African Union

PAU
Pan African University
Université PanAfricaine

Institute for Water and Energy Sciences

Pan African University
Institute for Water and Energy Sciences (incl. Climate Change)

Book of Master Thesis Posters

Edition 2019

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Book of Master Thesis Posters

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"The time has come for reinforced focus on our people as the driver of the development in Africa.

To enable our people to deliver, we must provide a viable environment through the implementation of policies which favour investments in the areas of progress. In addition, our people must be empowered with the resources and space needed to thrive, which will create worthwile advancement towards actualising our shared goals."

H.E. Moussa Faki Mahamat

Chairperson,
African Union Commission

"Our vision as African Union, is to have every African child in school.

We are striving towards a literate and numerate Africa, as the foundation for our transformation as a continent, seeking to leverage science and technology in our development. That is the only way we can fully imbibe capital and technology to achieve the Africa We Want, and so urgently needed."

H.E. Amb. Kwesi Quartey

Deputy Chairperson,
African Union Commission

Department of Human Resources, Science and Technology

"In developing and implementing policies and programmes as per our mandates in the three respective divisions of Science and Technology, Education and Human Resources, and Youth Development, we have endeavoured to turn our commitments into action in four key areas namely: promoting research and publications on science and technology; promoting cooperation between members states in education and training; empowering young people and providing opportunity for youth; and promoting knowledge and education to spur growth in Africa."

H.E. Prof. Sarah Anyang Agbor

African Union Commissioner,
Human Resource, Science and Technology

Dr. Mahama Ouedraogo

Director of Human Resources, Scence and Technology

Dr. Beatrice Njenga

Head of Education Division

Prof. Kassa Belay

Rector of the Pan African University

Foreword

It is my pleasure to share with you the **Book of Master Thesis Posters** of the fourth cohort of the Pan African University Institute of Water and Energy Sciences (including climate change) (PAUWES). This book summarizes the research works, and the different expertise developed by these students throughout their two years training, moreso during their master thesis research. The research projects addressed various research priorities of the Research Agenda of the Institute and were conducted after the students' successful completion of their course work requirements. Additionally, they were conducted with a practice-oriented approach that focussed on different case studies in at least twenty three African countries. The thematic areas were on water, energy and climate change with engineering and policy focus respectively.

In a bid to ensure that our graduates effectively participate in building the continent as future leaders in water and energy, part of our mandate is to promote research, in addition to assisting and supporting job placement of graduates in the continent. It is with great confidence that we believe that this Book of Posters will contribute in achieving this mandate; not only in improving the visibility of our graduates in terms of research, but also in providing potential employers with tangible and relevant information on the graduates' know-how and expertise to enhance their smooth integration in the job market.

As an institute, we pride ourselves in fostering the academic setting required to ensure the success of our students. I must acknowledge also that this 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 and institutional partners of PAUWES involved in one way or another in the frame of the master thesis research.

Prof. Abdellatif Zerga

Director,
Pan African University Institute
for Water and Energy Sciences (incl. Climate Change)

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Acknowledgement

This PAUWES Book of Posters was compiled and designed by Axel Nguedia Nguedoung and Brian Omondi Oduor, under the supervision of Dr. Erick Gankam Tambo leading the Research Unit at PAUWES.

We would like to thank the Entrepreneurship and Employability Unit as well as the Academic Unit at PAUWES for the preparation of different information and inputs that were used in the finalisation of this report.

Our esteemed gratitude would also be expressed to all the partner institutions for their continued support in the supervision of the students in their respective research projects until their successsful completion. These institutions include:

Policy and Development Institutions

- The African Observatory of Sciences Technology and Innovation of the African Union
- The Islamic Devlopment Bank

Research Institutions

- Center for Development Research- University of Bonn, Germany
- Center for Renewable Energies Development, Algeria
- Eurac Research, Italy
- West African Science Service Centre on Climate Change and Adapted Land Use, Burkina Faso

Private sector

- KYA-Energy Group, Togo

Academia and Universties

- Alexandria University, Egypt
- Ardhi University, Tanzania
- Center for Energy, Petroleum and Mineral, Law and Policy, University of Dundee, United Kingdom
- Covenant University, Nigeria
- Faculty Institute of Agricultural Sciences, Demoratic Republic of Congo
- Institute for Technology and Resources Management in the Tropics and Subtropics, Germany
- International Institut of Enginnering of Water and Environment- 2iE, Burkina Faso
- Jomo Kenyatta University of Agriculture and Technology, Kenya
- KIM University, Rwanda
- Kibabi University, Kenya
- Kwame Nkrumah University of Science and Technology, Ghana
- Lancaster University, United Kingdom
- Mekelle University, Ethiopia
- University of Alexandria, Egypt
- University of Energy and Natural Resources, Ghana
- University of Ibadan, Nigeria
- University of Chester, United Kingdom
- University of Kwazulu-Natal, South Africa
- University Libre de Bruxelles, Belgium
- University of Nairobi, Kenya
- University of Rwanda, Rwanda
- University of Science and Technology Mohamed Boudiaf, Algeria
- University of Tlemcen, Algeria
- University of Venda, South Africa
- York University, Canada

Pan African University

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. PAU strives to foster academic excellence and enhance the quality of education while promoting the attractiveness and global competitiveness of African higher education and research. PAU objectives include among other: proividing the opportunity for advanced graduate training and postgraduate research to motivated African students; and promoting mobility of students and teachers, as well as harmonizing programs and degrees within the African continent.

PAU has five thematic institutes :

1. Pan African University Institute for Basic Sciences,Technology and Innovation (PAUSTI) at Jomo Kenyatta University of Agriculture and Technology (JKUAT), Juja, Kenya;
2. Pan African University Institute for Life and Earth Sciences including Health and Agriculture (PAULESI) at the University of Ibadan (UI), Ibadan, Nigeria;
3. Pan African University Institute for Governance, Humanities and Social Sciences (PAUGHSS) at the University of Yaounde II, Soa, Cameroon;
4. Pan African University Institute for Water and Energy Sciences (including Climate Change) (PAUWES) at the University of Tlemcen, Tlemcen, Algeria;
5. Pan African University Institute of Space Sciences (PAUSS), Southern Africa, host country and host university still to be determined.

PAU
Nurturing Quality,
Exemplifying Excellence

PAUWES

The degree programmes

The Pan African University Institute for Water and Energy Sciences (including climate change) (PAUWES) is one of the five hubs 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 regard 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 a diversity of academic perspectives by attracting faculties from across Africa and around the world, as well as providing our students with the tools and training needed to ensure their future success.

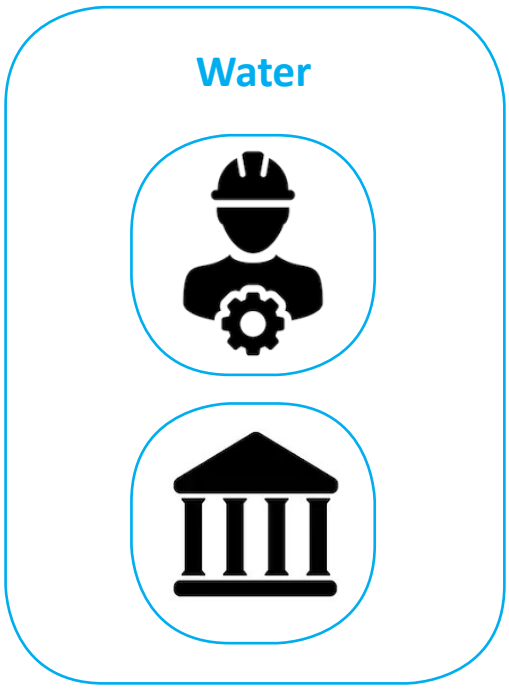
PAUWES offers four degree programmes

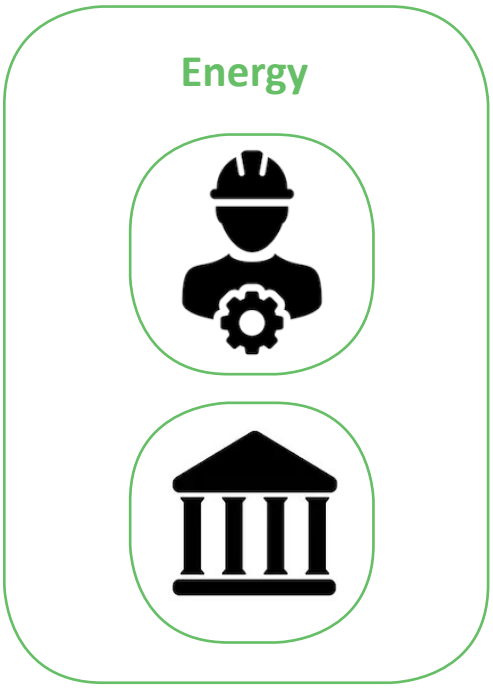
Master of Science (M.Sc.) in Energy:

- Engineering Track
- Policy Track

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

- Engineering Track
- Policy Track





PAUWES

Research

The mission of PAU and PAUWES is to serve Africa. It is clear that on the spectrum between pure science and application, research at PAUWES commits to having a strong application oriented focus. PAUWES' role is to be able to do qualitative and quantitative research not only driven by demand but also innovative and creative at the same time. A key role of PAUWES is seen in providing science-based advice to policy makers at the national, regional and Pan-African level. In addition to PAUWES providing scientific knowledge, it also positions itself as a think-tank and leader in shaping future strategies. Training scientists to answer societal questions and communicate with other spheres is an integral part in the education of students and scientists at PAUWES.

To fulfill its mandate;

- PAUWES focuses on practice-oriented thematic research as well as research dealing with socio-economical, nexus and interdisciplinary issues in the field of water, energy and climate change;
- PAUWES capitalises on the youth dividend on the continent by fostering research leading to entrepreneurship or creation of start-ups to generate employability and income in African countries;
- PAUWES strives to develop new and strengthen already existing strategic networks and collaborations on the continent and beyond. This is of paramount importance for the future of PAUWES and PAU in general.

For the successfull implementation of research at PAUWES, several measures are envisaged inlcuding the importance of strenghtening interlinkages of research activities with Masters and PhD programmes so as to integrate their research capacities in the research mandate of PAUWES. In this regard, the co-supervision of Master and Doctoral students in inter-/multi-disciplinary research context, jointly with African and internationally renowned institutes working on PAUWES priorities in Africa, is recommended to initiate or strengthen existing collaboration.

Key Research Priorities of PAUWES

Water

- Water Management
- Water and Environment
- Water and Food Security
- Water Economy and Governance

Energy

- Technological Development
- Energy Resources Assessment
- Energy Stakeholders and Society
- Energy Economics and Energy Policy
- Energy, Water, Food Security and Climate Nexus

Climate Change

- Risk Assessment
- Mitigation Research
- Adaptation Research
- Vulnerability Assessment
- Climate Impact Modelling, Downscaling and Prediction of Climate Change

Nexus Research

- Water-Energy Nexus
- Energy-Climate Nexus
- Water-Climate Nexus

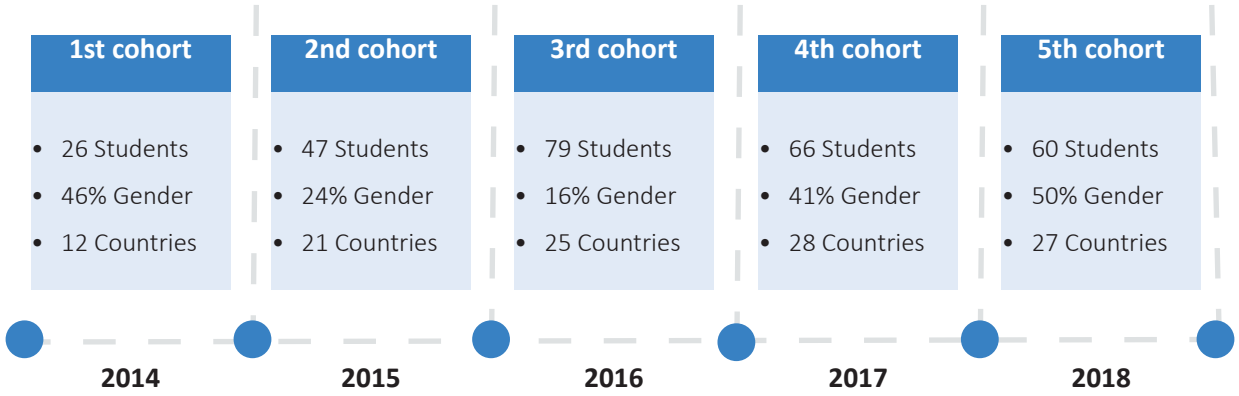
PAUWES

General information

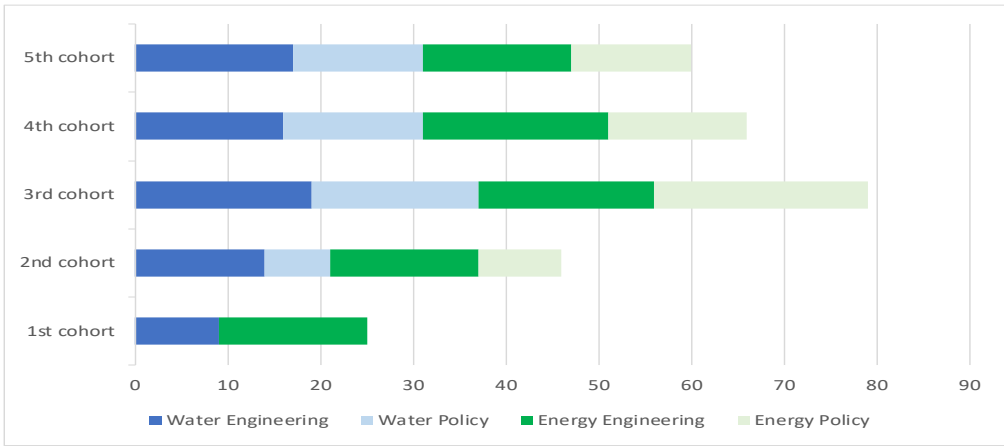
Since its effective operation in 2014, PAUWES has enrolled 279 students from at least 34 African Union member states with a female gender representation of about 33%. So far, four student cohorts have graduated totalling to 218 students, with the most recent graduation (for the fourth cohort) held in early October 2019. The fifth cohort of 60 students, are currently ongoing with the programme and are expected to graduate in the fall of 2020.

The table below summarises the general statistics of the institute over the past five years regarding the students enrollment, gender balance, and countries of origin. The lower figure shows the student distribution with respect to the different tracks.

Cohorts general information



Students distribution per track and per cohort



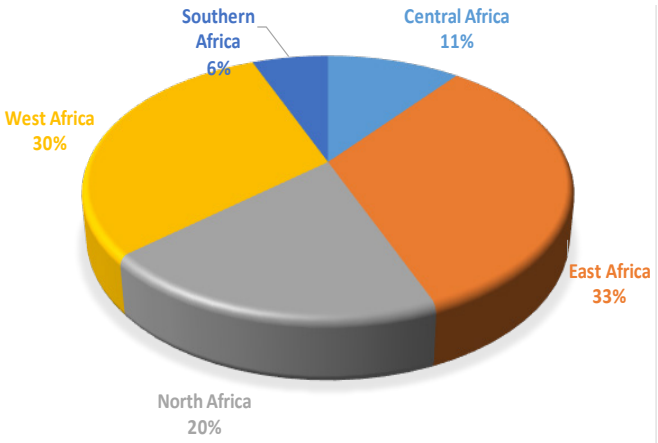
Graduates Class of 2019

General information

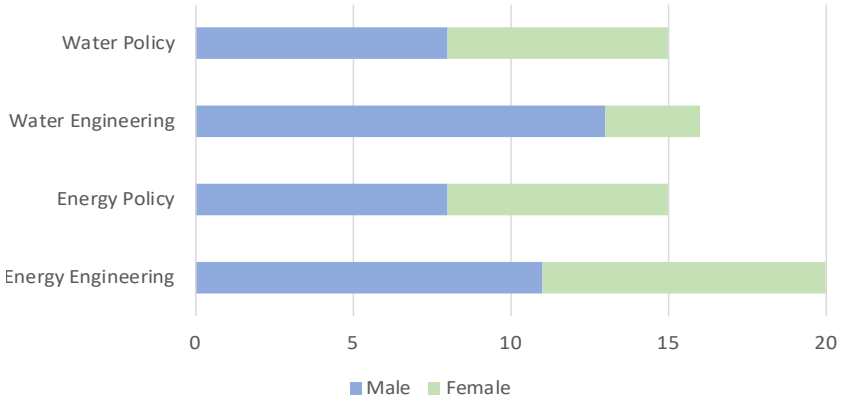
The Graduate class of 2019 is the fourth cohort of the institute. It compised 66 students from 26 African Union member states from the five regions of the continent. More than half of the students of this cohort were from the Western and Eastern African regions of the continent. The gender representation of this cohort was 41% female. The charts below summarize the general information on the cohort.

Students nationalities

Students regional distribution



Students' gender and track distribution



Graduate Class of 2019

Mobility and research

This Book of Master Thesis Posters is dedicated to the PAUWES graduate class of 2019. It presents a short summary of the topics addressed by the graduates during their master thesis research in poster format. The reseach works conducted during the master thesis addressed different issues and challlenges on the continent in line with the research priorities of the institute in the areas of energy, water, climate change and nexus research.

Mobility

During the fourth semester, which mainly focusses on research, the students conducted their respectives research projects, that among other things included a research internship and a master thesis research with different partner institutions of PAUWES. Notably was that this cohort registered a high level of mobility in their research with over **45%** of the students having conducted their research case studies including internships outside their home countries. The research internships were conducted in three main geographical regions: Africa, Europe and Middle East as shown herein.

Mobility- Master thesis & Research internship

Country case studies

Case studies

Using an applied oriented research approach, the students' research case studies were conducted in at least twenty three African countries distributed across the five different regions of the continent.

Master of Sciences

Energy Engineering

Graduate CV.

An Open-Source Approach to Wireless Internet of Things (IoT): Smart Agriculture Proof-of Concept Using FIWARE

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Abstract

The purpose of this work is to demonstrate a novel approach for water resources management in precision agriculture by exploiting a context information management framework, FIWARE. The outcome is a complete context-aware and scalable system combined of the various Generic Enablers provided by FIWARE, capable of making autonomous irrigation decisions (using Complex Event Processing) which are not solely based on sensor-related measurements, but further on the integration of different sources of information such as weather forecast data from OpenWeatherMap. Optimal management of water resources according to the predicted weather conditions has been achieved within the system.

BACKGROUND/CONTEXT

In the sector of IoT, the cloud is used to host the various components responsible for processing, filtering, and storing the data. This fast adoption of the cloud computing paradigm led to the appearance of many cloud computing service providers offering services in the form of Software as a Service (SaaS) (1) , Infrastructure as a Service (IaaS), and Platform as a Service (PaaS). However, many of these providers use a closed-source platform and propose vendor linked solutions which always puts services under the provider's control, decreasing flexibility for customization or further development and generating extra costs. Therefore alternative open-source platforms supporting smart application commence are taking place, and one example is FIWARE (2). It is used to serve as a middleware in a smart application connecting smart devices and managing the sensed data to monitor the environment parameters, identify events and patterns, and take action accordingly.

PROBLEM STATEMENT/RESEARCH QUESTION

How can a Wireless Sensor Network (WSN) system be implemented for Environmental Monitoring purposes using an open-source approach to maintain its low cost, but still with a high degree of reliability?

OBJECTIVES

1. To put together many open-source building blocks in a complementary way,
2. To build a complete easily scalable system capable of taking autonomous decisions integrating various sources of information, in compliance with the IoT paradigm.

METHODOLOGY

The proposed architecture encompasses different functional blocks :

Core Context Management :

The Orion Context Broker Generic Enabler Context Data orchestrator.

Quantum Leap Generic Enabler responsible for the storage of data into CrateDB

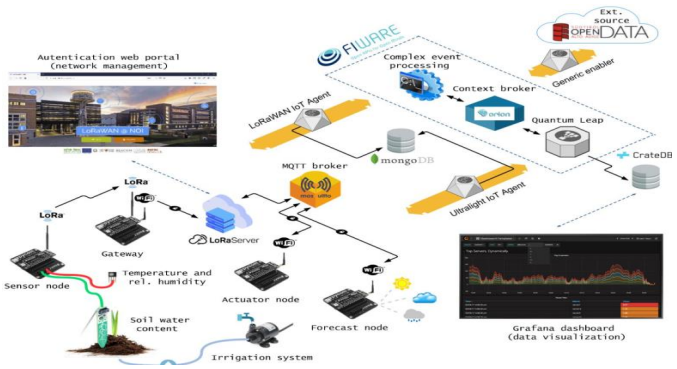
Interface with Iot, Robots, and Third-Party Systems:

IoT Agent for Ultralight –LoRaWANa bridge between HTTP/MQTT the LoRaWAN protocol and NGSI

Context Processing, Analysis, and Visualization:

Perseo is responsible for Complex Event Processing reacting to events in real-time

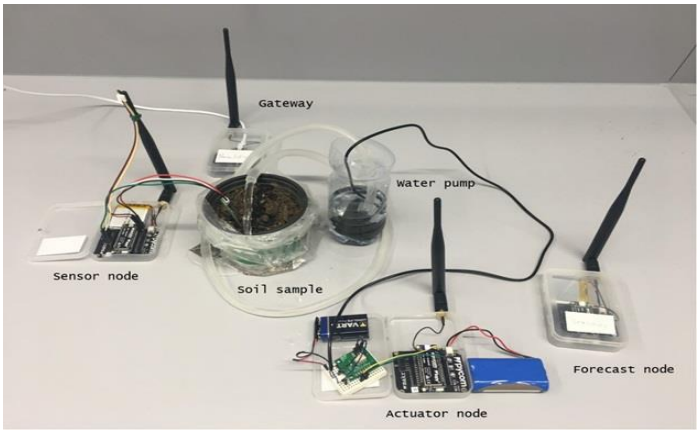
Grafana is responsible for the creation of dashboards visualization, and analytics.



RESULTS AND DISCUSSION

weather forecasts for the next 6 hours are acquired in system. The water pump is triggered when the soil water content in the soil pot is less than 20% under sunny condition. Instead, the drought threshold is lowered to 10% when the weather forecasts predict a rain event within 6 hours. complex event processor, which fires the irrigation action according to the user irrigation rules. This way, we are able to test the prototype in all the possible working conditions. The three microcontrollers of the system are powered by LiPo batteries and can be distributed in the field with ease transferring data within 10 km (in-sight distance) from the gateway,

The latency of the system is lowered by more than one order of magnitude (from seconds to sub-seconds) with respect to similar applications which exploit traditional data, management models. Moreover, the scalability and the integration of other sources of information is facilitated as many connectors (agents) are already available on the FIWARE website, and other target-specific connectors (generic enablers) can be developed through a dedicated syntax.



CONCLUSION

The implemented prototype was able to

1) Record sensor measurements in a reliable and timely manner;
2) Forward them to the cloud instantly for further processing, visualization, and storage;
3) Acquire context information from external sources (weather forecasts, satellite images) to deduce and predict events;
4) Allow the system to react to events immediately after they occur by triggering actions
5) Secure, supports big data analysis tools, complex event processing
6) Easily scalable and upgradeable.
7) Exploits Open API standards

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2. López-Riquelme, J. A., Pavón-Pulido, N., Navarro-Hellín, H., Soto-Valles, F., & Torres-Sánchez, R. (2017).A software architecture based on FIWARE cloud for Precision Agriculture. Agricultural Water Management, 183, 123–135. https://doi.org/10.1016/j.agwat.2016.10.020

The entire master thesis report is available under the following link:

http://pauwes-cop.net/library/handle/1/355

An Assessment of the Impacts of Climate Change on Hydropower Potential in West Africa Case study :Bamboi catchment (Black Volta)

Graduate CV.

Tariro Cynthia Mutsindikwa , Dr Yacouba Yira & Prof. Rabani Adamou[a]
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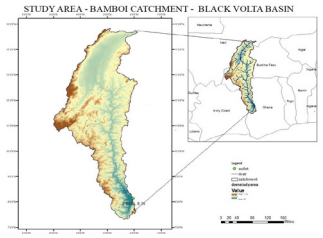
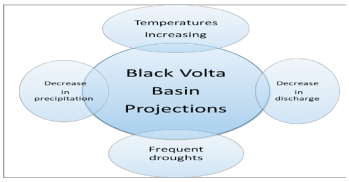
The study evaluated the impacts of future climate change on the hydropower potential of the Bamboi catchment (Black Volta) in West Africa using a conceptual rainfall-runoff model (HBV light model). The HBV model was successfully validated for the catchment with coefficients (NSE, KGE, R^2) ranging from 0.59, 0.73 and 0.57 respectively for calibration and validation phases. Two climate simulations MPI-ESM-REMO of CORDEX and GFDL-ESM2M-WRF of WASCAL both under RCP4.5 were applied to the validated hydrological model to simulate the catchment runoff. Historical & projected discharge data was converted to hydropower potential following a run-of-river hydroelectricity generation approach. The model mean ensemble projected a temperature , precipitation ,discharge increase of (0.8 and 2.8 °C) ,(11% and 6.6 %) and (10.9 % and 3.7 %) respectively for the 2020-2049 and 2070-2099, respectively . On the contrary an overall decrease of hydropower production by -8.9 % and -7.5% is envisaged for the 2020-2049 and 2070-2099, respectively.

BACKGROUND/ STUDY AREA

- West Africa /CIREG project area
- Ghana , Ivory coast , Mali & Burkina Faso
- Total area 134200km^2
- Population projection **8 million** by 2025
- Temp range **15 to 44** °C
- Rainfall **1000 to & 1400mm**



PROBLEM STATEMENT/RESEARCH QUESTION



OBJECTIVES

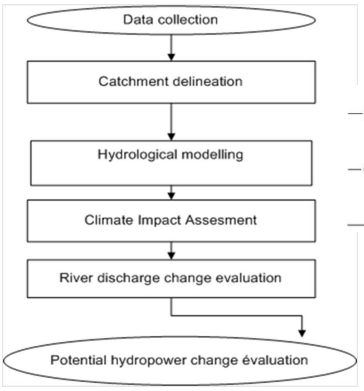
General objectives : To assess the impact of climate change on hydropower potential of Bamboi catchment .

Specific objectives :

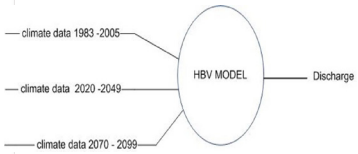
1. To set up the conceptual hydrological simulation model HBV light for the Bamboi catchment.
2. To assess the impact of future climate change on the hydrological regime of the catchment through scenario (RCP4.5) application comparing a reference period **(1983-2005)** to two future periods **(2020-2049)** and **(2070-2099).**
2. To assess the impact of climate change on hydropower potential of the catchment based on runoff data

METHODOLOGY

Methodology

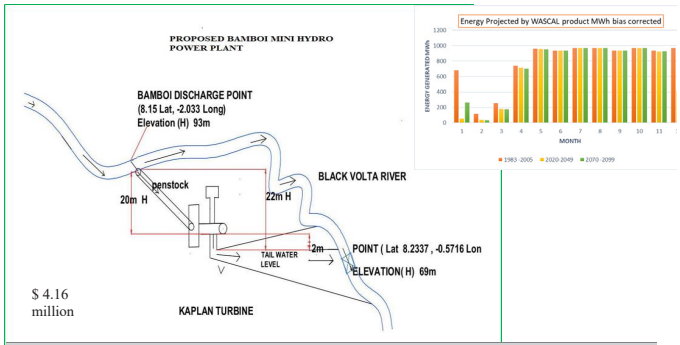


Hydrological modelling



RESULTS AND DISCUSSION

1.3MW Bamboi power plant



Hydro power potential by season

	1			2		
	MPI-ESM-REMO - CORDEX			GFDL ESM2M- WRF of WASCAL		
Climate model	Historical (1983 -2005)	Projected (2020-2049)	Projected (2070-2099)	Historical (1983 -2005)	Projected (2020-2049)	Projected (2070-2099)
Bias corrected						
Precipitation	575.483	612.137	595.37	574.483	638.6	637.24
Discharge	218.993	238.527	230.545	200.89	229.795	229.51
PET	2282.01	2338.84	2397.63	2599.9	2704.93	2649.12
AET	360.378	377.602	368.817	377.583	413.075	412.267
Non-Bias corrected						
Precipitation	1249	1295.81	1269.11	722.72	1028.69	1012.8
Discharge	673.402	769.659	775.564	314.862	485.785	424.974
PET	2282.01	1992.86	1844.21	2123.68	2716.95	3086.11
AET	581.13	529.93	497.284	411.465	546.323	591.509

- Both models CORDEX and WASCAL models are agreeing.
- Hydro power is projected to decrease in future for both future periods as compared to the reference period

CONCLUSION

Based on projections

- Temperature , rainfall and discharge is likely to increase over the Bamboi area, by (0.8 °C to 2.5 °C) , (+11 % to +6.6 %,) and (+10.9 % to +3.7 %) for the 2020 -2049 and 2070-2099 respectively.
- PET and AET are likely to increase over the Bamboi area, by ((+2.1 % to +2.4 %)((+1.9 % to +2.7 %) for the 2020 -2049 and 2070-2099 respectively.
- Hydropower potential is likely to decrease by - 8.9% under RCP 4.5 (2020-2049) relative to (2070-2099) but will increase slightly above the baseline to -7.5%.
- Climate change is likely to increase the hydropower development & electricity cost in future.
- For all 3 projections it is clear the turbine will be operating at full potential every day in wet season and operating from 5 to 80% potential at least in the dry season.

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1.Mbaye, M. L., Hagemann, S., Haensler, A., Stacke, T., Gaye, A. T. (2015). Assessment of Climate Change Impact on Water Resources in the Upper Senegal Basin (West Africa). *Climate Change*, *4*, 77–93. Retrieved from doi:10.4236/ajcc.2015.41008, 2015;

The entire master thesis report is available under the following link:
http://pauwes-cop.net/library/handle/1/327

Assessment and Optimization of Flexy Energy Approach: Case Study of Bilgo Village, Burkina Faso West Africa

Graduate CV.

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Abstract

Access to electricity is essential for infrastructural development, economic growth and better living standards in any country. In the case of West Africa, the access rate remains very low especially in rural areas when compared to other developed countries in the world, due to the high cost of grid extension. In other to improve electricity access in Burkina Faso an approach as been developed known as the flexy energy concept. This concept composed of a PV generator and diesel generators without batteries. The storage aspect in this concept is no included due to the high investment cost of batteries and the environmental concern associated with them at the end of there lifetime. However, for the energy management of the system an optimal storage unit can be considered that is capable of meeting the load for few hours of autonomy.

BACKGROUND/CONTEXT

Over 620 million people live without access to electricity in the Sub-Sahara Africa (*IEA, 2014*). This situation is even worst in rural areas due to the high cost of grid extension, scattered population, poor terrines and high poverty rate. In case of Burkina Faso inorder to improve the access rate in the country, an approach as been developed known as the flexy energy concept (*Yamegueu, 2011*). This concept composed of a PV/diesel hybrid system without storage. The storage aspect is not considered in this concept due to the high investment cost of batteries and other environmental concern associated with them. This concept has been implemented in Bilgo Village and the power plant composed of 30 kW_p solar PV array and three diesel generators of 70 kVA combined capacity. This power generation source has been used to supply electricity to over 2008 people in Bilgo Village (*2iE Foundation and SONABEL*). For the sustainability and reliability aspect of the power plant an energy management strategy is considered in this study. In this work, an optimal storage capacity was proposed which is capable of meeting the load demand for an optimal hours of autonomy.

PROBLEM STATEMENT/RESEARCH QUESTION

- ✓ Excess electricity production by the PV/diesel systems
- ✓ Power stability issue due to mismatching between the peak load and maximum power generated .
- ✓ Extended operating hours of diesel generators

OBJECTIVES

The main objective of the study is to identify the most optimal storage system that should be incorporated into the PV/diesel hybrid system based on the flexy energy concept in Bilgo Village, Burkina Faso.

METHODOLOGY

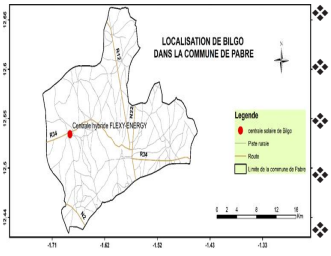


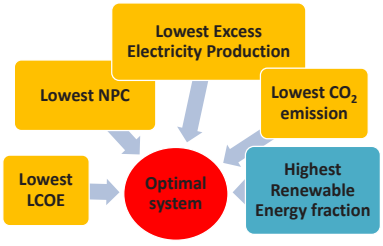
Figure 1: Map of Bilgo Village

- ❖ Bilgo village is located in Pabre Commune
- ❖ It lies between latitude 12° 31.8 N and longitude1° 40.8 W
- ❖ It is situated at 30 km from the capital city Ouagadougou.
- ❖ It has 303 households and 2008 inhabitants.
- ❖ The main economic activities in the village are agriculture and animal rearing

Power generation scenarios were considered:

- ✓ Diesel generators only (2*20 kVA & 30 kVA)
- ✓ PV/diesel generators without storage
- ✓ (30 kW_p and 70 kVA)
- ✓ PV/diesel generators with storage unit
- ✓ (30 kW_p , 70 kVA and 1270 Ah)

The objective of this three simulation scenarios is to identify the most optimal system configuration based on the following criteria with HOMER.

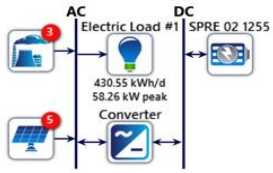


RESULTS AND DISCUSSION

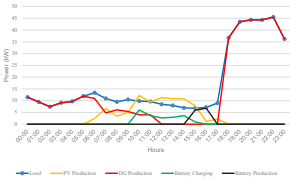
Table 1: Caparison of Optimization scenarios

Optimization Scenarios to obtain the Optimal System Configuration					
Scenario	**LCOE (US$/kWh)**	**NPC (US$)**	**Excess electricity production (kWh/yr)**	**RE Fraction (%)**	**CO_2 emission (kg/yr)**
A	0.5816	1,307,126	0	0	134,116
B	0.604	1,357160	29,732	11.9	122,861
C	0.524	1,177,376	0	27.1	94,304

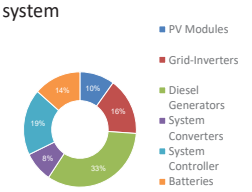
❑ Configuration of Optimal system



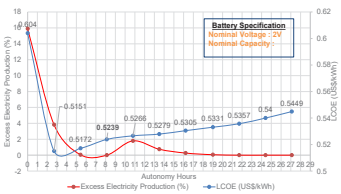
❑ Performance of the optimal System



❑ Share of Capital cost Breakdown for the Optimal system



❑ Optimal storage system performance



CONCLUSION

- ✓ **PV/diesel/battery** was found to be the most optimal system.
- ✓ The LCOE and the NPC for the optimal system was reduced by **13.25%** and **9.9%** when compared to scenarios A and B respectively.
- ✓ The optimal storage unit was capable of meeting the demand for the village for able **5 – 8 hours** of autonomy.
- ✓ The sensitivity analysis result shows that the NPC and the LCOE depends on the **fuel price** .
- ✓ The operating and maintenance cost of running diesel generators was reduced because of the batteries
- ✓ The amount of CO_2 emission from the optimal system was reduced by **26.68%** and **23.24%** annually when compared to scenarios A and B respectively

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Assessment of Biofuel Potential on Marginal Lands and from Waste Vegetable Oil Resources in Ghana

Graduate CV.

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Abstract

Climate change and its numerous effects has called for the need to consider green and clean-sourced energy alternatives. Biofuel promises to be a great option. This research aims at Assessing the Biofuel Potential on Marginal Lands and from Waste Vegetable Oil Resources in Ghana. Questionnaires were used to determine Waste Vegetable Oil resources from households, wayside vendors and hotels. AHP and TOPSIS were used to select energy crops based on ecological requirements. It was also revealed that, 685 litres of WVO can be generated monthly as biodiesel feedstock. Our potential per from WVO and from the selected energy crops can reduce GHG emissions by 4.076123939tCO_2e. Considering the potential of biofuel in Ghana. It will be expedient to consider introducing biodiesel into our energy sector especially as transport fuel in our quest to minimize GHG emissions and to augment the heavy reliance on fossil fuels.

Keywords: Biodiesel, Waste Vegetable Oil, Green House Gases, marginal land, Jatropha

BACKGROUND

Globally, the transport sector is dominated by fossil fuels, Climate change has been of great concern in recent times. Green House Gas (GHG) emissions from the use of these fuels can be used reduced by using cleaner fuels. Literature revealed that, several works and tests has been done on biofuels; biodiesel and bioethanol are promising alternatives until electric cars become very popular. Ghana's bioenergy policy aims at integrating 20% of biofuel into the transportation sector by 2030. 69% of Ghana's land cover is agricultural land. Almost, every dish in Ghana has a part of it being fried, large quantities of Waste Vegetable Oils (WVOs) are produced daily by hotels, households, and wayside vendors, etc. this is either released into local sewage systems as "ditch oil" or reused in some kitchens. People reuse till too dark to be used others just discard. Making use of this WVOs and energy crops can help a great deal reduce our load on fossil fuels.

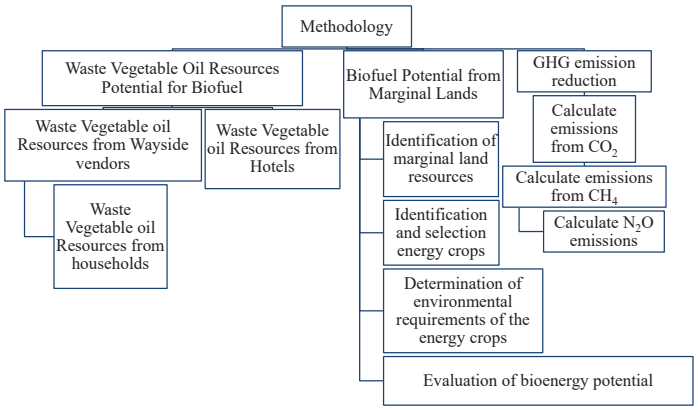
PROBLEM STATEMENT/RESEARCH QUESTION

- High GHG emissions from road transport
- Buses grounded due to lack of funds for fuel
- Biofuel 10% integration by 2020 yet nothing as at June 2019

OBJECTIVES

- To estimate the potential of biofuels production from marginal lands, waste vegetable oil and lignocellulosics.
- To assess the suitability of bioenergy crops production on marginal lands in Ghana.
- To evaluate the GHG emissions reduction through production of biodiesel and bioethanol

METHODOLOGY



RESULTS AND DISCUSSION

From the survey, it was realized that we can get 20.4 litres of WVO from 101 households in Accra monthly and 175 litres a month from 32 wayside vendors. An average amount of 489.6 litres of WVO can be obtained from 9 hotels in Accra every month. Also, from the selected biofuel sources; neem jatropha and sugarcane bagasse, we can reduce GHG emissions by 4.076123939tCO_2e.

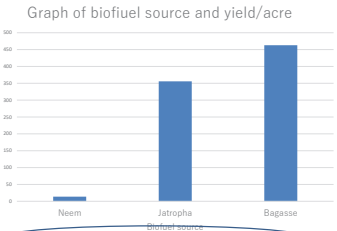


Fig. 2 Graph of biofuel source & yield /acre

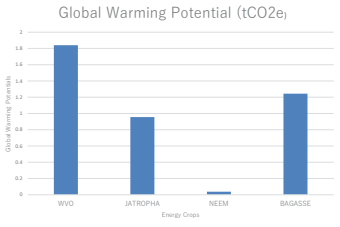


Fig. 3 Global warming Potential tCO2e

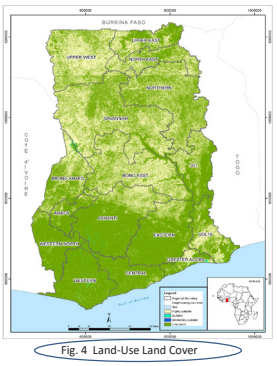


Fig. 4 Land-Use Land Cover

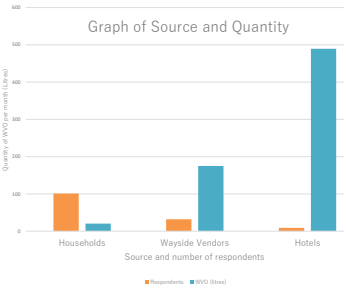


Fig. 5 Biofuel Source and quantity of WVO

CONCLUSION

In conclusion, considering the potential of biofuel in Ghana:

- it will be expedient to consider introducing biodiesel into our energy sector especially as transport fuel, making use of our waste vegetable oil resources, energy crop production on marginal lands and unused agricultural land in our quest to minimize GHG emissions and to augment the heavy reliance on fossil fuels.
- We should consider cultivation of energy crops on post-mining lands as well as non-cultivated agricultural lands since the non-agricultural land is limited.
- There should be more investments in development of biofuels (biodiesel

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The entire master thesis report is available under the following link:

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Graduate CV.

Design of a Co-Digestion Biogas Plant for Households: Case of Rwanda, Gicumbi District.

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Abstract

The research work consisted of designing and evaluate the techno-economic feasibility of a centralized co- digestion (human feaces and caw dung) bio- digester plant for sustainable energy supply , for cooking and water heating in the rural communities of Rwanda. The pilot of study was at Gicumbi District in the northern Province of Rwanda. The daily energy need for the residence in study was quantified by the mean of field survey and questionnaires. The plant capacity to sustain that amount of energy was designed and economic parameters were determined using RETScreen Software.

BACKGROUND/CONTEXT

Use this space to describe the context/background of your study.
In Rwanda, like worldwide, energy plays a fundamental role in social and economic development as well as poverty eradication. Households of Rwanda are the dominate consumers of primary energy at 91% of total energy mix, followed by the transport 4%, industry 3%, and public services 2%. Households also dominates in electricity consumption with 51% mainly for lighting, followed by industries 32%, public sectors16% and export 1 %. Only for cooking and heating water activities, households rely on biomass (99%), where 86% comes from firewood, 11% from charcoal, 2% from crop wastes; and other fuels account for 1%.
As such, for environmental sustainability and needs to reduce the reliance on the firewood for the country, diversification and further energy alternatives that include biogas was introduced in the National energy program, with intention of providing clean , reliable, affordable and environmental friendly energy sources for the communities.

PROBLEM STATEMENT/RESEARCH QUESTION

Rwanda is one of the rapid developing countries in the region, with high population growth of 2.4% as of 2018, along with high urbanization rate . Thus, the trend for energy demand is getting higher with crucial focus on the household sector that effectively relies on firewood for cooking purposes. In this regard, this work intended at contributing to knowledge by providing a mean to get clean and reliable cooking fuel from biogas through cogenerating caw dung along with human feaces.

OBJECTIVES

- To design a co- digestion bio-digester plant for biogas provision in the households.
- To use human faeces in co-digestion to provide energy security for rural communities.
- To provide affordable and clean cooking fuel for rural households in Rwanda.
- To reduce pressure on the forest cutting for firewood gathering and charcoal harvesting in order to enhance the environmental sustainability.

METHODOLOGY

- Qualitative and quantitative interviews with sampled respondents were applied.
- Questionnaires, documentations and observations were also used for data collection.
- Simple random and purposive sampling techniques were used to obtain data from the field.
- Numerical computation to estimate the plant parameters was applied
- And hence, Arch card for drawing digesters and RETSCREEN software for financial analysis were used.

RESULTS AND DISCUSSION

The monthly energy consumption rate was quantified and tabulated in table 1. Based on the biogas to other fuel sources equivalence, the corresponding biogas to charcoal consumption were estimated and the plant size was designed accordingly.

Table 1 .. Energy consumption rate for cooking and heating water

No.	Fuel type for cooking and heating water	Average consumption per day per household	Average consumption per day per total residence	Amount per month per household	Total consumption per month per total residence	Unit price in RWF	Total Price in RWF
1	Charcoal	1.2kg	5.8 kg	35kg	175kg	300	52,500
2	Dung cake	0	0	0	0	0	0
3	Firewood and crop residues	Unspecified	Unspecified	Unspecified	Unspecified	unspecified	-
4	Biogas	Unspecified	Unspecified	Unspecified	Unspecified	unspecified	-
5	LPG	0.6kg	3kg	18kg	90kg	1,083	97,500
6	Electricity	0	0	0	0	0	0
7	Others	No value	No value	No value	No value	No value	No value

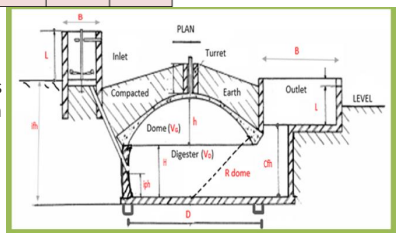
The data this table contains were obtained from the field survey. And each five households were considered to share the same digester plant, being considered as total residence per plant.

Table 2. Bio-digester plant's parameters with the respective values

Plant parameter	Symbol	Value	SI unit
Total plant volume	V_H	30.82	m^3
Digester volume	V_D	25.6	m^3
Gas holder volume	V_G	5.22	m^3
Digester diameter	D	4	m
Digester height	H	2	m
Dome radius	R	2.45	m
Dome height	h	0.75	m
Compensation chamber flow height	Cfh	2.38	m
Inlet and outlet tanks breadth	B	1.88	m
Inlet and outlet tanks Length	L	1.25	m
Inlet flow height	Ifh	2.55	m
Inlet pipe height	Iph	0.3	m
Slurry displacement inside digester	d	0.24	m
Slurry displacement in inlet and outlet tanks	X	0.61	m
Overflow height	Oh	2.4	m
Pressure head	Ph	0.26	m
Height of inlet relative to slurry overflow outlet	a	>0.3	m
Height of the gas outlet relative to the slurry overflow outlet	b	>0.1	m
Height of slurry overflow outlet relative to the height of slurry drying bed	c	>0.35	m

With numerical computation, all the plant parameters were estimated and tabulated in the table 2.

The plan of digester plant was hence designed, with inclusion of all physical parameters.



CONCLUSION

- Energy is a backbone for economic development globally Rwanda inclusive.
- The plant size of 30.82 m^3, with 25.6m^3 of digester volume, 5.22 m^3 of gas holder, able to provide 2.9 m^3 of biogas per day was designed.
- The use of this bio- digester plant would save 2.1 tons of charcoal per year per 5 households.
- Based on the overall findings of this study, co-digestion biogas technology was found to serve as an economic and environmentally friendly way to provide fuel for cooking and water heating in the rural

REFERENCES

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Design of Stand-alone Solar-Wind-Hydro Based Hybrid Power System: Case of Rural Village in Malawi

Graduate CV.

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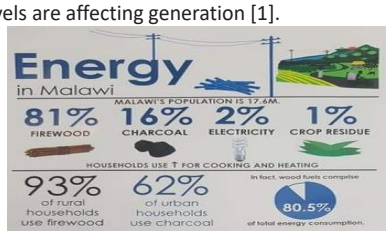
Abstract

Malawi has current electrification rate of less than 10% and the generation company is unable to satisfy the existing demand of electricity. Thus, the aim of the study is to design stand-alone hybrid renewable energy system for Dwangwa villages with estimated load of 5,556.31 kWh/day. HOMER modeling tool was used to design the system. The best hybrid system combination was hydropower-wind-solar-battery. The initial capital cost was $2,662,638 and cost of energy was $0.134/kWh. However, cost of electricity in Malawi on the grid is $0.11/kWh which makes the system expensive. Therefore, the study has shown that this hybrid system is not economically viable. However, Government intervention can help to make the system monetarily acceptable and viable.

BACKGROUND/CONTEXT

Malawi is largely dominated by hydroelectric power on Shire River. However, low water levels are affecting generation [1].



Without such access to electricity, it is difficult to carry out productive economic activities [1].

Therefore, this proposed hybrid system is aimed at sizing a hybrid renewable energy system that minimises cost and ensure its affordability for rural settlers.

PROBLEM STATEMENT/RESEARCH QUESTION

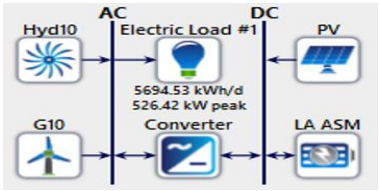
In Malawi, the electrification rate is less than 10% of population and dominated by hydropower which is greatly affected by low water levels. Grid extension is constrained due to low generation, old and high cost of transmission infrastructure. However, most Malawians live in rural areas hence poor economic activities. Thus, hybrid system for rural electrification is one of the solution.

OBJECTIVES

- To estimate of the small hydropower potential of Dwangwa River
- To estimate of solar PV potential in Dwangwa
- To estimate of wind energy potential in Dwangwa
- To estimate the load profile of the under study population
- To optimize and do sensitivity analysis of the hybrid system

METHODOLOGY

Energy demand for Dwangwa area was 5,556.31kWh with peak load of 302.93 kW. HOMER modelling tool was used with the following configuration:



Available head for hydropower is 100m. The table below gives the summary of input costs and life time of the system components.

Component type	Capital cost ($)	Replacement cost ($)	O&M cost ($)	Lifetime (Years)
Solar PV (1 kW)	2822	2822	28.22	15
Wind turbine (1 kW)	2120	1696	42.4	25
Hydro (1 kW)	1790	895	35.8	30
Battery	225	157.5	2.25	5
Converter (1 kW)	1445	1156	17.34	15

Three scenarios were considered to determine best design flow for hydro:

Scenario 1: The design flow of 159 L/s, available 100% time of the year.

Scenario 2: The design flow of 400 L/s, available 95% time of the year.

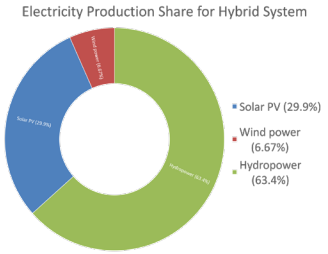
Scenario 3: The design flow of 637 L/s, available 91% time of the year.

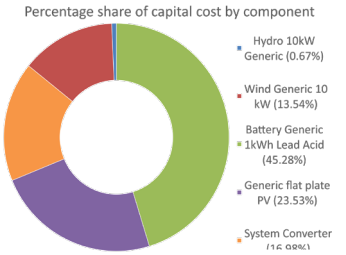
RESULTS AND DISCUSSION

The scenario 1 was the best system design with wind-solar-hydro with 5358 batteries and 313kW converter. The table gives summary of production.

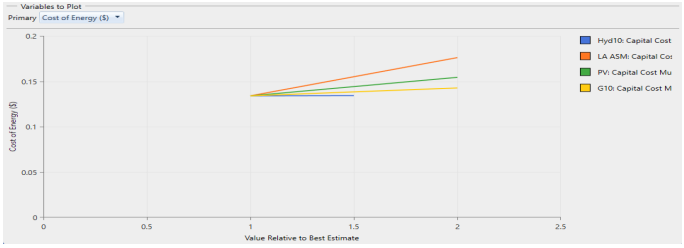
	Power capacity (kW)	Hours of Operation (hrs/yr)	Levelized Cost ($/kWh)
Wind turbines	170	6,456	0.196
Solar PV	444	4,332	0.076
Hydropower	140	8,760	0.00101

The system's initial capital was $2.66 million and cost of energy was $0.134/kWh. However, 63.4% of production is from hydropower.





Sensitivity analysis: The three design flow showed that the best design flow was 159 L/s. Other sensitivity variable considered were initial cost multiplier of components. Thus, spider plot (capital cost versus cost of energy), shows that if capital cost of battery (LA ASM) increases, it has greater impact on the cost of energy. However, hydropower (Hyd10) has relatively little impact on the cost of energy.



CONCLUSION

The optimal system design of hydro-wind-solar and battery with design flow of 159 L/s. The initial capital was $2,662,638. The cost of electricity in Malawi is $0.11/kWh [2] while the proposed system is $0.134/kWh which is relatively expensive for rural settlers. However, looking at energy situation in Malawi, rural communities might remain without electricity. Therefore, with collective effort from Government and other organisation, this kind of energy system would improve living standards of the rural community.

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http://pauwes-cop.net/library/handle/1/322

Graduate CV.

Design of a Solar Dryer with Integrated Thermal Storage Based on Sorption Materials

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Abstarct

Dried mangoes companies now in Burkina Faso are using gas-fired dryers however Burkina Faso is not a gas producer country; the gas is expensive even after the subsidies and the national strategy is about removing natural gas subsidies, which will make the drying activity unprofitable according to mangoes producers. Since Burkina Faso has abundant solar irradiance, it is preferable to utilize it in drying mangoes. But the problem is, the interment nature of solar energy. Sorption material is technology is used nowadays to perform energy storage which can packed on solar dryer. The addition of such thermal energy storage to the solar dryer can make it beneficial. According the spreadsheet simulation solar dryer with dehumidifier and thermal storage unit can compete gas dryer.

Problem statement

Burkina Faso produces annually 154000 -252000 tonne mangoes[1] . Some of this vast production, export as fresh mangoes, some converted to juice and export it and some dried then export also. On the dried mangoes sector, all the enterprises rely on the natural gas dryers. The challenge here is that the gas is expensive and in some time they faces shortage and this is because Burkina Faso is not natural gas producer country. In the meantime, Burkina Faso has high solar potential and the average annual solar radiation is 19.8 MJ/m^2 per day. The idea of constructing solar dryers is not new in Burkina Faso. There are many trials had been done but none of them succeed. The use of the conventional solar dryers faced some constraints, the solar dryer required 3 days to dry the mangoes however the gas dryer needs alone 8 hours to dry the same amount [2]. More, the designed solar dryers used to have small drying capacity compared to gas dryer so they were not preferable form the economical point of view. The last trial was semi industrial design to dry 500 kg pre cycle but the issue was that the entry air was humid and almost saturated [3].

RESEARCH QUESTION

What would be the best design for the solar drying system in the context of Burkina Faso?

Could the usage of sorption beds significantly increase the performance of the solar dryer, especially during rainy seasons?

OBJECTIVES

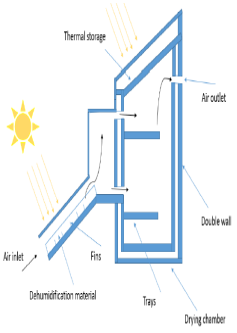
Develop a static design for a solar drying system with built-in thermal energy storage for mangoes in Burkina Faso.

METHODOLOGY

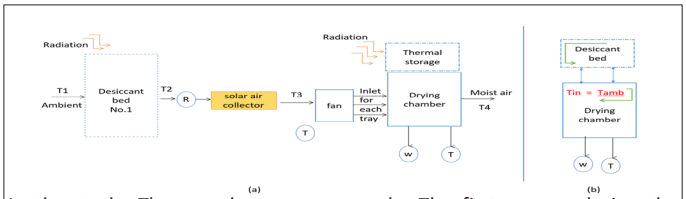
Mangoes are planted in the Sudanese climate zone, we choose the village Bankandi which It is 187 km from bobo-dioulasso city to be the place for the design experiments. The advantage of this village is that it has ground weather station.

Out of the four varieties of mangoes in Burkina Faso [1], we chose Amilie to be considered for the experiments and its drying characteristics was considered as input for the design tool. The reason was that Amilie is available from April to June and the climate conditions in this period is challenging compared to other periods.

The design was done to dry 100 kg of mangoes which has inside moisture content 85 % w.b [2]. the slices should be dried to have only 15 % w.b inside moisture content [2] in 24 hour maximum and without using more than 60 °C air in the drying process. The solar collector efficiency assumed 30 %. The proposed dryer mainly consists of four parts, which are solar air collector which has sorption material inside, drying chamber and thermal energy storage. The parts are assembled in one structure similar to indirect cupboard design, as shown in Figure 1



The dryer working strategy at the daytime differs from its from the nighttime is shown in the Figure 2.



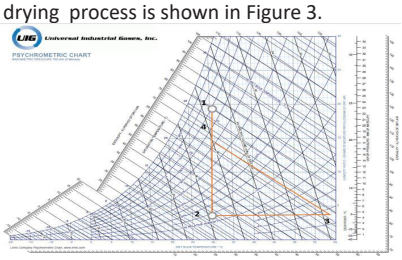
In the study, Three tools were proposed. The first one to design the needed solar air collector and the drying chamber, the second tool to design the dehumidifier unit and to determine the amount of material required, the third one to design thermal storage.

To evaluate the model, different calculations had been performed in spreadsheets as summarized in Table 1. The aim was to determine the solar drying system size using the average ambient conditions in the harvesting season.

No.	Definition
1	Common ideal drying process
2	Common real drying process
3	A dehumidifier is introduced
4	The drying was made was sorption material only
5	A thermal storage with a dehumidifier are introduced in the process

RESULTS AND DISCUSSION

The results shown that around 38.1 m^2 solar collector is needed in case no.1 and more than three times this area was required in case no.2. When dehumidifier unit introduced in case no.3, solar collector area decreased to 50.9 m^2 . The case no.4 shows that 218 kg of silica gel can dry the mangoes totally. In case no.5, 30 m^2 solar collector area was needed, 40 kg of silica gel were required for the dehumidifier and 178 kg for the thermal storage and the drying process is shown in Figure 3.



CONCLUSION

- Solar dryer with thermal storage and dehumidifier is good alternative to gas dryer in Burkina Faso.
- Using the three proposed design tools are solar dryer can designed at any other place.

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The entire master thesis report is available under the following link:

http://pauwes-cop.net/library/handle/1/365

Feasibility Study and Energy Applications of Advanced (2G and 3G) Biofuels in South Africa

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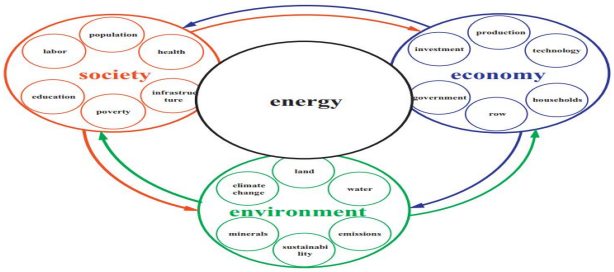
Graduate CV.

Abstract

The use of edible crops for biofuel production has been questioned on the point of sustainability. There are indirect and direct environmental impacts associated, mostly stressing the soil, land and water. Producing biofuel using non-edible crops is being revolutionized globally. Feasibility study of advanced biofuels and energy applications is required to boom biofuel industry in South Africa. A technique called residue to product ratio was used to generate data on crop residues. Excel spreadsheet was used for results analysis. About 13.5 Mt of crop residues from 19 crops were made available which can generate 4.9 GL of bioethanol per year using biochemical route conversion technology. The outcome will impact on policy development in biofuel sector by government of South Africa and can be used as a model for Africa as a whole.

BACKGROUND/CONTEXT

First generation biofuels being produced from edible crops have sustainably and ethics issues. Advanced biofuels revolves around non-edible feedstock hence a question about their sustainability is raised by reseachers [1].



PROBLEM STATEMENT/RESEARCH QUESTION

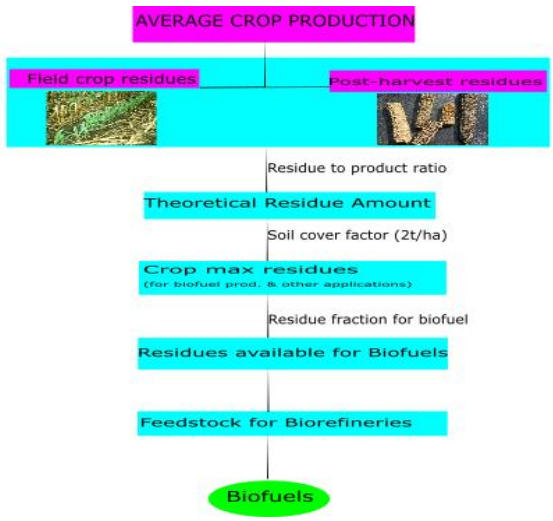
Producing biofuels from food crops is not being regarded as a wise way of achieving SDG especially the goal number 7 and the agenda 2063 when bearing in mind that African continent is full of hungry-prone because of food security issue around the world. Feasibility study and energy applications of advanced biofuels in South Africa will contribute to the development and use of biofuels from renewable resources in the continent.

OBJECTIVES

A. To quantify potential crop and their residues which can be generated in South Africa
B. To estimate amount of energy which can be generated from availed residues

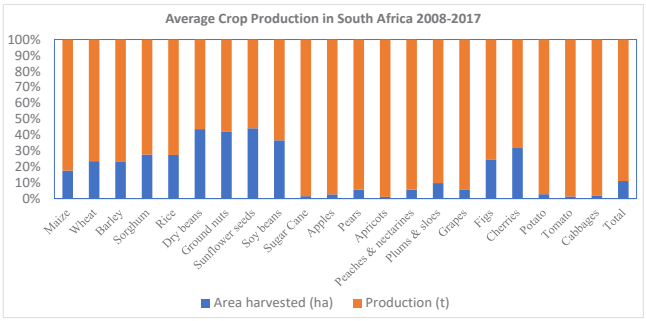
METHODOLOGY

To characterize crop residues available for biofuel production in South Africa, crop production and harvested area have been taken into account. The protocol used to assess the availability of crop residues for biofuel production is shown in the figure below.

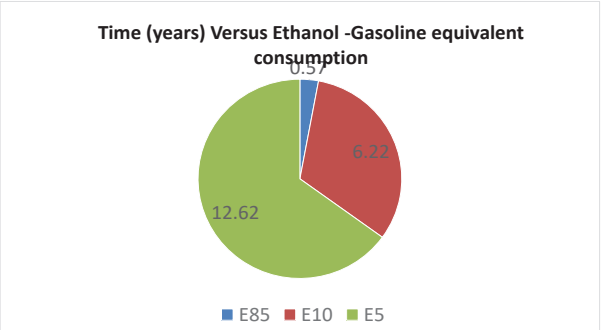


To ensure data quality, average production for a 10-year consecutive period (2008-2017) was chosen as our study time frame.

RESULTS AND DISCUSSION



The highest theoretical residues in South Africa is generated from maize (~28 Mt) followed by sugarcane (~6 Mt)[62. The 3rd, 4th and 5th theoretical residues generation came from wheat (~3 Mt), sunflower seeds (~2 Mt) and soybeans (~1 Mt) respectively. The least amounts of residues are generated from figs and cherries with an infinitesimal contribution to the residues in total. About 43 Mt residues can be generated theoriticlally from 21 major crops crown in South Africa but only 13.5 from 19 potential crops can be used to produce biofuels. Using biochemical conversion route , ~4.9 Gl of bioethanol cab be generated annually in South Africa Which can replace gasoline during 0.57 years using E85 as shown in the following figure.



CONCLUSION

- In conclusion, the present work studied the feasibility of producing biofuel from crop residues in South Africa.
- 21 major different crops grown in SA which are grouped into: grains, oilseeds, deciduous fruits and vegetables were used in the study and only 19 have potential to generate residues for biofuel production.
- An estimated 13.5 Mt of crop residues are potentially available in South Africa per annum to be harnessed for sustainable biofuel production
- 4.9 GL of bioethanol can be generated using biochemical conversion route.
- The results presented here are theoretical potential therefore might not be the same technically, as the concept of efficiency and losses will be taken into account in practical situation.

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The entire master thesis report is available under the following link:

http://pauwes-cop.net/library/handle/1/323

Graduate CV.

Multi-Criteria Decision Making for Energy Planning in Democratic Republic of Congo: Case Study of Idjwi island

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Abstract

Energy planning involves multiple actors and objectives most of the time in perpetual conflict. Energy planning in many developing countries is still not well-handled and depend mostly on the priorities of actual political authorities. Investors and young entrepreneurs most of the time lack reliable results for energy planning. This study used the Analysis Hierarchy Process (AHP) relies on the judgments of experts to derive priority scales was used to evaluate the energy resources of Idjwi island in the DRC. The weights obtained from AHP were used to rank alternative energy resources for Ijwi island using the Technique of Order Preferences to Similarity to Ideal Solution (TOPSIS). The combination of the two MCDA methods reduces the uncertainty and reinforce the reliability of the decision. Two surveys were conducted in this research, one for the rural community in Idjwi to determine their preferences, priority, economic situation. The second survey was conducted for the energy experts in the region to analyse the importance of the criteria. This thesis aims at ranking the different energy resources for rural electrification in the Idjwi Island. The small hydropower and solar photovoltaic sources were the first alternatives to power the Island. TThe renewable energy resources of the DRC is also included.

BACKGROUND/CONTEXT

The population of DRC is growing fast more than 80 million in 2017 (The World Bank, 2018).More than 60% living in rural area (INS, 2015). In another hand, the electricity access rate still low, it has increased from 6.48% in 2001 to 9% in 2011. With exception of the capital city with an electrification rate of 59.5%, the provinces have electrification access below 5% (1% as a national average). (MRHE, 2014).

More than 71 million of Congolese from DRC live without access to electricity, and this represents 12% of the African population (MRHE, 2014). Moreover, according to the INS, 42 million of the habitants of DRC living without electricity are living in the rural areas (INS, 2015).

The Idjwi Island, located in the East of the DRC in the middle of the Kivu lake (2.1651° S 29.056091 °E), has 250 000 habitants living without electricity. Less than 10% of this population own very small Solar Home Systems (SHS) for lighting. An optimum power generation mix for rural electrification has not yet been tapped in the current research in DRC.

PROBLEM STATEMENT/RESEARCH QUESTIONS

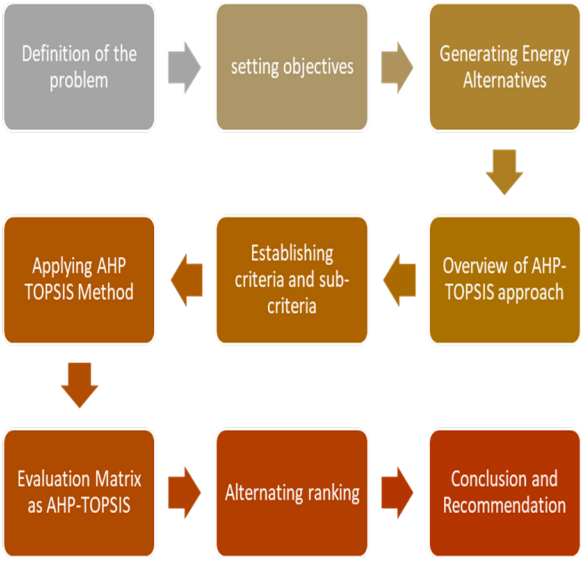
What are the priorities and preferences on energy project for the Idjwi rural community?

Using the best MCDA methods, which alternative source fit to electrify rural community of the Idjwi Island in DRC?

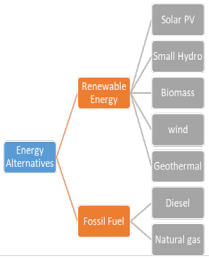
OBJECTIVES

- To determine the priorities and preferences of the rural community of Idjwi Island on energy projects
- To determine the preferable source of alternative energy in Idjwi island using the best method for multicriteria decision making method

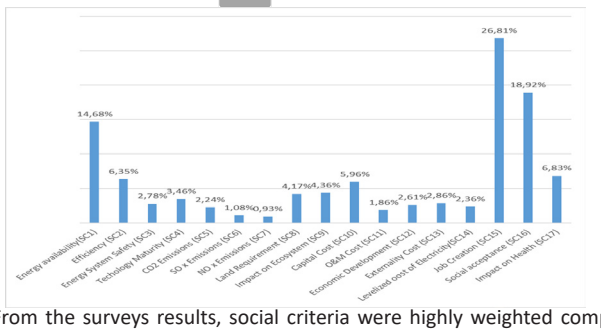
METHODOLOGY



RESULTS AND DISCUSSION



	Si+	Si-	Ci	Rank
Solar PV	0.098	0.109	0.5259	2
Small Hydro	0.089	0.1048	0.5395	1
Biomass	0.104	0.06088	0.3689	5
Wind	0.11	0.04983	0.3115	7
Geothermal	0.122	0.06112	0.33706	6
Diesel	0.9388	0.10069	0.5174	3
Natural Gas	0.077	0.07705	0.5078	4



From the surveys results, social criteria were highly weighted compare to other criteria such as technical, economic and environment. The respondents consulted showed the importance of job creation for rural community by an electrification project and the acceptance of the community of any project as their priority. The two first places of relevance were for Small Hydro mini-grid and Solar PV energy. This result shows how renewable energies can meet the energy needs of Idjwi Island and improve the social life of the community

CONCLUSION

Based on the available energy resources of the Idjwi island in the DRC, this thesis work has been devoted to select the best source of energy to electrify the Idjwi Island. A step by step methodological framework for selecting energy alternative was formulated in this work using two Multi-Criteria Decision-Making methods (AHP-TOPSIS). One scenario was developed which consists of the fact that Social aspects of the project were the priority followed by technical, economic and environmental for any energy project at Idjwi. Throughout of this research, the Small Hydropower Plant System (SHPS) and solar photovoltaic were ranked the two first alternatives to power the Idjwi island. The SHPS has a closeness parameter to an ideal solution of 0.5395 and solar PV of 0.5259. Further research can be oriented on the sizing of the hybrid solar-small hydro based on the results of this project to meet the energy needs of the local community.

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The entire master thesis report is available under the following link:
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Realization of a Reduced Model of a Water Distillation Station by Solar Energy: Case Study in Africa for Consumption or Irrigation

Graduate CV.

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Abstract

One of the major challenges of this century is the access to water that has become quickly recover. Plenty of water sources are available on the earth but few of them can be used for drinking water purpose. Oceans and other reserves such as brackish water are salty to be directly consumable. Desalination is one of the solutions to mitigate the problem of water scarcity. In the village of Tlemcen, the freshwater was characterized by an insufficient production which could not cover the actual needs. Water was provided to the districts twice per week only for a few hours. Tlemcen has a high potential for solar power, as solution, thermal solar energy will be used to distil the seawater. This work includes a dimensioning engineering part, allowing the distillation directly captured from the sea, in the region of EL BEKHATA in Tlemcen, for the water supply the summer population of this beach.

PROBLEM STATEMENT

- Global water consumption has increased compared to the amount of freshwater supply.
- The majority of water sources cannot be used for drinking, oceans and other reserves such as brackish water are too salty to be directly consumable.
- In the village of Tlemcen, the drinking water supply was characterized by an insufficient production which could not cover the actual needs.
- Water was provided to the districts twice per week only for a few hours.
- The problem concerning water distillation by solar energy functionality depends on the sun radiation, which is intermittent. This has an effect on the number of the working hours needed to distillate water.

HYPOTHESYS/RESEARCH QUESTION

Achieve a drinking water for domestic sector or irrigation for agriculture sector based on sea water or brackish water by distillation, to mitigate the problem of the shortage of freshwater compared to the water demand and to use solar panels on nighttime.

Is the new system will be have better efficiency compared to the used methods?

OBJECTIVES

- Provides water to the agricultural industry.
- Helps preserve current freshwater supplies.
- Unlimited ocean water as source.

METHODOLOGY

In this study we are interested in the supply of drinking water by distillation of seawater by solar energy.

This work includes a dimensioning engineering part, allowing to distil the water directly captured from the sea in the region of El-Bekhata.

We have developed a model of a prismatic prototype composed of three essential compartments.

The 1st compartment that we used is the glass prism, its has a form of a pyramid with square base so that can absorbs the maximum of solar energy concidering the direction of the sun. We have also developed a brine reception and distillate reception system, as well as the installation of measurement tools.

The 2nd part of the model is the elevating table, on which the distillation prism is placed with a locking system, this system will allow the maintenance and control of the tray without touching the prism.

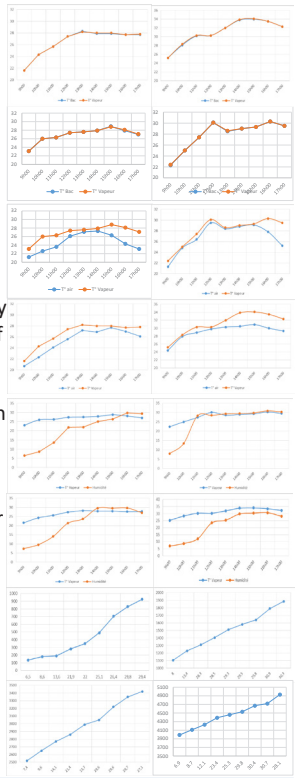
The 3rd part concerns the different measuring tools that we have installed to carry out mainly the measurement of the moisture of the prism and the different temperatures (air, brine, steam) . All are connected on an electronic table to transmit the date to the Arduino Uno card to the computer program that we established display the measured values on an LCD screen or transmits them to a computer as database.

Our experimental distillation project was placed on the terrace of the laboratories of the technology faculty of Tlemcen depending on different temperature and humidity measurements .

The analyzed salinity indicates that distilled water is good for domestic consumption.

RESULTS AND DISCUSSION

- The $T°_{water\ inside\ the\ prototype}$ is virtually the same.
- The $T°_{evaporated\ water}$ is always higher than that of the $T°_{air}$ and there of the $T°_{water\ in\ the\ bench}$.
- The $T°_{air}$ decreases from 15h, against that of the value remains high given the significant condensation of water vapor.
- In the early morning, the humidity increases timidly to the $T°_{vapor}$.
- At around noon that the humidity approaches the $T°_{vapor}$ and is kept practically constant, this is due to the concentration of vapor condensation at the end of the day.
- Humidity evolution not exceeding 30% between 9h and 12h, where is between 12h and 9h, it is more than 220%, then a stabilization of the variation in the afternoon does not exceed 20%.
- The increase of volume of distilled water as a function of humidity from May 30 to June 04, 2019.
- Moisture increases, drops of water form on the walls, and slide to accumulate in the permeate reservoir.
- For all the curves, the slope of the straight lines reaches 70% per hour.



CONCLUSION

In this study, we are interested in the supply of drinking water by solar distillation of seawater. Solar still have good chanced to success in Algeria.

It useful to use a reduced model of solar distillation, our choice was on the region of EL-Bekhata that is a favorable place for this type of projects.

Laboratory analysis of the distillate salinity shows that it is completely free of salinity, which has been confirmed that our distilled water can be clean for consumption.

Finally, our project has two components, a research component on the phenomenon of solar distillation of seawater and salt water.

On the other hand, and engineering component, where the location of this type of project in certain beaches remains a very profitable economic investment for the population around these beaches of the summer population.

REFERENCES

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2- D. W. Medugu and L. G. Ndatuwong, (2009), 'Theoretical analysis of water distillation using solar Still',International Journal of Physical Sciences, 4 (11), pp. 705-712.

The entire master thesis report is available under the following link:
http://pauwes-cop.net/library/handle/1/369

Solar Water Pumping Systems for Rural Water Supply and Small-scale Irrigation Schemes in Africa

Graduate CV.

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Abstract

Non-renewable energy usage in irrigation and water supply threatens the energy security and contributes to climate change in Africa which may lead to loss of economic and environmental viability due to widely use of diesel motors. This study analyzed the technical, social and economic feasibility of solar water pumping system as an alternative clean energy source. Literature review, site visit and physical observation, interview, consultation, and designing software were the methods used in this study. This research found that system oversizing and downsizing affects the technical and economic performance, 11 out of 17 surveyed projects have negative NPV, Investment cost of the systems increases with an increase of array capacity, and the average installed cost is USD 5.6/watt.

BACKGROUND

In Africa irrigation is a key to safeguard harvest most of the year. Nevertheless, irrigation is way too expensive for many farmers (Mossali 2014). Groundwater resources have been proved to be the best water source that can be used to supply water in rural communities while facilitating the smooth running of social economic development of African countries (Malak 2016). A research conducted in Dangila Area of Ethiopia in 2014 shows that solar water pumping is more attractive for small scale irrigation systems compared to large ones in remote areas. (Zegeye, Tadiwos and Aman 2014). In this framework this research will deliver sole opportunity for financiers and other clients through looking deeper into the combination of all Nature and purpose of such projects; Cost of project and means of finance; Technical viability; and Economic and Financial Viability of the system.

PROBLEM STATEMENT

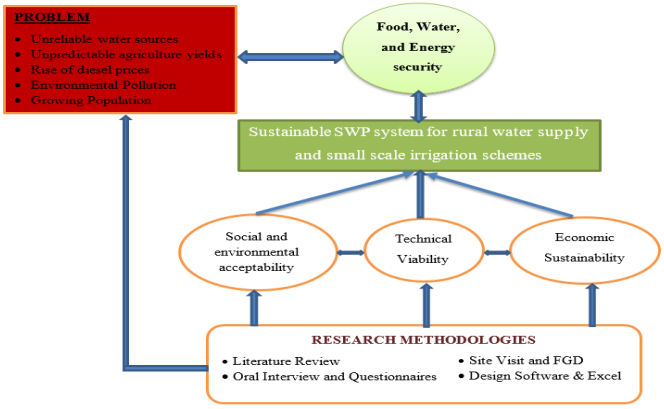
Agricultural sector faces difficulties due to lack of water, lack of environmental and economical friendly technologies of pumping water, rise of diesel prices (Lahmidi 2013). Apart from agriculture, access to clean and reliable water supply for rural areas in Africa is still a major problem (Malak 2016), to ensure SDG 7 and 6, full utilization of ground water in rural areas using Solar water pumping systems is required.

OBJECTIVES

To examine the most effective and efficient solutions and propose a cost-effective solar water pumping system for rural water supply and small-scale irrigation in Africa.

METHODOLOGY

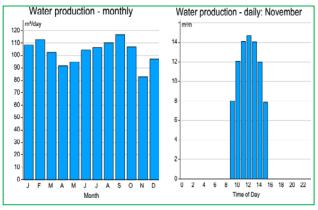
In this study learning sites were obtained from different parts of Africa through site survey, review of appraisal reports, working papers, and articles. Among of the countries which were included are the United Republic of Tanzania, Kenya, Ghana, Cameroon, Senegal, Rwanda, Ethiopia, Egypt, Morocco and Zambia. The figure below explains the methodologies used to tackle the problem.



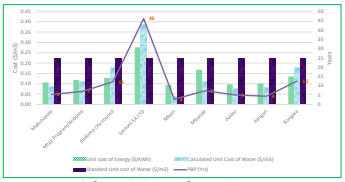
RESULTS AND DISCUSSION

The results describes the Technical, Economic, and Social Status of different surveyed projects in Africa. Social and financial status of the surveyed areas especially in Tanzania are explained more in the full report.

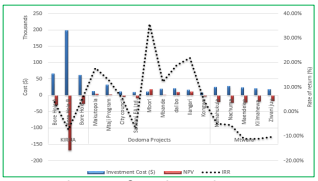
	Before re-design	After re-design
Array Capacity	27.6 kW	8.1 kW
Pump Power	5.5 kW	5.5 kW
Investment	198 318.05 USD	31,155.33 USD
Annual Water Production	23,652 m³	37,600 m³
NPV	-167697.5	41190
IRR	-7%	44%
PBP	48 Years	4 Years



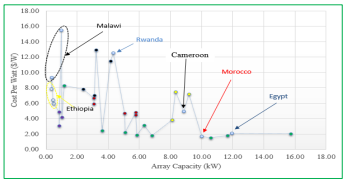
Technical and financial performance of Re-designed system at Kirua-Kahe



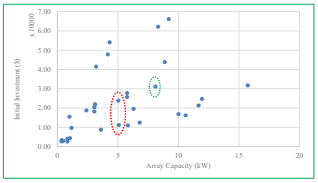
Financial feasibility of Dodoma Projects



IRR and NPV of evaluated projects



Installed cost per watt



Investment cost Vs Array Capacity

CONCLUSION

- Solar water pumping systems have been well organized at community level but the lack of knowledge acts as adaptation setback.
- Systems oversizing hinders the economic performance, increases the investment cost and leads to less profitability.
- Lack of knowledge on funding sources is a major financial challenge that faces most farmers or water users in Africa.
- Clouds cover, population increase and Boreholes depths variation hinders the performance of Solar Water Pumping Systems.

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The entire master thesis report is available under the following link:
http://pauwes-cop.net/library/handle/1/313

Stand-alone Hybrid Renewable Electrical System for Powering a School in Remote Area: Case of Bechar and Djelfa, Algeria

Graduate CV.

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Abstract

ProvideThe aim of this study is to find the optimum system configuration of a hybrid power system that can supply electricity to a school in remote area in High land and south of Algeria. A school compound from the region of Bechar contains school , zaouia, dorm and staff house , is selected with a peak load of 29.77 kW, In addition a primary school in region of Djelfa was selected with a peak load of 4.81 kW , HOMER software was used to model the power system. After a comparison between 07 configurations a PV,WECS system configuration has been chosen it has 26.9 kW -PV and there are 02 wind turbines and 30 batteries . The LCOE was 0.235 $/kWh. That was for the Bechar site , Regarding the Djelfa's school a PV,WECS system has been chosen ,it has 7.23kW -PV ,3 wind turbines and 24 batteries with a LCOE of 0.397 $/kWh

BACKGROUND/CONTEXT

Algeria is the largest country in Africa with sizable hydrocarbon potential and enormous solar potential but unfortunately 70 % of the economic ravenous are coming from hydrocarbon ,In order to increase the exploitation of the renewable 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 [2]

PROBLEM STATEMENT/RESEARCH QUESTION

Despite the high electrification rate of 99% in the country [3], electricity faces numerous blackouts and shortages especially during summer, because of the hot climate and the need for air conditioning

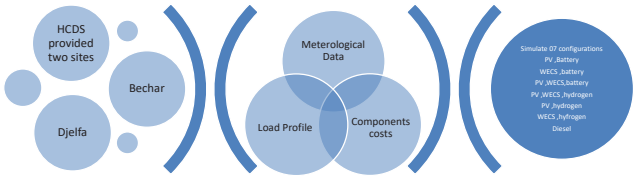
Renewable energies represent an economic solution for the case of isolated sites. However, solar and wind are intermittent. Hybrid systems can tackle this issue, combining solar PV with wind is an attractive solution that provides reliable and economical renewable power generation

OBJECTIVES

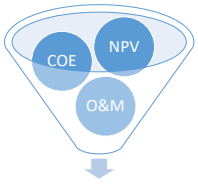
Find the best system to power a school on the Sahara region and on the high lands region

Modelling and designing a hybrid power system associated to fulfill the electricity demand of a schools in Bechar and Djelfa in affordable, reliable and sustainable way with cost-effective solution.

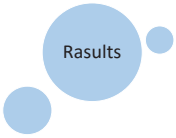
METHODOLOGY



1/Fond the sites 2/Input data 3/Simulation

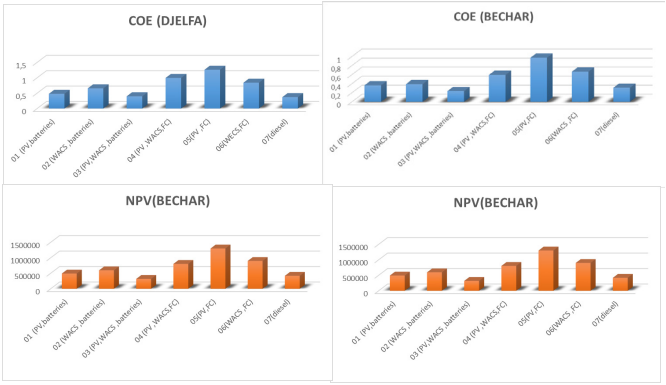


4/Comparaison



5/Results

RESULTS AND DISCUSSION



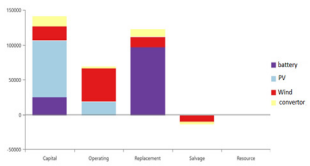
The optimum systems for both sites are hybrid systems(config 3)

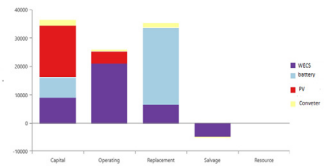
Bechar

- A 26.9 kW -PV and 02 wind turbines and 30 batteries with COE equal to 0.235 $/kWh.
- The total electricity production is 120.739 kWh/year with 43.7% generated using PV panels and 56.3% generated using wind turbines

Djelfa

- 7.23kW -PV ,3 wind turbines and 24 batteries with COE of 0.397 $/kWh for Djelfa
- The total electricity production is 21.336 kWh/year with 59.4% generated using PV panels and 40.6% generated using wind turbines





CONCLUSION

A techno-economic comparison between the different configurations showed that: the most suitable system for the first case of Becher is the PV wind, batteries system with a COE equal to 0.235$ / kWh ,For Djelfa region, the cheapest system is the diesel system, with a COE of electricity equal to 0.370$,then the PV wind battery system comes after with a COE equal to 0.397$. a 7 % difference between the two. The PV wind battery system is though better because it has no GHG emissions

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Study and Design of 20kw$_p$ Grid-connected Solar Photovoltaic System. Case Study: Ambatolampy, Madagascar

Graduate CV.

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Abstract

This study aimed to design a grid connected SPV system in the district of Ambatolampy (Madagascar). The study consisted firstly of assessing the location in order to identify the favorable site to install the system, followed by the system sizing. Evaluation of the system revealed that 93 modules and 1 central inverter are needed for the system and those modules should be north oriented with a tilt of 19°. The annual energy produced by the SPV system is equal to 34,20 MWh/year with a LCOE of 486Ariary/kWh and payback time of 11.02 years which is less than the SPV system lifetime that makes the project profitable.

BACKGROUND/CONTEXT

The electricity generation mix of Madagascar consists of: diesel, hydro, SPV, to the fewer extent of wind and biomass.

However, the country still heavily depends on expensive fossil fuel for electricity generation, up to 70% of the electricity consumed in the country is generated by diesel power plants. In addition, it has been estimated that there are 799 outages due to power breakdowns on the medium voltage network every year.

In contrast, Madagascar is endowed with solar energy. Almost all regions of the country receive over 2,800 hours of sunshine per year, with the daily solar radiation ranging from 1,500 to 2,100 kWh/m^2.

Therefore, electricity generation using grid connected SPV system can be an opportunity to tackle the existing electricity problems in the country.

PROBLEM STATEMENT/RESEARCH QUESTION

Insufficient electricity supply: the Electricity Supply Industry encountered difficulties in handling the sharp evening peak power demand.
Overreliance on fossil fuels: Fossil fuel are expensive and its use for electricity production is harmful to the environment.

OBJECTIVES

To design a grid connected solar photovoltaic system and investigate the impact of such systems on Madagascar electricity supply industry.

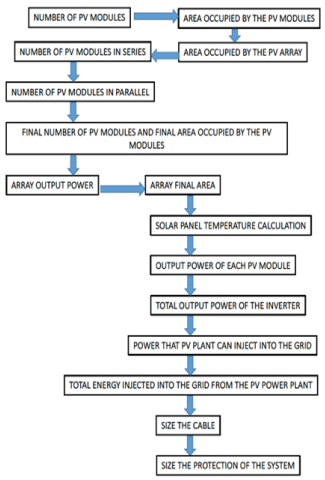
METHODOLOGY

SITE ASSESSMENT

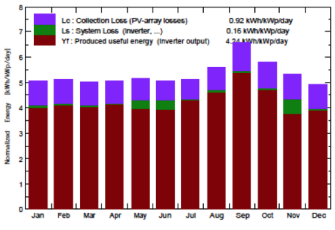
IDENTIFY A FAVOURABLE SITE FOR A PV SYSTEM:

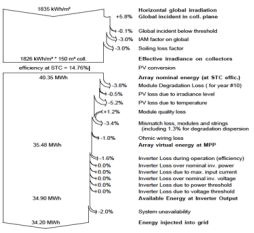
- Electrical load
- Solar resource
- Local climate
- Topography
- Available area
- Accessibility
- Module soiling

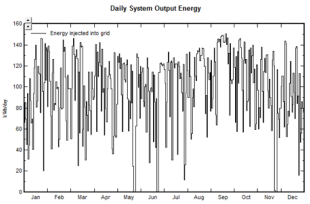
TECHNICAL ASSESSMENT

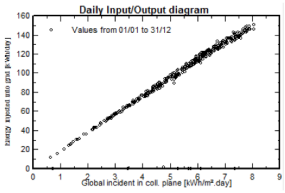


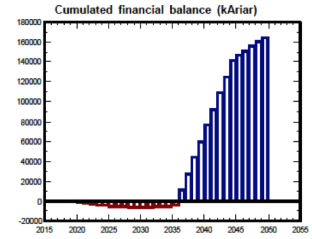
RESULTS AND DISCUSSION

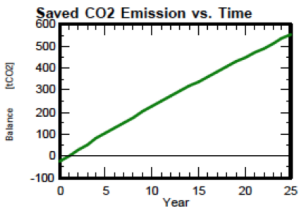












CONCLUSION

The system will generate on average about 34200 kWh of electricity a year with an annual average performance ratio of 79.7%, peaking in the month of July.

Furthermore, the project ensures a good profitability for the investor since its simple payback period is 11 years which is found within the project life span, and the investor will earn a profit of 164,767,000 Ariary at the end of the project, which makes the feasibility of this project unignorable.

Last but not least, the project stands the chance of saving about 555.2 tons of CO_2 over its entire life which is a significant figure of GHG emissions mitigation.

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Study of Hybrid Power System development and Optimization of a Micro-hydropower plant: The case of Kigwena in Burundi

Graduate CV.

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Abstract

A significant characteristic of the power sector in Burundi is a very low electrification rate (about 10 %), mainly dependent on hydropower (95 %) and with frequent power outages in dry seasons. This study aimed to identify a simple, reliable, viable and cost-effective hybrid power system to compensate the power supply of an existing micro-hydropower plant (Kigwena). From this study, using HOMER software, the most suitable complementary energy resource to Kigwena hydropower plant was solar PV and utility grid for smoothing unexpected intermittencies. These renewable energies were found to be the most techno-economical viable option to upgrade the capacity of the hydropower with the lowest LCOE of $US\$\ 0.0334\ /kWh$. This cost was within the range in comparison to the current electricity tariff in Burundi ranging from $US\$\ 0.023/\ kWh$ to $US\$\ 0.072/kWh$. The study would be a replicable model for other areas facing similar challenges.

BACKGROUND/CONTEXT

The exhausting fossil fuel energy and climate change issues have made a dual pressure to the world, and consequently is leading to an urgent development of renewable energy technologies. As these sources are intermittent, integrating two or more resources that can compensate the drawbacks of one another was found to be a solution to overcome this problem (Fathima & Palanisamy, 2015). For the case of Burundi, the over-dependence on hydropower as the one main renewable energy source for its electricity generation has been hampering the economy of the country. According to Renewable Energy & Energy Efficiency Partnership (REEEP), the total electricity production in Burundi had registered a reduction of 40% due to a reduced volume of water in 2009 (REEEP, 2012).

PROBLEM STATEMENT/RESEARCH QUESTION

Main dependence on one source of energy (hydropower) makes the country vulnerable to climate extremes. ABER started constructing micro-hydropower plants in rural areas to satisfy their energy demand. However, these plants which rely on climatic conditions are facing power cutoffs in supply on a daily basis mainly during dry seasons (Hamududu & Killingtveit, 2012).

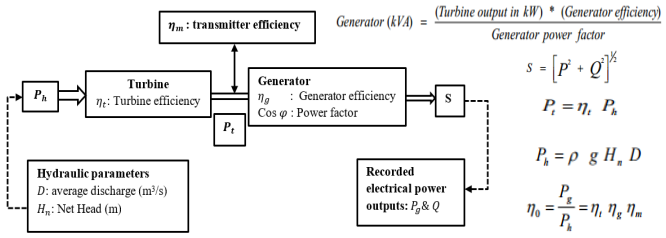
Key question: How can energy production fluctuations from micro-hydropower plants (MHP) be optimized to contribute to electricity supply reliability and access in rural areas?

OBJECTIVES

To identify a simple, reliable, viable and cost-effective hybrid system that would reduce the electricity production intermittency, especially power cutoffs for consumers supplied by Kigwena MHP.

METHODOLOGY

❑ Performance of Kigwena MHP



$$Generator\ (kVA) = \frac{(Turbine\ output\ in\ kW)\ *\ (Generator\ efficiency)}{Generator\ power\ factor}$$

$$S = \left[P^2 + Q^2\right]^{1/2}$$

$$P_t = \eta_t\ P_h$$

$$P_h = \rho\ g\ H_n\ D$$

$$\eta_0 = \frac{P_g}{P_h} = \eta_t\ \eta_g\ \eta_m$$

❑ Hybrid system optimization in HOMER software

$$C_{NPC} = \frac{C_{ann,\ tot}}{CRF(i,\ R_{proj})}$$

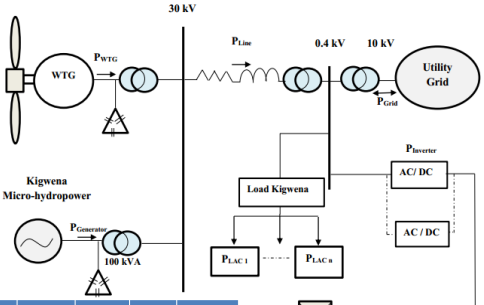
$$CRF(i,\ n) = \frac{(1+i)^n}{(1+i)^n - 1}$$

$$COE = \frac{C_{ann,\ tot}}{E_{prim}\ E_{def}\ E_{grid,sales}}$$

Optimization for the available energy sources was evaluated based on two major economic output metrics which are Net Present Cost (NPC) and Levelized Cost of Energy (LCOE).

$C_{ann,\ tot}$ is the total annualized cost, i the discount rate, R_{proj} the project lifetime, and $CRF\ (i,\ n)$ is the capital recovery factor. i is the discount rate and n the lifetime of the project.

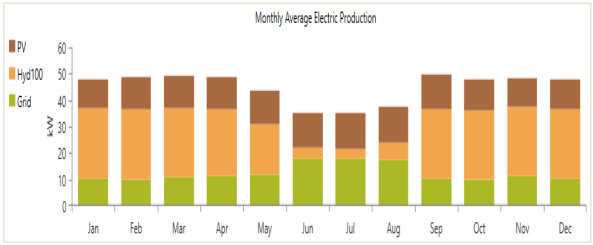
RESULTS AND DISCUSSION



Year 2018	P [kW]	Q [kVAr]	S [kVA]	P_h [kW]	D [l/s]
January	36.05	31.85	48.10	40.50	50.75
February	36.49	26.55	45.13	38.00	47.62
March	35.88	35.88	50.74	42.73	53.54
April	19.65	21.45	29.09	24.49	30.69
May	14.28	16.85	22.08	18.60	23.30
June	4.74	2.52	5.37	4.52	5.66
July	3.72	2.03	4.24	3.57	4.47
August	6.78	3.19	7.49	6.31	7.90
September	24.05	23.38	33.54	28.24	35.39
October	23.40	24.57	33.93	28.57	35.80
November	33.92	32.99	47.32	39.85	49.93
December	29.09	28.81	40.94	34.47	43.19

Quantity	Value	Units
Carbon Dioxide	-856	kg/yr
Carbon Monoxide	0	kg/yr
Unburned Hydrocarbons	0	kg/yr
Particulate Matter	0	kg/yr
Sulfur Dioxide	-3.71	kg/yr
Nitrogen Oxides	-1.81	kg/yr

The optimum combination was of solar PV, hydropower and utility grid as an indirect storage with the lowest LCOE of US$ 0.0334 /kWh, with conservation equivalent of quantity of emissions given in kg/year.



CONCLUSION

- ❖ The huge variations in intensity of streamflow make MHP less reliable in power generation.
- ❖ RE in HPS was found to be a way to complement MHP.
- ❖ Burundi needs to invest in HPS (MHP, PV) to meet the growing energy demand.
- ❖ Both on/off-grid system should be encouraged in order to decentralize power production to meet the demand.

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Graduate CV.

Techno-economic Analysis of a Hybrid Power System for Rural Electrification in Niger: Case of Ngonga Zarma Village

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Abstract

Energy is significant in fuelling sustainable development for all by 2030, as is the current global agenda.. The lack of electricity has greatly crippled the economic and social development of the villages in Niger. The study analyses the techno-economic feasibility of a hybrid system for electrification of rural communities in Niger with Ngonga Zarma as a case study. The micro-grid analysis tool HOMERPro was used to design and simulate the power system under two scenarios of grid and off grid connection. The grid connection scenario was found to be the possible way to electrify the community with a system configuration of 35kW Solar PV, 30 kW diesel genset and 16 batteries. The system had a renewable energy fraction of 62.4% solar from a total electrical energy output of 93,901kWh/yr and an LCOE of 0.137$ with the NPC at $221153. Through hybrid systems ,the renewable energy fraction of Niger can be increased so as to meet the 30% energy mix agenda by 2030.

BACKGROUND/CONTEXT

Conventional sources of energy currently dominate the total primary energy supply in the world, with a percentage share of 79.5% and renewables at 10.4% (REN21, 2017).The world has looked to the use of alternative energy sources such as renewable energy sources (RES) and efforts to reduce emissions, increase efficiency in energy use and production as a solution. with more than 500 million people in Africa not having access to electricity and many more without access to clean energy cooking. Nearly 80% of the people without access to power is from rural areas in the sub-Saharan, thus hindering the social-economic growth of rural communities (IEA, 2014). Available and affordable electricity important to improve the livelihood in rural communities.

PROBLEM STATEMENT/RESEARCH QUESTION

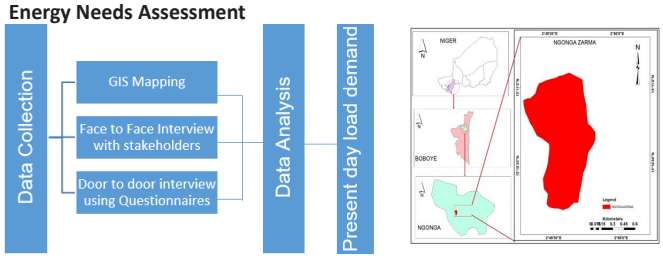
Low electricity access rate in NIGER currently at 12.3% with rural communities at 0.9%.Low productivity in businesses in rural communities, insecurity and lack of access to clean water. According to the situation in Niger, Hybrid renewable energy systems will accelerate the government plans for electrification of rural areas and the spread of micro-grids to isolated communities for socio-economic development in the country.

OBJECTIVES

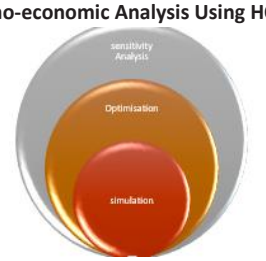
- To determine the energy demand of Ngonga Zarma and establish her load demand curve
- To assess the relevant renewable energy sources for the proposed hybrid system based on the existing potential in the area.
- To model and simulate a hybrid system with various renewable energy technologies using HOMER Pro software
- To optimize the energy generation costs based on suitable renewable energy technologies
- To analyze the feasibility of connecting the system for either the on-grid/off grid hybrid system for the village.

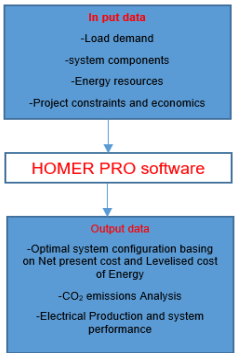
METHODOLOGY

❖ **Energy Needs Assessment**



❖ **Techno-economic Analysis Using HOMERPRO**





$$NPC = \frac{C_{ann,tot}}{CRF \cdot \tilde{G}_T} \quad LCOE = \frac{TLCC}{\sum_{t=1}^{T} \frac{Ep}{(1+r)^t}}$$

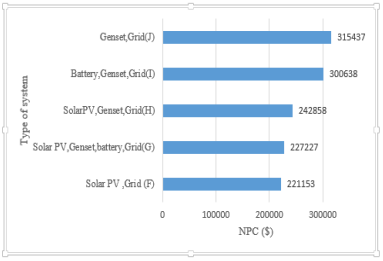
$$P_{PV} = Y_{PV} f_{PV} \left(\frac{\tilde{G}_T}{\tilde{G}_{T,STC}}\right)\left[1+\alpha_P (T_c - T_{c,STC})\right]$$

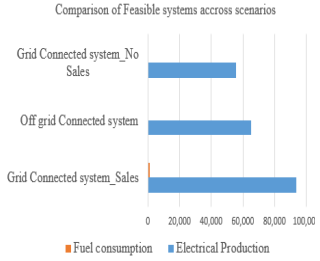
RESULTS AND DISCUSSION

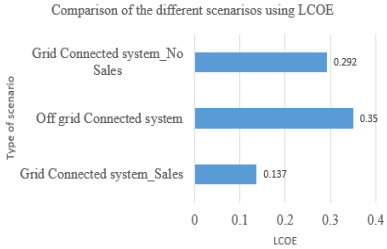
❖ Optimal system

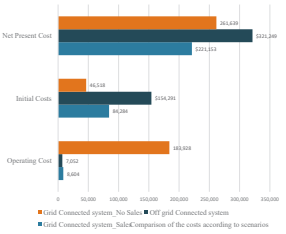
System Configuration	Solar PV	Diesel Genset	Battery	Grid	Converter	Renewable fraction
Solar PV, Grid, battery (F)	35		16	100	21.7	61.8
SolarPV,Grid,Battery,Genset (G)	35	30	8	100	22.1	60.2

❖ Net present cost of the System F

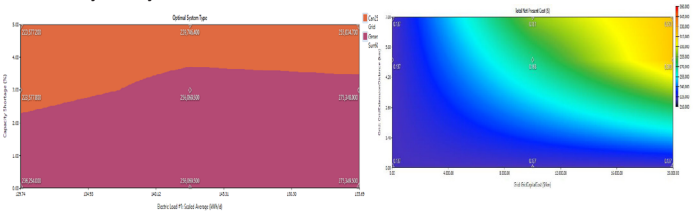








Sensitivity Analysis



CONCLUSION

- The solar PV system with battery and grid (F) had an NPC value of $221,153,AC production of 93,901kWh/yr and LCOE of 0.1374.
- Hybrid power systems are of great value in the electrification of rural communities far from the grid for example Solar PV diesel with storage system
- Solar PV systems essential for hybridization of existing unreliable and expensive diesel generators.
- Community micro grids important for increasing the generation capacity of NIGELEC ,Niger and consideration of grid connection in the long term.

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Master of Sciences

Energy Policy

Assessing Impacts of Energy Efficiency Policies on Future Energy Demand in Secondary Cities, Case study of Musanze-Rwanda

Graduate CV.

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Abstract

Urbanization is occurring fastest in developing countries, with the least developed countries expected to have the highest population growth rates. Cities in these countries are going to increasingly be important sites of energy demand. Rwanda has ambitious targets to hook up thousands of households to the energy access each year, and with the high projected economic growth forecast for the country, demand for electricity by all economic sectors in Rwanda will almost certainly increase for the foreseeable future. Modeling and scenario techniques through LEAP (Long Range Energy Alternatives Planning System) software to predict the future energy demand. This study showed that with effective implementation of the energy efficiency policies would save about 27.5% of energy and reduce energy fuel demand in 2040.

BACKGROUND/CONTEXT

Current years, the energy consumption in urban areas has brought important studies, moreover the impacts of generating decentralized renewable energy and a demand-side strategy towards greenhouse gases emissions reduction are major factors to urban energy planning goals (Collaço et al., 2019). Nowadays, the world is facing excessive population density mostly in least developing and developing countries as urbanization is arising at high rate between 2010 and 2050 (Madlener & Sunak, 2011).

Over 50% of the world's population now dwells in urban areas, however these cities are consuming approximately 75% of energy use. Sub-Saharan Africa currently has 13% of the world's population but is only responsible for 4% of its energy demand and much of this demand is from traditional biomass fuels(IEA, 2014a). The future energy demand of Sub-Saharan Africa is likely to be significantly urban, over 75% by 2040 will be the city share of total demand rising to over 75% by 2040. Universal access to modern energy and energy efficiency implementation, as proposed in the Sustainable Energy for All goals, could reduce energy demand by 17% by 2040(SEA, 2015). Rwanda, biomass takes high share of the total energy consumption, it has 85% of all energy demand. Residential sector is the first dominant of energy consumer, with 82%, followed by transport with 8%, industries at 6% and other sectors at 4% (MININFRA, 2018).

PROBLEM STATEMENT/RESEARCH QUESTION

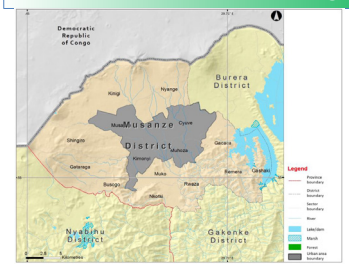
Due to the estimated increase in economic activities, electrification rate and demographic growth in Rwanda, more sufficient energy supply would be needed to meet the future raising demand. Rwanda has ambitious targets to develop green secondary cities that will contribute reaching urbanization 32% by 2018 and 35% by 2020, respectively goals set by EDPRS 2 and Vision 2020(Government of Rwanda and GGGI, 2015).

OBJECTIVES

The main objective of the project is to evaluate and analyze impact of energy efficiency policies on future energy demand in secondary cities. And the specific objectives of this study:

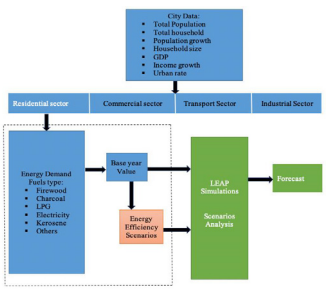
- To evaluate energy resources, energy development and associated policies in Rwanda,
- To develop the long-term energy scenarios for secondary cities,
- To forecast energy savings resulting from the energy efficiency policies

METHODOLOGY



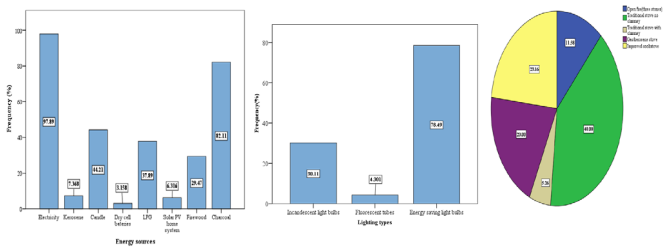
- ❑ The district area is 530.4 km².
- ❑ The total urban population of Musanze City in 2012 was 99,387 and
- ❑ population growth 2.53%.

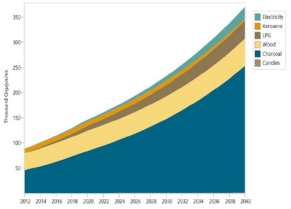
- ❑ The study involved the qualitative and quantitative data, collected using descriptive research design.
- ❑ A household survey for Musanze city was done on a total of 356 Households were surveyed.
- ❑ Data is processed by using SPSS and MS excel then the data is analyzed and simulated in LEAP.



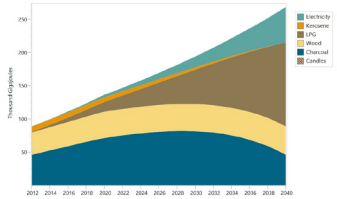
- ❑ **Energy Business as Usual (BAU) Scenario**: How the future demand in the absence of new and explicit energy efficiency policies and mitigation measures.
- ❑ **Energy efficiency Scenarios** including efficient lighting LPG usage and sustainable usage of biomass

RESULTS AND DISCUSSION

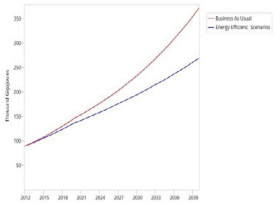




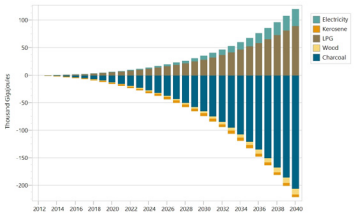
BAU scenario



Energy Efficiency scenario



BAU and EES scenario projections



Avoided fuel VS BAU scenario

CONCLUSION

❑The results showed that four energy sources predominate: electricity, charcoal, firewood and LPG.

❑However, there were urban households with greater diversity of energy sources in urban households, also including electricity (97.89%), candles (44.21%) and liquefied petroleum gas, or LPG (37.89%). Charcoal use is much higher at 82.11%, whereas firewood use is only 29.49%.

❑The results found show that total demand is 370.4 thousand Gigajoules on business as usual scenario, instead total final energy fuel is 268.5 thousand gigajoules on Energy efficiency Scenarios.

❑This study showed that with effective implementation of the energy efficiency policies would save about 27.5% of energy and reduce energy fuel demand in 2040.

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❖ *Collaço, F. M. de A., Simoes, S. G., Dias, L. P., Duic, N., Seixas, J., & Bermann, C. (2019). The dawn of urban energy planning – synergies between energy and urban planning for São Paulo (Brazil) megacity. Journal of Cleaner Production. https://doi.org/10.1016/J.JCLEPRO.2019.01.013*

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Community Acceptability Of Renewable Energy In Africa: Implications For Climate Change Action In Sekoukou, Niger

Graduate CV.

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Abstract

Niger possesses a vast amount of renewable energy potential but still battles with numerous challenges in its energy sector with the increasing effects of climate change, also escalating the socio-economic predicaments of the country. Studies have revealed community acceptability as one approach to resolving such energy crises; however, acceptability is narrowly being discussed, especially within the context of African communities. The study aimed at understand the factors that influence the acceptability of renewable energy and its implication on climate change actions in Sekoukou community in Niger where electricity and clean cooking sources are in dearth. The adaptation of both quantitative and qualitative data collection techniques and analyses, lead to the conclusion that financial model that targets the poorest of the poor as well as education to break the socio-psychological ties to firewood are needed to influence acceptance of renewable energy in the Community.

BACKGROUND/CONTEXT

The prevalence of inadequate social, cultural and institutional consideration for innovation and technology serves as one reason for the many failed renewable energy project implementation in Africa. For many, renewable energy project is about finding an empty land and fixing solar panels to provide light for the people because they lack electricity. This mindset coupled literature gap on the relationship between acceptability of renewable energy and climate change actions particular at communities' levels in Africa explains why more than 80% of the continents' population are still without electricity.

PROBLEM STATEMENT/RESEARCH QUESTION

Like most African countries, Niger has 12.93% energy access rate (urban rate: 63.1%, and rural rate: 0.93%) despite its energy potentials. Base on the available renewable potential and progressive policy frameworks, energy access gap ought to have closed up considerably, but the reverse is the case. It even turns out to be more problematic due to the high risk of climate change, which is rendering the entire socio-economic development of the country in shams. This study intends to therefore ascertain the level of community acceptability for renewable energy in Sekoukou community and its implication for climate change action towards achieving the triple benefit of sustainability, climate change mitigation and development in Niger Republic.

OBJECTIVES

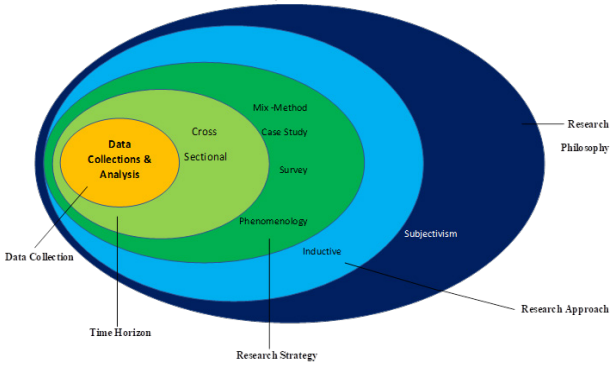
To understand what acceptability of renewable energy means to Sekoukou community.

To examine community participation in renewable energy and climate change project processes using gender-sensitive participatory model.

To identify policy options in Niger that can help accelerate the implementation of renewable energies at community levels

METHODOLOGY

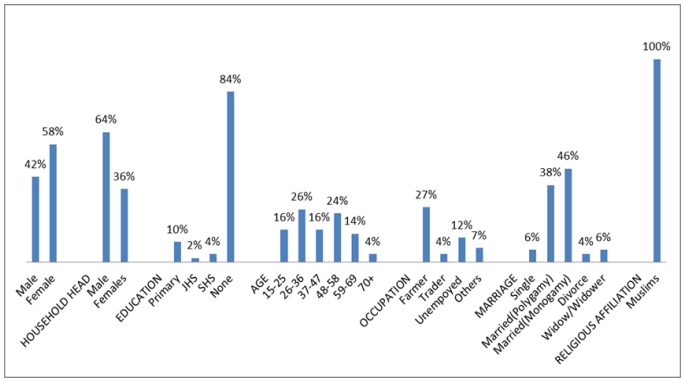
The study location- Sekoukou community is 46Km away from Niamey-Capital of Niger, with a population of 863 (318 males, 545 females). Out of 102 households in the community 50 were selected for interview.



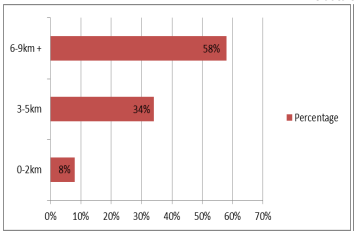
Graphical Representation of Research Methodology. Adopted from Research Onion Model by Saunders et al. 2009.

RESULTS AND DISCUSSION

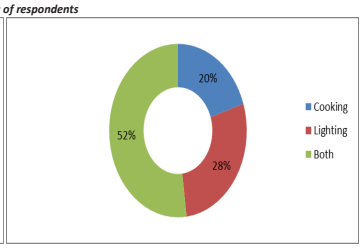
Data gathered revealed that challenges associated with firewood accounts for 92% of respondent's willingness to change their energy sources. A gender sensitivity analysis also revealed that Sekoukou community is at a take-off stage. A higher level of knowledge was also exhibited by respondents on causes of climate change and their preparedness to adopt and mitigate to its horrid impact in the community.



Bio data of respondents



Distance covered to fetch wood



Respondents preference for energy

A Focus group discussion however revealed that some sections of the community were not satisfied with the position and utilization of a solar project in the community.

CONCLUSION AND RECOMMENDATIONS

Findings indicates that there is generally a positive perception of the benefit of solar energy, clean cooking fuels and the dangers associated with climate change. Cultural perception and cost viability however remain a commonly cited concern regarding acceptance of alternative energy sources. The study therefore recommends an extensive educational and promotional campaign on improved cookstoves as well as a financial model that will target the poor to have access to improved cooking stoves and fuels. More so, values and culture of the people, as well as respect for traditional leadership, should also be handled with absolute care and tactfulness, to enhance acceptability and sustainability of renewable energy projects in Sekoukou.

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Contributions of Renewable Energy to Sustainable Development in Africa: Case Study of Solar Energy in Rwanda

Graduate CV.

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Abstract

Rwanda is a small and landlocked country located in East-Central Africa. It has abundant renewable energy resources and solar energy is one of them with the total annual potential of approx. 66,38 TWh. The solar energy contribute to 2.2% for electricity production and the most used technology is solar home system. To study the contributions of solar energy to sustainable development (SD) in Rwanda the triangular approach and mixed research methodology were used focusing on the three dimension of SD. The result showed that solar energy has a significance impact on social dimension, followed by environmental dimension and the last is the economic dimension. The solar energy is contributing significantly to the development of Rwanda. However, more effort are needed in R&D, policy framework, and creating awareness to ensure the energy sustainability se and achieve the universal energy access.

BACKGROUND/CONTEXT

- Globally, energy has been recognized as essential and life blood for humanity to develop and flourish. However, in SSA the electricity access rate is only 43% despite the abundant energy resources available on the continent (IRENA, 2013).
- We are facing energy crisis due to fossil fuels depletion and concerns of greenhouse gas emissions. Keeping in mind also the current growth rate and industrialization on the continent that lead to the exponential rising of energy demand (Favretto et al., 2018).
- The way forward and sustainable solution are needed specifically for developing countries to consider the sustainable development by ensuring the energy sustainability that meets the current energy needs without compromising the future energy needs.

PROBLEM STATEMENT/RESEARCH QUESTION

Rwanda's electricity access is under **50%** and a big part of its Population who live without access to electricity are in rural areas far from the grid. The country aims to achieve the universal energy access by 2024 and move from a developing country to a middle-income country. How Rwanda or other developing countries can ensure their development and at the same time be sustainable? What are the contributions of of renewable energy (solar energy) to sustainable development in Rwanda?

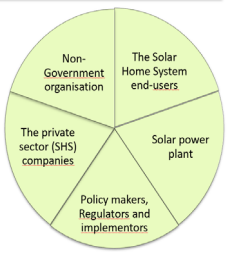
OBJECTIVES

- To evaluate the contributions of existing solar energy projects to social, economic, and environmental aspects in Rwanda.
- To identify the potential economic, Social and Environmental gains if the solar energy exploitation is increased.

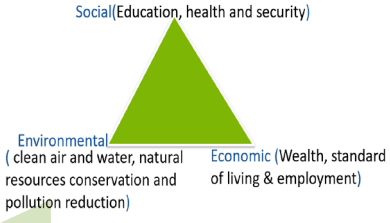
METHODOLOGY

The Mixed research methodology was used for data collection, both primary and secondary data were collected. The triangular approach and SPSS software were used for data analysis.

Analysis of the potential interviewees



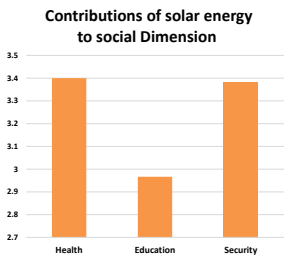
Approach for SD assessment

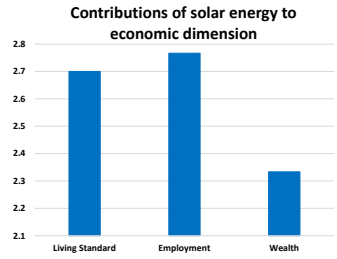


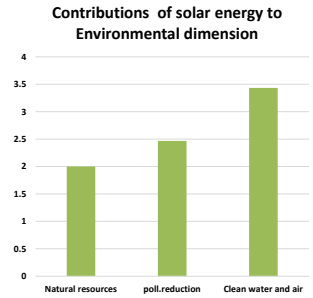
Questionnaire Design

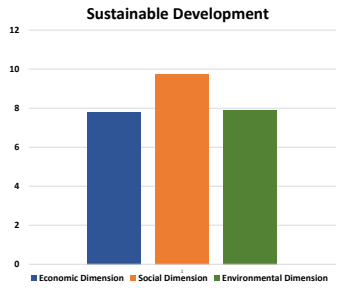
- Considering the characteristics of the community as well as the dimensions of the sustainable development components.
- Semi structured questions.
- The following scale **5- Extremely, 4- A lot, 3- Moderate, 2- Just a little, 1-Not at all-** was used for interviewees to express their thought about solar energy impacts in Rwanda.

RESULTS AND DISCUSSION









- Solar energy has a significance impact on social dimension, followed by environmental dimension and the last is the economic dimension.
- By adopting solar, Rwanda would create jobs for millions of Rwandans and provide an alternative of electricity access to rural areas far from the grid; this would also boost the economy, hence giving Rwanda extra flow of money from trading carbon credit while preserving the environment and help the country to diversify its energy mix and reduce CO2 gas emission.

CONCLUSION

- ❖ The hypothesis was supported by the result that the solar energy progression could impact positively the sustainable development in Rwanda.
- ❖ Communities in rural areas are developing and feel connected to the rest of the world.
- ❖ Lacking of the supportive infrastructures and low power of purchasing hinder solar energy dissemination.

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Diffusion of Renewable Energy Technologies and Socio-economic Development A Ripple Effect Analysis of Two Policy Choices: Inclusive Clean-burning, Fuel-efficient Cook-stoves and Solar PVs for Street Lighting, Institutional and Home Applications in Hoima District, Uganda

Graduate CV.

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Abstract

This study analysed the ripple effect of inclusive improved cook-stoves and PVs in Hoima District, Uganda. Three elements were assessed: adoption of, investment level and the market for improved cook-stoves and the socio-economic benefits of PVs for street lighting, home and institutional use in the development of rural livelihoods. A mixed research methods was used. Using SPSS version 20 and STATA version 13.0 software, the regression model indicated that access to information, training service and technical support facilitate the adoption at 1% level, but are backed up by artisanal fabricators producing different sizes and designs of stoves at segmented prices, satisfying the customers' choices and preferences. Age, distance from fuel sources and from the market negatively affect the adoption at 10% level. Investment is still low, but highly influenced a high ready market. PVs significantly provide reliable energy services at 10% level for sustainable socio-economic progress, significantly transforming rural communities.

BACKGROUND/CONTEXT

Energy is the life-breath and blood of every modern society; it is an **indispensable** element in all aspects of life, especially **economic and human development**. The universal access to modern energy is directly linked to all of the Sustainable Development Goals (SDGs); it is a weapon for combating poverty, fostering economic growth and improving health and gender equality (OECD/IEA, 2017) thus a catalyst for Agenda 2063. However, 2/3 of the population In Sub-Sahara Africa do not have access to electricity and those connected rely on the underdeveloped, costly and unreliable grid, an impediment to development. Solid biomass predominates the region causing health issues. The region is the most vulnerable to climate change due to lack of resilience. Fortunately, there is **abundant solar PV potential** and PVs can be installed anywhere. This, **coupled with biomass technology advancement** for improved cook-stoves can **foster the acceleration of both Agendas 2030 and 2063**, leading to a transformed modern African Economy.

PROBLEM STATEMENT/RESEARCH QUESTION

Energy Poverty: Over 70% of Ugandans lack access to electricity; 64% use firewood; 30% use charcoal and 52% use wick canister candles (hazardous)
Growing Popn: Increased economic activities, energy demand, co2 emissions leading to climate change.
Vision 2040: Universal access to modern energy: more investments being carried out, but less analytical and empirical based evidence

OBJECTIVES

To assess the diffusion of RETs and its impact on socio-economic development by examining the adoption of, investment level and market for improved cook-stoves and determining the socio-economic benefits of solar PVs for street lighting, institutions and home applications in the development of rural livelihoods.

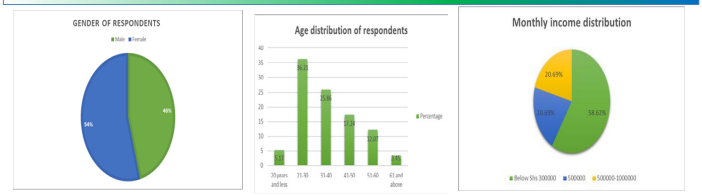
METHODOLOGY

Research Design
- Mixed methods approach
- Cross-sectional research design.

Target population: users and fabricators of clean burning, fuel-efficient cook-stoves, PVs users and area planners.
Sampling units: households, local authorities and institutions.
Sampling Technique and Sample Size
- Multi-stage sampling technique

Research Instruments
A semi-structured questionnaire was used
Data collection techniques
Questionnaires with open and closed-ended questions, observation, focus group discussions, key informative interviews and photography.
Pilot study
Pre-study for data accuracy
Data processing and analysis
The analysis of quantitative descriptive primary data were done with the aid of SPSS version 20 and STATA version 13.0 software and qualitative used descriptive/narrative analysis.

RESULTS AND DISCUSSION



Figures 1, 2 & 3: Accessibility and adoption of clean burning, fuel-efficient cook-stoves

Variables	Coefficients	Std. Err	z	P-Value
Age	-0.084	0.018	-4.667	0.065
Gender	0.134	0.153	0.876	0.051
Education level	0.019	0.01	1.9	0.002
Experience	0.014	0.05	0.28	0.079
Household size	0.026	0.029	0.896	0.032
Household income	0.870	8.35	0.104	0.000
Household Head Occupation	0.218	0.1	2.18	0.000
Distance to fuel source	-1.107	1.367	-0.809	0.017
Access to information	0.032	0.172	0.186	0.004
Distance to Market	-0.057	0.069	-0.826	0.074
Training Service	0.061	0.083	0.734	0.000
Technical support	0.537	0.512	1.048	0.000
Constant	2.019	3.541	0.572	0.001
Number of observation =58			Prob > chi2	= 0.0000
Pseudo R^2 = 0.7342				

Fig 4: Regression analysis of accessibility and adoption of improved stoves

Variables	Coef.	Std. Err.	T	P>t
Income level	0.533	0.113	4.716	0.000
Access to credit	1.717	0.87	1.973	0.000
Household size	1.008	1.4	0.72	0.067
Primary occupation	0.392	0.593	0.661	0.000
Access to market	0.297	0.075	3.96	0.052
Expenditure level	0.881	0.191	4.612	0.002
Constant	1.85	2.353	0.786	0.000
Number of observation=15			F(6. 139)	= 67.96
Prob > F			=	0.0000
R-squared			=	0.7718

Fig 5: Regression analysis on investment and market for improved cook-stoves

Variables	Coef.	Std. Err.	T	P>t
Access to modern energy service	0.582	0.754	0.772	0.000
Money saving	0.264	0.418	0.631	0.000
Effective energy provision	1.1	1.909	0.576	0.867
Enhance business activities and hours	0.427	0.602	0.709	0.000
Improve income generation	0.738	0.897	0.823	0.075
Improve communication system	0.654	0.827	0.791	0.040
Saving energy cost and security	0.691	1.372	0.503	0.613
Reduce emission of greenhouse gases	0.39	0.218	1.789	0.080
Increase environment sustainability	0.6	0.681	0.881	0.000
Improve illumination	0.063	0.409	0.154	0.016
Increase employment opportunities	0.335	0.131	2.557	0.000
Improvement of study conditions	0.67	0.859	0.779	0.006
Improved air quality	0.012	0.295	0.041	0.013
Improvement of health conditions	0.382	0.158	2.418	0.742
More safety	0.014	0.277	0.050	0.057
Increase business opportunities	0.51	0.783	0.651	0.000
Constant	0.582	0.154	3.779	0.000
Number of observation=73		F(16. 129)		= 53.75
Prob > F		= 0.0000	R-squared	= 0.7468

Fig 6: Regression analysis on socio-economic benefits of solar PVs

Benefits of Solar Powered Street Lights:
- Cheaper to operate and maintain
- More reliable than the grid
- Convenient to install
- Environmental friendly
- Boost businesses
- Promote security & safety
- Reduce accidents, crimes & traffic jam

CONCLUSION

- More women in cooking systems than men
- Access to information, training services, technical support facilitate ICS adoption at **1%** level Gender and household size 5% level, Experience at **10%**
- Negative influence: Distance to fuel sources and market **10%**
- Investment of ICS still low, but influenced by access to credit, incomes levels and ready market.
- Market for ICS is high (demand)

Socio-economic benefits of PVs
- Jobs, money savings, increased working hours at 1% level
- Improved communication systems, illumination, air quality and safety at 5% level
- income generation at 10% level.

Other benefits:
- Reliability, reduced emissions, increased energy security, reduced deforestation leading to socio-economic transformation in an environmentally sustainable manner.

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http://pauwes-cop.net/library/handle/1/311

Graduate CV.

Energy Access And Impact Analysis Of Biogas Harnessing On Mau Forest Conservation

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Abstract

The Mau Forest Complex sits within Kenya's Rift Valley and is the largest indigenous montane forest in East Africa but 25% of the forest has been lost due to human activity. This study analysed energy access by communities living next to the forest using multi-tier framework methodology and it was found out that 98% of households use on average 920 kg of firewood annually. Two future scenarios were analysed; business-as-usual and bio-digester and clean cookstove adoption. Based on projections, fuelwood demand will triple by the year 2040 but this is reduced by 50% with adoption of bio-digester and clean cookstoves scenario. A household with a 4m^3 will spend 50% less firewood and cattle ownership per household will reduce by 80%. This will reduce pressure on forest encroachment.

BACKGROUND/CONTEXT

The Mau Forest Complex sits within Kenya's Rift Valley and is the largest indigenous montane forest in East Africa. It serves as a critical water catchment area for the country, but human activity including; agriculture, logging, settlements, fuel and charcoal burning, has reduced the forest by 25%. (Nabutola, 2010). The communities who settled around the forests have, over the years made it their home and source of livelihood. They need it for wood fuel for cooking, and to generate income by charcoal selling to the cities and towns.

One of the solutions to these, according to a special task force appointed by former Prime Minister Hon. Raila Odinga, is to uproot the communities and replant the trees. This decision was faced by serious opposition from Rift valley leaders who saw the solution proposed as a reckless displacement of population before crafting an alternative settlement scheme for the communities. The lasting solution to conserve the forest is still pending, yet the daily needs of the communities in terms of cooking and charcoal for sale, has to be met by the forest.

PROBLEM STATEMENT/RESEARCH QUESTION

Does improving energy access and harnessing of biogas by communities living next to MAU forest contribute to conservation of forest and improved living standards?

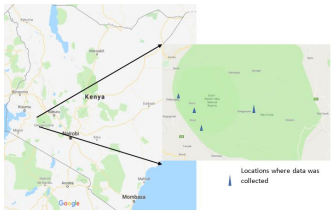
OBJECTIVES

1. To assess rate of electricity and energy for cooking access by communities living next to MAU forest.
2. To evaluate correlation between adoption biogas technology and demand for firewood and charcoal in southern rift region of MAU forest.

METHODOLOGY

Study Area

This study was focused on south western Mau, where data collections was done in regions of; ; Londiani ward to the north, Chebangang in Kimulot ward towards the south east, Nyangores ward to the south, and Olenguruone in Kiptagich ward.

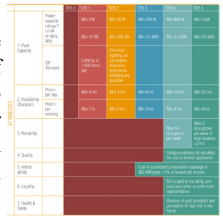


Data collection

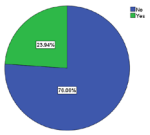
Structured questionnaires were used to collect data from the households. Focus was given on background data of the household, electricity access and services, cooking solutions, health, and quality of cooking fuel. This process was facilitated by use of android app, Hedera collect.

Analysis

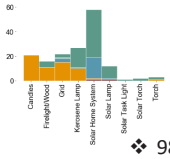
Multi-Tier Framework (MTF), was adopted, where access to energy was measured in the spectrum of levels, from Level 0 (tier 0) (without access) to Level 5 (tier5) (the highest level of access). For example, Access to electricity was measured based on standards (attributes) of multiple levels, independent from the energy technology.



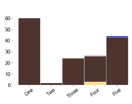
RESULTS AND DISCUSSION

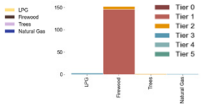


Knowledge about biogas technology in the region.



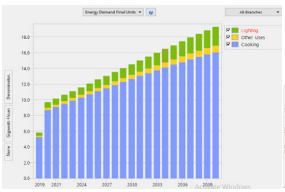
Primary energy sources for lighting



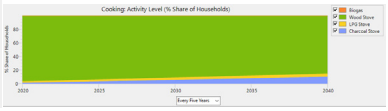


- 98% of the residents use firewood as primary cooking fuel.
- 89.5% of the users are categorized in tier1 due to inconvenience based on time taken in firewood collection and preparation

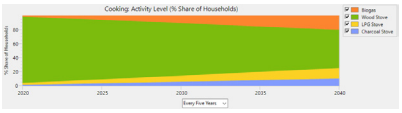
Energy demand according to Business as Usual (BAU) scenario



Key Parameters	Assumptions in BAU
GDP growth rate	5.4% till 2040
Population Growth rate	2.5% till 2040
Urbanization growth rate	37.5% by 2040



Bio-digester and clean cookstove adoption scenario.



Introduction of a 4m3 biodigester per household at yearly adoption rate of 1%.
Improved access of clean charcoal and LPG stove to 10% and 15% respectively by 2040

CONCLUSION

- Grid electricity access in the region is currently at 17% while the use of solar home systems, currently stands at 36%. 48.1% of the residents are categorized in *tier 5* while 37.6% are categorized to be in *tier 1* and *tier 2*.
- Firewood is the main cooking fuel adopted by the residents in the region. A household uses approximately 920kg of firewood per year. 89.5% of the residents have been categorized to be in *tier 1*.
- On average a household owns 10 cattle with a two acre piece of land. Due to limited space, residents resort to forest encroachment in search of livestock feeds. With two dairy cows, producing 20 kg of dung each, a household is able to produce 4,818 m^3 of biogas annually which is equivalent to 428.3 kg savings on firewood.
- By adopting bio-digester and clean cookstove scenario, demand for firewood will be reduced by 50% by the year 2040.

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The entire master thesis report is available under the following link:
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Enhancing the role of local government in promoting sustainable energy transitions in Ghana. A case study of Wa Municipality

Graduate CV.

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Abstract

This study examined local government agencies' involvement in Sustainable Energy (SE) initiatives and how their role in such initiatives can be enhanced in Ghana. Interviews, Focus Group Discussions and document reviews were used to gather data from local government agencies and key actors engaged in SE initiatives in the Wa Municipality. Results showed that local government agencies played a facilitative rather than a direct role in SE initiatives. Policy frameworks fail to outline strategies to integrate SEs into local government plans. The study recommends the integration of SE planning and implementation into local government plans and proposes a decentralized framework to this effect.

BACKGROUND/CONTEXT 0

Local governments play a crucial role in Sustainable Energy Transitions. Yet, planning for such energies remains centralized in many sub-Saharan African countries including Ghana **(Rawn & Louie, 2017)**.

Centralized energy planning fails to incorporate variations in socio-economic and ecological factors in a region which influence the success of any intervention (**Hiremath, Shikha & Ravindranath, 2007)**

This has created the need for more decentralized approaches and hence, the need to involve local governments.

PROBLEM STATEMENT/RESEARCH QUESTION

Local governments have a limited mandate with regards to decentralized renewable energy generation in Ghana (**Bawakyillenuo, Olweny, Anderson, & Borchers, 2018).**

As a result, very little is known about the holistic state of energy at the local/districts level; hence, making effective planning for sustainable energy issues highly impossible **(Bawakyillenuo & Agbelie, 2014).**

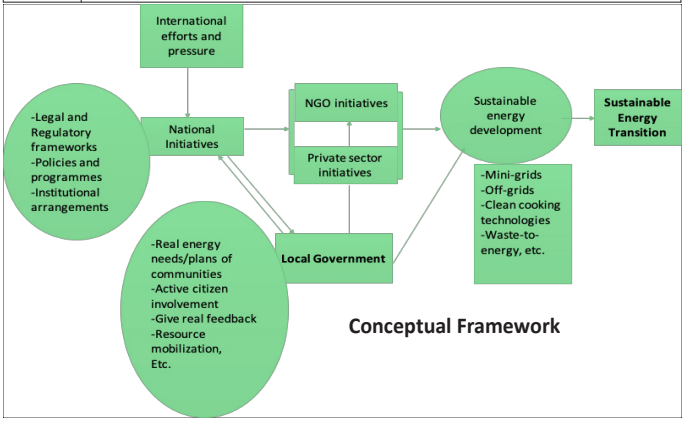
Main Question: How can the role of local government be enhanced in promoting sustainable energy transitions in Ghana?

OBJECTIVES

To examine actor involvement in sustainable energy initiatives in Wa municipality; how sustainable energies can be integrated into local government plans and; the institutional capacity of local government agencies to undertake sustainable energy planning and implementation.

METHODOLOGY

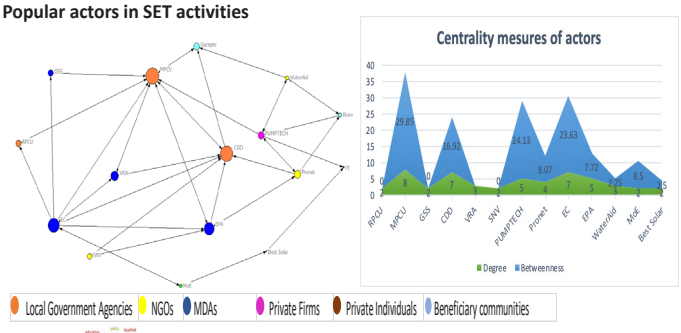
RESEARCH APPROACH		Data collection methods	Instruments	Sampling technique	Units of Inquiry
Concurrent Mixed Method	Qualitative	-Face-to-Face Interviews, -Focus Group Discussion, -Document review	-Interview guide -FGD guide -Data extraction sheet	Purposive	-institutions that deal with sustainable energies in the municipality - Beneficiary communities
	Quantitative	Questionnaire administration	Structured questionnaire	Purposive	Local government agencies
Sample size	13 institutions, 2 local communities . Data were analyzed with NetDRAW and Atlas.ti. **The study area was Wa Municipal District in the Upper West Region of Ghana.**				

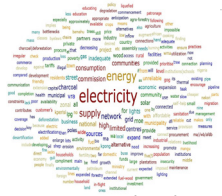


Conceptual Framework

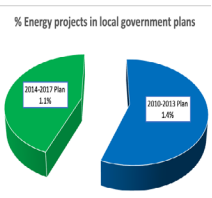
RESULTS AND DISCUSSION

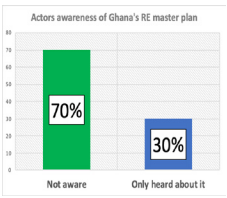
Popular actors in SET activities

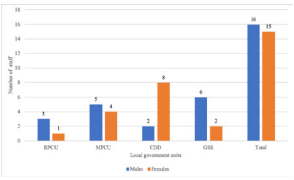




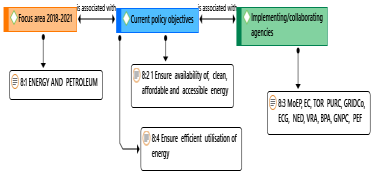
Energy-related keywords in the plans







No. Staffs in local government agencies

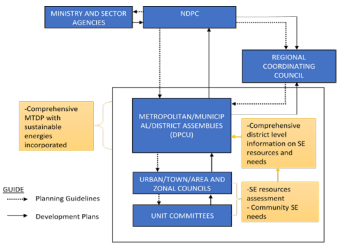


Policy objectives and their implementing agencies in the NMTDPF, 2017-2021

CONCLUSION

Despite being the most popular actors in sustainable energy initiatives at the district level, local government agencies play a facilitative rather than a direct role in sustainable energy development in Ghana.

Their role in SETs in Ghana is limited because planning for sustainable energies remains centralized with key policy frameworks failing to assign the responsibility to plan and implement projects on such energies to the MMDAs.



A proposed framework for decentralized energy planning (adapted from Inkoom, 2009)

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The entire master thesis report is available under the following link:
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Graduate CV.

Overcoming the Challenges of Rural Electrification through Stakeholders' Participation in Policy Making: Case of Cameroon

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Abstract

Electricity remains a vital resource in meeting the sustainable development goals as it is a major driver for the economy. With only about 20% of rural electricity access in the country, about 46% of the country's population risks economic stagnation. This study sought to find out the challenges to rural electrification in Cameroon and proposed a model for rural electrification. Using the survey research design, the study was qualitative with both primary and secondary sources of data collection. Major findings included poor living conditions and limited economic growth in rural areas. Limited co-ordination of the rural electrification sector was a key barrier to rural electrification. A model was proposed to promote stakeholder participation and decentralised energy generation.

BACKGROUND/CONTEXT

Electricity and clean energy access is necessary for any society's development. Clean energy access is instrumental for economic activity, absolute health and wellbeing of communities (Chaurey & Kandpal, 2010). Meeting this energy needs is very necessary in order to attain the United Nations Sustainable Development Goals of which energy itself is one of them (UNGA, 2015). About 1.1 billion people worldwide lack access to modern electricity services. Access to electricity is particularly crucial to human development. It is estimated that 85% of the 1.2 billion people in the world living without access to electricity reside in rural areas, which is attributable to the marginalisation of the poor as well as their long distance from established electrical grids (Javadi, Rismanchi, Sarraf, Afshar, Saidur, Ping & Rahim, 2013). Energy plays a pivotal role in shaping the growth of Cameroon and its 2035 Emergent Economy Vision emphasises this in great detail. With only about 20% of rural electricity access in the country, about 46% of the country's population risks economic stagnation.

PROBLEM STATEMENT/RESEARCH QUESTION

Despite the moderate electricity access levels in Cameroon compared to neighboring countries, very few rural facilities are electrified. With the creation of the Rural Electrification Agency in 1998, coupled with a 9.3 % increase in rural electrification rates in 2018, the study asks the question of why there is still a low rates of rural electrification in Cameroon?

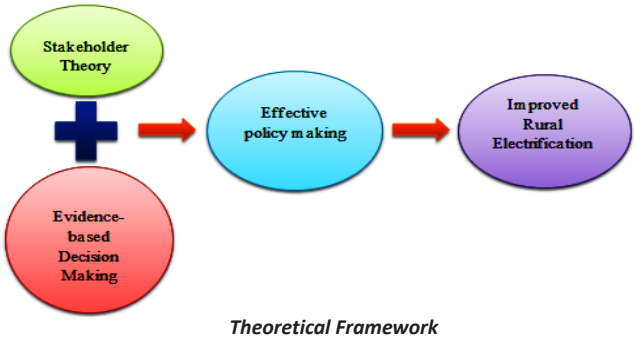
OBJECTIVES

To contribute to the sustainable development goals of energy for all and promoting local development through clean energy systems and stakeholder participation.

METHODOLOGY

The study used the survey research design. With the study being qualitative, data collection was through primary and secondary sources with the semi-structured interview and personal observations as instruments for primary data collection.

One rural community (Mongossi) and the Rural Electrification Agency served as case studies. Imploring the purposive sampling technique, a sample of 10 respondents were selected for this study and data was analysed through in-depth content analysis. A theoretical framework for the study was designed based on the stakeholder and the evidence-based decision making approaches.



Theoretical Framework

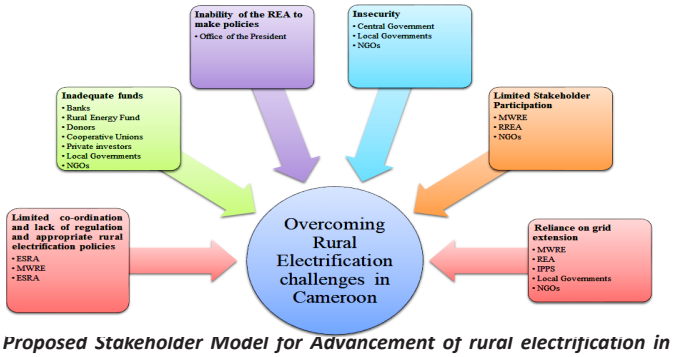
RESULTS AND DISCUSSION

Implications of No electricity Access on Rural Areas like Mongossi

✓Poor Living Conditions
✓Limited Economic Growth
✓Rural-Urban Migration

Factors that hinder the improvement of rural electricity access in Cameroon

❖Limited co-ordination of the rural electrification sector in Cameroon
❖Lack of powers by the REA to make Rural Electrification Policies
❖Lack of funds
❖Lack of grassroots and other stakeholders' participation in the policy making process
❖Insecurity
❖Reliance on grid extension for rural electrification



Proposed Stakeholder Model for Advancement of rural electrification in Cameroon

CONCLUSION

- Every industrialised society relies on electricity and other energy sources to power industries and other sectors of the economy. While Cameroon envisions becoming an emerging economy by 2035, energy is needed for the accomplishment of this task.
- The lack of electricity access needs to be addressed in order to stimulate economic growth (SDG 8) in rural economies and promote access to clean and modern energy forms for all Cameroonians by 2030 (SDG 7).

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Potential Role of Renewable Energy into Energy Mix to Overcome Energy Shortfall in Niger. Case of Sékoukou Village

Graduate CV.

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The lack of access to energy is a major obstacle to the development and the improvement of living conditions for developing countries. The most West African developing countries are characterized by extreme poverty and energy insecurity, although their potential for renewable energy is considerable. The increase in the share of renewable energy in the national energy mix remains one of the main energy policy issues that the many stakeholders in developing countries like Niger are facing. This is often due to the lack of existing studies on the potential of its renewable energies. This work trays to identify the potential of renewable energy and the role it plays in the Niger's national energy supply to overcome the energy deficit. During the study, the energy ne eds that were taken into account for households were mainly in electricity and cooking. The surveys were conducted on 60 households in Sekoukou's village with of nearly 70 households. This study has made possible to identify the potential renewable energy sources in the village of Sékoukou and the estimation of their potential. Sékoukou village has a big energy potential consists to four sources of energy: sun, wind, wood and green waste. The solar potential already exploited allows to Sékoukou's people to improve their living conditions. The integration of renewable energy in energy mix can accelerate the potential economic activity of Sékoukou.

BACKGROUND

Access to modern energy is seen as a prerequisite for sustainable development (Ouedraogo, 2012). The depletion of fossil fuel, rising prices and concerns about environmental impact are now forcing stakeholders to seek alternative forms of energy for the energy mix that respond to energy demand and environmental issues. At the time of the energy transition, the use of renewable energy sources is a solution that is attracting worldwide interest, with technological advances and its maturity, the cost of connecting these energy sources is becoming interesting.

In most developing countries such as Niger, access to energy remains a major challenge, especially for those living in rural areas. This situation is largely due to an energy sector heavily dependent on the outside and bad balance in the energy mix.).On other hand, Niger has enormous potential in terms of energy resources, although conventional and renewable.

PROBLEM STATEMENT/RESEARCH QUESTION

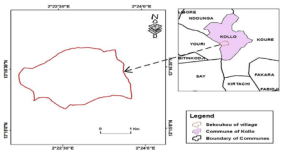
The country is characterized by a low access rate especially in rural areas. The current access rate is 12.93% of which % 0.93 in rural areas and 71.48 in urban areas (ANPER, 2019). Firewood represents **94.55%** of final household energy consumption (EIS,2018. The country's energy dependence on the outside world is about **70%** in terms of electricity and imports about **42%** of the wood energy.

This study seeks to harness the renewable energy potential of Niger to address the issue of the energy shortfall through the designing a policy for the integration of RE into energy mix.

OBJECTIVES

The general objective of this study is to determine renewable energy role in Niger energy mix to overcome energy shortfall in rural area and to deduce the strategies and mechanism to be adopted to accelerate the process of integration of renewable energies

METHODOLOGY



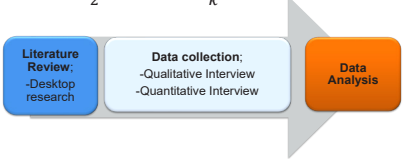
Name	Sékoukou
Location	13°16'25.49", 2°22'0.66" Sékoukou is the village of KOLLO, which is located about 144km of Tillaberi region
Main income generation activities	Agriculture, Fishing, breeding Irrigation
Farm animal heads	500
Main agricultural product	Millet, Sorghum, Rice, Beans
Main Language	Zarma
Main energy source use	Solid biofuel (wood), solar energy, Battery and human energy

Energy resources assessment

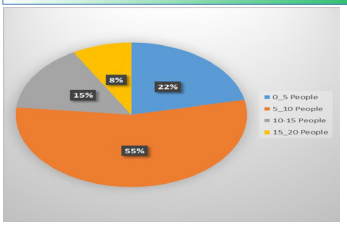
For the assessment of the potential of energy resources we proceeded with the following methods:

Energy received daily in Sékoukou village is given by: $E_{S1} = S * I_r$ and the real energy is given by :$E_{S2} = E_{S1}$ r: The availability rate of solar energy is giviven by: $\mathbf{r} = \frac{\textbf{Power available}}{\textbf{Power installed}} * \mathbf{100}$

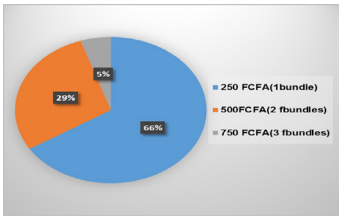
The recoverable energy potential after calculating the average cubic velocity by the Weibull distribution of the wind speed frequencies is therefore written: $P_2 = \frac{1}{2}\rho\, c\, \Gamma\,(1 + \frac{3}{k})$



RESULTS AND DISCUSSION



Distribution of Sékoukou village household size

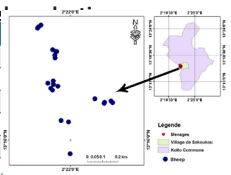


Distribution of wood consumption for cooking per household

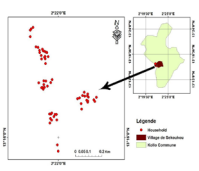
Potential of biomass fue

Produce	Mass in kg
Millet	73750
Rice	84400
Beans	16500
Sorghum	14300
Gombo	3950
Corn	600

Amount of agricultural production



The number of households with sheep in Sékoukou

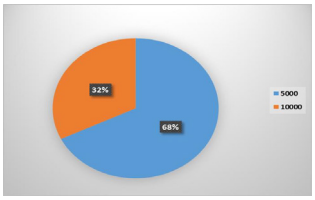


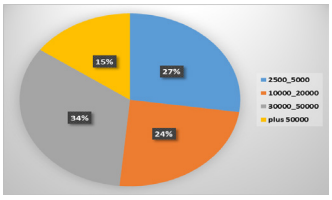
The number of households with chicken

Solar energy and wind potential of the Sékoukou

The theoretical energy potential is: **Es_1 = 41520000 kwh And** the real energy is: Es_2 = **5397600 kWh**.

The wind potential of Sékoukou village is P2= 282.833 W.





Fair price allocation ready to invest in clean and efficient fuels by households

CONCLUSION

The increase in the share of renewable energy in the national energy mix remains one of the main energy policy issues that the many stakeholders in developing countries are facing.

- Sékoukou village have a RE potential that can make up for the deficit in electrical energy; - Four sources of energy have been identified in Sékoukou which are sun, wind, wood and green waste; - And in short, a brief policy for the implementation of an integrated energy development policy and a business model for the village have been proposed.

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The entire master thesis report is available under the following link:

http://pauwes-cop.net/library/handle/1/326

The System Dynamics of Electricity Demand-Supply Gap in Sudan: The Socio-Economic Impacts and Integrated Modelling Approach

Graduate CV.

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Abstract

Sudan among the medium electrification rate in Africa, in spite of the remarkable energy resources and the huge potential of renewable energy. Economy of Sudan is growing at fast pace in which with increasing demand for electricity. Khartoum the capital of Sudan has been subjected to frequent electricity outage since 2011 after the secession of South Sudan which left a significant effect on the thermal power plants productivity which the country was depending on. Urbanization level in Khartoum is another challenge to the electricity sector and one of the main variables causing the demand-supply gap. System Dynamics approach is used for understanding the interconnection between the electricity subsystem and the variables. In order to meet the growing demand of electricity per capita.

BACKGROUND/CONTEXT

In planning electricity conservation, demand and supply, electricity balance information of the energy systems is of great use. However, electricity balance is influenced by technical and non-technical factors together with the socio-economic challenges, the main characteristics of the electricity demand-supply gap such as the exponential growth of the population and energy Consumption and the increasing level of urbanization, energy losses and administrative losses. Due to the interconnected nature of energy balance components, it is evident that accurate and reliable predictions of professional responses of societies are becoming extremely important due to their help in planning and managing energy resources. Electricity demand-supply gap is one of the most important challenges that facing most of the developing countries in Sub-Saharan African countries and some of Asian countries, Sudan is among

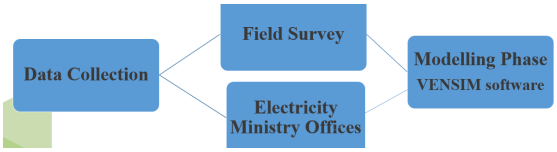
PROBLEM STATEMENT/RESEARCH QUESTION

Sudan's electrical power sector has been subjected to poor infrastructure, frequent power cut off and many parts in daily bases. The citizen who are affected by the electricity supply interruption create a sense of complaints to the government, due to the fact that the absence of the electricity is affecting their lives socially and economically. Based on the current status of power shortage in Sudan, the country is facing challenges to build strong economic, and industrialization and modernization cannot be achieved without proper access to electricity. People living in Khartoum are subjected to regular power outage, as a result of the fast-growing communities and urbanization level which over load the old notational grid.

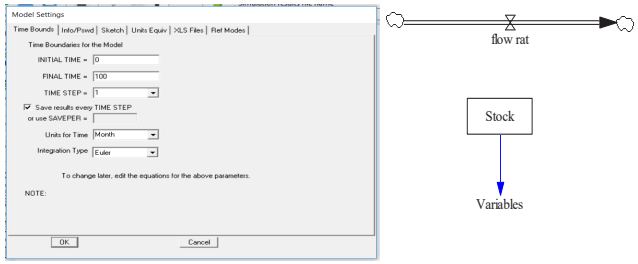
OBJECTIVES

The global objective of the study is to assess the electricity demand-supply gap and its impact on socio-economic development of the livelihood of the capital Khartoum, Sudan.

METHODOLOGY

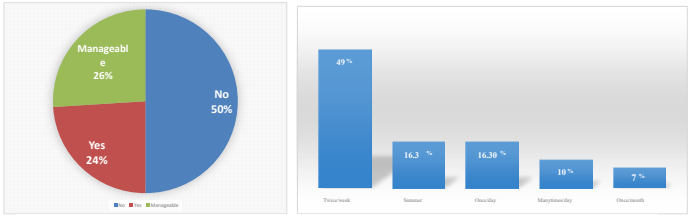


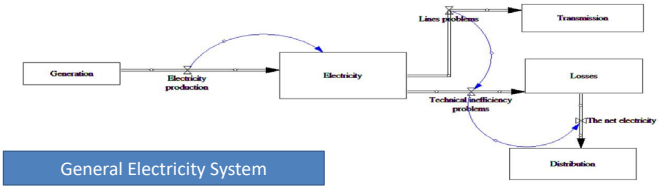
VENSIM Modelling



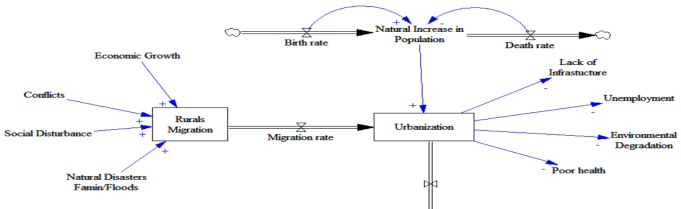
RESULTS AND DISCUSSION

Electricity price affordability and Electricity Frequent Outage





General Electricity System



Urbanization

CONCLUSION

- The results of study indicated that income level, is medium and low level, the majority of the citizens are living far from the capital's centre.
- Over 80% of the respondents are willing to adopt the renewable energy.
- The results indicated that Urbanization is one of the main reasons of the electricity demand-supply gap.
- The study showed the economic impact on the electricity sector because it has a direct effect on the electricity plan in terms of extension networks and the addition of new generation to meet the increasing demand for electricity by providing the necessary money to implement the required development projects in the electricity sector.
- The study revealed the significant usage of system dynamics approach in energy systems, the successful analysis for the interactions among the subsystems and their variables.

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- *Application of system dynamics in electricity supply systems*

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The Impact of Innovation on Renewable Energy Consumption in Nigeria

Graduate CV.

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Abstract

This study investigates the impact of innovation on renewable energy consumption in Nigeria using a time series data of 1996Q1- 2017Q4. The empirical result indicated that for objective one, GDP, Innovation and trade openness had a positive relationship with renewable energy consumption while, CO2 emission and Oil rent had a negative relationship with renewable energy consumption. The result of objective two indicated no causality among the variables however, there was a unidirectional causality from oil rent to renewable energy consumption and also a unidirectional causality from innovation to carbon dioxide emission

BACKGROUND/CONTEXT

Energy undergirds civilization and has powered worldwide economic changes over the last two and a half centuries (World Economic Forum, 2013). The energy sector of Africa is crucial to its sustainable development process, yet it is deemed as being one of the most poorly developed energy systems in the world (Annual Energy Outlook, 2014). Though Nigeria is abundantly blessed with both conventional and non-conventional energy sources, yet the country still suffers from inadequate supply of energy. Due to population boom, inevitable industrialization, rural-urban migration, more agricultural production and improving living standards, the demand for energy in Nigeria continues to increase. Satisfying this rapid growth in energy consumption with fossil fuels can have a significant impact on the climate. The role of innovation on energy is very important in not just increasing access to energy but also addressing the issue of high energy consumption resulting in the negative influence on the environment. The country needs to develop a technologically driven renewable energy sector that will harness the nation's resources to complement its fossil fuel consumption and guarantee energy security, thus this study seeks to investigate the impact of innovation on renewable energy consumption.

PROBLEM STATEMENT/RESEARCH QUESTION

1. To what extent does innovation affect the renewable energy consumption in Nigeria?
2. What is the causal and Long-run relationship among innovation, renewable energy consumption and economic growth in Nigeria?

OBJECTIVES

To determine the impact of innovation on the renewable energy consumption in Nigeria.

To examine the causal and the long-run relationship among renewable energy consumption, Economic growth, innovation, carbon emission, trade Openness and oil rent in Nigeria

METHODOLOGY

Model for Objective 1.

$$REC_t = X_t M' + \sum_{i=-m}^{i=m} \emptyset_i \Delta GDP_{t-i} + \sum_{i=-n}^{i=n} \omega_i \Delta INNO_{t-i} + \sum_{i=-j}^{i=j} \delta_i \Delta CO2_{t-i} + \sum_{i=-l}^{i=l} \theta_i \Delta TO_{t-i} + \sum_{i=-k}^{i=k} ¥_i \Delta OR_{t-i} + \varepsilon_t \quad \ldots 3.3$$

Where

$M = [C, \alpha, \beta, \gamma, z\ ], X = [1, GDP_t INNO_t CO2_t TO_t\ OR_t]$

And m, n, j, L and k are the lengths of leads and lags of the regressors

Model for Objective 2

$$\begin{bmatrix} REC_t \\ GDP_t \\ INNO_t \\ CO_{2t} \\ TO_t \\ OR_t \end{bmatrix} = A_0 + A_1 \begin{bmatrix} REC_{t-1} \\ GDP_{t-1} \\ INNO_{t-1} \\ CO_{2t-1} \\ TO_{t-1} \\ OR_{t-1} \end{bmatrix} + A_2 \begin{bmatrix} REC_{t-2} \\ GDP_{t-2} \\ INNO_{t-2} \\ CO_{2t-2} \\ TO_{t-2} \\ OR_{t-2} \end{bmatrix} + A_3 \begin{bmatrix} REC_{t-3} \\ GDP_{t-3} \\ INNO_{t-3} \\ CO_{2t-3} \\ TO_{t-3} \\ OR_{t-3} \end{bmatrix} + A_4 \begin{bmatrix} REC_{t-4} \\ GDP_{t-4} \\ INNO_{t-4} \\ CO_{2t-4} \\ TO_{t-4} \\ OR_{t-4} \end{bmatrix} + A_5 \begin{bmatrix} REC_{t-5} \\ GDP_{t-5} \\ INNO_{t-5} \\ CO_{2t-5} \\ TO_{t-5} \\ OR_{t-5} \end{bmatrix} + A_6 \begin{bmatrix} REC_{t-6} \\ GDP_{t-6} \\ INNO_{t-6} \\ CO_{2t-6} \\ TO_{t-6} \\ OR_{t-6} \end{bmatrix} + \begin{bmatrix} \varepsilon REC_t \\ \varepsilon GDP_t \\ \varepsilon INNO_t \\ \varepsilon CO_{2t} \\ \varepsilon TO_t \\ \varepsilon OR_t \end{bmatrix} \quad \ldots\ldots\ldots\ldots 3.4$$

RESULTS AND DISCUSSION

Objective one - Results

	Coefficient	Std. Errors	t-Statistics	Prob
GDP	1.09E-05	2.56E-06	4.255541	0.0001
INNO	0.240902	0.096246	2.502989	0.0155
CO2	-7.948629	1.442577	-5.510022	0.0000
TO	0.001132	0.032881	0.034438	0.9727
OR	-0.003202	0.060127	-0.053251	0.9577
C	86.48746	1.831538	47.41779	0.0000

Dynamic Ordinary Least Squares (DOLS)

Objective two - Results

VAR Granger Causality/Block Exogeneity Wald Tests

Date: 07/22/19 Time: 20:39
Sample: 1996Q1 2017Q4
Included observations: 80

Dependent variable: REC

Excluded	Chi-sq	df	Prob.
GDP	7.236178	8	0.5114
INNO	2.990909	8	0.9349
CO2	8.357308	8	0.3994
TO	5.047482	8	0.7525
OR	17.20600	8	0.0280
All	41.22221	40	0.4169

Dependent variable: GDP

Excluded	Chi-sq	df	Prob.
REC	8.581001	8	0.3789
INNO	5.513753	8	0.7015
CO2	12.39153	8	0.1346
TO	4.185422	8	0.8400
ORR	3.487409	8	0.9002
All	25.13733	40	0.9679

Dependent variable: TO

Excluded	Chi-sq	Df	Prob.
REC	6.413969	8	0.6010
GDP	10.62476	8	0.2239
INNO	4.299653	8	0.8291
CO2	2.515487	8	0.9610
ORR	6.665908	8	0.5731
All	26.31934	40	0.9528

Dependent variable: ORR

Excluded	Chi-sq	Df	Prob.
REC	1.418995	8	0.9940
GDP	4.293964	8	0.8297
INNO	10.72315	8	0.2179
CO2	7.422229	8	0.4918
TO	12.47089	8	0.1314
All	52.36115	40	0.0911

Dependent variable: INNO

Excluded	Chi-sq	Df	Prob.
REC	4.931499	8	0.7649
GDP	0.350544	8	1.0000
CO2	4.034520	8	0.8540
TO	2.666625	8	0.9535
ORR	1.686414	8	0.9892
All	19.53423	40	0.9973

Dependent variable: CO2

Excluded	Chi-sq	Df	Prob.
REC	5.133172	8	0.7433
GDP	3.231462	8	0.9190
INNO	32.69749	8	0.0001
TO	3.108181	8	0.9274
ORR	8.577928	8	0.3791
All	55.69336	40	0.0506

CONCLUSION

- The empirical study reveals that innovation is a catalyst for renewable energy consumption which means that innovation will further increase renewable energy consumption in Nigeria.
- Thus, increasing renewable energy consumption requires investment in technological innovations. To stimulate investment and innovation in renewable energy, policy makers need to focus not just on core climate policies but on broader investment conditions and different policies, ranging from investment and competition to trade and financial markets.
- If policies for broader investment environment do not make investment conditions favorable deployment and innovation of renewables technologies as well as the effectiveness of climate policies will be hindered.

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Master of Sciences

Water Engineering

An Assessment of Climate Change Impact on Water Related Ecosystem Services (WRES) including Hydropower Potential in The Kandadji Catchment in West Africa.

Graduate CV.

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Abstract

This study assesses the impacts of climate change on water related ecosystem services (WRES) including hydropower potential in the Kandadji catchment in West Africa using the conceptual rainfall-runoff modeling HBV-Light and two regional climate simulation datasets (GCM-RCMs) retrieved from WASCAL high resolution regional climate simulation under RCP 4.5.

Keywords: *Climate change impact; Hydrological modeling; ecosystem services, bias correction, water resources.*

BACKGROUND/CONTEXT

Water related ecosystem services are the services the community benefits from having a water resources. Water related ecosystem services contribute in the development of the individuals, community or nation taking into account the value and its importance but there are a lot of challenges occurring when it comes to water resource management, allocation and use.

There is a concern that climate change and variability will have negative effect on both economic development and human development of the community around Kandadji catchment in Niger River -West Africa.

The current integrative study aims to assess the impact of climate change on three major water related ecosystem services, namely domestic water supply, crop water availability, and hydropower generation using hydro-climatic modelling tools and climate scenario application at Kandadji catchment in Niger River, West Africa.

PROBLEM STATEMENT/RESEARCH QUESTION

Recently, studies have shown a temperatures increase by more than 0.7° Celsius (°C) across Niger, with typical rates of warming greater than 0.15°C per decade (USAID and USGS., 2010).

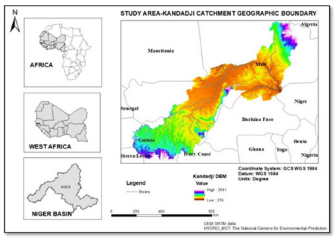
The Niger River is currently facing challenges to provide water related services and is to be aggravated as a result of climate change and variability.

KEY QUESTION: What is the expected impact of climate change on the hydrological regime of the catchment?

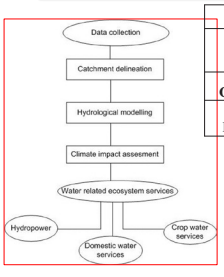
OBJECTIVES

To assess the impact of climate change on water related ecosystem services (WRES) including hydropower potential on Kandadji catchment in West Africa.

METHODOLOGY



- A drainage area of about 596,795 km².
- A transboundary catchment
- Niger country is the primary user of the water resource is located at the outlet of the catchment where there is also a big hydropower dam
- Its a CIREG project area out of three basins of the project (Volta, Mono and Niger)

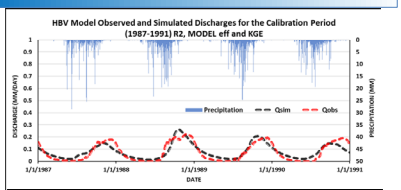


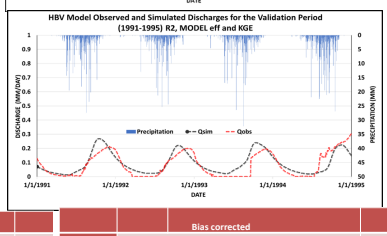
RCP 4.5 _12km Resolution			
GCM/ESM	RCM	Experiment	Characteristics for West Africa
GFDL-ESM2M	WRFV3.5.1	hist./proj.	Parameters differ from observation/multi-model ensemble mean.
HadGEM2-ES			

Station ID	Long	Lat	Observed Parameter
	Decimal Degree		
Weatherdata-98-103	-10.3125	9.8352	Temperature, Precipitation, Wind, Solar radiation, Relative humidity
Weatherdata-20113	1.2500	20.1388	
Weatherdata-1610	0.0000	16.0798	
Weatherdata-148-41	-4.0625	14.8309	
Weatherdata-117-75	-7.5000	11.7086	
Weatherdata-130-59	-5.9375	12.9575	
KANDADJI	0.9833	14.6167	Discharge

RESULTS AND DISCUSSION

Annual SPI:		
Year	Annual SPI Index	
1979 - 1980	2.51	Warming Period
1980 - 1981	1.16	
1981 - 1982	1.14	
1982 - 1983	0.28	
1983 - 1984	-0.42	
1984 - 1985	-0.12	
1985 - 1986	0.71	Calibration
1986 - 1987	0.54	
1987 - 1988	0.19	
1988 - 1989	0.81	
1989 - 1990	0.58	
1990 - 1991	0.19	
1991 - 1992	0.70	Validation
1992 - 1993	0.41	
1993 - 1994	0.57	
1994 - 1995	1.06	





	Non-bias corrected					
	R.C.P 4.5					
RCM–GCM	Historical/Reference		Future (2020-2049)		Future (2070-2099)	
WRF	Precipitation (mm)	Discharge mm/yr	Precipitation (mm)	Discharge mm/yr	Precipitation (mm)	Discharge mm/yr
GFDL-ESM2M	1510.72	268.67	1843.25	360.83	1849.06	540.93
HadGEM2-ES	1454.82	269.37	1842.97	337.33	1959.52	474.34

	Bias corrected					
	R.C.P 4.5					
RCM–GCM	Historical/Reference		Future (2020-2049)		Future (2070-2099)	
WRF	Precipitation (mm)	Discharge mm/year	Precipitation (mm)	Discharge mm/yr	Precipitation (mm)	Discharge mm/yr
GFDL-ESM2M	493.32	83.98	391.01	27.19	509.90	57.37
HadGEM2-ES	364.07	27.36	591.35	67.34	673.71	78.04

- The SPI for the period indicates that 1987-1995 both calibration and validation periods are near normal with index values ranging from -0.99 to 0.99
- Model Goodness of fit criteria was very good for both validation and calibration of the model.
- Temperature increase signal is projected for the periods 2020-2049 and 2070-2099 by both RCM-GCMs in the catchment.
- Projected increase in future discharge, increase remain lower than the additional water demand due to population growth.
- Annual hydropower, Ecological flow and crop water supply will increase but their annual pattern will show a mixed trend as a decrease in projected for some months

CONCLUSION

- The bias collection was necessary for historical observed and historical model simulated data
- Both GCMs show that Temperature is projected to increase slightly during the near-future (2020-2049) and increase more future (2070-2099)
- A reduction in precipitation during the rainy season projected by GFDL-ESM2M and a significant increase of the precipitation is projected by HadGEM2-ES.
- The catchment indicates a large potential of the hydropower production and irrigated land for agriculture.
- The water supply for the community seems to face challenge since the addition water demand was greater than the additional water use which explains the fact that there will be shortage in water supply.

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An Assessment of Climate Change Impact on Water Related Ecosystem Services (WRES) including Hydropower Potential in the Dano Catchment (Volta Basin)

Graduate CV.

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Abstract

This study assesses the impact of future climate variability and change on stream water related ecosystem services (WRES) including hydropower potential in the Dano catchment (Volta basin). The study utilized a modelling approach.it was used the representative concentration pathways 4.5 (HadGEM2-ES, GFDL-ESM2M) of WASCAL high-resolution regional climate simulation between a refence period and two future periods (2020-2049 & 2070-2099) . The projected annual discharges change signals, show an increase of 25 % to 68 % by 2049 and at the end of the century this increase reaches 80.65 % to 109 %. The analysis shows that the precipitation, temperature and evapotranspiration change indicated that streamflow is more related to precipitation than to temperature. The projected discharge increase will translate in an increase of all explored WRES in the future except the satisfaction of additional domestic water use that will decrease because of population growth. These results imply adopting efficient water use techniques and harnessing the highlighted WRES potential in the catchment.

BACKGROUND/CONTEXT

The United Nations Environment Programme (2014) reported that in the Niger and Volta basins there will be significant temperature increase, possible increase in rainfall in sahel zone in June, July, August, increased evaporation, greater drought probabilities, more rainfall variability and unreliability, and reduced river flow. The impact of climate change on precipitation and water availability is therefore of major concern for policy makers in the Volta Basin of West Africa, whose economy mainly depends on rainfed agriculture and hydropower generation.(P. Taylor et al. 2010). Indeed, WRES are projected to change in coming decades because of changes in the water cycle, as a consequence of changes in the spatial and temporal distribution of precipitation and the form of precipitation on the earth (Chang and Bonnette 2016) The effects of climate change on WRES are expected to be felt strongly in Africa, because the continent as a whole is one of the most vulnerable due to its high exposure and low adaptive capacity (IPCC 2013).

PROBLEM STATEMENT/RESEARCH QUESTION

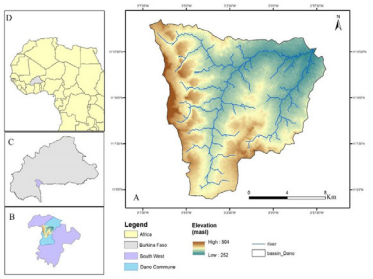
The current study helps to resolve this concern through the assessment of climate change impact on water related ecosystem services (WRES) including hydropower potential using the medium scale catchment of Dano as case study. What is the expected impact of climate change on WRES what are the future WRES demand and challenges?

OBJECTIVES

To contribute the adaptation to climate change in the field of water resources management through the assessment of climate change impact on WRES in the Dano catchment.

METHODOLOGY

The area of the of catchment is around 196 Km² and it is between 11 ° and 12 ° north latitude and 3 ° and 4 ° west longitude.



1- Hydrological modelling

2-Projected climate signal and its impact on streamflow

-Input Data :Température, Precipitation, Wind speed, Relative humidity, Solar radiation, discharge Observed dataset and Simulated climate Data(WASCAL high-resolution regional climate simulation ensemble for West Africa) (rcp4.5: GFDLESM, HadGEM2) 1980 to 2005, 2020-2049, 2070-2099.
-Data evaluation and correction (Quantile Mapping)
-Hydrological modelling uncorrected and bias corrected
-Signal change and magnitude uncorrected and bias corrected of Precipitation/ Mean Temperature/Actual Evapotranspiration (AET)/Potential Evapotranspiration(PET) / Discharges

3-Climate change impact on Water Related Ecosytem Services (WRES)

Indicators for WRES uncorrected and bias corrected :
-Hydropower generation/Domestic water uses/Population per capita use (x l/day)/ Ecological flow (95%)/ Agricultural water availability

RESULTS AND DISCUSSION

Projected climate signal and its impact on streamflow

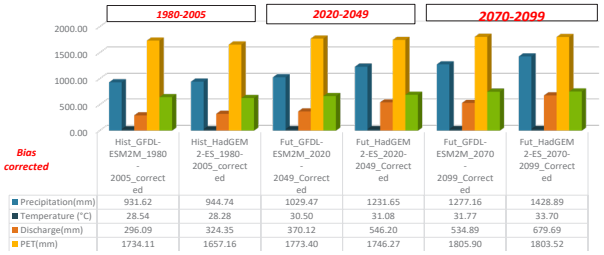


Fig diagram comparing Historical (1980-2005) and projected (2020-2049 and 2070-2099) of annual Average of precipitation, temperature, Potential evapotranspiration (PET), Actual Evapotranspiration (AET) and discharges (Qsim) of two emission scenarios

Climate change impact on Water related Ecosytems services WRES

Tables: result of comparison between historical and future Total annual water demand and capacity

	historical_GFDLESM_1980-2005	GFDLESM_2020-2050	GFDLESM_2070-2100
Qsim(m3/s) BC	4 646 671.9	5 839 493.3	8 439 105.9
Additional Domestic water demand (m3/s) BC	0.0	14 276.1	126 697.0
Additional Domestic water used (m3/s) BC	0.0	3 815.1	37 021.3
ecological flow BC	1 603.3	1495.7	3 242.6
crop water available BC	4 645 068.6	5 834 182.5	8 398 841.9
Energy (MWh) BC	671.4	839.3	1212.9

	historical_HadGEM_1980-2005	HadGEM_2020-2049	HadGEM_2070-2099
Qsim(m3/s) BC	5 268 091.4	8 640 980.5	10 844 573.1
Additional Domestic water demand (m3/s) BC	0.0	14 276.1	126 697.0
Additional Domestic water used (m3/s) BC	0.0	4 228.3	37 821.3
ecological flow BC	1 625.9	1 673.1	3 373.6
crop water available BC	5 266 465.5	8 635 079.0	10 803 378.1
Energy (MWh) BC	761.2	1 241.9	1 558.6

CONCLUSION

Scenario Application in hydrological modelling, trend, Signal change and magnitude

	1980-2005	2020-2049	2070-2099
Precipitation		10 to 30 %	37 to 51.4%
Mean Temperature		1.9 to 2.8 °C	1.9 to 2.8 °C
Potential Evapotranspiration(PET)		2.3 % 5.3%	4.1 to 8.8 %
Discharges		25 % to 68 %	25 % to 68 %

Climate change impact on WRES

WRES	1980-2005	2020-2049	2070-2099
Hydropower generation	671.4 Mwatt to 761.2 Mwatt	25% (167.87 MWatt) to 63%, (480.72 MWatt)	80% (541.5 MWatt) to 104.8 % (797.4 MWatt)
Additionnal Domestic water uses	0	3815.1 m3 to 4228.3 m3	37 021.3 m3 to 33593.01 m3
Ecological flow (95%)	1603.25 m to 31625.85 m3	-6.7% (-107.57 m3) to 2.9 % (47.3 m3)	102.25 % (1639.37 m3) to 107.5 % (1747.7 m3)
Agricultural water availability	4645068.6 m3 to 5266465.5 m3	25.6% (1 189 113.838 m3) to 64 % (3368613.492 m3)	80.8 % (3 753 773.2 m3) to 105 % (5536912.584 m3)

The projected discharge increase will translate in an increase of all explored WRES in the future except the satisfaction of additional domestic water use that will decrease because of population growth. Therefore, the projected increase in future discharge will not be sufficient to counter balance the dd additional water demand associated to population development. These results imply adopting efficient water use techniques and harnessing the highlighted WRES potential in the catchment.

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The entire master thesis report is available under the following link:

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Assessing the Sustainability of Drainage System in Irrigated Agricultural Land: A Case Study of Kano River Irrigation Scheme in Nigeria

Graduate CV.

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Abstract

The Kano River Irrigation Scheme is the largest Public Irrigation Project in Nigeria covering an irrigable area of about 16,000 ha as at the 2019 records. The scheme is operated 100% by gravity with the Tiga Reservoir upstream of the command area as the only source of water. The study assessed the agricultural water management putting forward the agricultural drainage system using a multidisciplinary and systematic approach to highlight opportunities and problems in the irrigated agricultural land. Qualitative, GIS and Remote Sensing techniques, and Socio-economic analysis were employed. Based on the analysis, drainage is misused causing 48% of the irrigated area to be waterlogged and seepage through unlined canals of 29.18% was observed. Although, the agricultural benefits shows positive output, drainage systems are critical to the sustainability of the irrigation scheme.

BACKGROUND/CONTEXT

Agriculture was and is still the cornerstone of the Nigerian economy employing about 65% of its labor force irrespective of its crude oil dependence. Nigeria record 325,000 ha of irrigated areas (ICID,2018). Yet that less than one-tenth of irrigation potential in the country.Out of the 62 public irrigation schemes in Nigeria, three projects account for 90 % of the irrigated area. In all cases, none of the irrigation schemes is operating effectively; not even the top-ranked, which is the Kano River Irrigation Project.

PROBLEM STATEMENT/RESEARCH QUESTION

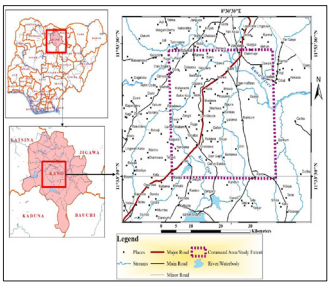
Irrigation and drainage practices have been found to be the key issues of of the direct (water ponding, waterlogging and salinity) onsite and indirect effects (pollution, depletion and destruction) off-site of the kano River Irrigation command area.

Overarching question: What is the role of agricultural land drainage in agricultural water management to sustain irrigated agriculture in the Kano River Irrigation Scheme?

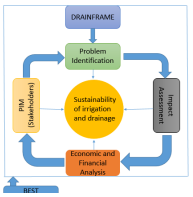
OBJECTIVES

The objective of the study is to highlight the potential of agricultural drainage for sustaining irrigated agriculture in the Kano River Irrigation Project by assessing the typology, impacts and agricultural benefits of drainage system management.

METHODOLOGY



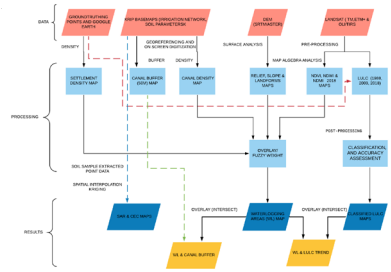
- Location: latitudes 11̊ 30’ and 12̊ 03'N and longitudes 8̊ 30’ and 9̊ 40’E
- Planned area: 74860 ha ; Irrigated area: about 16,000 ha
- Water Source: Tiga Reservior
- Abstraction Method: Gravity
- Annual Evapotranspiration: 1016 mm
- Annual Rainfall: 750 mm



Economic and Financial analysis;

- Crop yield response function: $Y_r = 100 - b\,(EC_e - a)$
- Net Farm Income: NFI = GFI - VC – FC

The DRAINFRAME was used as a tool to direct the research using qualitative method in problem identification.

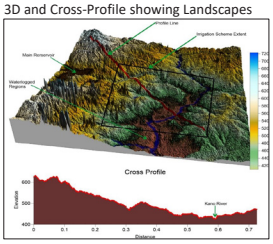


Impact Assessment

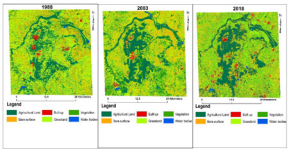
- Satellite data acquisition (Landsat 5 TM, Landsat 8 OLI & DEM 30m)
- NDVI, NDWI & NDMI determination
- LULC classification
- Accuracy assessment
- Mapping of Waterlogged areas

RESULTS AND DISCUSSION

3D and Cross-Profile showing Landscapes



Land Use and Land Cover Maps



Land Use and Land Cover Analysis

LULC Classes	Area (Km²)			Area (%)		
	1988	2003	2018	1988	2003	2018
Agricultural Land	262.83	278.18	306.3	21.58	22.84	25.15
Bare surfaces	275.12	257.7	242.48	22.59	21.16	19.91
Built up	10.46	12.8	18.65	0.86	1.05	1.53
Grassland	420.76	559.99	407.51	34.55	45.98	33.46
Vegetation	241.73	104.39	238.71	19.85	8.57	19.6
Waterbody	7.01	4.85	4.27	0.58	0.4	0.35
	1217.91	1217.91	1217.92	100	100	100

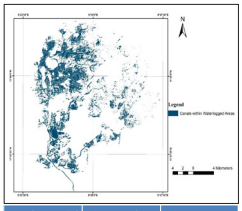
- PS: NFI =NGN 163,780; 3% ISF
- FWO Project: NGN 125,113: 4% ISF
- FW Project: NGN 235,765: 5% ISF

Economic Crop Budget Analysis

PS = Present Situation
FWO = Future Without Project
FW = Future With Project
ISF = Irrigation Service Fee

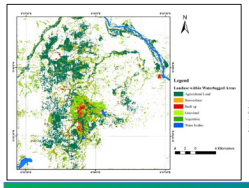
The economic and financial analysis indicate higher NFI with increasing ISF for PS and FW. But NFI decreased for FWO despite increased ISF.

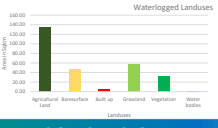
Waterlogged areas within canals (50m Buffer)



- 50m buffer applied in the entire irrigation network indicated 29.18% lies within waterlogged areas
- Likely Seepage and leakage due to unlined canals, excess irrigation and extreme rainfall

Area (50m Buffer) sqkm	Area (within Waterlogged) sqkm	% within Waterlogged
244.04	71:20	29.18





Waterlogged area within the LULC:

- 48% Agricultural Lands
- 16.86% Bare surfaces
- 1.85% Built up areas

This is an increasing trend from 1988 to 2018.

CONCLUSION

- Based on the problem identification analysis, drainage canals surveyed are in obliteration, mostly silted up, weed infested and regarded as “extra fertile” cultivable lands.
- NDVI, NDWI & NDMI indices for water moisture ranged from (-0.46 to +0.76), (-0.84 to +0.64) & (-0.86 to +0.96) respectively providing a suitable range for waterlogging areas estimation.
- Participatory Irrigation Management (PIM) exists traditionally as “*aikin gayya*” and can easily be scaled up using the tacit knowledge of the water users, especially farmers.
- Based on waterlogging area estimation within the command area, 48% (279.79 km^2) of the area considered (1217.91 Km^2) is waterlogged including off - command cultivated areas.
- DRAINFRAME is a useful tool for drainage related studies.

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The entire master thesis report is available under the following link:

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A Study of Hydroelectric Power Supply in the West of Algeria

Graduate CV.

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Abstract

Algeria has enough hydrocarbon reserves that cover its present energy needs. Alternative energy resources, namely renewable energies have to be developed in order to both provide for its future energy needs and as alternative sources of income as well. In this thesis, a study is presented of the performance of a micro-hydropower plant by using supply water system. A water supply network in the west of Algeria with high enough piezometric head is considered to be an important source of hydroelectric power generation. Both design and cost analyses have been carried out of a micro hydro power station mounted on this supply system. If 100% efficiency is considered, the generated power reaches 136KW.

BACKGROUND/CONTEXT

- Africa has the weakest power per capita of 620 kWh/year, which drops to 153 kWh/year when Sub Saharan Africa (SSA) is considered.[4]
- Using micro hydropower in the water supply system (WSS) can reduce the cost to 40 % from total amount. This distribution must be compatible with the demand in both quantity and quality. [5]

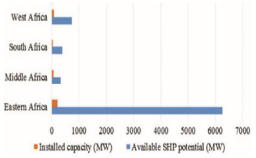

Figure1. SHP potential in regions of Africa.[6]

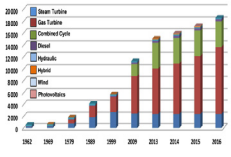

Figure.2: Evolution of installed power by technology over the period (1962 -2016) – MW in Algeria [7]

PROBLEM STATEMENT/RESEARCH QUESTION

Presently, Algeria has enough hydrocarbon reserves that cover its present energy, alternative energy resources, One of the renewable energy resources that can be developed is hydroelectric energy from water supply networks.

-What is the approval process to install the micro-hydropower system?
And which type of turbine may be used in our case study?
-How much will it cost to develop the micro-hydropower system?

OBJECTIVES

This work is to estimate the quantity of energy that can be produced by using this type of installation for a specific area to provide more energy stability, reliability and increase the power output delivered.

METHODOLOGY

In water supply line, the pressure head could be removed from the system without causing pressure below the minimum at any other point by installing a hydro-turbine. Then, the excess energy will be converted into useful energy by means of electricity.

Figure.1 Geographical location of the Wilaya of Oran

Figure6: Location of the hydropower plant.

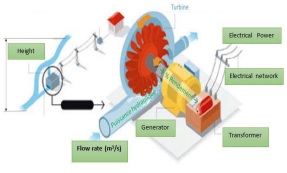

Figure.5: Operating principle of a hydroelectric plant.

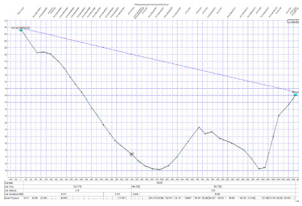

Figure3: Piezometric profile for maximum flow rate Qmax = 744.7m³/h

RESULTS AND DISCUSSION

The turbine is the main part of a hydropower plant. It is the part which delivers the machine to produce electrical energy. In the present study an impulse Pelton turbine is used. The design of the turbine resume in table below:

Table1: Dimensions of the Pelton wheel components

Parameters	Dimension
Flow rate	0.21 m³/s
Net Head	69.1m
Velocity of water through the nozzle	36.82 m/s
the radius of the nozzle	0.042m
Power output of turbine Po	135.23KW
Speed of the turbine	270 rpm
Width of the buckets	0.42m
Number of buckets n	22
Specific speed, Ns	15.73 rpm

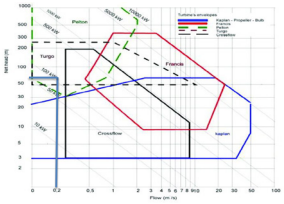

Fig7: Area of use of the different types of turbines (net drops, flows, powers).

Cost estimate of the electromechanical components

According to Giovanna a new methodology proposed to estimate the cost of electro-mechanical equipment; this methodology decomposes the cost of electro-mechanical equipment into three terms:

$$C_{EM} = a \times H_m^b + c \times Q_{l/s}^d + e \times P_{KW}^f + g$$

Where a, b, c, d, e, f and g are correlation constants and depend on the type of turbine.

Table 2: Depreciation of the installation

Charges and amortization	AMOUNT (DZD)
Amount of acquisition of the hydroelectric power station DA	46 384 036.09 [Da]
Annual power recovered	1191360 .00 [KWH]
Annual cost of electricity purchase according SONELGAZ tariff	3021090.4 [Da]
Sale price to SONELGAZ	2870035.88 [Da]
Amortization (purchase price / selling price) year	16 years

CONCLUSION

- In order to make investment decisions for the development of small hydropower projects, both technical feasibility and financial viability are considered to be the foremost requirements.
- The installation of the hydroelectric power plant at the 2.4Km level downstream of the Belgaid reservoir on the Kristel supply line allowed us to generate an estimated power of 1.191360 GWh/year, this recovered energy will allow us to relieve in electricity the towns of Ain Franine and Kristel both situated at the Daira of Bir Eldjir.
- Despite the low power recovered and estimated at 136 kW, our goal is to sensitize the public authorities, policymakers, politicians to opt for this renewable and inexhaustible energy coming from water which is in abundance in our region.

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The entire master thesis report is available under the following link:
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Flood Inundation Modeling in the Gourou Watershed of Côte d'Ivoire, West Africa

Graduate CV.

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Abstract

Since 1989, Côte d'Ivoire has experienced floods in 1996, 2007, 2008, 2010, 2014, 2015, 2016, and recently in 2017 and 2018. Their occurrences and amplitudes will increase due to climate change and the increasing urban population. The study was conducted to construct hydrological and hydrodynamics models couple with GIS for flood inundation mapping in Gourou watershed in Côte d'Ivoire. HEC-HMS and HEC-RAS models were used to achieve the specified objective. The result of hydrological modeling showed that the HEC-HMS model simulated fairly well the peak discharges. The result showed peak discharges of 347.6, 322.2, 283.4, 250.5, 234.7 m3/s for 100, 50, 20, 10 and 5 years return periods respectively. From the result of hydrodynamics model, it was obvious that the floodplain inundated areas increase slightly with an inundated area of 21.05, 20.24, 19.47. 18.79 and 18.32 Ha for 100, 50, 20, 10 and 5 years return period respectively. The WSE profile showed a great variability as water is moving from upstream toward downstream. The maximum water depth reached by water in the overbanks is 2m.

BACKGROUND/CONTEXT

- According to the Emergency Events Database (EM-DAT, 03 Jan 2019), Africa is the third continent most affected by floods events in terms of occurrence, total deaths, injured, affected and homeless.
- Abidjan which is the capital city of Côte d'Ivoire faced urban flood on 11th May 2018 and 19th June 2018. The flood originated from a heavy rainfall event.
- The case of Abidjan is very critical. In fact, due to the uncontrolled urbanization process, the population used to settle in flood-prone areas. Several studies pertaining to the flood hazard problem of Gourou watershed have been done. Nevertheless, research on the integration of GIS and hydrologic modeling has not been done in the area.

RESEARCH QUESTION

- How accurate can the observed peak discharge be simulated by the selected modeling approach?
- How does the inundation pattern vary along the canal?
- What are the causes of the frequent occurrence of flood in Gourou watershed?
- What type of measure (structural and non-structural) would work best to alleviate the flood risk in the study area?

OBJECTIVES

Main objective: **To construct hydrological and hydrodynamics models couple with GIS for flood inundation mapping in Gourou watershed.**

Specific objectives:

- To calibrate and validate HEC-HMS model for Gourou watershed
- To estimate the flood hydrographs in the watershed and used them as the inputs of the hydrodynamics model;
- To develop floods extent map for a return period of 5, 10, 50 and 100 years with associated water depth;
- To recommend mitigation measures for flood disaster risk management in the watershed.

METHODOLOGY

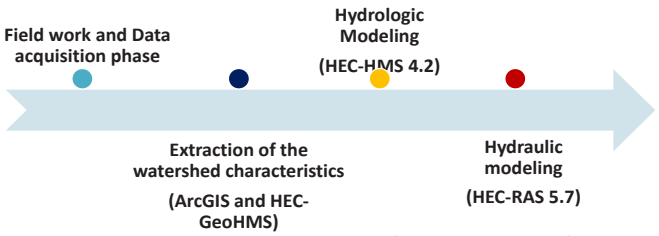
❖**Location:** 5° 10'N and 5° 38' North & long. 3° 4' West and 5° 21' West.

❖**Drainage Area:** 27 km²

❖**Shared between 5 municipalities:** Abobo, Cocody, Attécoubé, Adjamé, Plateau.

❖The watershed is highly urbanized.

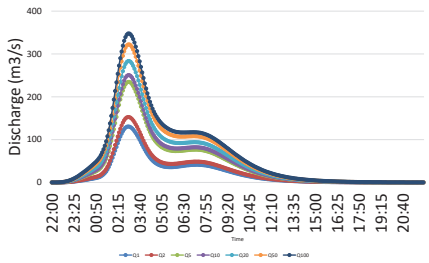
This study required four (04) main phases:



RESULTS AND DISCUSSION

Hydrologic Modeling

- **NSE:** 0.74 for calibration and 0.92 for validation.
- **RMS Error**: 13.5 for calibration and 12.2 for validation.
- Coefficient of correlation [**CORR**] : 0.91

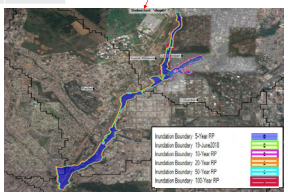


Flood hydrograph for different return period

Hydraulic Modeling

Affected Land Use	5-year	10-year	20-year	50-year	100-year
Forest	0.049	0.053	0.054	0.054	0.054
Mixed Agriculture and Vegetation	2.430	2.466	2.528	2.608	2.858
Built-Up Area	15.836	16.266	16.888	17.574	18.140
Total area	18.32	18.785	19.47	20.24	21.052

- Most of the inundated areas are built-up area.
- The maximum water surface level in the overbank is 2 m for 100 year return period.
- The water velocity is around 10 m/s in main the main channel.



CONCLUSION

- Flood extent has been estimated and inundation mapping was performed satisfactory but many difficulties were encountered about the quality of data.
- Sensitivity analysis was performed for the hydrologic model and the effects are acceptable.
- HEC-HMS and HEC-RAS are suitable for flood study in the watershed.

Perspectives

- Use of a long series of discharge data to improve the quality of the calibration of the model parameters.
- To calibrate the manning's roughness value.

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Hydrological Modelling for Water Balance Components and Flood Hazard Assessment under Climate Change in Mono, Lower Basin, Benin and Togo

Graduate CV.

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Abstract

Climate change is expected to increase both the magnitude and frequency of extreme precipitation events, which may lead to more intense and frequent river flooding. This study evaluated the impact of climate change on water balance components and flood hazard in the Lower Mono river Basin through rainfall- runoff modelling (HBV-light model). The projection from two WASCAL, high resolution Climate model GFDL-ESM2M and HadGEM2-ES under RCP 4.5 were used to force HBV-model. The projected climate change signal for the Basin indicated an average increase for both climate model, 17% and 32.5% for precipitation; 0- 3.83°C then 3.83- 5.30°C for temperature; 0.5% and 29% for discharge respectively by 2050 and 2100 relative to 1983-2005.

BACKGROUND/CONTEXT

Flood is the most common form of natural disaster that disturbs human activities, causes loss of human lives and destroy properties (Asumadu-Sarkodie & Owusu, 2016). It has been reported that flood hazards events will increase under conditions of **climate change** and put a heavy burden on people's lives, livelihoods and on the economy (Walz & Sassen, 2019). Many urban and rural areas located within the Mono River Basin, the largest river shared between Togo and Benin are hit almost every year by flooding which is caused by the overflow of the River.

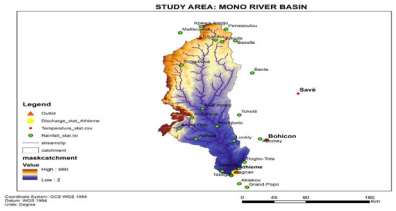
PROBLEM STATEMENT/RESEARCH QUESTION

Flood is predicted to become more frequent, dominant and serious in the coming years (Mureithi et al., 2015). The vulnerability with these natural risks is high in West Africa and Togo and Benin in particular, where the populations living in the **Mono, Lower Basin** tend to occupy the most exposed zones. Past and recent scientific researches undertaken in the Basin focused more on Flood characteristics, flood risk and vulnerability (Ago et al., 2005; Amoussou, 2010; Fernando, 2014; Ntajal, 2016).

OBJECTIVES

Evaluate the impact of climate change on water balance components and flood hazard in Mono, lower basin through rainfall - runoff modelling

METHODOLOGY



- **Extends over** 560 km from North to South
- **Drainage area**: 23119 km2
- **Population**: >2 millions
- **Annual max rainfall** (1405.47 mm) and **min** (840.56 mm)
- **Mean max temperature** 27.95°C

Hydrological modeling: HBV-light model

Calibration: 1986-1990	Validation: 1990-1992 and 2010

↓

Bias correction application on GFDL-ESM2M and HadGEM2-ES output

Quantile mapping	Future discharge simulation

↓

Climate change signal detection on water balance components

Analysis of trend in precipitation, temperature, discharge and evapotranspiration

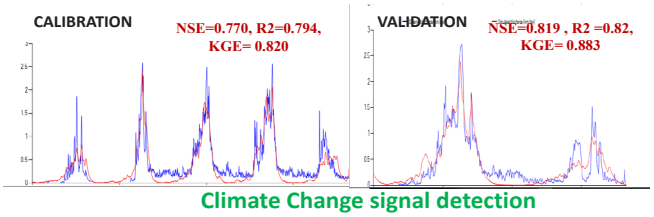
↓

Flood frequency analysis and its change due to climate change

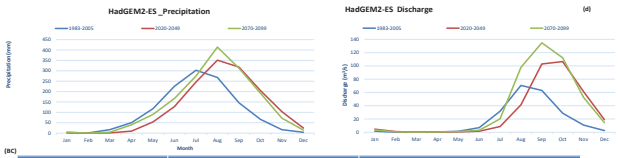
Flood quantiles and return period	% change in future quantiles/reference 1983-2005

RESULTS AND DISCUSSION

Hydrological modeling: HBV-light



Climate Change signal detection



Climate models	HadGEM2-ES			GFDL-ESM2M		
Period	(1983-2005)	2020-2049	2070-2099	1983-2005	2020-2049	2070-2099
Precipitation (mm)	1216.8	19%	35%	1228	+15%	+30%
Temperature (°C)	30.1	1.17°C	3.20°C	24.72	+6.50°C	+7.41°C
AET (mm)	1008.3	9%	20%	1047	+29%	+44%
Discharge (mm/day)	218.3	59%	102%	196	-58%	-44%

Climate Change impact on flood frequency

Return period	HadGEM2-ES		GFDL-ESM2M		AVERAGE	
T	2020-2040	2020-2049	2020-2049	2070-2099	2020-2040	2070-2099
50	+37.43	+34.75	-39.53	-38.60	-2.1	-3.85
20	+41.49	+47.61	-44.08	-40.32	-2.59	+7.29
10	+45.25	+61.63	-48.07	-42.17	-2.82	+19.46
5	+50.59	+83.33	-53.10	-44.31	-2.51	+39.02
3	+57.14	+109.24	-57.94	-46.54	-0.8	+62.7
2	+66.24	+146.80	-63.13	-49.15	+3.11	+97.65

CONCLUSION

- Both models, GFDL-ESM2M and HadGEM2-ES, exhibits an overall increase in future precipitation and temperature. As for discharge, HadGEM2-ES indicates an increase whereas GFDL-ESM2M shows a decrease. The opposite signals in discharge based on different climate products make it difficult to consider the results for decision making.
- The finding also underlines While HadGEM2-ES simulations under RCP 4.5 illustrate an increase in flood frequency, GFDL-ESM2M depicts a decrease.
- Results suggest for future flood management under climate change in Mono river basin to consider both increase and decrease in the flood frequency as the study shows that both trends are plausible.

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Management of a Sewerage Network in an Urban Area by Coupling GIS and Hydraulic Modeling: Case Study of Kwame Nkrumah University of Science and Technology (Ghana)

Graduate CV.

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Infrastructures are very important in the socio-economic development of a country and the protection of the environment. Their deterioration is more or less rapidly over time and faces serious challenges in term of management in many developing countries. The study coupled GIS and a Hydraulic modeling (MOUSE) to elaborate the geodatabase for the KNUST Sewerage network and analyze it management problem. The network was simulated in dry and rain period. In dry period the result has shown that about 99.62% of the network have the normal circulation of the sewage. A self-cleansing condition was not met by 0.38% of the network. During rain period, 16% of the network had overflow as well as some of the manholes. In general the management problem that KNUST sewerage faces is the undersized of some of the pipe and manholes, the invert slope and the non coverage of some of the manholes.

BACKGROUND/CONTEXT

Sewerages are essential sanitation infrastructures in urban area and have to be carefully maintained and managed (Ana & Bauwens, 2007). They contribute to the sustainability management of water and protected the environment. Most of the sewer line in Africa have been existed since colonial time and most of them are under-designed. Rapid urbanization is the factor that influence most both the quantity and the quality of the sewage discharge (Hussein Abed Obaid & All, 2014). In Ghana, conventional wastewater treatment plants are underused because of the poor sewage collection system. Only the small proportion of the sewage generated from urban area are generally connected to a sewer line (Adu-Ahyiah & Ernest Anku, 2001)

PROBLEM STATEMENT/RESEARCH QUESTION

***Lifetime of the infrastructure*:** Most of the sanitation infrastructures in Africa are out of date.

***Data availability*:** difficile access to the sewerage data, their components are under-ground and their management are behind.

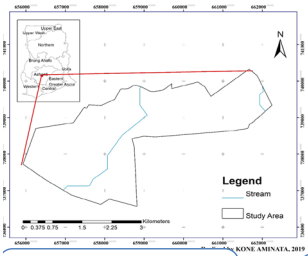
***Sizing*:** Most of the sewerage network are undersized.

Research key question: is the sewerage network of KNUST is well conveying the overall sewage to the wastewater treatment plant?

OBJECTIVES

To elaborate model of the database and analyze the management system of KNUST sewerage network by coupling GIS and hydraulic modeling.

METHODOLOGY



- The **largest** university of Kumasi Metropolis, (Ghana)
- Located in the **Eastern** part of Kumasi,
- **16 km² area**
- Students population **42 590 in 2016**
- Tropical climate type with an average temperature **of 26.3°C**

Picked the coordinate of **manholes location**

- ❑ **Topographic map**
- ❑ **Meteorological data**
- ❑ **Master plan of the existing sewerage**
- ❑ **connected facilities population**

Map the network with **ArcGIS**

Create the **geodatabase** of the Network

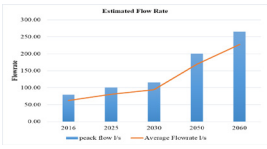
Diagnostic and **planning**

2nd diagnostic with **Mike MOUSE**

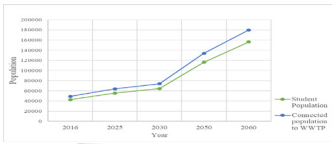
Scenarios
- Dry period simulation
- Wet period simulation

Create the **hydraulic profile** of the sewerage

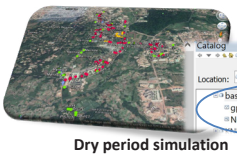
RESULTS AND DISCUSSION



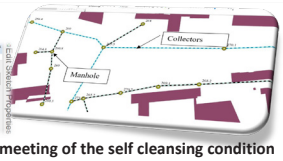
Projected Population



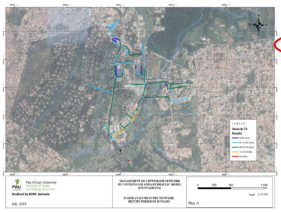
Geodatabase creation



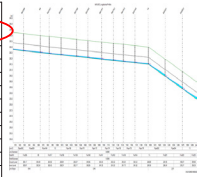
Dry period simulation



The nonmeeting of the self cleansing condition

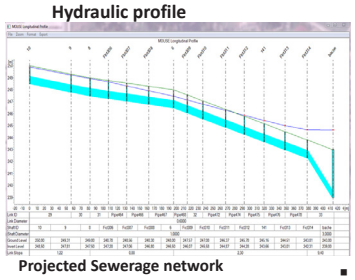


	1	2	3	4
Slope (%)	0.002	0.002	0.002	0.002
Velocity (m/s)	0.010	0.010	0.020	0.330
Length (m)	22.350	84.950	19.840	32.070
Diameter (m)	0.400	0.400	0.400	0.400
Area (m²)	0.126	0.126	0.126	0.126
Q (m³/s)	0.001	0.001	0.003	0.041
V/ps (m/s)	0.876	0.876	0.876	0.876
Qps (m³/s)	0.110	0.110	0.110	0.110
Q/Qps	0.011	0.011	0.023	0.376
V/Vps	0.011	0.011	0.023	0.377

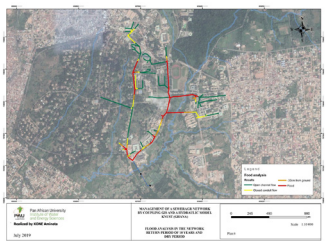


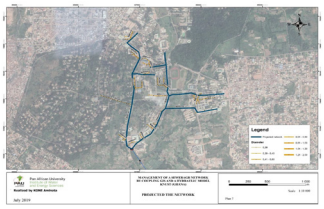
Hydraulic profile

Wet Period simulation



Projected Sewerage network





- The dry period simulation showed that about 4% in yellow of the network do not meet the self cleansing condition
- All the network in red colour represented in the wet period simulation highlight the overflow in these part of the network.
- About 5.4 km pipe of the projected sewer line diameter should be changed.

CONCLUSION

✓ Generally, the management problem of the KNUST sewerage network is due to the invert slopes that cause stagnation in the pipes,

✓ The high flow rate generation in wet period, and the non-coverage of some manholes, to these, it is added the under-sizing of some pipes and some manholes as well and some section of the pipe do not meet the self cleansing condition due to the low slope.

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❖ Obaid, H. A., & Al. (2014). Modeling Sewer Overflow of a City with a Large Floating Population. (August 2017). https://doi.org/10.4172/2157-7587.1000171.

The entire master thesis report is available under the following link:
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Modelling the Impact of Climate Change on Water Resources in Ghana: A Case study of the Densu River Basin

Graduate CV.

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Abstract

Climate change continues to pose a threat to the sustainability of water resources. In this research, the Water Evaluation and Planning (WEAP21) system was used to assess the impacts of future climate change on water resources in the Densu River Basin. The results indicate that the Densu River Basin will experience a temperature rise and reduction in rainfall. These changes will lead to a reduction in the river streamflow. Consequently, the water demand for domestic and irrigation uses will not be met for the study period. It is recommended that research on climate change adaptation for water management in the Densu River Basin should be conducted to ensure proper management of the water resources.

BACKGROUND/CONTEXT

Adequate freshwater supply is fundamental for sustaining social and economic activities (Marquès, Bangash, Kumar, Sharp, & Schuhmacher, 2013). However, the sustainability of the freshwater sources is a great challenge due to several factors such as high rate of population growth, increased socio-economic activities and especially climate change (Sun, McNulty, Cohen, & Myers, 2005; Li, Deng, Huang, Zhang, & Huang, 2013; Arsisoa, Tsidua, Stoffberg, & Tadesse, 2017). The African continent in the past years has seen a rise in the earth temperature and it is expected to be warmer (3-6ºC) with variation in rainfall by end of 21st century (Niang, et al., 2014; Sylla, Nikiema, Gibba, Kebe, & Klutse, 2016) as a result of changing climate. These changes is likely to affect the hydrological cycle, and it could have significant impacts on the availability (quality and quantity) and distribution of water resources (IPCC, 2014; Hrdinka, Vlasák, Havel, & Mlejnská, 2015; Arsisoa, Tsidua, Stoffberg, & Tadesse, 2017) in Africa.

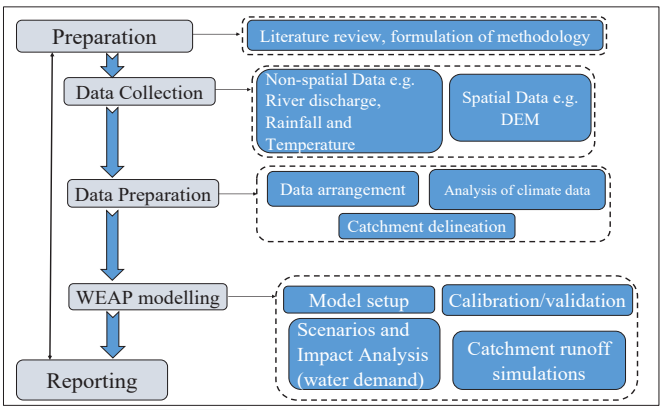
PROBLEM STATEMENT/RESEARCH QUESTION

Climate change is predicted to impact the availability and quality of water resources. However, the extent to which the hydrology of the Densu River Basin will be altered as a result of Climate Change is unknown due to limited climate studies on the river basin.

OBJECTIVES

The main objective is to assess the impact of future climate change on water resources in the Densu River Basin for irrigation and domestic water supply.

METHODOLOGY

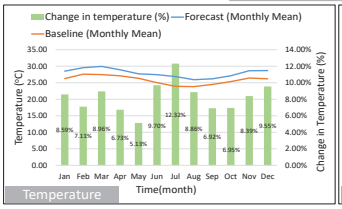


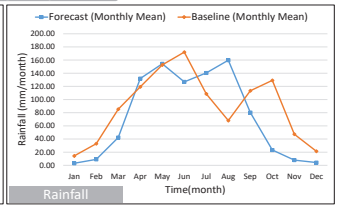
Scenario Assumptions

Parameters	Unit
Domestic Demand	80l/c/d for baseline and scenario 1 (WRC, 2007)
	100l/c/d for scenario 2 (assumed)
Irrigation Demand	15000m³/ha/year for baseline and scenario 3 (WRC, 2007)
Population growth rate	2.2% annual growth (GSS, 2013)
%Population directly dependent on the river discharge	67% for baseline (WRC, 2007)
	60% for scenario 1 and 2 (assumed)

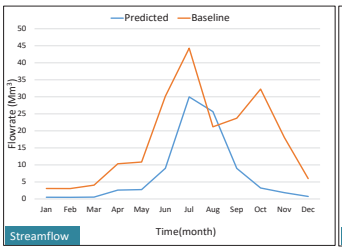
RESULTS AND DISCUSSION

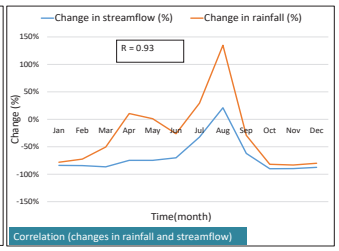
Climate Change Projections

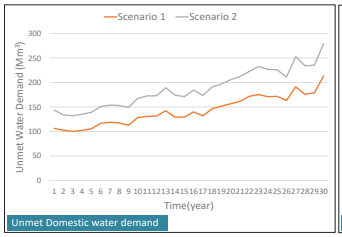


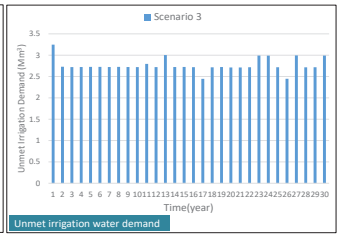


Climate Impact Analysis









CONCLUSION

- The Densu River Basin is expected to be warmer (8.2%) with reduced rainfall (-17%) in the future
- The streamflow of the river is expected to decline by -58%
- There will be extreme water shortages in the future for both domestic and irrigation water use
- From the results of this research, it can be established that climate change will have a devastating impact on water resources in the Densu River Basin

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Rainfall-Intensity Duration Frequency Analysis and Peak-flow Estimations for Flood Risk Management options within Gountiyena basin in Niamey, Niger.

Graduate CV.

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Abstract

Information on peak discharge and related probabilities is essential for engineering structure designs. Many basins are ungauged and therefore, data for statistical analyses are missing and input for sophisticated hydrological modeling is insufficient. Design storm estimations based on intensity duration frequency analysis and peak discharge estimations is an essential component for planning water management interventions. The study aims to contribute to flood risk reduction within the Gountiyena basin in Niamey/Niger through intensity duration frequency analysis and peak discharge estimations based on a 5-minutes interval rainfall from 1990 to 2017 for two stations. The Gumbel distribution was applied for the intensity duration frequency analysis while the Rational and the Soil Conservation Service-Curve Number methods were used for peak discharge estimations. Short rainfall durations produced high rainfall intensities with increasing return period. The intensities varied from 100mm/hr to 226mm/hr for both stations for 1-year and 50-years return period respectively. Estimated average peak discharges vary from 84m3/s (1-year return period) to 290m3/s (50-years return period). The results can serve as basis for decision making for planning water management interventions. Alternatives on appropriate flood management options were summarized and described.

BACKGROUND

Cities are social hubs and its life depends on services and utilities (transport, electricity, water, education, housing and employment. Today, 55% of total population live in urban areas and will reach 68% by 2050 *(United Nations, 2017)*. Increased urban population means increased surface sealing, less infiltration and increased runoff generation. Increased urbanization and rapid urban population growth are said to have contributed significantly to the increased urban flooding

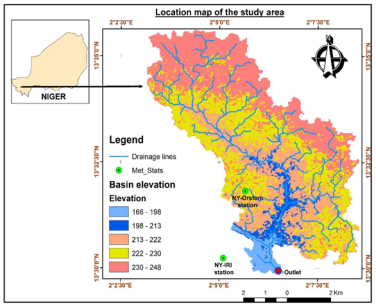
PROBLEM STATEMENT

Niamey is a rapidly growing and developing metropolitan city. The city has seen massive rural-urban migrations of people fueled by extreme events such as droughts mostly notable from the 1971 drought. Most recently, the city has experienced frequent flooding. The increased urban flooding can be attributed to increased urbanization and insufficient drains. Engineering designs are based on estimations. The current research aims to generate fundamental information with intention to transform current flood situation of the Gountiyena basin.

OBJECTIVE

To contribute to flood risk reduction within Gountiyena basin through Intensity Duration Frequency analysis and Peak Discharge Estimations.

STUDY AREA



- Population 1, 302, 910
- Bound by longitude $2^0 2'30"$ E & $2^0 7' 30"$ E and Latitude $13^0 30' 0"$ N & $13^0 35' 0"$ N
- Elevation 160m - 250m amsl
- Annual average temperatures 30^0 C
- Hottest month April, 45^0 C
- Annual average rainfall 500 mm (May to August)

METHODOLOGY

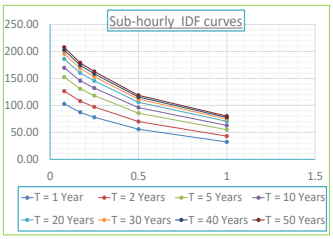
Intensity duration frequency analysis

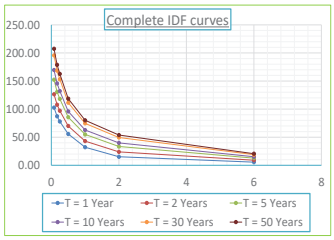
- Extraction of the AMS from the raw data from 1990 to 2017
- The fitting AMS into selected distributions (EasyFit and Ms. Excel)
- The goodness-of-fit test (Chi-square and Kolmogorov-Smirnov tests)
- Distribution parameter estimations
- Gumbel frequency factor KT computation

Peak Discharge Estimations

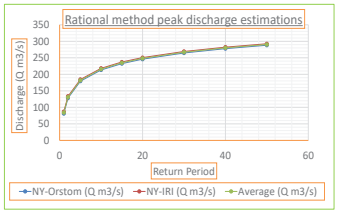
The Rational and SCS-CN methods were applied for Peak Discharge Estimations

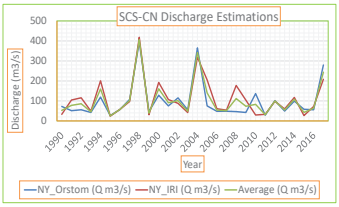
RESULTS AND DISCUSSION





Short rainfall duration gave high rainfall intensities with increasing return period. The goodness of fit (chi-square and Kolmogorov-Smirnov) test confirmed our sample data obey the gumbel distribution.





The average peak discharge for the entire period is $140m^3/s$ and $105m^3/s$ for both methods. The Rational projected an increasing peak discharge with increasing return period.

CONCLUSION

- IDF curves for the study area were developed and peak discharges were estimated for the future up to 50 years return period.
- The discharge estimations and the IDF analysis indicates an increasing trend in both rainfall intensity and peak discharges
- The results tally with West Africa climate projections which predict an increasing trend in the frequency of rainfall events *(Akumaga & Tarhule, 2018; New et al., 2006; SYLLA et al., 2015)*
- The results can serve as basis in flood management and the overall engineering structure designs for development projects

RECOMMENDATIONS

- Instrumentation of the study area, which can later allow in-depth study of the intensity duration frequency analysis within the basin
- Development of an integrated flood risk management
- Development of early warning system
- Increase awareness on the causes and impacts of flooding, and riparian area management

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Graduate CV.

Spatial and Temporal Drought Characterization in View of the Best Irrigation Practices in Central Malawi

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Abstract

This study sought to characterize the temporal and spatial variations of droughts in view of the best irrigation practices in Central Malawi. Hydro-meteorological data from 1977 to 2017 was processed in DMAP, CROPWAT, XLSTAT, and ArcGIS 10.3 to determine drought indices, crop water requirements and best irrigation practices for the region. This study used different drought monitoring indices in DMAP. Results showed that Central Malawi experienced mild and moderate meteorological droughts, frequent moderate agricultural droughts and extreme hydrological droughts. This study recommends growing of cassava as a drought resistant crop, rainwater harvesting and usage of drip and micro-sprinklers irrigation systems.

BACKGROUND/CONTEXT

✔ Malawi has been experiencing different types of disasters which are increasing in frequency, duration and severity. Droughts are the most recurring (Chabvunguma et al., 2014). These have caused havoc in agriculture production, water resources and the economy of the country (Malawi Government, 2006).

✔ Inadequate knowledge of drought characterization and distribution about best crops to grow and best ways of irrigation has led to poor choices of disaster risk management strategies in Central Malawi.

✔ Kasungu Agricultural Development Division (ADD) in Central Malawi experiences uneven rainfall distribution both spatially and temporally leading to food insecurity as most people depend on rainfed agriculture.

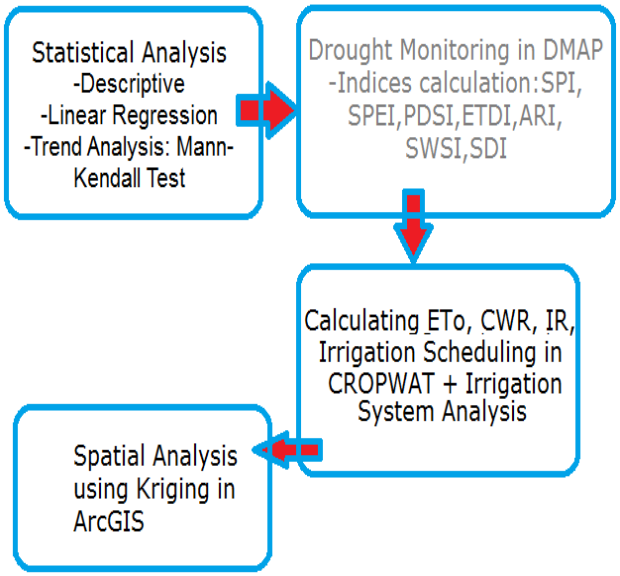
PROBLEM STATEMENT/RESEARCH QUESTION

- ❑ Many drought indices to aid drought monitoring exist but the utilization of these indices in drought analysis in Malawian setting has necessarily not been done sufficiently.
- ❑ Despite this vulnerability to drought conditions, no study has ever been done in the region to characterize droughts.

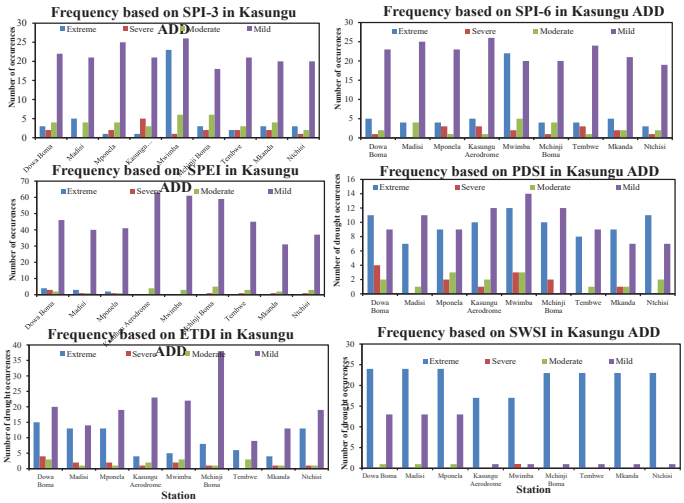
OBJECTIVES

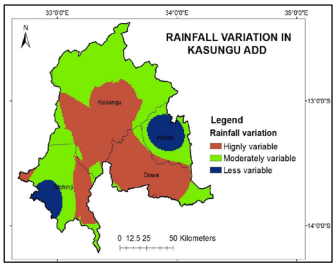
- ❑ To characterize spatial and temporal drought characteristics in Kasungu ADD in Central Malawi.
- ❑ To determine ETo, CWR, IR and best irrigation practices and drought risk management strategies in the region

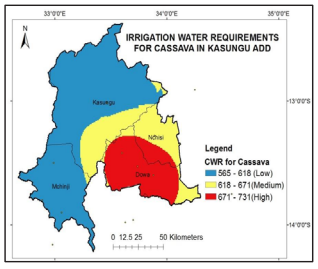
METHODOLOGY



RESULTS AND DISCUSSION







CONCLUSION

- ❑ Kasungu ADD has experienced more of moderate and mild droughts (meteorological and agricultural) and extreme hydrological droughts.
- ❑ Mann-Kendall test in corroboration with linear regression analysis revealed decreasing trends in the rainfall patterns of most areas in the ADD.
- ❑ Climate-smart irrigation technologies such as drip irrigation and micro-sprinkler irrigation are not largely practiced in the ADD.
- ❑ Most high yielding crops grown in the ADD require frequent irrigation but during longer periods of time as shown by the crop water requirements and scheduling.
- ❑ No single drought index is sufficient because they give different results which need a very critical analysis.

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The entire master thesis report is available under the following link:
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User Friendly Numerical Hydraulic Model for Complex Pipe Networks: Case Study of Mbale School Zone Uganda

Graduate CV.

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Abstract

Whenever there are substantial variations in quantity of demands within a metropolitan water network, it is necessary to assess the pipe network. The present study aims at developing a user-friendly numerical hydraulics model for analysing compound pipe networks: the case study of Mbale School Zone in Uganda. The model was developed by the V-Model approach, written in visual basic language, to implement improved hardy cross Algorithm. The model has been developed to analyze steady flows, velocities, head losses and pressure at the nodes for a network with a maximum of four (4) loops. Costing of the pipes is also done by the model. The model was tested, validated and results compared with EPANET software. It was found that the discharge results from the program and EPANET showed consistency as coefficient of determination R^2, was found to be unity (1), thus reliability of the model.

BACKGROUND/CONTEXT

Worldwide, all languages have a word for water. In Swahili, a language widely spoken in East Africa, Water is called "Maji". However we say it, water is a very essential resource for the existence of all life forms on earth (Sonaje & Joshi, 2015). Water plays voluminous central roles such as navigation, irrigation, power production, recreation, machine cooling and raw material cleaning in factories and receiving wastewater (Ahmed, 1997). Its delivery to communities is by branched, looped or combined pipe network. The population of Uganda has continually enlarged at an average annual growth rate of 3.0 percent. By mid-year 2017, Uganda Bureau of Statistics (UBOS) projected the population to be 37,730,300. This has led to high demand and low pressures in the water networks. Therefore, development of reliable user friendly water network model can help engineers and scientists quantify the head losses and flow in the water distribution system.

PROBLEM STATEMENT/RESEARCH QUESTION

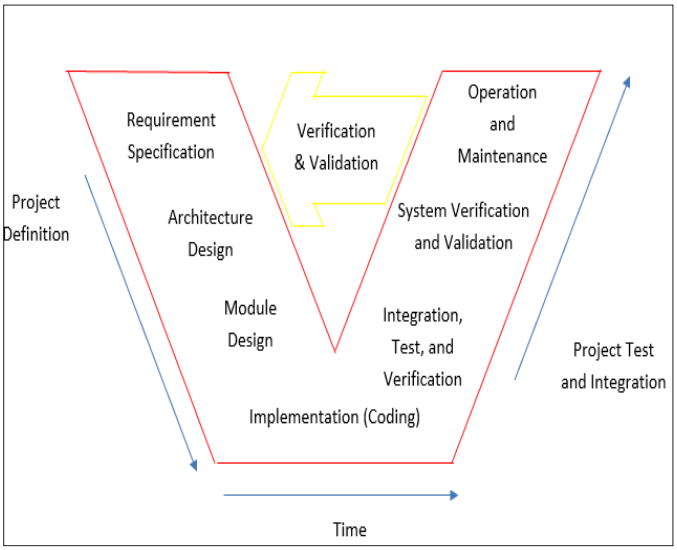
According to UBOS, Mbale district population census in 2002 was estimated at 332,571 persons, with the population projection figures of 568,800 in 2019. The ever increasing population has led perpetual growth in water demand and low pressures in pipe networks. This will necessitate rigorous analysis of flows and pressure before more customers get connected to the network. Therefore, this study aims to develop a user friendly numerical hydraulics model to efficiently analyse and cost complex pipe network.

OBJECTIVE

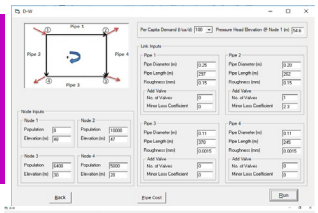
To design and implement a user friendly numerical model for complex pipe networks.

METHODOLOGY

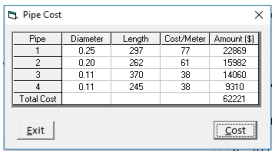
The V-Model Approach was Adopted for this study.



RESULTS AND DISCUSSION

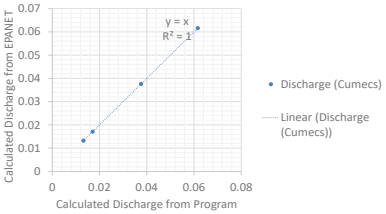


Pipe	Program Output Q_{New} (m^3/s)	HL (m)	V (m/s)	EPANET Output Q_{New} (m^3/s)	HL (m)	V (m/s)
1	0.0616	1.803	1.25	0.0616	1.791	1.25
2	0.0376	2.084	1.20	0.0376	1.907	1.20
3	0.0132	5.501	1.39	0.0132	5.491	1.39
4	0.0171	5.782	1.80	0.0171	5.775	1.80



Single Loop Pipe Cost

Node	Program Output Pressure [m]	EPANET Output Pressure [m]
1	28.16	28.16
2	21.62	21.61
3	3.34	3.55
4	14.53	14.73



CONCLUSION

In the face of the challenges encountered during the model development, the:

- ✓ Main AIM was achieved.
- ✓ Model was tested and Validated
- ✓ Coefficient of determinant R^2 = Unity (1) for the computed flows for the single, two, three and four loops considered.

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4. Erickson, J. J. (2016). The Effects of Intermittent Drinking Water Supply in Arraijan, Panama (Doctoral Thesis). University of California, Berkeley.

The entire master thesis report is available under the following link:
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Graduate CV.

Water Harvesting Structure Sustainability

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Abstract

WH involves the collection of rain that falls onto the roofs, grounds and runs off. Abougoudam District in Chad has only three months of rainfall with a very long dry season. The objective was to analyse WH practices in arid regions and propose sustainable structures that incorporated the technical feasibility and design, economic and socio-cultural acceptability to be implemented in Abougoudam district and other arid regions of Africa. A field survey in Chad and literature review were conducted. The results revealed that rain with a probability of more than 50% might be considered to supplement water. The soil map showed 40 to 60% of vertisols to be avoided for WH. 100% of the local community were ready to adopt WH. water spreading weirs, Hafir systems, Sand dam and combination of the zaï pit and stones lines were proposed. The sustainability of these structures could be achieved through a national policy.

BACKGROUND/CONTEXT

Over the last decade, climate change has influenced changes in the frequency of droughts and precipitation trends in arid and semi-arid areas of Africa.

Two hundred (200) million of African population suffer from chronic water shortages and one-quarter(1/4) lack food.

Chad was pointed out as a country suffers from a very high food insecurity according to the hunger map 2018 of the World Food Program(WFP) hunger map.

It will not be possible to achieve the SDGs (end hunger, food, poverty, health, water, and sanitation) without an African water revolution (green water).

Water harvesting(green water) is the collection and storage of rainwater and runoff in a natural or artificial storage facility to be used instantly or before the beginning of next season to provide water needs for humans and livestock consumption, the irrigation of annual crops, pastures and trees and for groundwater recharge.

PROBLEM STATEMENT/RESEARCH QUESTION

Abougoudam District has nine months without rainfall but water is only available in the month of july,august and september. Water Harvesting structures could be adopted to bridge the gap between dry and rainy season.

OBJECTIVES

The objective of this study is to analyse the various water harvesting practices in arid regions and propose sustainable structures that incorporated the technical feasibility and design, economic and socio-cultural acceptability to be implemented in Chad and other arid parts of Africa.

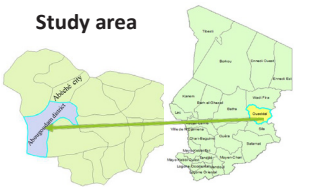
METHODOLOGY

The district of Abougoudam is located about 20 km south-west of Abéché in Ouaddaï region. It is between 13 ° and 14 ° North latitude and 20 ° and 21 ° East longitude.

Its area is estimated at 2320 Km² with a population of 62 161 inhabitants

The area has an estimated domestic livestock population of 365426

Study area

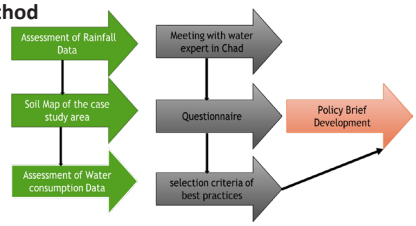


Map of Abougoudam District shaded in grey colour

Map of Chad showing Ouaddaï Region shaded in yellow colour

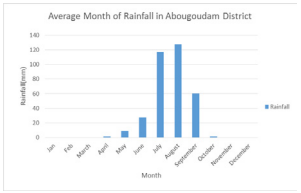
Research method

Field survey in Chad and desk study were conducted to assess the best practices of water harvesting structures to be adopted in Abougoudam District.



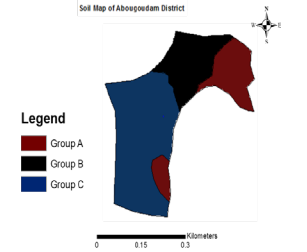
RESULTS AND DISCUSSION

Rainfall variability in Abougoudam District



Domestic Water Supply

No	Description		Remark
1	Number of functional hand pump	16	
2	Number of non-functional hand pump	6	
3	Quantity of water pumped by borehole per day(m^3)	128	$8m^3 \times 16 = 128m^3$ = 128000 liters
4	Number of functional open wells	25	
5	Quantity of water pumped by open well per day(m^3)	200	$8m^3 \times 25 = 200m^3$ = 20,000 liters
6	The total quantity of water pumped by both hand pump borehole and open well per day(m^3)	328	$(200 \times 120 = 328m^3$ = 328000 liters
7	The average quantity of water available per day	5.17	$\frac{328000}{62161} = 5.17$ l/p/d
8	Number of people per water point	1517	1 water point(borehole/open well) for 1517 people



- Sandy soils are not suitable for water harvesting(WH).
- Loamy soils are the most suitable for WH.
- Group B:Vertisols should not be considered for water harvesting

Design of Rainfall

Year	Rainfall(mm)	Sort of Rainfall	(mm)	Rank(m)	Probability(P%)
1999	539.7	2018	998.8	1	4.8
2000	288.1	1999	539.7	2	9.5
2001	312.5	2012	395.8	3	14.3
2002	369.6	2017	390.1	4	19
2003	371.1	2015	375.2	5	23.8
2004	368.1	2003	371.1	6	28.6
2005	346.6	2002	369.6	7	33.3
2006	275.3	2004	368.1	8	38.1
2007	327.7	2005	346.6	9	42.9
2008	163.2	2007	327.7	10	47.6
2009	123.9	2001	312.5	11	52.4
2010	224.1	2014	297.2	12	57.1
2011	201.2	2000	288.1	13	61.9
2012	395.8	2006	275.3	14	66.7
2013	239.1	2016	251.5	15	71.4
2014	297.2	2013	239.1	16	76.2
2015	375.2	2010	224.1	17	81
2016	251.5	2011	201.2	18	85.7
2017	390.1	2008	163.2	19	90.5
2018	998.8	2009	123.9	20	95.2
I	II	III	IV	V	VI

Assessment of the Questionnaire using SPSS

- Average family size is 10 with maximum of 40 and minimum of 4.
- 100% were willing to adopt WH and contribute to O&M of the structures

Meeting with water experts in Chad

- Weak Financial capacity of the government to adopt WH.
- Weak Financial capacity of beneficiaries to adopt WH

CONCLUSION

Water spreading weirs,sand dams,zai pits and stone lines have proven to regenerate land and improve crop yields which is a way to fight food insecurity and improve water supply for humans and livestock and off season irrigation. The local communities got most of their drinking water from the wells in the wadi which has become part of their culture. Therefore, the above water harvesting structures were proposed for the District of Abougoudam.

The government has the responsibility to provide water for her population and the population also have the responsibility to provide water for themselves. The future of WH in Chad will depend on public-private partnership through sponsorship by donor organization especially the United Nations and IsDB in their attempt to eradicate poverty and foster environmental sustainability in order to achieve the SDGs(goal number 2and 6).

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The entire master thesis report is available under the following link:
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Master of Sciences

Water Policy

Graduate CV.

Assessing Climate Change and Variability Impacts on Water Resources and Smallholder Agriculture in the Offin Sub-Basin of Ghana

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Abstract

Climate change and variability have become issues of global and regional concern. Ghana's over-dependence on climate-sensitive sectors has greatly contributed to the high vulnerability of the country. This study assessed climate change and variability impact on water resources and smallholder agriculture in the Offin sub-Basin of Ghana. Negative trends were identified for rainfall and streamflow, whereas a positive trend was observed for temperature. Changes in rainfall and temperature in the basin, to an extent steered changes in streamflow. Farmers and indigenes in the basin did have a general knowledge of climate change and the challenges it poses on their farming activities. Various means by which these farmers had been coping with the impacts of climate change and variability were assessed, even as a means of contributing to building resilience in these climate-sensitive sectors.

BACKGROUND

- The effects of climate change and variability are significantly evident especially in Sub Saharan Africa, Ghana inclusive, where resources are not sufficient for effective adaptation and mitigation strategies
- Sub-Saharan Africa countries continue to exhibit vulnerability to variability and change in climatic factors such as temperature, rainfall, as well as extremities bringing about events like droughts, dry spells, and floods, which are becoming highly pronounced in the region with time.
- Ghana as a country, relies heavily on ecosystem services, in terms of food, water, raw materials, and others. These services are disadvantaged and limited by climate change and variability impacts.
- Meanwhile, Water resources and smallholder agriculture inevitably do contribute largely to socio-economic development in Ghana.

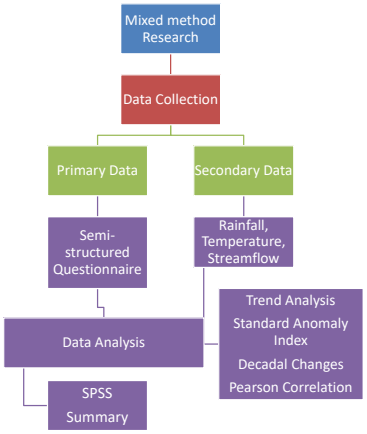
PROBLEM STATEMENT/RESEARCH QUESTION

- Water serves as a fundamental input to most economic activities in the country, yet water resources have experienced first-hand harshness from climate change and variability.
- Agriculture is undoubtedly a pillar of the economy of Ghana, as it serves as the greatest employer in the country, employing about 60% of the population, the majority of whom are small-holders. Climate change and variability have however contributed to stagnating growth in this sector.

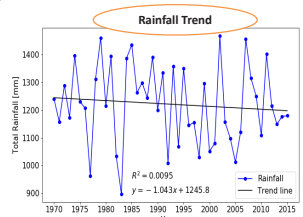
OBJECTIVES

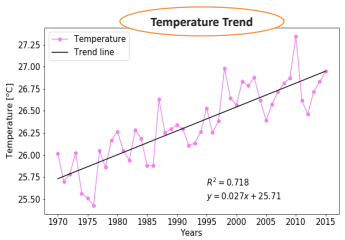
- To evaluate climate trends and smallholder farmers' perceptions of climate change and variability in the Offin sub-basin.
- To examine the effects of rainfall and temperature on river flow for the period of 1980 to 2009 at annual and monthly scales.
- To identify challenges faced by smallholder farmers due to the changing climate and evaluate adaptation strategies practiced in water management and smallholder agriculture in the basin.

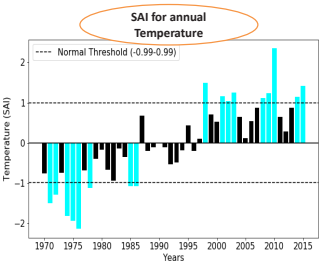
METHODOLOGY

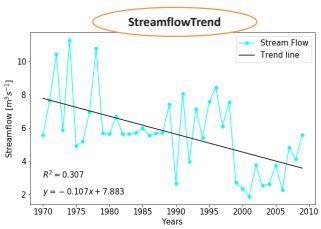


RESULTS AND DISCUSSION









Pearson Correlation

Variables	Correlation Coefficient (r)	Strength of Linear Relationship	Coefficient of determination (R^2)
Rainfall – streamflow (monthly)	0.68	Moderately positive	0.46
Rainfall – streamflow (annual)	0.29	Positively weak	0.08
Temperature – streamflow (monthly)	-0.61	Moderately negative	0.37
Temperature – streamflow (annual)	-0.51	Moderately negative	0.26

Adaptation Strategies by Farmers

Strategy	Response	
	Yes (%)	No (%)
Usage of irrigation	76 (58.5)	54 (41.5)
Water and soil moisture conservation	32 (24.6)	98 (75.4)
Practice of crop diversification	112 (86.2)	17 (13.1)
Flood protection	17 (13.1)	112 (86.2)
Tree planting on farms	58 (44.6)	72 (55.4)
Planting some climate resistant crops	65 (50)	65 (50)
Changing planting dates	113 (86.9)	17 (13.1)
Alternative income source	65 (50)	65 (50)

CONCLUSION

- Changes in rainfall and temperature do influence changes in streamflow
- Respondent farmers generally had knowledge on climate change and variability, as well as the challenges posed on their farming activities by these phenomena. This can be used as basis to enhance their adaptation capacity
- With over 50% of farmer respondents consenting to relying on the river for their crop water needs, it is key to look into water management strategies that would foster the sustainability of water resources in the country.

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The entire master thesis report is available under the following link:
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Assessment of Hydrological Water Balance in Lower Nzoia Sub-catchment: Towards Improved Water Governance in Kenya

Graduate CV.

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Abstract

This research reinforces that water availability in a given area can be linked to Land Use Land Cover (LULC) changes and water balance. Having operational adaptive capacity of water governance systems can therefore enable community resilience in case of changing environment and climate. Image differencing technique was adopted in carrying out LULC change detection using the from-to analysis. Estimation of hydrological water balance of 2018 LULC was determined as a way of understanding the hydrological characteristics of the area. The finding shows that there is increasing urban/ built-up area as well as population over thirty years time period while with no or limited focus on adaptive capacity. If the currents state of things continue, addressing cases of water disasters may be challenging.

BACKGROUND/CONTEXT

Hydrological information of the catchment systems is of great use in conflict management, planning water conservation, agricultural design, drainage and flood control. Over the years, studies on comparative analysis between water balance and other influences such as the climate, morphology, land use and soil have been conducted in various parts of the world. Water balance study is becoming extremely important in helping water practitioners and civil society to make informed decisions. Hydrologic responses are dependant on decisions that are accurate and reliable predictions in order to facilitate planning and managing water resources Source: Bao, et al., 2012; Alam, M. A., Rajat, K., & Janmeet, S.,2016

PROBLEM STATEMENT/RESEARCH QUESTION

Increasing water demand; Lower Nzoia Irrigation Development Project (LNIDP) has already kicked off

Pressure from increasing population while sustaining environmental flow

Less focus on adaptive capacity; understanding how human and natural systems might influence water availability

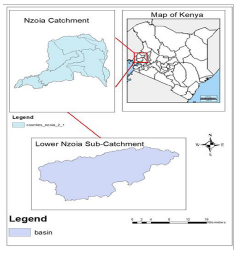
Key Question: What will happen if these problems remains Business As Usual in coming years with changing climate?

OBJECTIVES

To assess hydrological water balance of Lower Nzoia Sub-Catchment in order to determine how Land Use/Land Cover change and water balance can influence or be influenced by adaptive capacity constraints of water governance in the study area.

METHODOLOGY

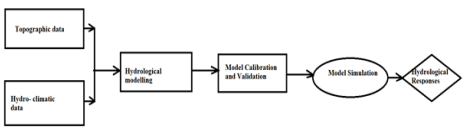
-Part of Nzoia Catchment
-Covers an area of about 534.24km^2
-Lies in an agriculturally productive area
-Wuoroya River is one of the water sources
-The elevation is between 1179m & 1524m
-Ugunja and satellite towns in the study area continues to expand



Study Design Process

Methods: supervised classification approach for LULC; SWAT modelling for estimating water balance and water yield; unstructured questionnaires for conducting interviews

Datasets: United States Geological Survey (USGS), Soil and Terrain Database for Kenya (KENSOTER), Kenya's Hydro-meteorological stations, and Global Weather Data for SWAT.



LULC change detection between 1988,2003 & 2018
Water balance and water yield of the area for 2018
LULC map
Water governance system
Incorporation of adaptive capacity in policies and constraints

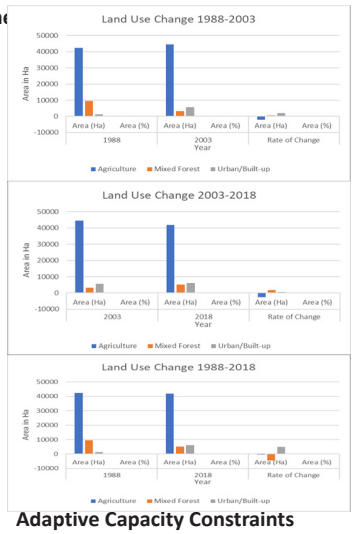
RESULTS AND DISCUSSION

Land Use Land Cover Change Over the

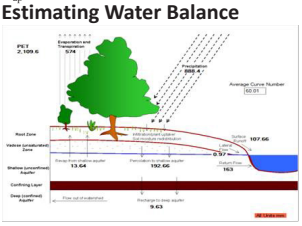
Land Use/ Year	1988 Area (Ha)	1988 Area (%)	2003 Area (Ha)	2003 Area (%)	Rate of Change Area (Ha)	Rate of Change Area (%)
Agriculture	42449.84	79.48	44408.85	83.12	-1959	3.64
Mixed Forest	9598.9504	17.97	3374.6488	10.56	561.33	-7.4
Built-up	1357.65	2.54	5640.9896	6.317	2016.99	3.77

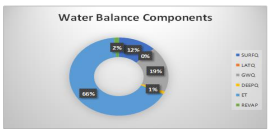
Land Use/ Year	2003 Area (Ha)	2003 Area (%)	2018 Area (Ha)	2018 Area (%)	Rate of Change Area (Ha)	Rate of Change Area (%)
Agriculture	44408.8544	83.12	41975.462	78.57	-2433.394	-4.55
Mixed Forest	3374.6488	6.32	5246.7068	9.82	1872.058	3.50
Urban/Built-up	5640.9896	10.56	6202.322	11.61	561.3324	1.05

Land Use/ Year	1988 Area (Ha)	1988 Area (%)	2018 Area (Ha)	2018 Area (%)	Rate of Change Area (Ha)	Rate of Change Area (%)
Agriculture	42449.8496	79.48	41975.4624	78.56	-474.387	-0.91
Mixed Forest	9598.950 4	17.97	5246.706 8	11.6	-4352.24	-6.36
Urban/Built-up	1357.65	2.54	6202.322	9.82	4844.672	7.28

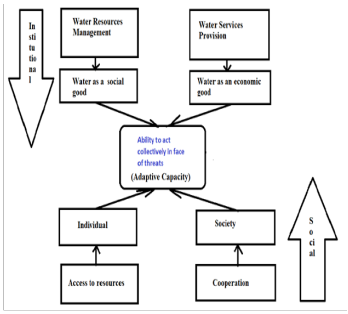


Estimating Water Balance





Adaptive Capacity Constraints



CONCLUSION

- The comparison between 1988 and 2018 LULC shows that there is increased built-up area and if this continues in the future, it may lead to a lot of environmental and ecological problems. More built- up land leads to increased impervious areas hence increased run-off and less water infiltration therefore in turn influencing water balance and water yield.
- Modeling results of this study suggest that SWAT model is a useful tool in assessing hydrology of a river catchment as well as in predicting water yield. In addition, the embedded SWAT model in GIS environment ensures results to be highly productive as a tool to support policies and decision making.
- Even though there is impressive water policy development in Kenya, adaptive capacity has not been incorporated into these policies.

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Assessment of Needs and Options for Sustaining Ecological Water Supply to Ruaha National Park in Tanzania through Damming Ndembera River in Iringa, Tanzania

Graduate CV.

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Abstract

Ndembera River is one of the rivers that flow its water into the Great Ruaha River (GRR) in Tanzania. Since 1993, GRR flow started to cease during dry period due to over-abstraction of water for upstream irrigation activities. The study used WEAP system to analyze different options for restoring yearly flow of the river and ensuring sustainable access to clean water, energy, food, and ecosystem nexus. The improvement of irrigation systems was found to reduce the irrigation water demands from 33.2MCM (2018) to 22MCM (2050). Construction of Lugoda dam was found to increase irrigation water demand coverage from 80.87% to 98.17%. Also, impoundment of Ihefu swamp and construction of Ndembera reservoir ensured 100% water demand coverage for ecology and other demand sites in all periods of the year.

BACKGROUND/CONTEXT

Globally, the recognition of the flow regime of the river for ecosystem management is gaining the priority, and the role of environmental flow has become ever more significant (Bhattacharjee, 2014; Ayele, 2016).

The promotion of SDG 1, 2, 6, 7, 13 & 15 has aggravated the competition over water access from the river.

Over abstraction of water for irrigation activities conducted in Great Ruaha River (GRR) Basin has been resulting in seasonal drying of the river. This has been affecting the livelihood of ecosystems in Ruaha National Park (RNP) and other sectors.

Hence, this thesis is meant to give insightful information about available options for restoring ecological water flow in RNP.

PROBLEM STATEMENT/RESEARCH QUESTION

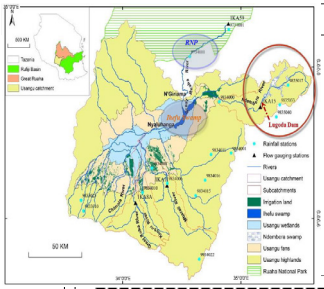
Despite the abundant water resources available in Ndembera river in Tanzania during wet season, many sectors particularly RNP found in the basin suffer from lack of water in the river during dry season.

Lack of water for ecology in the RNP and other water demand sectors results into loss of ecosystems and sectoral conflicts.

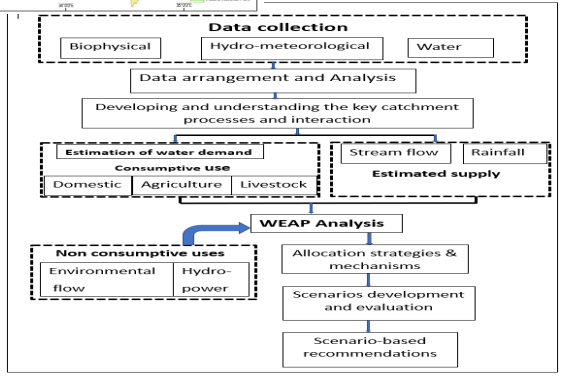
OBJECTIVES

To analyze engineering and other options suitable for addressing the challenges currently associated with water requirements for ecological sustenance of the Ruaha National Park in Iringa, Tanzania.

CASE STUDY AREA & METHODOLOGY



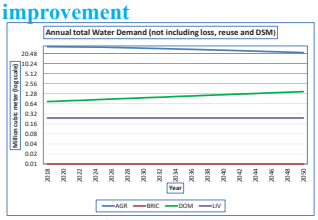
- Ndembera River flows into GRR throughout the year
- Ndembera sub catchment covers 3190km^2 and GRR basin 68000km^2
- Wet period (November – April) and dry period (may – October)
- The precipitation 500 - 700mm/year
- Average temperatures range between 15 °C and 32 °C



RESULTS AND DISCUSSION

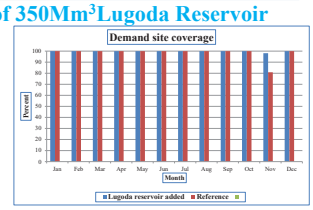
Scenario I: Irrigation system improvement

- Agricultural water abstraction decreased from **33.2**Mm^3 (2018) to **22**Mm^3 (2050)
- Increase in the total annual domestic water demand from **0.75**Mm^3 (2018) to **1.49**Mm^3 (2050)

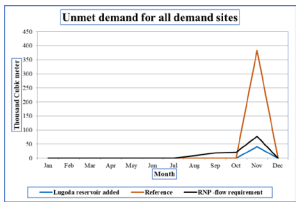


Scenario II: Construction of 350Mm^{3}Lugoda Reservoir

Increase in water demand coverage for agriculture sector in November from 80.87% to 98.17%

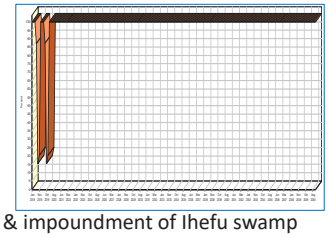


Scenario III: Introduction of EFR for RNP



Scenario IV: Construction of 150Mm^3 Ndembera reservoir

All water demand sites coverage



Construction of ndembera reservoir & impoundment of Ihefu swamp Ensures **100%** water coverage for EFA & other demand sites to be met from 2020 to 2050

CONCLUSION

- The thesis work has been devoted to the assessment of needs and options for sustaining ecological water supply to RNP in Iringa, Tanzania.
- Efficient use, abstraction practices and construction of reservoirs can ensure yearly flow of GRR, which is one of the most important ecological reserve and economic activities of the country.
- Meeting the ecological water supply in RNP can help to sustain ecosystems, boost socio-economic activities and alleviating the implications associated with lack of water in the river.
- WEAP system analysis results provided a basis for understanding needs and deriving practical and feasible options for restoring the yearly flow of GRR and hence enabling to sustain ecological water supply to RNP.

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The entire master thesis report is available under the following link:

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Assessment of the Quality of Bottled Drinking Water Produced in African Cities. Case Study: Kigali City, Rwanda

Graduate CV.

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Abstract

The new trends of climate change and development which goes with industrialization, urbanization and intensive agriculture have tremendous effect on the quality drinking water sources. Hence in developing countries where financial capacity is low may affect the quality of drinking water produced for public supply, reason why bottled water demand keeps on increasing which may unfortunately have quality gaps. This research was carried out in Kigali city aiming to assess the physicochemical quality of bottled drinking water sold in Kigali by testing selected 15 parameters; **pH, Turbidity, TDS, EC, Nitrate, Potassium, Calcium, Magnesium, Iron, Alminium, Fluoride, Chloride, Sulfate, Total Alkalinity and Sodium.**

BACKGROUND/CONTEXT

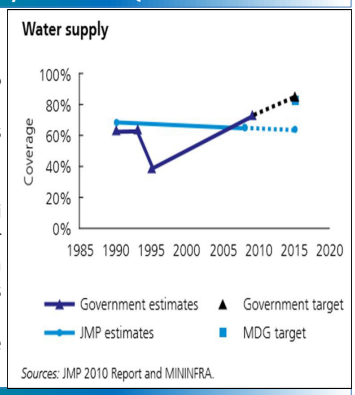
Water accounts **60% of the body weight** and the average **water intake of 2 liters per day** for adults is needed for normal functioning. According to WHO-UNICEF-JMP, 2017; eight hundred forty four **(844) million people globally** in 2015 were living **without access** even **to basic drinking water services** and sadly **58%** of 159 million people who were still collecting **drinking water directly from surface water** in 2015 lived in **sub-Saharan Africa**. National, Regional and International **initiatives** have been established to ensure **full accessibility** of safe drinking water (**SDGs, Agenda 2063, Vision 2020,** etc). Kigali, capital city of Rwanda, like some other African cities is experiencing a rapid development, which goes with potential sources of pollution to drinking water sources.

PROBLEM STATEMENT/RESEARCH QUESTION

The global consumption of bottled drinking water has been increasing by an average of 12% per year in 2017.

Unfortunately, bottled water's safety also depends on factors. Moreover, diversity of bottled drinking water brands in Kigali where some of them do not bear the standardization mark from RSB pushed on to carry out this research.

Moreover, water supply coverage is not yet at 100%.



OBJECTIVES

To test the physicochemical parameters of bottled water and tap water,

To compare the physicochemical parameters of bottled water and tap water with concentration presented on bottle labels.

To compare the quality of bottled and tap water with RSB and with WHO drinking water quality standards and brand among themselves.

METHODOLOGY

Research Design

Primary and secondary data have been collected.

Sampling

A total number of 24 water samples were collected by a completely randomized research design method. A triplicate of 7 brands bottled water and a triplicate of tap water.

Water Analysis and Data Processing

Spectrophotometer machine was used for analysis of some parameters; **titration** and direct reading on **appropriate equipment** for others.

Analysis of Variance (AoV) in **Statistix 10** Analytical Software has been done **to test the significance** of concentrations between water brands.

Microsoft excel was used for **graphical comparison and representation** of parameter concentration in brands, WHO & RSB **standards** values and concentration written on bottle **labels.**

RESULTS AND DISCUSSION

Mineral Composition of Selected Bottled Water (by brand) Produced in Kigali in June 2019

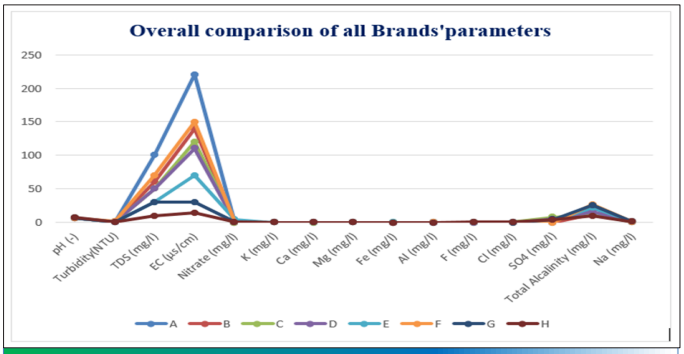
Treatment	pH	EC	NO3	K	Ca	Mg	Fe	Na
Water Brands (WB)	---------- Mean-values ----------							
A	6.133e	220a	0.01a	0.096b	0.0673b	0.0990a	0.100a	0.943c
B	6.466c	140c	0.04a	0.09ab	0.099ab	0.0977b	0.039b	0.936c
C	6.900b	120d	0.07a	0.09ab	0.0673b	0.098ab	0.097a	1.100b
D	6.500c	110e	0.33a	0.10ab	0.100ab	0.098ab	0.040b	1.360a
E	6.066e	70.0f	4.07a	0.09ab	0.3950a	0.098ab	0.099a	0.740d
F	6.333d	150b	0.24a	0.100a	0.098ab	0.0993a	0.001b	0.913c
G	6.800b	30.0g	0.44a	0.09ab	0.099ab	0.098ab	0.001b	1.180b
H	7.133a	14.3h	0.30a	0.10ab	0.099ab	0.0990a	0.004b	1.23ab

Analysis of variance

Sources of variation	df	pH	EC	NO3	K	Ca	Mg	Fe	Na
Rep	3	---------- p-values ----------							
WB	7	**0.0000**	**0.000**	0.489	0.436	0.4414	0.098	**0.0001**	**0.0000**
Error (MS)	16								
Total	23								

Means with the same letter are not significantly different at **0.05** Probability level, **P** values in bold are significant.

pH for 4 brands: A, B, E and F were found slightly below the lower guideline value. Discrepancies have been observed also on **Turbidity** of brand B, C, D and H that was slightly higher than RSB recommended maximum limit. Other parameters were within limits.



CONCLUSION

All brands of bottled drinking water and tap water produced and sold in Kigali city were found within permissible limits of RSB and WHO guidelines for drinking water quality. However some brands had a little lower pH and slightly higher turbidity but did not affect the overall drinking quality. Discrepancies were also found on the labelled mineral contents to the measured ones even though they had no impact on RSB and WHO limit.

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The entire master thesis report is available under the following link:
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Defeating Fluorosis in Rural Kenya using the Kilimanjaro Concept: A Feasibility Study in Naivasha

Graduate CV.

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Abstract

The only feasible sources of water that the local communities in Naivasha have been forced to sort after, is groundwater and rainwater. Data on the quality of water is not readily available, the local population do not have the power to know and be in control of the fluoride concentrations they consume in their drinking and cooking water. The study aimed at providing possible simple and sustainable non treatment options easily implementable in the rural areas that will enable universal safe drinking water provision in Naivasha a possibility. Findings reveal that, there's need for formulation of corporate accountability policies that will ensure the multimillion horticultural industry, conference tourism, fishing, and geothermal exploitation in Naivasha reflect on the thriving capacity of the local population in terms of safe water provision.

BACKGROUND/CONTEXT

WHO | UNICEF JMP progress report had a special focus on inequalities and revealed that there's a growing injustice with access to water and sanitation driven by personal wealth and the populations most at risk of being left behind in terms of basic services provision, are the poorest and fragile living in rural remote areas (WHO, 2017).

Scientific and technical reports are increasingly predicting a strong probability of hard time ahead for the victims of high fluoride consumption in the African population and the three major arguments are: the lack of a frugal defluoridation technology, the insufficient education on water safety among the affected population and high poverty rate (Ndé-Tchoupé et al. 2019).

Fluoride contamination of the groundwater in some parts of Naivasha Sub County has exposed the population to fluoride-related health hazards and this water challenge has resulted to serious socioeconomic implications.

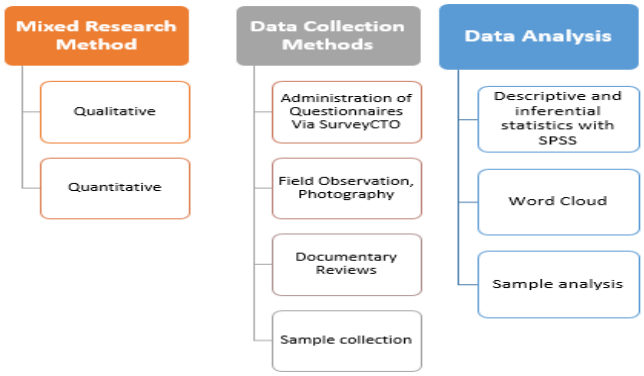
PROBLEM STATEMENT/RESEARCH QUESTION

The population in Naivasha Sub County is growing and will spur further in about five years upon the anticipated developments (CIDP 2018-2022). The proposed water networks (NTISUDP 2014-2034) run through the urban areas leaving out the rural areas. Among the fluorosis victims and their children, fluorosis coping strategies are close to none. There has been fluorosis eradication programmes on track, but they have not been delivering for the poor person in the remote areas of Naivasha.

OBJECTIVES

- To carrying out a hydrocensus assessment of drinking water sources in Naivasha
- To find out the water quality of the drinking water sources in Naivasha
- To understand the human health implications associated with drinking the groundwater with high level Fluoride
- To evaluate the performance of blending harvested rain water with water of high Fluoride concentration in reducing Fluoride in drinking and cooking water.

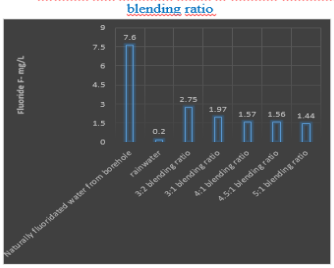
METHODOLOGY



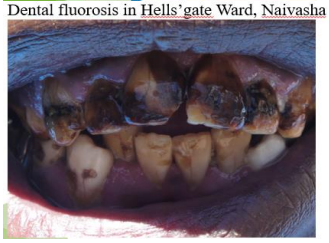
RESULTS AND DISCUSSION

The suitability of water blending in Lowering Fluorosis

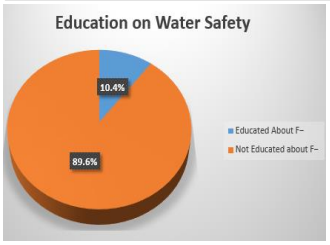
Type of water and blending ratios to achieve optimum blending ratio



Dental fluorosis in Hells'gate Ward, Naivasha



Education on Water Safety



- The blending ratio values reflect the extent of reduction of fluoride concentration in borehole water using the water blending technique. The findings prove that water blending is effective for reducing fluoride concentration in water as fluoride was diluted to the recommended WHO nontoxic level of below 1.5mg/L.
- There is a lack of professional help in terms of water safety.
- The education system has not been able to create awareness on fluorosis.

CONCLUSION

- Borehole water within Naivasha Sub-county has exposed the residents to higher fluoride levels.
- The study recommends the legislative to give legal right to safe water provision in Naivasha through the implemention of integrated policies between water and energy that will ensure community water projects are offered cheap electricity and water solutions, because the area is geothermal rich and Mount Longonot being the reason behind the geothermal potential is also the reason behind high fluoride aquifers in the area as a result of its previous volcanic activities.

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The entire master thesis report is available under the following link:

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Effects of Urbanization on Groundwater Quality in African Cities: A Case Study of Accra, Ghana.

Graduate CV.

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Abstract

Population influx in African cities have caused the emergence of slums. Most urban slum dwellers depend on groundwater sources because of their availability and affordability. Due to the dense living conditions of the slums, wells and boreholes are situated in locations that expose the groundwater to possible contamination. A study was therefore conducted to determine the effects of urbanization on groundwater quality in Accra. Microbial analysis of 20 groundwater samples from 5 slums in Accra showed that there is faecal matter presence in the groundwater consumed. Physiochemical analysis also indicates 4 slums are experiencing lead poisoning with 3 communities exposed to increased levels of nitrate and manganese. Water quality indictors such (E.coli, total coliform, salt indicators, Pb, Mn and No^{3-}) have exceeded the WHO safe limit.

BACKGROUND/CONTEXT

Urbanization is at its peak in today's Africa as most people migrate to cities for greener pastures. African cities accounts for the largest growth in urban population growth over the last two decades at 3.5% per year(Muggah 2018). The reality of the urban growth in Africa is just an expansion of urban land into peri-urban centres and proliferation of slums (Group 2012). Slum dwellers lack access to potable water and proper sanitation systems. The increase in water demand causes over dependence on groundwater. The Congestion in slums results in siting wells in unsanitary locations thereby compromising the water quality.

PROBLEM STATEMENT/RESEARCH QUESTION

Population explosion in Accra has increased the dependency of slums on well and borehole water. The vicinity of these slums are unsanitary due to the presence of landfills and improper waste management.

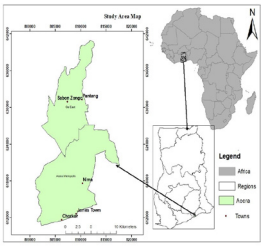
Main question: How does the quality of groundwater in urban slums relates to World Health Organization(WHO) standards.

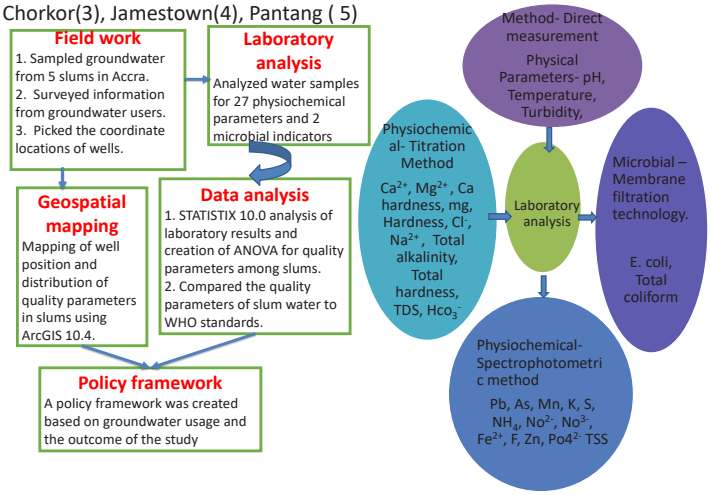
OBJECTIVES

- To determine the effects of urbanization on the groundwater quality in Accra slums.
- Determine the geospatial distribution of water quality parameters in the slums of Accra.
- Compare the physiochemical and microbial water quality parameters to the standard guidelines of WHO.

METHODOLOGY

Accra-Ghana
Population: 4.6 million
Small land coverage: 225.7 kilometers square
Elevation : 61m above sea level
Weather: Tropical , warm and dry along the coast. Average temperature of 30°C , wet and dry seasons.
Landscape: Flat geographical terrain
Slums under study: Nima (1), Sabon Zongo(2), Chorkor(3), Jamestown(4), Pantang (5)





RESULTS AND DISCUSSION

Comparison between the mean water quality parameters per slum and WHO standards

Parameters	S.I Unit	WHO	Nima	Sabon Zongo	Chorkor	Jamestown	Pantang-Abokobi
pH		6.5-8.5	5.09	7.35	6.09	6.52	6.17
Turbidity	NTU	5.00	0.94	0.99	1.41	3.69	1.54
EC	µs/ m	150 .00	147.05	255.08	372.47	79.78	42.03
TDS	mg/L	1000.00	735.3	344.1	1862.4	398.5	210.1
Total Hardness	mg/L	500	292.50	400.00	717.50	215.00	167.50
Ca	mg/L	200 .00	150.00	222.50	462.50	155.00	110.00
Mg^{2+}	mg/L	150.0	142.50	177.50	255.00	60.00	57.50
Cl^{-}	mg/L	250 .00	416.60	727.3	1063.40	227.40	119.9
HCO^{3-}	mg/L		62.22	191.62	100.04	91.50	77.47
Na	mg/L	200.00	270.37	472.00	690.16	147.60	77.85
Total Alkalinity	mg/L		51.00	196.00	82.00	75.00	63.50
F	mg/L	1.50	0.20	0.18	0.54	0.56	0.59
K	mg/L		28.10	48.53	27.45	60.18	15.85
Fe	mg/L	0.30	0.03	0.02	0.13	0.05	0.05
S	mg/L	250 .00	60.50	85.25	87.75	91.00	39.25
Mn	mg/L	0.10	0.11	0.02	0.73	0.05	0.12
NO^{3-}	mg/L	50.00	67.43	54.12	27.06	73.48	36.41
NO^{2-}	mg/L	3.00	0.06	0.07	0.06	0.00	0.00
Pb	mg/L	0.01	0.25	0.00	1.00	0.25	1.50
NH^{4+}	mg/L	1.50	1.31	0.31	0.56	0.11	0.78
$PO4^{3-}$	mg/L	30.00	0.29	0.64	0.12	0.97	0.17
As	mg/L	0.01	0	0	0	0	0
Zn	mg/L	3.00	0.05	0.11	0.02	0.34	0.06
TSS	mg/L	0.00	0.25	0.00	0.00	0.00	12.50
E. coli	CFU/100mL	0.00	18.25	149.75	12.50	89.50	249.00
Total Coliform	CFU/100mL	0.00	90.75	237.75	162.75	185.25	490.25

The mean values In red have exceeded the WHO Standards indicated in green

Major outcomes

- Faecal matter contamination of water in all slums
- Lead poisoning in all slums except slum 2
- Nitrate exposure in slum 1, 2 and 4
- Presence of manganese in water from slum 1, 3 and 5
- Possible salt water intrusion in coastal slums

CONCLUSION

- The location of boreholes and wells in slums within the city of Accra have negative impacts on the quality of groundwater.
- All the groundwater samples from the selected slums are bacterially contaminated.
- Physiochemical analysis indicates that , all the coastal slums are experiencing possible salt water intrusion because all the salt indicators have exceeded the WHO safe limit .
- Four out of the five slums are experiencing lead poisoning and most of these slums are also exposed to nitrate and manganese hence the groundwater from the five studied slums is not safe for human consumption.
- Buffer zones should be created between landfills, pit latrines and the well locations in other to prevent further contamination of groundwater.

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The entire master thesis report is available under the following link:

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Hydrological Response to Land use and Land Cover Change (LULC) in Katonga River Basin, Uganda

Graduate CV.

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Absract:

Land use and land cover changes (LULC) in Katonga River basin have had a negative impact on the fresh water resources leading to the reduction on the quantity and flow characteristics of water. The study examined land use change impacts on the hydrology and hence produce the potential results based on the historical changes and the future scenarios of the river basin. The modelling of the basin focused on hydro-meteorological for a period 1990-2018 using HBV and the Eto calculator from FAO. To evaluate the model performance calibration and validation was performed using periods (1991-1995) and (2006-2010) respectively. The values obtained for the Model efficiency/NSE is **0.43**, Criterion coefficient **R2 0.57** and **KGE 0.477** for the calibration period and **0.39**, **0.41**, and **0.54** respectively for the validation period. It was concluded that streamflow trend of the basin was greatly affected by land use/ cover changes with more negative impacts evident.

BACKGROUND/CONTEXT

Most of the river basins in Africa face serious degradation (Cook *et al*., 2009). River catchment degradation is of concern in contemporary river basin management in tropical systems (Abell *et al*., 2008). This degradation is driven by increasing population pressure, which place a heavy burden on natural resources (Mosepele *et al*., 2018).

PROBLEM STATEMENT/RESEARCH QUESTION

Most of the anthropogenic activities in the country depend on the fresh water sources which are supplied from the lakes and rivers in various regions. But due to land use and land cover changes the hydrological cycle has been interrupted greatly because of human activities such as deforestation, increase in built up areas, more cultivated lands and several other land use changes. The changing use of land from sustainable to unscientific agriculture, overgrazing, and unlimited forests exploitation is pointedly shifting the hydrologic characteristics of the Katonga River basin.

Driving Questions:

i. How does the land use and land cover change occur for the period 1990 to 2018?

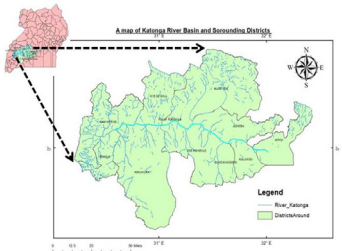
ii. How did the land use and land cover changes impact on the stream flow of River Katonga?

iii. How was the stream flow affected by future continuous land use and land cover changes of the river basin?

OBJECTIVES

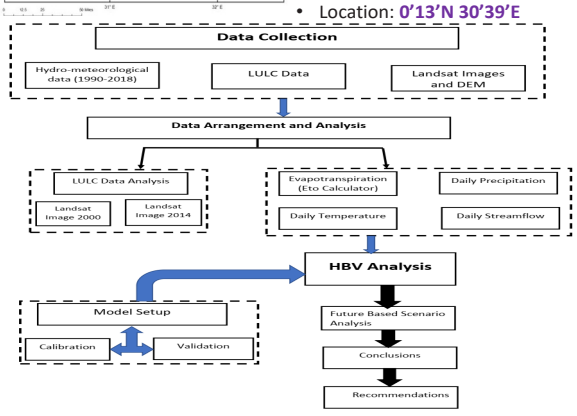
The main objective of this study was to predict and model the impact of land use/cover change on streamflow in Katonga River basin using HBV model.

METHODOLOGY



The River basin is located in the topography of 1500-2500 metres above sea level in south west side and 1100 metres above sea level towards Lake Victoria. The maximum temperature ranges from **28.6** to **28.70C.**

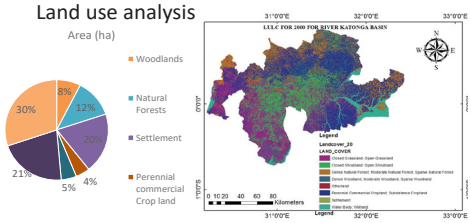
- Minimum temperature: **18.20C**
- Mean annual rainfall: **900-1500 mm** River length: **220km**
- Location: **0'13'N 30'39'E**



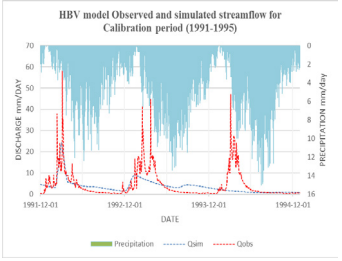
RESULTS AND DISCUSSION

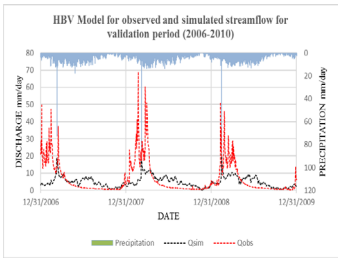
Land use analysis

Land use/Cover Class for 2000	Area (ha)	Percentage
Woodlands	1501064	8%
Natural Forests	2472365	12%
Settlement	3880308	19%
Perennial commercial Crop land	885612.8	4%
Subsistence Crop land	953128.5	5%
Water Body	4241091	21%
Wetland	6013436	30%

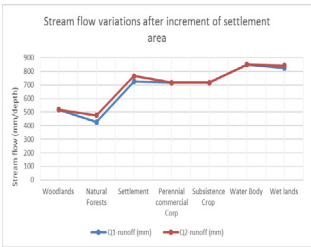


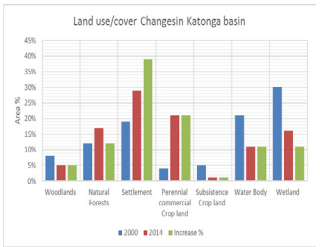
Calibration and validation of HBV Analysis





Future Land use and cover Scenarios analysis for Katonga River basin





CONCLUSION

- ❖ The study satisfactorily estimated how changes in land use and cover changes affect the stream flow volumes of the Katonga river basin.
- ❖ The HBV model analyzed the basin characteristics eliminating out the snow factor because it's not applicable in the area of study.
- ❖ Before application the model was calibrated for 5 years events (1991-1995) using the parameters as provided by HBV model and then validated for five events (2006-2010).
- ❖ The streamflow trends were simulated, with a demonstrated increase in settlement of 10% deducting from natural land forest and wet lands by 5% and a significant increase in streamflow was recorded in the basin.
- ❖ The changing use of land from sustainable to unscientific agriculture, overgrazing, and unlimited forests exploitation is pointedly shifting the hydrologic characteristics of the Katonga River basin.

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Impact of Community Participation on Sustainability of Water and Sanitation Projects in Rural Areas. Case Study of Musanze District, Northern Province of Rwanda

Graduate CV.
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Abstract

This research was conducted to evaluate the impact of community participation on sustainability of water and sanitation projects in rural areas where the services are usually significantly low compared to cities. Data was collected using questionnaires with projects beneficiaries and water and sanitation District officials. It was observed that sufficient attention was not given to community involvement in different stages of projects implementation hence the recommendation of incorporating the user centered design methodology in projects initial stages in order to involve the community and ensure project sustainability.

BACKGROUND/CONTEXT

- Still today, 3 out of 10 people in the world are without access to safe water and 6 in 10 homes lack safely managed sanitation (UNICEF, 2017).This shows how progress remains difficult, no matter how essential water is for human life.
- There are large inequalities when it comes to water and sanitation, developing countries are lagging behind, a big difference between the urban and the rural, and the rich and the poor neighborhoods, gender inequalities also.
- Rwanda's main challenge to achieve its 2020 target of 100% access to basic water supply and sanitation has been the funding gap for WASH services in scattered settlements in difficult and hilly terrain (MININFRA, 2017). In 2008, Musanze Distrit as the case study, was among the least served districts in the country in terms of water, sanitation and hygiene (WASH) services (Murtaza et al., 2017)

PROBLEM STATEMENT/RESEARCH QUESTION

Improved water and sanitation infrastructure that does not deliver is one of the major problems of the global water and sanitation challenge. However community participation is identified as one of the prerequisite for the improved performance of the services , hence this study.

OBJECTIVES

To assess the way sustainability of water and sanitation projects is being addressed at the initial stages, to assess community involvement in project planning, in project implementation and in project management

METHODOLOGY

➢Musanze District as the study focus is one of the 30 Districts of Rwanda, it has extremely challenging geographical conditions which make the implementation of water supply and sanitation facilities project activities very difficult

➢This study involved the primary data and secondary data:
The primary data involved quantitative and qualitative data
The tools used to collect the primary data included:

❖Closed and open ended and questionnaires addressed to the users of the public water and sanitation facilities;

❖Interviews to the District and Sectors' water and sanitation officials

The primary data was analysed using SPSS software
The secondary data was collected using relevant reports

Sample Size Determination

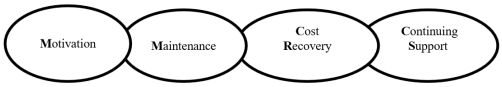
$$n=\frac{N}{1+N\,(e)^2}$$

N = the total population of the 3 villages
e = level of precision (0.050)
n = sample size
Source: Yamane (1967)

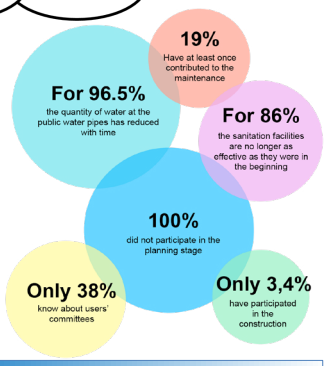
Projects Sites	Sample Size of Users	Water and Sanitation Officials
Gataraga	63	1
Gitega	65	1
Rwinuma	61	1
Total	189	3

RESULTS AND DISCUSSION

The literature suggested that the design of projects should include elements of sustainability at initial stages. In their study (R. C. Carter et al., 1999) they offer the ''sustainability chain,'' involving a four essential links to achieve sustainability:



It was noted that there are measures put in place at the District level to ensure community involvement and sustainability.
However among all the respondents:



CONCLUSION

- Sustainability issues we re inadequately addressed during initial stage of projects, and the sustainability of visited projects was at risk
- Sufficient attention was not given to community involvement in different stages of projects implementation including design, construction as well as operations and maintenance
- Rwanda has achieved one milestone by addressing sustainability and community participation in the water and sanitation policies, however much work is still needed to put that into effect.

RECOMMENDATIONS

- The planning stage should be given concerted efforts in order to incorporate the user centered design methodology for as to produce interventions that fully solve community problems
- People should be mobilized to build interest in sustaining the initiated project services
- Proper training and technical support at all levels and for all groups engaging in water and sanitation projects implementation and management should be given priority
- More emphasis should be placed on institutional support (re-training, resourcing, and reform) of the local Government (districts and sectors) in order to ensure proper application of the policies

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Measuring Innovation in the Water Sector to support Monitoring and Evaluation of Science, Technology and Innovation Strategy for Africa (STISA) 2024: The Case study of Sustainable Agriculture.

Graduate CV.

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Abstract

An Monitoring and Evaluation (M&E) tool was developed to measure innovation in the water sector for sustainable agriculture, which is one of the flagship programs of Science, Technology and Innovation Strategy for Africa (STISA) 2024. To achieve that objective, a desk review was conducted for a better understanding of innovation in agricultural water management. Also, an innovation measurement framework was developed and tested through a survey based on the Community Innovation Survey (CIS) model with a focus on product and process innovation within a reference period 2016 to 2018 inclusive, to public and private sector units. The feedback of the survey helped to modify and adapt the CIS questionnaire in the context of measuring innovation in water management in agriculture (sustainable) at the supply and demand side. The results showed that the framework could be applied to measure innovation in the public and private sectors, in line with the latest definition in the Oslo Manual, 2018. A set of key success indicators was derived from the results, which would help to quantify the innovation progress in the concerned domain. This framework is designed to be used for innovation measurement at the national level, and a guideline was proposed for its good use.

BACKGROUND/CONTEXT

Science, Technology, and Innovation (STI) are known as a multifunctional tool, able to boost the achievement of the continental goals in Africa. STISA-2024 is an AUC ten-year program aiming to fill the gap of STI demand to impact essential sectors such as "agriculture, energy, environment, health, infrastructure development, mining, security, and water, etc." At the same time, STISA-24 had been developed as a successor of the Consolidated Plan for Action (CPA) adopted in 2005. CPA suffered from the absence of a Monitoring and Evaluation (M&E) which made it difficult to demonstrate its achievements and the contribution of STI in addressing Africa's challenges, especially the contribution of research to solving the needs in agriculture, food and nutrition security, infrastructure, health, human capacity development, and poverty reduction. While existing studies are framing the monitoring and evaluation system of economic sectors and private enterprises, there is no specific framework to measure innovation in agricultural water in Africa. This study aims to develop a monitoring and evaluation tool to measure the innovation progress in the water sector, especially the water management for sustainable agriculture.

RESEARCH QUESTIONS

- ❑ What measurement framework is suitable to evaluate innovations of STISA flagship programs in the water sector for sustainable agriculture?
- ❑ How to harmonized and validate the developed measurement framework?
- ❑ What are the targeted key success and performance indicators that could be used to monitor and assess the agricultural water innovation in Africa?

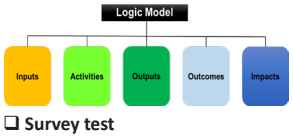
OBJECTIVES

❖ **To develop a monitoring and evaluation tool to measure innovation progress in the water sector for sustainable agriculture.**

i. To develop a suitable framework for sustainable agricultural water innovation measurement in Africa;
ii. To test the framework through a case study measurement of water innovations for sustainable agriculture in Africa.
iii. To provide appropriate performance indicators for innovation measurement in the water sector for sustainable agriculture.

METHODOLOGY

❑ Framework development



❑ Steps Towards the Framework

1. Defining Objectives for Water Innovation
2. Identifying Stakeholders
3. Defining Intended Outcomes and Impacts
4. Innovations activities
5. Defining the outputs
6. Defining the program inputs

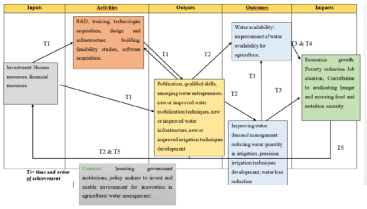
❑ **Survey test**

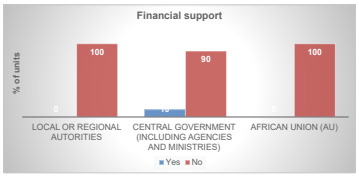
CIS model questionnaire, with a focus on **product and process Innovation**; The targeted populations are enterprises also called "units". Reference period: three years from 2016 to 2018 inclusive. The survey was conducted by addressing the developed questionnaire by email under google form, by phone, and face to face interview in order to increase the percentage of the respondent. The countries where units/enterprises were found are Algeria, Togo, Benin, Chad, and Rwanda.

❑ **Performance indicators** were derived from the findings after the survey; Also some reference documents were used as a guideline (OECD, 2013, 2015).

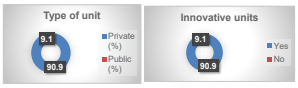
RESULTS AND DISCUSSION

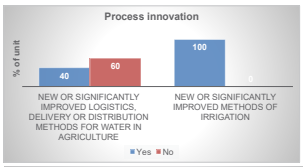
❑ **Developed Innovation Framework**

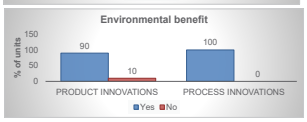




❑ **Test Survey Results**







❑ **Key success indicators**

- ➢ Merging/ Partnership
- ➢ Unit's geographical coverage scale
- ➢ Innovative units
- ➢ R&D and capacity building for innovations
- ➢ Ongoing or abandoned innovation activities
- ➢ Public and financial support
- ➢ Innovation cooperation
- ➢ Unit with environmental benefits

CONCLUSION

STISA 2024 is set as part of the AU Agenda 2063, to meet the need of STI. Its expected outcome is to impact sectors like agriculture and water among others, but can not be measurable without an M&E tool.

The M&E is composed of:

- ❑ Measurement framework
- ❑ Survey questionnaire based on the CIS model with a focus on product and process innovations, and
- ❑ Key performance indicators.

This tool is accompanied by a short guideline for its use.

The logic model is a nonlinear model, we recommend a real engagement of all the stakeholders in order to avoid the risk of non-achievement.

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The Impact of Land Use and Land Cover Change on Water Resources and its Implication for Smallholder Farmers in Rwanda. A case study of Lake Cyohoha

Graduate CV.

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Abstract

Lake Cyohoha North currently faces decline in water quantity and quality. Lake Cyohoha is the primary source of irrigation water for the community and sustains other socio-economic benefits. The study utilized remote sensing approach to assess the impacts of LULC supplemented by socio-economic survey within the catchment. Remote sensing results reveal significant reduction in forests and open land and increase in agricultural land, -8.58%, -17.26% and 28.19% net change respectively which affected 61.04% and 29.37% decrease in wetland and the lake size. Also, socio-economic survey showed that reduction in crop and fish production, coupled with prolonged droughts, increased the number of local communities eating once a day to 80%. Finally, the DPSIR Framework was developed.

BACKGROUND/CONTEXT

Anthropogenic activities have affected the quality and quantity of most lakes across Africa (Zhu et al., 2019) since the mid-twentieth century. In Rwanda, surface water quality and quantity depletion has been one of the major challenges for the population. Poor management of the lake Cyohoha catchment, consequently, coupled with repeated droughts enhanced degradation and food insecurity for farmers (UNEP, 2007).

PROBLEM STATEMENT/RESEARCH QUESTION

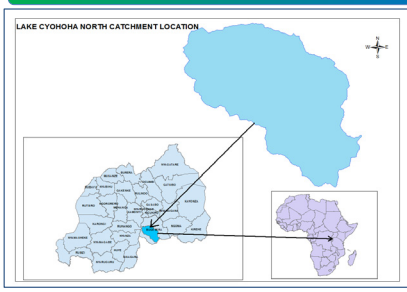
The problem has manifested itself through poor management of the catchment which promoted excessive growth of water hyacinth and other aquatic weeds to cover a wide surface of the lake and resulted in extreme reduction of the lake size and quality of water.

Question: What is the relationship between land use, land cover, and changes on Lake Cyohoha between 2000 and 2018?

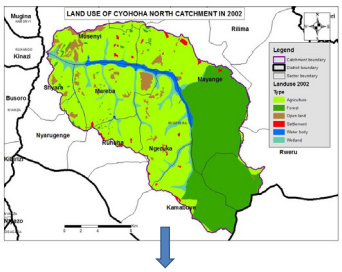
OBJECTIVES

To investigate the effects of LULC change on Lake Cyohoha using remote sensing, in order to minimize unsustainable development practices and trigger better practices on the management of water resources.

METHODOLOGY



- Location: 2.2302° S, 30.0752° E
- Lake Cyohoha North is estimated to 25km long and 0.30-1 km wide.
- Series of swamps up to 9 km separate the lake and the river Akanyaru.
- The dominant vegetation is dry savanna.



- Research design: Quantitative & qualitative method
- Sampling technique: Purposive sampling
- Sample size: 100 smallholder farmers, 10 sector land managers and 2 officers (RWFA&REMA)

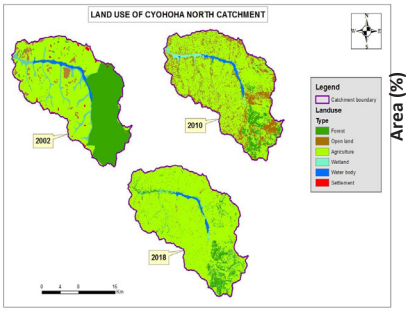
Detection and analysis of drivers of LULC changes were conducted through a desktop study of LULC maps using Geographical Information Systems (GIS). Also, socio-economic survey was employed to study LULC change impact on smallholder farmers.

Spatial analyst tools → Reclass → Reclassify → Processed image

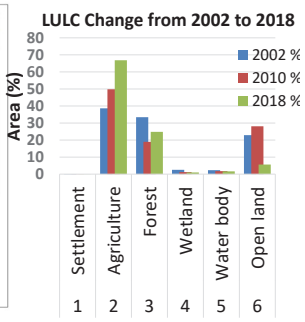
Flowchart of data processing in ArcMap 10.5

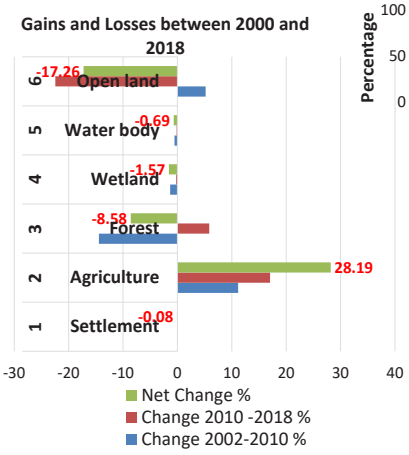
Interviews and documentation → **DPSIR Framework**

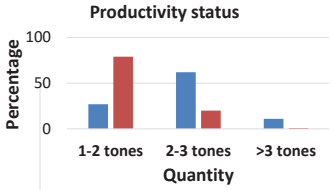
RESULTS AND DISCUSSION



LULC change of Lake Cyohoha North Catchment 2002, 2010 & 2018







Driving factors of LULC change were grouped into proximate and underlying causes (adapted DPSIR framework, cfr thesis) as a fundamental prerequisite for developing effective policy responses.

CONCLUSION

- Open lands and forests had the highest loss (-17.26%) and (-8.58%) mostly due to the increased demand for food security because of population growth.
- Agricultural land had an increase up to 28.19%, owing to the government's policy of subsidizing agricultural inputs and agriculture transformation to fight food insecurity.
- Analyses reveal that poor management practices of the catchment had negatively impacted the Murago wetland and Lake Cyohoha North, 61.04% and 29.37% decrease in wetland and the lake size.
- The overall production was 2-3 tones (62%) before 2000 and became 1-2 tones (79%) in 2018, which explains the reduction in number of meals per day where 80% eat once a day.

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The Right of Use and Economics of Irrigation Water in Uganda: A Comparative Analysis of Small-Scale Irrigation Schemes in Eastern, Northern and Western Uganda

Graduate CV.

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Abstract

Utilization of water resources for the purpose irrigation could be a means of increasing agricultural productivity in Uganda other than depending on rain-fed agriculture in the face of climate change; to meet the ever-increasing demand for food and the need to eradicate poverty. In this study, a social survey was conducted, and a cross-sectional research design was adopted where 46 farmers and 64 farmer groups were randomly surveyed from 16 purposively selected Small scale Irrigation Schemes in Eastern, Northern and Western Uganda. It was observed that not all these schemes were exhibiting the same level of productivity and profitability with others not being able to recover the return on initial investment by means of their current production methods while others are able to recover the initial cost of investment after a period of just 3.2 years keeping all production factors constant.

BACKGROUND/CONTEXT

According to National Agricultural Census conducted between 2008 and 2009 by UBOS; it was reported that Irrigation was being practiced by only 0.9% of the approximately 3,600,000 Agricultural Households that responded. This implied that agriculture was predominantly rain-fed. Eastern region registered the highest number of Agricultural Households with 53.5% of all households surveyed.

PROBLEM STATEMENT/RESEARCH QUESTION

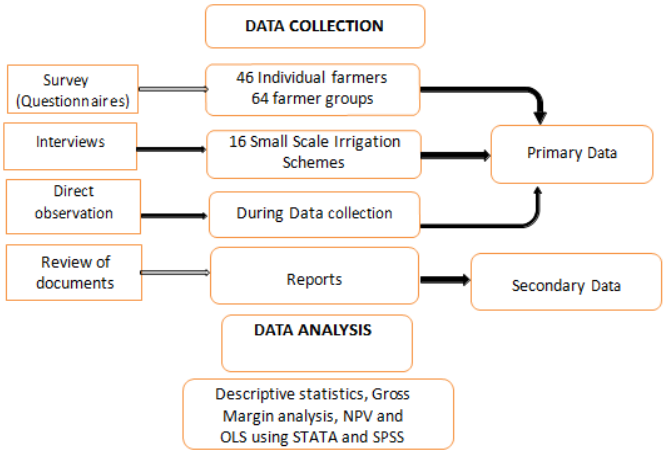
Effects of global climate change on crop production is alarming; in the year 2010, drought accounted for 38% loss in beans production and 36% loss in maize production while in 2014, Uganda registered Uganda shillings 2.8 trillion loss of Gross Domestic Product (GDP) equivalent to 8% and 87% loss to agro-based industries (Mwaura et al 2014).

Despite the low agricultural crop production being realized in most parts of Uganda as a result of relying on rain-fed agriculture, farmers have shown laxity in adopting irrigation yet the country has a huge irrigation potential that is evident with numerous fresh surface water sources consisting of lakes, rivers and swamps covering over 15% of her total surface area; on the contrary the ratio of cultivated area under irrigation to the irrigation potential is only 0.5%.

OBJECTIVES

i. To examine the profitability of using irrigation water in Uganda.
ii. To examine the sustainability of small-scale irrigation schemes in Uganda.
iii. To investigate the factors influencing productivity of irrigation water in Uganda.
iv. To determine farmers' willingness to pay for Irrigation water in Uganda.
v. To assess the implications of water user rights and costs on adoption of irrigation in Uganda.

METHODOLOGY



RESULTS AND DISCUSSION

Profitability analysis for watermelon and tomato crops in Andibo and Bukatabira SSISs

Crop.	Area (acres) grown	Gross return per season (shillings)	Gross return for 7 acres per season (shs)	Gross return for 7 acres per year (shs)	Production cost per year for 7 acres (shs)	Net return per year
Bukatabira						
Tomato	2.5	19566300	54785640	164356920	43,050,000	121,306,920
Water melon	1.9	5460300	20116895	60350684	25,620,000	34,730,684
Andibo						
Tomato	0.5	2225400	31,155,600	93466800	43,050,000	50,416,800
Water melon	1.5	16173000	75,474,000	226422000	25,620,000	200,802,000

Economic analysis of sustainability of Bukatabira and Andibo SSISs

Particulars	Bukatabira		Andibo	
	Tomatoes	Watermelon	Tomatoes	Watermelon
NPV (Shs.)	1,905,395,295	173,870,575	358,336,000	3,366,040,000
BCR	4.6	1.3	1.5	6.2
PBP	4.3	14.9	12.9	3.2
ARR	23.3	6.7	7.7	30.8

Tobit regression analysis of sustainability of SSISs

Variables	Coefficient	Std. Err.	P>t
Affordable system	6.453	2.133	0.001
Reliable water supply	-2.636	0.919	0.007
Enough water availability	0.697	0.248	0.015
Access to investment funds	0.401	0.546	0.0081
Labor availability	1.940	0.602	0.000
Availability of extension services	0.516	0.575	0.049
Security	0.983	0.410	0.087
Quality of inputs	0.021	0.117	0.000
Conducive land and water policy	0.388	1.512	0.197
Benefit on farmer's investments	0.289	4.685	0.000
Constant	1.058	0.528	0.002
Number of Obs = 46		Prob > chi² = 0.0000	
Log likelihood = -951.91224		R^2 = 0.815	

Factors Influencing Farmers' Willingness to Pay for Irrigation Water (OBJ 4)

Variables	Coefficient	Standard Errors	P value
Age	-0.076	0.024	0.014
Gender	0.036	0.044	0.414
Household size	-0.013	0.009	0.066
Education level	0.056	0.037	0.009
Off farm income	0.119	0.082	0.002
Access to credit	0.074	0.043	0.000
Land size	-0.694	0.206	0.071
Rate of rain fall	-0.967	0.296	0.000
Money gained from harvest	0.391	0.676	0.067
Money paid per season	0.035	0.028	1.923
Cost of Inputs	-0.766	0.322	0.921
Constant	1.802	0.508	0.000
Number of observations = 46		Prob>F = 0.0000	
F (11,34) = 83.35		R^2 = 0.7372	

Factors influencing productivity of irrigation water (OBJ 3)

Using Ordinary Least Square (STATA 13)	Variables	Coefficient	Standard Errors	P value
	Land size/plot	0.649	0.319	0.084
	Labor source	-0.447	0.305	0.057
	Family size	1.295	0.211	0.000
	Gender	0.178	0.055	0.086
	Age	-0.621	0.176	0.073
	Education level	0.162	0.232	0.005
	Fertilizers	0.191	0.077	0.001
	Type of irrigation system	0.774	0.267	0.000
	Volume of water used	0.995	0.09	0.013
	Off farm income	0.749	0.361	0.052
	Market price of produce	-0.298	0.583	0.000
	Distance to Market	-0.138	0.137	0.077
	Access to agricultural credit	0.697	0.213	0.000
	Farming experience	0.319	0.304	0.000
	Extension Service	1.421	0.113	0.035
	Cooperative membership	0.224	0.306	0.081
	Constant	0.774	1.402	0.000

Implications of water user rights and costs on adoption of irrigation in Uganda (OBJ 5)

Variables	Coefficient	Standard Error	P>|t|
Volume of water supplied	-0.245	7.743	0.109
Price of water for irrigation	0.728	0.220	0.000
Extension services	1.461	2.925	0.000
Training opportunities	1.527	4.571	0.020
Access to agricultural information	0.230	0.748	0.000
Off farm production	0.338	0.555	0.000
Contribution rate on maintenance	0.497	1.000	0.059
Personal serving	0.412	0.493	0.011
Cooperative membership	0.932	0.682	0.000
Soil fertility test	-0.694	3.735	0.481
High agricultural productivity	1.325	2.077	0.078
Constant	1.031	0.831	0.000
Number of obs.	46		
LR chi2(11)	114.33		
Prob > chi²	0.00		
Pseudo R^2	0.09		
Log likelihood	-1267.24		

i. Out of the 46 model farmers surveyed, 76.09% were males while 23.91% were females. The low number of women may hinder the productivity, profitability and sustainability of SSISs.
ii. Majority of the farmers (89.13%) were married.
iii. Tomato crop is more profitable at Bukatabira SSIS while watermelon crop is more profitable at Andibo SSIS.
iv. Factors such as family size, level of education, fertilizer use, type of irrigation system and farming experience have positive significant influence on productivity whereas factors like labor source, age, price of produce, distance to market and access to agricultural credit have negative significant influence on the productivity of irrigation water.
v. Four factors namely; rate of rainfall, level of education, off farm income and access to credit significantly influenced farmers' willingness to pay for irrigation water.

CONCLUSION

1. The high NPV of 1,905,395,295 shillings and BCR of 4.6 for tomato at Bukatabira SSIS and NPV of 3,366,040,000 shillings and BCR of 6.2 for watermelon at Andibo SSIS indicated that it was worth investing in irrigation water.
2. Factors such as affordable system, labor availability, quality of inputs used, benefit on farmer investments and access to investment funds have high significance and contribute positively to the sustainability of SSISs.

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Unlocking Finance for Advanced Irrigation Technologies in Chad

Graduate CV.

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Abstract

Agriculture in most of the countries in Sub Saharan Africa is rainfed and where irrigation is practiced inadequate surface method is used. This research used a mix method to analyzed current socio-economic and environmental setups of Djaramaya scheme. Appraisal investment techniques were used to assess the sustainability of drip irrigation technology under high-value crop development. The results showed that 45% of the studied area is suitable for Advanced Irrigation Technology. The estimated NPV (positive) and C/B ratio (=2.76) at 12% discounted rate suggested that the investment in drip under tomato crop is economically viable and farmers would be able to recover the initial investment (IRR=25%) at the end of the third year. Moreover, Guerdane's Public-Private Partnership (PPP) arrangement in Morocco was found to be suitable for the viability of Djaramaya scheme from which best practices can be transferred to Chad.

BACKGROUND/CONTEXT

Nearly 236 million in Sub Saharan Africa (SSA) were undernourished in 2017 due to food shortages (FAO, 2018). The global crop production is estimated to double by 2050 to meet the pressing food demand and end global hunger (Valin et al., 2014). Irrigation remains a crucial component of agriculture, where cereal production in the world would drop by 20% without it (Ja¨germeyr et al., 2015). Most of previews studies have concentrated on the aspects of efficiency of irrigation systems; However, little studies have been carried out in translating the research into practice by critically assessing the adaptability of Advanced Irrigation Technologies together with an appropriate financial model.

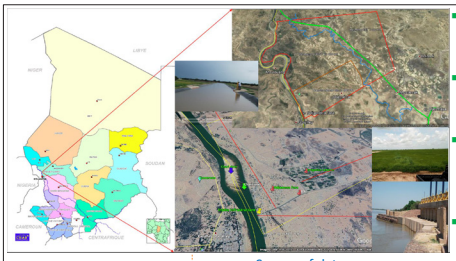
PROBLEM STATEMENT/RESEARCH QUESTION

In Chad, irrigation accounts for less than 1% (out of 6% of cultivated lands), despite the availability of fertile soils (39 million hectares) and abundant water resources (MARE, 2015). During the last decade, the government have initiated many large scale irrigation project, however, due to poor planning and implementation, inadequate financial model as well as high operation and maintenance costs and farmers inclusiveness, several completed and ongoing projects failed to reach their initial goals. Djaramaya project, case study of the current research, is one of the schemes that faces these challenges.

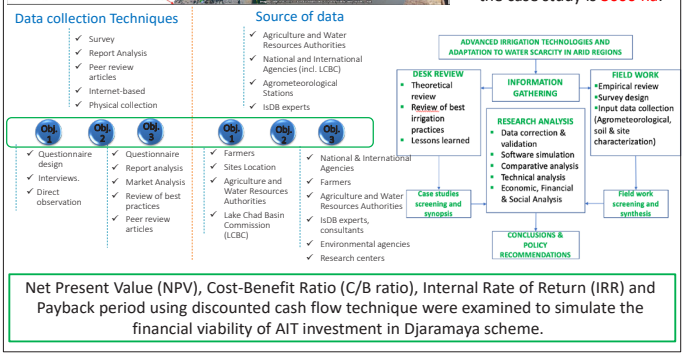
OBJECTIVES

To develop a conceptual Advanced Irrigation Technology (AIT) under high-value crop development for adaptability in arid areas in Chad by critically analyzing the sustainability of the proposed AIT in Djaramaya irrigation scheme.

METHODOLOGY

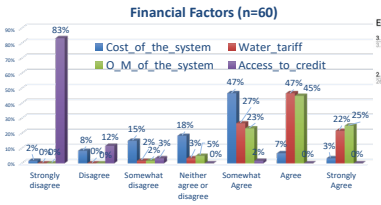


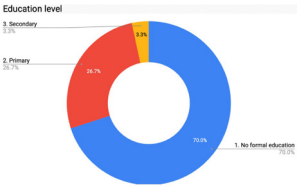
- Djaramaya, located at 45 km North of the capital city of N'Djamena.
- Accessible via N'Djamena - Djaramaya - Dandi National road.
- The project covers a total area of 20 000 ha located on both sides of the National road.
- The total area concerned by the case study is 3000 ha.



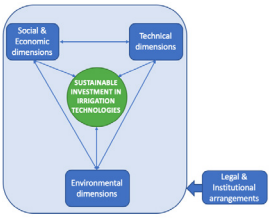
Net Present Value (NPV), Cost-Benefit Ratio (C/B ratio), Internal Rate of Return (IRR) and Payback period using discounted cash flow technique were examined to simulate the financial viability of AIT investment in Djaramaya scheme.

RESULTS AND DISCUSSION

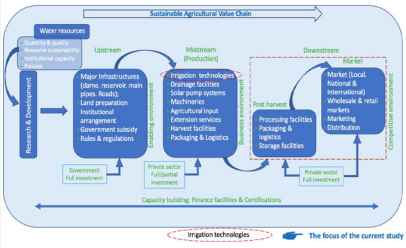




Type of Irrigation technology	Cropping patterns	Percentage (%)	
		Wet season	Dry season
Surface Irrigation technologies	Staple crops	82,81%	0
Advanced irrigation technologies	High value crops	17,19%	44,66%
Total		100%	45%



Financial Indicators	Values
Net Present Value (USD)	8 360,57
Present value of benefits (USD) at 10%	17 872,67
Present value of costs (USD)	9 512,11
Benefit/Cost (B/C) Ratio	1,88
Internal Rate of Return (IRR)	24%
Payback period	3 years
Discount rate	10%



CONCLUSION

- The Chadian government can promote AIT for sustainable agricultural development by establishing regional programs encouraging farmers' investment in such technologies. A strong institutional arrangement could highly attract and give confidence to private sector to involve in the country's irrigation development programs.
- The establishment of a PPP framework in the irrigation sector requires a consistent technical assistance in creating an enabling environment for the private sector participation (policies, institutional and legal framework, risks and their mitigation, bank guarantees, insurance, etc.)
- The government of Chad, through the ministry of agriculture, can learn from the Guerdane PPP model in Morocco or the Megesh-Seraba in Ethiopia by initiating some capacity building programs with the support of its development partners.

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Water Quality Monitoring and Vulnerability of the Community to Cholera: A Case Study of Chitungwiza, Zimbabwe Urban Area

Graduate CV.

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Abstract

Chitungwiza is the third populated city in Zimbabwe, battling with high population pressure straining the dilapidated water and sanitation infrastructure, hampered with shortage of water. People has resorted to use ground water, which the study examined 13 hand dug wells analyzed for bacteriological analysis, 7 boreholes were analyzed for physio-chemical. Document surveys on community water supplies indicators such as quality, quantity, cost, non-revenue water, and status of public sanitation infrastructure was conducted. Results analyzed showed high levels of pH and high nitrates in 1 borehole was above WHO standards. 90% of the public toilets were dysfunctional and 75.4% water coverage, 65.5%non-revenue water and lack of public policy on water quality monitoring.

BACKGROUND/CONTEXT

77.923 cases of cholera, 1227 cholera deaths recorded in East and Southern Africa in 2018. 90% cholera cases connected to drinking contaminated water. Influx of urban population, straining the water and sanitation infrastructure. Poor surveillance systems on water quality monitoring plus dilapidated water infrastructure coupled with shortage of water supply which has led to water rationing. Need to protect public health, aligns with SD1 &6. Source: UNICEF., 2018; WHO., 2011

PROBLEM STATEMENT/RESEARCH QUESTION

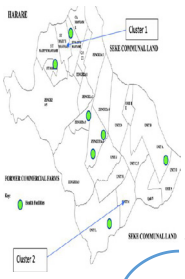
Cholera outbreak deaths were 177 in Zimbabwe, need to break the cycle of cholera outbreak, through strengthening the water quality surveillance system. Growing population leading to increase in demand of water, inadequate public health knowledge on water collection, handling, transportation and storage.

What is the water quality status from the boreholes and shallow wells, and public sanitation is it exposing the community to cholera.

OBJECTIVES

To monitor water quality and recommend control mechanisms to protect community water supply sources and identify public sanitation problems and forward mechanisms to reduce vulnerability of the community to cholera outbreak.

METHODOLOGY



- Chitungwiza third populated city in Zimbabwe.
- population 330 310 census (2010)
- Water problems: water rationing, cholera outbreak

Water quality monitoring

- 13 shallow wells, bacteriological analysis,
- 7 boreholes chemical analysis

Community survey

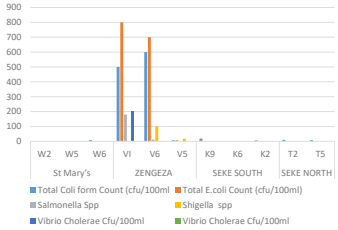
- Water supply indicators such as quality, quantity, cost, non revenue, document survey.
- Survey on public sanitation infrastructure
- Mixed research qualitative and quantitative data collection such as interviews, questionnaires

Proper water sources management. Improved public health knowledge on water collection, transportation, storage practices

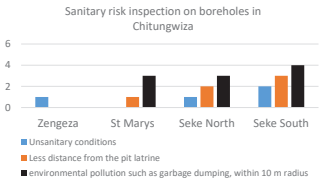
RESULTS AND DISCUSSION

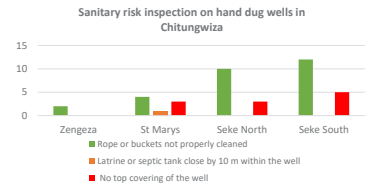
Water quality results from boreholes, wells

Water parameters	Maximum	Minimum	Mean	Standard Deviation	WHO Guideline Value
PH	7.44	5.49	6.54	0.65	6.5 – 8.5
Color	0	0	0	0	15
Turbidity	105	0.01	11	25.45	5
Chloride	29.6	0.42	18.6	7.35	600
Sodium	120.08	100	29.6	8.793	200
Nitrate	96.52	24.25	39.11	28.18	50
Total hardness	211.1	200.1	205.26	4.95	500
Sulphate	580	3.17	50.6	2.079	250
zinc	0.2	0.1	0.18	0.04	3.0
Iron	0.3	0.1	0.13	0.08	0.3

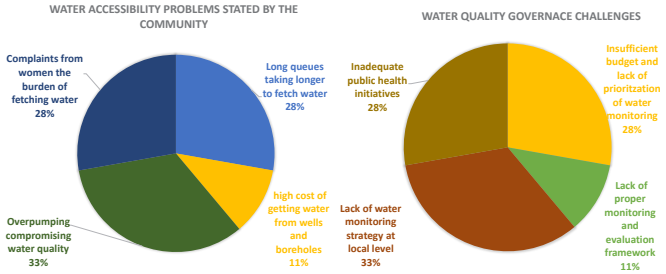


Community Sanitary risk assessment





Water accessibility and governance challenges



CONCLUSION

- 90% of the public toilets not functioning posing a serious risk to cholera outbreak. Need for public private partnership to rehabilitate the water and sanitation infrastructure
- High non revenue of 65.4%, and low water coverage 0f 75.4%.
- District has a high pH above WHO Standards and high sanitary risk. Need for public health education of best practices on water collection, handling, transportation and storage.
- Gender disparities women more involved in water collection and no provision to allow access to water for old people and disabled.
- No lack of frequent water quality monitoring on water sources. Need for a water safety plan.

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Water Quality Indices as Important Tools for Water Quality Assessment in WWTP: The Case of the Waste-water Treatment Plan of Ain El Hout Tlemcen

Graduate CV.

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Abstract

The scarcity of conventional water resources represents for Algeria a major concern. Considering the vulnerability of available water resources to the impact of climat change, population growth as well as socio-economic factors, a situation of severe water scarcity occurs. This project seeks to study the feasibility of reusing the treated domestic wastewater for agricultural purposes as an adaptation measure to climate change. The reuse of treated wastewater represents the alternative for the preservation of the available water resources and the promotion of the agricultural sector. The present study is intented to calculate water quality index (WQI) of an urban wastwater treatment plan, in Ain El Hout in Tlemcen town , in order to ascertain the quality of water used in agriculture, to analyze the water quality parameters in discharged effluents and to assess the water quality indices for the effluents discharged from WWTP.

BACKGROUND/CONTEXT

In regions suffering from water scarcity, wastewater is no longer considered as waste to be disposed but as an integral part of potential water resources. Algeria is presently looking at improving water availability by adopting a new water resources policy and new alternatives that enable to ease the crisis. Treated wastewater represents a promising alternative that is not only constantly available but also increasingly available, with the development of cities, tourism and industry. In the agricultural sector, reuse of wastewater is a technique that adds to the value of the water resources while it protects the environment (Bahri et al 2012). According to the National Sanitation Office (2013) the quantities of water treated and reused in agricultural irrigation, reached in 2013 a volume of 19 million m3 for the irrigation of 12,000 ha. Algeria has published in this framework a ministerial decree establishing the National standards of the use of treated wastewater for agricultural purposes.

PROBLEM STATEMENT/RESEARCH QUESTION

What is the physico-chemical quality of the treated wastewater from the WWTP of Ain El Houtz? What are the hazardous material existing in the wastewater? And What is the water quality indices to detect the pollution level ?

OBJECTIVES

The main objective of this project is to assess the performance of the WWTP with respect to the removal of physical and chemical pollutants and evaluate the quality of the water produced from it through comparison with the required standards using the WQI and , then Propose the different processes for prevention and rehabilitation for WWTP.

METHODOLOGY

Case study: The wastewater The treatment plant of the city of Tlemcen is located north of the capital "Tlemcen Ville", west of Chetouane "Daïra" on the Route of Ain El Hout designed for a population of 150 000 eq / hab of a capacity of 30,000 m3 / d, it is carried out National Office for Sanitation.

Description of the treatment processes of the wastewater

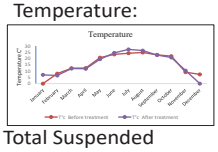
Water Quality Analysis:

In order to assess the quality of the treated wastewater, a series of analyzparameters were carried out. Sampling of the treated wastewater has been done using automatic samplers. The analyzes were carried out in the laboratory of the plant. The physico-chemical parameters that are usually analyzed in the laboratory are: Temperature, pH, Electrical conductivity, Total dissolved salts (TDS), Total suspended matter (TSM), Dissolved oxygen (DO), Biological oxygen demand (BOD5), Chemical oxygen demand (COD), Phosphates (PO43-). Nitratenitrogen (NO3-N), Ammonium nitrogen (N-NH4+).

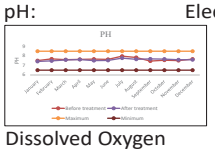
RESULTS AND DISCUSSION

Physico-Chemical Parameters results (2016):

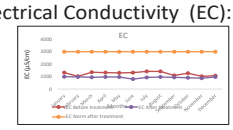
Temperature:



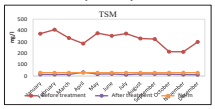
pH:



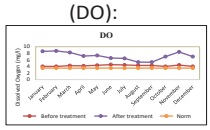
Electrical Conductivity (EC):



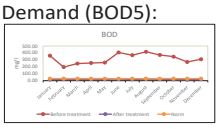
Total Suspended Matters (TSM):



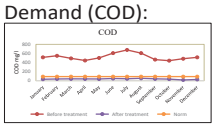
Dissolved Oxygen (DO):



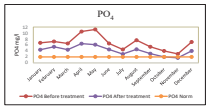
Biological Oxygen Demand (BOD5):



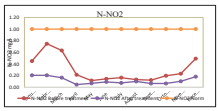
Chemical Oxygen Demand (COD):



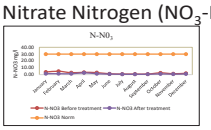
Phosphates (PO_4^{3-}) :



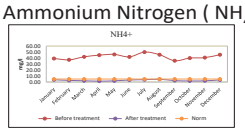
Nitrite- Nitrogen (N-NO2)



Nitrate Nitrogen (NO_3-N):



Ammonium Nitrogen (NH_4^+-N):



Water quality index (WQI):

Definition : Water quality index provides a single number that expresses overall water quality at a certain location and time, based on several water quality parameters. **Calculation : WQI=∑ q_n Wn/ ∑Wn**

The quality rating or sub index (q_n) : $q_n = 100[V_n - V_{io}] / [S_n - V_{io}]$ and $Wn = K/Sn$.

Wn= unit weight for the n^{th} parameters. **Sn**= Standard value for n^{th} parameters **K**= Constant for proportionality.

Results:

WQI using WHO standards : WQI=271

WQI using Algerian standards WQI= 74.7

WQI	WQS	Usage Possibilities
0-25	Excellent	Drinking, irrigation, industrial
26-50	Good	Drinking, irrigation, industrial
51-100	Poor	Irrigation, industrial
76-100	Very Poor	Irrigation
Above 100	Unsuitable for drinking and fish culture	Proper treatment is required before use

CONCLUSION

The study focused on the interpretation of the physico-chemical data and from it we can conclude that the quality of the treated wastewater is satisfactory for the reuse in irrigation. But concerning the WQI calculations, we can conclude that the treated Water could not be used for drinking. However, this treated water could be used for irrigation according to Algerian standards. It is worthnoting that this treated water don't follow international WHO standards and it can not be used either for drinking or irrigation.

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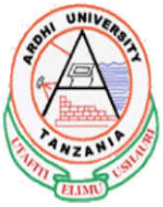

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