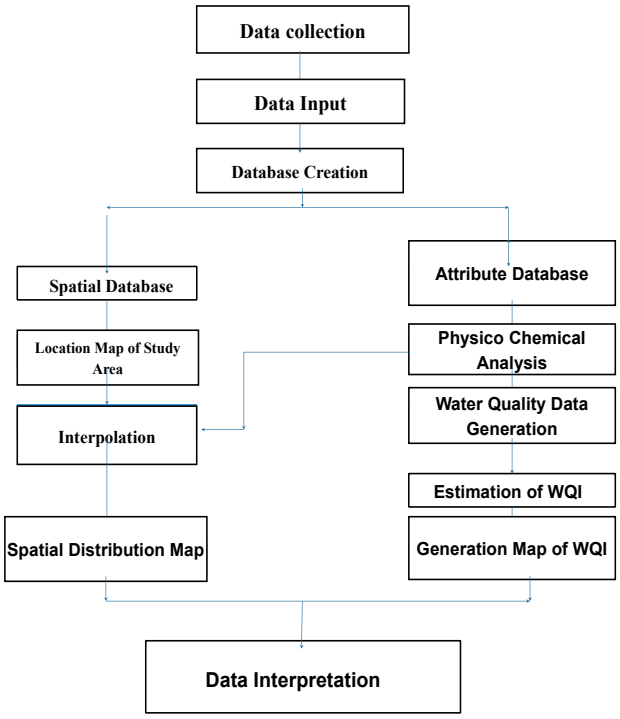
PROBLEM STATEMENT/RESEARCH QUESTION

- Due to reject of wastewater treatment plant and agricultural activities.
- Presensence of two saline mountains after arin period is percolated in the groundwater.
- The ignorence of local communities and lack of management and strategic planning from the government.

OBJECTIVES

To assess the groundwater quality for drinking water using Gis and WQI.

METHODOLOGY



RESULTS AND DISCUSSION

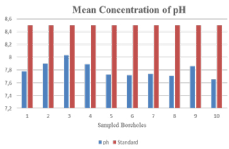


Figure 5:Mean concentration of pH

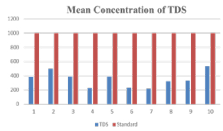


Figure 7:Mean Concentration of TDS

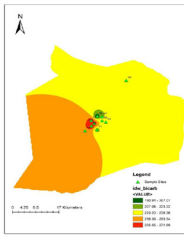


Figure 26 :Spatial distribution map of bicarbonate (mg/l) in Naãma

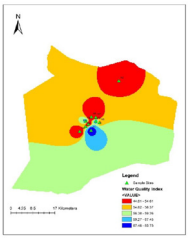


Figure 27: The value of WQI for groundwater sample

ID	Sample Stations	WQI	Classification
1	Naama (N3)	53.76706	Good Water
2	Naama (F1)	85.86922	Good Water
3	Naama(N2)	52.57544	Good Water
4	Naama (F13)	48.09789	Excellent Water
5	Naama (N4)	48.21005	Excellent Water
6	Naama (N6)	44.6105	Excellent Water
7	Naama (N7	49.10983	Excellent Water
8	Naama (N5)	54.22632	Good Water
9	Naama (F2)	62.58127	Good Water
10	Naama (N8)	63.75071	Good Water

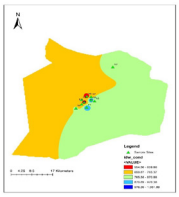


Figure 17:Spatial distribution map of EC (mg/l) in Naãma

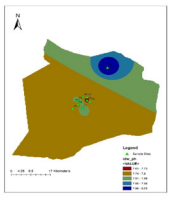


Figure 16:Spatial distribution map of pH in Naãma

The value of pH of water samples in the study area are ranges from 7.65 to 8.0

It was found that the majority of the groundwater samples which are located in Nord-West to South-East.

The spatial of EC in the study area are ranging from 551 to 1084 (µδ/cm).

The entire water quality index (WQI) of groundwater in Naãma was found to be excellent and good

CONCLUSION

The result of physico-chemical parameter which were chosen from different boreholes are in the permissible limit . Except bicarbonate parameter was found exceed the permissible limit.

The computation of WQI found that 40% of the groundwater samples were classified to be in excellent water and the rest of 60% were found to be good water class.

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