COMMONWEALTH SCHOLARSHIPS

CSC Evaluation and Monitoring Programme

Soil Health in Bangladesh and Canada: Understanding Degradation, Heavy Metals, and Carbon Sequestration

Shayeb Shahariar

In Bangladesh, the integrity of the food chain is under threat from soil degradation. A healthy soil contains a minimum of 2 to 5% organic matter; however, according to the Soil Research Development Institute (SRDI), most soil in Bangladesh has very low (≤1%) to low (1 – 1.7%) organic matter. The continued degradation of soil in Bangladesh means that there is a rising reliance on nitrogen, phosphorous, and potash fertilisers, and a continuing risk of food insecurity in the region.

Furthermore, soil scientists are grappling with the challenge of carbon sequestration. Soils partly consist of decomposed organic plant matter, which allows them to sequester some of the carbon that plants absorb from the atmosphere during their lifecycle. If natural soils are converted to farmland, the carbon trapped in the soil can be released into the atmosphere as carbon dioxide. Whilst this process has the potential to contribute to global warming, it also presents an opportunity. According to MIT, soils could sequester over a billion tonnes of carbon annually. With proper management, they have the potential to serve as carbon sinks, removing carbon from the atmosphere and storing it safely underground.

In addition to these challenges, parts of Bangladesh are struggling with unsafe levels of heavy metals such as arsenic in the soil and water, a problem exacerbated by excessive phosphate fertiliser use, as this contains heavy metals. These metals, including arsenic, can enter the food chain and pose serious health risks to humans as they are toxic and can accumulate in the body over time, leading to heavy metal poisoning. This problem is not exclusive to Bangladesh; many countries worldwide face similar concerns.

These are the challenges that are the focus of Commonwealth Alumnus Shayeb Shahariar's work. Shayeb is an expert in soil biogeochemistry and sustainable soil management, and he employs these skills in countries around the world, including Bangladesh. In collaboration with the Bangladesh National Agricultural Research Institute, he is working with Bangladeshi researchers to support them in improving the quality of Bangladesh's soils. He also works as a Research Scientist with Agriculture and Agri-Food Canada, a Canadian government research institute where he researches climate resilient approaches to agriculture. He is also collaborating with Iwate University in Japan and the Chinese Academy of Sciences, where he explores how plants can be used to remove heavy metals from polluted soils (phytoremediation).

Shayeb Shahariar was awarded a Commonwealth Scholarship in 2012 to undertake an MSc in Environmental Management at Liverpool Hope University. Following the completion of his MSc, he went on to complete a PhD at the University of Saskatchewan in Canada. He is currently working as a Research Scientist at Agriculture and Agri-Food Canada, where he specialises in soil science and works across various projects investigating soil health and nitrogen use efficiency under diversified cropping systems. He is working in collaboration with the Bangladesh National Agricultural Research Institute on a project promoting sustainable farming practices leading to increased soil health and quality in Bangladesh. Under the project, the University of Saskatchewan will host 16 PhD students and 20 post-doctoral students from Bangladesh. In addition to this project, Shayeb also works in collaboration with Iwate University in Japan to understand how plants can play a role in removing toxic heavy metals from soils. In the future, he hopes to expand his work on Synchrotron-based soil spectroscopy and imaging by applying advanced techniques across Asia, Europe, and North and South America.

From Bangladesh to the UK to Canada: Learning across the Commonwealth

Shayeb became interested in soil science whilst studying for his undergraduate degree. Studying at the University of Dhaka, he completed a BSc in Soil Water and Environmental Sciences, followed by an MSc in Environmental Science. Later, he became a Scientific Officer at the Bangladesh Council of Scientific and Industrial Research (BCSIR). Even whilst completing his undergraduate and Master's degrees in Bangladesh, Shayeb was looking ahead to the future. It had been a lifelong dream of his to study in the UK, and he was looking for opportunities to continue his education. He began applying for scholarship funding, and in 2012 he successfully secured a Commonwealth Scholarship to study for an MSc in Environmental Management at Liverpool Hope University.

Shayeb completed his MSc in Environmental Management in 2013. This achievement proved to be a vital stepping stone on his career path. Even whilst studying at Liverpool Hope University, Shayeb knew that he wanted to continue his studies and apply for a PhD. Having already studied in Asia and Europe, he sought out opportunities to complete his PhD in North America. His UK study experience was essential to supporting this ambition; Shayeb believes his University of Dhaka MSc may not have been sufficient to make him a competitive candidate in the PhD application process:

> 'I would say, North American PhDs, they look for a very specific and mature student. The Master's, actually, the research work I did in Bangladesh, and also the publication, it was good, but maybe not good enough for competition to secure a full-funded PhD.'

Immediately upon the completion of his Master's, he applied for a PhD programme at the University of Saskatchewan in Canada. Shayeb credits the Commonwealth Scholarship for enabling him to secure this PhD. The prestige and reputation of the scholarship was one of the factors that enabled Shayeb to stand out in his PhD interview:

> 'Everyone knows about Commonwealth Scholarships. So, somehow, my supervisor got fascinated. I got that connection and also that trust.'

Shayeb secured a PhD offer that was conditional upon him completing his MSc at Liverpool Hope University.

Shayeb reflects that agricultural knowledge in Saskatchewan is highly localised to the Prairie region of Canada. He therefore believes that taking on international PhD students to study agriculture and the environment in the province requires an additional level of trust from supervisors. Shayeb believes that the Commonwealth Scholarship provided the additional level of trust and understanding that he needed to help him to secure the offer of a PhD. This trust was built on a mutual understanding of the Commonwealth:

> 'Who doesn't know the Commonwealth Scholarship? And also, the King is still the head of the state in Canada. I believe that trust and rapport were established through my Commonwealth Scholarship. It provides a strong connection to have a Scholarship in Canada.'

Shayeb's move to Canada was transformative, and he sees his Commonwealth Scholarship as a key step in enabling him to accomplish this:

> 'I would say the Commonwealth Scholarship fostered me to come into that place. I always appreciate it.'

Working in the glasshouse at the College of Agriculture and Bioresources, University of Saskatchewan.

At the University of Saskatchewan, Shayeb's PhD research fell under the Global Institute of Water Security (GIWS) and Agriculture and Agri-Food Canada's (AAFC) Research Affiliate Program, where he researched soil salinity, hydrology, nutrient management, carbon stocks, and biogeochemistry under different land use scenario in the Prairie Pothole Region. Whilst studying for his PhD, he developed skills in the field of soil spectroscopy and Synchrotron-based imaging. Spectroscopy can be used to assess the health and quality of soils, for instance, by assessing the proportion of the soil that is made up of organic matter.

Working with Agri-Food Canada to understand sustainable approaches to farming in the Canadian prairies

During his PhD, Shayeb was offered the opportunity to work with Agri-Food Canada as a Research Assistant and, lately, as a Research Scientist under the Postdoctoral Research Program. Agri-Food Canada is a Canadian federal government research institute which aims to support Canadian agriculture through initiatives that promote innovation and competitiveness. Shayeb was invited to join this organisation as a soil expert. He joined a team of researchers working in more than 20 centres across Canada. Initially, Shayeb was brought on board to support a research project based in Indian Head, a small town located 300km south of Saskatoon in Saskatchewan. The project examined wetland soil biogeochemistry, focusing on climate-related issues including greenhouse gas emissions, carbon sequestration, and the relationship between land use and hydrology and salinity. Shayeb worked on this project as part of his PhD research.

Collecting water samples from wetlands at Indian Head Research Farm, Saskatchewan, for Agriculture and Agri-Food Canada.

This initial contact with Agriculture and Agri-Food Canada led to further opportunities for Shayeb. He was recognised for his skills and experience, and after the completion of his PhD he was invited to work on a larger federally funded research project. This project works across the three Canadian prairie provinces: Alberta, Saskatchewan, and Manitoba. Through the project, Shayeb works to understand how diversifying cropping practices can improve the resilience of the Canadian agricultural industry in the face of a changing climate:

> 'In the Canadian prairies, canola and wheat are two major crops that dominate the cropping systems. But consider what you can include in that cropping system, like leguminous crops such as pulses, mustards, flax, and different specialty crops such as quinoa, sunflower, etc. Diversify the system to fight with the climate change.
>
> I'm evaluating how rotating these diverse crops into the existing cropping systems is helping to maintain productivity, improve nitrogen use efficiency, and address the climatic variability across the prairies.'

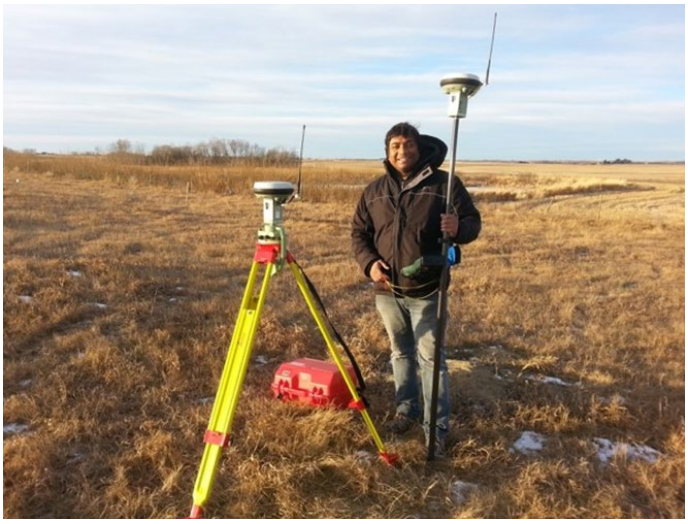
For Shayeb, the importance of this project is twofold. Whilst he is working to secure the Canadian agricultural sector in the face of the changing climate, he is also examining the ways in which the impact of the sector on the climate can be reduced and uphold soil health. Through his research, he encourages a balance between productivity and climate-conscious farming:

> 'We have to be really careful about choosing a cropping system and diversify it. How we can better manage between our agricultural productivity and also soil health and the environment. Agriculture versus environment, so we have to balance.'

Conducting soil sampling in the field at Indian Head Research Farm, Saskatchewan, for Agriculture and Agri-Food Canada.

With this in mind, Shayeb is looking at the efficiency of nitrogen use, specifically regarding the planting of canola. The use of nitrogen fertilisers is a key issue in relation to climate change. When nitrogen fertiliser is added to soils, reactions take place that result in the release of nitrous oxide gas. According to the UN, nitrous oxide is 300 times more potent in warming the atmosphere than carbon dioxide, and the gas remains active for more than 100 years. For Shayeb, this is a key area of interest, as it feeds into Canada's climate change goals:

> 'One of the major drivers in Canada right now is that by 2030, we want to reduce by 30% the greenhouse gas emission from 2020. So, it means we have to reduce the nitrogen fertiliser application into the soil. So, nitrogen use efficiency is one of the biggest things.'



Completing an RTK-GPS survey of field sites for a Digital Elevation Model (DEM).

Shayeb is optimistic that his work on this project will drive the Canadian government to commit to policy changes toward diversified cropping systems:

> 'I think the project I'm working on will drive a decision as a federal government decision in Canadian agriculture. We should diversify our cropping systems by modifying the crop rotation to adapt to climate change.'

Giving a talk about ongoing research projects to farmers and industry professionals at Agriculture and Agri-Food Canada's field day.

Seeking Development Impact: Working with the Bangladesh Agricultural Research Council (BARC)

Although Shayeb began his career working on projects in the Canadian prairies, he knew that the skills and techniques that he had acquired through his MSc and PhD had the potential to be transformative in other countries. Shayeb recognised that many Bangladeshi scientists emigrate, resulting in a shortage of trained professionals who can implement change in the country. Despite no longer living in Bangladesh, he was driven by a desire to employ his skills to support his home country:

> 'I think it's time to pay back your country. Maybe I can train with my knowledge, whatever I got, and then I can give my knowledge to Bangladeshi scientists, and they can do their best. So, for sustainable agriculture, food security, soil security, and soil health.'

Shayeb credits his Commonwealth Scholarship for fostering his commitment to development impact:

> 'I always follow the Commonwealth Scholarship Commission's activities and focus on the impact of Commonwealth Scholars worldwide.'

It was with this goal in mind that Shayeb sought out opportunities for international collaboration. It was Shayeb's PhD supervisor who first pointed him to a research project working with the Bangladesh agricultural sector through a partnership with the Global Institute for Food Security (GIFS) through the University of Saskatchewan and BARC. In Saskatchewan, agricultural trade with Bangladesh is an important industry. According to the government of Saskatchewan, the province exported $4.3 billion worth of agri-food goods to the Indo-Pacific region in 2023, and Bangladesh makes up a significant proportion of these exports. Products exported include lentils, peas, chickpeas, wheat, and potash, a potassium-based fertiliser. This trade relationship provides a strong incentive for Bangladeshi and Canadian agricultural researchers to work in collaboration.

Within Bangladesh itself, the agricultural sector has great potential. Many of the growing conditions in Bangladesh are ideal; the soil is soft, there is sufficient moisture, and the temperature is good for growth. However, the sector faces many challenges, including soil nitrogen, phosphorous, and potassium shortages and low soil organic matter. Shayeb knew that work was needed to secure the food system in the face of Bangladesh's growing population and the increasing threat of climate change:

> 'Another thing is the population pressure and climate change. There is a population pressure, lots of population growth, and increasingly less and less land. There is extreme heat, extreme precipitation, and that's shifting the cropping patterns.'

A group of soil scientists from the Soil Resource Development Institute and the University of Saskatchewan visiting a soil site in Gazipur, Bangladesh.

Furthermore, the quality of the soil in Bangladesh poses problems for the industry. The proportion of soil that is organic matter in Bangladesh is extremely low:

> 'Bangladeshi soil often has less than 0.5% organic matter. Ideally, in soil science, as we say, it is better if you have 2 to 5%. We have higher 2-5% organic matter-rich prairie soil in Canada. But in Bangladesh, we have less organic matter due to soil organic matter degradation, fewer crop residues returned to the soil, higher temperature and moisture that favours decomposition, washing of carbon due to flooding, and washing the carbons to the seas.'

Shayeb knew that this was an area in which his expertise could be applied. He knew that Saskatchewan, a leader in agriculture, had valuable skills and tools that could be applied in Bangladesh:

> 'You may be aware that Bangladesh is a developing country that faces challenges in food security and soil health maintenance. They need new technology and want to understand how Saskatchewan made this possible.'

In partnership with the BARC, he sought to support Bangladeshi researchers investigating the soil quality and health in Bangladesh. The BARC operates under the Bangladesh Ministry of Agriculture and is responsible for strengthening Bangladesh's national agricultural research capability.

Examining tropical red soil from the Madhupur Tract in Gazipur, Bangladesh.

Shayeb identified his work in Bangladesh as a key change that he has been able to affect in his community as a result of the Commonwealth Scholarship:

'I have had the opportunity to get involved in a research partnership with the National Agricultural Research Institutes in Bangladesh through the Bangladesh Agricultural Research Council.
During my post-doctoral work, I became involved with the Global Institute for Food Security at the University of Saskatchewan and became a part of the collaboration with the Bangladesh Agricultural Research Council.

This collaborative research project aims to enhance the research capabilities of Bangladeshi researchers in four thematic research areas of plant genomics and phenomics, post-harvest food loss prevention, soil water management, as well as soil health and quality, ultimately contributing to sustainable agriculture and food security in Bangladesh. The capacity-building project seeks to empower agricultural researchers in Bangladesh by providing them access to advanced tools, innovative techniques, and essential knowledge needed to advance their research, including soil and agricultural practices. By enhancing their skills and expertise, these researchers will be better equipped to tackle challenges in the agricultural sector and contribute to sustainable agriculture in the region.'

Shayeb felt that knowledge exchange and capacity building needed to be the cornerstones of this collaboration. He sought to pass on the skills and knowledge that he had acquired through his MSc and PhD. Plans are currently in place to host Bangladeshi researchers to study at the University of Saskatchewan, working across multiple different subject areas:

> 'We hope that around 16 PhD students and 20 postdocs will come from Bangladesh. They are all researchers from various National Agricultural Research Institutes who will join the University of Saskatchewan for advanced education and training. We have four research themes covered. This program focuses on plant genomics and phenomics research, which includes post-harvest food processing and handling, as well as soil water management and soil health quality, in which I am involved with.'

Shayeb has taken on the responsibility of co-leading the team studying soil health and quality. In this part of the project, four researchers will focus on different aspects of soil health and quality assessment:

> 'We expect to get four PhD students and two post-doctoral fellows in different sub-thematic areas under the soil health and quality theme. From soil microbiome and soil health, soil nutrient management, coastal saline soil management, and conservation agriculture. We aim to enhance the capabilities of scientists for future research by utilising the modern and advanced technologies employed here at the University of Saskatchewan.'

Teaching field courses in the Canadian prairie, focussing on Chernozemic grassland soils.

Through this collaboration, Shayeb has been able to share knowledge of approaches that were already widely adopted in Saskatchewan which could be directly applied to the Bangladesh context. For example, one key conservation agriculture strategy involves no-till farming, leaving the 'stubble' of a crop in the soil after harvesting so that it can decompose in the soil. This increases the soil's level of organic matter. This and other strategies could be readily employed in Bangladesh:

> 'We need to return most of the stubble, including the lower part of the pants, the roots, and other crop parts, leaving them in the field to practice conservation agriculture. That's what we are doing in Saskatchewan.'

In this strategic research project, Shayeb aims to collaborate with Bangabandhu Sheikh Mujibur Rahman Agriculture University (BSMRAU) in Gazipur City, Bangladesh. In collaboration with this university, the College of Agriculture and Bioresources at the University of Saskatchewan aims to establish a dual degree programme with the BSMRAU. The degree programme will be focussed on the development of Bangladesh agriculture.

Collaborating with the Netherlands on the Bangladesh Delta plan

Shayeb's capacity building work in Bangladesh led to other opportunities for international collaboration. For example, he has been collaborating with a team of researchers from the University of Wageningen in the Netherlands. The Dutch government has been heavily involved in Bangladesh's agriculture and water management sector, and they were instrumental in the development of Bangladesh's Delta 2100 plan. This plan, approved by the government of Bangladesh in 2018, was developed in close consultation with the Netherlands and lays out plans for the long-term management of Bangladesh's river delta. The University of Wageningen has partnered with the University of Saskatchewan to work in Bangladesh, and the two universities recently held a joint symposium. Shayeb has been called upon as an expert in soil salinity, and he is working in partnership with researchers at the University of Wageningen to understand soil salinity and saline soil management in Bangladesh's coastal belt.

Beyond Bangladesh: Heavy metals in Japanese soil

In addition to his work in Bangladesh, Shayeb is involved in multiple other small-scale projects that include international collaboration. Since he has studied around the world, Shayeb is uniquely well-positioned to facilitate international collaborations:

> 'I did my undergrad in Asia, my Master's in Europe, and my PhD in North America. Look, I covered half of the whole world.'

For example, he is currently working in collaboration with the Institute of Soil Science, the Chinese Academy of Sciences and Iwate University in Japan on a project focusing on the presence of heavy metals in soil. Over time, heavy metals like lead, cadmium, caesium, mercury, and arsenic can accumulate in soils. If untreated, these metals can make their way into the food chain, where they can pose a threat to human health. In Japan, caesium deposited during the Second World War is the main heavy metal of concern. In collaboration with Iwate University, Shayeb is investigating methods by which caesium can be safely removed from the soil by being absorbed into plants:

> 'I want to examine how caesium is absorbed by the roots of Arabidopsis model plants and how it is removed. I want to image that using a Synchrotron technique. You can image the elements entering the roots. It's really cool science.'

This is a further example of how conservation farming techniques can help to secure food chains.

Visiting a gold mine site contaminated with heavy metals in Quebec, Canada, to study phytoremediation techniques.

Shayeb identifies the opportunity to collaborate internationally as the most significant change he has experienced as a result of his Commonwealth Scholarship:

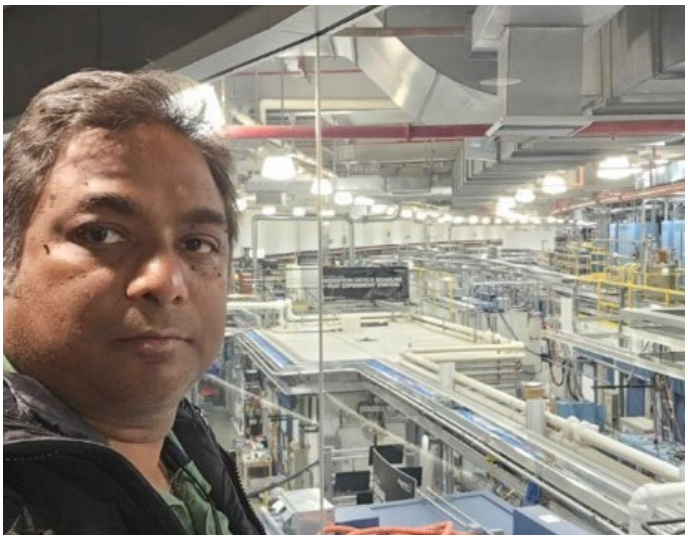
'I was able to explore the world's most advanced research tools and techniques (for example, Synchrotron science and techniques) from these regions, which helped me become an international researcher and collaborate internationally with the reputed researchers in my field.

For example, I have a research collaboration with the Institute of Soil Science, Chinese Academy of Science; Iwate University, Japan; Advanced Photon Source, Argonne National Laboratory, USA; Environmental and Molecular Science Laboratory, Pacific Northwest National Laboratory, USA, and Canadian Light Source, Canada, to work with Synchrotron techniques and its application in soil and plant sciences.'

Using cutting-edge technologies to understand carbon sequestration in soil

Although many of Shayeb's research projects focus on the big-picture issues of climate change and food security, he is also interested in understanding the soil biogeochemical processes that drive changes in soil health. At the University of Saskatchewan, Shayeb has access to Canada's only Synchrotron. A Synchrotron is a particle accelerator that produces different kinds of light in order to study the properties of materials at a molecular level. Shayeb is using the Synchrotron to gain a better understanding of the process by which carbon is sequestered and stabilised in soils.

> 'Why does organic matter sequester, and what is the connection with soil minerals? It's a field of biogeochemistry and advanced frontier science that I am always eager to explore.
>
> What is happening in the soil? How can carbon be better stabilised? I am focusing on land use practices and soil management to enhance soil health and boost soil organic carbon sequestration.'



Visiting the Advanced Photon Source at Argonne National Laboratory in Illinois, USA.

Using this advanced technology, Shayeb is working to understand the molecular processes that inhibit or enable carbon sequestration in soils. By investigating this, Shayeb hopes to gain a better understanding of why some soils sequester carbon more effectively than others. This is knowledge that has the potential to be applicable worldwide, including in Bangladesh:

> 'You can see it linking back to Bangladesh. In the soils of Bangladesh, we don't have much calcium and magnesium there. So, might that be one of the factors affecting organic matter stabilisation and thus sequestration?'

Currently, Shayeb is working in collaboration with researchers from the Institute of Soil Science, Chinese Academy of Sciences, Canadian Light Source, Canada, Argonne National Laboratory, and Environmental Molecular Science Laboratory, USA, using the advanced Synchrotron techniques to investigate the role of Calcium and Iron in organic matter stabilisation and sequestration.

Looking ahead: Plans for the future

Looking ahead, Shayeb hopes to be able to use his skills in further international contexts. Whilst so far, he has focused predominantly on his work in Canada and Bangladesh, in the future, he hopes to conduct similar projects in Europe, South America and Africa.

For Shayeb, all of his projects, whether based in Canada, Bangladesh, or elsewhere, share a common goal. Across all of his work, he hopes to apply his research in order to help secure food systems, particularly in the face of the growing threat of climate change:

> **'Food security is a global issue. Climate change is everywhere. And everyone wants a sustainable agricultural production system to ensure food security and address climate change. That's the broader goal.'**

Find out more about Shayeb Shahariar's work:
https://orcid.org/0000-0001-6559-0548

https://scholar.google.ca/citations?user=PH3i1tEAAAAJ&hl=en

Read Shayeb's most recent publications:

Short rotation willow to restore degraded marginal land and enhance climate resiliency within the Prairie Pothole Region: A potential nature-based solution:
https://www.sciencedirect.com/science/article/pii/S277241152400020X?via%3Dihub

Groundwater table prediction and seasonal variation influenced by short rotation willow plantation on marginal riparian lands of the Prairie potholes in Canada:
https://www.sciencedirect.com/science/article/pii/S2352009424001093?via%3Dihub

Elevated salinity and water table drawdown significantly affect greenhouse gas emissions in soils from contrasting land-use practices in the prairie pothole region:
https://link.springer.com/article/10.1007/s10533-021-00818-3

More about the Canadian Light Source a Synchrotron research facility at the University of Saskatchewan:
https://www.lightsource.ca/index.php