



COUNCIL FOR SCIENTIFIC AND INDUSTRIAL RESEARCH-GHANA

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*Cover: Ghana's rich Solanum spp.
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Photo credit: Dr. Daniel Ashie Kotey*

VISION

Using the transforming power of S & T for wealth creation

MISSION

To become the force for accelerated social and economic development of Ghana through examining, exploring and creating science and technology catalysts for public and private wealth creation



From the DG's desk

Bowing out with gratitude

My journey with the research community began in 1987 at CSIR-Forestry Research Institute of Ghana (CSIR-FORIG) in Kumasi. With the support of my seniors, peers and subordinates alike, I rose through the ranks to become Director of the institute. I believe that the experience and exposure gained at CSIR-FORIG prepared me for the high office of Director-General.

As the saying goes there is time for everything under the sun. Therefore, it is now time for me to bid farewell to our cherished staff. Although I am exiting the Council, I am pleased that we were able to achieve certain successes which includes the preparation of the CSIR Charter which was subsequently approved by the Governing Council. The CSIR Charter is a document made up of the consolidation of key corporate policies that effectively guide the management of CSIR for ease of reference by staff. In addition, there has been an increase in the Research Scientists' publication rate from 0.5 in 2014 to 0.8 papers per scientist in high-impact journals as indexed by SCOPUS. Data from the 2018 Annual Reports of the 13 CSIR Institutes indicate that CSIR Scientists published a total of 458 scientific papers in 2018. CSIR staff with Ph.D. or who are enrolled in a Ph.D. programme increased from 29% of Senior Members in 2013 to 68% of Senior Members as of 2018. As of the end of 2019, almost 138 staff had enrolled for Ph.D., 75 staff

had enrolled for their Master's programmes (MA, MBA, MSc, and MPhil) and 36 staff had enrolled for their BSc and BA degrees.

Finally, CSIR is currently generating 31% of its total expenditure through revenue generation. Thus, CSIR currently meets the Councils' directive that it generates at least 30% of its recurrent expenditure through revenue generation.

On this note, I wish you well and urge you all to work diligently to use the transforming power of science, technology and innovation (STI) as the drivers of development in the 21st century to develop Ghana and contribute our quota to that of the sub-region.

My appreciation goes to our creator for giving me the strength and resilience to serve the Council for Scientific and Industrial Research (CSIR) for the past thirty-five (35) years and to the CSIR Governing Council for appointing me as the Director-General for 7 years.

Finally, my gratitude also goes to the Management and staff of CSIR for their unwavering support during my tenure of office as the Director-General of this great Institution. I thank you and may God bless us all.

*Prof. Victor Kwame Agyeman, Esq. FGA, FGIF
Director-General, CSIR*

News

Form a formidable group to press home your demands - Dr. Marfo to scientists

- The Chairman of the Parliamentary select committee on Environment, Science and Technology has urged Scientific Research Institutions to bridge the gap between policymakers and scientists and also demonstrate their contribution to Ghana's economy.
- He also urged Scientists to form a formidable group to canvass support for research financing by providing data which will serve as a solid basis to spur government towards increasing funding for research.

Dr. Emmanuel Marfo who is also the Member of Parliament (MP) for Oforikrom in the Ashanti Region, further urged the agencies to expand their request for research financing by exploring opportunities externally while government puts systems in place to achieve its quest of allocating one-percent funding to research. He commended MESTI for the efforts in cushioning the funding for research last year, but said "more needs to be done".

He spoke at a one-day interactive seminar organised by the Parliamentary Select Committee on Environment, Science and Technology in collaboration with the Ministry of Environment, Science, Technology and Innovation (MESTI) and its agencies including CSIR, National Regulatory Authority (NRA), the National Biosafety Authority (NBA) and the Ghana Atomic Energy Commission (GAEC) as part of a capacity building programme for members of the Committee.

The seminar organized on the theme 'Financing Science Research and Development was to come up with a roadmap to achieve the national

goal of effectively financing 'Research and Development'. Topics discussed included **vision of science, technology and innovation, bridging science and development** and **Ghana's research and development roadmap**.

Hon. Dr. Emmanuel Marfo, who also chaired the seminar, re-emphasized the need to increase the percentage government allocates to research activities since it is inadequate. On his part, the Director-General of CSIR, Prof. Victor Kwame Agyeman urged government to take a cue from countries that support research activities, and the gains they have made.

Currently, the source of funding for research at the Council according to Prof. Victor Agyeman emanates from government, a few private sector groups and the Council's internally generated funds (IGF).

"In addition to government funding that they (foreign countries) receive, the private sector is heavily involved in funding research. That is what we have lacked in this country for some time", he noted.

Although the Director-General accepted that, investing in research is quite expensive, he was quick to urge private sector players to be encouraged to come on board to push development within the science and technology space.

The Committee also visited the CSIR-Crop Research Institute, the CSIR-Building and Road Research Institute and the CSIR-Forestry Research Institute of Ghana in Kumasi to familiarize themselves with the activities of the CSIR.



Seated from right: Prof. Paul Bosu, the Deputy Director General, CSIR, Some members of the Parliamentary Select Committee on Environment, Science and Technology: Dr. Hamza Adam, Deputy Ranking Member, Dr. Dickson Adomako Kissi, Vice Chairman, Prof. Victor Agyeman, Director General, CSIR, Dr. Emmanuel Marfo, the Chairman of the Select Committee, Mr. Yao Gumado, Ranking Member, Mrs. Adelaide Ntim, Member.

Source: Corporate Affairs Division, CSIR Head Office

Prof. Victor Agyeman (Esq, FGIF, FGA), joins League of distinguished academic personalities

The Director-General of the Council for Scientific Industrial Research (CSIR-Ghana) Prof. Victor Kwame Agyeman (Esq. FGIF, FGA) has been inducted into the Fellowship of Ghana Academy of Arts and Sciences (FGA) as a Professor of Forest Ecology (Sciences Section). The induction ceremony was held on Tuesday 23rd November 2021 at the Auditorium of the Ghana Academy of Arts and Sciences (GAAS), Accra.

Prof. Agyeman, joins the league of distinguished academic personalities as an accomplished Chief Research Scientist with a PhD in Forest Ecology and one of the leading authorities in Tropical Forest Ecology and Management in Africa. He was elected on the strength of his scholarly and professional achievements in the field of Tropical Forest Ecology and R & D.

The induction was administered by His Eminence, Emeritus Prof. Samuel Kofi Sefa-Dedeh, FGA, President of Ghana Academy of Arts and Sciences (GAAS) on Tuesday 23rd November 2021

during the 2021 Founders' Week Celebration, which was held from Tuesday 23rd to Friday 26th November 2021.

Prof. Agyeman has also received the following awards:

- i. The Korean Global Agricultural Technology Cooperation Award. A prestigious award given by the Rural Development Administration (RDA) of the Ministry of Agriculture, Food and Rural Affairs of the Republic of Korea. Prof. Agyeman was selected from a list of 100 nominees from 22 Countries all over the world
- ii. A Rockefeller Foundation Fellowship/ Grant to give two lectures at Tufts University in Boston, USA
- iii. CORAF Honorary Award for African Regional Champions of R&D

Source: Corporate Affairs Division, CSIR Head Office



Prof. Victor Kwame Agyemang displaying his induction certificate

Ghana National Chamber of Commerce & Industry (GNCCI) pays courtesy call on CSIR

- A delegation from the Ghana National Chamber of Commerce and industry (GNCCI) has paid a courtesy call on the Director-General (D-G) of CSIR to discuss business opportunities and strengthen relationship.
- One of the key functions of CSIR is to transfer its technologies and innovations to support the private sector for industrial growth.
- GNCCI is established by a Legislative Instrument with the mandate to ensure the growth and profitability of businesses in Ghana

Prof. Victor K. Agyeman, D-G of CSIR in welcoming the delegation, expressed delight at the step taken by the GNCCI to reach out to CSIR. Among the key functions of CSIR, the D-G outlined is to transfer the technologies and innovations it develops to support the private sector for accelerated industrial growth of the country.

For his part, Nana K. Agyenim Boateng, the Greater Accra Regional Chairman of the GNCCI who led the delegation, explained that GNCCI is established by a Legislative Instrument with the mandate to ensure the growth and profitability of businesses in Ghana, and that they consider collaboration with CSIR as essential to achieving their objectives.

The interactions are expected to strengthen the relationship between CSIR and the Chamber to facilitate development of new products, especially in the area of manufacturing and agro- processing.

Present at the meeting were Prof. Paul P. Bosu, the Deputy Director-General of CSIR and Mrs. Genevieve Yankey, the Director of Administration.

The GNCCI team included Mr. Imram Kwakye, Regional Vice Chairman and Daniel Osei Torgbor Regional Head (Accra Chamber).

Source: Corporate Affairs Division, CSIR Head Office



Front row (L-R): Prof. Paul Bosu, Deputy Director-General of CSIR, Ms. Patricia Fobi Antwi, Accounts Officer, Accra Regional Branch GNCCI, Mr. Imram Shams Kwakye, Vice Chairman, Accra Regional Branch, GNCCI, Prof. Victor K. Agyeman, Director-General, CSIR, Nana Agyenim Boateng, Chairman, Accra Regional Branch GNCCI, Mrs. Genevieve Yankey, Director of Administration, CSIR, Mr. Daniel Osei Torgbor, Accra Regional Branch Manager, GNCCI.

Prof. Oteng-Yeboah Wins International Award

A former Deputy Director-General of CSIR, Prof. Alfred Apau Oteng-Yeboah has received the International Union for Conservation of Nature's (IUCN) highest conservation award, the John C. Phillips Memorial Medal, for his dedication to establishing a mechanism for placing biodiversity on the political agenda, chairing and laying the foundations for managing the International Partnership for the Satoyama Initiative and inspiring young minds as a Professor of Botany.

The J. C. Phillips Memorial Medal is presented once every four years on the occasion of the IUCN World Conservation Congress to recognize outstanding service in the field of the conservation of nature and natural resources. The award – which is an engraved medal has been presented at every General Assembly and Congress since 1963 to a number of distinguished conservationists. Past recipients of the Award have included HRH, The Prince of the Netherlands, Indira Gandhi, HM Sultan Qaboos Bin Said of Oman, Professor E. O. Wilson, Dr Luc Hoffmann, Dr José Aristeo Sarukhán Kermez and Maria Tereza Jorge Pàdua, each of whom has contributed their vision, wisdom and perseverance to furthering the global conservation cause.

The IUCN was established on 5 October 1948, in Fontainebleau, France, when representatives of governments and conservation organizations spurred by UNESCO signed a formal act constituting the International Union for the Protection of Nature (IUPN). The initiative to set up the new organisation came from UNESCO and especially from its first Director-General, the British biologist Julian Huxley. The IUCN

has observer and consultative status at the United Nations and plays a role in the implementation of several international conventions on nature conservation and biodiversity. It was involved in establishing the World Wide Fund for Nature and the World Conservation Monitoring Centre

Prof. Oteng-Yeboah was the Deputy Director-General of the Council for Scientific and Industrial Research (CSIR) from 1998 to 2006 and served as board/council member of a number of Ghanaian public institutions, including the Environmental Protection Agency (EPA), and the Ghana Commission for UNESCO. He has been a passionate leader and promoter for the conservation movement for many years.

Among others, Prof. Oteng-Yeboah served as Vice-Chair for the Standing Committee of Convention on the International Trade on Endangered Species of Wild Fauna and Flora (CITES). He also served as a member of the International Advisory Committee for UNESCO Biosphere Reserves for a three-year assignment, during which he provided support for the revision of the establishment of new Biosphere Reserves.



Prof. Oteng-Yeboah with his J.C. Phillips Memorial Medal

CORAF honours champions of R&D in West and Central Africa

The Director-General of CSIR, Prof. Victor Kwame Agyeman and seven other prominent African chief scientists have been honored for their lifetime contributions to research and development (R&D) in West and Central Africa (WCA). The laureates include Dr. Paco Sereme, Burkina Faso, Dr. Famoi Béavogui, Guinea; Prof. Abdulai Jalloh, Sierra Leone; Dr. Djondang Koye, Chad; Prof. Daniel Franck Idiata, Gabon; Dr. Oumar Chaib Hassanty, Democratic Republic of Congo (DRC) and Mr. Nathanaël Mapungu Buka, Chad.

This occurred at an event organized on the sidelines of the 13th General Assembly of CORAF in the Chadian capital of N'djamena. CORAF, through its Chairperson of the Board of Directors, Dr. Angela Moreno paid tribute to these researchers for their leadership and contributions to advancing the science and research agenda in West and Central Africa.

CORAF is an international non-profit association of National Agricultural Research Systems (NARS) in 23 West and Central Africa (WCA) countries, covering over 40% of Africa's population, thus making it the largest sub-regional research organization on the African continent. It was established in 1987 and assigned responsibility to coordinate and facilitate groundbreaking and cutting-edge research outputs needed to unlock the agricultural potential of West and Central Africa. It is the largest of the four Sub-Regional Organizations (SROs) under the Forum for Agricultural Research in Africa (FARA).

The other three organizations include the Association for the Strengthening of Agricultural Research in Eastern and Central Africa (ASARECA), the Center for Coordination of Agricultural Research and Development for Southern Africa (CCARDESA), and the North African Sub-Regional Research Organization (NASRO).



Prof. Agyeman displaying the award after receiving it from Dr. Angela Moreno, Chairperson of the Board of Directors of CORAF

R & D News

Utilizing Pozzolana Cement and Burnt Clay Bricks as Cost-Effective Construction Material to Boost National Development

Author: Mark Bediako

*CSIR-Building and Road Research Institute,
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Currently, the world population is estimated around 7 billion and it grows progressively every year. The United Nations has predicted that by 2050, there would be an addition of 3 billion people to the current population. Due to population growth, there is evidence of unstoppable consumption of finite resources such as limestone for cement production, aggregates for concrete and mortar for human consumption and satisfaction.

The Ghanaian economy is also expanding annually due to population growth coupled with urbanization. Thus, the government of Ghana is embarking on many infrastructural developments including road construction, railway development as well as affordable housing for the citizens. The private sector is reinforcing the efforts of government with the construction of a significant share of these infrastructural projects. However, limited supply of some essential construction materials has contributed to high cost of infrastructure delivery in the country. For example, limestone used to produce cement is not available in Ghana. This, therefore, makes developers depend on imports from cement dealers, making the price very high and unstable. In the last decade, cement price in Ghana has increased by about two fold. Aggregates such as sand and chippings are gradually going into extinction and if care

is not taken, in the not soon distant future, the country will struggle to get these finite resources for construction. In view of the foregoing, there is the urgent need to bring on board innovative measures that could counter this menace.

For more than three decades, the Council for Scientific and Industrial Research-Building and Roads Research Institute (CSIR-BRRI) has been drumming the importance of utilizing clay pozzolana and burnt clay bricks in the Ghanaian construction industry.

Clay pozzolana can reduce cement content in a concrete or mortar matrix by up to about 50% , reduce cement cost by about 30% and eventually reduce the total cost of construction. From the laboratory data and available literature, the replacement of cement with clay pozzolana attains similar properties of mortar and concrete as the unblended ones. Burnt clay bricks also have the potential of reducing masonry (plastering and rendering as well as bonding of the bricks) cost by about 25%.

CSIR- BRRI has successfully constructed many buildings scattered around the country using these two materials, clay pozzolana and burnt bricks. In all the projects executed by the institute, clients made savings ranging from 15% - 25% on the overall cost of the buildings. With pozzolana cement, the Institute used the material as mortar to bond burnt clay bricks for a 3- km brick walling project for the Aboadze thermal plant in Takoradi. The Oduom Electricity Company of Ghana (ECG)

office and the Afia Kobi market all in Kumasi were built totally with pozzolana cement. The Silicon hotel and the Ejisu model school project all located in Kumasi were also developed using burnt clay bricks.

Successful execution of building projects using clay pozzolana and burnt bricks has attracted the interest of a significant number of builders to these products. Aside the cost benefits that builders accrue from the use of these materials, there are also engineering and environmental benefits and impact. On the engineering side, adding clay pozzolana to cement enhances the longevity of cement-based products (mortar and concrete) than using only cement. With bricks, the inherent behaviour of providing thermal comfort due to its low thermal conductivity and their resistance to high temperature make them more resilient to our tropical weather compared to sandcrete blocks.

On the environmental benefits, the use of clay pozzolana to replace cement and also bricks to replace sandcrete blocks is proven to provide a low embodied energy. This means that the two materials have a lower carbon footprint than pure cement base materials. In recent

times, work carried out by the writer on clay pozzolana indicated that the embodied carbon of clay pozzolana concrete was approximately 15% lower than only Portland cement concrete. The advantage of lower carbon materials for construction has a positive effect on building resilience to climate change since higher carbon content in the atmosphere facilitates global warming.

Ghana's infrastructure and housing development could reduce cost and do more if the nation consciously focuses on local based materials such as 'pozzolana' cement and burnt clay bricks. The need to use these materials for infrastructure development need no further emphasis. The writer recommends a conscious policy from government through the Ministry of Local Government and the Ministry of Education to use these materials especially for school buildings in the districts. Many other on-going government projects including one-district-one-factory (1D1F), hospital construction projects could be tied to such cost-effective and environmentally friendly materials. This cost-effective way of construction using clay pozzolana and burnt clay bricks could significantly boost the construction output and create sustainable jobs in the country.



Plastering stage of the ECG office at Kentikrono, Kumasi



Burnt brick building at Tikrom, Ashanti region

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Leveraging state-of-the-art Civil Engineering laboratory for sustainable national development

Author: Mark Bediako

CSIR-Building and Road Research Institute, Head of Advanced Materials Division

Since the introduction of sustainable development by the United Nations in the 1960s, it has been the one single most important issue shaping the world into a better one. Population growth and urbanization in many African countries have resulted in a corresponding high rate of infrastructural development. Currently around the globe, many nations are suffering from shortage of some finite raw materials including construction materials such as sand and stones for concrete and in infrastructure and residential buildings. In Ghana, the current population is approximately 31 million and is projected to reach 40 million by 2050. Meeting the demands of the increasing rate of population requires a commensurate expansion and construction of roads and residential facilities.

As such, the government of Ghana is embarking on the construction of many infrastructure projects, reinforced by private developers. The boom in the construction industry means that the country is using so much of finite resources (cement, sand, stones, etc). However, unnoticeably, this has led to a further dwindling of these materials. Currently, there have been reported cases of short supply of sand in some parts of Ghana including Accra and Kumasi.

Sustaining development to meet population growth by government and private developers requires a more innovative means to ensure prudent use of materials. One area of the construction sector where there is little or no prudent use of materials in Ghana is the concrete industry. From hindsight, the concrete industry either overdesign or under design concrete parameters. Poorly designed concrete has a negative impact on the life cycle of infrastructure.

Most of the times, such structures do show excessive cracks and sometimes exposed iron rods in reinforced concretes.

The existence of effective concrete laboratory comes in handy in the area of good design practices for the industry. Research has posited that the construction industry is not complete when there is the absence of state-of-the-art civil engineering laboratory facilities. Modelling the life cycle of infrastructure using key laboratories facilities such as surface resistivity, rapid chloride permeability (RCPT) apparatus, ion migration is available in such laboratories. In addition to the modelling activities are tools to analyze the strength properties of civil engineering materials. Such facilities include universal strength testing machine used to check flexural, compressive and tensile strength as well as elastic moduli be it static or dynamic. Currently many of the developed countries are using non-destructive tools such as ultrasonic pulse velocity (UPV) and rebound hammer, digital scanners to check the healthiness of infrastructure.

Research has posited further that the construction industry is not complete without state-of-the-art civil engineering laboratory facilities. Many developed nations have relied upon such facilities and have been able to use finite materials prudently as well as predict the longevity of structures. For instance, in the Netherlands and many other European countries, the life cycle of buildings is known from the laboratory before construction. In the United States, concrete bridges are built to last longer through the efforts of laboratory services. Modelling the life cycle of infrastructure using key laboratories facilities such as surface resistivity, rapid chloride permeability (RCPT) apparatus and ion migration is available in such laboratories.

In line with the provision of sustainable national development, the CSIR-Building and Road Research Institute (CSIR-BRRI) has set up a Civil engineering laboratory to help government and private developers ascertain prudent use of materials and predict the durability of concrete infrastructure, steel works, and other building materials. Some of the key services offered in the laboratory include the use of non-destructive methods (UPV, digital rebound hammer), durability of concrete using RCPT method, compressive strength determination of concrete and mortar, Alkali silica reactive (ASR) test, shrinkage and all tests on Portland cement including heat of hydration using isothermal calorimeter. The laboratory boasts in the fact that certain laboratory works such as RCPT, UPV testing, ASR and heat of hydration are performed only in CSIR-BRRI.

The civil engineering laboratory has lived up to expectation by helping both research and commercial activities. Many builders have benefited from our services especially in the area of preventing the use of inferior concrete and over-use of materials for concrete. A typical example is the construction of the Kejetia market by Contracta-Ghana where the laboratory support the project with sound technical laboratory data on their concrete.

Since the inception of the laboratory, many services have been provided to many builders and academic institutions. Some of the clients the laboratory has dealt with include Sageo Satom based in Togo, Contracta-Ghana, Amandi-Ghana, Shimizu Dai Nippon JV, CRCEG Ghana Limited and many more.

For academic institutions, the departments of Physics, Material Science and Engineering, Civil Engineering and Building Technology all in KNUST, the department of Materials Science and Engineering, University of Ghana, as well as the department of the construction and wood technology, at the Appiah Menka University all utilize the laboratory for student projects.

Though the laboratory continues to impact the construction industry yet the dearth of knowledge with regards to ascertaining material properties in the construction industry is a bottle-neck. Therefore, to bring on board many builders to appreciate the contribution of laboratory services in the construction industry, there will be the need for workshops and round-robin activities for contractors and consultants as well as the academia in the industry.

The state-of-the-art civil engineering laboratory at the CSIR-BRRI places Ghana auspiciously in the context of the UN goal for the benefit of the country. Only one thing is required: The use of the laboratory for scientific analysis and predictions in place of speculations.



Engineer from Shimuzu testing concrete for the Assin Praso-Cape Coast road project at the Civil engineering Lab

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Pushing the boundaries of Science and Innovation

Leveraging ICT and Solar Energy to develop innovative Agricultural technologies, CSIR-IIR Shows the way

One of the major problems that inhibit growth in the agricultural sector is the heavy reliance on rainfall as the main source of water for planting and the lack of irrigation facilities. It is estimated that, only a meagre percentage of 1.6%, or 31000 hectares of land out of the total irrigable lands are under fully controlled irrigation in Ghana. The major practice has been smallholder rain-fed farming using rudimentary technologies which has unfortunately dominated the agricultural sector. Ghana is currently experiencing a changing rainfall pattern which is evident in the changes in the onset and cessation of the rainy season and changes in the frequency and duration of rainfall. This has resulted in a shift in the rainfall regime towards a longer dry season and a shorter rainy season. The net effect of these changes is a decline in yield, which ultimately affects the livelihood of farmers.

Another area of growing concern in agriculture is the issue of the ageing farmer population. According to Ministry of Food and Agriculture, the average age of farmers in Ghana is 55 years which gives a clear indication of low level of youth involvement in agriculture. These aged farmers have to travel or walk long distances to their farms and sometimes at odd hours, which is sometimes unsafe and introduces more drudgery into their activities. Most Ghanaian youth think of agriculture as a back-breaking labour which is old fashioned and unprofitable

Ghana is blessed with inexhaustible resource for solar energy which can be tapped through

solar water pumps to facilitate all-year farming in Ghana. Also, Information and communication technologies (ICTs) are already bringing new vibrancy and potential to agricultural practices around the world and can, therefore, be explored in Ghana for agricultural development.

Leveraging ICT and Ghana's abundant sunshine to develop innovative agricultural technologies will not only make farming more appealing to the youth but also tackle climate change and advance food security in Ghana.

The Institute of Industrial Research of the Council for Scientific and Industrial Research (CSIR-IIR) with funding from the Canadian Government, through the Modernizing Agriculture in Ghana (MAG) Program, has carried out research and developed a remotely controlled solar irrigation system which works with a mobile phone application that makes it possible to remotely control the solar powered irrigation pump.

The innovative set-up comes handy with three different technologies; solar system, irrigation system and the mobile technology which is a multipurpose interface for sending instructions such as turning the pump ON and OFF for irrigation and also viewing water flow data. The system makes it possible for data of flow rate to be displayed instantaneously on the app and can be accessed or monitored remotely from any location provided there is internet access.



App Display on Smart Phone



Interface of Mobile Software Application



Controlling Pump Remotely with Mobile Phone Application

To test the system for efficiency and reliability, two independent set ups have been developed and tried. A fixed solar PV structure on a one (1) acre demonstration farm and a mobile solar trailer, with each equipped with a cyber-irrigation system;

- For the demonstration farm, a 2kilowatt solar pv system was used to power a 3hp submersible pump installed into a drilled borehole, to supply water for irrigation through well designed drip and spray tube irrigation systems.
- The second system, a mobile solar cyber irrigation trailer also consists of 0.5kilowatt solar pv system, which powers a 0.75hp surface pump. The solar PV system was mounted to serve as the roof and to shield batteries, inverter and charge controller against weather conditions.



Fixed Mount Structure for Solar System



Mobile Solar Cyber Irrigation Trailer

It is worthy to note that the ideation process and concept development for the technology which began in 2017 was done by CSIR-Institute of Industrial Research with a seed grant of Ten Thousand Ghana Cedis (GHC 10,000) from CSIR-Competitive Research Grant Scheme (CRGS). In 2020, the CSIR secured funding support from the Canadian Government through the MAG project which helped with the successful demonstration of the technology on a one-acre farmland as a pilot scale of the technology.



The technology is currently being used by a young farmer, on the projects' one (1) acre demonstration field for all year-round organic vegetables production. It is our expectation that the technology will be adopted for use by farmers at all levels (small, medium or largescale farmers)

The technology will offer farmers in the country, the opportunity to minimize the over-dependence on rain-fed agriculture. It also has the potential to increase annual yield by 2-3 times more as compared to the conventional

way through all-year round farming while giving farmers ample time to engage in other secondary economic activities. Introducing the technology into farming will also attract the youth and make it more lucrative.

Using solar energy coupled with an efficient irrigation system can save money, water and time. Farmers can, therefore, take advantage of the abundant solar energy and scarce water resources during the dry season to ensure efficient water management, increase productivity and improve livelihoods.

The remotely controlled solar irrigation system is sustainable, therefore suitable for all year-long farming which would consequently produce greater economic outcomes. Due to the simplicity in operation, the mobile application can be operated by farmers at all levels. It will also help reduce farmers workload and make farming more appealing to younger people.

This technology has successfully been piloted and offered farmers in the country the opportunity to minimize the over-dependence on rain-fed agriculture and provides sustainable technology from the inexhaustible solar energy resource.



CSIR-IIR MAG Project team interacting with farmer association executives, agricultural extension officers and farmers at the Mankessim, Central Region, Ghana



Demonstrating the operation of mobile solar cyber system to a section of farmers

The application of this technology is not limited to only farms but also can be used to pump water for domestic and commercial uses such as irrigating lawns, gardens, pumping into over tanks or reservoirs etc

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Sarifix-The Innovit Biofertilizer (*Rhizobium Inoculant*)

Biological fertilizers (Biofertilizers) are products that are formulated with beneficial microbes to enhance crop nutrition, soil and environmental quality thereby contributing to food security. Biofertilizers play important roles in nutrient cycling, promoting plant growth and development, and building plant resilience to abiotic and biotic stress. They are applied to seed, soil and plants at planting or during plant establishment, and exist (come) in granular, liquid, and powdered forms.

Nitrogen-based biofertilizers contain nitrogen fixing microbes (e.g., *Rhizobium sp.*, *Azotobacter sp.*, *Azospirillum sp.*, *Azolla sp.* etc) that fix nitrogen (N) for plants uptake (Kalayu, 2019). Phosphorus-based biofertilizers are formulated with phosphate solubilizing and mobilizing microbes (eg. *Arbuscular mycorrhizal fungi*) that enhance the uptake of phosphorus, water and other nutrients from the soil to the plant (Kalayu, 2019; Faye et al, 2020). Plant growth stimulator or biofertilizer like Plant Growth Promoting Rhizobacteria (PGPR; *Pseudomonas putida* and *P. fluorescens*) stimulate plant resistance against pest and disease as well as environmental stress (Kalayu, 2019)

In Ghana, *Rhizobia* inoculants are the most widely used biofertilizers among producers (farmers) in the grain legumes (soybean, groundnut and cowpea) value chain. This is because legumes form a major component of the farming systems. The *Rhizobia* fix N biologically through symbiotic association with leguminous plant.

Plants require 16 essential elements: carbon, hydrogen, oxygen, nitrogen, phosphorus, potassium, calcium, magnesium, sulfur, iron, zinc, manganese, copper, boron, molybdenum, and chlorine as food for their growth and development. Among these elements, phosphorus and nitrogen are most limiting

nutrients in smallholder farming systems in Ghana. This is because such farming systems are generally characterized by cereal-legume systems with minimal or no use of external inputs (mineral fertilizers, improved varieties, pesticides). As a result, crop yields are low or declining due to poor soil quality.

Additionally, most farmers are poorly resourced to purchase mineral fertilizers especially mineral N fertilizers to replenish their infertile soils for greater productivity because of high cost and limited access. Therefore, biological nitrogen fixation (BNF) by legumes offers a cheaper alternative to correct the N deficiency in their cropping system than the use of mineral N fertilizer.

The BNF is an important process in cereal-legume cropping systems. The process involves the conversion of atmospheric N to a form (ammonia) usable by plants through soil bacteria called *Rhizobia*. Leguminous crops such as groundnut, soybean and cowpea form a symbiotic association with soil *Rhizobia* to biologically fix N into the soil. This process can contribute a substantial amount of fixed N, up to 80 % required by crops in agricultural system. However, inoculation with *Rhizobium* biofertilizer can significantly enhance the amount of N fixed by legumes. The quantity of N fixed by *Rhizobium* varies with the species of legumes and the prevailing environmental conditions. *Rhizobium* can fix about 50-100 kg N ha⁻¹ thereby reducing the use of mineral N fertilizer. *Rhizobium* biofertilizers have been reported to increase the yield of leguminous crops by 10-35% (Hungria et al., 2006)

Using *Rhizobium* inoculants or biofertilizers for grain legume production is economically cheaper and environmentally friendly compared to using mineral N fertilizer for grain legume

production. Thus, Rhizobia biofertilizer have minimal negative environmental impacts (nitrates leaching in ground water, green-house gas emissions,) compared to mineral N fertilizer.

Inoculating grain legumes with commercial Rhizobium biofertilizers on farmers field started in 2011 under the N₂ Africa Project (putting nitrogen fixation to work on smallholder farmers Africa) phase I and II. The N₂ Africa project focused on disseminating improved legume production technologies (improved seed, mineral P and K fertilizer and *Rhizobium* inoculation) to smallholder farmers in Northern Ghana (formerly, Northern, Upper East and Upper West Regions) from 2011-2017. The *Rhizobium* inoculants were imported from the United Kingdom (UK) and Kenya for inoculating soybean. AGRA soil health 005 program (2010 – 2013) partnered with the N₂Africa project to disseminate soybean-Rhizobium inoculation technology among smallholder farmers.

Then, EMBRAPA (phase I and II) project funded by the Brazilian government also promoted the Rhizobium inoculation in cowpea and trained selected SARI staff in Rhizobiology and inoculant production in Brazil. After the training, a small inoculant production Lab was put in place at the soil chemistry section where cowpea inoculants were produced for research purposes (2011-2016). These projects disseminated the *legume-Rhizobium* inoculation technology through both on-station and no-farm adaptive research trials, demonstration fields, farmers field day, field school, farmers exchange visit and the electronic media.

Based on the successes of these projects, AGRA SHP 025 came to being from 2014 to 2017 under 'Enhancing Soil Health in Northern Ghana; Inoculants Production, Distribution and Utilization through Private-Public Partnership. The project scaled-up the commercialization of the legume-rhizobium inoculant technology in northern Ghana through Private-Public Partnership using

the aforementioned dissemination strategies, as well as built the capacity of CSIR-SARI staff and private partner's staff in commercial inoculant production and other stakeholders along the grain value chain.

AGRA SHP 025 also established and equipped a commercial *Rhizobium* inoculant production laboratory at CSIR-SARI in Nyankpala. The first commercial *Rhizobium* inoculant (33 kg peat-based inoculant) was produced in 2017 under the brand name SARIFIX. Since then, production keeps increasing annually. Currently, the Lab produces commercial inoculant for Soybean, Groundnut and Cowpea producers (farmers). Other projects that provided support for the operationalization of the inoculant laboratory included M-BoSs, SAPIP and PASUSI project.

The benefits of *Rhizobium* Biofertilizers in grain legumes cropping systems include:

- Improving growth, biomass and grain yield of legumes and their nutritional quality (protein content). *Rhizobium* biofertilizers have been reported to increase the yield of leguminous crops by 10-35%.
- Stimulating nitrogen fixation biologically. *Rhizobia* can fix approximately 50-100 kg n ha⁻¹ which can potentially minimize the use of mineral n fertilizers.
- Helping in crop rotation or intercropping systems, the succeeding crops usually cereal, benefit from the residual n contributed by the inoculated legume.
- Improving soil and environmental quality (minimizing ground water pollution and greenhouse gas emissions)
- Increasing the biodiversity of soil

The current users of the technology include:

- Farmers (commercial and smallholder farmers),
- Scientists from Universities and Research Institutions
- Seed Producers (seed companies)
- Agro-input dealers

- Agricultural science students
- Non-Governmental Organizations

Potential beneficiaries of the technology include Research Institutions and Universities that are currently not using the technology, Farmers (nucleus farmers, out-growers, farmer-based organizations, etc.,) outside the mandate areas of CSIR-SARI, Planting for Food and Jobs (PFJ) as an accompanied technology to the legume seeds, Rearing for Food and Jobs (RFJ), Agro-input dealers, Donor Funded Agricultural-related Projects, legume grains processing companies, poultry farmers, students (Agric. science and other biophysical science students).

Policymakers can also be seen as beneficiaries because they formulate policies which affect inputs (seed and fertilizer) use at the farm level and marketplace. These policies would influence availability of inputs and how input use is promoted.

The adoption of rhizobium technology alongside other add-on technologies such as phosphorus fertilization, improved climate-smart seeds and effective agronomic management (weeding, correct spacing, and right plant population), can double the yield of the farmers thereby doubling their income for improved livelihood.

In legume-cereal rotation system where the legumes are inoculated with *Rhizobia*, the N nutrition required by the succeeding cereal in the rotation system can be reduced by 50%. Thus, reducing the cost of procuring mineral N fertilizer and by same margin reducing the cost of production and reduced environmental effects.

Rhizobium inoculation also improve other components of the yield, such crop residue or stover dry matter, which can be sold to generate extra income for the farm households. For example, groundnut and cowpea stover are sold to livestock farmers in the Upper East and West Regions to raise extra income for the

farm household. In crop/livestock integration cropping systems in northern Ghana, crop residues are used to feed farm animals while the manures from the animals are used to fertilize the soil.

At the farmers level, Rhizobium inoculation increases economic yield of grain legumes. Research conducted at CSIR-SARI revealed that inoculation with elite effective *Rhizobium* strains increased yield of soybean (15% -35%), cowpea (40-100%), (Boddey et al., 2016) and Groundnut (20-50%) (CSIR-SARI., 2018) in northern Ghana.

The increased use of the inoculants will create a demand for Phosphorus based-fertilizers as these are required to enhance BNF processes in the legumes, and which will inure to the benefit of both agro-input dealers, fertilizer blending companies like YARA and fertilizer policy makers. This provides employment and additional income for these associated technology providers.

The biofertilizer technology is relatively cheap and can easily be afforded by smallholder farmers especially women who are usually marginalized in access to credits and quality inputs.

For smallholder famers who cannot afford to purchase and apply the right quantity of mineral N fertilizer required by their leguminous crops, Rhizobium biofertilizer technology serves as a low cost, environmentally friendly, and a sustainable way of addressing soil fertility (especially N) decline on smallholder farms. This will increase their farm productivity and income

Children and women also benefit from the technology in terms of improved human nutrition and well-being. Rhizobium inoculation of grain legumes increases their protein content, and consumption of these grains can help reduce malnutrition especially in children and women who are comparatively marginalized in the consumption of animal protein (milk, meat, and egg).

The Rhizobium technology squarely fit into the mandate of the institute (CSIR-SARI) thus providing farmers in the Northern, Upper East and Upper West Regions with appropriate technologies to increase their food and fiber crop production based on a sustainable production system which maintains and/or increases soil fertility. In this case, the legume crops in its research mandate, cowpea, groundnuts, soybean, Bambara groundnuts, and cereal (maize) to be in rotation.

SARIFIX has been found to increase farm productivity, the technology has been widely disseminated and huge market has been created for it. CSIR-SARI is open to public-private partnership to scale-up production to meet the huge demands for SARIFIX.



Cowpea Biofertilizer (*Rhizobium inoculant*)



Inoculation Kits



Soybean Biofertilizer (*Rhizobium inoculant*)



Biofertilizer (*Rhizobium inoculant*)



Groundnut Biofertilizer (*Rhizobium inoculant*)

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Compiled by: Edwin K Akley, Abdul Aziz Abdul Latif, Mawuli Yevu, Deborah A. Gumanga and Jessica Y. Ohene

Contact: Dr. Francis Kusi (Ag. Director of CSIR-SARI, Nyankpala) *Pictures of various types of Rhizobium Inoculants Produced in CSIR-SARI*

Bridging the gap between technology and end-users

Dr. Jonas Osei-Adu is a Senior Research Scientist (Agricultural Economist) with the Council for Scientific and Industrial Research -Crops Research Institute (CSIR -CRI) with a strong passion for developing effective systems for technology dissemination to end-users.

Dr. Osei Adu's passion has evolved over the years from his work at the Socio-Economic section of the institute where he came to the realization that farmers and other end-users have limited access to improved agricultural technologies.

As the Research Facilitator for the Innovation Platform (IP) under the AusAID Crop small ruminant project, Dr. Osei-Adu led the team to successfully disseminate information on the dual-purpose cowpea and groundnut varieties and recorded a high adoption rate among farmers and end users. Dr. Osei-Adu was also the National Focal person for IPs under the West Africa Agricultural Programme (WAAPP) and led the dissemination of several improved varieties of maize, cassava and sweet potatoes across the country.

In 2016, Dr. Osei-Adu developed a more sustainable system for technology dissemination. He also wrote a proposal and won a grant of GHC2,400,000.00 for the establishment of the CSIR-CRI Agricultural Productivity Technology Centre (APTC) in the same year. The APTC since its inception, has successfully packaged information on CSIR-CRI developed technologies into production guides and videos, which are accessible to end-users. The Centre also offers training for targeted end-users and clients as a way of disseminating technologies and building their capacity.



The establishment of CRI-TV, an online platform for effective technology dissemination was part of the proposal for setting up of APTC. In 2020, with support from the Director of the Institute, CRI-TV was born with Dr. Osei Adu as the General Manager.

CRI-TV has covered major CSIR corporate events such as; CCST Graduation ceremonies for 2020 and 2021, 31st Research Staff Association (RSA) Annual General Meeting, 32nd RSA Annual General Meeting and 3rd Scientific Conference, the Mercury AMF Virtual Workshop and the CSIR Commercialization Awards programme. Visits by distinguished personalities to CSIR-CRI such as the Minister for Science, Environment and Innovation and the Indian High Commissioner to Ghana have also been successfully covered by CRI-TV.

Under Dr. Osei-Adu's dynamic leadership, CRI-TV is building synergies with other CSIR Institutes to generate and create content for broadcast. **The Project, Women of Science** and **Kids Farm** are currently the most watched programmes on CRI-TV.

Dr. Osei-Adu envisages a transition from CRI-TV to CSIR TV, a much bigger online platform, which will serve as mouthpiece for CSIR with great content on science, technology and innovation within the next 5 years.

Dr. Osei-Adu is an accomplished academician with 66 publications to his credit, which include; 18 refereed journal papers, 16 technical reports, 10 conference papers, 13 posters, and 9 handbooks and manuals. He was the co-chair for the international conference on food security in New York USA in 2018, Director's special award winner in 2017, Best Research Scientist for RCM/Socio Economics Division in 2013 and Best worker for Socio Economics Division in 2009.

He is currently the Coordinator for the USAID funded CORAF-PAIRED Project and the Coordinator for the Agricultural Productivity Technology Centre (APTC), which is funded by the World Bank through the Skills Development Fund (SDF). As a Monitoring Evaluation and Learning (MEL) Specialist, Dr. Osei-Adu was the Leader of Management of M&E for the CAY-Seed Project in Ghana and Nigeria, MEL Officer for the USAID funded Feed the Future projects at CSIR-CRI, African Development Bank (AfDB) funded Support for Agricultural Research for the Development of Strategic Crops (SARD_SC) in Africa project and AfDB funded Dissemination of New Agricultural Technologies in Africa (DONATA) project.

Dr. Osei Adu holds a PhD in Agricultural Economics from the Kwame Nkrumah University of Science and Technology (KNUST), Kumasi-Ghana.

He is married with four daughters.

Going the extra mile



Mrs. Naomi Appiah is a Senior Marketing Officer and Head of the Commercialisation Division (CD) at the CSIR-Forestry Research Institute of Ghana (CSIR-FORIG)

Since her appointment as Head of CD in June 2016, Mrs. Naomi Appiah has developed and implemented clear-cut strategies and tactics which have resulted in significant increases in internally generated funds (IGF) of virtually all FORIG commercial products i.e. honey, prekese syrup, forest tree seeds and seedlings, and furniture and wood products.

From a monthly production of between 80 to 100 (250 mls) bottles of CSIR prekese syrup in the laboratory before 2016; FORIG has been recording a monthly production of 2,400 since August 2020 to meet the ever-increasing demand of clients. A related product, prekese teabag has also been developed and is being piloted as value addition to the FORIG prekese

brand and plans are far advanced for commercial production. From a net income of a little over GHC 1,000,000.00 in 2016, proceeds from the Institute's net IGF have more than tripled over five years under Naomi's dynamic leadership.

Naomi played a pivotal role in reactivating the transfer of CSIR-FORIG technologies to the general public through the delivery of training in alternative livelihood programmes in snail farming, bee keeping and mushroom cultivation. She has led the training team to train about 2000 clients over a four-year period and penetrated new markets in Ghana; Members of Parliament, Metropolitan, Municipal and District Chief Executives and the general public. Geographical coverage of training programmes has also broadened from only Accra and Kumasi to include towns and cities like Sunyani, Obuasi, Sekondi-Takoradi, Yeji, Ho and Battor. Naomi and her team have also trained people from Nigeria, Cote d'Ivoire and Togo

In 2019, Mrs. Appiah joined Prof. Paul Bosu and Mr. Elvis Nkrumah (two technical experts on the training team) to undertake a one-week study tour of the beekeeping industry in Kenya sponsored by a client who was preparing to invest in the beekeeping industry. One of the immediate outcomes of the tour was the relocation of the beekeeping training activities from in-doors to the CSIR-FORIG Yenku Field Station (near Winneba), to make it more practical- oriented.

It is worth mentioning that more than 65% of all trainees currently own small to medium scale farms, with about 10% of them into the commercial production of snails, honey or mushrooms. In December 2020, a beneficiary of the programme. Mr. Kingsley Nuro, received an award as the Best Farmer (Non-Traditional Products category) in Adumasa District of the Ashanti Region

Mrs. Naomi Appiah, serves on a number of Committees. At CSIR-FORIG, she is a member of the Institutional Management Committee,

Commercialization Management Committee, Wood Sales Committee, Wood and Furniture Testing Management Committee and the Editorial Committee of the Ghana Journal of Forestry. Outside the institute, Mrs Appiah serves on the Management Board of the Ghana School of Marketing. In December, 2017, she received the CSIR-FORIG Director's Special Award for *"Her remarkable role as a skilled Marketer who has immensely contributed to increased revenue generation of CSIR-FORIG"*. She has to her credit, two Refereed Journal articles, four handbooks, 10 manuals and a number of reports. She has been secretary to the Editorial Committee of the Ghana Journal of Forestry (GJF) for the past 18 years.

Naomi holds an MBA in Marketing, from the Kwame Nkrumah University of Science and Technology (KNUST) Business School in 2010 as well as a B.A in Publishing Studies from the same University.

Naomi is married with three children.

Milestones & Appointments

DR. (MRS.) ADELAIDE AGYEMAN

Dr. (Mrs.) Adelaide Agyeman is the Deputy Director of CSIR-Science and Technology Policy Research Institute (STEPRI) in Accra. Prior to her appointment as Deputy Director on 1st November 2018, she had served the Council a little over 30 years since 1st October 1988. Dr. Mrs. Agyeman, by dint of her research prowess has been promoted from Principal Research Scientist to Chief Research Scientist in January 2021.

Her area of specialization or expertise is Applied Statistics. Dr. Mrs. Agyeman has contributed immensely to the advancement of Research and Development (R&D) within the Council.

Adelaide has been involved in the following research activities; Generating Evidence for Distributional Impacts of Innovation and SME Support in Ghana (GE4DISS-Ghana) from 2021 to 2024, Strengthening STI Systems for Sustainable Development in Africa, Phase 1 (2021-2022) and building resilience against climate change: Social transformation research (REACH-STR) from 2019 to 2025.



DR. ANTHONY YAW KARIKARI

Dr. Anthony Yaw Karikari is the Deputy Director at the CSIR- Water Research Institute, Accra . Prior to this appointment in September 2021, he was the Head of the Environmental Chemistry and Sanitation Engineering Division.

Dr. Karikari's area of specialisation includes Water and Wastewater quality Assessments, Aquaculture, Sediment quality, Pollution studies and Integrated Environment and Water Management.

As part of his achievements, he was part of the team that undertook the RECIRCULATE Project that led to driving eco-innovation in Africa and building capacity for a safe circular water economy. This project also involved the assessment of drinking water and wastewater quality of drains at Madina Zongo and Gbegbeyise in Accra (2018-2022). Lancaster University-led Global Challenges Research Fund (GCRF) sponsored project.



By dint of hard work, Dr. Karikari was promoted from Principal Research Scientist to Chief Research Scientist in January 2021. He has served the Council for over 32 years.

MRS. PHYLLIS NKETIA

Mrs. Phyllis Nketia joined the CSIR- Building and Road Research Institute, Kumasi in December, 2003 as an Assistant Administrative Officer (MIS) a grade she stayed on for 6 years until her new grade as an Administrative Officer. She was later transferred to CSIR Head Office on 1st May, 2013 to augment the staff strength of the Human Resource Management.

By dint of hard work, she has risen through the ranks to the grade of Principal Administrative Officer on 1st July, 2021.

Mrs. Nketia holds a Master's Degree in Business Administration (Logistics and Supply Chain Management) from the Kwame Nkrumah University of Science and Technology, Kumasi. She also possesses an Advanced Executive Certificate in Human Resource Management from the Graduate School of Governance and Leadership in Accra.

Phyllis is a member of the Chartered Institute of Human Resource Management Practitioners (CIHRMP), Ghana and also the CSIR Administrators of Ghana (CAAG). She is currently the Head of Division in charge of Senior Members at the Head Office.



MR. AMEYAW A. NYAMEKYE (ESQ)

Mr. Ameyaw A. Nyamekye is the Corporate Head for the CSIR Legal and Intellectual Property Matters. He was appointed as a Legal Officer at CSIR on 1st October, 1995. Ameyaw has through dedication and hard work, risen through the ranks from a Legal Officer to a Principal Legal Officer (July, 2021). He holds an LLB certificate and an MA certificate in Comparative Literature all from KNUST.

As Corporate Head of CSIR Legal and IP Division, he provides legal advice to the Council through the Director-General, and develops innovative measures for addressing legal issues facing CSIR. He has also provided legal inputs in the development of the CSIR Intellectual Property Rights Policy. Mr. Nyamekye serves on all major Council Committees including Directors Management Committee (DMC), Executive Committee (EC) providing legal advice on critical issues.

He was called to the Bar in 2008.



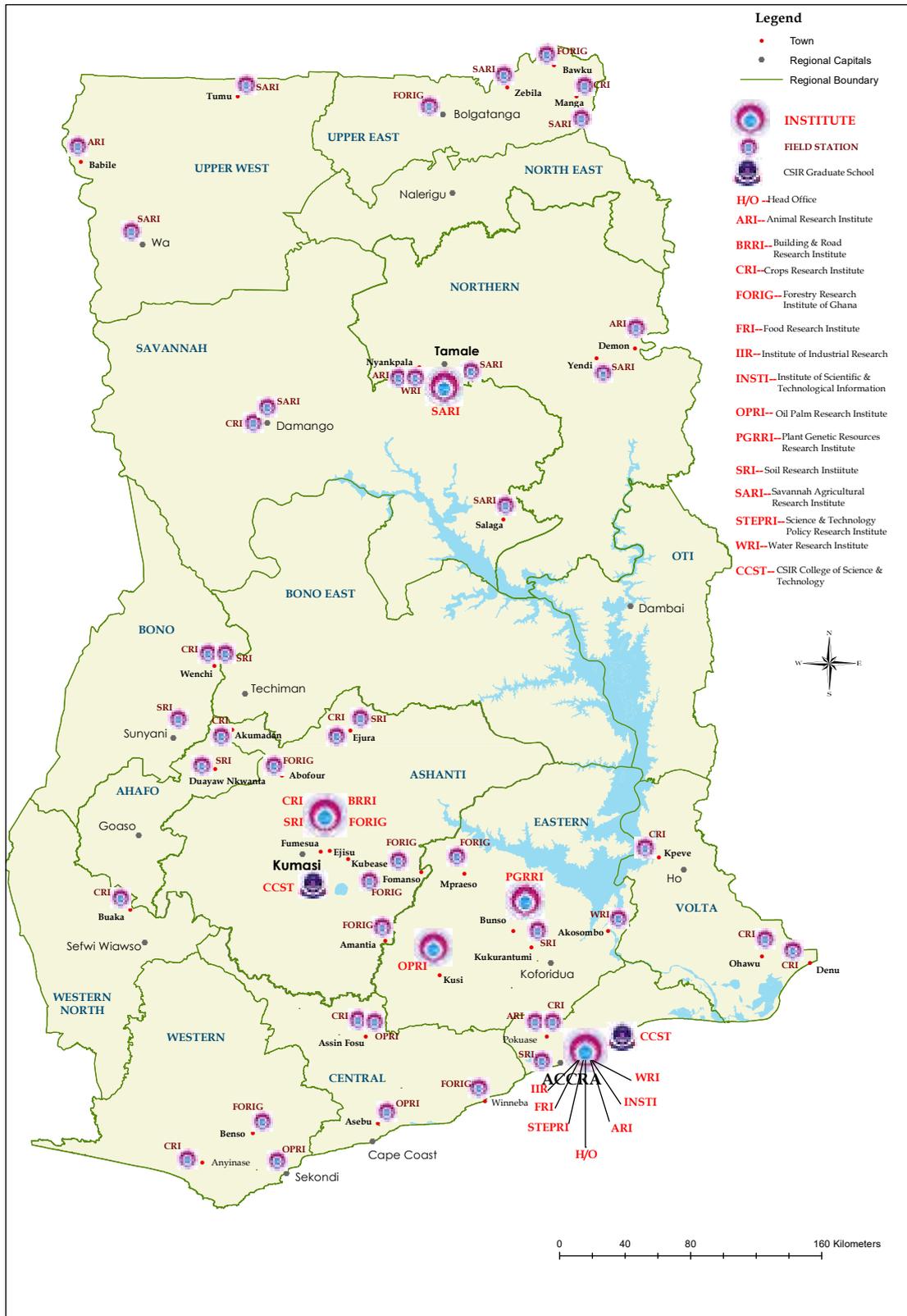
Some facts about bees and honey



1. Ancient Egyptians are on record to have been the first to use honey. Archeologists discovered honey in the tombs of the Pharaohs, which were estimated to be over 3,000 years. The honey was still in good state.
 2. Bees are social insects i.e they live in groups or colonies and exhibit a **caste system**.
 3. A standard beehive can contain anywhere from 10,000 to 60,000 individual bees.
 4. A beehive consists of a **Queen**, a few hundred **Drones** and a large number of **Workers**.
 5. The queen bee is the only reproductive female in the colony and lays about 1,500 eggs per day. The workers are also females but are not capable of laying fertilized eggs. The drones are males and their only role in the hive is to fertilize the queen. Drones mate with the queen only once (about three days) and thereafter they are of no real use in the colony.
 6. The colour, smell and flavour of honey can vary based on the geographical location, soil and plant(s) from which pollen and nectar are collected.
 7. Apart from its use as food and in beverages, honey can also be used to treat cuts, infections, colds, and more.
 8. Natural honey has a tendency to crystallize when the room temperature drops considerably or if left standing for a long time.
 9. It is important to note that crystallization of honey does not necessarily mean that it has been adulterated. Also crystallized honey does not mean that it has gone bad. However, adulteration of honey occurs within the society and so you must watch out!
- You may contact **CSIR- Food Research Institute** or **CSIR- Forestry Research Institute of Ghana** if in doubt about the quality of your honey.

OUR FOOTPRINTS

INSTITUTES & FIELD STATIONS OF CSIR - GHANA



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