African Union

Institute for Water and Energy Sciences

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

Book of Master Thesis Posters

Edition 2020

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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 fifth cohort of the Pan African University Institute of Water and Energy Sciences (including climate change) (PAUWES). This book summarizes the research works of the graduates successfully completed in different African countries despite the unprecedented COVID-19 pandemic context. It is a snapshot of the graduates' expertise developed these last two years in their respective training programmes at the institute, moreso during their master thesis research. With a practice-oriented approach, the different research projects addressed specific challenges identified on the continent on the topics of water, energy, climate change, and nexus in the continent and aligned with the research priorities of the institute's Research Agenda. Also, they were conducted on different case studies in all the five regions of the continent with engineering and policy approaches respectively.

To ensure the effective contribution of our graduates in the development of the continent through the application of the competencies acquired in different domains related to water, energy, and climate change while allowing a smooth transition to the labor market, this Book was designed to share and disseminate the students' profiles and expertise with the different stakeholders in the water and energy sectors on the continent. It contributes to increase graduates' visibility and provide stakeholders on the continent with relevant information on their know-how and expertise for their better integration in the job market.

This achievement so far could not have been possible without the unwavering support of the PAUWES' project partners - 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); and the continuous collaboration and commitment of all research and institutional partners involved in one way or another in the frame of the master thesis research particularly in this COVID-19 pandemic context.

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 under the supervision of Dr. Erick Gankam Tambo leading the Research Unit at PAUWES.

We would like to thank 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 especially in this unprecedent COVID-19 pandemic context. These institutions include:

Policy and Development Institutions

- The African Observatory of Sciences Technology and Innovation of the African Union
- The African Water Association
- The National Agency of Renewable Energies and Energy Efficiency of Burkina Faso (ANEREE)

Research Institutions

- Center for Development Research- University of Bonn, Germany
- Reiner Lemoine Institute, Germany
- Santiago de Compostela University. Sustainable Energetic Application Group (CLRLA-UNESCO), Spain
- West African Science Service Centre on Climate Change and Adapted Land Use, Burkina Faso

Private sector

- GVE Projects Ltd, Nigeria
- RED+ HUB, Kenya
- Hydroconcept, Senegal

Academia and Universties

- Centre for Sustainable Development, Lund University, Sweden
- Covenant University, Nigeria
- Eagerton University, Kenya
- Ethiopian Institute of Water Resources, Ethiopia
- Gloab Urban Studies, Berlin, Germany
- Ibn Zohr University, Morocco
- International Institut of Enginnering of Water and Environment- 2iE, Burkina Faso
- Jimma Institute of Technology, Ethiopia
- Jomo Kenyatta University of Agriculture and Technology, Kenya
- Kibabi University, Kenya
- Kwame Nkrumah University of Science and Technology, Ghana
- Lund University, Sweden
- National Institute of Water, University of Abomey Calavi
- Faculty Institute of Agricultural Sciences, Demoratic Republic of Congo
- Makerrere University, Uganda
- Namibian University of Science and Technology, Namibia
- Omdurman Ahlia University, Sudan
- University of Alexandria, Egypt
- University of Nairobi
- University of Science and Technology Mohamed Boudiaf, Algeria
- University of Sfax, Tunisia
- University of Tlemcen, Algeria
- University of Zambia, Zambia
- University Sidi Mohamed Ben Abdellah, Morocco

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.

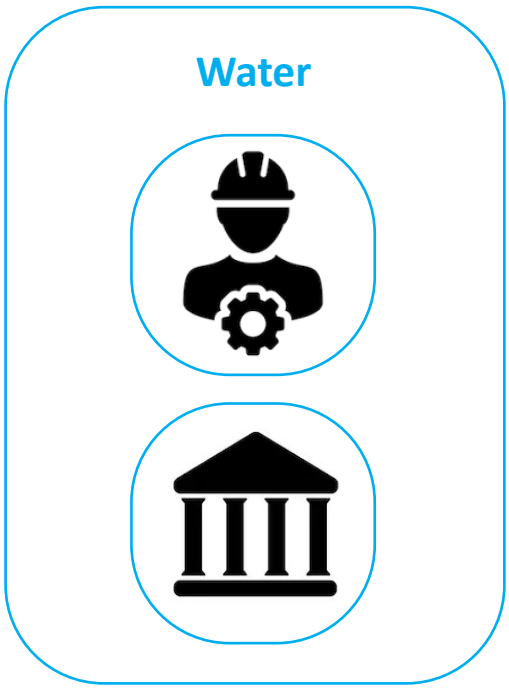
PAUWES offers four degree programmes

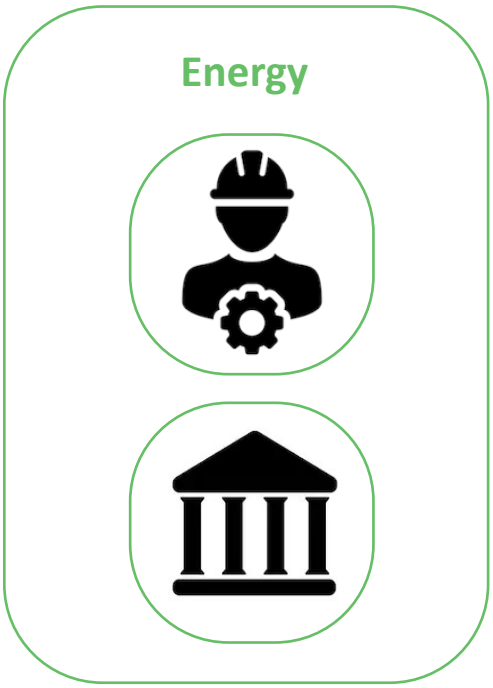
Master of Science (M.Sc.) in Energy:

- 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

Link to the Research Agenda

PAUWES

General information

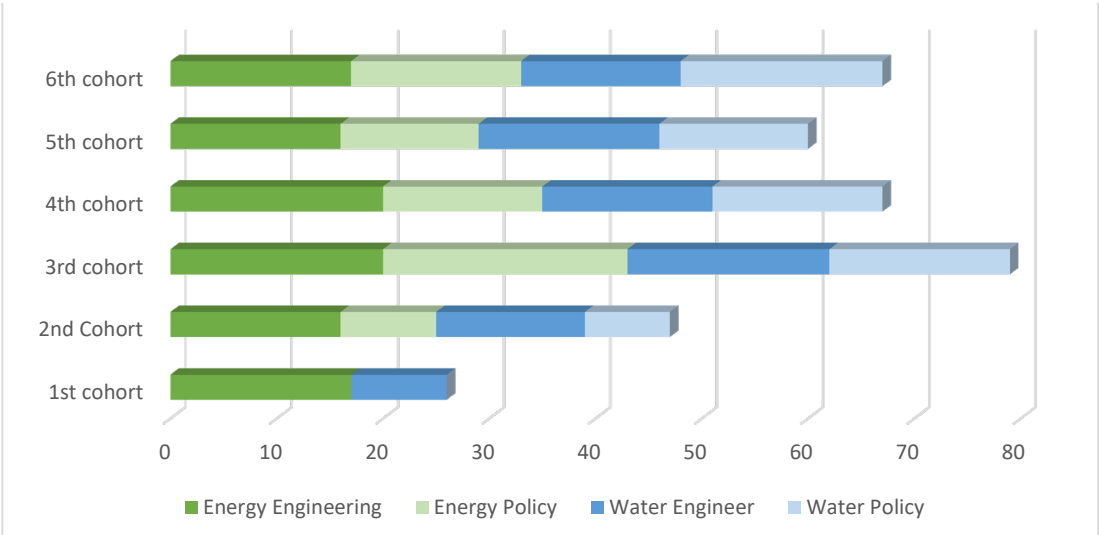
Since its effective operation in 2014, PAUWES has enrolled 346 students from at least 34 African Union member states with a female gender representation of about 33%. So far, five student cohorts have graduated totalling to 278 students, with the most recent graduation the fifth cohort held in early Dcember 2020. The sixth cohort of 67 students, are currently undertaking their courses and are expected to graduate in the fall of 2021.

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

Cohorts general information

1st cohort	2nd cohort	3rd cohort	4th cohort	5th cohort	6th cohort
- 26 students - 46% Gender - 12 countries	- 47 students - 24% Gender - 21 countries	- 79 students - 16% Gender - 25 countries	- 67 students - 41% Gender - 28 countries	- 60 students - 50% Gender - 27 countries	- 67 students - 38% Gender - 29 countries
2014	2015	2016	2017	2018	2019

Students distribution per track and per cohort

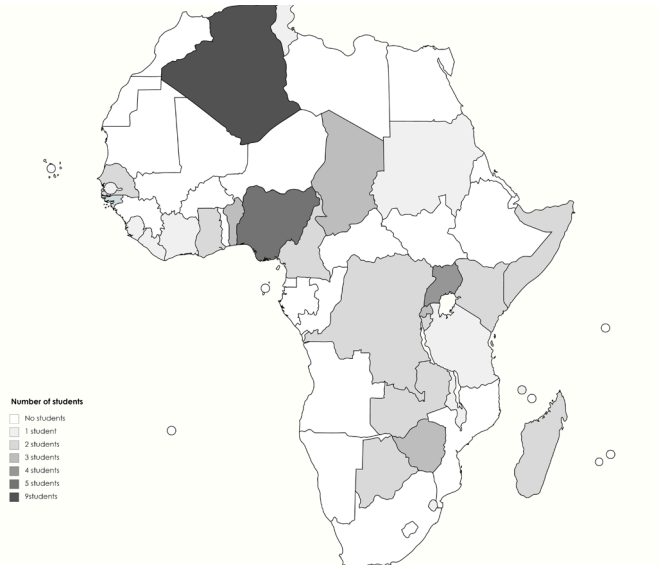


Graduates Class of 2020

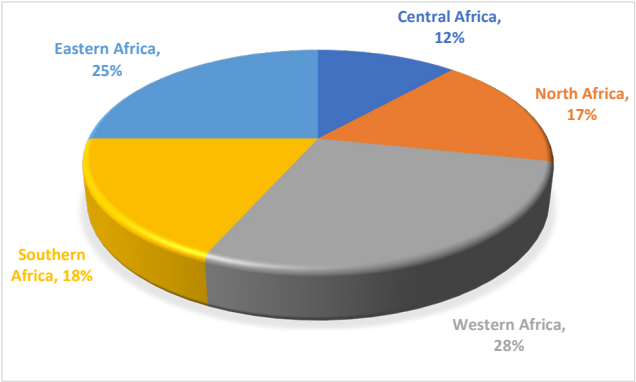
General information

The Graduate class of 2020 is the fifth cohort of the institute. It comprised 60 students from 27 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 cohort was recruited with a **perfect gender balance**. The charts below summarize the general information on the cohort.

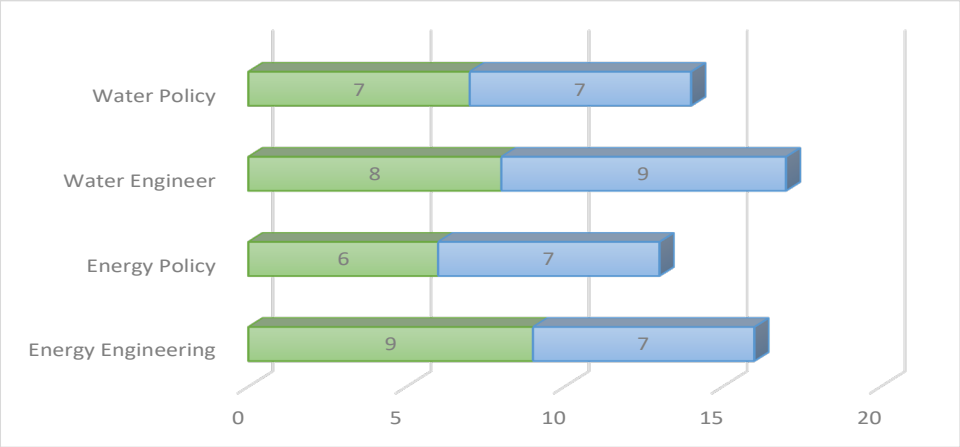
Students nationalities



Students regional distribution



Students' gender and track distribution



Graduate Class of 2020

Mobility and research

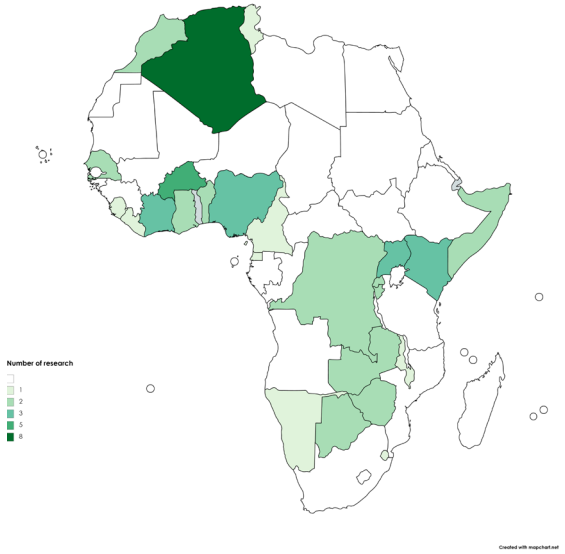
This Book of Master Thesis Posters is dedicated to the PAUWES graduate class of 2020. It presents a short summary of the topics addressed by the graduates during their master thesis research in poster format. The reseach works conducted during the master thesis addressed different issues and challlenges on the continent in line with the research priorities of the institute in the areas of energy, water, climate change and nexus research.

Mobility and continent coverage

Despite the unprecedant context of the COVID-19 pandemic, the fourth semester which mainly focusses on research, was completed by the students not without facing some challenges. They conducted their respective research projects, which included a research internship and a master thesis research with different partner institutions of the PAUWES' network across the continent.

With a focus on applied oreinted research, the graduates conducted their research works in different case studies in countries across the five regions of the continent as depicted on the chart on the right side. Most countries covered by these researches were however, in the Western and Southern Africa.

besides specific research addressing specific case studies in an African country, it is to acknowledge that few researches were conducted with a wider scope covering both the Sahel region (two researches and the whole continent (1 research work).



Master thesis research geographical coverage

Master of Sciences

Energy Engineering

Graduate CV.

Assessment of Willingness and Purchasing Capacity for Solar Home Systems in Rural Communities and Possibilities of investment: Case Study of Somaliland/Somalia, Togdheer Region

Mohamoud Aden Dualle, Dr. Samuel Asumadu Sarkodie
Nord University, Norland, Norway
Contact details: Mohamoud.aden5@gmail.com

Abstract

This study aims to explore the rural communities experience and attitudes towards Solar Home System (SHS), assesses their socio-economic status, identifies the main challenges of getting SHS and analyzes roles of government, donors and private firms towards achieving households' sustainable energy level in Somaliland/Somalia. A survey questionnaire was conducted in Somaliland (north part of Somalia) specifically Burao town and six near villages. The finding of the survey shows that 87 percent of the respondents are satisfied with their solar home systems. The main challenges facing rural communities for using the solar home system are initial cost, lack of subsidies, maintenance problems and lack of training and information. The study indicates government roles are missing in rural areas and the study recommends public intervention.

BACKGROUND/CONTEXT

The rural poor in remote locations are marginalized by the matter of energy access (Bhattacharyya, 2013). In rural parts of sub-Saharan Africa, solar photovoltaic (PV) products are recognized as a leading solution to long-term electrification and improvement (Stojanovski et al., 2017).

Somaliland/Somalia the rural electrification rate is very low. Hence, it is important to investigate peoples' willingness and their capacity for acquiring solar home system and possibilities of reducing the cost of the technology.

PROBLEM STATEMENT/RESEARCH QUESTION

The electricity access rate of Somaliland/Somalia is estimated at 15 percent, meaning that around 11 million Somalis lack access to electricity services (World Bank, 2018). Also, there is no study showing people's willingness and purchasing capacity for solar home systems (SHS) in rural communities and their understanding of the benefits of such technology.

Main question: What are the main challenges for rural communities in practicing solar home systems?

OBJECTIVES

To explore the rural communities experience and attitudes towards SHS, assess their socio-economic status, identify the main challenges of getting SHS. Furthermore, the research analyzes roles of government, donors and private firms towards achieving households' sustainable energy level

METHODOLOGY

Research Design
There is no previous studies of this topic. Hence this study is planned as an exploratory approach while the non-probabilistic sampled method was adopted.

Target Population
The target population of this research is 104 households under Burao district and five private renewable energy suppliers.

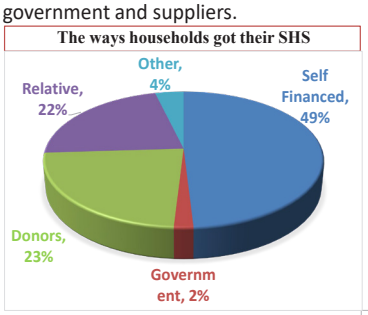
Secondary Data
World Bank, AfDB, IRENA, IEA, Shuraako reports, Somali government, Published papers and other sources

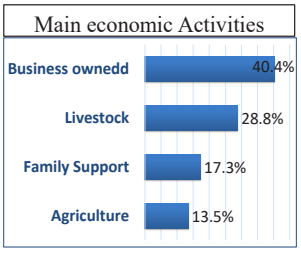
Primary Data
Survey questionnaires were used. The researcher visited villages, met households that have Solar Home Systems (SHS) as well as private energy enterprises and collected closed-ended questionnaires.

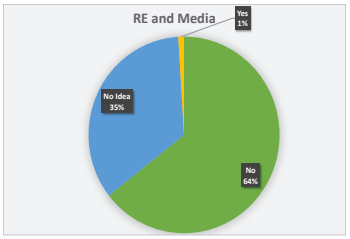
Data Analysis
Excel 2016 was analyzed by the data.
Then, results and discussion s were drafted.

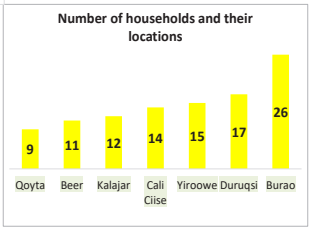
RESULTS AND DISCUSSION

The findings indicate the rural communities mainly rely on biomass and fossil fuels for cooking and lighting. The small portion that practise solar home systems they face higher investment and maintenance cost. However, they have positive satisfaction for the solar products and willing to invest as well as upgrade, if they get some supports from donors, government and suppliers.









CONCLUSION

Key conclusions are given below:

- Most of the respondents (i.e. 87%) are **satisfied** with their current SHS in northern Somalia (Somaliland).
- 62% of interviewees are willing to **upgrade** their SHS if they get means of cost reduction from government and donors. Also, 52% of households that don't use solar lighting are interested to purchase and they said we like our children to get electricity for lighting and TVs for entertainments.
- The biggest **obstacles** of SHS deployment in rural communities are capital cost, maintenance problems, lack of government subsidy, and very limited training and information.
- 62.5% of households covered by the survey live in **poverty**.
- **80%** of solar suppliers are willing to bring solar home systems and other electronics in rural places but they need government and donors' participations.

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An Assessment of the Viability of Solar Photovoltaic Electrification Systems for Households in Botswana

Keene Edith Bontshitswe, Dr. Emmanuel Donkor[a]

[a]Kwame Nkurumah University of Science and Technology, Kumasi, Ghana

bontshitswekeene@gmail.com

Abstract

This study assessed the economic viability of solar PV electrification system for residential use in Botswana. The size of the complete system has been determined using PVsyst to define the required PV module, size of storage, charge controller and inverter to meet the required load. The economic assessment using the Levelized Cost of Electricity (LCOE) was carried out in the Microsoft excel. The LCOE of 0.145USD/kWh was obtained, which does not compare favorably with the prevailing grid electricity tariff for residential sector (0.096USD/kWh). In this view a government subsidy of about 53% is recommended as an investment support to make PV electrification for residential use competitive with grid electricity.

BACKGROUND/CONTEXT

Access to electricity in Botswana is low(Fagbenle, 2001; P. K. Jain et al., 2002; Ketlogetswe & Mothudi, 2009; Mahachi et al., 2015). However, recent assessment of the climatic conditions of the country suggest that the country has a high potential for the development of solar PV systems to augment power supply, particularly in settlements that are largely disconnected from the main national grid. However Economic analysis of solar PV electrification systems has not been carried out for self-consumption in Botswana. The foregoing establishes a premise for an assessment of the viability of investing in the development of Solar PV systems for households in Botswana.

PROBLEM STATEMENT/RESEARCH QUESTION

Government target to achieve 25% usage of renewable energy by 2030 as well as increasing electricity coverage in the country. Solar PV electrification systems for households must be viable, if not, the government should provide financial assistance

Main question: are solar PV electrification systems for households viable in Botswana given the current level of grid tariff.

OBJECTIVES

This study seeks to determine the viability of solar PV electrification system in Botswana and how such systems can sustainably be adopted to augment the power needs of households in Botswana; estimating the size of system capacity required to power selected household appliances in Botswana and assess the economic feasibility of estimated size of the system capacity given the current level of grid tariff.

METHODOLOGY

PV sizing and design

- $E_{demand} \leq E_{supply}$
- Energy consumption inventory data was randomly collected.
- Power consumption (demand), $E = L \times Q \times T$ (PVSyst)

Parameter	method
Degrading value	0,5% Crystalline silicon (D.C Jordan, 2011)
Cost of the system	Quantity x Unit price
Discount rate	5%
Escalating rate	$a_g = \left(\frac{E_{T1}}{E_{T0}}\right)^{\frac{1}{(T_1 - T_0)}} - 1$

Parameter	Value
Discount rate	5%
Electricity tariff	0.096US$/kWh
Tariff escalation rate	3.8%
Annual degradation rate	0.5%
Installed cost	5 113.98US$
Specific cost	1.26US$/kW
O&M @1% capital investment	1%
Inverter replacement cost	681.08
Battery replacement cost@ year 10	1720.10
Battery replacement cost@ year 20	1720.10
Life	25years

Parameter	Definition	Formulae
LCOE	Metric commonly used to compare the cost competitiveness of alternative electricity generating systems (Comello et al., 2017).	$LCOE = \frac{I + \sum_{t=1}^{t=25} \frac{C_{OM} + C_{BR} + C_I}{(1+d)^t}}{\sum_{t=1}^{t=25} \frac{E_t}{(1+d)^t}}$
Discounted Payback Period	The time (in years) it takes for an investment cost to be recovered.	$Payback\ period = \frac{I + \sum_{t=1}^{t=25} \frac{C_{OM} + C_{BR} + C_I}{(1+d)^t}}{\sum_{t=1}^{T} \frac{Q_t \times P_t}{(1+d)^t}} \times T$
NPV	Amount of cash flow (in present terms) that a project generates after repaying the invested capital and required rate of return on that capital (Rattiner, 2009)	$NPV = \sum_{t=0}^{T} \frac{R_t}{(1+d)^t}$

RESULTS AND DISCUSSION

System parameters

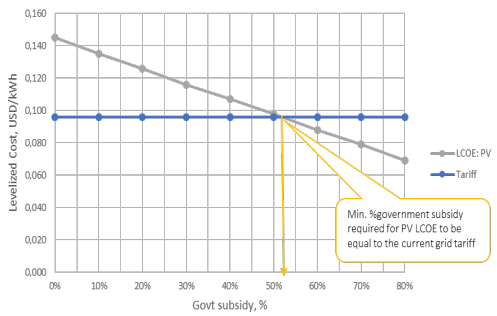
Parameter	Value
Power production	5080kWh/year
Performance ratio	0.73
Module area	15.6m²
Battery capacity	1000Ah
Number of PV modules	8
Number of batteries	10

quantity	appliance	power rating(W)	hours of use	daily energy demand (Wh)
1	Television	75	4	300
1	TV decoder	24	4	96
5	Incandescent bulb	40	5	1000
2	Mobile phone charger	30	2	120
1	Fridge/freezer		24	1030
1	Domestic appliance	1000	5	10 000
	Daily energy required			12 546

Key financial indicators

Parameter	LCOE
LCOE	0.145 USD/kWh
NPV	-222.85 USD
Payback period	25.73 years

Effect of government subsidy on LCOE



CONCLUSION

In conclusion, the LCOE for solar PV systems for residential use is higher than the prevailing utility rate thus rendering them not viable. However, some financial support can be provided to households in order to provide electricity for them especially where cost of connecting to the national grid is prohibitive. The government should offer 53% financial assistance or subsidies to households to aid in the prevalence of solar PV systems for residential use (stand-alone) there by adding social value to its people as well as achieving its goal to increase electrification rates.

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Graduate CV.

Construction and Experimental Investigation of a Solar Dryer with Integrated Thermal Storage based on Sorption Materials

Bignon Stéphanie NOUNAGNON, Dr.-Ing. habil. Kokouvi Edem N'TSOUKPOE[a]
[a]International Institute for Water and Environmental Engineering (2IE), Burkina Faso
Contact details: geraldinenounagnon@gmail.com

Abstract

As an environmentally friendly solution to improve solar dryer performance, Sorption Thermal Energy Storage (STES) technology has been investigated experimentally in a forced convection indirect solar dryer for drying mangoes in Burkina Faso. The dryer's air collector includes two desiccants beds based on silica gel, to lower the ambient air specific humidity and thereby enhance the drying air's capacity. Furthermore, a thermal storage bed with silica gel is integrated at the top of the drying chamber to perpetuate the drying process during the night and thus shorten the overall drying time.

BACKGROUND/CONTEXT

Solar drying appearing as one of the most interesting applications of solar energy has been revealing to be non-effective at commercial scale. Indeed, solar energy intermittency causes products rewetting during nights, leading to long drying cycle. Burkina Faso, the world leader in organic dried mango production and, which provides 25% of the total supply of dried mango to Europe (Jovanovic, 2018 as cited in Mulder et al., 2019), depends mostly on gas fire dryers although receiving good solar radiation through the year (GHI ≈ 5.5kWh/m²).

PROBLEM STATEMENT/RESEARCH QUESTION

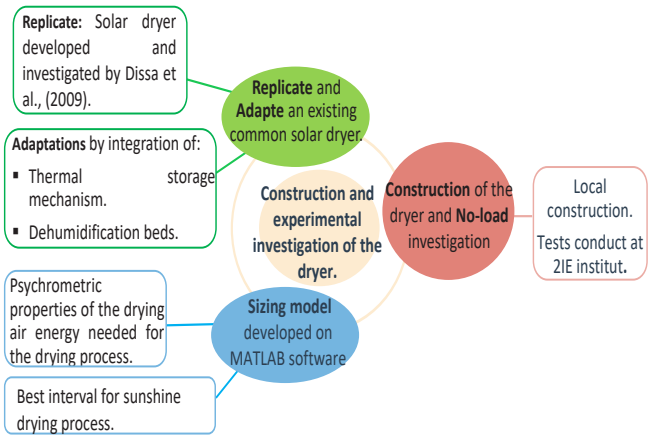
To date, no proven gas resource exists in Burkina Faso. Besides, the country's Intended National Determined Contributions planned reducing the greenhouses gas emissions by 18.2% by 2030. Burning natural gas leads to carbon dioxide emission (around 117 Ibs of CO2/Btu of gas) and accounts for 15 to 30% of the total production cost, although being subsidized by the government.

Research question: What are the technical performances of a solar dryer combining thermal storage unit and desiccant bed (all based on a sorption material) on the drying process of mangoes fruit?

OBJECTIVES

The research focuses on the design, construction, and experimental investigation of a solar dryer with integrated dehumidification bed and thermal storage unit based on sorption material to improve the performance of mango's solar dryer in Burkina Faso. Specifically, the study aims at contributing to the setting up of the prototype, proposing comprehensive experimental investigation protocol of the dryer and set up a tool for sizing and economic analysis of solar dryer with integrated STES technology using MATLAB software.

METHODOLOGY



RESULTS AND DISCUSSION

No-load measurements have been conducted on July 23rd and 24th 2020 under natural convection within the local weather conditions, at LabEREE, 2IE located at Kamboinsin, Burkina Faso.

DAY 1: Outlet air temperature peak was 91°C at 1pm and at 4pm the temperature was 61°C.

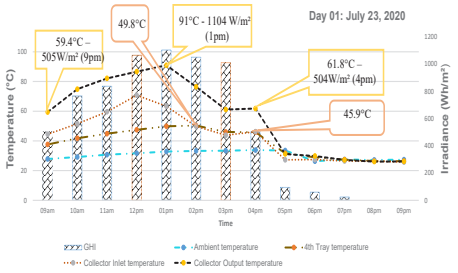


Figure 1: Day 1: No load experimentation results.

DAY 2: Outlet air temperature peak was 74°C at 11am and at 4pm the temperature was about 55°C.

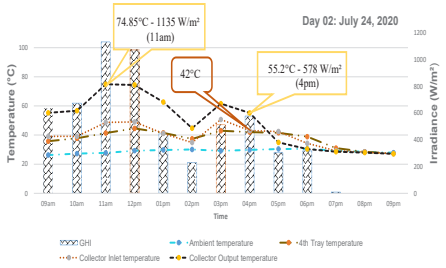


Figure 2: Day 2: No load experimentation results.

CONCLUSION

Design, construction and experimental investigation of a solar dryer with STES for mango.

Selection of reference solar dryer and adaptation. Integration of desiccant bed and thermal storage based on silica gel 3A.

Construction of the dryer and No-load investigation

Peak collector temperature: 91°C – 74.9°C; 60°C up to 4pm.

- Due to the COVID 19 pandemic restrictions, during the harvesting period of mango in Burkina Faso (April to July) the achievement of the Dryer Performance Index (DPI) was not possible.

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Design, simulation, prototyping and IoT-Based testing of an innovative tropical greenhouse with an energy efficient cooling system powered by a standalone Hybrid HAWT-Solar PV energy system: Case study of DR Congo-Kinshasa /Plateau de Bateké weather conditions (savannah tropical climate)

Constant KUNAMBU MBOLIKIDOLANI, Professor Dr. Venkatta Ramayya(a)
(a) Jimma institute of Technology, Ethiopia
Contact details : consmboli@gmail.com/ constant.kunambu@unikin.ac.cd

Abstract

This study geared towards identifying challenges that exist within the greenhouse industry in DR.Congo and developing an innovative greenhouse more adequate to local weather conditions with an energy efficient cooling system powered by a standalone hybrid energy system and affordable so, to boost agricultural-yield impacted by several factors, including lack of technologies, poor energy access and climate change effect. A meticulous design and simulations were carried out using different software and a prototype was built in Kinshasa/Plateau-de-Bateké using an innovative greenhouse cooling configuration. We emphasized more on the simplicity of technology, use of local materials, affordability and energy efficiency.

BACKGROUND/CONTEXT

In many countries of Africa including the Democratic Republic of Congo, farmers suffer from high yield losses, which are mainly caused by technology limitation, poor energy access, dependence on rain-fed agriculture, limited public investment and the climate change effect.

DRC has a huge agricultural potential and for a long time, the agricultural sector has been considered as an interesting development perspective that could contribute to the economic take-off of the country. And one of the ways chosen by Congolese government to promoted modern agriculture in Kinshasa is the greenhouse technology at DAIPN Center.

PROBLEM STATEMENT/RESEARCH QUESTION

Kinshasa presents a complex weather condition for existing greenhouse technologies having savannah tropical climate with dry winter, an average annual T=25.5°C, average relative humidity 82.5, heavy rainfall of 1,400 mm, average wind speed of 3 m/s and an average solar radiation of 4.62 KWh/m²/d. Greenhouse deployment in Kinshasa requires a suitable cooling technology. Current cooling technologies demand large investments and involve high-energy consumption in tropical climate.

OBJECTIVES

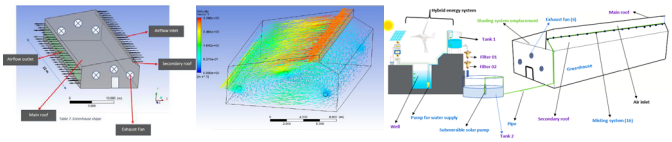
The objective of this study was of designing, sizing, simulating, prototyping and testing an innovative greenhouse with an energy efficient cooling system adequate to the savannah tropical climate of Kinshasa/DRC, in emphasizing more on the greenhouse energy efficiency, affordability and the use of locally available materials.

METHODOLOGY

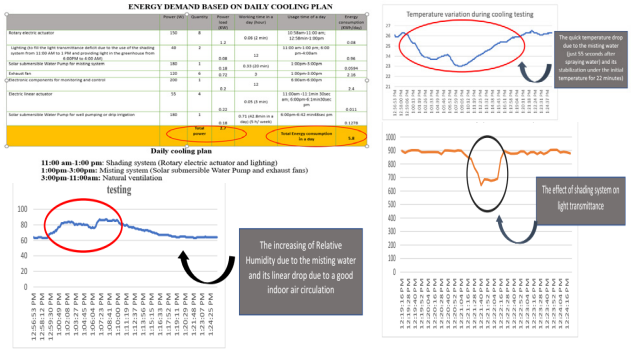
In general, the methodology of conducting this research and building the prototype is based on some steps, such as:

- Description of case study area
- Data collection and analysis
  - ✓The effect of climate change on food production in Kinshasa /Plateau de Bateke;
  - ✓Solar irradiation resources, relative humidity, rainfall, temperature, wind speed and the evaluation of the level of greenhouse management.
- Greenhouse design and physical model of the proposed system
- CFD simulation
- Design and sizing of the power energy system
- Conception of the configuration of our full-scale greenhouse
- Greenhouse cost estimation analysis
- Prototype construction and IoT based testing
- Results and discussion
- Conclusion and recommendations

RESULTS AND DISCUSSION



Our greenhouse has a "modified shed roof" (13.5 m * 32 m). The structure has a side height of 8m with an air inlet opening oriented perpendicular towards the main direction of wind flow facing West direction. The misting system located above the secondary roof sprays water in a direction parallel to the slope of the main roof and sustained by 6 exhaust fans for cooling system. A window fixed on electric linear actuators is designed to open and close the air inlet opening. A shading system mounted on electric rotary actuators is temporarily rolled up or unrolled below the main roof. Moreover, a lighting system is used to compensate light deficits due to the shading system. To optimize the energy consumption of the greenhouse, a specific timing is set for different cooling components (natural ventilation, misting system, shading system and exhaust fans).



CONCLUSION

Our greenhouse was designed and tested for savanna tropical climates in emphasizing more on the simplicity of technology, use of locally materials, affordability and energy efficiency. A specific cooling configuration was proposed based on energy efficiency and the running cost. The proposed greenhouse cooling system is mainly based on natural ventilation sustained by a misting system, a shading system and 6 exhaust fans.

The configuration based on the designed energy usage planning saves significantly the entire greenhouse energy consumption; only 5.8382 KWh/day in summer and 1.7KWh/day in winter. The energy consumption was optimized by a specific timing set for different cooling components.

The prototype provided 1°C to 7 ° C of cooling compared to the outside temperature with an increase in relative humidity of 1% to 24%. Our greenhouse cost was estimated at 3.99 USD/m², which made it affordable.

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The entire master thesis report is available under the following link:
http://repository.pauwes-cop.net/handle/1/423

Design and Development of Energy Audit software using Python

Ferhat AGDOUCHE [(a)], Dr.Mohamed Choukri BENHABIB [(b)]

[(a)]PAUWES Institute, [(b)]Tlemcen University.

Contact details: azul3100022@gmail.com

Abstract

Energy plays a key role in the life of buildings and different facilities. The alarming energy usage growth over the last few decades requires a better understanding on how it is consumed through an energy audit. The goal of this work is to design and develop a software named NRGAudit for energy diagnosis with focus on the lighting system in buildings. NRGAudit is a computer tool that aims to assist energy experts to identify the potential energy savings based on the economical analysis provided by the software. As a result of this work, recommendations were made, regarding future development of the software for more authenticity, accuracy and availability in offline and online options.

BACKGROUND/CONTEXT

Today, energy represents a more than significant operating budget for buildings and facilities[1]. The ever-increasing cost of energy is pushing the building owners to act quickly by implementing an energy audit which is a key step to understand the energy consumption and explore the different saving opportunities.

The energy audit can be relatively a complex operation to execute and time consuming. Consultants and other experts in energy companies carry out most of their energy auditing and diagnostic missions following determined step which impose a certain complexity which requires powerful tools therefore, we decided to develop a software package for energy auditing of buildings with the focus on the lighting system.

PROBLEM STATEMENT/RESEARCH QUESTION

Energy used in the buildings accounts for 20% of global delivered energy consumption in 2018[2]. So to understand how the energy is consumed can be complex therefore developing tools and application is a must for a better understanding and results therefore our main question is:

How to develop an effective, accurate and methodological energy audit software that provides a technical and economical analysis of the lighting system within buildings for consultants and other energy experts?

OBJECTIVES

1. Define a clear methodology of the energy audit process for lighting system;
2. Translate the auditing methodology into an algorithm;
3. Develop the software for energy auditing using Python language.

METHODOLOGY

Our methodology was based on comparison between the results obtained from manual calculations and the results from the software in relation the energy auditing of lighting system at PAUWES building. The following summarizes the steps to achieve our objectives:

1. Data collection of the lighting system in PAUWES building;
2. Define the inputs and outputs;
3. Develop software for energy auditing of the lighting system using Python;
4. Test and debug the software;
5. Compare the results obtained from the software with the manual calculation results.

Figure-1: Methodology flowchart

RESULTS AND DISCUSSION

Lamp type	Quantity	Power per Unit[W]	Time usage [h/day]	Total days/ year
CFL Lamp	18	80	22	260
LFL Lamp	102	36	84	260

Table-1: Summarize of current lighting system at PAUWES building

Lamp type	Quantity	Power per Unit[W]	Time usage [h/day]	Total days/year
LED Lamp	120	18	106	260

Table-2: Summary of Proposed upgrades of lighting system at PAUWES building

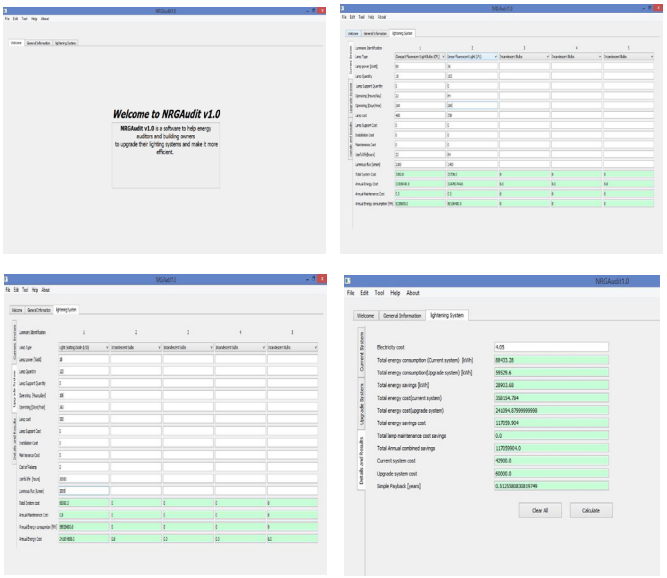

Figure-2: Simulation of the tables using our developed software.

The results we obtained from the simulation with the software we developed the manual calculation were precisely identical. The difference was that using the software enabled us to save a lot of time, produce more detailed results and process complex data within a short duration.

CONCLUSION

Our ***NRGAudit 1.0 software*** integrates the field of energy audit of lighting systems for buildings. The software is a tool decision support for auditors in energy diagnosis of companies through the analyzing of the results generated and the structuring of the information.

As recommendations regarding further development of the software it would be interesting to define an exact and accurate auditing methodology for different possible scenarios. Also, develop a web application version of the software in order to ensure the online and offline options.

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Graduate CV.

Life Cycle Estimation of Rural Electrification PV-based for Extreme Climatic Sahel region (Algeria, Mauritania, Burkina Faso, Senegal and Chad)

MAHAMAT HABIB BECHIR, Prof. María Ángeles López Agüera[a]
[a]Santiago de Compostela University, Spain
Contact details: habiboubechir@gmail.com

Abstract

The present work focuses on the analysis for both technology and design the most appropriated to cover the energy needs of a typical Sahel rural community. For that, this work evaluates both the most appropriate local solution in term of LCA, thus the EPBT of different technologies of solar panels and batteries have been evaluated. Likewise, some possible designs have been studied, with and without batteries, as well as the possibility of using water tanks as accumulation systems. In addition, to avoid oversizing of photovoltaic systems, a sizing algorithm based on the probability (LLP) of power drop has been studied.

BACKGROUND/CONTEXT

Sustainable development should provide a solution in order to fulfil the basic human needs (Bjørn 2017). Development required that everybody must have access to sustainable, reliable, affordable and clean energy (World-Bank 2018). The Sahel rural areas are highly affected by the change in climate, lack of water, worse agriculture yield which lead to high rate of poverty and hunger. The endowment of renewable resources assumed that renewable technologies could increase and improve energy access particularly in remote rural areas (Ouedraogo et al. 2015).

PROBLEM STATEMENT/RESEARCH QUESTION

Analyse both the technology and design the more appropriated to cover the energy needs of a typical community in the Sahel region.

- What Photovoltaic and battery technology is sustainable and adequate in the Sahel region? For each studied PV technology, what is the LCA approach response?
- What is the basic working process of the proposed designs?
- Does optimization reduce the overall cost and increase reliability of a PV system?

OBJECTIVES

Identify the adequate and sustainable among the PV and battery technology with regard to the Sahel climate conditions, by applying the LCA study and then proposing a sustainable design based on a standalone PV and pumped water, coupled with battery storage and Pumped hydro system for electrification purposes and finally integrate of the LLP optimal sizing method in order to avoid oversizing

METHODOLOGY

PV and Battery selection

Battery	Li-ion	NaS	NiCd	NiMH	PbA	PSB	VRB	ZnBr
Production (MJ/Wh)	0.98	1.09	3	2.2	1,15	2.8	3.5	1.5
Manufacturing (MJ/Wh)	1.2	0.6	2.1	2.1	0.46	0.59	0.74	0.6
Transportation (MJ/Wh)	1.52	1.24	2.88	2.53	1.01	2.37	1.04	0.383
Efficiency (λ)	0.95	0.83	0.85	0.85	0.84	0.65	0.8	0.73
Cycle life at 80% DOD	15000	4800	950	1600	1250	1000	13000	2000
Life time (Year)	18	15	14	7.9	5	14	17	9
Open circuit Voltage (V)	3.3	2	1.2	1.35	2	2	2	2.15

- $\mathbf{EPBT} = \frac{\mathbf{CED}}{\mathbf{E_p}}\left(\frac{\mathbf{MJ}}{\mathbf{MJ/year}}\right)$
- $\mathbf{Ep} = \mathbf{IR} \times \mathbf{E_e} \times \mathbf{PR} \times \mathbf{A}$

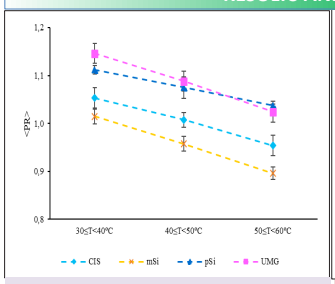
IR (MJ/m2/year): the global horizontal solar irradiation; Ee (%): The module efficiency; PR(%): The performance ratio; A (m²): The PV module area.

Loss of load probability (LLP) sizing method

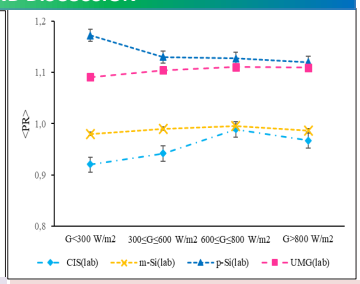
Battery state of charge: $SOC_t = \min\left(SOC_{t-1} + \frac{E_{DC}(t) - L(t)}{CS}; 1\right)$

An Algorithm is developed in order to obtain the isoreliability curves, then to analyse the economic and environmental constraints and to select the optimal (CS, CA) pair.

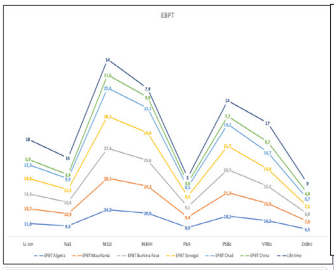
RESULTS AND DISCUSSION



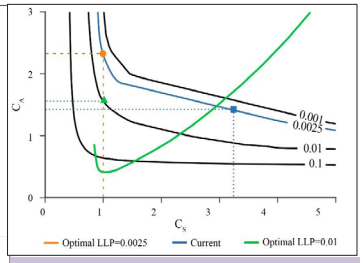
Performance ratio variation by varying the temperature classification range.



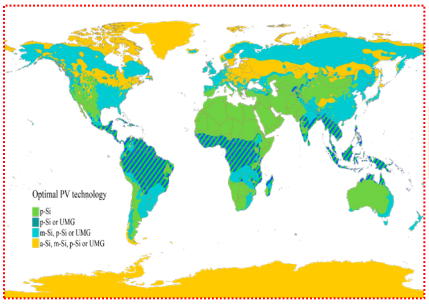
Performance ratio variation by varying the radiation



The EPBT of each battery technologies with its respective life time.



Domestic PV installation reliability and LCA curves



p-Si, is the Optimal technology for the Sahel climate conditions.

CONCLUSION

- The optimal PV and battery technology for the extreme Sahel condition are: Polycrystalline (p-Si) and Lithium-Ion (Li-ion).
- The system design is sized using the LLP method in order to avoid the oversizing.
- It has been proposed different scenarios based on CLEWs model with and integration of a water pumping system the last is gathered by a pumped hydro system

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2. Ouedraogo, Bachir I., S. Kouame, Y. Azoumah, and D. Yamegueu. 2015. "Incentives for Rural off Grid Electrification in Burkina Faso Using LCOE." *Renewable Energy* 78:573–82.

Graduate CV.

Modelling an Artificial Intelligence-based Energy Management System for Households/Minigrid in Nigeria

Rabiat Ohunene Abdulaziz, Dr. Erick Tambo (a)
(a) PAUWES, UNU-EHS
Rabiat.abdulaziz@aims-Cameroon.org

Abstract

The aim of this work is to model an Artificial intelligence-based energy management for households in Nigeria. Genetic algorithm was used on smart meter-like data to optimize the energy consumption of households (i.e. low, middle and high income earners) for 24 hours in both weekday and weekend. We develop an energy management system in household to simulate the data. Based on experimental results; the energy saved during weekday for household are 16.74%, 9.9% and 32.55%, for the three households, and that of weekend are 6.11%, 19.39% and 32.20%. The algorithm will help consumer to reduce electricity cost in an household.

BACKGROUND/CONTEXT

Among the major concerns and pressing issues in the world today is the is the issue of energy security and access, energy efficiency as well as energy conservation. The demand for energy is on a constant increase as the world population and consumption is growing rapidly **(Wang & Srinivasan, 2015)**.

According to (**IEA, 2019**) up to 600 million people have no access to electricity and 900 million people lacking access to clean cooking fuel in SSA. Only about 1% of rural population in some SSA countries (for example South Sudan, D. R. of the Congo, Chad, Central African Republic, Guinea, Niger, Mauritania, Burkina Faso) have access to electricity(**Mazzoni, 2019**).

PROBLEM STATEMENT/RESEARCH QUESTION

Attentions are majorly focus on the urban region because of remoteness and thus cost of extending electricity to the rural settlements.

Research question: How can an artificial intelligence-based system be adopted at the household in rural Sub-Saharan African specifically Nigeria, in order to reduce electricity cost for consumers and peak demand management at peak hours for the households and mini-grids?

OBJECTIVES

Aim : To model an automated system working with the principle of Artificial intelligence that can reduce power consumption cost household level as well as household peak demand.

Specific objectives :

- Obtain typical load profile of a mini-grid setting (household and commercial load profile).
- To develop a simulation of smart meter like data.
- Propose an energy management system to optimize electricity consumption during a week day and weekend in a household.

METHODOLOGY

Mathematical formulation of the problem

$$\min \sum_{i=1}^{J} P_{x_i}^{c} \cdot t_{x_i} \cdot R \cdot Z_{x_i}$$

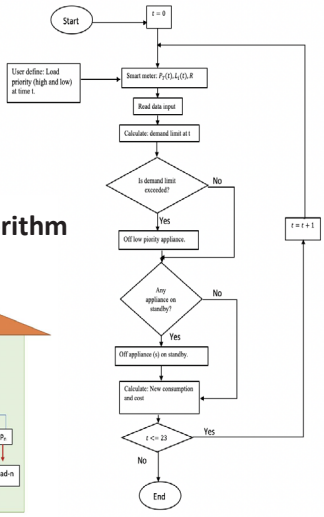
Subjected to:

$$\sum P_{x_i}^{c} < U_t^{Cm} \text{ and } Z_{x_i^1} = 0$$

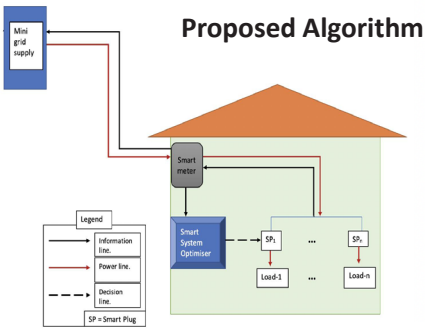
$$U_t^{cm} = \sum P_{x_i^h} .$$

$$P_{x_i}^{c} < L_{x_i} \text{ and } Z_{x_i} = 0$$

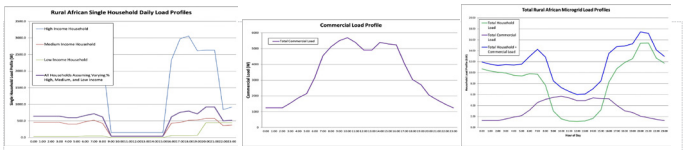
$$Z_{x_i} \epsilon \{0,1\}$$



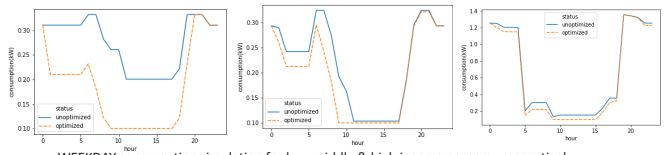
Proposed Algorithm



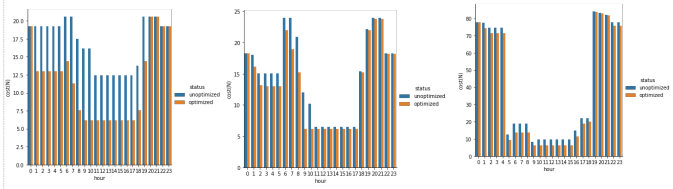
RESULTS AND DISCUSSION



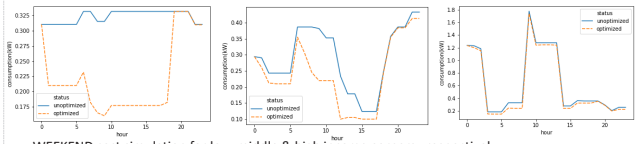
Load profiles for Households(high, middle & low), commercial and total load profiles, respectively.



WEEKDAY consumption simulation for low, middle & high income earners, respectively.



WEEKDAY cost simulation for low, middle & high income earners, respectively.



WEEKEND cost simulation for low, middle & high income earners, respectively.

Table 1: WEEKDAY optimization

	High income			Middle income			Low income		
	Unopti.	Opti.	gap(%)	Unopti.	Opti.	gap (%)	Unopti.	Opti.	gap (%)
Consumption	21.01	17.49	16.74	354.81	319.68	9.9	6.57	4.43	32.55
Cost($Naira$)	1302.59	1080.55	16.74	5.72	5.16	9.9	407.60	274.95	32.55

Table 2: WEEKEND optimization

	High income			Middle income			Low income		
	Unopti.	Opti.	gap(%)	Unopti.	Opti.	gap (%)	Unopti.	Opti.	gap (%)
Consumption	15.08	14.16	6.11	7.01	5.65	19.39	7.76	5.26	32.20
Cost($Naira$)	935.10	877.99	6.11	434.81	350.52	19.39	481.36	326.34	32.20

CONCLUSION

The objective of this research is to develop an automated system working with the principle of Artificial intelligence that can reduce power consumption and cost at the household level using simulated data from already existing mini-grid systems and exploring the consumer 's electricity consumption behaviour. The households were classified into three classes; High, Middle- and Low-income earners.

The proposed system has displayed a very good potential for energy management at the household level by cutting off electrical appliances which are not being used but fully consuming electricity as well as appliances on standby.

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Graduate CV.

Optimal Sizing and Techno-Economic Analysis of a Hybrid Power System: A Case Study of Busitema Health Centre III in Busia District-Eastern Uganda.

Onesmas Gumisiriza, Prof Olayinka S. Ohunakin(a)
(a) Covenant University
onesmasguma44@gmail.com

Abstract

This study dealt with the optimal sizing and techno-economic analysis of a hybrid Power system for Busitema Health Centre III. The load demand for the health Centre was 3.979 kWh. The Net Present Cost, energy output and Levelized Cost of Electricity of the optimal system was determined through simulations using HOMER software. Various combinations were obtained from the HOMER optimization simulations. The results showed that a solar PV-diesel hybrid system having configuration of 15.75 kW Solar PV, 10 kW diesel generator, and 9 Strings of battery each with capacity of 375AH, with a renewable energy fraction of 85.5% solar, and a total electrical energy output of 26,231kWh/yr, gives the optimal configuration. It was recommended that future research be considered in extending such work to other similar potential sites.

BACKGROUND/CONTEXT

Energy is an engine for economic growth and development of any given country. For a sustainable development, access to energy services must be reliable, affordable and with low GHG-emitting sources **(AGECC 2010).** Over 620 million people, do not have access to electricity and nearly 730 million rely on traditional solid biomass for cooking **(OECD/IEA 2014).** Hybrid energy systems such as PV –wind systems, offer the most adequate solutions for the electrification of remote areas. The combination of different types of energy technologies depend greatly on the resources locally available in each geographical area. Optimization of the hybrid power Generation systems guarantees the lowest investment with the use of renewable energies.

PROBLEM STATEMENT/RESEARCH QUESTION

The government of Uganda intends to increase the use of modern renewable energy sources from 4% to 61%. Energy access objectives in Uganda have been included in National Development Plans II and III **(GOU 2015)**. However, even with such efforts, millions of people in the country still lack access to reliable and modern energy services. The uncontrollable nature of renewable energy resources among other factors necessitates combination of different renewable energy resources to form a hybrid system which can be flexible, cost effective, reliable and efficient.

Main Question. What is the suitable hybrid power system configuration that sustainably and optimally meets the energy needs of Busitema Healthy Centre III?

OBJECTIVES

1.To investigate the energy demand of Busitema Health Centre III in Busia Eastern Uganda.

2.To model the different physical components that build up the hybrid power system.

3.To simulate and optimize various Renewable energy technologies using HOMER Pro software.

4.To perform a techno -economic analysis of the hybrid electricity generation system of the case study.

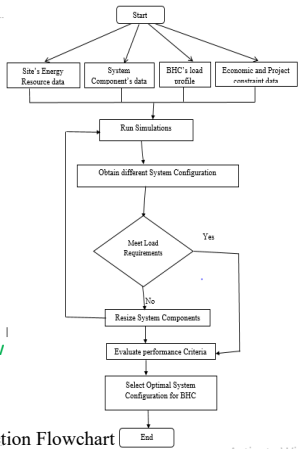
METHODOLOGY

The HOMER Pro Tool x643.13.2 installed in the computer lab of Ndejje University in Uganda was used in this work.

The meteorological data used was collected from the national meteorological Centre at Luzira Kampala.

The case study was located at coordinates of 0.4669 Latitude and 34.0900 Longitude, 1,198 meters above sea level.

The electrical load (3.979KW) was obtained by site visit and having an interview with the "in charge" of the Health Centre.

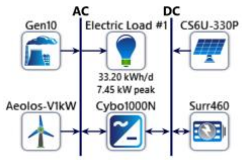


Energy System Configurations Selection Flowchart

RESULTS AND DISCUSSION

Load Profile of the Health Centre.

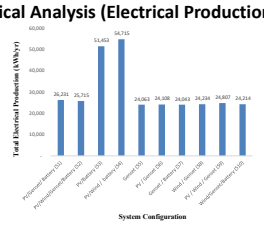
Schematic of the Simulated Hybrid System



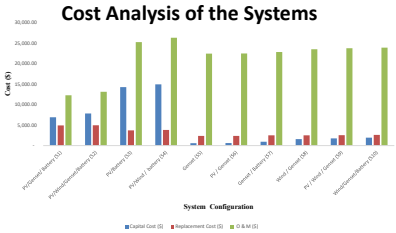
System Components and their Sizes

System Configuration		Size of Solar PV(Kw)	Number of Wind Turbines	Size of Diesel Generator (kW)	Size of Batteries (Units)	Size of Convertor (kW)
PV/Genset/ Battery	S1	15.78		10	9	6.20
PV/Wind/Genset/Battery	S2	15.29	1	10	9	6.17
PV/Battery	S3	33.17			26	7.37
PV/Wind /Battery	S4	35.13	1		24	7.36
Genset	S5			10		
PV/Genset	S6	0.05		10		0.06
Genset/Battery	S7			10	1	0.25
Wind/Genset	S8		1	10		
PV/Wind/Genset	S9	0.58	1	10		0.38
Wind/Genset/Battery	S10		1	10	1	0.19

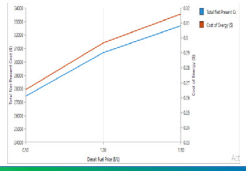
Technical Analysis (Electrical Production)



Cost Analysis of the Systems



The Impact of Diesel Fuel Price on Optimal Solution



CONCLUSION

The wind energy potential of the study area is considerably low, thus insufficient for a large and independent wind power system,

However the analysis showed that if wind is integrated with other energy sources, a viable solution can be obtained.

The configuration S1 consisting of solar PV, Genset and battery stood out as the appropriate optimal system.

The NPC of the optimal configuration was 22,427 USD and LCOE was 0.265 USD/kWh. The LCOE is about 39% higher than the 2019 electricity tariff developed by UMEME.

The optimal solution displayed better performance in the other categories such as electrical production, fuel consumption and CO_2 reduction

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Graduate CV.

Optimal Sizing and Techno-economic Feasibility of a Hybrid Energy System for Rural Electrification: A Case of Nakwamoru Village, Kenya

Jennifer Mbithe PENNINAH, Prof. Olayinka S. OHUNAKIN
Covenant University,Berkeley
jennifermbithe85@gmail.com

Abstract

This study optimally sizes and analyses the techno-economic feasibility of various hybrid system configurations for Nakwamoru Village, consisting of 522 households. Interviews, questionnaires and document reviews were used to gather data of the village. The results showed that the most optimal hybrid system configuration consists of 174 kW of PV panels, 314 batteries, and 65 kW of the converter to meet the daily electric load of 522.34 kWh. Sensitivity results indicate that an increase in solar radiation will reduce both COE and NPC, and an increase in inflation will increase the NPV while reducing the COE.

BACKGROUND/CONTEXT

Sustainable energy provision has a strong interrelationship with the socio-economic advancement of any country**(Ahmad et al., 2018).**
Technology improvement and population growth has dramatically increased the energy demand. To match the increasing demand with supply, the world has looked into improving the energy supply by looking into providing energy from RES to ensure the security of supply amidst fears of diminishing fossil fuel reserves in the future (**Eltamaly & Mohamed, 2018).**
Alternative energy resources have become attractive due to their reliability in power supply and minimal environmental impact compared to fossil fuels leading to massive attention towards these energy sources to meet the present and increasing energy demand **(Lipu et al., 2017).**

PROBLEM STATEMENT/RESEARCH QUESTION

Despite the high universal electricity access rates of 75%, there are still Kenyans without electricity, especially those living in remote rural areas. The off-grid energy systems deployed in rural areas in Kenya are single resource or diesel/solar or diesel/wind hybrid energy systems with limitation of high cost of operation and intermittence nature of RES **(Micangeli et al., 2017).**
Main question: What is the optimal hybrid system configuration that can sustainably and economically satisfy the community's energy demand?

OBJECTIVES

Main Objective: To investigate the techno-economic feasibility of a hybrid power system for rural electrification in Kenya.
Specific Objectives: Assess the renewable energy resources feasible in the area for the proposed hybrid system, Estimate the energy demand for the community and establish a load demand curve, Optimally size the hybrid system using the available renewable resources to satisfy the energy demand of the community, Examine the contributions of the proposed hybrid system on the community's socio-economic and environmental benefits.

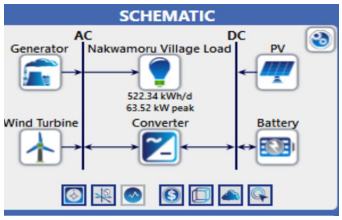
METHODOLOGY

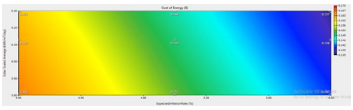
- Literature Review, Questionnaires, Observations and Interviews were used to collect the required data in this research.
- A validated questionnaire was used to collect data on the appliances currently in use in the community, duration of use and the current sources of supply of energy in the community.
- Sample size of 250 households, 2 primary schools,1 secondary school,2 churches, administration office and shops.
- This study's approach concerning obtaining solar resource and wind resource data involves using meteorological data from previous reputable and trusted research-SWERA DATABASE.
- Data preliminary analysis is done using Microsoft excel-Resources (Solar and wind)and load analysis.
- HOMER Pro micro grid software tool was used for sizing and optimization of the HRES and sensitivity analysis.

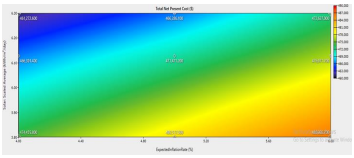
RESULTS AND DISCUSSION

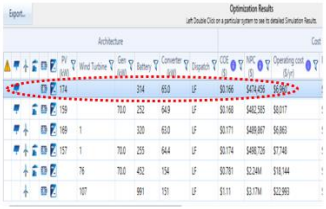
Annual average solar radiation of 6.13 kWh/m2/day

Annual average wind speed of 3.97m/s at 50 m height.









An increase in solar radiation will reduce both COE and NPV; an increase in inflation will increase the NPV while reducing the COE.

CONCLUSION

- The average annual solar radiation is 6.13 kW/m2/day, while the average yearly wind speed is 3.97 m/s. This shows a high potential for solar energy exploitation for electricity provision in this region.
- The community's total daily consumption is 522.34 kWh/day, with a residential load having the highest demand of 85% of the total daily load.
- PV/Battery hybrid system is the optimal system configuration, and it comprises a 174kW PV panel capacity,314 storage batteries, and a 65Kw capacity converter.
- The optimal power system has an NPC of $ 474,456, with an LCOE of $ 0.166/kWh. The COE is 17 % lower than the current LCOE ($ 0.20/kWh) for residential tariffs in Kenya.
- The proposed hybrid system would contribute both socio-economic and environmental benefits to the community, thus improving the community's standards of living.

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Graduate CV.

Technical Assessment of Coal Bed Methane Potential for Improved Electricity Supply and Access in Zimbabwe

Nyashadzashe P T Kunaka, Prof. Paul Chisale
Namibian University of Science and Technology
Nashkay5@yahoo.com

Abstract

The Research study assessed the feasibility of producing Coal Bed Methane (CBM) for electricity generation to increase supply and access in Zimbabwe. Questionnaires and Literature reviews were the modes of data collection. A sustainability assessment was done using Hybrid AHP-TOPSIS methodology whilst DWSIM Simulator was used to characterize the CBM and design the best method of combustion for electricity production. The results concluded that it is technically feasible to exploit CBM for electricity production. The study recommends the installation of a CBM Power Plant with Carbon capture.

BACKGROUND/CONTEXT

Coal Bed Methane is a form of natural gas found in coal beds. Unlike coal, it is a cleaner energy source because it does not contain Sulphur compounds and has better combustion characteristics Therefore, exploiting CBM is an attractive alternative compared to using coal as fuel.

Zimbabwe has proven reserves equivalent to 163.3 times its annual consumption. This means that, according to British Petroleum (2016), Zimbabwe had about 163 years of Coal left, at the then consumption levels. Therefore, Coal Bed Methane for electricity production is an alternative that this study explores.

PROBLEM STATEMENT/RESEARCH QUESTION

Due to electricity outages and low economic development Zimbabwe needs to invest in new energy technologies and sources to meet the high electricity demand and increase the supply.

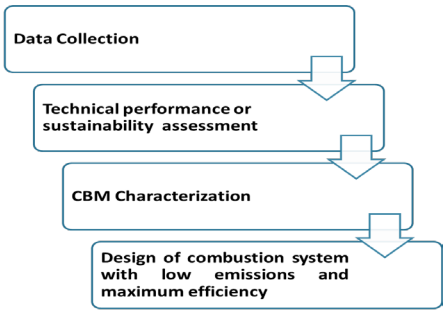
Q: How can Coal Bed Methane (CBM) be harnessed as a potential fuel for electricity production with reduced greenhouse gas emissions ensuring its sustainability as an energy source compared to the other existing energy technologies?

OBJECTIVES

1. To assess the Technical performance (Sustainability) of Coal Bed Methane electricity production compared to the other existing energy technologies.
2. To characterize the CBM found in Zimbabwe
3. To determine and design the best method of combustion with low emissions for maximum efficiency.
4. To ascertain environmental and economic impacts of CBM electricity supply and access.

METHODOLOGY

- Data collection by reviewing literature and distributing questionnaires.
- Hybrid AHP-TOPSIS Methodology was used for the sustainability assessment of Coal Bed Methane in Zimbabwe
- DWSIM Simulator version 6.1 was used for CBM characterization and combustion system design



RESULTS AND DISCUSSION

Overall weights for the criteria and sub criteria from AHP

Main criteria	Weights (%)	Sub-criteria	Weights (%)	Final weights of sub-criteria with respect to main criteria (%)
Technical	23,08	Resource availability (TWh/yr)	59,71	13,78
		Efficiency %	11,94	2,76
		Energy system safety	8,50	1,96
		Technology maturity	19,85	4,58
Environmental	15,37	GHG emission (gCO2e/kWh)	33,33	5,12
		Land requirement (m2/GWh)	66,66	10,25
Economic	46,17	Capital cost ($/kW)	18,16	8,38
		O&M cost ($/kW.yr)	27,28	12,60
		LCOE $/kWh	54,56	25,19
Social	15,37	Health impact	75,10	11,54
		Social acceptance	24,90	3,83

TOPSIS Ranking

RELATIVE CLOSENESS TO THE IDEAL SOLUTION		
COAL	0,6130410	Best 1
CBM	0,5886969	Best 2
HYDOPOWER	0,5278959	Next 4
SOLAR (PV)	0,5623067	Next 3
BIOMASS	0,1393671	Last 5

CBM was ranked as the best alternative second to coal concluding that it is feasible as a source to increase electricity access and supply as well as reduce GHG emissions.

CBM Characterization Results

Calculation Results	
Selected Stream CBM	
Molar Weight	16,4403
Ideal Gas Specific Gravity	0,567638
Compressibility Factor @ NC	1
Compressibility Factor @ SC	1
Compressibility Factor @ BR	1
Specific Gravity @ NC	0,567638
Specific Gravity @ SC	0,567638
Specific Gravity @ BR	0,567638
Mass LHV @ 0 °C (kJ/kg)	48492,4
Mass LHV @ 15 °C (kJ/kg)	48484,6
Mass LHV @ 20 °C (kJ/kg)	48481,5
Mass LHV @ 25 °C (kJ/kg)	48478,7
Mass HHV @ 0 °C (kJ/kg)	53918,1
Mass HHV @ 15 °C (kJ/kg)	53833,2

Ideal Gas Vol. LHV @ SC (kJ/m3)	33711,8
Ideal Gas Vol. LHV @ BR (kJ/m3)	33134,8
Ideal Gas Vol. HHV @ NC (kJ/m3)	39548,9
Ideal Gas Vol. HHV @ SC (kJ/m3)	37430,7
Ideal Gas Vol. HHV @ BR (kJ/m3)	36773,5
Vol. LHV @ NC (kJ/m3)	35568,8
Vol. LHV @ SC (kJ/m3)	33711,8
Vol. LHV @ BR (kJ/m3)	33134,8
Vol. HHV @ NC (kJ/m3)	39548,9
Vol. HHV @ SC (kJ/m3)	37430,7
Vol. HHV @ BR (kJ/m3)	36773,5
Ideal Gas Wobbe Index @ NC (kJ/m3)	52492,6
Ideal Gas Wobbe Index @ SC (kJ/m3)	49681,2
Ideal Gas Wobbe Index @ BR (kJ/m3)	48808,9
Wobbe Index @ NC (kJ/m3)	52492,6
Wobbe Index @ SC (kJ/m3)	49681,2
Wobbe Index @ BR (kJ/m3)	48808,9
Motor Octane Number (MON)	134,817
Methane Number (MN)	91,39

The ideal gas LHV was 33 711.8 kJ/m3 while for Natural gas it was 35 213.1 kJ/m3 (similar) thus CBM will have the same performance in the combustion system and release almost the same amount of energy as natural gas during combustion.

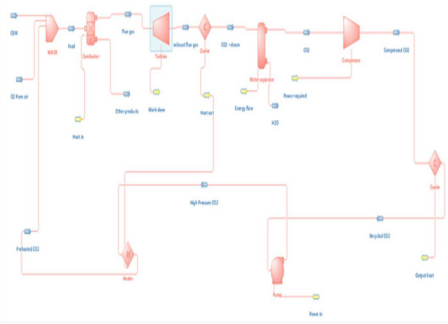
Simulated results of Power Plant designed

PROPERTIES TABLE			
Turbine	Adiabatic Efficiency	75	%
Turbine	Power Generated	21703,4	kW

The high turbine efficiency showed that maximum combustion performance was obtained.

CONCLUSION

CBM Power Plant with Carbon Capture technology



From all the objectives carried out in this research it can be concluded that the research question/s was comprehensively answered, that is:
Employing a CBM gas turbine power plant with carbon capture to generate electricity which can increase supply and access in Zimbabwe. This will be sustainable because the CBM gas is readily available in Zimbabwe, will improve the quality of life of the people and mitigate climate change by implementing carbon capture technology to reduce the GHG emissions.

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Graduate CV.

Techno-economic Analysis for Stand alone Solar Water Pumping System for Farm Irrigation; A case study in Sudan

Shimaa Abdelhafeez, Prof. Mohamed Sid-Ahmed(a)
(a) Omdurman Ahlia University, Omdurman, Sudan
mohamedsidahmed5@gmail.com

Abstract

This study intends to provide techno-economic analysis of solar water pumping system. Interviews and surveys were conducted with decision-makers and farmers to identify barriers and drivers for this technology deployment in Sudan. The HOMER software is used to evaluate both the environmental and economic viability of the proposed systems. The results have shown that implementing photovoltaic systems for irrigation is more profitable compared to diesel systems, the Levelized cost of energy for the solar and Diesel systems are 0.249 and 0.364 $/kWh, respectively. There were policy framework, technical and economic barriers with infrastructure issues and market challenges for this technology.

BACKGROUND/CONTEXT

- Agriculture is a main economic sector contributing 27% to the country's GDP. Nearly half of the national workforce is engaged in agriculture [1]. However, the agricultural sector is affected by climate change due to the variability of rainfall and drought.
- Improving the irrigation system is a key strategy to enhance agricultural productivity and stimulate economic development to achieve agricultural sustainability[2].
- Solar water pumping technology can be implemented to minimize the dependency on fossil-based electricity generation.
- Agriculture is one of the sectors that can solve issues regarding the increase in population and energy demands in the country by providing enough food stock and bioenergy such as energy crops and biomass[3].

PROBLEM STATEMENT/RESEARCH QUESTION

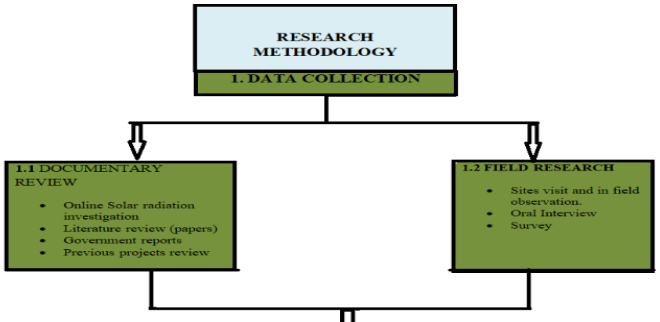
The demand for food in Sudan is growing dramatically due to the increasing country population and decreasing of the cultivated land. The irrigation process becomes expensive due to the scarcity and increase of fuel prices while the electricity access is a critical issue currently being faced by the Sudanese transitional government which is planning to include renewable energy technology especially solar to tackle this issue.

Main Questions: Is the use of solar water pumping is more attractive (technically, socially, and economically) than non-renewable energy water pumping technologies, in Sudan?
What are the barriers that hinder the use of solar water pumping for agricultural irrigation in Sudan?

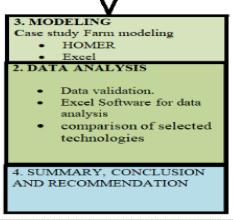
OBJECTIVES

To analyze and examine the technical and economic aspects of the solar water pumping system compared to diesel water pump for small-scale irrigation in Sudan and identify the barriers for implementation of this technology for irrigation purposes.

METHODOLOGY

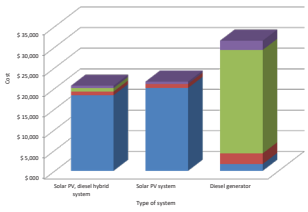


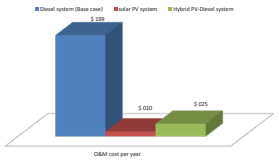
Category of respondents	Sample Size	Sampling techniques
Farmers	60	random sampling
Agronomists	2	Purposive sampling
Irrigation Experts	2	Purposive sampling
Administrative staff	2	purposive sampling
Total	66	

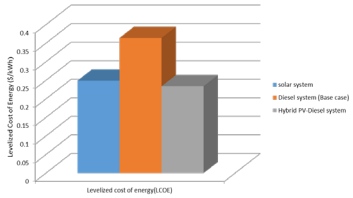


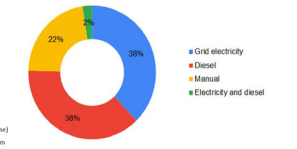
Conceptual Framework

RESULTS AND DISCUSSION

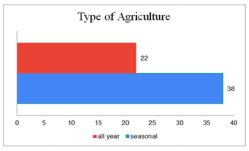




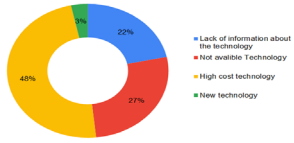


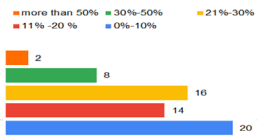


Type of energy sources used for irrigation



Possible barriers to adopt PVWP technology in Sudan





the percentage of irrigation cost out of total cost

Pollutants emission per year from the pumping system

Emission (kg/yr)			
Pollutant	Diesel	Hybrid PV/Diesel	Solar PV
Carbon Dioxide	5075	173	0
Carbon Monoxide	32.0	1.09	0
Unburned Hydrocarbons	1.40	0.0477	0
Particulate Matter	0.194	0.00662	0
Sulfur Dioxide	12.4	0.424	0
Nitrogen Oxides	30.1	1.03	0
Total emission	5151.049	175.59832	0

CONCLUSION

Relying on interviews, software results and observations, it is concluded that Sudan in general and Al-Ailfun district specifically have abundant resources for irrigation schemes using solar water pumping technology, this could significantly improve agricultural production and the status of food security which would improve the standard of living for farmers and country's economic development. Furthermore, many farmers are struggling to sustain their agriculture activity due to fuel scarcity and electricity outages, this is affecting the production of the farms. Therefore, the involvement of all stakeholders including government institutions, the farming communities, researchers, private sector and non-government organizations is a must to fill the capacity gaps and assist in the deployment of alternative solutions such as SWP.

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Techno-economic Analysis of Hybrid Energy System for Rural Electrification in Liberia. Case Study of Cavalla

Graduate CV.

Alvin Tepo Togba, Prof. Amine Boudghene Stambouli
University of Science and Technology of Oran
alvintepotogba@gmail.com

Abstract

The study unravels the status quo Sustainable Energy for All agenda as vision by the ECOWAS states in achievement of it's ambitious goal of 100% renewables in 2030 as enshrined in the EREP. Global Energy perspective, the ECOWAS regional approach and how Liberian as a state can integrate HES into her energy mix is captured herein. Data gathered have been assisted with by ECREEE through UNIDO, the LRREA, LEC and other stakeholders in the energy market of Liberia. After analysis, the researcher concludes that HES, especially Hydro as base load is the most preferred solution for Liberia.

BACKGROUND/CONTEXT

- 85% of the 1.2 billion people worldwide living without access to electricity reside in **rural areas**, attributed to the marginalization and long distance from grids.
- Renewable energies still constitute less than 2% of sub-Sahara Africa's energy mix.
- This has created the need for more d approaches and hence, the need to involve local governments

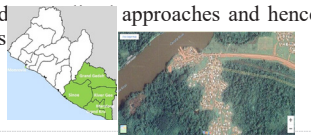


Figure 1. Grid Connections in West Africa [4]

PROBLEM STATEMENT/RESEARCH QUESTION

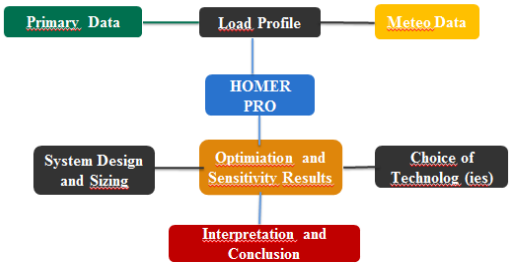
- According to (ECREEE, 2019) the major challenge for economic growth and social development in West Africa is related to energy poverty.
- The planning and implementation of sustainable energy projects remains centralized in Liberia often carried out by state owned agencies such as the LEC.
- Electrification rate in Liberia is very low when compared to many countries globally with a total access rate of just 21.4% in 2019 with the electrification access rate having urban and rural access around 80% and 20% respectively [LEC 2019].

OBJECTIVES

- ✓ Identifying the existing approaches for decentralized electricity production being used.
- ✓ Design least cost HES suitable for rural electrification
- ✓ To develop an economic cost model for the system
- ✓ Perform techno-economic analysis for the system using HOMER Pro as modeling tool and identifying the existing approaches for decentralized power gen.

METHODOLOGY

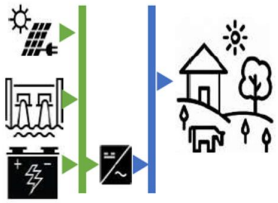
Methodology Flow Chat



RESULTS AND DISCUSSION

Table 2. Social Load Assumptions [4]

Social Loads Assumptions	Values
Social Center	2 kW
Health Center	5 kW
Hospital	15 kW
Electricity consumption pattern for social loads	2/3 energy consumed during daytime and 1/3 during evening and night



(b). Off Grid Rural System Architecture

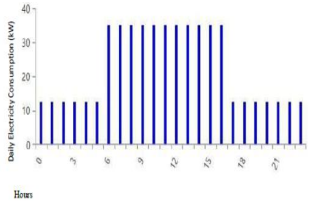


Figure 16 Social Load Profile for Rural Village(Author's Analysis based on Assumptions from Table 2)

Table 3. Summary of Input Costs Parameters

RE Equipment	CAPEX	Operation and Maintenance	Expected Lifetime	Replacement Cost (where applicable)	Efficiency	Source
PV System	850-2000 €/kW	10 €/kW/year	25 years	850-1500 €/kW	20.4 %	[49] [50]
AC DC Converter	650 €/kW	0	20 years	600 €/kW	90 %	[49]
Electric Batteries	200 €/kWh	5 €/kWh/year	10-12 years	200 €/kWh	90 %	[51]
Pumped Hydro Storage	800 €/kW[5]	40 €/kW/year	25 years[5]	800 €/kW	81 %	[6] [7]

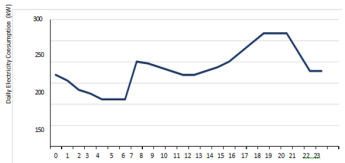


Figure 15 Rural Hourly Residential Electricity Load Profile (Author's Analysis, see Appendix .

Table 5. Results of Off Grid Scenario Simulations[5]

Result Specification	Parameter	Unit	Category 1 (PV+PHS)	Category 2 (PV+ Electric Batteries)
System Architecture	PV	MW	1.6	2.2
	PHS	MW	1.4	0
	Electric Battery Storage	MWh	0	14.9
	Converter	kW	523	906
Economic Specifications	NPC	€	6.15 Million	12.3 Million
	Capital Cost	€	5.54 Million	9.29 Million
	COE	€/kWh	0.25	0.4

Table 4. Results of Off Grid Scenario Simulations[5]

Result Specification	Parameter	Unit	Category 1 (PV+PHS)	Category 2 (PV+ Electric Batteries)
System Architecture	PV	MW	1.7	2.2
	PHS	MW	1.4	0
	Electric Battery Storage	MWh	0	14.9
	Converter	kW	665	906
Economic Specifications	NPC	€	10.1 Million	12.3 Million
	Capital Cost	€	9.53 Million	9.29 Million
	COE	€/kWh	0.4	0.4

[5] The results are calculated considering the capital cost of construction for both reservoirs

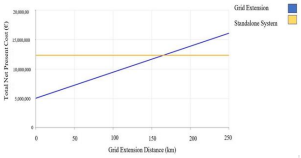


Figure 22 (b). Breakeven Grid Extension Distance for Category 2 (2.2 MW Flat Plate PV and 14.9 MWh Electric Battery Storage) with Additional Costs of Electrification

Table 6. Average Load Demand with Corresponding Population and BGED

Scaled Average Load Demand per settlement(kWh/day)	Population	Breakeven Grid Extension Distance (km)
4315	45000	115.29
2100	22500	67
1000	11250	41
500	5625	26.63
276.375	2812.5	19.44

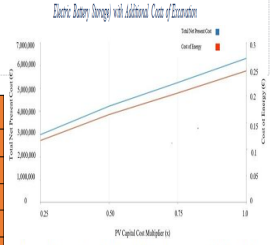


Figure 23. Sensitivity of COE and NPC with respect to PV Capital Cost

CONCLUSION

Limitations & Future Work

- Study scope limited to only Solar PV and Hydro; future study can delve in other RES (gen-set or biomass).
- Lack of accurate cost models data, outdated secondary info on Energy in Liberia is another limitation of the study.
- National lockdowns, offices closures etc. has been a major barrier to the researcher being in the field full-time.

CONCLUSION

- Solar penetration extension in Liberia as a response to low electrification rates.
- The costs of deploying storage could be further reduced if future policies allow mechanisms.
- Definite need of adding solar energy or SSHP to present energy mix.

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The entire master thesis report is available under the following link:
http://repository.pauwes-cop.net/handle/1/419

Wind energy resource forecasting: Dakhla and Laayoune case studies

Chahardine Hassani Ali, Prof. Hassane Bouzahir (a)
(a) Ibn Zohr University, Agadir, Morocco
Author's email address: chahardine94@gmail.com

Abstract

This report reviews some MCP methods and a statistical method known as Weibull distribution function with some other methods chosen to adjust its parameters. All the studies conducted in this report are done with the use of wind data available in both sites Dakhla and Laayoune which contributed to the estimation of their wind potential characteristics. Dakhla and Laayoune area has a large wind potential which is still far from being totally exploited. The site wind potential assessment and estimation of its future electricity production is a key step before construction of a wind farm.

BACKGROUND/CONTEXT

In order to implement installation of a highly performant wind farm with a good quality of wind speed, different studies and methods including MCP are required to predict the wind behavior in a given area. Wind speed and direction are the most important factors and mostly used in MCP for power generation forecasting and they can vary at all time scales. Hence, the methods of analysis and prediction of wind behavior are indeed of high importance for a good operation of wind turbines and wind farms. The assessment of wind energy potential in Laayoune and Dakhla is necessary and plays a very important role in the wind farm design, and the evaluation of wind energy is based on the wind speed forecasting.

PROBLEM STATEMENT/RESEARCH QUESTION

Dakhla and Laayoune are best known for good wind speed and to implement the installation of wind turbines or wind farms, some studies were necessary to assess and evaluate wind energy production in the sites with the use of some mathematical tools namely three MCP methods (method of ratio, OLR,GOR) and Weibull distribution functions (Probability Density Function or PDF and Cumulative Distribution Function or CDF). Those tools are used to estimate potential and also to correlate sites.

OBJECTIVES

- To estimate and evaluate wind energy potential of the two sites, Dakhla and Laayoune.
- To correlates the two sites.
- To study and compare different method of adjustment of Weibull distribution function in the two sites in order to find the most accurate one.
- And also, to compare the commonly used MCP methods to find out the most accurate among them in our case studies.

METHODOLOGY

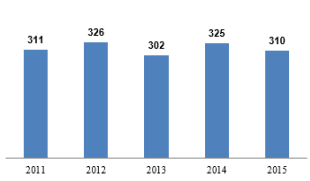
Choice of the sites: we chose these two sites because we have for them, a large series of hourly average wind speed and direction which represent 43824 recording sequences (speeds) for each site.

Data collection: The data were collected at a height of 50 m above the ground, averaged and stored every hour for a period of five years (from 01/01/2011 until 31/12/2015) well above the standard duration one year with the use of anemometers.

Computer resources: Matlab software and Microsoft excel.

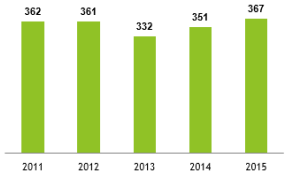
RESULTS AND DISCUSSION

Annual wind power density (W/m²) in Laayoune



Long-term average = 315 W/m²

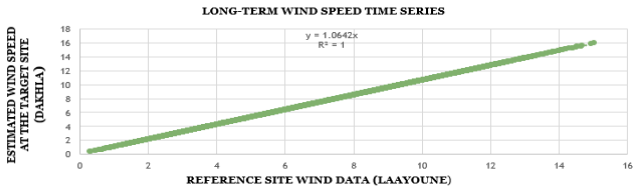
Annual wind power density (W/m²) in Dakhla



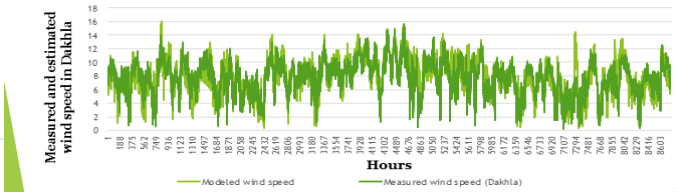
Long-term average = 355 W/m²

MCP wind data analysis
Method of ratio (R=1, very good correlation)

Plot of the long term measured vs estimated wind speed time series at the target site



Measured and estimated wind speed time series at the target site



CONCLUSION

The two sites are acceptable for producing energy by wind with an everage power density exceeding 300 W / m² .

The error calculation in estimating the wind power density showed that the maximum likelihood method is the only method capable of providing high precision estimates to the studied sites.

The existing correlation between the two sites is estimated with the use of three MCP methods which are the method of ratio, the ordinary linear regression (OLR) and the general orthogonal regression (GOR) giving respectively different values 1, 0.72243 and 0.7498 of the correlation coefficient (R).

The method of ratio seems to perform better than the others with R=1 indicating a very good correlation between the two sites.

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Master of Sciences

Energy Policy

Graduate CV.

A pre-feasibility Study of Rooftop Grid-tied Solar PV for Manufacturing Industry in Lusaka Zambia

Chanda Karen Chalwe , Prof Masinde Wanyama [b],
[b] *Center for Regional Integration, Johannesburg, South Africa,*
contact: chandachalwe@gmail.com

Abstract

Manufacturing industries utilize diesel power generation to supplement grid-supplied power to support their production activities where electricity supply is unreliable. This has often led to an increased energy budget and the cost of doing business in a country, in this context, Zambia. This study sort to investigate the feasibility of grid-tied rooftop solar PV to supplement the energy demand of the manufacturing industries within Lusaka city. Seven manufacturing industries were studied, highlighting their location, electricity consumption, the rooftop areas as well as the motivation to invest in rooftop solar PV systems. The study concluded that of the cumulative 6.8MWh energy demand from the seven industries, 27.6% can be met by rooftop solar PV systems. However, policy provisions for these systems are inadequate in Zambia and the SADC region coupled with a reluctant pursuance of developing supportive policy such as net-metering.

BACKGROUND/CONTEXT

Increasing population, industrial and manufacturing activities is resulting in a rise of energy demand [3]. Among the Agenda 2063 aspirations of the African Union is to industrialize Africa, which requires reliable energy supply. Contextually, Zambia reliance on hydropower (85%) has been subject to climatic impacts of drought since 2014 [2]. For Lusaka city, which is the primary hub for manufacturing industries in Zambia and hosts 15% of the total population, the increasing energy demand needs to be met (Mulenga, 2003). Rooftop solar PV systems present an opportunity for self-power generation to reduce the demand burden on the grid [3].

PROBLEM STATEMENT/RESEARCH QUESTION

There is competing access to energy in Zambia between the industrial sector and the residential sector [1] [5]. This has resulted in low access to the required energy volumes for industrial sector growth, as well as low abilities to meet household demand, hence posing energy security concerns. The phenomenon is largely attributable to the limited diversification of the country's main energy source, which currently relies heavily on hydropower, whereas, solar energy could be an alternative [2]; [3]. Adequate evidence on the solar potential of Zambia has been established in several research works, which suggest that advancement in the adoption rates of solar PV technology for electricity, has a great potential of increasing energy access and security [4] [5].

OBJECTIVES

The overall objective of this study was to comprehensively examine how feasible it is for manufacturing industries in Lusaka Zambia to adopt a rooftop grid-tied solar PV electricity to supplement their energy demands.
Specifically, it sought to:

1. Assess the determinants of grid-tied Solar PV adoption among selected industries in Lusaka.
2. To determine the energy consumption levels of industries.
3. To determine the energy generation potential of each site and rooftop areas.
4. Assess the feasible policy alternatives to enhance solar PV adoption among industries in Zambia.

METHODOLOGY

Preliminary Phase

Initial Literature Review
Conceptualisation of Academic Gap
Formulation of Research Objectives
Extensive Literature Review

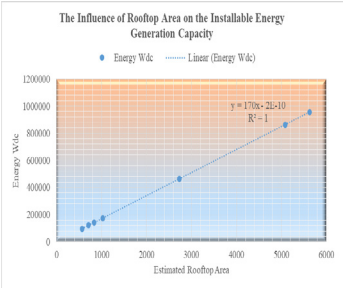
Main Survey Phase

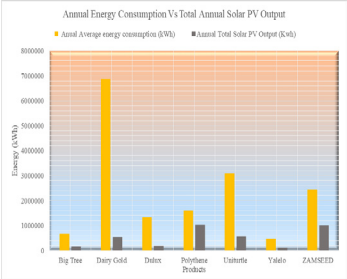
Profiling of seven manufacturing Industries using GPS and ArcGIS
Assessment of the Determinants of Solar PV Adoption using a survey questionnaire/checklist
Energy needs assessment from the electricity bill
Technical Solar PV generation potential using NREL PVWATTS Calculator

Post-Survey Phase

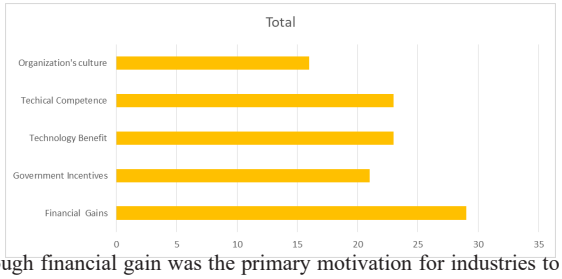
Presentation and Analysis of Results in Excel Spread sheet /Megastats
Discussions
Assessment of Feasible Policy Options by reviewing policy documents
Conclusions and Recommendations

RESULTS AND DISCUSSION





Regression analysis showed that the total installable solar PV capacity was simultaneously increasing with the rooftop area and ultimately, the solar PV output.
On average and cumulatively, the results suggested that solar PV output energy can cater for 27.6% of the average annual energy requirements of the selected industries in this study



Although financial gain was the primary motivation for industries to invest in rooftop solar PV, the dissuasion was that solar PV is good but not the best option to meet their electricity demand because of the heavy processing machinery used, except if the functionality of the technology is demonstrated amongst industrial energy users.
The review of policy documents reviewed that Zambia has the lowest electricity tariffs in the SADC region, which falsifies the trues cost of electricity and does not encourage rooftop solar PV investment.

CONCLUSION

In conclusion, the uptake of solar PV amongst Commercial and Industrial users hinges on different factors, namely; the company's culture and shared beliefs on the energy technology, the technical and economic factors as well as the policy and regulatory provisions in a country. Therefore, small scale distributed generation technologies such as rooftop solar PV will only be adopted to the extent that these factors are satisfied.

REFERENCES

1. Haanyika, C. M. (2008). Rural electrification in Zambia: A policy and institutional analysis. *Energy Policy*. https://doi.org/10.1016/j.enpol.2007.10.031
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An ex post Evaluation to determine and enhance the Sustainability of International Development Partner's funded Renewable Energy Projects in Namibia

Graduate CV.

Emmanuel Bernard Muzingwani, (a) Prof. Dr. Kosta Mathey

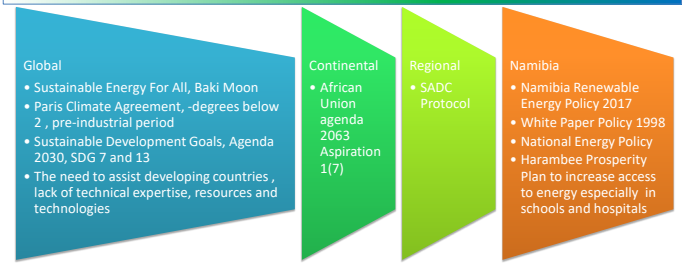
(a) Global Urban Studies Institute , Berlin

muzingwanib@gmail.com

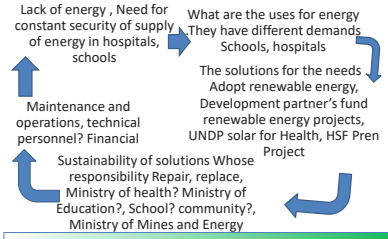
Abstract

The study assesses the benefits brought by International development partners' funded renewable energy projects in Namibia. Drawing on a case study approach, the research analyses the determinants of sustainability of the renewable energy projects that include financial, technological, social and environmental. In the absence of operations and maintenance funds, lack of involvement of beneficiaries, absence of proper personnel with technical expertise to monitor the systems, the systems are likely not to be sustainable. The study recommends strategies to counter the challenges that includes putting in place solar revolving fund, special assistance programme, policy support for handover of renewable energy projects.

BACKGROUND/CONTEXT



PROBLEM STATEMENT/RESEARCH QUESTION



Without a strong focus on sustainability, health facilities' roofs (school) can turn into graveyards of non functioning solar systems (KOIS). The main research question is how to determine and enhance the sustainability of International development partner's funded renewable energy projects in Namibia

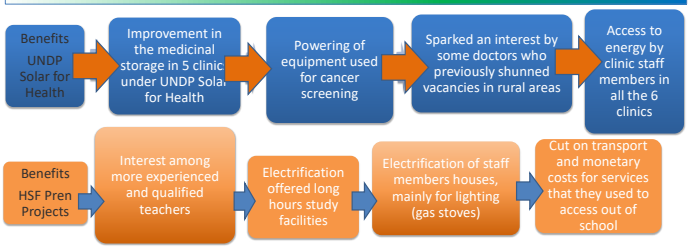
OBJECTIVES

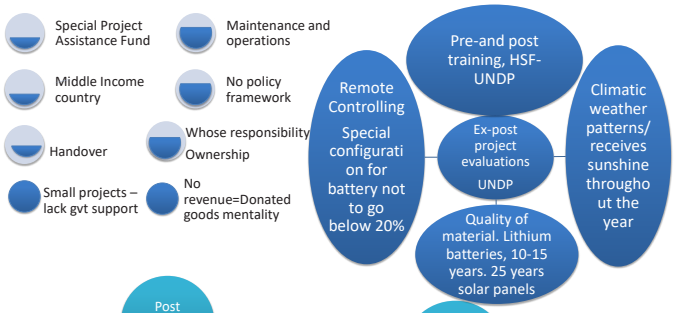
1. To evaluate the benefits of renewable energy projects funded by International Development partners in Namibia
2. Evaluate the sustainability of the benefits of selected International development partner's funded renewable energy projects on access to energy in rural Namibia
3. Identify the challenges that affect the sustainability of renewable energy projects in Namibia
4. Develop recommendations that enhance the sustainability of International development partner's funded renewable energy projects in Namibia.

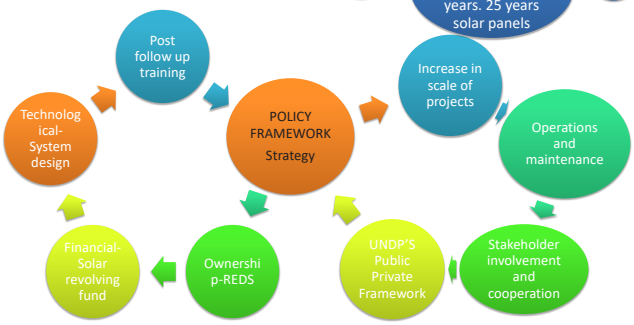
METHODOLOGY

Category of Respondents	Sampling techniques	Data Collection Instruments	Sample size
Project coordinators International Development Partners	Purposive sampling. They were responsible for planning, implementation and evaluation of the projects	In depth interviews and focus group discussions structured questionnaires and project documentary review. They implemented and monitored project activities.	6) Pren Project Hanns Seidel Foundation, UNDP Solar for Health, DFRN,
Community members and beneficiaries	Purposive sampling. They are the beneficiaries hence possess the required information on their involvement in the projects	Focus group discussions, in depth interviews and structured questionnaires	(20) beneficiaries of Tsumkwe, and Gam mini grids, (5) Health workers at 5 rural clinics, (10) teachers at the rural schools and community members
Ministry of Energy and Mines Policy experts. Regional Council	Purposive sampling. Ministry involved in Namibia's renewable energy policy formulation and development	A combination of In-depth telephone interviews, face to face interviews skype as well as zoom call	5) Ministry of Energy policy experts (6) Regional council representatives
Research and Academic professionals in the area of renewable energy	Purposive sampling	In-depth interviews and documentary review	(6)Namibia Institute of Energy Researchers, Lecturers from the University of Namibia and Namibia University of Science and Technology
Meteorological Services	Purposive	In-depth Interviews, meteorological data	**1 representative / Personal Observations**

RESULTS AND DISCUSSION







CONCLUSION

The information gathered by this research shows an interlink between ex-post evaluation and sustainability . The important message of the study could be that relying on one single institution for renewable energy projects is not sustainable hence the need for cooperation among stakeholders. The study gathered that 11 out of 12 projects studied are not sustainable 5 years from now if they are not given to the REDS to manage, especially on collection of revenue. In terms of technological sustainability given that all the systems have remote monitoring , they are likely to be sustainable. If properly looked after the solar panels are likely to last for between 15-25 years while batteries for 5 years. The lack of funding post project implementation for operations and maintenance is likely to affect their replacement with the exception of Tsumkwe system

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Graduate CV.

Development of the Sustainable Transition Map for the Sahel Region in terms of CLEWs Protocol

Moses S Bass , Prof: Angeles Lopez Agüera (a)
(a) University of Santiago de compostela, Spain
Email: mosessbass@gmail.com

ABSTRACT

Since 2014, the Committee for Local and Regional Leaders Appointment (CLRLA) have implemented Sustainable Communities Projects under the sponsorship of the United Nations Educational, Scientific and Cultural Organisation (UNESCO) in different regions of the globe. The aim of this study is to identify priority locations in the Sahel region of Africa for the start of Sustainable Communities Project. Five Sahelian countries including Algeria, Burkina Faso, The Gambia, Mauritania and Senegal have been studied in the context of Water, Energy and Land (CLEWs). The results show that Burkina Faso and The Gambia have the least progress in terms of energy, water and land and the study therefore recommends that the first sustainable communities projects should be implemented in Burkina Faso and The Gambia which will be followed by Mauritania and Senegal.

BACKGROUND/CONTEXT

It is globally projected that the demand for food, energy and water will rise greatly in the near decades due to the pressures emanating from unsustainable economic development, increased urbanization, population growth as well as climate change (Hoff, 2011). Integrated resources assessment approach such as the Climate, Land, Energy and Water systems (CLEWs) emerged as a way of enhancing tradeoff in policies and strategies aimed at addressing water, energy and land challenges (Bazilian, 2011). Thus, the concept of Sustainable Community Project (SCP) was developed in 2012 by the Special Committee for Local and Regional Leaders Appointment (CLRLA) as a more ambitious and practical approach geared towards contributing to the achievement of the Sustainable Development Goals (SDGs) in an integrated manner.

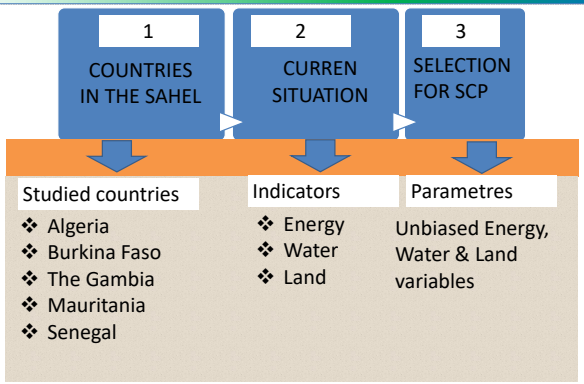
PROBLEM STATEMENT/RESEARCH QUESTION

In principle, the UNESCO project's approach is to implement a first project to enable and promote the cascading effect of reproducibility. For this reason, each SCP is usually started with one or two pilot projects that serve as an example for further development. Selecting the location and sizing of these pilot projects is crucial to ensure the success of the entire project. The research question is therefore, How will priority countries be selected from the Sahel region to develop a Sustainable Communities' Project in terms of Energy, Water and Land (CLEWs)?

OBJECTIVES

The main objective of this work is to identify priority locations for the development of an SCP in the Sahel region. In order to ensure unbiased decision-making, the development of a logical table of decisions based on the CLEWS protocol is considered. Specific objectives, a deep study of the current situation as well as the short-term expectations of the Member Countries of the Sahel and the corresponding design of a logical decision that allows to prioritize the different possible locations for the first SCP pilot projects.

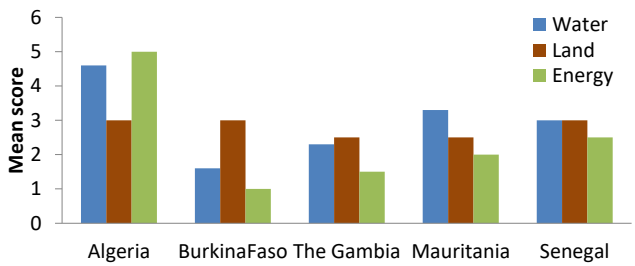
METHODOLOGY

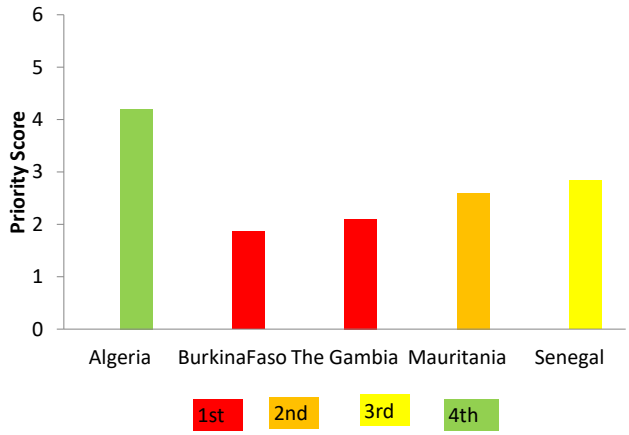


Data Sources

FAOSTAT · AQUASTAT · WHO UNICEF JMP · TRACKING SDG 7 The Energy Progress Report

RESULTS AND DISCUSSION





CONCLUSION

- The main objective of this study is to identify priority locations for the development of an SCP in the Sahel region in terms of the CLEWs
- To achieve this objective, five Sahelian countries including Algeria, Burkina Faso, The Gambia, Mauritania and Senegal are taken as case studies
- The results shows Burkina Faso and The Gambia as the countries with the least progress in terms of Energy, Water and Land.

RECOMMENDATIONS

- Burkina Faso and Gambia should be considered as first priority countries for a SCP in the Sahel followed by Mauritania and Senegal
- specific locations in the selected countries should be identified

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Evaluating the Transition to Green Economy in Kenya to Combat Climate Change: A Case Study of Nairobi City

Graduate CV.

NGUNGI JUDY MBEKE, NZIOKA J. MUTHAMA
Wangari Mathai Institute of Peace and Environment , University of Nairobi
judyngungi@gmail.com

Abstract

This study examined how adoption of renewable technologies in the country contributes to green economy transition and reduce the impacts of climate change. The objectives that were answered: the level of renewable energy technology adoption in urban residential households, how the existing energy and climate change policies are influencing RET adoption, modeled a renewable energy driven scenario. Results showed that public awareness of RET is low. A demand side management scenario would be achieved through increase of renewable use and implementing existing policies which will reduce the amount of greenhouse gases being released in the environment by 2040

BACKGROUND/CONTEXT

Green economy is one that is socially inclusive, resource efficient, and with low carbon (UNEP 2020). Energy transition is aimed at increasing the use of renewable energy technologies and reduce greenhouse emission Zoboli, S. S. (2017). .

Implementation of Nationally Determined Contribution will reduce emissions that cause global warming and thus reduce the impacts of climate change such as flooding, prolonged drought etc.

Increase of population into the urban cities continues to lead to increase in energy demand and there is need for transformation in the energy sector.

PROBLEM STATEMENT/RESEARCH QUESTION

Adoption of renewable energy sources in urban residential areas is being advocated as a way to encourage energy transition.

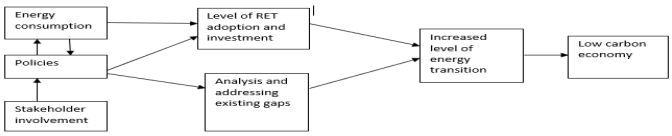
There is however, limited research that evaluates how the increase in energy demand in Nairobi city impacts the level of emission and the achievement of Kenya's nationally determined contribution

OBJECTIVES

1. To determine how the adoption of renewable energy technology and energy-efficient appliances in residential urban households' impacts energy demand and GHG emissions in Kenya
2. To determine the effectiveness of policies and stakeholder involvement in influencing renewable energy technology adoption.
3. To model a renewable energy- climate action-driven scenario for Kenya

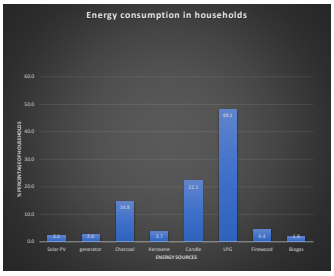
METHODOLOGY

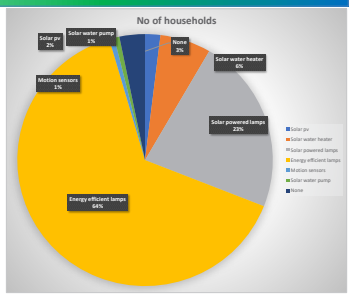
Conceptual framework



Research question	Instrument used	Sampling techniques	Units of inquiry
➢ How is the adoption of renewable energy technology (RET) in residential urban households' impacts energy demand and GHG emissions in Kenya?	Questionnaires	Random sampling	272 Urban households in Nairobi county
➢ How effective are the existing policies are influence renewable energy technology adoption? ➢ What is the role of stakeholder's involvement in renewable energy technology adoption and investment	Document review Interview sheet	Purposive sampling	Identified key respondents in government institutions
➢ What will the scenario for climate action driven in 2040 be?	LEAP software SEI. (2002).	Secondary availed data	Micro-economic and energy data for the country from accredited sources

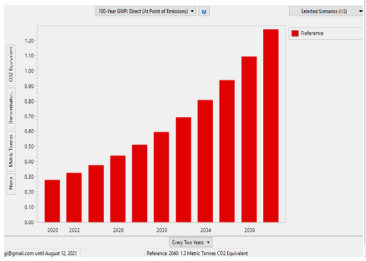
RESULTS AND DISCUSSION

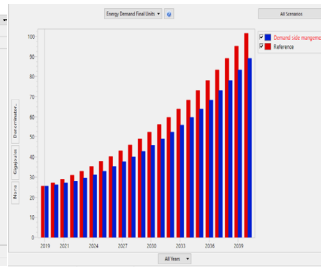




Energy consumption in households

RET adoption in urban houses





BAU scenario CO2 emissions equivalent DSM scenario CO2 emission

CONCLUSION

Lack of information with most consumers viewing investment of solar PV and solar water heaters of low priority to them continues to hinder RET adoption. An evolving carbon financing market and the lack of awareness among consumers in all sectors make it difficult for them to participate in the clean development mechanism or voluntary carbon market projects. Clean and affordable energy is key in seeing the shift of green economy but there is a need to involve the public consultations and awareness of new infrastructure that come with energy transition as this plays a key role in the achievement of sustainable development goals in Kenya.

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Graduate CV.

Influence of Social Factors on Energy Recovery Options from Solid Waste Generated in Markets: A Case of Central Division of Kampala

Anthony Osinde, Eng. Dr. Swaib Semiyaga[a]
[a]Makerere University, Kampala, Uganda
Contact details: aosinde91@gmail.com

Abstract

This study determined the influence of social factors on energy-recovery technology and also evaluated the most suitable technology for recovering energy from solid waste generated within markets in Kampala. Questionnaires, key informant interviews and literature review were used for data collection from the market vendors, authorities and sector key players. Results show that social aspects within the markets does not directly influence the technology option but rather the nature and quantity of waste generated. Landfill gas recovery was evaluated the most suitable technology option followed by Anaerobic digestion, incineration and Gasification being the least suitable. The study recommends adopting favourable policies for independent power producers and Public-Private partnership

BACKGROUND/CONTEXT

Increasing rate of waste generation is attributed to urbanization and population growth. African Urban Population is projected to triple from 470 million in 2015 to about 1.2 billion by 2050 (United Nation., 2014).

In East Africa, annual waste generation is projected to increase to over 60% annually by 2030 (Aryampa *et al*, 2019).

In Kampala city, the per capita solid waste generation has increased from 0.34 to 0.38kg/capita/day. MSW & its management is an issue of worldwide concern (Khajuria *et al*., 2010). Developed countries have adopted Waste-to-Energy technologies, turning solid waste into RE resources (Zurbrügg *et al*., 2013)

PROBLEM STATEMENT/RESEARCH QUESTION

The high intensity of moist solid waste is not only bulky to handle but also associated with high management challenges and costs leading to management inefficiencies and irregularities (Aye & Widjaya, 2006).

On the other hand, there is an increase in urban energy consumption due to an increase in population (Mukwaya, 2016; Li & Yao, 2009 and Karekezi & Majoro, 2002).

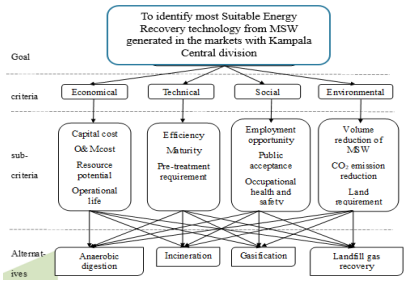
Key question: What is the most suitable technology option for waste-to-energy conversion for market wastes in Kampala central division.

OBJECTIVES

To determine the influence of social factors in establishing the energy recovery options from solid waste generated in markets in the Kampala central division; Examining the current status of solid waste management in markets in Kampala central division; Assessment of people's attitude towards energy recovery options from solid waste; and evaluating the suitable and applicable energy recovery option from the solid waste.

METHODOLOGY

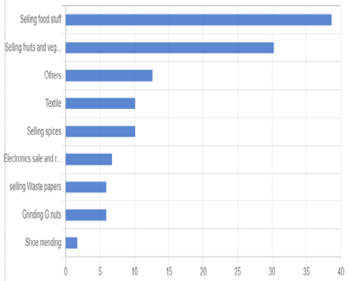
RESEARCH APPROACH		Data collection methods	Instruments	Sampling technique	Units of Inquiry
Mixed Method	Qualitative	❖ Key informant Interviews, ❖ Focus Group Discussion, ❖ literature review	❖ Interview guide ❖ FGD guide ❖ Data extraction sheet	Purposive	❖ Authorities responsible for solid waste management and public health
	Quantitative	Researcher administered Questionnaire	Structured questionnaire	Random	❖ Market vendors and traders
Sample size	3 largest food markets if Kampala central . Data were analyzed with kobo toolbox, MCDM (AHP) and Superdecission software.				



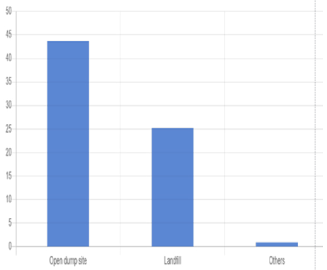
The Multi Criteria Decision Making tool known as Analytical Hierarchy Process (AHP) was used in evaluating the Energy recovery technology option. 4 major criteria and 12 sub criteria were adopted for the evaluation.

RESULTS AND DISCUSSION

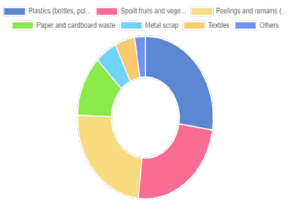
Main occupations in the markets



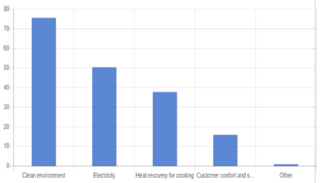
Disposal mechanism in place



Waste composition



Attitude of the respondents about energy recovery



Calculated weights from pairwise comparison

Name	Normalized	Idealized
1 Economical	0.521530899384491 49	1.0
2 Technical	0.27646153408863661	0.53009617342887128
3 Social	0.059950196565300103	0.11495042122346551
4 Environmental	0.14205736996157181	0.27238533733902881

Overall priority score of the WtE technologies

Name	Graphic	Ideals	Normals	Raw
1 Anaerobic digestion		0.879573	0.287098	0.095699
2 Incineration		0.760042	0.248082	0.082694
3 Gasification		0.424054	0.138414	0.046138
4 Landfill Gas Recovery		1.000000	0.326406	0.108802

CONCLUSION

- ❖ The solid waste management strategy in the three market are similar. All the markets have a transfer site from which the waste is picked for final disposal at kiteezi landfill.
- ❖ Social demographic factors of the market vendors such as age, level of education, level of income among others did not have direct influence on the energy recovery technology option
- ❖ Energy and resource recovery is crucial in institutional waste management due to the ability to minimise waste as well as enhancing production in terms of energy generated.
- ❖ Kampala Capital City Authority and the market institutions are missing out on the potential to generate energy from waste, boost their income and minimise expenditure in waste collection and transportation through energy recovery

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Graduate CV.

Parametric Estimates of the Effects of Renewable Energy Consumption and Environmental Sustainability on Economic Growth In Africa

Chinedu Miracle Nevo, Prof. Emmanuel Donkor (a)

(a) Kwame Nkrumah University of Science and Technology, Kumasi, Ghana

Author's email address: chinedunevo@gmail.com

Abstract

This study seeks to parametrically estimate the effects of renewable energy consumption and environmental sustainability on economic growth in Africa. Employing the System GMM estimation technique, the study found that renewable energy adoption and development will lead to an increase in economic growth in Africa since its consumption has a positive and significant relationship with gross domestic product (GDP), both in the long-run and short-run while environmental sustainability has a positive but insignificant effect on economic growth. The study, therefore, recommends that African countries and governments should intensify efforts towards developing the renewable energy sector, especially using relevant policy instruments.

BACKGROUND/CONTEXT

This study focuses on the effect of renewable energy consumption on economic growth in Africa and how previous studies have discussed it. Tugcu et al (2012) investigated renewable energy, nonrenewable energy and economic growth in MENA region. Epaphra & Kombe (2017) investigated how energy policies and institutions affect economic growth in Nigeria and Ghana. However, most previous literature ignored the importance of environmental sustainability in the relationship between renewable energy consumption and economic growth, and also didn't spread their sample well enough across Africa. Therefore, this study assesses the effects of both renewable energy consumption and environmental sustainability on economic growth in Africa while controlling for the effects of other factors such as: access to electricity (Dogan et al. (2016), gross fixed capital formation, labour force participation and total country population (Singh & Richmond (2019).

PROBLEM STATEMENT/RESEARCH QUESTION

The study is guided by three core research questions:

1 Is there a significant relationship between renewable energy consumption and economic growth in Africa?

2 What is the nature of the relationship that exists between environmental sustainability and economic growth in Africa?

3 To what extent does environmental sustainability serve as a moderating factor on the nexus between renewable energy consumption and economic growth in Africa?

OBJECTIVES

1. To investigate the effect of renewable energy consumption on economic growth in Africa.

2. To analyse the effect of environmental sustainability on economic growth in Africa

3. To investigate the moderating role of environmental sustainability on the nexus between renewable energy consumption and economic growth.

METHODOLOGY

- Sources of Data:
  - World Development Indicators (WDI) database of the World Bank (WDI, 2018).
  - Time period of 2008 to 2014
- Study Units: Panel of thirty-seven African countries
- Variables:
  - dependent variable (the natural logarithm of GDP),
  - the endogenous variables (the one-year lag of GDP),
  - the explanatory variables (REC and CO2 emissions), and,
  - the control variables (GFC, LABFORCE, ACCELC and AGRIC)
- Estimation Methods:
  - Generalised Method of Moments (GMM)

Models

Objectives One and Two

$$lnGDP_{i,t}=\alpha_1 lnGDP_{i,t-1} - \beta_1 CO2_{i,t}+\beta_2 REC_{i,t}+\gamma_1 ACCELC_{i,t} + \gamma_2 GFC_{i,t} + \gamma_3 LABFORCE_{i,t} + \mu_i + \delta_t + \varepsilon_{i,t}$$

Objective Three

$$lnGDP_{i,t}=\alpha_1 lnGDP_{i,t-1} - \beta_1 CO2_{i,t}+\beta_2 REC_{i,t}+\gamma_1 ACCELC_{i,t} + \gamma_2 GFC_{i,t} + \gamma_3 LABFORCE_{i,t} + \gamma_4 MOD_{i,t} + \mu_i + \delta_t + \varepsilon_{i,t}$$

RESULTS AND DISCUSSION

Results (Objectives one and two)

Variable	Coefficients
lnGDP_1	0.9631**
	(55.88)
CO2	1.01e-08
	(0.22)
REC	0.0007**
	(2.27)
ACCELC	0.0006*
	(1.85)
lnGFC	0.0293**
	(2.14)
lnLABFORCE	0.0052
	(1.38)
No. of Obs.	206
Time Dummies	Yes
Number of Instruments	31/35
F Statistic	1.20e+07
GMM Instrument Lag	1
AR (2)	0.363
Hansen test	0.139

*Note: Robust options used; t-statistics in parentheses; ***p < 0.01, **p < 0.05, * p < 0.1 indicate significance at 1%, 5% and 10% respectively. Estimations made using xtabond2 routine in Stata.*
Source: Author's computation using Stata 15

Long-run GMM Coefficients of REC, ACCELC and lnGFC

Variable	Coefficients
REC	0.0190707**
	(2.61)
ACCELC	0.0152493**
	(2.53)
lnGFC	0.7935176**
	(10.38)

*Note: z-statistics in parentheses; ***p < 0.01, **p < 0.05, * p < 0.1 indicate significance at 1%, 5% and 10% respectively. Estimations are done using nlcom routine in Stata.*
Source: Researcher's Computation using Stata 15

Results (Objective three)

Parametric Estimates for the Effect of MOD on lnGDP, Controlling for ACCELC, lnGFC and lnLABFORCE (t-values in parentheses)

Variable	Coefficients
MOD	2.61e-09
	(1.27)
No. of Obs.	206
Time Dummies	Yes
Number of Instruments/Groups	32/35
F Statistic	5.56e+06
GMM Instrument Lag	1
AR (2)	0.368
Hansen test	0.118

*Note: Robust options used; t-statistics in parentheses; ***p < 0.01, **p < 0.05, * p < 0.1 indicate significance at 1%, 5% and 10% respectively. Estimations are done using xtabond2 routine in Stata.*
Source: Researcher's Computation using Stata 15

CONCLUSION

- Objective 1: Renewable energy consumption has a positive and significant effect on economic growth in Africa
- Objective 2: Environmental sustainability has a positive but insignificant relationship with economic growth in Africa. While this is against a priori, it emphasizes Africa's heavy dependence on fossil fuel.
- Objective 3: Environmental sustainability plays a positive but insignificant role on moderating the relationship between renewable energy consumption and economic growth in Africa.

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Graduate CV.

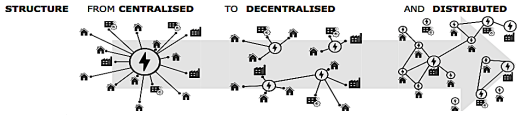
Policy Framework for the Promotion of Digital Technology in Mini-grid Sector in Sub-Saharan Africa. Case of Blockchain Technology

Mirana Njakatiana Andriarisoa, Dr Erick Tambo
Contact details: njakatianamirana@yahoo.fr

Abstract

The present research aims at analyzing in what extent the study and improvement in the policy and regulation around digital technology and mini-grid sector can promote the implementation of peer-to-peer (P2P)energy trading enhanced by blockchain in Sub-Saharan Africa. Four specific objectives were addressed, first to review the current situation on digital technology, blockchain and peer-to-peer energy trading in Sub-Saharan Africa with conducting a SWOT analysis. Secondly, the policy and regulation framework in relation to blockchain and peer-to-peer market in SSA has been assessed, before proposing a conceptual modelling for policy and regulations framework for the implementation of these technologies. The proposed model has been validated with the case of Kenya.

BACKGROUND/CONTEXT



Over the past few decades, disruptive technologies promoting decentralization have been affecting the energy sector. Innovative finance such as blockchain technology is one of them and 36% of the use of blockchain in the renewable energy sector are for P2P energy trading (IRENA, 2019).

PROBLEM STATEMENT/RESEARCH QUESTION

47% of the population in SSA still do not have access to electricity (IEA et al., 2020). Peer-to-peer energy trading using blockchain is a promising approach to solve that issue. However, this technology is just at its very early stage in the region and policy and regulation is a prerequisite for its implementation (Mengelkamp et al., 2017).

Main Question: In what extend the study and improvement in the policy and regulation around digital technology and mini-grid sector can promote the implementation of P2P energy trading using blockchain in SSA?

OBJECTIVES

To propose a policy and regulation framework required for the introduction and promotion of smart peer-to-peer energy trading using blockchain technology in the mini-grid sector in SSA.

METHODOLOGY

Literature review → Desktop research → Expert interview → Proposition of a conceptual model for policy framework → validation of with the case study

Qualitative research

Methods applied	Instruments	Key features	Outcomes
Desktop research	Data extraction sheet	Documentary analysis	Secondary data: - digital technology indicators - blockchain and P2P energy situation - Policy and regulation on P2P and blockchain
Interview	Interview protocol	Online interview was conducted with the CEO of Rehub company	Primary data on: - policy and regulation situation and challenges in Kenya - information about the project

Methods for data analysis: **The SWOT analysis**

Elaboration of the conceptual modeling: **Bobrow's principle**:

1/ Discipline breakout → 2/ Minimum conditions → 3/ Safeguards → 4/ Placement (time) → 5/ Oppositional analysis → 6/ Borrowing → 7/ Tinkering → 8/ Backward mapping → 9/ Forward mapping

RESULTS AND DISCUSSION

SWOT analysis of the implementation of P2P energy trading and blockchain in SSA

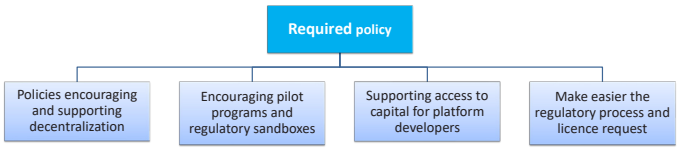
STRENGTHS
- Promising cheaper cost of energy when using blockchain
- Blockchain can ensure an efficient, transparent and robust trading system
- Optimization of supply and demand management
- Reduce the stress on the grid and avoid building new generation capacity

WEAKNESSES
- Low advancement of digital technology in Africa
- Low awareness and preparedness for 4IR in the region
- Low current and planned use of 4IR

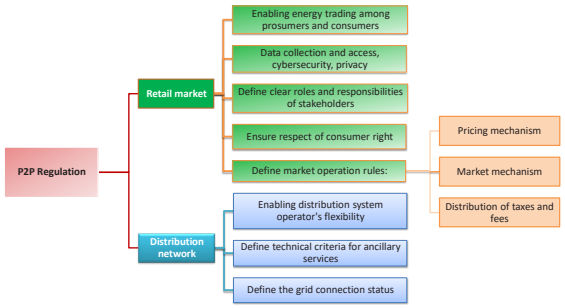
OPPORTUNITIES
- Expansion of investment in mini-grid sector in SSA
- Decreasing cost of stand-alone solar technology
- Boom of SHS with mobile payment and PayGo mechanism
- High cost of battery

THREATS
- Competition with the national energy company
- Subsidization of the price of energy from the main grid
- Absence of policy and regulation
- Weak regulatory environment

Conceptual modelling for the policy framework



Conceptual modelling on the regulatory requirements for P2P



CONCLUSION

- Africa still lags behind in terms of new digital technology.
- The policy and regulation in SSA is not embracing yet the implementation of P2P energy and blockchain but there are promising opportunities.
- The main elements in the policy framework are the promotion of decentralization, and supporting the exploration of the new digital technologies.

Recommendations
- Guideline for policy-makers of any SSA countries
- No "one size fits all" solutions, the model may require adaptation
- Necessity of accompanying measures such as promoting education and skills in digital technology

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Graduate CV.

Valuation of CO2 Emissions Reduction from Renewable Energy and Energy Efficiency Projects in Africa: The Case Study of Burkina Faso

Rice Verouska SEUTCHE NONO, Dr Marie SAWADOGO[a]

[a]*International Institute for Water and Environmental Engineering (2IE), Ouagadougou, Burkina Faso*

Contact details: nonoveka@yahoo.fr

Abstract

This study investigated on the impacts of renewable energy (RE) and energy efficiency (EE) projects on CO2 emissions in Burkina Faso, and determined their potential for the clean development mechanism (CDM). The CDM approved methods: AMS-II.C., AMS-II.L., AMS-I.A., AMS-I.F., AMS-I.D. and AMS-III.AR. were applied. Results revealed that, 68709.424MWh and 9430.446MWh were saved and displaced by the EE and RE projects respectively annually, accounting for 48157.668tCO2e emissions reduced annually, that is 63.12% reduction from baseline scenario, representing a huge CDM potential. This increases the sector's attractiveness for private investments, as it could generate 48157.668 Certified Emissions Reduction yearly, which could yield about $4815766.8, considering a carbon price of $10/tCO2e and a 10 year crediting period. Policies promoting the registration of such projects to the CDM are essential to boost the sector, and enable the country/region benefit from the sustainable development this mechanism offers.

BACKGROUND/CONTEXT

The growing energy demand over the last decades resulted in increasing energy related greenhouse gas emissions; 20.5 GtCO2 in 1990 to 33.1GtCO2 in 2018 (IEA, 2019c). Africa accounts for about 2% of these emissions, but is the most vulnerable region to climate change impacts (IEA, 2019a). The CDM was designed to enable developed countries to meet their emissions reduction targets, by supporting the development of low carbon projects in developing countries in exchange of certified emissions reductions, thereby contributing to the achievement of sustainable development in these countries. In 2020, Africa is host to only 253 (5 in Burkina Faso) CDM projects out of 8377 globally (UNEP DTU Partnership, 2020) .

PROBLEM STATEMENT/RESEARCH QUESTION

Burkina Faso is a landlocked country of the Sahel which highly vulnerable to climate change impacts. It's electricity mix comprises of 57% fossil fueled thermal plants, 36% electricity imports, 7% Hydro and about 1% Solar (ADF, 2015). Electricity access is at 20% countrywide, with 58% urban and 2% rural. Some RE and EE projects were implemented in a bid to achieve the country's RE and EE Action Plan targets: 50% renewables in the mix and 95% electricity access by 2030 (SE4ALL, 2019). Capitalizing the emissions reduction potential of these projects via the CDM is imperative to boost the sector, and improve the country's energy security while curbing carbon emissions.

Research questions: How do the non CDM registered RE and EE projects implemented Burkina Faso influence the level of carbon emissions? What is their CDM potential?

OBJECTIVES

Make an inventory of non CDM registered RE and EE projects implemented in Burkina Faso; determine their impact on carbon emissions and their potential for the CDM.

METHODOLOGY

An inventory of non CDM registered RE and EE projects implemented in Burkina Faso from 2012 to 2020 was done. The secondary data about the projects and some country data were provided by the 2iE and different national entities, including the Ministry of Energy through the ANEREE and the ABER. Other information was from open access journals, reports and different websites. According to project category, one of the following approved CDM methods was applied to determine a project's CO2 emissions reduction and its state of additionality:

EE projects

AMS-II.C.: Small-scale Methodology, Demand-side energy efficiency activities for specific technologies - Version 15.0.

AMS-II.L.: Small-scale Methodology, Demand-side activities for efficient outdoor and street lighting technologies - Version 02.0.

RE projects

AMS-I.A.: Small-scale Methodology, Electricity generation by the user - Version 17.0.

AMS-I.F.: Small-scale Methodology, Renewable electricity generation for captive use and mini-grid -Version 03.0.

AMS-I.D.: Small-scale Methodology, Grid connected renewable electricity generation -Version 18.0.

AMS-III.AR.: Small-scale Methodology, Substituting fossil fuel-based lighting with LED/CFL lighting systems ---Version 06.0

RESULTS AND DISCUSSION

Table 1. Annual energy savings and emissions reduction by EE projects

Project	Annual energy savings (MWh/year)	Annual emission reductions (tCO2e/year)
600 LED lamps in University Hostels	35.689	17.345
1500000 LED lamps in 375000 households	60225.000	29269.350
10500 LED lamps for street lighting	5746.829	4022.781
4500 LED lamps for street lighting	1492.820	2150.153
1926 solar street lights with LED lamps installed in Ouagadougou.	700.150	817.695
1400 solar street lights with LED lamps installed in rural localities. (Project 175 rural localities)	508.936	594.378
TOTAL	**67500.339**	**36871.701**

→ Energy savings
→ Emissions reduction
→ Avoidance of additional generation capacity installation
→ Quick access to electricity
→ Reduction of electricity imports
→ Increase country energy security
→ Quick access to electricity

Table 2. Annual energy displaced and emission reductions by RE projects

Project	Annual energy displaced(MWh/year)	Annual emission reductions (tCO2e/year)
385 Infrastructures, off-grid solar PV systems in schools and health facilities	465.474	226.220
On-grid solar PV systems in medical centres and public buildings	2.154	1046.973
Off-grid solar PV kits in City Halls	71.668	34.831
Solar Back up project, off grid	1851.331	899.747
On-grid solar PV systems installed in different institutions	4376.686	2127,070
Off-grid solar PV systems in rural schools and CSPS	274.067	219.254
Rural electrification with solar PV micro grids	687.709	550.167
Ziga solar PV power plant	1656.188	804.907
Bilgo hybrid solar PV-diesel generator power plant	45.169	21.952
Distribution of 25000 certified solar lamps, Lighting Africa, in 400 primary schools in off grid rural areas (2016-2020).	--	2300.000
Distribution of 8500 solar lamps to primary school pupils in off-grid rural areas	--	782.000
TOTAL	**9430.446**	**11285.967**

Table 3. Total energy saved, energy displaced, emissions reduced and CERs generated

Energy saved/year	**68709.424 MWh**
Energy displaced/year	**9430.446 MWh**
Emission reduced/year	**48157.668 tCO_2e**
Number of CERs/year	**48157.668**
Number of CERs for a 10years crediting period	**481576.68**
Total CERs sales revenu in 10 Years (10USD/CER)	**4 815 766.8 USD**

63.12% reduction
Contributing to INDC
Attraction for Private Investment
All projects proven additional.
Key for the CDM

CONCLUSION

The RE and EE projects implemented in Burkina Faso negatively impact GHG emissions **(-63.12%)** and contribute to the achievement of country INDCs;

They have a great CDM potential (48 157.668 tCO2e/year) and attractiveness for private investments (481576.68USD/year from CERs);

Other African countries also host such projects; Harnessing such potential via project registration to the CDM will contribute to country/region sustainable development; improve Africa's poor representation at the CDM.

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

http://repository.pauwes-cop.net/handle/1/437

Master of Sciences

Water Engineering

Graduate CV.

Assessing the Potential of Groundwater Recharge: A case study of Palla Road wellfields, Botswana

Gontle Thuto Rankgomo, Prof. John Gathenya[a]
[a]Jomo Kenyatta University, Kenya
Contact details: rankgomogt27@gmail.com

Abstract

This is a feasibility study on the assessment of managed aquifer recharge in the Palla Road wellfields, Botswana. The investigation was carried out on spatial observations using dual model: the soil water balance and QSWAT+ model. Results showed that there is a relative amount of precipitation that is received in the area however, it is lost through evapotranspiration. Therefore, artificial groundwater recharge is found to be one of the alternatives to improve and diversify the current available water resources. Moreover, the investigation recommends for capacity building in the general public and improved mechanisms to ease access to groundwater data.

BACKGROUND/CONTEXT

2.5 billion people depend on groundwater solely for their basic human needs Hassan (2018). Moreover, Conti (2016) affirms that groundwater is the most abstracted raw material on earth. However, globally groundwater resources are limited and they are declining in terms of quality and quantity due to contamination and climate change impacts Singh et al. (2019).

Lindhe et al (2014) consider artificial groundwater recharge (AR) as an efficient technique that can be used to increase the available water quantities for water supply as well as to improve the water quality.

PROBLEM STATEMENT/RESEARCH QUESTION

Most of the anthropogenic activities in Botswana are highly dependent on groundwater resources. Over the years good sites for dam establishment have been regarded to be scarce by the United Nations Development Programme UNDP (2011). Moreover, this lead to a decentralized approach through the North South Carrier (NSC) as means of improving the water supply particularly in Gaborone thus, the Palla Road wellfields were connected for an intermittent supply. Due to this, alternative water resources need to be explored in order to augment the available surface resource including artificial groundwater recharge.

OBJECTIVES

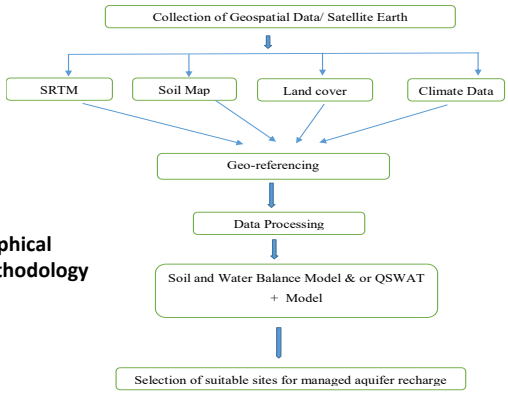
- To identify and assess suitable areas for artificial groundwater recharge for storage in Palla Road wellfields.
- To obtain the hydrological characteristics of Palla Road aquifer (precipitation, evaporation).
- To evaluate managed aquifer recharge potential based on the hydrological characteristics.
- To identify suitable areas for artificial aquifer recharge.
- To assess the variability of groundwater recharge in Palla Road wellfields.

METHODOLOGY

The first phase of the methodology consisted a reconnaissance visit in order to have in depth knowledge on the study area. During the visit the borehole characteristics were observed.

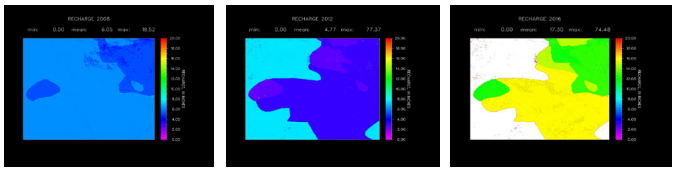
The investigation was further carried out using spatial observations of the following variables: land cover, digital elevation model, soil map for simulation in the QSWAT+ and soil water balance model using 2009-2019 climate data.

Graphical Methodology

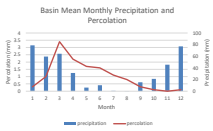


RESULTS AND DISCUSSION

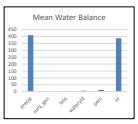
Soil Water Balance Model Results



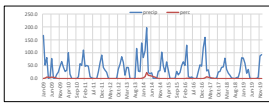
QSWAT + Model Results



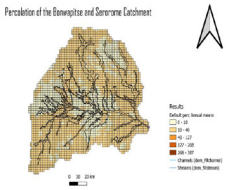
Percolation vs Precipitation in various months of the year

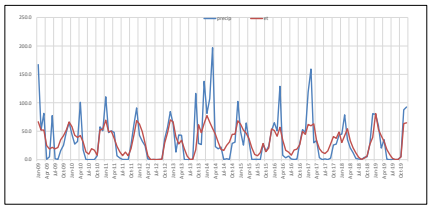


Mean water Balance

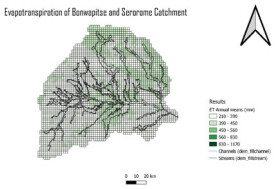


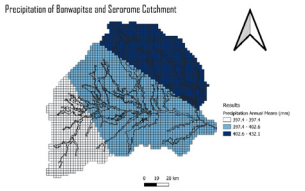
Precipitation vs Percolation in Palla Road





Precipitation vs Evapotranspiration in Palla Road





CONCLUSION

Based on the findings of this research groundwater management is imperative in Botswana as it provides water for most of the country. The Palla Road wellfields have great potential for artificial groundwater recharge. Implementation of the technique should be further investigated so as to improve the natural groundwater recharge and thus ensuring a better water supply.

Also, managed aquifer recharge serves as a solution to diversify the current available resources.

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

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Assessment of Groundwater Potential and Quality using GIS and Remote Sensing Techniques: Case study of Kirundo Province, Burundi

Graduate C

Clovis. Ntakarutimana *^ supervision of Prof. Dr.-Ing. Benedict M. Mutua**
E-mail: clovisntakarutimana@gmail.com
**Kibabii University, P.O. Box 1699 – 50200, Bungoma, Kenya. (E-mail: bmmutua@kibu.ac.ke)

Abstract

Many developing countries are facing the challenge of getting safe and sufficient water. This has called for exploration on groundwater to meet the deficit. For sustainable and effective groundwater management, this study investigated the groundwater potential and its quality in Kirundo Province, Burundi using GIS and Remote Sensing techniques. The objective was respectively achieved through the model developed and the computation of different water quality indices. Results show that the majority of the province lies under very low and low groundwater potential and has unsuitable water quality class. However, the study has identified potential zones for groundwater exploration. The results obtained from this study will help the policy makers and water managers to make informed decisions.

BACKGROUND/CONTEXT

Naturally, water is unequally distributed on the earth where groundwater represents around 90% of all accessible freshwater resources (Zhu and Schwartz, 2011). Groundwater as source of water is of great importance in the livelihoods of the world population. Therefore, the scarcity of groundwater resources slows down the socio-economic development globally, where the impact is more pronounced in developing countries. Obviously, a judicious understanding of the factors contributing to groundwater quality and quantity is highly needed in addition to acquiring adequate techniques. In this regard, this study assessed the groundwater potential and quality using the GIS and RS techniques in Kirundo Province, which is among the areas that lack safe and sufficient water in Burundi.

PROBLEM STATEMENT/RESEARCH QUESTION

- Safe drinking water scarcity associated with food insecurity;
- Groundwater which is widely used for domestic purposes, is in most cases untreated;
- Inadequate scientific knowledge on groundwater quality and its potential in the Province;
- As results, the groundwater exploitation has been unsustainable and ineffective.

OBJECTIVES

The main objective was to assess the groundwater potential and its quality using Geographical Information System (GIS) and Remote Sensing (RS) techniques in Kirundo Province.

With the following specific objectives that were to:

- Assess the suitability of groundwater for its drinking and agricultural purposes;
- Identify groundwater potential zones; and
- Map spatial variation of groundwater quality in the Province.

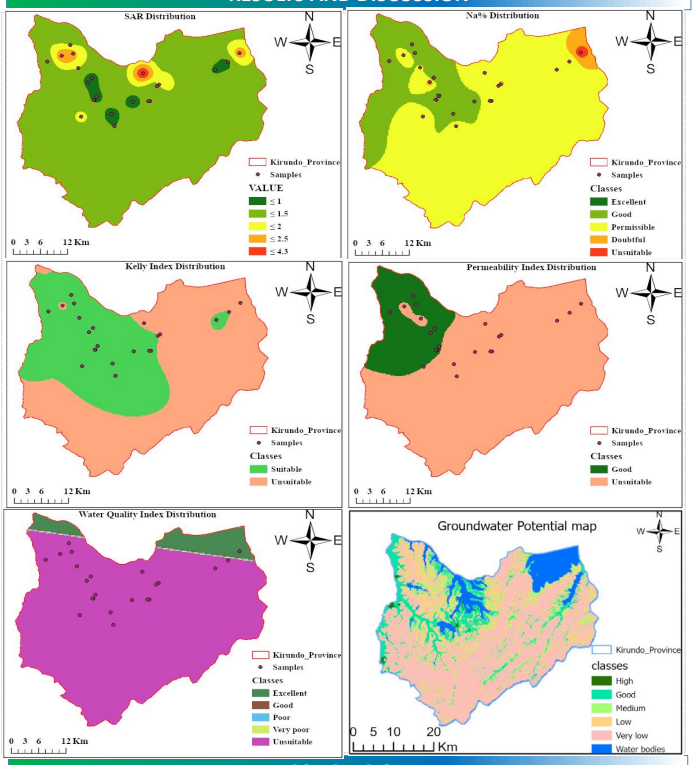
MATERIALS AND METHODS

The research activities included; data collection and preparation, development of thematic maps, data analysis and data processing using GIS techniques. Some data sets such as DEM and satellites images were collected and analysed using remote sensing and GIS techniques. The other data related to geology, soil and groundwater quality were obtained from different institutions and organisations including IGEBU, NCA and OBM while others were collected from the field.

Afterwards, depending on their type and intended use, the data sets were prepared and used to extract necessary information. The groundwater potential zones were identified using eight (8) thematic maps with the help of GIS and remote sensing techniques associated with the analytical hierarchical process method. Different water quality indices were calculated for the assessment of the groundwater suitability to its drinking and agricultural purposes based on the results of physio-chemical analysis of water samples from different boreholes/wells located in Kirundo Province.

Finally, the groundwater quality was assessed and spatially represented using the ArcGIS Pro software.

RESULTS AND DISCUSSION



CONCLUSION

- More than 90% of the entire province is under unsuitable water quality class for human consumption. Based on the EC, SAR and Na% indices, the results show that the groundwater of Kirundo Province is suitable for agricultural purposes. However, based on KI and PI values, the results show that suitable groundwater for irrigation have respectively been presented into 40.2% and 17.8% of the study area.
- The biggest part of the entire study area is under very low and low groundwater potential especially in South-Eastern and Eastern parts of the Province.
- Through the water quality indices together with the selected chemical parameters, the groundwater quality was spatially presented for the entire study area for better interpretation meant to inform policy makers.
- This study has identified zones with potential groundwater for exploration.

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Assessment of the Impact of Land Use Changes and Conservation Practices on Soil Loss and Sediment Yield using GeoWEPP Model: A Case Study of Mwogo Sub-catchment, Rwanda

[1]MUGIRANEZA CYUZUZO Honorine, [2]Prof. Dr.-Ing. Benedict M. Mutua, [3]Dr. Caroline W. Maina
[1]Corresponding Author: cyuzuzohonorine02@gmail.com
[2]Kibabii University, Kenya
[3]Egerton University, Kenya

Abstract

This study assessed the impact of land use changes and conservation practices on soil loss and sediment yield using GeoWEPP model in Mwogo sub-catchment of Nyabarongo reservoir catchment. The calibrated and validated model was used to simulate runoff depth, soil loss and sediment yield under different scenarios. Results showed that soil loss and sediment yield of Mwogo sub-catchment are severe and above tolerable soil loss limit. Therefore, adopting no tillage and converting most critical hillslopes to grassland and forestland can reduce runoff depth, soil loss and sediment yield. This would lead to reduction of sediment load into the reservoir. The results from this study are very useful to water resource managers in making informed decisions for sustainable catchment management.

BACKGROUND/CONTEXT

Surface water bodies are essential resources that provide water for different activities. However, human activities have increased the sediment transported by global rivers through soil erosion by 2.3±0.6 billion metric tons per year (Karamage *et al*., 2016). According to the study conducted by Vanmaercke *et al*. (2014), the lowest sediment yields were observed in Western Africa, while Southern and Eastern Africa are generally characterized by higher sediment yield values. One such a country in Eastern Africa that is facing challenges of soil erosion and sedimentation of rivers and reservoirs is Rwanda (RIWSP, 2016). Hence, it is important to evaluate the amount of soil loss and sediments from the catchment of the reservoir so that appropriate conservation measures can be implemented.

PROBLEM STATEMENT/RESEARCH QUESTION

Nyabarongo reservoir catchment continues to experience soil erosion caused by increased mining activities, poor agricultural practices and deforestation. These activities are carried out on a mountainous area with steep slopes. The eroded soils contribute to high sediment loads in Nyabarongo river thereby resulting in reservoir sedimentation.

Main Question: How effective are conservation practices and land use changes in reducing the magnitude of soil loss and sediment yield within Mwogo sub-catchment?

OBJECTIVES

This study aimed at assessing the impact of conservation practices and land use changes on soil loss and sediment yield in Mwogo sub-catchment using GeoWEPP model. The specific objectives were to calibrate and validate the GeoWEPP model for Mwogo sub-catchment; estimate annual runoff depth, soil loss and sediment yield of Mwogo sub-catchment using GeoWEPP model based on current land use/land cover; and assess the impact of conservation practices and land use changes in reducing soil loss and sediment yield of Mwogo sub-catchment using GeoWEPP model.

METHODOLOGY

For achieving objectives of this study, the following methodology was used:

To setup GeoWEPP model, the required input parameter (DEM.asc, soil map.asc, soils.txt, soilsdb.txt, landcov.asc, landcov.txt and landusedb.txt) were prepared using ArcGIS 10.4.1 and uploaded into GeoWEPP. The watershed was delineated based on a selected outlet point, and TOPAZ was used to generate the sub-watersheds. The model simulations were executed considering watershed method. TOPWEPP program was used to generate the output results. For calibrating and validating GeoWEPP model, the observed streamflow data was converted into daily runoff depth using the drainage area of the sub-catchment, and Calibration was done manually by using trial and error method. For evaluating the performance of the model, The Nash-Sutcliffe Efficiency (NSE), coefficient of determination (R^2) and Percent bias (PBIAS) statistical criteria were used to check how well the model simulation matched the observed data. To assess the effect of conservation practices, no tillage management was adopted for all agricultural land use/land cover (no tillage Scenario 1). Also, no tillage Scenario was simulated on 25% of most critical hillslopes (no tillage Scenario 2) as well as on 50% of most critical hillslopes (no tillage Scenario 3). On the other hand, to evaluate impact of land use changes, all agricultural land use was converted to grassland (grassland Scenario 1) and forestland (forestland Scenario 1). Also, 25% and 50% of hillslopes that have been identified as having highest soil loss and sediment yield were converted to grass land use (grassland Scenarios 2 and 3), and also to forest land use (forestland Scenarios 2 and 3), respectively.

RESULTS AND DISCUSSION

Table 1: Model Sensitivity Analysis Results

Runoff (mm)	Sediment Yield (ton/ha)
Effective Hydraulic Conductivity	Effective Hydraulic Conductivity
	Critical Shear
	Rill Erodibility
	Inter-rill erodibility

Table 2: Calibration and Validation Results

Statistical Parameter	Runoff (mm)	
	Calibration	Validation
R^2	0.75	0.88
NSE	0.65	0.52
PBIAS	3.75	7.05

Table 3: GeoWEPP Model Simulation Results under Current Land use/Land Cover (Base Scenario)

Parameter	Predicted	Unit
Average annual runoff depth	418.4	mm/year
Average annual soil loss per unit area	194.6	ton/ha/year
Average annual Sediment delivery per unit area	25.4	ton/ha/year

Table 4: Reduction in Runoff Depth, Soil Loss and Sediment Yield under No Tillage Scenarios 1,2 and 3 compared to Base Scenario

Parameter	No Tillage Scenario		
	1	2	3
Runoff depth reduction compared to BS (%)	24.7	14.6	20.5
Soil loss rate reduction compared to BS (%)	90.3	28.6	52.1
Sediment yield reduction compared to BS (%)	97.2	50.4	76.1

BS: Base Scenario

Table 5: Reduction in Runoff Depth, Soil Loss and Sediment Yield under Grassland Scenarios 1,2 and 3 compared to Base Scenario

Parameter	Grassland Scenarios		
	1	2	3
Runoff depth reduction compared to BS (%)	44.9	21.4	30
Soil loss rate reduction compared to BS (%)	95.7	39.1	56.8
Sediment yield reduction compared to BS (%)	72.8	40.9	64.2

BS: Base Scenario

Table 6: Reduction in Runoff Depth, Soil Loss and Sediment Yield under Forestland Scenarios 1,2 and 3 compared to Base Scenario

Parameter	Forestland Scenarios		
	1	2	3
Runoff depth reduction compared to BS (%)	32.3	18.6	25.1
Soil loss rate reduction compared to BS (%)	95.2	35	48.5
Sediment yield reduction compared to BS (%)	69.7	25.6	55.9

BS: Base Scenario

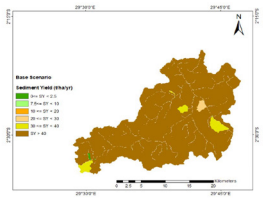

Figure 1: Sediment Yield Map of Mwogo Sub-Catchment under Current Land use/land Cover (Base Scenario)

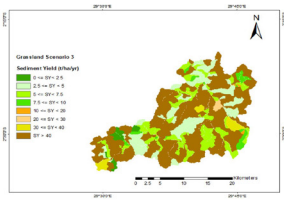

Figure 3: Sediment Yield Map of Mwogo Sub-catchment under Grassland Scenario 3

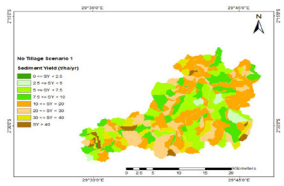

Figure 2: Sediment Yield Map of Mwogo Sub-catchment under no Tillage Scenario 1

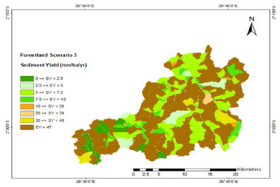

Figure 4: Sediment Yield Map of Mwogo Sub-catchment under Forestland Scenario 3

CONCLUSION

- The simulated runoff is sensitive to effective hydraulic conductivity only, while sediment yield is sensitive to critical shear, effective hydraulic conductivity, rill and interrill erodibility. The GeoWEPP model evaluation showed a satisfactory model performance as per the results from the selected statistical criteria used in this study;
- The predicted soil loss and sediment yield within Mwogo sub-catchment are severe and above the annual tolerable soil loss limit of 10 -12 ton/ha; The no tillage management practice, grassland and forestland Scenarios adopted can be used to reduce runoff depth, soil loss and sediment yield of Mwogo sub-catchment. Reduction in runoff depth, soil loss and sediment yield were found to range between 14.6-44.9%, 28.6-95.7% and 25.6-97.2%, respectively.

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

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Design of a Sustainable Water Supply Network for Goma Township in Democratic Republic of Congo

Graduate CV.

Utashi Ciraane Docile, Prof. Dr.-Ing. Benedict Mutua (a), Prof. Chérifa Abdelbaki (b)

(a) Kibabii University, Kenya

(b) University of Tlemcen, Algeria

Contact details: vciraane@gmail.com

Abstract

In Sub-Saharan Africa, the population growths have outpaced the capacities of water supply systems. In the DR Congo, 57.6% of the Goma township is covered by a water supply network that is characterized by low level of reliability and poor hydraulic performance. Therefore, this study provides a solution to this situation through the estimation of the water demand at the horizon 2045, the assessment of the existing network, and the design of a sustainable alternative. The findings constitute a master plan for water professionals and propose structures to ensure the provision of clean and potable water to all the city-dwellers of the Goma township.

Keywords: Design, Water Supply, EPANET, Urban, Sustainability

BACKGROUND/CONTEXT

- Water is very important for cities, townships, and villages.
- Many Sub-Saharan utilities struggle to cover and to supply water to an entire settlement (Banerjee & Morella, 2011; Eberhard, 2019).
- The DRC passed from 36% to 24.79% coverage between 2004 and 2014, a situation that led to many of its inhabitants to use untreated water sources (Ibnet, 2018).

PROBLEM STATEMENT

The existing water supply system in the Goma township is outdated to support the fast growing water demand. The consequences of this situation are: water shortages, diseases (Cholera, Typhoid, Ebola, etc.), social and economic burdens to city-dwellers, and financial deficits for the utility.

OBJECTIVE/RESEARCH QUESTIONS

The objective of the study was to design a sustainable water supply network for the Goma township, in Democratic Republic of Congo.

Research Questions:

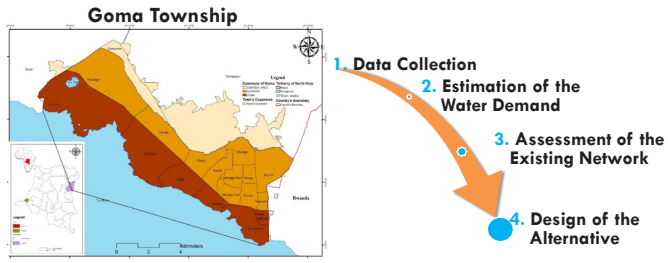
i. How sufficient is the actual water supply in the township and how would the demand increase for the next 25years?

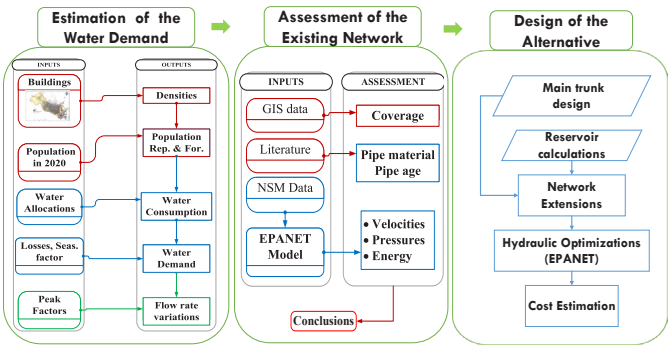
ii. How efficient is the current distribution network?

iii. Which alternative should be implemented for a sustainable distribution of water in the township?

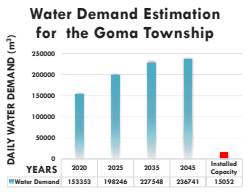
iv. How efficient is the proposed alternative?

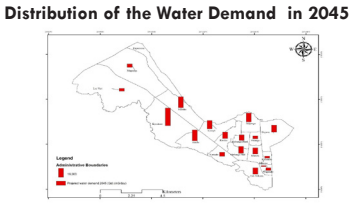
METHODOLOGY

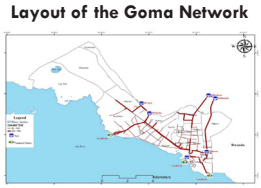


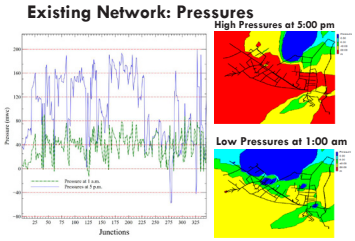


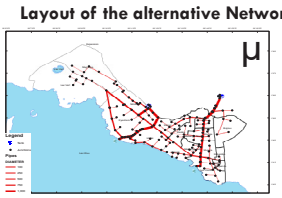
RESULTS AND DISCUSSION

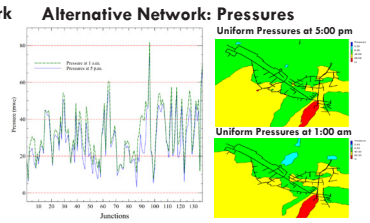












CONCLUSION

i. In 2045, the water demand will approximatively reach 15 times the production capacity of the existing water supply infrastructures;

ii. The existing water supply network of Goma township is inefficient and ineffective (physical and hydraulic characteristics);

iii. The sustainable alternative network for Goma township is a combination of the pumping scheme from Lake Kivu with a renewable source of energy; and

iv. The network simulations have shown that a supply through reservoirs is preferable to the existing shift between pumps and tanks.

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Graduate CV.

Evaluation and Comparison of Remote Sensing-based Precipitation Products in Casamance basin, SENEGAL

Aicha Marie Augustine NDECKY, Dr. -Ing. Navneet Kumar[a]
ZEF, University of Bonn[a]
aichamandecky@gmail.com

Abstract

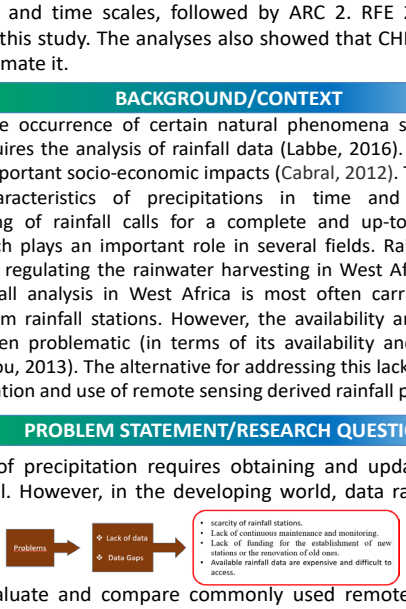
This study involves the comparison and evaluation of four remote sensing derived rainfall products (CHIRPS-0.05, ARC 2, RFE 2 and TRMM3B42RT) at four-time scales (daily, monthly, annual and seasonal) to assess their performance in the Casamance basin. The evaluation and comparison were carried out through statistical evaluation methods and Inverse Distance Weighting. The study demonstrated that CHIRPS-0.05 is the best performing rainfall product, at all levels and time scales, followed by ARC 2. RFE 2 only performed poorly in the annual analysis, while TRMM-3B42RT performed very poorly throughout this study. The analyses also showed that CHIRPS-0.05 and TRMM3B42RT always tend to overestimate rainfall, whereas RFE 2 and ARC 2 tend to underestimate it.

BACKGROUND/CONTEXT

Assessing the occurrence of certain natural phenomena such as floods and drought requires the analysis of rainfall data (Labbe, 2016). These phenomena have very important socio-economic impacts (Cabral, 2012). This implies a study on the characteristics of precipitations in time and space. A better understanding of rainfall calls for a complete and up-to-date database of rainfall, which plays an important role in several fields. Rainfall is one of the main factors regulating the rainwater harvesting in West Africa (Vischel et al., 2015). Rainfall analysis in West Africa is most often carried out from data collected from rainfall stations. However, the availability and access to these data are often problematic (in terms of its availability and quality) (Bodian, 2014; Panthou, 2013). The alternative for addressing this lack of data availability is the application and use of remote sensing derived rainfall products.

PROBLEM STATEMENT/RESEARCH QUESTION

The study of precipitation requires obtaining and updating data at the station level. However, in the developing world, data rainfall has several gaps.

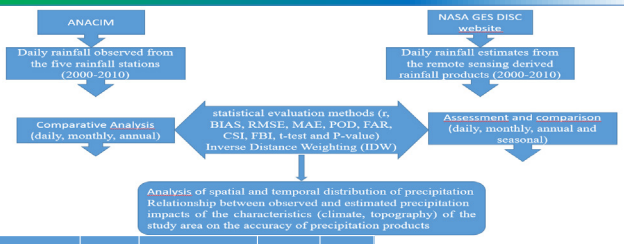


How to evaluate and compare commonly used remote sensing derived precipitation products for the Casamance basin in Senegal?

OBJECTIVES

Analyse the rainfall characteristics at Casamance basin; evaluate the performance of remote sensing derived rainfall products using ground measured data; Comparison of different remote sensing derived rainfall products for the Casamance basin; evaluate the spatiotemporal variation of rainfall in Casamance basin; and determine the more indicated and adequate remotely sensed rainfall product for Casamance basin.

METHODOLOGY

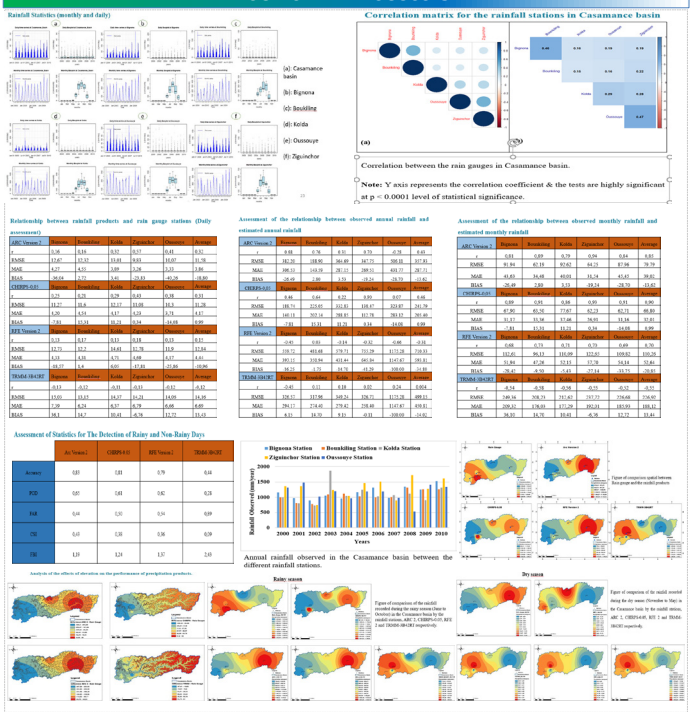


Statistical Metric	Unit	Equations	Range	Perfect Value
Correlation Coefficient r	-	$1-\frac{6\sum_{i=1}^{n}[X(i)-Y(i)]^2}{n(n^2-1)}$	-1 to 1	1
RMSE (Root Mean square error)	mm	$\sqrt{\frac{\sum_{i=1}^{n}(S_i-G_i)^2}{n}}$	0 to ∞	0
MAE (Mean Absolute error)	mm	$\frac{\sum_{i=1}^{n}\lvert S_i-G_i\rvert}{n}$	0 to ∞	0
Bias	%	$\frac{\sum_{i=1}^{n}(S_i-G_i)}{\sum_{i=1}^{n}G_i}*100\%$	−∞ to ∞	0
POD (Probability of Detection)	-	$\frac{N_{11}}{N_{11}+N_{01}}$	0 to 1	1
FAR (False Alarm Ratio)	-	$\frac{N_{10}}{N_{11}+N_{10}}$	0 to 1	0
CSI (Critical Success Index)	-	$\frac{N_{11}}{N_{11}+N_{01}+N_{10}}$	0 to 1	1
FBI (Frequency Bias Index)	-	$\mathrm{FBI}=\frac{N_{11}+N_{10}}{N_{11}+N_{01}}$	0 to ∞	1
Accuracy	-	$\frac{N_{11}+N_{10}}{n}$	0 to 1	1

Table of Indices used to evaluate the characteristics of the precipitation and the performance of satellite precipitation estimates.

Notation: **n**, number of samples; **Si**, satellite precipitation; **Gi**, gauged observation; **N11**: Satellite is > 0 and gauge is > 0; **N10**: Satellite is > 0 and gauge equals 0; **N01**: Satellite equals 0 and gauge is > 0; **N00**: Satellite equals 0 and gauge equals 0.

RESULTS AND DISCUSSION



CONCLUSION

In conclusion, this study demonstrated that CHIRPS-0.05 is the best performing rainfall product at all levels and time scales followed by ARC 2. RFE 2 only performed poorly in the annual analysis, while TRMM-3B42RT performed very poorly throughout this study. It was also noted that ARC 2 and RFE 2 often had similar results, sometimes close to those of CHIRPS-0.05. This is justified by the fact that ARC 2 and RFE 2 have similar algorithms. It has been noted that the change in elevation had an influence on the accuracy of remote sensing products except for RFE 2. The analyses also showed that in general CHIRPS-0.05 and TRMM3B42RT always tend to overestimate rainfall, whereas RFE 2 and ARC 2 tend to underestimate it.

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Graduate CV.

Flood Reduction through Flood Risk and Vulnerability Assessment and Mapping in Hadejia River Basin, Nigeria

Abdulrahman SHUAIBU, Dr. Aymar Y BOSSA(a), Dr. Jean HOUNKPE (b)
(a) (INE/UAC/Benin),(INE/UAC/Benin) (b)
Contact details: shuaibua@abu.edu.ng

Abstract

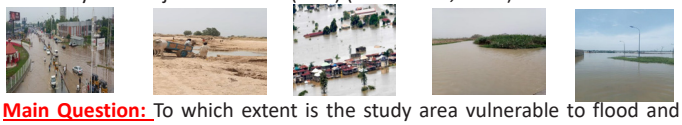
Flood risk reduction is of significance importance for coping capacity and resilience of flood prone basin. This study aimed at developing GIS-based flood risk and vulnerability mapping and assessment integrated with Analytical Hierarchical Process (AHP) in order to reduce the risk and vulnerabilities associated with floods in Hadejia River Basin. Accordingly, combining the flood hazard (FHI) and socio-economic vulnerability (FVI) indices of the basin reveals the highest flood risk at the downstream and central upstream portion of the basin. This research has significant importance in developing strategic measures through which the aftermaths of flood in the basin will be reduced.

BACKGROUND/CONTEXT

Floods are considered amongst the most catastrophic, frequent and widespread natural disasters worldwide causing severe economic and environmental damages as well as destruction of livelihoods (Chakraborty & Mukhopadhyay, 2019; Mishra & Sinha, 2020). About 47% of weather-related disasters are as a result of floods (Vishwanath & Tomaszewski, 2018). In 2018, flooding in Nigeria has a ffected more than 1.9 million persons across 12 states in Nigeria (WHO, 2018). More recently in 2019, Flood in Nigeria has severely affected more than 200000 people and 5000 ha of crop land was destroyed while 1875

PROBLEM STATEMENT/RESEARCH QUESTION

Heavy precipitation was recently predicted in major river basins in Nigeria which may result in severe flooding. About 15million people resides currently in Hadejia River Basin (HRB) (Umar *et al.,* 2019).

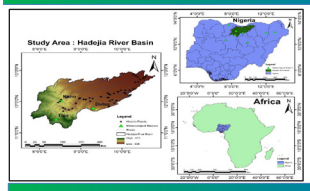


Main Question: To which extent is the study area vulnerable to flood and what are the most vulnerable areas in Hadejia River Basin?

OBJECTIVES

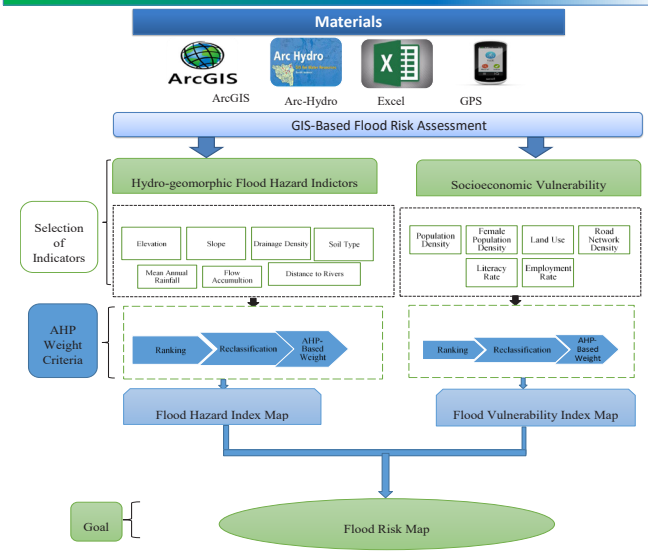
The objective of this work is to develop a GIS-based flood risk and vulnerability mapping integrated with Analytical Hierarchical Process (AHP) in order to reduce the risk and vulnerabilities associated with flood in Hadejia River Basin.

STUDY AREA

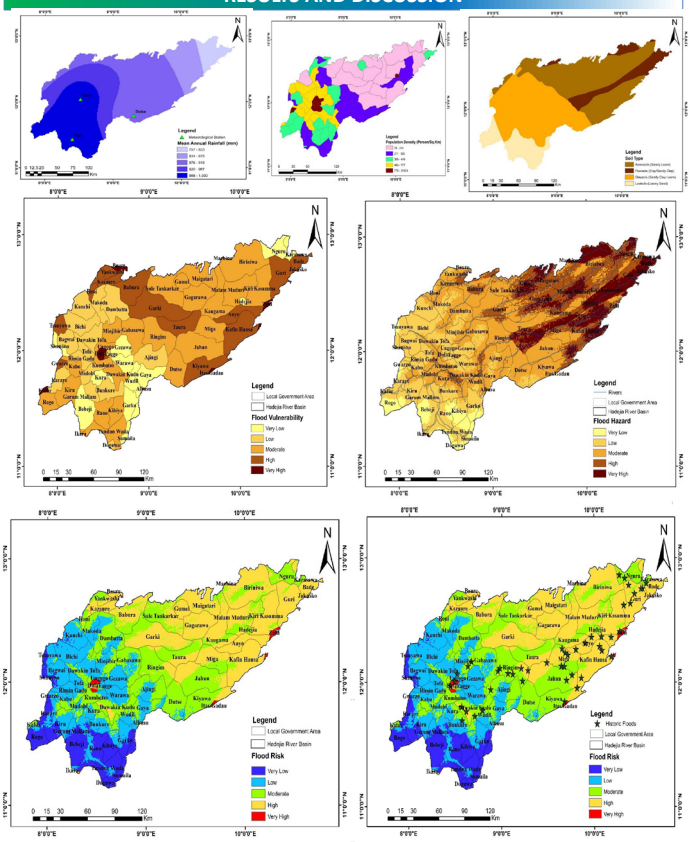


The study area is Hadejia River Basin located in Nigeria. The river basin has an area of about 30,569 Km^2 and is located between the latitudes 11°32´08.4´´N to 12°26´24.8´´N and longitudes 8°07´50.0´´E to 10°01´50.9´´E.

METHODOLOGY



RESULTS AND DISCUSSION



CONCLUSION & RECOMMENDATIONS

The analysis of flood risk disaster at Hadejia River Basin reveals that a substantial parts of the watershed is under flood risk disaster. The MCA in conjunction with AHP approach were successfully applied and were validated to be very efficient and sound in flood disaster risk assessment in Hadejia River Basin.

- ❖Structural and non-structural flood control measures should be adhered to in the catchment
- ❖Further researches should incorporate influence of climate change impact on flood risk
- ❖Land use of the basin should be planned and monitored

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Graduate CV.

Modelling the Impacts of Climate Change on Water and Crop Productivity in Ogun-Osun River Basin, Nigeria

Oludare Sunday Durodola, Khaldoon A. Mourad[a]
[a] Centre for Sustainable Development, Lund University, Sweden
durodolaoludare@gmail.com

Abstract

African countries such as Nigeria are anticipated to be more susceptible to the impacts of climate change due to large dependence on rainfed agriculture. In this regard, the impacts of climate change on water requirements, yields and crop water productivity of rainfed maize and soybeans in Ogun-Osun River Basin, Nigeria were evaluated for baseline period (1986 – 2015) and future period (2021 – 2099) under RCP 4.5 and RCP 8.5 scenarios. The results show that maize will be negatively affected but soybeans will perform better under climate change. This study certainly offers useful information on suitable adaption measures of climate change.

BACKGROUND/CONTEXT

IPCC has warned that global climate change is a result of the increase in anthropogenic activities globally (IPCC, 2018). Climate change poses several uncertainties in terms of the natural ecosystem, water resources and agricultural production. Temperature is expected to rise and will cause shifts in patterns and quantities of precipitation, which will likely lead to increasing the occurrence of floods, droughts and heatwaves (Klutse et al., 2018; Boonwichai et al., 2018).

Several studies in Nigeria have shown that the increase in temperature, droughts and floods will affect agricultural production. It is anticipated that some crops will need more water than before and yields will reduce.

PROBLEM STATEMENT/RESEARCH QUESTION

It is predicted that climate change will alter rainfall patterns. Meanwhile, in Nigeria, the majority of farmers depend highly on rainfed agriculture whereas rainfed agriculture is vulnerable to climate change. It is becoming increasingly difficult to grow crops as climate change impacts on agriculture intensifies.

Main research question: What will be the impacts of climate change on water and crop productivity in Ogun-Osun River Basin, Nigeria

OBJECTIVES

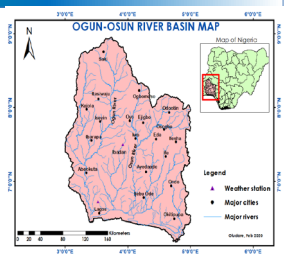
The main goal of this research is to model the impacts of climate change on water and crop productivity in Ogun-Osun River Basin, Nigeria, throughout the following objectives:

1. Estimate seasonal water requirements, yields and crop water productivity.
2. Simulate the future changes in seasonal water requirements, yields and crop water productivity under different climate change scenarios,
3. Evaluate the effect of supplemental irrigation on future yield and water productivity under different climate change scenarios.

METHODOLOGY

The study area is Ogun-Osun River Basin located in the south-western region of Nigeria. The basin is located between latitude 6° 33' - 9° 00' N and longitude 2° 40' - 5° 05' E.

It is characterized by tropical climate as well as wet and dry seasons.



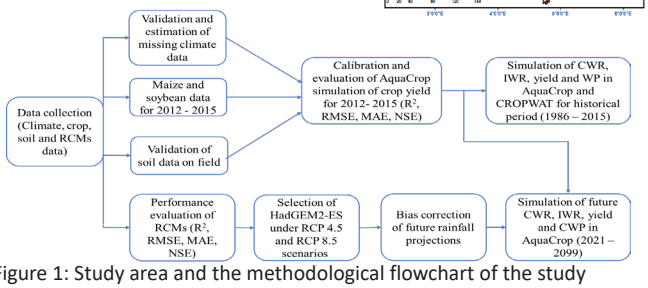


Figure 1: Study area and the methodological flowchart of the study

RESULTS AND DISCUSSION

1. Low yields of about 1.8 to 2.1 ton/ ha was observed within the basin for the baseline while water requirement is largely depend on the rainfall pattern. Decline in water requirement is attributable to reduced growing cycle of crops (Fig. 2) .

2. Maize yield is projected to continually decline under both scenarios up to 12%, compared to soybeans yield which is projected to increase up to about 40%. (Fig 3).

3. Supplemental irrigation can improve crop yields up to 10%.

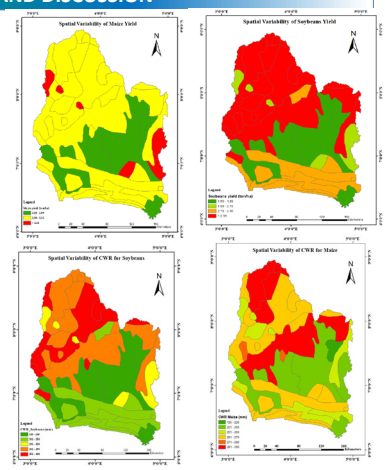


Figure 2: Spatial variation of yields and water requirements

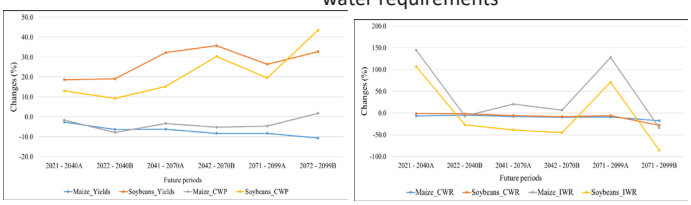


Figure 3: The future changes in yields and water requirements

CONCLUSION

Huge inter-seasonal variability exists within the parameters studied while water requirements are largely influenced by projected rainfall pattern. Climate change will affect the two crops differently depending on the future periods. Maize will be negatively affected but soybeans will perform better. A proposed policy framework is presented in Fig 4.

Last but not least, climate change should not be a nightmare but rather a wake up to all stakeholders to figure out the appropriate adaptation measures.

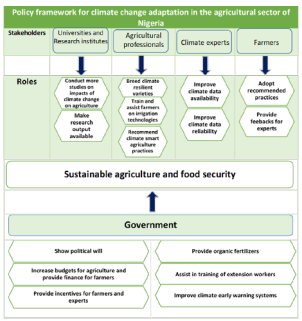


Figure 4:Proposed policy framework

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Graduate CV.

Simulation of Impacts of Land-use and Land Cover Changes on Water Balance in Oued Fez basin (Morocco)

Victo Nabunya, Abdelkader El Garouani (**USMBA, FST-Fez)**
Vinabsharon@gmail.com

Abstract

The Oued Fez basin has undergone severe land-use changes in the past 30 years. The changes in the basin's water balance are attributed to the changes in land-use and land cover. The assessment was conducted using two LULC maps, 1988 and 2018 respectively and climatic data (1988-2018), with calibration done using 17 random points of observed stream flow data (2009-2011). The impacts of land-use change on the long term annual average water balance indicated an increase in; water yield (1.20%), and surface runoff (5.10%), reductions in: ET (0.44%), lateral flow (1.49%), water in shallow aquifer (10.28%), and water deep aquifer (10.37%).

BACKGROUND/CONTEXT

Previous studies in Morocco have been associated to impacts of land use on sediment yield, water quality and run off but limited studies assessing impacts on water balance components (Briak et al., 2016; Chadli et al 2016). According to Legrouri et al., (2012) over the last 30 years, the total level of recharge in the Saïss aquifer has been decreasing as a result of increasing average temperature and a reduced amount of precipitation.

Remote sensing and Geographic Information System (GIS) are essential tools in obtaining accurate and timely spatial data of land-use and land cover, also as analyzing the changes in a study area (Reis, 2008). The Soil and Water Assessment Tool (SWAT) is one of the mostly commonly used scenario based model, for assessing the impacts of land use on hydrological processes from watershed scales to global scales (Johnson et al., 2015; Kerkez et al., 2016).

PROBLEM STATEMENT/RESEARCH QUESTION

Worldwide, aquifers are under severe threat of depletion and deprivation (Legrouri *et al.*, 2012). The Saïss aquifer in Morocco threatens to deplete, as it is affected by declining levels of precipitation, coupled with an increase in average temperatures by 1°C (Legrouri *et al.*, 2012). The contribution of land-use changes to the water balance in the Oued Fez basin is unkown. Similarly the current condition of Saïss aquifer in regards to contribution of land use changes to the water balance of the basin is not known. The study aims to find out: How land-use change has impacted

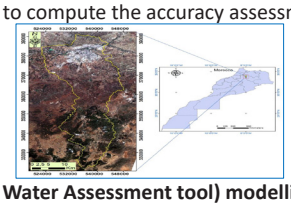
OBJECTIVES

1) To assess the changes in land-use between 1988 and 2018 within Oued Fez basin.
2) To calibrate and validate the model for the Oued Fez basin.
3) To assess the impacts of land-use change on water balance within the Oued Fez basin.

METHODOLOGY

1. Land use classification for 1988 and 2018.

images classification was conducted using the maximum likelihood supervised classification method, while the validation of LULC maps was the error matrix to compute the accuracy assessment.



2. SWAT (Soil & Water Assessment tool) modelling

Firstly, the model was calibrated with observed data (random points) that was collected between (2009-2011) by Perrin et al 2014. Calibration was conducted by adjusting the CN2, and ESCO, SOL_AWC.

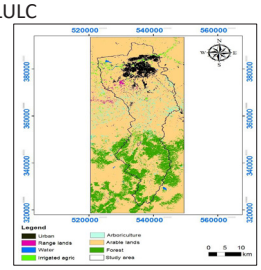
Secondly, two scenarios were established, (i) LULC map 1988, (ii) LULC 2018 with same climatic data period i.e (1988-2018)

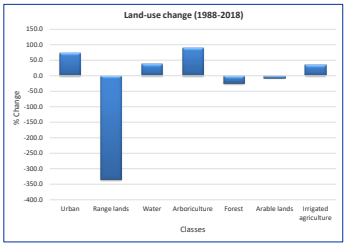
3. Evaluation of performance

This was computed by use of the various statistical tools including NSE, PBIAS and coefficient of determination, R^2. The evaluation is done by comparing the observed and simulated data.

RESULTS AND DISCUSSION

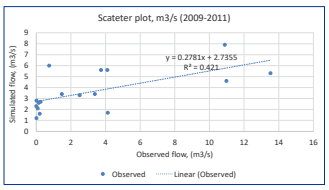
Figures below show the LULC classification(2018) and percentage changes in LULC

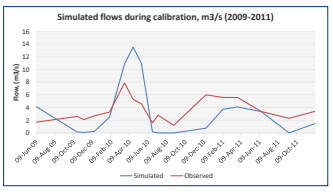




Hydrological simulations & evaluation of model performance.

An NSE value of -2.45, PBIAS 9.70 and R^2 of 0.421 were obtained during the calibration period. The figures below shows the scatter plot obtained during calibration and impacts of Land-use change on water balance.





Impacts of LULC on water balance

LULC	PCP (mm)	Total water yield (mm)	ET (mm)	Surface runoff (mm)	Lateral flow (mm)	GW Shall AQ (mm)	GW Deep AQ (mm)
1988	426.6	132.08	275.9	89.93	8.15	31.33	2.66
2018	426.6	133.69	274.7	94.76	8.03	28.41	2.41
% Change		1.20	-0.44	5.10	-1.49	-10.28	-10.37

CONCLUSION

- Significant changes in land-use were observed between 1988 and 2018, with the biggest land-use conversion being the reduction in range lands by (333.62%), and increase in arboriculture, and urban by (90.43%), (72.71%), respectively.
- The simulation of land-use changes indicated considerable changes in water balance components in the Oued Fez basin. The percentage changes in the various water balance components in the basin indicate an increase in the; total water yield by 1.20%, and surface runoff by 5.10%, reductions were also noted for: ET by 0.44%, lateral flow by 1.49%, ground water in shallow aquifer by 10.28%, and groundwater deep aquifer by 10.37%.

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The entire master thesis report is available under the following link:
http://repository.pauwes-cop.net/handle/1/436

Graduate CV.

Simulation of the Spatial Distribution of Soil Erosion Risk in Mellah Watershed, North-Eastern Algeria

Asma Bouamrane , Habib Abida
University of Sfax, Tunisia
Contact details: asmabouamrane199@gmail.com

Abstract

The aim of this study is to identify and map soil erosion sensitivity in Mellah watershed, using The RUSLE, AHP and FR models. GIS and Remote Sensing techniques were used to identify a set of factors influencing erosion. The obtained results showed that very high sensitivity area represent 4.2%, 9.8% and 10.1% for RUSLE, FR and AHP respectively. For the validation and based on field observations. The values of the Area Under the Curve were 93.6%, 93.1%, and 95.7% for RUSLE, AHP and FR models respectively, which represent an excellent performances. The final maps may be considered as a decision support tool to conserve the watershed.

Key word : Mellah ,Erosion,RUSLE,AHP,FR,ROC.

BACKGROUND/CONTEXT

Soil erosion is considered as one of the most natural hazards which threatened human societies and environments. According to statistics, nearly 75 billion tons of soils are eroded each year around the world, (Borrelli et al,2017) The Mediterranean regions, especially under semi-arid climates do not escape to this challenge, due to climate condition, morphological and anthropogenic factors .According to the Algerian Ministry of Agriculture and Rural Development, 50 million hectares were estimated to be eroded. The assessment and the quantification of soil erosion are important because the corresponding results may serve as a decision-making tool for the implementation of appropriate soil conservation strategies, and management practices to mitigate erosion impact.

PROBLEM STATEMENT/RESEARCH QUESTION

Soil erosion is widespread in Mellah Watershed. It negatively affects agricultural productivity, reduces water infiltration and water availability. There is therefore a need to evaluate the importance and extent of this natural hazard in order to propose solutions and measures for its control. In this context, water erosion in this basin is assessed using different sources of data and different simulation methods.

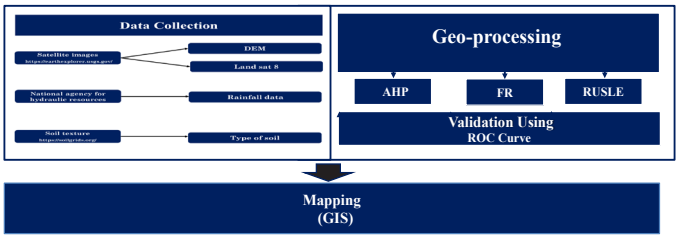
Research questions:

1. What is the major source of erosion in the catchment?
2. How can erosion affect the agricultural sector?
3. What is the data required to evaluate soil erosion?
4. What are the most exposed areas to erosion risk?
5. What are the necessary strategies to mitigate this natural hazard?

OBJECTIVES

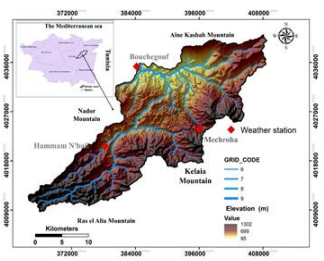
- Predict the spatial distribution of soil erosion in Mellah Watershed ;
- Develop soil erosion risk map using geographic information systems ;
- Simulate soil erosion risk maps using RUSLE, FR and AHP methods ;
- Compare and evaluate the performance of the obtained results .

METHODOLOGY



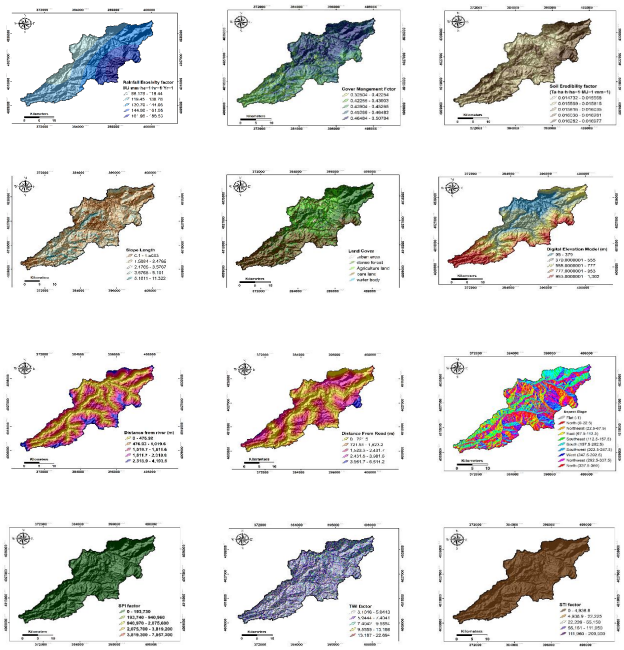
Case study :

Mellah Watershed is a sub-basin of the large Seybouse Watershed, located in North-eastern Algeria .It covers an area of 550 Km². It lies between the latitudes 36.216°N and 36.512°N and longitudes 07.487° E and 07.983°

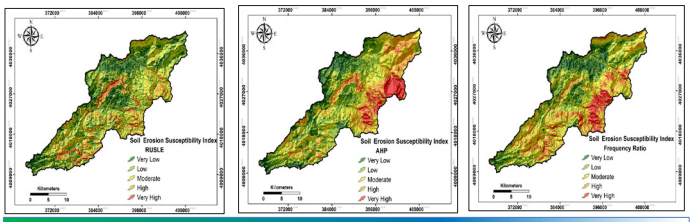


RESULTS AND DISCUSSION

Conditioning factors



Soil erosion suscibility maps



CONCLUSION

- The erosion susceptibility map using a GIS-based semi quantitative ,statistical and empirical approach's was mapped and validated ;
- Several erosion conditioning factors were prepared in GIS;
- The results indicated satisfactory prediction rates of 0,9565 ,0.9361 and 0,9312 for RUSLE, AHP and FR respectively;
- The proposed approach's can be applied to other basins, especially to those with very limited data (Ungauged basin).

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

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The Impact of Climate Change on the Interactions between Water, Energy and Food Systems in the Victoria Nile Sub-Basin

Joash BWAMBALE, Dr. Khaldoon A Mourad (a)

(a) Lund University, Sweden

jobwa23coltd@gmail.com

Abstract

Water and energy are crucial resources for agricultural production. These resources remain very limited to most farmers in Uganda resulting in food insecurity while climate change is expected to worsen the situation. The Crops Water Requirement (CWR) and Crops Irrigation Requirement (CIR) for maize and rice were simulated using CROPWAT model under two climatic scenarios (RCP4.5 and RCP8.5) while the crop productivity/yield was simulated using AquaCrop model. In addition, the impact of climate change on the pumping energy demand for irrigation was assessed. Results indicate that climate change has a significant negative impact on CWR, CIR and the subsequent pumping energy demand as well as crop yield. Interestingly an increase in rice production is observed during the August to December season. The study highly recommends on farm adaptation strategies to overcome the adverse effect of climate change.

BACKGROUND/CONTEXT

Water is a limiting factor for both crop and animal production. Despite the abundant water resource, food security in the region is still unrealized in most communities due to the increased population growth rate and rain-fed agriculture.

Irrigation will be inevitable hence water withdraws are expected to increase by 50% in 2050. The amount of water resource for agriculture is limited and is not increasing.

Most literature are in consensus and predict a significant negative impact of climate on rain-fed crop production in Sub-Saharan Africa.

Waithaka *et al.* (2013) and Dale *et al.* (2015) provided a good district level detail on yield variations under different climatic scenarios but did not evaluate main staple crops such as maize, which pose a higher food security risk than cash crops like coffee and tea.

The Government of Uganda (GoU) has established a National Irrigation Master Plan (NIMP) to reduce the growing food production challenges resulting from climate change, poor resource distribution and management practices.

The NIMP does not deliberate on the energy implications associated with irrigating a large portion of land

Implementing policies in one sector without looking at their impact on other sectors could lead to inconsiderate decisions

PROBLEM STATEMENT/RESEARCH QUESTION

Agriculture accounts for the largest withdrawal of the limited water resources. Climate change would have impacts on crop growth and water intake pattern, as well as the amount of irrigation water that crops need to grow well (Zhou *et al.*, 2017).

Moreover, the NIMP clearly stipulates the agricultural aspects but does not discuss the energy implications of this irrigation pathway especially under climate change.

OBJECTIVES

To study the impacts of potential climate change on CWR and CIR for the Victoria Nile sub-basin under different climate change scenarios using CROPWAT (crop simulation model);

To evaluate the effect of climate change on crop productivity using a bio-physical crop simulation model, AquaCrop;

To estimate the future pumping energy demand (for irrigation) under different climatic scenarios taking into consideration site-specific crop water requirements

METHODOLOGY

Case Study Area: Victoria Nile Sub-Basin

- Daily climate data observed from 9 Meteorological stations was used and Man-Kendal test and sen's slope approach were done for trend analysis.
- RCP4.5 and RCP8.5 of HadGEM2-ES downloaded from Cordex –Africa with reference period (1971-2005) and the future scenario (2021-2099) were bias-corrected using Quantile Mapping technique in R software.
- The study was Separated into 4 Agro-ecological zones and developed study area soil map
- CWR and CIR were determined using CropWat Model while crop yield was simulated in AquaCrop Model.
- The Energy demand for irrigation was determined in Matlab software using site specific crop water requirements

RESULTS AND DISCUSSION

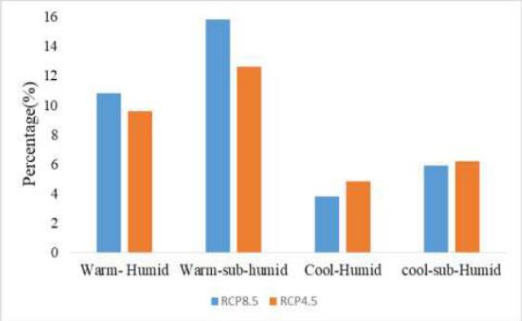
The CWR will increase for both climate scenarios in the near, mid and far future. The increase could be attributed to the high temperatures expected for both RCP4.5 and RCP8.5.

A general decrease in maize production is predicted under climate change. The average ranges of maize yield decrease for the near, mid and far future compared to the base period of 1986-2016 are 1-10%, 2-42% and 1-39% respectively.

In addition, the model predicted an increase in rice yield for both seasons except for the warm-sub-humid zone during the March to May season. However, the magnitude of increment depends on the period and climate scenario considered. The predicted increment ranged from 0.3% to 42.2% for RCP4.5 and from 1% to 52.3% for RCP8.5

Although the projected decline in Maize production may seem modest in the near future, the consequences for the region's food production and socioeconomic status could be substantial given the heavy reliance on rain-fed agriculture and maize production for nutritional needs, economic value and social importance

Furthermore, the pumping energy needs are expected to increase by 3.6% per year due to climate change and also by 2.7% per year due to increase in the irrigated land as per the NIMP



Percentage change in pumping energy demand by 2035

CONCLUSION

The case study area has received abundant rainfall but its seasonal variability and distribution was critical to sustain crop productivity

There is a significant negative impact of climate change on the crop water and irrigation requirement for maize and rice crops

There is a reduction of as high as 42% in Maize yield predicted. A slight increase in rice yield is observed in the August to December season

A sharp increase in pumping energy demand for irrigation is observed in the future (30 – 40.5 GWh and 28 – 35.8 GWh per year for the RCP8.5 and RCP4.5

RECOMMENDATIONS

1. According to the research results, the following is recommended;
2. Changing planting date back-wards or forward by 10 to 26 days followed with research.
3. Selection of shorter-maturing crop varieties and resilient crops
4. Adopt irrigation technologies to meet the crop water deficit expected
5. Use of water-saving technologies in irrigation

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

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Graduate CV.

The Impact of Climate Variability on the Flow of Wadi Boukiou (Tafna, Algeria)

Nisrin BERREZOUG [a], Prof KAMILA BABA HAMED [a] ,Prof ABDERRAZAK BOUANANI [a]
University of Tlemcen, Algeria
berrezougnisrin@gmail.com

Abstract

This study was aimed to assess the influence of the climate variability on the flow of wadi Boukiou watershed which characterized by a semi-aride climate. The application of different climate indices using Meteorological Drought Monitoring software indicates that our basin has experienced wet periods ranging from 1974/1975-1981/1982 and 2008/2009-2017-2018, while dry periods are spread out between 1981/1982-2008/2009 with a trend to dryness. The HBV model has been successfully applied in our basin using current climatic inputs and observed flows, where the overall performances of the model was good both on calibration (NSE=75%, R^2=0.80) and validation (NSE=76%, R^2 =0.91)

BACKGROUND/CONTEXT

Drought indices are a useful tool for monitoring different types of drought (meteorological, agricultural and hydrological drought), as they facilitate communication of climate anomalies to different water users. Many indices based on different variables have been developed to identify and quantify drought episodes. **(Salehnia & al, 2017).** Studying the negative impact of drought on water resources has become increasingly urgent in Algeria, It is therefore necessary to monitor rigorously the quantity of this resource. Thus, water resource management require well-defined rain-flow models. Modeling hydrological behavior is an effective substitute for time-consuming flow measurements. **(Abebe & Kebede, 2017)**

In this context, the wadi Boukiou watershed was the subject of this study

PROBLEM STATEMENT/RESEARCH QUESTION

Over the past century the Mediterranean area has undergone climatic variations where drought is one of their dramatic consequences. **(Djellouli, 2017).** It caused by a semi aridity climate, the irregularity of rainfall and flow rate , and by the increase in temperatures.

To understand and assess the impact of this climate variability, especially the problem of drought on water resources, this research sought to response on: which indices will be able to track drought intensity? And, how does the performance of the semi-distributed model in Boukiou basin?

OBJECTIVES

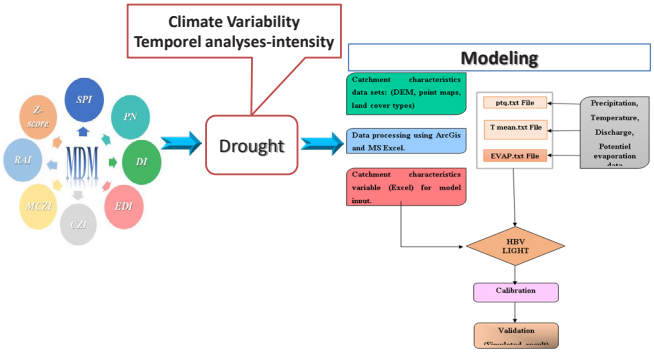
The overall objective of the present study is to investigate the impact of climate variability using the semi-distributed HBV Light model, for prediction of response of Boukiou basin to a rainfall events.

METHODOLOGY

Data Collection: The data used in this research were collected from the National Agency of Hydraulic Resources (A.N.R.H) in Tlemcen.

Table.1: Characteristics of the measurement stations

	Stations	Code	Coordinats			Observation Period	measured parameters
			longitude	Latitude	Altitude (m)		
Hydroclimatic station	**Djebel Chouachi**	160518	01°31'W	35°14' N	130	1974/1975-2017/2018	Rainfall Discharge
Climatic station	**Zenata**	605310	01°46'W	35°01'N	247	1974/1975-2017/2018	Temperature



RESULTS AND DISCUSSION

The result of monitoring meteorological drought in our watershed show an irregularity from one period to another, and both Standardized precipitation index "SPI" and "Z-Score" index gave the best result as shown in (the figure.1)

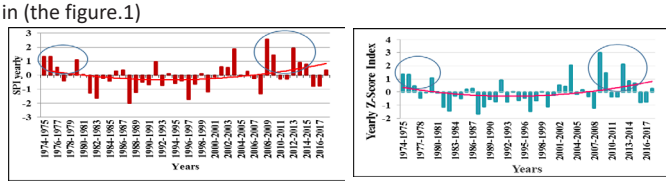
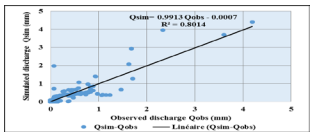
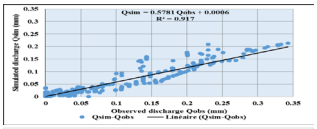


Figure.1: the yearly evolution of Z-Score and SPI indices at Boukiou watershed (1974/1975-2017/2018)



correlation between Qsim - Qobs during calibration phase (1st September 2001-31st August 2010)

Visualizations of calibration quality for HBV Light model (1st September 2001-31st August 2010)



Correlation between Qsim - Qobs during validation phase(1st September 2010-31st August 2014)

Visualizations of validation quality for HBV Light model (1st September 2010-31st August 2014)

CONCLUSION

Based on the analysis, some conclusions have been drawn from this study:

1. Z-Score is an index easy to calculate, and the SPI is the complex index however it done a better result than the other indices.
2. The application of different **climate indices** using **"MDM" software** indicates that our basin has experienced **wet periods** ranging from 1974/1975-1981/1982 and 2008/2009-2017-2018, while **dry periods** are spread out between 1981/1982-2008/2009 with a trend to dryness.
3. HBV-light model has been proven to be very effective to simulate the observed discharge and the calculated discharge effectively in Boukiou watershed. The model was satisfactory calibrated and validated producing (NSE=75%, R^2=0.80) and (NSE=76%, R^2 =0.91) respectively.

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3. **Djellouli , F. (2017).** Persistance de la variabilité climatique et occurence de la sécheresse : La modélisation "pluie-débit" outil d'identification .Application à un bassin versant d'oued el Hammam (Nord-ouest Algérien. thèse de doctorat. 208p. Université de Tlemcen, Algérie.

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

http://repository.pauwes-cop.net/handle/1/404

Graduate CV.

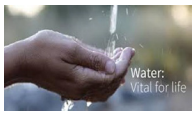
Water Management in transboundary Rivers: Allocation and Governance, the case of Medjerda River Basin

Andrianirina Sedera RAJOSOA, Khaldoon A, Mourad
Professor at the Lund University, Sweden
Rajosoa,sedera65@gmail.com

Abstract

Decisions related to water resources management are shaped by a range of considerations from traditional economic factors and physical constraints to political considerations such as the need to manage political support within a single state or to navigate complex international relationships with riparian countries. The main objective of this research is to assess the sustainability of the current transboundary water management strategies at the Medjerda River Basin (MRB) and to propose a transboundary water management strategy that can help to sustain water resources at the MRB, The result show that, the demand for water in MRB is satisfied from 2020 to 2050 for the different consumption Centre's according to all scenarios,

BACKGROUND/CONTEXT



- lack of management and cooperation may create conflicts in using the shared water resources,
- 150 countries, 2.8 billion people, are sharing about 276 transboundary river basin
- Water allocation is considered one of the big challenges that faces water managers and decision-makers,
- Management of transboundary water resources can deliver benefits for individuals living in shared basins and aquifers

PROBLEM STATEMENT/RESEARCH QUESTION

- causing floods in Tunisia,
- using traditional irrigation techniques will increase drought probability,
- land-use change in the MRB

OBJECTIVES

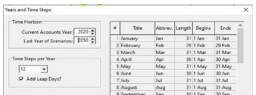
The main objectives: To assess the sustainability of the current water management practices and strategies and to propose a transboundary water management strategy to sustain water resources at the MRB

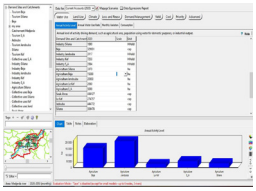
Specific objectives:

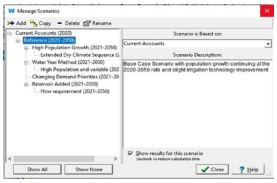
To assess the historical change of water uses and governance practices;
To assess stakeholder's involvement in water related issues;
To assess water quality and conservation measures;
To assess current (2020) and future (2050) water budget;
To propose a sustainable transboundary water resources management strategy

METHODOLOGY

- Cartographical presentation,
- Assessing water resources (Quantitative and Qualitative),
- Assessing water demand,
- Assessing water budget
- Sustainable transboundary water resource management strategy





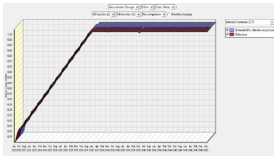


- The WEAP model used in the study involves multiple parameters,
- Different scenarios have been defined to determine the measures that make it possible to reach a water balance

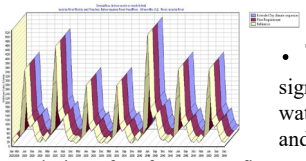
RESULTS AND DISCUSSION

- The results of the application of the WEAP 21 model in the Medjerda watershed are presented in cartographic and graphical form by considering four scenarios:

❑Reference scenario
❑Climate scenario
❑ High population growth scenario
❑ Industrial Development scenario

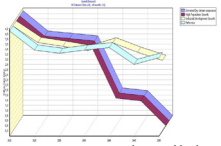


Groundwater storage trends up to 2050.

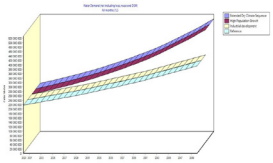


Evolution of surface water flows.

- The Medjerda watershed area still has significant potential in terms of resources in water that can be exploited both as groundwater and surface water



Unmet Demand at all demand sites



The water demand with all the scenarios

The results of the Unmet Demand for2020-2050 for the two scenarios (Reference and high population growth) show that the demand sites are satisfied for both scenarios. The unmet demand varies from 4 Mm^3 to 0 m^3 (High Population growth and Climate scenarios) and to 3 Mm^3 for the reference scenario.

For the water demand, The result show that, for the years of the scenarios of climate and the high population growth, the water demand varies from 218 Mm^3 to 509 Mm^3 and for the reference scenario vary from 218 Mm^3 to 395 Mm^3 in 2020 and 2050, respectively, which means water demand is insufficient for consumption, especially during prolonged periods of drought, in the case of climate change.

CONCLUSION

- The practices of transboundary waters resources are a source of friction between basin states competing for scarce resources,
- The WEAP is very favourable for establishing a water resources management plan,
- The results of the Unmet Demand show that The demand sites are satisfied for some of them in the both countries and not satisfied for other sites,
- Water demand is insufficient for consumption, especially during prolonged periods of drought, in the case of climate change

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Water Resources Modelling in a Context of Climate Change in Côte d'Ivoire

HALIME Abdoulaye Affadine, Dr. Karima BENHATTAB [a]
[a] Hydraulic Department, University of Oran, Algeria
affadinehalima@gmail.com, benhattabhaseni@yahoo.fr

Abstract

During the period 1961-2000, Côte d'Ivoire, has been challenged by irregular rainfall distribution leading to frequent extreme events (drought and floods), resulting in agriculture losses. The methodological approach consisted to perform statistical test on annual rainfall, to characterize the daily rainfall extreme events and the meteorological drought by the use of climate's indices based on **ETCCDI** and the Standardized Precipitation Index. A hydrological model GR2M at monthly scale (Mouelhi 2006 version) was performed at five basins. It was found that the North and South of Côte d'Ivoire present a significant decreasing trend. Pettitt test showed a break in the time series around **1969-1982**. The SPI-6 and SPI-12 indicated that most of frequent drought in term of severity, duration and frequency was observed after 1980. The annual total precipitation (**PRCPTOT**) is highly decreasing while the Consecutive Wet Days (**CWD**) and the monthly maximum 1-day precipitation (**R*1day**) showed an increasing trend. The results obtain shows that the GR2M performs well in **Semien** as the average Nash criterion is greater than **0.75.**

BACKGROUND/CONTEXT

Climate change is a global issue that affects many countries around the world (IPCC, 2013). However, Sub-Saharan Africa is considered the most vulnerable to climate change impacts because of its high dependence on agriculture and natural resources, warmerbaseline climates, increasing temperature, low precipitation, and limited adaptive capacity (Hassan & Nhemachena, 2008). The most significant impact on climate change has been the long-term reduction in rainfall in the semi-arid regions of Africa. Thus, West Africa has experienced a decrease in annual rainfall since 1970 (Goula Bi et al., 2010).

Côte d'Ivoire has been experiencing different types of disaster that are increasing in intensity, duration, and severity.

PROBLEM STATEMENT/RESEARCH QUESTION

- ❖ Extreme climates events are the major challenges that humanity faces.
- ❖Côte d'Ivoire is a country based on rain-fed agriculture and it has a strong dependence on river flow for the power generation and fisheries for its economy (Soro et al., 2017).
- ❖The spatial and temporal variability of rainfall has a significant impact on the water resources availability and agricultural production.

Research Question:

How the extreme climates have evolved in Côte d'Ivoire? How the climate change/variability impact the rainfall/runoff relationship in a conceptual model?

OBJECTIVES

To analyze spatial and temporal variability of extreme rainfall condition and its impact in rainfall/runoff modelling in Côte d'Ivoire.

METHODOLOGY

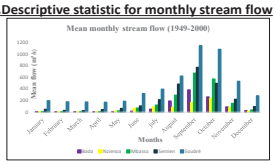
Litterature review	• Similar studies related to the topic ;
Data processing	• SIEREM Database ; • ORSTOM researchers database; • Reference times serie database; • Microsoft Excel and R softwares were used.
Statistical analysis	• Descriptive analysis on annual and monthly rainfall and streamflow time series ; • Pettitt and Mann Kendall test on annual rainfall ; • R software was used ;
Rainfall Climate Indices	• Twelve rainfall indices calculation from the Expert Team on Climate Change Detection and Indices (ETCCDI) ; • RclimDex software was use with daily rainfall data to perform those indices ;
SPI 6 and 12 months	• SPI 6 and 12 time scales were used to charactarize agricultural, meteoroligical and hydrological droughts; • Monthly time series were used with Rainfall Drought Indices Tool (RDIT) to determine the SPI;
Hydrological modelling	• A monthly empirical hydrological modelling GR2M was conduct with R software namely with AirGR package on five basins(Semien, Soubré, bada, Mbasso, Nzienoa).

RESULTS AND DISCUSSION

1. Descriptive statistic on annual rainfall time series

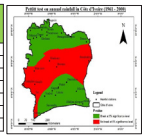
Stations Name	Coordinates		Min (mm)	Max (mm)	Mean (mm)	Standard deviation (mm)	Coefficient of variation	Skewness	Kurtosis	% of NA
	Latitudes	Longitudes								
Abidjan aéroport	5.25	-3.9333	1059.00	2756.00	1804.00	409.12	0.23	0.13	-0.96	10.00
Adiaké	5.30	-3.3	1181.00	2563.00	1844.00	370.94	0.20	0.18	-0.92	0.01
Tabou	4.42	-7.37	1219.00	3351.00	2246.00	427.43	0.19	0.29	0.05	0.01
Bouna	9.27	-2.98	0.00	1500.80	895.20	339.09	0.38	-0.96	1.36	6.66
Man aero	7.40	-7.52	1150.00	2190.00	1619.00	249.09	0.15	0.21	-0.73	0.00
Odienné	9.50	-7.5667	991.70	1796.60	1434.70	226.70	0.16	-0.40	-0.93	2.70
Ouangolodougou	9.83	-5.15	0.00	1339.60	956.90	331.95	0.35	-1.52	1.74	7.92

2.Descriptive statistic for monthly stream flow



3. Break (Pettitt test) results on annual rainfall

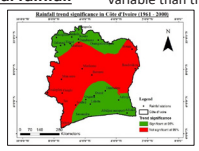
Climatics zone	Stations Name	Z	P-value	Ho test significance level 5%	Q sen
Sub-tropical	Odienné	-3.20	0.00136	Rejected	-10.33
	Ouangolodougou	-2.77	0.00555	Rejected	-8.81
Humid tropical	Bouna	-1.38	0.16900	Accepted	-6.05
	Man aero	0.54	0.59200	Accepted	2.80
Sub-equatorial	Abidjan aéroport	-3.274	0.00106	Rejected	-17.13
	Adiaké	-4.09	0.00004	Rejected	-20.09
	Tabou	-0.41	0.68300	Accepted	-2.32

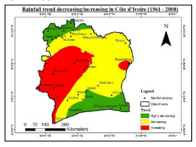


- ❖ The month of August, September and October have the highest amount of stream flow (Q = **335.13** in **Bada** to **2,745.5 m³/s** in **Soubré**).
- ❖The mean annual flow varies from **65.11 m³/s** for **Nzienioa** to **438.45 m³/s** for **Soubré.**
- ❖The CV shows that the monthly flow in all stations during the summer period is highly variable than the winter.

4. Mann Kendall test results on annual rainfall

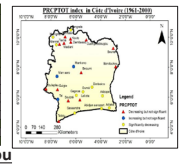
Climatics zone	Stations Name	Z	P-value	Ho test significance level 5%	Q sen
Sub-tropical	Odienné	-3.2040	0.00136	Rejected	-10.3310
	Ouangolodougou	-2.7730	0.00555	Rejected	-8.8100
Humid tropical	Bouna	-1.3750	0.16900	Accepted	-6.0490
	Man aero	0.5360	0.59200	Accepted	2.8000
Sub-equatorial	Abidjan aéroport	-3.274	0.00106	Rejected	-17.1300
	Adiaké	-4.0890	0.00004	Rejected	-20.0870
	Tabou	-0.4080	0.68300	Accepted	-2.3160



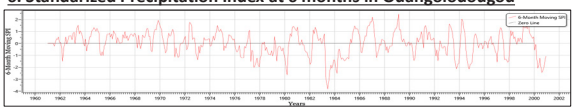


5. Rainfall indices

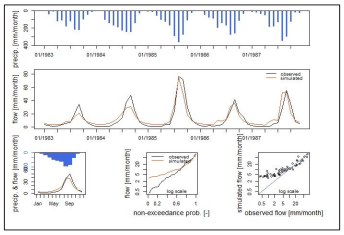
Indices	Abidjan aéroport			Adiaké			Sassandra			Oumé		
	P-value	Slope estimate	Significant trend at 95%	P-value	Slope estimate	Significant trend at 95%	P-value	Slope estimate	Significant trend at 95%	P-value	Slope estimate	Significant trend at 95%
R10	0	-0.705	Yes	0	-0.547	Yes	0.001	-0.268	Yes	0.008	-0.208	Yes
R20	0.001	-0.201	Yes	0	-0.192	Yes	0	-0.269	Yes	0.005	-0.183	Yes
R40	0.021	-0.0807	Yes	0.013	-0.08	Yes	0	-0.194	Yes	0.003	-0.103	Yes
R50	0.234	-0.041	No	0.022	-0.056	Yes	0	-0.169	Yes	0.014	-0.05	Yes
R*1day	0.122	-0.656	No	0.505	-0.264	No	0.01	-1.613	Yes	0.422	-0.289	No
R*5day	0.107	-1.378	No	0.299	-0.727	No	0	-4.089	Yes	0.225	-0.721	No
R95p	0.172	-3.609	No	0.062	-3.634	No	0	-13.256	Yes	0.003	-5.558	No
R99p	0.108	-2.786	No	0.272	-1.428	No	0.008	-5.137	Yes	0.421	-0.965	No
SDII	0.568	-0.015	No	0.116	-0.029	No	0	-0.174	Yes	0.285	-0.026	No
PRCPTOT	0.085	-11.994	Yes	0	-10.1	Yes	0	-19.672	Yes	0	-12.316	Yes
CWD	0.042	-0.066	Yes	0.051	-0.048	Yes	0.503	-0.033	No	0.61	-0.011	No
CDD	0.038	0.279	Yes	0.275	0.11	No	0.449	0.125	No	0.034	0.35	Yes

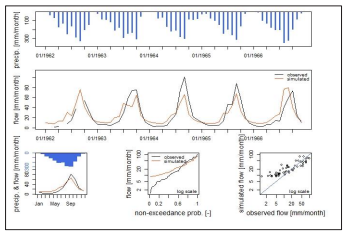


6. Standarized Precipitation Index at 6 months in Ouangolodougou



7. Best/Poor performing period for the calibration Semien





CONCLUSION

❖Due to its agriculture-based economy (30% of GDP), Côte d'Ivoire is one of the most vulnerable countries to climate change.

❖The SPI revealed that Cote d'Ivoire has experienced more of moderate and severe droughts (agricultural and meteorological drought) and extreme hydrological droughts. These droughts reached their peak 1982.

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Master of Sciences

Water Policy

Graduate CV.

Assessing the impacts of Climate Change in Senegal, a Case Study of Casamance Region

Salimata FALL, Bara DIAKHATE[a]
[a] **Hydroconcept, Dakar, Senegal**
Contact detail: salimatafall@hotmail.com

Global warming has several impacts in the Casamance region. Historical records of hydrological and climate data were the parameters used to evaluate the impacts of climate change in the region. Results showed that climate change in Casamance is not negligible. The climate underwent abnormal evolutions during the period going from 1987 to 2016. There was much fluctuation in both rhythm and quantity of precipitation and a considerable decrease in the Casamance river flow in the past. The aggression of the vegetation cover, deforestation, GHG, and biomass combustion in Casamance have increased the risk of vulnerability to climate change.

BACKGROUND/CONTEXT

During current and recent past times, climate change has been a subject of concern for both scientists and policy makers over the world.
The effects of climate change often lead to weather disturbances and associated harsh natural disasters, and threaten both directly and indirectly human life on earth. Casamance, the wettest area in Senegal, has suffered from strong climatic variability since the early 1970's (Sané et al., 2010). The main manifestations of this climatic variability relate to more or less significant rainfall deficits and the rise in temperatures.
This deterioration in climatic conditions results in the salinization of soil and water, the acceleration of the decline in agricultural and the destruction of natural resources (Sané et al., 2010).

PROBLEM STATEMENT/RESEARCH QUESTION

Understanding climate change impacts is vital for developing sustainable mitigation measures and will help decision makers for a better planning approach in resources management. These adaptation plans will contribute to the realization of agenda 2063 of the African Union and the realization of the United Nation Sustainable Development Goals (SDGs) especially SDG 13 and subsequently SDGs 6, 3, 2 and 1.

OBJECTIVES

- To identify and evaluate the causes, impacts and the strategies for resilience and adaptability for climate change in Senegal and in Casamance at a local level.
- to set out appropriate strategies and precaution measures to reduce damages caused by climate-related natural disasters.

METHODOLOGY

Data Collection

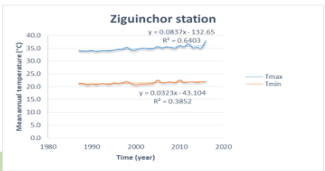
The data used consist in temperatures (minimum, maximum, and average), cumulative rainfall and streamflow data. Climate data were collected with the National Agency for Civil Aviation and the Meteorology of Senegal (ANACIM). All data came from Ziguinchor and Kolda stations. Streamflow data was collected with the Ministry of Water and Sanitation of Senegal. The sample size was based on the recommendations of the World Meteorological Organization which advocates the use of a minimum observation period of 30 years for any study on climate change.

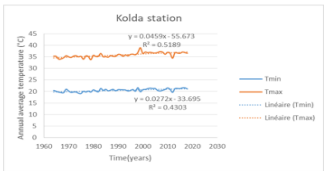
Data Processing Methods

This study is based on the assessment of historical records of temperature, precipitation and streamflow data, recorded since 1987 until 2016. All these historical records were used to make a clear trend of those parameters.
The plotting of trends for analysis was made using Microsoft excel.

RESULTS AND DISCUSSION

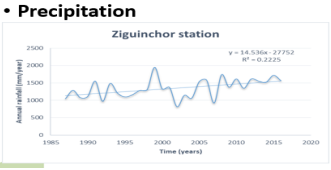
- **Temperature**

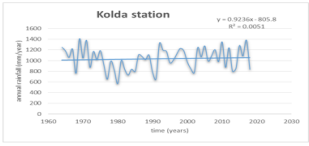




The plotted temperature trends testify the rise of the temperature in the considered stations. According to recent climatological data, the climate of the region of Ziguinchor underwent abnormal evolutions during the period going from 1987 to 2016. Thus, these data show that the climatic parameters such as the temperature, the pluviometry were modified.

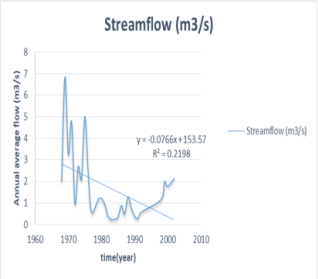
- **Precipitation**





Both rhythm and quantity of precipitation have been varying especially during the period 1970 à 2016. Indeed, the evolution of the pluviometry from 1989 to 2016 testifies to modifications of the climatic conditions of the region.

- **Streamflow trend at Kolda station**



There has been a variation of the flow over the period 1964-2002 at the Kolda station.
Around the years 1964 to 1977, there was an increase in the flow of the river whereas it returned to a considerable decrease from 1977 until 1995.
There has therefore been a considerable decrease in the flow of the river in the past.

CONCLUSION

The consequences of CC remain visible in general and in particular in the region of Ziguinchor which weighs more heavily on its agriculture and its forest, its water resources, and its coastal areas.
But sometimes there are mitigation and adaptation strategies consistent with the changing climate, such as: reducing GHG emissions and carbon sequestration.
In brief, the results of this study indicate that the observed climate change in Casamance has impacts on many sectors. It is important to note that climate change driven natural disasters events in Casamance have been also amplified on the other hand by human activities and by high density of the population that survive on agriculture.

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An Analysis of the Physico-chemical and Microbial Quality of Sachet Water in Lilongwe, Malawi: Implication on Public Health and WASH Policies

Kizito Ngumbira, Pro. E. Donkor
Kwame Nkrumah University Science Technology
ngumbirak@yahoo.com

Abstract

In Malawi, sachet water is popular but not regulated, and information about its quality is unclear and rarely available. This study investigated the physico-chemical and microbial quality of hand-filled sachet drinking water in Lilongwe City, Malawi, and its public health and WASH policy implications. The study deployed an experimental design and sachet water samples (n = 90) were randomly purchased from area 1, 18, 25, 36, 49, and 57. The results showed that majority of the samples (72.22%, n = 90) were contaminated with *E coli* hence not suitable for human consumption. Since the country does not have regulations and legislation governing the production and marketing of sachet water, the study recommends the formulation of the same to safeguard the health of consumers.

BACKGROUND/CONTEXT

Many people in the developing world lack access to a safe water supply (Gonçalves *et al.*, 2019). In Malawi only 67% of population has access to potable water sources (WHO/UNICEF, 2015; Mkwate *et al.*, 2017) while 15% of population lack access, and fetch water from unimproved sources 2018 (NSO, 2018). 78% of population have access to potable water in Lilongwe city however, Increased population and frequent water supply interruption has led to increase in other sources of potable such as sachet water. Sachet water is popular in the city and provide marginalized people access to potable water unfortunately it is not regulated (Manjaya *et al.*, 2019). Information about sachet water quality is unclear and rarely available despite increase in consumption (Manjaya *et al.,* 2019).

PROBLEM STATEMENT/RESEARCH QUESTION

In Malawi formal water sachet manufacturers are non-existent (Manjaya *et al.*, 2019). Informal vendors only use tap water or any source to tie plastic sachets which are then cooled in refrigerators or put in cooler boxes with ice blocks and later sold to consumers. The proliferation of these hand-tied sachet drinking water items brings up the issue regarding whether they are cleanly produced, particularly while considering the poor condition in the urban area combined with sporadic monitoring of sachet water producers by regulating agencies is taken into account (Boakye-Ansah *et al.,* 2016).

OBJECTIVES

This study aimed at assessing physico-chemical and microbial quality of sachet water in Lilongwe, Malawi and its implication on public health and WASH policies. The specific objectives were To establish the sources and treatment of water bagged in the sachets, determine the physico-chemical properties and microbial composition of the sachet water, To produce scientific based knowledge for stakeholders and policy makers that will help improve sachet water industry and evaluate the public health and policy implications on production and use of sachet water in the cities and urban centres by consumers.

METHODOLOGY

Random sampling procedure using a rand between (1,58) function in excel was adopted for selecting sampling location. From each location 15ss samples were collected randomly and kept in their unique tied polythene tube. Laboratory samples were filled in clean and pre-treated one liter plastic bottles (triplicate). Samples were analyzed at Central Water laboratory using standard procedure. Physical parameters were analyzed by using Multi-Meter (EC), pH Meter(pH)and Turbidimeter (Turbidity). Chemical parameters were analyzed by using Titration Method (Chloride), Spectrophotometer (Fluoride), UV/ Vis Spectrophotometer (Nitrates), Atomic Absorption Spectrometer (iron, Manganese) and Metalyser (Arsenic). For microbial Analysis, plate count was used (*E. Coli*). Data was analyzed using Microsoft Excel (2016) and SPSS (version 21) to generate descriptive statistical, whisker and boxplot, error bars. To establish statistical differences, One-Way ANOVA was adopted, and Pearson Correlation Coefficient (95% confid. level) was employed to detect relationships between parameters.

RESULTS AND DISCUSSION

Table 1: Summary results of physico-chemical and microbial characteristics of sachet water samples (n = 90)

Parameters	Units	Min.	Max.	Mean	Med.	SD	CV	SC	MS 214
pH	NA	6.15	8.02	7.32	7.42	0.39	0.053	5.6	5.0 - 9.5
EC	µs/cm	105	515	155	152	40.61	0.262	33.1	1500
TDS	mg/L	63	309	93	91	24.35	0.262	37.2	1000
Turbidity	NTU	0.01	4.99	0.94	0.69	0.90	0.954	0.1	0.1 - 1.0
Cl^-	mg/L	8.8	39.6	16.64	15.8	5.27	0.32	34.8	200
F^-	mg/L	0.02	2.55	0.41	0.37	0.31	0.76	1.9	0.7 - 1.0
NO_3	mg/L	0	2.72	0.08	0.02	0.30	3.70	33.6	10
Fe	mg/L	0.004	0.663	0.089	0.055	0.115	1.29	10.9	0.20
Mn	mg/L	0.002	0.604	0.013	0.002	0.065	5.00	1.3	0.10
As	mg/L	BI	BI	BI	BI	NA	NA	NA	0.05
E. coli	cfu/100mL	0	3166	266	21	682	3	0.39	0

MS: *Malawi Standard*, BI : Below detection, SD: *Standard deviation*, CV: *coefficient of variation*, SC: *sigma capabili*

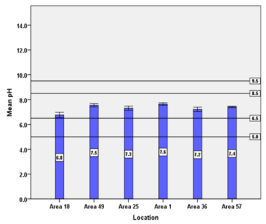

Figure 1: Mean plots with error bars of sachet water quality (pH) in different areas compared to M 214 and WHO standards

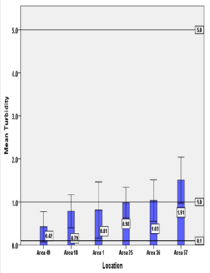

Figure 2: Mean plots with error bars of sachet water quality (pH) in different areas compared to M 214 and WHO standards

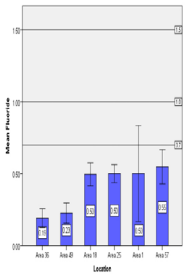

Figure 3: Mean plots with error bars of sachet water quality (Fluoride) in different areas compared to M 214 and WHO standards

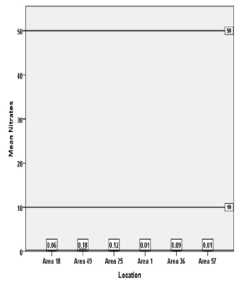

Figure 4: Mean plots with error bars of sachet water quality (Nitrates) in different areas compared to M 214 and WHO standards

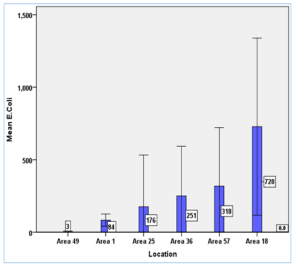

Figure 5: Mean plots with error bars of sachet water quality (E.coli) in different areas compared to M 214 and WHO standards

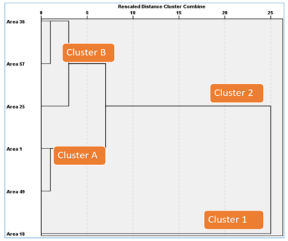

Figure 6: Hierarchical classification (HAC) of water sachet based on evaluated physico-chemical and microbial parameters

CONCLUSION

- Study shows that sachet water was partly contaminated with faecal matter mainly due to poor hygienic practices during production
- Study also revealed that most of physico-chemical parameters were within limits except for Turbidity and fluoride that complied partially
- However, failure to comply with microbiological standards signify that the water is of poor quality hence not suitable for human consumption
- There is need to promote hygienic practices, the use of HWTS and formulation legislation and regulation to control sachet water industry.

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An Assessment of the Socio-economic Challenges for the Provision of WASH Services during Emergency Situation: Gado-badzere refugee Camp

Chanel lynne Assouah Essoubat, Dr. Andrews Ako Ako
lynne.Assouah@yahoo.com

Abstract

Emergency situations can occur as a result of slow or rapid onsets. During such circumstances the affected populations become refugees or Internally displaced people(IDPS) who often require fundamental and immediate needs such as water, food, sanitation which when provided to them on time can help break the cycle of disease transmission and improve their wellbeing. A total of two hundred and twelve (212) households were surveyed within the camp through a questionnaire. This was accompanied with key interviews, field observation and secondary data. The identified socio-economic hurdles for the provision of WASH services in the camp were Financial constraints, behaviour complexities& cultural factors, A total of 31 Boreholes, 12 standpipes unevenly distributed were found in the camp, the average volume of water available per person per day were 16liters which was above that of 15liters in emergency situations. Water points were located within the perimeters and the waiting time at the source was between 3-5minutes. There are still many apprehensions regarding the number of persons per latrines and toilets, number of people per garbage can, access of WASH services to vulnerable groups, and challenges. This study can be very beneficial for the wellbeing of refugees in the world in general and particularly in Africa

BACKGROUND/CONTEXT

All calamities, disasters or emergencies greatly affect distinct human beings, their families, their societies, and the nation as a whole in which these events take place. They all request quick and operative response to physical necessity in which water and sanitation fall and also longer-term recovery and reconstruction(Carter, 2015, p. 5). It is under such conditions that Water, sanitation and hygiene (WASH) programme designs and actions help in the provision of these services and also safeguards health by preventing occurrences of water related diseases like cholera and also preserve their dignity.

PROBLEM STATEMENT/RESEARCH QUESTION

- ❖ Cameroon like many other countries have been welcoming refugees attacked by Civil wars, political strife etc in the next-door countries, predominantly from Central Africa, Chad, Nigeria, Niger and Gabon Côte d'Ivoire is a country.
- ❖The increased pressure on scarce resources in Cameroon and access to WASH services during Pre/Post Emergency situations remains limited due to prevailing challenges

Research Question:

What is the effectiveness of WASH services in the camp and what are the socio-economic challenges that hamper the provision of these services?

OBJECTIVES

The overall objective is to assess the level of access to water, hygiene, and sanitation within the refugee camp, and analyse the socio-economic challenges in meeting the WASH objectives

METHODOLOGY

Literature review

- Similar studies related to the topic

Data collection

- ❖Random sampling technique
- ❖Primary data was used in this study and data was collected in a qualitative manner,
- ❖This was done through a structured questionnaire,
- ❖key informant interviews (phone call interviews),
- ❖Field observation

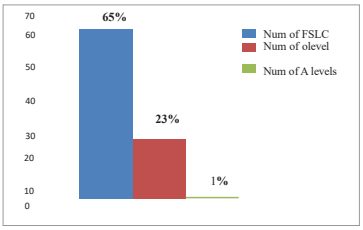
Data analysis

- ❖After the data collection process
- ❖The data was analysed in a quantitative manner
- ❖The raw data was entered on excel
- ❖After the data was prepared on excel, it was then imported into SPSS

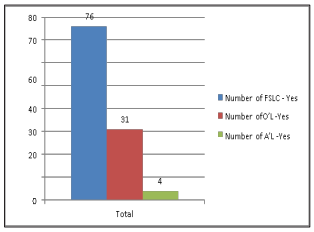
RESULTS AND DISCUSSION

1. Age distribution of sampled population

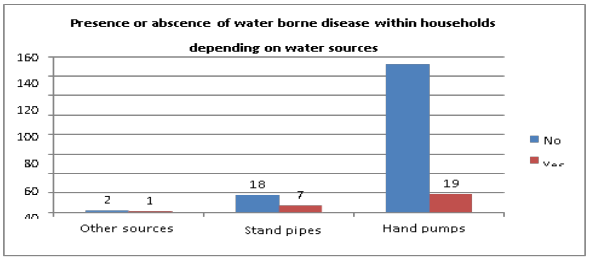
2. Educational attainment among women



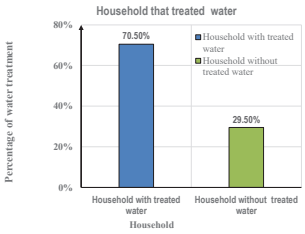
3. Educational attainment among men



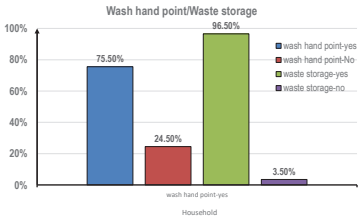
4. Prescence or abscence of water borne diseases



5. Households that treated water



6. Wash hand point/waste storage



CONCLUSION

❖Parameters such as the average amount of water needed per person per day conforms to the international sphere standards.

❖There are still many apprehensions regarding the number of persons per latrines and toilets, number of people per garbage can, access of WASH services to vulnerable groups, and challenges.

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Effect of Non-Revenue Water on the Operation of African Water Utilities: Case studies of Burkina Faso and Cote d'Ivoire

Graduate CV.

Djalia Umutangampundu, Dr Simeon Kenfack [(a)]

[(a)] **African Water Association (AfWA)**

Contact details: djalia012@gmail.com

ABSTRACT

This study analyzed and identified from a comparative point of view between two African water utilities; ONEA (Burkina Faso) and SODECI (Cote d'Ivoire), what could be the different challenges in solving the problems related to Non-Revenue Water (NRW). Questionnaires were used to gather data from institutions in charge of water management in Burkina Faso and Cote d'Ivoire. Results showed that failure to manage high level NRW in SODECI hinders its performance in delivering water services. The study recommends the Institutionalization of NRW Management department in all African water utilities.

BACKGROUND/CONTEXT

One of the key performance indicators for water utility's sustainability is **Non-Revenue Water** (NRW) **(Donkor, 2014).**

This is referred to as the difference between water volume that enters the distribution system and the one that reaches to the consumers **(Lambert et al., 2014; USAID&WBI, 2010; Alegre, 2000)**.

The Global annual NRW has increased from **32 billion m³ to 126 billion m³ in less than a decade** (**Liemberger & Wyatt, 2018; USAID/WBI, 2010**).

PROBLEM STATEMENT/RESEARCH QUESTION

An audit carried out on NRW in some 19 African water utilities, members of AfWA, revealed that **unbilled water represents one third or 37% of the total volume of water produced (AfWA, 2017).**

Utilities	Annual Water Production(million m³)	Non-Revenue Water (1/3 water Produced (million m³)	Average water tariffs (cfa/m³)	Annual Cost of Non-Revenue water
SODECI(Cote d'Ivoire)	208.815	69.605	401	173.5 million cfa 304,385.9 US$
ONEA(Burkina Faso)	87.626	29.208	504	14,720.8 million cfa 25.8 million US$

Consequently, African utilities fail to provide or expand water services to their consumers.

OBJECTIVES

Main objective

To understand the effect of NRW on the operation of African water utilities.

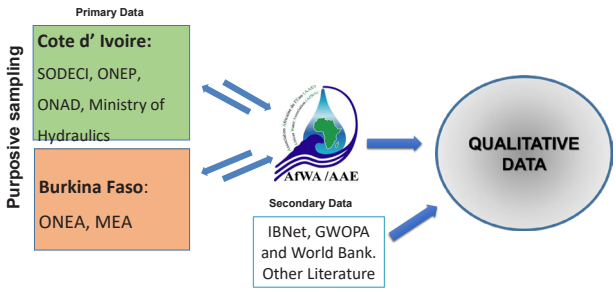
Specific objectives:

Review the Management of NRW in SODECI and ONEA;

Study the impact of NRW on the technical, financial, customer and institutional performance of each utility;

Propose a model for effective management of Non-Revenue Water in African water utilities, based on SWOT analysis.

METHODOLOGY



Questionnaires were designed in a way that they provided data on:

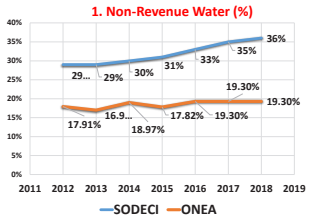
The level of Non-Revenue Water in Cote d'Ivoire and Burkina Faso

The impacts of NRW on **the technical, financial, customer and Institutional performance** of both utilities

SWOT analysis for effective management of NRW

RESULTS AND DISCUSSION

1. Non-Revenue Water (%)



2. Impact of NRW on the performance of utilities

Technical Performance	SODECI	ONEA
1. Water Supply Coverage (%)	71%	*92.44%
2. Nonrevenue water (%)	36%	19.3% 5m³/ km/Day
3. Bursts and leaks Thefts	1.5 break/km/yr ---------- ***1092 frauds	2.95 break/ km/ yr 9000 leaks/month Unknown frauds/yr 24 thefts(2019)

Financial Performance	SODECI	ONEA
1.Operating cost coverage ratio	*1.06 (2014) • 1 M usd/year for commercial losses • 70 M usd for technical losses	*1.23 (2017) • 200,000 usd for NRW monthly (technical an commercial losses)
2.Water tariffs Subsidized water	IBT pricing **401f/m³ Average tariff ----------	IBT pricing **504f/m³ average tariff 0-8 m³ at 188f/m³ for standpipes

Customer Performance	SODECI	ONEA
1. Continuity of water supply	**20 hours/day	**23 hours/day
2. Customer complains	***8959 repair interventions 98% of complains handling	*0.6% complains (2016) *96% complains handling within 3 days (2016)

Institutional Performance	SODECI	ONEA
1. Staff productivity	**2 staff/ 1000 connections	**2.7 staff/ 1000 connections
2.Water Governance	• Private Company • No chief in charge of NRW	• Public compan • Chief in charge of NRW

CONCLUSION

Despite that Burkina Faso is a waterless country, ONEA managed to keep constant the level of NRW at 19% and this has allowed it to supply water at 92.4% to the population; while SODECI's NRW level of 36% has affected all the sectors of performance especially the one on water supply coverage which is still at 71% despite that Cote d'Ivoire being a water resource country. SODECI needs a department in charge of NRW and ONEA needs to keep track of the number of frauds.

A proposed Conceptual model for effective management of NRW

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Graduate CV.

Establishing Efficient Monitoring, Evaluation and Learning Framework of Transboundary Water Governance and Management, the Case of Tanganyika Lake Basin

William NDIHOKUBWAYO, Dr. Azage Gebreyohannes[a]
[a]Ethiopian Institute of Water Resources, Addis Ababa, ETHIOPIA
Contact details: williamndihokubwayo@yahoo.fr

Abstract

This study focuses on establishing efficient monitoring, evaluation and learning (MEL) system of transboundary water governance and management based on case studies targeted to the sustainability of the Lake Basin. The finding of the study indicates that sustainability of governance and management over shared water resources in the lake basin can be achieved in advancing collaborative and adaptive learning and research activities emerged from MEL tools. The MEL framework was achieved using a participatory and non-participatory approach and a semi-structured survey interviews through appropriate indicators, data, analysis, reporting models and continues assessments supported by the stakeholders and partner institutions in the basin. The study recommends the public awareness ,transboundary water cooperation, Management and governance systems and a Community participation and involvement through a MSP (Multi Stakeholders platform) for effective MEL framework.

BACKGROUND/CONTEXT

Lake Tanganyika, the richest freshwater ecosystem is one of the Lakes that are under unstainable development patterns with direct impact on biodiversity (Kmentová et al., 2020) and water quality. The riparian countries (Burundi, DRC, Tanzania and Zambia) established Lake Tanganyika Authority in 2007 to manage, monitor and ensure the sustainability of the Basin (LTA secretariat, 2012).

PROBLEM STATEMENT/RESEARCH QUESTION

The shared Lake is facing many problems that are affecting different groups of people at all levels including sedimentation, pollution problems caused by the populations of cities and villages nestled on the shore of the Lake. The problem is mainly the results of poor management, monitoring, and governance system of the basin (Plisnier et al., 2018).

Main Question: What are the main constraints to the Lake Sustainability? Can the MEL framework be applied to Lake Tanganyika Basin for strengthening its governance system and sustainable Lake management?

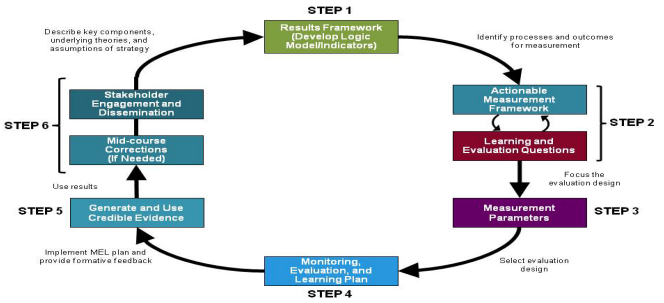
OBJECTIVES

To identify useful instruments that would help in establishing an efficient monitoring, evaluation and learning framework for sustainability of transboundary water governance and management system of Lake Tanganyika Basin shared by four countries.

METHODOLOGY

Research approach	MEL components	Data collection methods	Sampling techniques	Unit of inquiry	Main questions for MEL
Qualitative	1.Monitoring 2.Evaluation 3.Learning	-Face-to-face interview -LTA Documents review -Observations	Purposive	-Water management related institutions in Burundi -Fishermen Local government agencies and NGOs	Evaluation Q : -Why and how things work? MEL plan Q: -Who is intended to learn? -When and how learning will appear?
Quantitative		Questionnaire administration			
Sample size	-27 respondents, among them 7 experts in water management. Data were analyzed with SPSS and MS EXCEL -The study was conducted in three provinces in Burundian part of the basin (Bujumbura urban, Bujumbura Rural and Rumonge)				

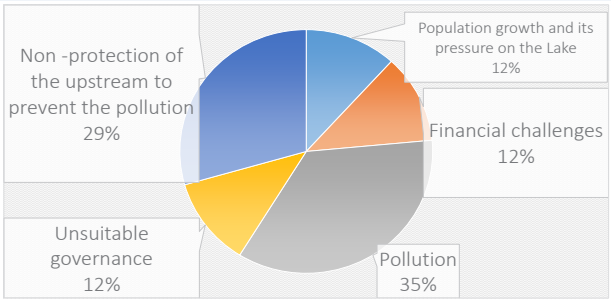
Conceptual Framework



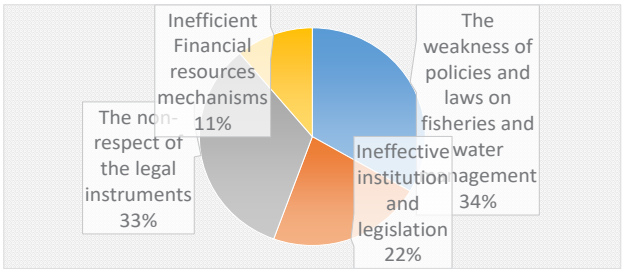
A Framework to understand MEL process (Shaw et al.,2003).

Framework application to good water governance principles (OECD, 2018)

RESULTS AND DISCUSSION



Challenges to sustainability of the Lake



Challenges to Governance and management of the Lake

CONCLUSION

Most projects of Tanganyika Lake implementation have not followed sustainability paths due to problems associated with poor system of transboundary water cooperation, management and governance systems, inadequate public awareness and least emphases given to community participation in projects. Furthermore, projects lack adequate policy for transboundary water management and a weakness in enforcing legal instruments which exacerbate the problems.

REFERENCES

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Implication of Water Policy and Water Utility Management Systems on the Performance of Water Quality Service Delivery in Africa: Case study of Cote d'Ivoire and Burkina Faso

Graduate CV.

Margaret Sima Kironde, Dr. Simeon Kenfack, Eng. Gilles Djagoun
African Water Association (AfWA)
magigesima01@gmail.com

Abstract

This study aimed to analyze the impact of policies and utility management systems on the water quality service delivery performance of Côte d'Ivoire and Burkina Faso water utilities. Structured questionnaires were used to produce primary data. Furthermore secondary data were from existing documents, journals, reports and books. The results demonstrated inadequacies and gaps in the utility management systems and policies causing deficiencies in water quality service delivery to the populations of respective countries. There is a need to have a comprehensive approach that addresses the challenges and gaps of good utility performance in Côte d'Ivoire and Burkina Faso and Africa.

BACKGROUND/CONTEXT

Capacities of many African utilities to cater for ever growing population with quality services is very poor, unsustainable and unreliable. Africa's population is growing fast more specifically in sub-Saharan countries. Water is an essential resource according to Dublin first Principle, In Sub-Saharan Africa, 42% of people have no access to basic water supply 72% have no access to basic sanitation.

The ability of utilities to provide a safely managed water service and to reach the unserved will be supported by their investment in efficiency improvement, policy and institutional capacity development, access to financing, and ability to respond to climate change even more than infrastructure investments.

PROBLEM STATEMENT/RESEARCH QUESTION

Most African utilities are still lagging behind to achieve SDG 6 due to ineffective management systems causing poor performance issues such as low operating and investment efficiency, ineffective policies, poor policies implementation and non competitive nature of the sector (Heymans et al, 2016).

RESEARCH QUESTION: What are the implication of policies and utility management systems on the water service delivery performance of Cote d'Ivoire and Burkina Faso water utilities?

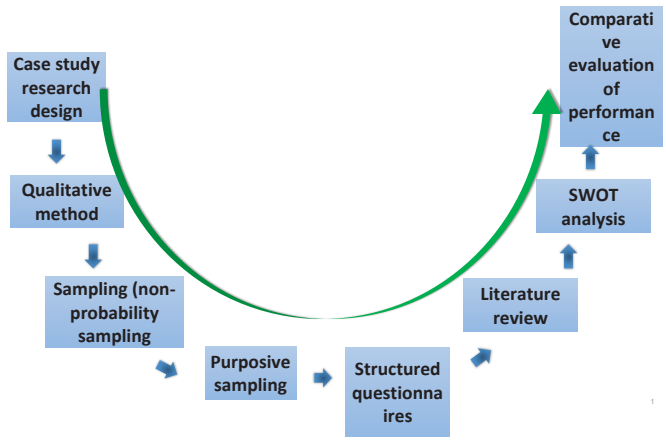
OBJECTIVES

To analyze the implication of policies and utility management systems on the water quality service delivery performance of Côte d'Ivoire and Burkina Faso water utilities.

Specific objectives

1. To use AfWA database of member water utilities to identify and map existing policies and management systems.
2. To benchmark the performance of water utilities in Côte d'Ivoire and Burkina Faso;
3. To conduct a comparative evaluation of the performance of Côte d'Ivoire and Burkina Faso water utilities.

METHODOLOGY



RESULTS AND DISCUSSION

Implication of management systems and policies on performance of water sector institutions in Côte d'Ivoire and Burkina Faso

CÔTE D'IVOIRE

Water policy systems	Water utility management systems	Institutional performance	Financial performance	Operational performance	Customer performance
❑Water code 1998 ❑Environmental code 1996 ❑Drinking water standards	• **Public-Private partnership** 1. MOH (Ministry) 2. ONEP (water asset management) 3. ONAD (sanitation services) 4. SODECI (private water utility)	❑Long term contracts with ministry ❑SODECI (Urban water supply) ❑Decentralization 2003 ❑SODECI (AfWA member)	❑Water and sanitation budget 2020 (291 billion CFA francs). ❑IBT ❑Constant tariffs	❑ONEP monitors SODECI'S operational performance ❑Household connection ratio :70% ❑Access to piped water: 71%	❑Urban water coverage: 83% ❑Rural water coverage:73% ❑Urban sanitation: 49% ❑Population growth/climate change

BURKINA FASO

Water policy systems	Water utility management systems	Institutional performance	Financial performance	Operational performance	Customer performance
❑Water management act 2001 ❑2004 decentralization law ❑National Water Supply and Sanitation Program (PN-AEPA) 2016-2030 ❑Environment and water sanitation policy	• **Public-Public partnership** 1. ONEA (Public water utility) 2. MEA (Ministry)	❑Short term contracts with ministry ❑Decentralization 2009 ❑ONEA (urban water supply) ❑ONEA (AfWA member)	❑Water and sanitation budget 2020 (84.7 billion FCFA). ❑IBT ❑Constant tariffs	❑MEA monitors ONEA'S operational performance ❑Household connection ratio: 65% ❑Access to piped water:86%	❑Urban water coverage: 92.4% ❑Rural water coverage: 65.3% ❑Urban sanitation: 37% ❑Population growth/climate change

CONCLUSION

- Burkina Faso as a waterless country with all the sectorial actors linked to the government, water service delivery performance are better than in Côte d'Ivoire with more available water resources and where water sector actors involve public and private actors.
- The good performing utilities still are affected with gaps in policies and facing management challenges in delivering water quality services affecting improvement of performance
- A good water quality service delivery calls for comprehensive strategies to combat the inadequacies at national, local, and utility levels.

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Graduate CV.

Implications of Water Policy on Coastal Pollution: A Case Study of Mogadishu Coast

Abdulrahman Mohamud Dirie, Prof. Dr. Nadia Badr El-Sayed[a]
[a]*University of Alexandria, Alexandria, Egypt*
Contact details: Cmderie@gmail.com

Abstract

This study examined the water policy of coastal pollution in Mogadishu as well as the effect of that pollution on Policy implementation for area under investigation. Interviews, Questionnaires and document reviews were used to gather data from coastal residents, governmental officials and other stakeholders related to marine issues. Results showed that the major source of the pollution was foreign ships (65%) and the most parameters that caused pollution in the selected locations were chemical parameters (44%). The study recommends an important process to formulate an appropriate, strong and updated policy, to establish strong centers who can monitor and protect our territorial water, participatory approach of policy formulation to conduct a further study on this area.

BACKGROUND/CONTEXT

In Somalia before 1991, pollution of the marine environment is limited and does not currently pose a serious threat to the economy of Somalia **(Messrs, Fowler, & Hamza, 1987**). After 1991 marine pollution has led to the lack of safe marine production, poor hygiene, and a lack of sanitation that make it an enormous contribution to disease rates **(Amina, 2018)**. Many practices have led to marine pollution including disposal of sewage waste and industrial discharges, that have been washed down from factories, and etc. (**Islam & Tanaka, 2004**).

PROBLEM STATEMENT/RESEARCH QUESTION

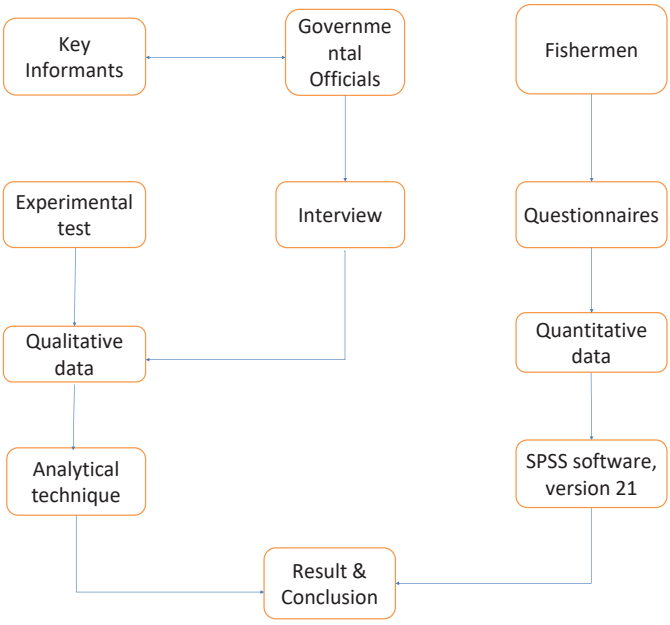
Mogadishu coastal pollution and its impacts have resulted in a number of environmental issues including the enrichment of enclosed waters with organic matter, pollution by chemicals such as oil, hazardous wastes and sediments due to land-based activities. This has been increased due to lack of strong government and policy in Somalia which can protect its territorial water. In addition, there is no research related to existing pollutants in Somali coast as well as its effects on marine environments and the human health.

Main Question: How the pollution affects on Somali coast? And did they implement the water, environmental policy or maritime code/law of the country, if NO why?

OBJECTIVES

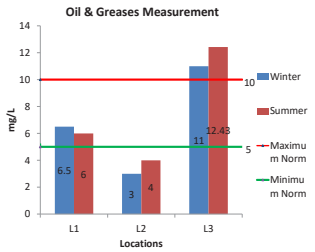
To assess and identify how the water policy, environmental policy and maritime code/law deal with coastal pollution and the effect of that pollution on Somali coast particularly Mogadishu coast, finally, to investigate the main cause of pollution.

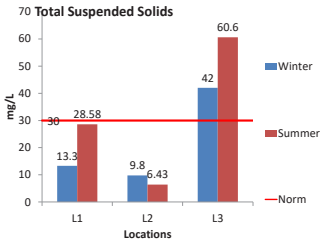
METHODOLOGY

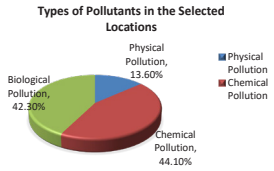


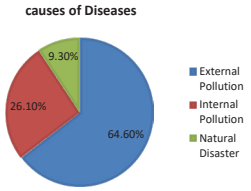
RESULTS AND DISCUSSION

Experimental test and questionnaire responses









CONCLUSION

The results were obtained from marine water tested showed that most of the results exceeded the acceptable standards of WHO and EPA, which is harm for the human health and marine life. The FGS did not formulate enough policies related to coastal pollution after 1991 as well as the government did not review the existed policies between which were formulated between 1960-1991. The Ministry of Fishery and Marine Resources (MoFMR) did not conduct coastal pollution prevention actions and did not form any policy related to how to tackle this issue. Therefore the absence and weakness of national marine policy caused unwanted action from the local people and foreign ships. Challenges encountered by the fishermen and the coastal residents are related to coastal pollution caused by themselves and the foreign ships.

This study recommended to make and formulate an appropriate, strong and updated policy which can correspond with the other policies in the globe in order to prevent the local and foreign pollution to the Somali territorial water, to establish strong centers who can monitor and do an accountability what the foreign ships do in the Somali territorial water, to allow participation of the different stakeholders in the different processes of marine policy making in order to consider the policy their inputs, ideas and concerns, finally, to conduct a further study to examine the feasibility of coastal pollution situation in the selected locations, as well as the other locations around the capital city.

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

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Improvement Strategy for Reducing Environmental Impact of a Wastewater Treatment Plant

Graduate CV.

Hidayat Mohammedi, Nadia Badr El-sayed (a), Cherifa Abdelbaki (b)
(a) Environmental Science Department Faculty of scienceAlexandria Univeristy
(b) Faculty of Technology, University of Tlemcen- Algeria
mouhammedihidayat@gmail.com

Abstract

A wastewater treatment plant must be able to operate satisfactorily during critical situations. That makes the management of the wastewater plant difficult because of disturbances that can be produce and which are difficult to characterize and predict. The slightest failure is harmful in an environment where performance is paramount. It is therefore necessary to ensure permanently the proper functioning of the wastewater treatment plant. To answer this question, a Design Failure Modes and Effect Analysis (DFMEA), based on the daily physico-chemical parameters of pollution, has been developed for the WWTP of Ain and crucial problems which penalize its operation and limit its reliability has been identified. Preventive and corrective actions are proposed.

BACKGROUND/CONTEXT

Non-conventional water resources such as treated wastewater can constitute a solution to reduce the intensive exploitation of water resources. Water reuse can be considered as an adaptation measure to preserve water resources.

Wastewater treatment technology is a very complex succession of unit processes, each of them designed to remove a specific pollutant from wastewater (Robescu, 2011).

Wastewater systems should insure good quality effluents with low costs, under a very restrictive legislation. Problems facing WWTP operators are various, such as covering energy costs, finding financing solutions for rehabilitation and modernization or expansion.

PROBLEM STATEMENT/RESEARCH QUESTION

The quality of treated water has direct relationship with the crops quality which in result affects the human health and the environment. If the WWTP is not functioning in the way it is supposed to do, it will affect the treated water quality (Mulutu, 2016). Therefore, risk analysis in WWTPs is quite important to detect and prevent possible accidents in the manufacturing process. This is why a performance study is necessary to ensure well-functioning of the plant and predict the main failures that harm the good functioning of this system.

Research question:

what are the problems in the treatment process and how can we prevent and? Or eliminate them

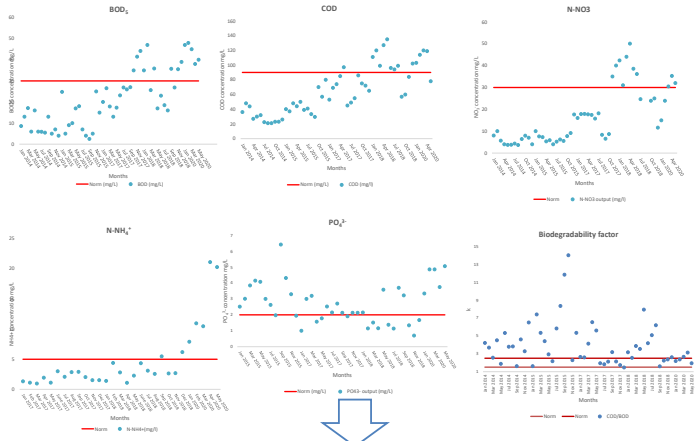
OBJECTIVES

The objective of this work is assessing the performance of Ain Temouchent waste water treatment plant in order to detect the failures in the system; by following the Design Failure Modes and Effect Analysis (DFMEA) and suggest the suitable solutions to the problems.

METHODOLOGY

- Build a database of the daily analysis of physico-chemical parameters of the effluent water
- multivariable analysis for the database and compare the treated water parameters with the WHO standards
- Establish a criticality diagram with Design Failure Modes and Effect Analysis (DFMEA)
- Recommend optimal solutions to resolve the problem

RESULTS AND DISCUSSION



Screen
Checking for clogging

Sandblaster
-Checking the absence of deposits
-Disposal of sands

Degreaser
-Checking for correct bubbling
-Removal of floaters
-Daily extraction (If manual operation) of sands and deposits of bottom of work
-Drain the basin when not in use.

For all basins
Measuring the sludge index on a weekly basis

Clarifier
-Do not interrupt the recirculation to concentrate the sludge before its extraction to the thickener. Or a maximum shutdown of two hours.
-Check that the sludge is properly collected along the entire length of the deck.
-Check that there are no deposits on the harrows.
- Evacuating or sealing floats by sprinkling

Aeration tank
-Adequate adjustment of ventilation according to load and hydraulic mode
-Never program a ventilation shutdown time of more than two hours.
-check the oxygen concentration in the pond
-Manual scraping if necessary to extract the foams
-Limit the waterfall to the clarifier

Thickener
Controlled power supply to avoid hydraulic shocks

- A storage block for all specific parts of each process to avoid long delays in delivery in case of failure.
- Building shelters for the drying beds in case of bad weather and avoiding continuous recirculation of sludge from the thickener to the aeration tank.
- Carry out periodic analyses (physico-chemical and microbiological) of the sludge since it is going to be reused for agriculture.
- in the laboratory. Install Install devices and sensors to measure dissolved oxygen, as well as sludge concentrations in the settling tanks and aeration
- Consider primary settling to reduce the TSM content.
- Think of making a Coagulation-Flocculation followed by a primary settling when the wastewater is non-biodegradable.
- Carry out treatment optimized for phosphorus removal to meet the standards

CONCLUSION

The principles failures detected:

- A surpass in TSM, NO3-, NH4+, COD, BOD5, concentrations.
- A significant increase in sludge concentration in biological basins that makes the sludge old, which causes the sludge to rise in the clarifier.

We propose the following solutions to be implemented

- The installation of a wall valve at the inlet of the WWTP, to ensure the flow measurements.
- The addition of adjuvants in the aeration basins as a preventive and curative solution to the rising sludge.
- Place dissolved oxygen and pH measuring devices in the aeration tank to ensure good degradation by microorganisms.
- Install detection devices for the sludge concentration in the settling tanks in order to know when the sludge must be extracted or recirculated.

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

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Graduate CV.

Integrating Household Water Treatment and Safe Storage Practices in Zambia's National Water Policy for Effective Regulation, Evaluation and Sustainable Water Provision

Claydon Mumba KANYUNGE, **Prof. I., A. Nyambe**
University of Zambia, Integrated Water Resources Management Centre
Claydonmumba@gmail.com

Abstract

Household Water Treatment and Safe Storage (HWTS) is an interim solution that can reduce the burden of waterborne diseases. The study was conducted in three peri-urban communities, Chaisa, Kanyama and Ngombe in Lusaka, Zambia. The study revealed that 42% of households treated their water by chlorination, boiling and SODIS (Solar Disinfection). Most households noticed a reduction in the occurrence of diarrhoeal diseases by using various HWTS methods. Zambia does not have any National Policy document that addresses HWTS. Several countries, such as Ghana and Tanzania, have formulated Strategic Plans that address HWTS, which Zambia can learn from.

BACKGROUND/CONTEXT

Water is vital for human health and well-being and it is required for achieving sustainable development. However, water can cause devastating effects as a carrier of pathogens that transmit diseases to a large population Providing universal access to safe, pathogen-free, reliable piped water supplies into households is the ideal solution to water-borne illness.

However, the high capital and maintenance costs of piped supply systems mean that universal safe piped water is likely decades away for many developing regions. is a proven intervention to improve drinki**Household Water Treatment and Safe Storage (HWTS)**ng water quality and reduce

PROBLEM STATEMENT/RESEARCH QUESTION

Zambia is among many states whose National Water Policy **does not** address HWTS and neither are there any institutions in the country that regulates or evaluates HWTS.

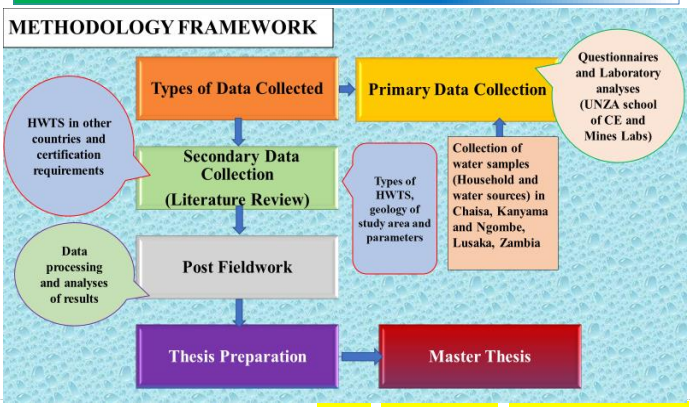
Limited research coverage in areas and among populations where water quality improvements would have an important impact on health. This has, therefore, resulted in **poor regulation and evaluation** of many HWTS by the government.

OBJECTIVES

The aim of the study was to **examine HWTS practices** in selected peri-urban communities and how Zambia can formulate national policies on HWTS regulations and evaluation.

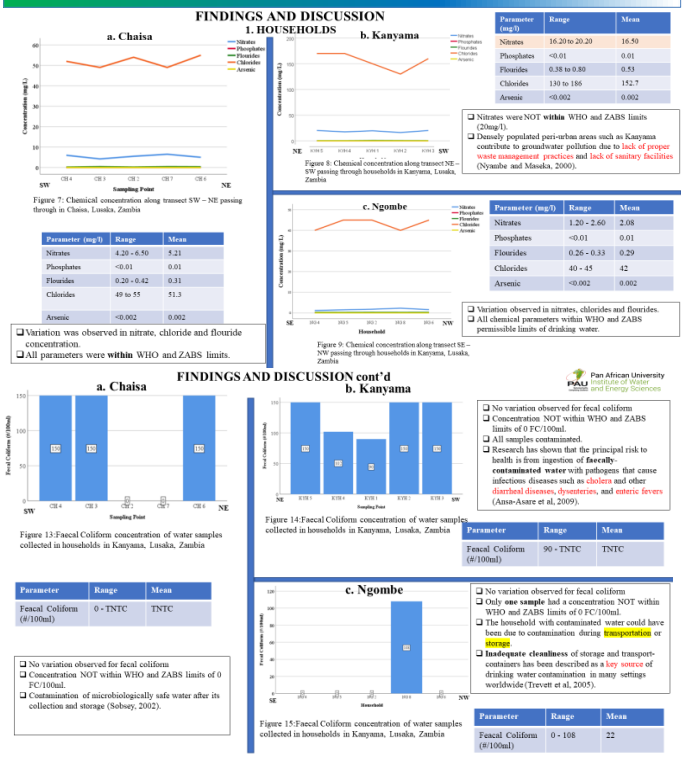
To **analyse the water quality** of household water stored in communities of Chaisa, Kanyama and Ngombe in Lusaka, Zambia To **analyse the Zambian National Water Policy** and the **Zambian Bureau of standards documents** with regards to HWTS challenges towards policy formulation of HWTS in Zambia challenges towards policy formulation of HWTS in Zambia.

METHODOLOGY



Water samples were collected from kiosks, shallow wells, municipal boreholes and private boreholes.
Twenty-six questionnaires were handed to each household.
A total of Forty-five water samples were collected in the study areas.
Fifteen samples were collected in each area

RESULTS AND DISCUSSION



Parameter (mg/l)	Range	Mean
Nitrates	4.20 - 6.50	5.21
Phosphates	<0.01	0.01
Flourides	0.20 - 0.42	0.31
Chlorides	49 to 55	51.3
Arsenic	<0.002	0.002

Parameter (mg/l)	Range	Mean
Nitrates	16.20 to 20.20	16.50
Phosphates	<0.01	0.01
Flourides	0.38 to 0.80	0.53
Chlorides	130 to 186	152.7
Arsenic	<0.002	0.002

Parameter (mg/l)	Range	Mean
Nitrates	1.20 - 2.60	2.08
Phosphates	<0.01	0.01
Flourides	0.26 - 0.33	0.29
Chlorides	40 - 45	42
Arsenic	<0.002	0.002

Parameter	Range	Mean
Fecal Coliform (#/100ml)	0 - TNTC	TNTC

Parameter	Range	Mean
Fecal Coliform (#/100ml)	90 - TNTC	TNTC

Parameter	Range	Mean
Fecal Coliform (#/100ml)	0 - 108	22

HWT METHOD (%)				OCCURRENCE OF DIARRHOEAL (%)		
	Boiling	Solar Disinfection	Do not treat	Decreased	Remained the same	None
				30	0	70
	10	0	70	25	13	63
	38	0	50			
	13	13	63	38	13	50

CONCLUSION

Water sampled from households and water sources in Chaisa and Kanyama were the **most contaminated** with faecal coliform. Water in these areas is NOT safe for consumption.
The study revealed that **73%** of the **11 households** that treat their water observed a **reduction** of diarrhoeal illnesses. Hence, HWTS are effective. Ghana and Tanzania both have strategies on HWTS and Zambia can learn from the two countries.
The most important challenge observed was the lack of research on the use and impact of HWTS technologies. Regulation and performance evaluations were not conducted.

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

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Mapping of Groundwater Flow Pattern: A Case of Jui and Allen Town Community, Sierra Leone

Graduate CV.

KOROMA Sahid Ali, Dr. Navneet KUMAR

Centre for Development Research (ZEF) University of Bonn, Germany.

email address: sahidjaffaali@gmail.com

Abstract

A study was carried out at Jui and Allen Town Community, located on the eastern part of Freetown using the global positioning system (GPS) and a Dipmeter to determine the groundwater flow pattern of the area. The longitudes, latitudes and elevations of fifty (50) hand dug wells or borehole locations distributed within the study area were measured and recorded. The depths to the water level in the hand-dug wells were measured directly with the aid of a Dipmeter. A computer-based software package known as Surfer was used to generate a water elevation contour map of the study area which revealed that groundwater flow direction is from the West to the Eastern part of the area.

BACKGROUND/CONTEXT

Groundwater as a resource plays several important roles below the earth's surface such as aiding fault movements, controlling the accumulation and migration of petroleum, earthquake generation and prediction and moving closer to the surface of the earth, groundwater plays an important role in several geomorphological processes such as slope development and stream bed erosion. The significance of groundwater has long been recognised in indigenous communities and this is being seen in the extra care afforded to those small wells or village springs (Calow et al., 1997). The need for both adequate and good quality water has increased extensively due to awareness and also technology and as a result, a good number of people now rely greatly on the exploration and exploitation of groundwater (Anomohanran, 2015).

PROBLEM STATEMENT/RESEARCH QUESTION

In most parts of Sierra Leone including the study area, a conceptual groundwater model has not been developed so a lot of people lack an understanding about the aquifer system.

This research is generally looking to address the following questions;

How is the static water levels in wells being measured or determined?

What is the surface elevation of well positions and possible flow direction of groundwater within the case study area?

Where can groundwater recharge and discharge areas be located?

OBJECTIVES

The main objective of this study is to investigate the baseline conditions of the existing groundwater in the study area and carry out a mapping exercise to determine the flow pattern or develop a groundwater flow map of the area.

METHODOLOGY

With the aid of a Dipmeter, metre rule and tape, the depth to the water level in fifty (50) boreholes or hand-dug wells were measured between the months of May and June. The Global positioning system (GPS) Garmin 550 was used for measuring the longitude, latitude and the surface elevation (with respect to the mean sea level) of each of the selected borehole or hand-dug well site in a UTM coordinate system within the study area.

The hydraulic head at various locations will be obtained by subtracting the static water level (SWL) from the elevation (E) obtained from the GPS reading with respect to the mean sea level.

Mathematical Model for Groundwater Flow

Groundwater is not static, it flows in an aquifer and its flow can be described using partial differential equation and associated initial-boundary conditions (Naji, Tawfiq, & Jabber, 2016). The simplest mathematical model of groundwater flow is Darcy's law which is an equation that describes the flow through a vertical section of an aquifer can be calculated using Darcy' law;

$$Q = \frac{KA\,(h1 - h2)}{L}$$

Where; ***Q***= flow (m3/day)

K= hydraulic conductivity averaged over the height of the aquifer (m/day) **A**= area (m2), ***(h1- h2)*** = difference in hydraulic head (m), ***L***= distance along the flow path to the point where h1 and h2 are measured (m).

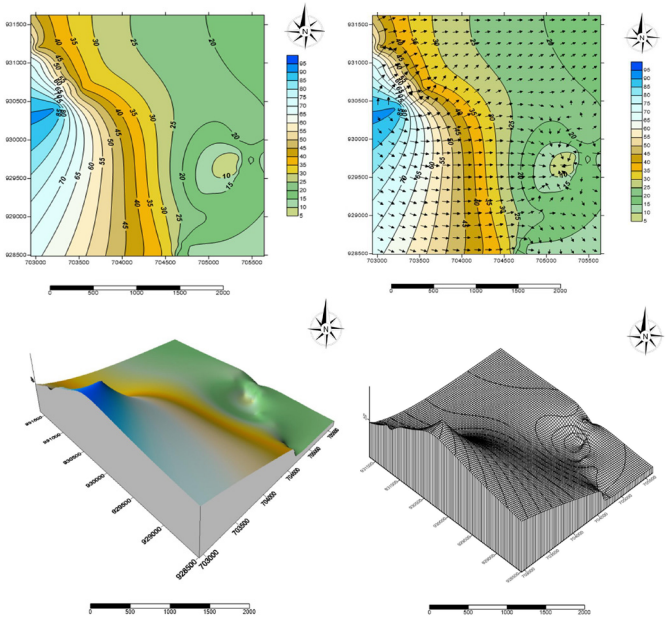
In order to determine the hydraulic head of each well, certain parameters measured in the field were used to calculate for the hydraulic head value derived from the formulae;

HH= (SE-DTW)

Where; ***HH***= hydraulic head (m), ***SE***= surface elevation (m) and ***DTW***= depth to water (m).

RESULTS AND DISCUSSION

The results generated from this study revealed a groundwater contour map, a vector overlaid map, a 3D Surface Map and a Wireframe Map and all of these maps are clearly showing the movement of groundwater or flow pattern from WEST to EAST.



CONCLUSION

The significant role that groundwater plays in the urban cycle is well established in many countries around the world, both in terms of quantity and quality (Mudd, Deletic, Fletcher, & Wendelborn, 2004). In this research, the water table contour map generated from the computer based program or mapping tool, Surfer, suggested or revealed lateral flow i.e. groundwater in the area is moving from west to east.

The spacing of the contours on the water table map generated by the Surfer package shows a clear indication of the hydraulic gradient. Some areas were seen to have a characteristic of steep hydraulic gradients where flow seems to be appreciable and where the hydraulic gradients are milder, the flow is expected to be rather sluggish. Also from the groundwater map, some zones were identified within the study area where flow seems to be diverging and these areas can be interpreted as possible recharge areas, and where the component of flow is downward.

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Water Resources Modeling in a context of Climate Change in Burkina Faso

Graduate CV.

Olivier Deryam, Dr Karima Benhattab
Oran University
oderyam@gmail.com

Abstract

This study aims to characterize climate variability in Burkina Faso. The data collected for this research concern daily rainfall recorded in nineteen stations and covering the period 1950-2000. The ETCCDI indices made it possible to characterize rainfall extremes. The standardized precipitation index was used to determine dry and wet periods. The results obtained from the analysis of daily rainfall data show that during the period 1950-200, rainfall is characterized by an alternation of wet phases (1960-1970) and (1971-1993) and a decreasing trend in annual precipitation. A hydrological model is an essential tool in the understading of the hydrological fucntionning of the catchment area and in the rational use of water resources as well as in the fight against natural disasters related to floods. This study recommands that these kinds of studies must continue because the historical study is very important for climate change investigation.

BACKGROUND/CONTEXT

In the last decade, Burkina Faso, Sahelian country located in West Africa has experienced consecutive extreme climatic events with a heavy magnitude. The Programme action national Adaptation à la variabilité et aux changements climatiques (PANA), mentioned that the country had droughts periods in the three last decades, in which the most years concerned were 1973-74 and 1983-84 and that have mostly affected ecosystems as well as the Burkina production systems. Agricultural activity occupies 86% of the rural population of Burkina Faso, whose practices remain traditional and whose production depends on climatic conditions. In the last years, there is evidence of global climate change on the planetary dimension (IPCC, 2007).

PROBLEM STATEMENT/RESEARCH QUESTION

The Programme action national Adaptation à la variabilité et aux changements climatiques (PANA), mentioned that the country had droughts periods in the three last decades, in which the most years concerned were 1973-74 and 1983-84 and that have mostly affected ecosystems as well as the Burkina production systems.

Main questions: How climate extremes have evolved in Burkina Faso?
How to assess the different rainfall extreme indices?

OBJECTIVES

Objective:

To see how a hydrological model behaves in a context of global change climate change.

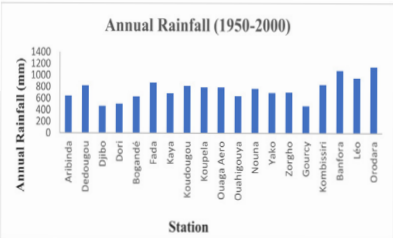
Specific objectives:

1. To characterize the hydro-pluviometric variability;
2. To focus on the hydro-pluviometric extremes;
3. To test the robustness of a hydrological model.

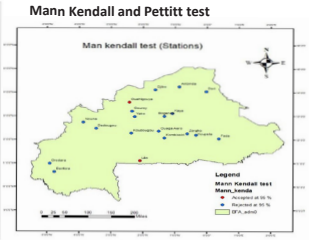
METHODOLOGY

Literature review	*Literature review of similar studies on the topic.*
Data Processing	*Reference times serie database.* *Softwares : Excel, R.*
Climate indices	Software: Rclimdex. 12 rainfall indices calculation (ETCCDI: expert team on climate change detection indices)
Statistical analysis	*Descriptive analysis on annual rainfall; Mann Kendall and Pettitt test. Software : Rstudio*
Rainfall/Runoff modelling	*A monthly empirical hydrological modelling GR2M.*

RESULTS AND DISCUSSION



Mann Kendall and Pettitt test



Station code	Station Name	Start	End	Mean	Std dev.	Max	Coef. of variation
1200000400c	Aribinda	1950	2000	647.2	134.83	929.5	0.21
120000790c	Dedougou	1950	2000	825.5	176.27	1149.5	0.21
1200009700c	Djibo	1950	2000	469.8	159.68	831.8	0.34
1200000100c	Dori	1950	2000	508.8	129.71	783.7	0.25
1200004300c	Bogandé	1950	2000	635.6	132.96	956.2	0.21
1200010300c	Fada	1950	2000	875.3	160.15	1314.1	0.18
1200014800c	Kaya	1950	2000	689.8	135.01	992.8	0.20
1200017200c	Koudougou	1950	2000	819.3	165.32	1229.4	0.20
1200017800c	Koupela	1950	2000	795.9	131.84	1118.8	0.17
1200000100c	Ouaga Aero	1952	2000	794.9	156.39	1183.2	0.20
1200024100c	Ouahigouya	1950	2000	645.8	143.90	964.7	0.22
1200023200c	Nouna	1950	2000	773.0	152.44	1083.2	0.20
1200035200c	Yako	1950	2000	700.5	148.5	1090.6	0.21
1200035800c	Zorgho	1950	2000	706.5	255.84	1200.6	0.36
1200012400c	Gourcy	1950	2000	470.4	121.94	843.5	0.26
1200016000c	Kombissiri	1950	2000	838.7	130.92	1061.5	0.16
1200001900c	Banfora	1950	2000	1083.9	215.12	1582.0	0.20
1200019000c	Léo	1950	2000	958.8	224.49	1375.3	0.23
1200023500c	Orodara	1950	2000	1145.5	215.94	1477.3	0.19

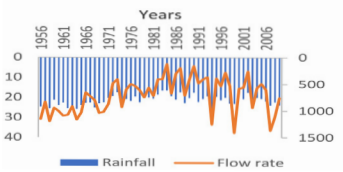
Statistical analysis of annual rainfall

	Léo			Nouna			Orodara		
Indices	Pvalue	Slope estimate	Trend (significant at 95%)	Pvalue	Slope estimate	Trend (significant at 95%)	Pvalue	Slope estimate	Trend (significant at 95%)
R1	0	-0.291	Yes	0	-0.315	Yes	0.004	-0.39	Yes
R10	0.031	-0.149	Yes	0	-0.206	Yes	0	-0.275	Yes
R20	0.232	-0.058	No	0.026	-0.083	Yes	0.52	-0.032	No
R25	0.13	-0.063	No	0.144	-0.045	No	0.615	-0.019	No
R50	0.821	-0.004	No	0.038	-0.036	Yes	0.022	0.0141	Yes
*R*1day*	0.398	0.226	No	0.048	-0.405	Yes	0.938	0.019	No
*R*5day*	0.842	-0.084	No	0.006	-0.876	Yes	0.861	0.062	No
R95p	0.69	-0.514	No	0.049	-2.52	Yes	0.072	2.417	No
R99p	0.932	-0.063	No	0.321	-0.787	No	0.402	0.656	No
SDII	0.411	0.024	No	0.198	-0.031	No	0.933	-0.003	No
PRCPTOT	0.042	-4.415	Yes	0	-6.16	Yes	0.029	-4.438	Yes
CWD	0.158	-0.029	No	0.018	-0.042	Yes	0.005	-0.063	Yes
CDD	0.023	0.795	Yes	0.73	-0.139	No	0.163	0.372	No

Boromo

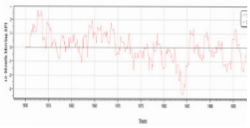
Boromo (Rain fall – Flow rate

Rainfall indices



Standard Precipitation Index

Banfora:



CONCLUSION

- Due to its geographical position and its agriculture-based economy Burkina Faso is one of the most vulnerable countries to climate change ir the world.
- Annual rainfall has experienced an alternation of wet and dry period: with a decreasing trend from 1984.
- The extremes rainfall indices are impacted by a decline of rainfall defici during 1950-2000 especially the consecutive dry days and the tota annual precipitation (PRCPTOT).

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Master Thesis Co-Supervision

Association Africaine de l'Eau (AAE)
African Water Association (AFWA)

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West African Science Service Centre on Climate Change and Adapted Land Use

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