CALL FOR INNOVATION RESEARCH GRANTS ON RESPONSIBLE ARTIFICIAL INTELLIGENCE FOR CLIMATE ACTION

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IDRC-SIDA-RUFORUM/WASCAL/A2063-IRG/2022: CALL FOR INNOVATION RESEARCH GRANTS ON RESPONSIBLE ARTIFICIAL INTELLIGENCE FOR CLIMATE ACTION

Project Title	RAGA: An Artificial Intelligence Based System for Predicting Groundwater Availability
Names of Principal Investigator and institutional affiliation with full addresses including email and telephone	Dr Cyril Dziedzorm Boateng Department of Physics College of Science Kwame Nkrumah University of Science and Technology (KNUST) Email: cyrilboat@knust.edu.gh Phone: (+233)559580392
Names of participating researchers and their institutions with full addresses including email	Prof D. D. Wemegah, Department of Physics, College of Science, Kwame Nkrumah University of Science and Technology (KNUST), ddwemegah@gmail.com Dr Marian Osei, Department of Meteorology and Climate Science, College of Science, Kwame Nkrumah University of Science and Technology (KNUST), marianosans92@gmail.com
Project site(s) areas of intervention (Include GPS coordinates if available)	Ghana
Total project budget	$46,605.00
Project start date	March, 2022
Short specific abstract of no more than 200 words (respect the word count).	Climate change and variability has been identified as the most significant human crisis to hit the world in the 21st century. Innovative solutions are required to bolster Ghana's capacity to counter and adapt to the adverse effects of climate change on water resources. The process of exploring and exploiting groundwater resources is very capital intensive with climate change exacerbating the reliability of these groundwater systems. We seek to develop an innovative web-based artificial intelligence driven open-source framework to predict groundwater availability in Ghana. We intend to achieve this aim by building a database of spatio-temporal hydrogelogical, and climate variables; developing AI algorithms and workflows for integration of varied data sources and prediction of groundwater availability and developing an open-source web-based application for rapid groundwater availability assessment to be used by stakeholders and the general populace. The outcomes of the project include the development and scaling of responsible AI innovation for climate action; increased contribution of African

	research to international AI policy and practice through research publications and policy briefs; increased capacity of African innovators and researchers through the training of Masters students and water practitioners and the achievement of development goals as regards to water availability and its consequences.

I. Cover Page (1 Page)

II. Executive Summary (500 words maximum)

Climate change and variability have been identified as the most significant human and environmental crises to hit the world in the 21st century with sub-Saharan Africa (SSA) being seriously affected. Africa in general and Ghana, in particular, is vulnerable because farming which is the main economic activity of majority of its populace is mainly rain feed. Hence, changes in the climatic parameters have a great impact on the livelihoods of the people and threaten to undo the developmental gains made over the past decades. Innovative solutions are therefore required to bolster the region's capacity to counter and adapt to the adverse effects of climate change especially on water resources. Without good quality water, people get hungry, get sick, end up poor or even die. As freshwater bodies run dry, due to reduction in rainfall amounts in most SSA countries as well as the pollution of existing rivers, there is the need to find alternative sources of potable water supply. Ghana in recent times has seen a rapid rise in the utilization of groundwater for domestic, agricultural, and industrial purposes. However, the process of exploring and exploiting groundwater resources is very capital intensive with climate change and variability further exacerbating the reliability of these groundwater systems. We seek to develop an innovative web-based artificial intelligence (AI) driven open-source framework to predict groundwater availability in Ghana using Groundwater Levels (GWLs) as a proxy. We will call this project RAGA: Rapid Assessment of Groundwater Availability. This project will shift the paradigm of groundwater monitoring from a static process to a dynamic process to allow for the adaptation of resilient water management systems in response to climate change and variability. This study intends to achieve its aim by building a database of spatio-temporal hydrological, geological and physiographical, climate and groundwater level (GWL) variables for Ghana; developing AI algorithms and workflows for integration of varied data sources and prediction of groundwater availability and developing an open-source web-based application for rapid groundwater availability assessment to be used by stakeholders and the general populace. The rapid assessment of groundwater availability will make it easy to check the levels of groundwater in any location before deciding to site a borehole. The outcomes of the project include the development and scaling of responsible AI innovation for climate action; increased contribution of African research to international AI policy and practice through research publications and policy briefs; increased capacity of African innovators and researchers through the training of Masters students and water practitioners and the achievement of development goals as regards to water availability and its consequences (e.g., SDG 1, 2, 6, 13; Agenda 2063; National Water Policy; National Water and Sanitation Strategy; Ghana Poverty Reduction Strategy; Africa Water Vision 2025).

III. Background (1 page maximum)

In the face of climate change and variability, the most significant human and environmental crisis to hit the world in the 21st century, innovative solutions are required to adapt. Africa is particularly vulnerable because climate change threatens to undo the developmental gains made over the past decades. It is particularly challenging for African countries to adapt and mitigate the effects of climate change especially as regards to the impact on water resources. Without good quality water, people get hungry, get sick, end up poor or even die. Apart from households and industries, small community water supply systems and irrigation systems in Ghana are increasingly becoming dependent on groundwater resources. In addition, illegal artisanal mining is posing a significant threat to fresh water bodies (Duncan, 2020). These conditions have combined to create a situation where currently, over 60% of total water requirements in Ghana are estimated to be provided by groundwater (Agyekum and Asare, 2016; Asare et al., 2021). The process of exploring and exploiting groundwater resources is capital intensive (data collection through geophysical investigations, drilling operations for installing wells, groundwater sampling and water chemistry analyses are expensive although necessary for the characterization of aquifer systems). Even though millions of Ghana cedis have been pumped in groundwater projects, failures in terms of dry and/or low yielding boreholes are rampant. Groundwater volumes in aquifer systems are not constant and determining sustainable and recoverable water resources is dependent on recharge from infiltration of precipitation. Climate change and variability therefore control the amount of water available to be utilized. In Ghana, climate change has been responsible for longer dry seasons and increasingly unreliable rainfall patterns (Asante and Amuakwa-Mensah, 2015) rendering groundwater systems unreliable. The challenge of reliable water supply systems adversely impacts agricultural output thereby affecting sustainable food production and increases poverty. Other consequences are related to the disproportionate burden on women and young girls who are often responsible for the traditional roles of water collection, cooking, cleaning and childcare. Furthermore, the non-availability of potable water leads to the use of unsafe water resources contributing to increase in waterborne diseases such as guinea worm. It is therefore of utmost importance that innovative systems are created to predict groundwater availability. This project proposes an AI system to rapidly assess groundwater availability to be known as the Rapid Assessment of Groundwater Availability (RAGA) across Ghana.

RAGA is aligned to the Government of Ghana's National Water and Sanitation Strategy, National Water Policy and Ghana Poverty Reduction Strategy's aim to ensure all people living in Ghana have access to adequate, safe, affordable, reliable and sustainable water services through the use of improved community water and sanitation services in rural communities and small towns. As part of the African Union's plan to transform African into a global powerhouse one of the major components of Agenda 2063 is a prosperous Africa, based on Inclusive Growth and Sustainable Development. This aspiration can only be attained if natural resources such as groundwater are sustainably managed and consumed by ensuring water security in a framework of climate resilience. This project will contribute to attaining this aspiration. Ghana has also signed on to achieving the United Nations Sustainable Development Goals by 2030. This project will help in achieving Goals 1, 2, 6 and 13 which are eradicating poverty; ensuring zero hunger, providing clean water and effective sanitation, and taking urgent action to combat climate change and its impacts for everyone. RAGA will tackle these key problems.

The intended beneficiaries of this project are the vulnerable populace in water scarce situations (women, farmers, and the poor), governmental agencies such as research institutions, water researchers and practitioners and commercial players in this industry. Over the past decades, the Geophysics Unit of the Department of Physics in Kwame Nkrumah University of Science and Technology (KNUST) has been involved in developing methods for the characterization and delineation of groundwater resources in Ghana using geophysics. The issue of greatest concern has been how to simplify the process of predicting groundwater availability and how this information can be brough to the doorstep of stakeholders. This project will provide the opportunity to do so.

IV. Literature Review (1 page maximum)

One of the most crucial sources of water in the world is groundwater resources. Groundwater is important for domestic potable water supply, agriculture and industrial development (Grönwall and Oduro-Kwarteng, 2017; Kwoyiga and Stefan, 2018; Qadir et al., 2007). To plan and manage groundwater resources, policy makers and water practitioners need to understand groundwater availability and accessibility. Groundwater level (GWL) is a direct and simple measure of groundwater availability (Adiat et al., 2019). Therefore, the ability to decipher past, current and future groundwater levels (GWL) can be insightful for stakeholders in developing strategies for cost effectively accessing and building sustainable water resources. This information can be very useful in the face of global depletion of groundwater resources and climate change challenges (Wada et al., 2010). However, modelling GWL is complicated due to the fact that it is influenced by different factors such as climate, topography, and other hydrogeological variables (Afzaal et al., 2020).

Various studies using different techniques such as physically based conceptual models, experimental models and numerical models have been applied to the challenge of predicting GWLs (Gupta et al., 2019; Izady et al., 2014; Omar et al., 2019). Challenges have cropped up as regards to the requirement for large volumes of data related to aquifer hydrogeological properties, and the sophistication of numerical techniques. Recently the availability of huge computing power and the ubiquity of artificial intelligence (AI) techniques have provided an alternative method to overcome the challenges of conventional numerical models. Researchers have used AI models such as multilayer perceptron, cascade forward, radial basis function, support vector regression (SVR) to predict GWLs but only in limited capacities (Band et al., 2021; Najafabadipour et al., 2022; Rohde et al., 2021). In a recent review on machine learning models in GWL prediction Tao et al. (2022), show that only four countries namely Iran, USA, China and India have conducted investigations of GWL prediction using AI models. They observed that countries in Africa may not have even explored AI techniques in predicting GWL yet. AI techniques have been extensively employed in other subsurface problems (Boateng et al., 2017, 2020) and therefore can accurately predict GWLs. In Ghana, even largescale modelling studies using numerical techniques for predicting GWL have been not been undertaken creating a significant knowledge gap. The gap being the ability to accurately characterize the changing state of an aquifer over time for sustainable groundwater management in the face of climate change and variability. This project intends to create a web-based portal incorporating an AI model to enable policy makers, the general public, water practitioners, researchers and other stakeholders rapidly assess groundwater availability in Ghana.

V. Objectives (1/2 page)

The main aim of this research is to predict groundwater availability in Ghana in the face of climate change and variability. To achieve this, we will develop a system which will be made accessible to groundwater practitioners and the general public through a web portal. The name of the system will be Rapid Assessment of Groundwater Availability (RAGA).

The specific objectives of the project are:

1. Build a database of spatio-temporal hydrogeological, climate and groundwater level (GWL) variables for Ghana.
2. Develop AI algorithms and workflows for integration of varied data sources and prediction of groundwater availability.
3. Develop an open-source web-based application for rapid groundwater availability assessment to be used by stakeholders and the general populace.

VI. Research Approach and Conceptual Framework (2 pages Maximum)

This study adopts a multidisciplinary approach. Due to the complexity of the varied factors that affect GWLs, it is necessary that the disciplines of hydrogeology, geophysics, computer science and climate science are brought together in an integrated framework to solve the problems presented in this proposal. The research design is divided into three work packages according to the specific objectives defined. The data required for analysis and interpretation will be acquired from our partners at the Centre for Scientific Industrial Research Water Research Institute (CSIR-WRI) in Ghana. They have the most comprehensive data on basins in Ghana. The Department of Physics has an active MoU with the CSIR-WRI covering data sharing with regards to research projects. We will activate that clause and use the data accumulated by the CSIR-WRI.

Before the actual implementation of the project activities, we will recruit two Masters students as research assistants. The research assistants will focus on developing the AI algorithms for integration of varied data sources and prediction of GWLs and develop an open-source web-based app for rapid groundwater availability assessment. The students will be fully funded throughout the duration of their postgraduate studies. The first objective which includes the acquisition of data and characterization of a spatial zone of investigation, preprocessing of data through addressing data gaps and sorting data and creating a database for storing training data for building models will be handled by the Principal Investigator (PI), Dr Cyril D. Boateng. The co-Principal investigators, Prof D. D. Wemegah and Dr Marian Osei will play a key role in creating the database. This database will include hydrogeological, climate and groundwater level (GWL) variables. The database should consist of data points from all these different types of variables so that they can be integrated as inputs with the GWL as an output in the training algorithms. The postgraduate students' research will be focused on specific objectives 2 and 3. The Principal Investigator will lead and supervise this aspect of the work. The co-PIs will assist with the supervision.

The main concept that underpins this project is a medium-term vision of facilitating easy access to spatiotemporal information on groundwater levels (GWLs) in Ghana. In the long-term we hope to have RAGA scaled up to the whole of Africa especially water scarce environments. This information is important for the general public who wish to drill their own household water supply systems, groundwater managers for community water sanitation systems, farmers, agricultural managers, industries which depend on groundwater, governmental institutions interested in water resource management, researchers and all groundwater practitioners. In particular, vulnerable populations such as farmers, women and the poor. The web-based app will have two interfaces: an administrative interface to for uploading data from across the country and a user interface to access the maps and animations of past and predicted GWLs. The algorithms and the web-based platform which will be made available to the public will reduce the unpredictability in determining optimum locations for drilling boreholes and sustainable groundwater resource management to reduce the effects of water scarcity and improve climate adaptation of vulnerable communities in Ghana. The administrative interface will facilitate the collection of more data for better prediction algorithms. Future predictions of groundwater availability will be necessary for efficient utilization of groundwater resources and climate change adaptation.

VII. Methodology (3 pages maximum)

The methods to be used to achieve the overall objectives have been divided into three work packages.

Work Package 1:

This work package is focused on building a database of spatio-temporal hydrogeological, climate and groundwater level (GWL) variables and developing hydrogeological conceptual models. The data will be gathered based on existing groundwater borehole locations across the country. Prior to this project, no work has been done on a centralized database for groundwater boreholes with all the requisite hydrogeological and GIS data collected for large scale AI predictive systems. This is even though many boreholes have been drilled under different projects over several decades. The constraints of hydrogeology require that different parameters be distributed both in space and depth for them to be relevant to building a geodatabase. The information pertinent to this study are the geographic and subsurface location of aquifers and their groundwater levels (GWLs). However, other information will be gathered and integrated into the geodatabase. Data such as aquifer properties, geometry, groundwater chemistry, hydraulic properties and climatic data will serve as an attribute database. The hydrogeological parameters such as aquifer properties, hydraulic properties will act as features that reflect the heterogeneity of the subsurface. In addition, geophysical data such as magnetic and gravity will be used as another set of input features to cater for the pervasive heterogeneity of the subsurface.

For this pilot study we will focus on getting data from our partner agencies. The main agency to gather data from is the Council of Industrial and Scientific Research (CSIR)-Water Research Institute (WRI). Other agencies we will reach out to are NGOs in the groundwater sector, Universities, corporate organizations and consultants who work or have worked in the groundwater sector. We will be on the lookout for drillers reports. These reports usually contain all the hydrogeological parameters with locations. The CSIR-WRI will play a major role as our partners on this project. Paper reports will be digitized as part of the project.

To build efficient algorithms for predicting GWLs at any point in time, we need long term data (decades in some cases). We will endeavor to gather data as far back as possible into the past so we can establish temporal variations in data. In this work package, our principal activity will be to collate data from all relevant agencies and create a single database for predicting groundwater levels (GWLs) in Ghana. Climate data from satellite or weather stations near the locations of the boreholes will also be acquired and will be sourced from Ghana Meteorological Agency G-MET and the Department of Meteorology and Climate Science at KNUST. The Department of Meteorology and Climate Science is a sister Department and they also have MoUs with the Ghana Meteorological Agency (G-MET). This activity will primarily fall within the domain of Dr Marian Osei (co-PI). Some examples of climate parameters we will be interested in are: rainfall, potential evapotranspiration, temperature, and humidity.

This stage also involves quality control of the data gathered. Quality control means visiting sites of boreholes, confirming data sources and elimination of duplicates. The data will be validated by the project team members by visiting locations to verify existence of boreholes. The criteria for adding data to the database will be based on data usefulness, data quality, data format and presentation, copyright, privacy, and confidentiality issues, regulatory access to the information, costs for ordering and age of the data. We will conduct Exploratory Data Analysis (EDA) to determine the characteristics of the dataset. After data acquisition into a single database, we will examine, process to reduce noise, resample to ensure time series observations of each well occur at regular intervals, address data gaps and extend data beyond its sampled range. We will then build a hydrogeological conceptual model for Ghana and divide the country into spatial zones. The project team will select a spatial zone within the country with enough data coverage for building the prototype Rapid Assessment of Groundwater Availability (RAGA). This selection will be based on the database we have created and the density of sampling locations within the different zones of the country. For groundwater availability mapping, a set of the relevant hydrogeological parameters (attributes) will be matched with the GWL in each well and at each temporal location. This will create a one-to-one mapping for our training models. We are now ready for application of the Artificial Intelligence tools.

Work Package 2:

This work package entails developing AI algorithms for integration of varied data sources and prediction of groundwater availability. It also involves applying different AI algorithms to our groundwater level prediction problem. The workflow is illustrated in *Figure 1* below. After the establishment of the database and the selection of the zone of interest, data from this zone is divided into training dataset and testing dataset. We will use attributes in our database as the input (predictor) variables. Developing an efficient AI algorithm depends on carefully choosing the input (predictor) variables. We will implement feature reduction techniques to lower the dimensions and make computation less expensive. Examples of feature reduction technique to be utilized are linear regression and Principal Component Analysis (PCA) to eliminate irrelevant features so as to avoid overfitting.

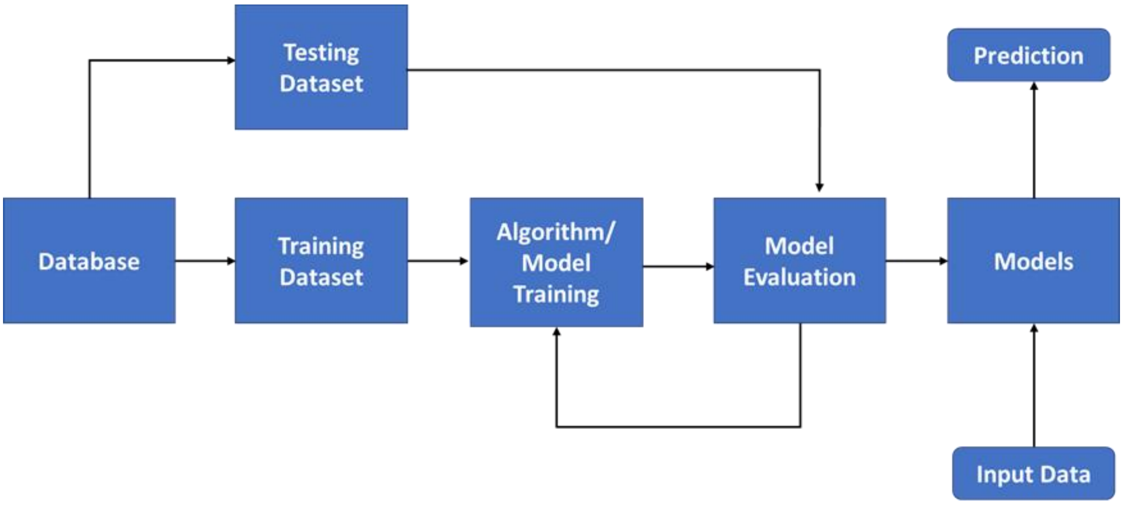

Figure 1. Workflow for developing artificial intelligence model.

After feature reduction, we will implement the learning algorithms. For this project, all the learning algorithms will be supervised algorithms. We will apply the following algorithms, Linear regression, Support Vector Regression, Artificial Neural Networks, and Decision Trees. The training dataset will be further split into training and validation datasets. We will train the algorithm using the 'training data' and tune the parameters using the 'validation data'. The performance of the final model or algorithm is then tested on the previously unseen testing dataset. We will then evaluate the performance of the algorithms using Root-Mean-Square-Errors (RMSE) and Mean Absolute Errors (MAE). The model is then ready to be deployed to predict future groundwater levels.

Work Package 3:

This work package involves designing an open-source web based for use by stakeholders and the general populace for rapid assessment of groundwater availability. Once we have trained and tested our model, this stage involves creating a web-based portal. The web application interface will be known as the Rapid Assessment of Groundwater Availability (RAGA). The application will provide ease of access to the AI algorithms developed for groundwater managers, stakeholders, practitioners and researchers. The interface will be developed on an open-source platform. The web-based portal will have two interfaces.

The first side will be a data upload interface for uploading new data on any new boreholes drilled in Ghana. The second interface will be used for accessing the prediction tool and maps of groundwater distribution in Ghana. We will use Python specific kits to deliver the web portal in this phase.

The administrator's interface will allow borehole data to be added to the database for improving the prediction model and enhancement of our database. The user interface allows any groundwater practitioner or any member of the public to check groundwater availability in a specific location. It will allow government agencies such as the Community Water and Sanitation Agency and the Ministry of Food and Agriculture to predict groundwater levels within their various operational zones. The portal will be hosted on a dedicated website. At the end of the project, RAGA will be made available to the general public, farmers and vulnerable communities requiring information on groundwater levels to adequately adapt to climate change effects.

VIII. Description of the innovation (1 page max.)

This project will shift the paradigm of groundwater monitoring from a static process to a dynamic process to allow the adaptation of affected and vulnerable populations to climate change and variability. The following are the innovations to be developed in this project:

1. The first of its kind digital attribute geodatabase including climate variables to predict GWL in Ghana.
2. Efficient AI prediction algorithms deployed for predicting groundwater levels in space and time;
3. An open-source web app to allow visualization, quantification and prediction of groundwater availability, leveraging both temporal and spatial interpolation.

Rapid Assessment of Groundwater Availability (RAGA) the system described by this project is an AI system that will allow the first largescale predictive analysis of groundwater level (GWL) mapping in Ghana. Understanding groundwater levels (GWLs), their trends and forecasting future levels is important for managing groundwater resources. In the face of climate change, it is even more paramount that the general public and stakeholders who use groundwater have enough information to adapt. This is especially in the case of the poor, vulnerable women, farmers and communities without access to potable water.

Since the relationship between predictor features of groundwater levels and the actual groundwater levels are nonlinear and complex, artificial intelligence algorithms can unravel these relationships. AI models utilize their ability to simulate and predict GWLs without requiring deep and comprehensive knowledge of the underlying topographical and hydro-geophysical parameters compared to physically based and numerical methods. The open-source web-based app will make the results of our research available to stakeholders and the general public.

The innovations outlined here will contribute to the AU Agenda 2063 goal on creating environmentally sustainable and climate resilient economies and communities. RAGA will also contribute to Government of Ghana's National Water and Sanitation Strategy, National Water Policy and Ghana Poverty Reduction Strategy and SDGs 1, 2, 6 and 13.

RAGA will ensure quality water supply to vulnerable communities, agricultural applications and industries around Ghana. It will also lower the cost of exploration for groundwater and reduce the probability of hitting dry and low yielding boreholes.

IX. Deliverables and expected results (1/2 page max.)

The deliverables and expected on this project are given below:

1. Development and scaling of responsible AI innovations for climate action:
    - A database of predictor attributes and groundwater levels for boreholes across Ghana.
    - AI algorithms for the prediction of groundwater availability in Ghana.
    - A web-based application for rapidly assessing groundwater availability (RAGA) open to government agencies, NGOs, research institutions, policy makers and the general public.
2. Increasing the contribution of African research to international AI policy and practice:
    - Publications: A minimum of two (2) peer reviewed articles in scientific journals.
    - Policy report to governmental agencies (Community Water and Sanitation, Water Research Institute and Water Resources Commission) on data gathering and expansion of the project to serve prepare the whole country for climate adaptation in terms of groundwater availability.
3. Building capacity of African innovators and researchers:
    - Training of groundwater practitioners on data gathering and the use of the rapid assessment of groundwater availability (RAGA) system.
    - Train two Masters students.
    - Enhance capacity of researchers in the Department of Physics and water practitioners across the country.

X. Gender and inclusion (1/2-page max.)

The project team will include two females: one co-Principal Investigator and one postgraduate team member. The postgraduate students on the project will therefore 50% male, 50% female ensuring gender equality. In terms of the whole team 40% will be female. Four out of five team members (80%) will also be young people under the age of 40 (The PI, one co-PI, two postgraduate students). Women and girls in Ghana are disproportionately affected by the lack of access to safe and reliable water sources. They are often responsible for collecting water for household use and are more likely to suffer from the consequences of water scarcity, such as increased time spent on water collection, reduced access to education, and increased health risks.

The RAGA project will address these gender disparities by improving access to reliable groundwater sources. By developing a web-based application for rapid groundwater availability assessment, the project will help women and girls make informed decisions about where to access water, reducing the time and effort required for water collection. Additionally, the project's focus on building a database of spatio-temporal hydrological, geological, and physiographical data can contribute to a better understanding of the impact of climate change on water resources, which can inform gender-sensitive water management policies. To ensure gender inclusion in the project, it will involve women and girls in the development and implementation process. This will be achieved through targeted outreach and engagement efforts, such as involving women's groups and organizations in the data collection and analysis process, and ensuring that the web-based application is designed with the needs and preferences of women and girls in mind. Other actions to be undertaken to ensure gender inclusion in the RAGA project include:

Gender disaggregated data collection: The project should collect gender-disaggregated data on the availability and use of groundwater resources to identify specific gender-based needs and priorities. This can be done by involving women and men in the data collection process and ensuring that the data collected captures the perspectives and experiences of both genders.

Gender-sensitive analysis: The project will conduct a gender-sensitive analysis of the collected data to be used for the project by identifying gender-based barriers and opportunities related to groundwater availability and use. This will help to identify the specific needs and priorities of women and men and guide the development of gender-sensitive interventions.

Gender-responsive design: The web-based application which will be developed as part of the project will be designed to be gender-responsive. This means that the application will be designed with the needs and preferences of both women and men in mind. For example, the application can be designed to be user-friendly for women, who are more likely to have limited digital literacy skills, and to include features that support the safety and security of women and girls.

Gender-sensitive stakeholder engagement: The project will involve women and men at all stages of the project, including planning, implementation, and monitoring and evaluation. Women should be included in decision-making processes and provided with opportunities to participate and contribute to the project's development.

Capacity building: The project will include capacity-building activities for women and men to support the development of skills and knowledge related to groundwater monitoring and management. This can include training on data collection and analysis, as well as on the use of the web-based application.

Gender-sensitive policy development: The project should contribute to the development of gender-sensitive policies and strategies related to water management. This can be done by sharing the project's findings with policymakers and stakeholders and advocating for the inclusion of gender considerations in policy development.

XI. Ensuring Responsible Artificial Intelligence (1/2-page max.)

The RAGA project will ensure Responsible Artificial Intelligence by doing the following:

1. Ensure Accountability: We will use responsible AI tools to inspect our AI models. Tools such as explainable AI and the TensorFlow toolkit will be used. We will also perform form tests such as bias testing or predictive maintenance.
2. Ensure Responsibility: We will use ensure that project team members and personnel who work on the AI systems are responsible to answer for decisions taken by the AI systems. The well-defined process for designing the AI system will ensure that errors in the system can be identified and tracked.
3. Ensure Transparency: Our database and algorithms will be open to stakeholders and the general public. A clear workflow of the processes for developing, deploying and how the AI algorithm works will be made available. Our database will organize in a simple and explainable in a way that a human can interpret. All decision-making processes will be documented to the point where if a mistake occurs, it can be reverse-engineered to determine what transpired. We will also ensure our data is not biased.

XII. Dissemination and communication (1/2-page max.)

There is a three-stage plan for dissemination of the knowledge generated from this project. The first stage is the inception workshop. Major stake holders and practitioners in the groundwater industry in Ghana will be invited to discuss the project plan and access to data. This workshop will run for one day and seek the views of various stakeholders. We will especially engage players in the groundwater industry to set the tone for the RAGA research project.

The second stage involves updates on social media for each major milestone e.g., recruitment of postgraduate students, all field trips will be announced via social media and traditional media to give visibility for the project.

Thirdly, at the end of the project, a dissemination workshop will be organized with stakeholders present for knowledge transfer. Beneficiaries will be trained on how to use the RAGA platform. The workshop will also deliberate on how to sustain and expand the RAGA project. The dissemination stage also includes the publication of scientific articles from the results of the project in reputable journals. We will also prepare policy briefs for policy makers and parliament to feed into new legislation as regards to groundwater resource management and data collection.

Furthermore, both traditional media and social media will be used to present results through quick to understand infographics so the general public can utilize the web-portal for water availability. Costs for the workshops and publications are provided for in the budget.

XIII. Sustainability (1/2-page max.)

The sustainability plan is outlined below:

- To ensure environmental sustainability, field trips for validation and any project related travel will be organized in such a way as to maximize the number of sites to be visited in an optimum way thus reducing the use of vehicles and therefore the carbon footprint of the project.
- To ensure social sustainability, access to the web-based apps will be tiered. Partner agencies and the general public can request for information free of charge. We will endeavor to have all stakeholders in the groundwater industry as partners on this project. For commercial users and other agencies, a maintenance fee for the system will be paid to make the project financially viable.
- To ensure financial sustainability, the results from this study will be used as a justification to apply for grants and funding for a nationwide deployment of this research. In future we will also seek funding to expand RAGA to regional scale in West Africa and to a continental scale. This should create a largescale prediction tool for groundwater availability across Africa. We will also consider deploying RAGA in areas of water scarcity to provide a reliable data source for understanding groundwater levels over time.

XIV. Project management

a) Team organization and qualification (1 page maximum)

	Name	Role
1	Cyril D. Boateng (PhD, MSc, Bsc)	Lead Researcher (Machine Learning Practitioner/Geophysicist) 1. Plan and manage project. 2. Oversee operations and daily activities. 3. Supervise project team and Masters students. 4. Plan & manage logistics and finances. 5. Ensure HSSE Policy is implemented
2	Prof D. D. Wemegah (PhD, MSc, BSc)	Co-Researcher (Groundwater Geophysicist) 1. Supervise field trips for validation. 2. Provide expertise on hydrogeological and hydrogeophysics aspects of the project. 3. Co-supervise students on the project
3	Marian Osei (PhD, MSc, BSc)	Co-Researcher (Climate Scientist) • Specifically, be in charge of the climate science aspects of the project. • Provide expertise on climate aspects of the project. • Co-supervise students on the project.

CVs have been attached in submission system.

b) Monitoring and Evaluation (1 page maximum)

Using the results framework and the activity schedule, the major milestones will be tracked and monitored to ensure we are following the intended schedule. The Office of Grants and Research in my University (the Kwame Nkrumah University of Science and Technology) will track each milestone on the timeline and ensure the targets are met. The major milestones are shown in the table below.

The funds will be disbursed through the KNUST Grant system. KNUST has an Office of Grants and Research that oversees the disbursement of any grants in the University. The College of Science accountant will be the custodian of the funds in the College of Science bank account. Disbursement of all funds will be based on the proposal and the policies of the University. The link to the policies that guide grants allocation and disbursement can be found here https://ogr.knust.edu.gh/policies . Each money spent will be covered by receipts. A spreadsheet detailing each expenditure on the project will be prepared and used for accountability purposes.

Date	**Milestone**
Month 7	A database of predictor attributes and groundwater levels for boreholes across Ghana.
Month 12	Artificial intelligence algorithms for the prediction of groundwater availability in Ghana.
Month 14	A web-based application for rapidly assessing groundwater availability (RAGA) open to government agencies, NGOs, research institutions, policy makers and the general public.
Month 16	Publications: A minimum of two (2) peer reviewed articles in scientific journals and Policy report to governmental agencies (Community Water and Sanitation, Water Research Institute and Water Resources Commission) on data gathering and expansion of the project to serve prepare the whole country for climate adaptation in terms of groundwater availability.
Month 17	Training of groundwater practitioners on data gathering and the use of the rapid assessment of groundwater availability (RAGA) system.
Month 24	2 Masters students graduate

c) Results/Logical Framework (3 pages maximum)

RESULTS/LOGICAL FRAMEWORK FOR THE PROJECT				
Goal	Intervention Logic	Objectively verifiable indicators of achievement	Sources and means of verification	Assumptions and Risks
	What is the overall goal of your project? 1. *Enhanced capacity to predict groundwater availability across Ghana in the face of climate change and variability.*	1. *Increase groundwater borehole success rates.* 2. *Decrease in groundwater exploration costs.* 3. *Increase in number of people using RAGA to predict groundwater availability.* 4. *Increase in number of people loading data into RAGA.*	1. *RAGA dashboard* 2. *CSIR-WRI Reports* 3. *Reports from water Resources Commission*	

Purpose	*What is the purpose of your project?* 1. *Development and scaling of responsible AI innovation for climate action* 2. *Increased contribution of African research to international AI policy and practice.* 3. *Increased capacity of African innovators and researchers.* 4. *Achievement of development goals as regards to water availability and its consequences e.g., SDG 1,2, 6, 13; Agenda 2063; National Water Policy; National Water and Sanitation Strategy; Ghana Poverty Reduction Strategy; Africa Water Vision 2025.*	1. *RAGA accurately predicting GWL in Ghana with climate change.* 2. *Increase participation of African AI researchers on this project in international conferences.* 3. *Different AI models generated for predicting groundwater availability.* 4. *Contribution to developmental goals.*	1. *RAGA dashboard and database.* 2. *Conference attendance numbers.* 3. *Department of Physics files.*	
Outputs	*What are the outputs that your project is expected to achieve?* 1. *A database of predictor attributes and groundwater levels for boreholes across Ghana.* 2. *Artificial intelligence algorithms for the prediction of groundwater availability in Ghana.* 3. *A web-based application for rapidly assessing groundwater availability (RAGA) open to government agencies, NGOs, research institutions, policy makers and the general public.* 4. *Publications: A minimum of two (2) peer reviewed articles in scientific journals.* 5. *Policy report to governmental agencies (Community Water and Sanitation, Water Research Institute and Water Resources Commission) on data gathering and expansion of the project to serve prepare the whole country for climate adaptation in terms of groundwater availability.* 6. *Training of groundwater practitioners on data gathering and the use of the rapid assessment of groundwater availability (RAGA) system.* 7. *Training of 2 Masters students.*	1. *Built digital database.* 2. *Working AI algorithms.* 3. *RAGA deployed online and live.* 4. *Two manuscripts accepted for publication.* 5. *Policy report presented to the relevant agencies.* 6. *Groundwater practitioners trained.*	1. *School of Graduate Studies (KNUST) files.* 2. *Office of Grants and research files.* 3. *Project files.* 4. *RAGA digital database.*	1. *There is an MoU with the CSIR-WRI which covers data sharing including (groundwater data).* 2. *Qualified and multi skilled students will apply for research assistant positions.* 3. *Equipment (computer) will be purchased on time.*

		7. *Two Masters students trained.*		
Activities	***What are the key activities to be carried out and in what sequence in order to produce the expected results?*** *1. Recruit Masters students.* *2. Inception Workshop.* *3. Purchase computer and accessories.* *4. Acquire secondary hydrogeological data on boreholes from government agencies, NGOs, consultants, water practitioners and Digitize paper data sources.* *5. Field work to validate data sources and locations.* *6. Pre-process data.* *7. Acquire climatic data at borehole locations.* *8. Build digital database.* *9. Select spatial zone for analysis.* *10. Develop algorithms and workflows.* *11. Test and validate algorithms and workflows.* *12. Build website to host algorithm for RAGA.* *13. Write journal articles and Write policy brief.* *14. Publish.* *15. Dissemination workshop.*	***Means:*** 1. Venue. 2. Drinking Water. 3. Venue for workshops. 4. Stationary. 5. Lenovo ThinkStation P920 rack with accessories. 6. External Hard drives. 7. Travel. 8. Field Related Travel. 9. Renting Vehicle. 10. Fuel. 11. Accommodation. 12. Feeding for research team. 13. Personnel 14. Access to climatic data. 15. Website Hosting and Design costs. 16. Publication costs.	***What are the sources of information about project progress?*** *1. Project files* *2. Admission Records of the university.* *3. Informational request.* *4. Workshop Training Record* *5. Proof of receipt* *6. Minutes of project meeting.* *7. Website hosting contract*	1. *Availability of enough data for AI models.*

d) Budget (1page max.)

The budget amounts with justification are shown below. The total costs for the project are $46,605. The detailed budget has been attached in excel format.

Budget Justification

Graduate Students Fellowship
On this project, 2 students will be supported for their postgraduate research. This is in line with our institutional mandate of training and capacity building and all recruited graduates will serve as research assistants on this specific project. This project will provide a fellowship for each student worth $1500 each per year. The fellowship covers tuition costs (=$1000) and accommodation (=$500). The costs for
The total postgraduate student fellowship per year is $3000.

Student Stipend
Each student will be given a stipend of $200 each month for one academic year they work under the project. The total student stipend for the year is $4800.

Field cost for Supervisors
The field cost for supervisors is $100 per month for one year. The total is $1200 over the two years.

Thesis writing and publication
Each student will be given $200 for thesis writing and publication. The total cost for this item is $400.

Publication cost
The publication costs of each student will be $300. The total cost for this item is $600.

Medical Allowance/insurance
Each student will be given $200 for medical allowance/insurance costs per year. The total cost for this item is $400 over the two years.

Specialized equipment:
Specialized equipment is essential for processing and interpreting data for the study. In order to design and execute machine learning algorithms on vast datasets, immense computational power is required. The most significant equipment is a workstation. A Lenovo ThinkStation with accessories will be used for processing and visualizing the data and for running complex machine learning algorithms. The total equipment costs equal $13,170.00.

Field Expenses
We have budgeted field expenses to cover per diem of investigators, research assistants, drivers, fuel for field vehicle, accommodation, local field guides, and hiring of vehicle. All these costs together will be at $500 per day @ 10 days (=$500*10). This is for validating data in our digital database. The total cost is $ 5,000.00.

Data and Website Costs
Data and website costs include any compensation for acquiring data from private individuals or consultants, purchasing external hard drives for storing data in transit and cost of website domain and hosting services. The total data and website costs equal $6,800.

Student laptops
Each student will be provided be provided with a laptop at $600 per laptop per student. The total cost of laptops is $1200.

Travel and Conferences (includes other related costs-Managed Directly at RUFORUM Secretariat)
Travel (International costs for RUFORUM Conference for 3 persons-2 students and PI) = $4000.

PI coordination costs
The cost of PI coordination is $200 per month. This involves compensation related to project management. The total cost is $2400.

Facilitation of partners participation in project activities
The cost of facilitation of partners participation in project activities includes transportation, feeding and accommodation for our partners such as CSIR-WRI when they visit the project team for deliberation on the project. An amount of $1000 is allocated to this item.

Costs of meetings and other activities at Departmental level

Costs of meetings and other activities at the Department level include interviews to recruit graduate students, inception workshop, progress meetings and dissemination workshop. An amount of $800 is allocated to this item.

Contribution to National Forums

Costs to cover contribution to national forums include travel and incidental costs related to going to any national forums to speak on the project. The cost is $300.

Total Direct Costs	**$45,070.00**

Institutional Overhead (Indirect Costs):
The total amount requested for Institutional overhead costs is 5% of the total research costs

Institutional Overhead (Indirect Costs)	$ 1535.00
Total Costs	**$46,605.00**

e) Timeline (2 pages maximum)

All innovation research projects are 18 months (use the template provided).

The IDRC-SIDA-RUFORUM-GRG project are three (2) year project.

	Year 1												Year 2						
	Semester 1						Semester 2												
Activity	1	2	3	4	5	6	7	8	9	10	11	12	*13*	*14*	*15*	*16*	*17*	*18*	Implementing body
Grant Disbursement																			RUFORUM
Recruit Masters students																			PI
Inception Workshop																			Research Team
Purchase equipment and accessories																			PI
Acquire secondary hydrogeological data on boreholes and																			Research Team

Digitize paper data sources.																			
Field work to validate data sources and locations.																			Research Team
Preprocess data																			Research Team
Acquire climatic data at borehole locations.																			Research Team
Build digital database																			PI
Select spatial zone for analysis.																			Research Team
Develop algorithms and workflows.																			PI & Graduate Student 1
Test and validate algorithms and workflows.																			PI & Graduate Student 1
Build website to host RAGA.																			PI & Graduate Student 2
Write journal articles and policy briefs.																			PI & Graduate Students
Dissemination workshop																			Research Team
Project close out.																			PI