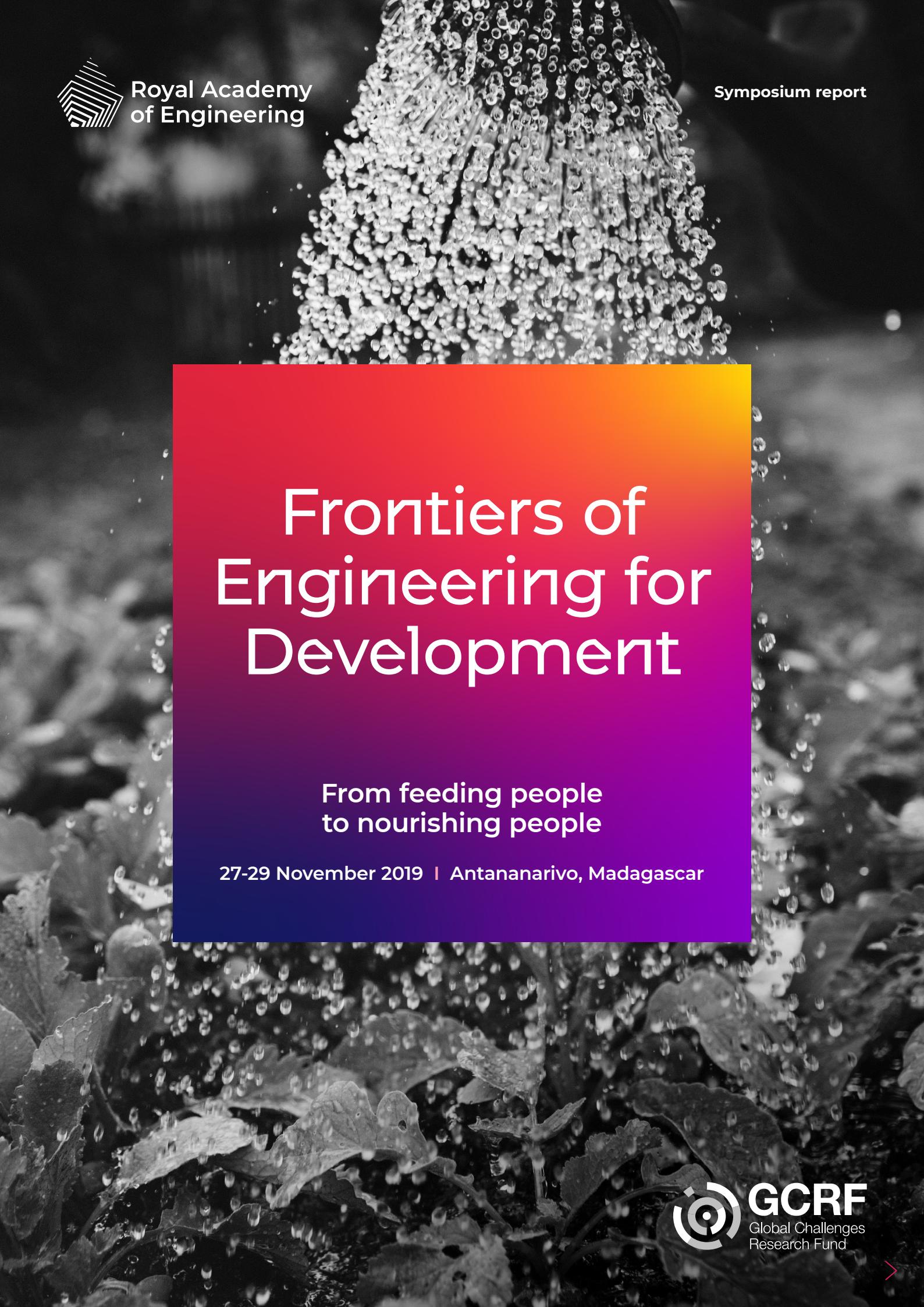

Royal Academy of Engineering

Symposium report

Frontiers of Engineering for Development

From feeding people to nourishing people

27-29 November 2019 | Antananarivo, Madagascar

GCRF
Global Challenges Research Fund

Royal Academy of Engineering

Introduction to Frontiers of Engineering for Development

Frontiers of Engineering for Development brings together 60 of the best early- and mid-career researchers and practitioners from industry, academia, NGOs and the public sector in multidisciplinary workshops that address fundamental development challenges.

The objectives of these symposia are to encourage collaborative work that addresses international development challenges and to promote cross-disciplinary thinking among the next generation of engineering leaders.

Competitively allocated seed funding is available to strengthen the collaborations developed at the symposia.

Contents

From feeding people to nourishing people

The eighth Frontiers of Engineering for Development event took place between 27 and 29 November 2019 in Antananarivo, Madagascar. This event was organised in partnership with Welthungerhilfe (WHH) Madagascar and was the second symposium under the overarching theme 'From Recovery to Resilience'. Sixty delegates from different disciplines and countries came together to discuss what needs to happen in order to move away from simply feeding people to nourishing people and how to achieve this transition in a sustainable and equitable manner globally.

The event was co-chaired by Dr Tahrat Shahid and Professor Noble Banadda. Dr Shahid is the GCRF Challenge Leader on Food Systems and has over a decade of international development and policy research experience in a variety of contexts. Her research interests include agricultural development, food security, nutrition, gender, and the politics of religion. She previously worked as a financial analyst at Morgan Stanley and held various analytical positions at the Central Bank of Turkey as well as the World Bank. Additionally, she focused on impact evaluation at Oxford Policy Management, including evaluations of agricultural cooperatives in Rwanda and mobile banking in Kenya. Prior to joining GCRF, she also led research for advocacy on agricultural policy, food security, and nutrition in sub-Saharan Africa for the ONE Campaign's Global Policy Team in London.

Professor Banadda is Head of Agricultural and Biosystems Engineering at Makerere University in Uganda. He earned his doctorate degree in chemical engineering at Katholieke Universiteit Leuven, Belgium. He then followed postdoctoral professional training at Massachusetts Institute of Technology (MIT). He is a member of the Malabo Panels of Experts; a fellow of the Uganda National Academy of Sciences; a council member of the Pan African Society for Agricultural Engineering; a member of the Makerere University Senate; an adjunct professor at Iowa State University (USA); a Research Fellow at Clare Hall at University of Cambridge (UK); a college member of the UKRI GCRF programme; and a candidate for extraordinary professor at Wageningen University (Netherlands).

Sixty delegates from different disciplines and countries came together to discuss what needs to happen in order to move away from simply feeding people to nourishing people

This report summarises the key points from the discussions and activities that took place at the symposium. It aims to capture the wide variety of knowledge, experiences and insights that were present.

The Academy would like to thank everyone who made the symposium such a success, especially the event chairs, the GCRF, and the group of talented, experienced and engaged delegates who came together in Antananarivo to help the transition from feeding people to nourishing people.

Agricultural revolution

How do we ensure it is driven by sustainability and system innovation?

Session co-chairs

Bruce Grieve, Director of the e-Agri Sensors Centre at the University of Manchester

Presentations

1. e-Agri: integrating sensors and electronic engineering to deliver networked, low-cost, smart agriculture

   Bruce Grieve, University of Manchester

2. Novel digital technologies to transform food production

   Simon Pearson, University of Lincoln

3. The role of vertical farming in enhancing nutrition security

   Sheila Etam, Ukulima Tech

With the growing demand for production of food to feed the increasing global population, there is a need for a revolution in agriculture. There is no denying that novel data-driven technologies are already transforming agriculture. High hopes are placed on decreasing cost of innovations in the sector, which would enable higher rates of crop production and make this revolution more sustainable and equitable. This session discussed some of the groundbreaking innovations, both technologies based and not, that have been revolutionising the agricultural sector across the globe.

Bruce Grieve from the University of Manchester introduced the unique concept of e-Agri, which seeks to inform the electronics and information technology community of the distinctive needs of modern agronomy and food science to help deliver future sustainable agriculture and food systems. His presentation introduced the concepts and motivations behind e-Agri and illustrated these with a series of research example from the e-Agri research group based at the University of Manchester. Bruce introduced various advances in agri-tech, related to: sub-surface impedance tomography; networked fungal pathogen sensing; mass producible low-cost wireless nodes for soil monitoring; high-sensitivity graphene-based protein-receptor biosensors; and close-proximity hyperspectral imaging. These technologies are used to show moisture around plants and of soils, which then helps to develop access to required elements or to verify plant disease models to cut the time of inspection and allow for speedier treatment. Crucially, these technologies are now relatively cheap and can communicate over considerable distance (<200 km). Although cost no longer presents a barrier to rolling these technologies out, making sure they are context-specific for each country/crop remains important.

The examples presented exemplified how engineering research can be translated from non-agriculture uses, be re-engineered, and then integrated with plant science and agronomy research to create novel ‘smart farming’ technologies.

The second presentation from Simon Pearson from the University of Lincoln discussed the potential to develop a range of low-cost digital technologies that can transform food production in both high and low- and middle-income countries. Establishing 'digital food systems' would contribute to achieving multiple UN Sustainable Development Goals, from eliminating hunger to promoting decent work and economic growth. More specifically, new technologies and digital systems can have positive impact on produce traceability and/or verification, waste reduction and on growing rates of obesity.

Technologies based on artificial intelligence, Internet of Things, connected supply chains, and distributed ledger technologies are already improving crucial aspects of food systems, such as inventory control, traceability of financial transactions and goods, as well as optimisation of resources to reduce food loss and waste. A good example of cross-sector opportunity was trialled by the Tesco supermarket chain in the UK where the refrigerators could help power the National Grid by creating a 'virtual battery' with the help of Internet of Things technology.

Simon showed video footage of various robots that can help optimise aspects of the food systems, such as moving things on site, sensing and mapping aspects of farming such as irrigation, picking up fruit as well as crop counting for crop forecasting and counting infestation rates and spotting them early in order to treat them.

Several challenges about the discussed technologies were highlighted by the group of delegates. There was significant scepticism that solutions based on robotics and smart technology in their current form would be suitable and/or achievable for smallholder farmers in developing contexts. Additionally, the importance of education and skills development was highlighted as knowledge and skills can be distributed unevenly within countries.

Next, Sheila Etam from Ukulima Tech shared her insights on the role of vertical farming in enhancing nutrition security. Over 10 million people in Kenya suffer from chronic food insecurity and poor nutrition. Additionally, land degradation cannot support healthy food production and produce quality is also a longstanding issue. Ukulima's solution is easy-to-maintain vertical gardens that can replace farming over large land areas. Some of the benefits include low-cost, year-long vegetable production making it affordable for community members to getw micronutrients and improve nutritional value. This solution is easy to use and can be used by everyone as it does not require any farming experience. It also does not require any chemical inputs since it is based on a pheromone trap. Most of Ukulima's existing set ups are urban residential areas and community gardens, which have an added value of increasing social elements of vertical farms and skills development. Ukulima Tech is now developing a monitoring system to improve the technology to monitor and track water inputs. To ensure access to food production is no longer a source of conflict, Ukulima Tech is scaling up in areas where there are active conflicts and community disruptions.

The presentations were followed by an interactive activity that mapped sustainable food chains for healthy people. Delegates were asked to map the elements, aspects and stakeholders that constitute a sustainable food system that contributes to healthy, nutritious diets. Each group formed a circle of approximately 20 people with the 'farmer' in the centre who held a ball of string. The delegates were then asked to throw the ball to each other while thinking of a necessary element of a food system, mapping the connections between each of the elements.

Delegates then reflected on the maps they created. There was a consensus that the number of connections was surprising. Some more obvious elements of food systems such as water, nutrients, technology, and infrastructure were linked up multiple times whereas seemingly less obvious aspects such as skills, training and consumer-related elements tended to be overseen.
This exercise highlighted the importance of an integrated approach in resolving some of the challenges in ensuring sustainable and equitable food systems. Policy coherence was highlighted as especially important.

Healthy diets

Can we improve nutrition globally by eating more sustainably?

Session co-chairs

Bibi Giyose, UN Food and Agriculture Organisation and African Union Development Agency, and Mangani Katundu, University of Malawi

Speakers

Rojee Suwal, Hellen Keller International
Trust Beta, University of Manitoba
Kahit Hien, FasoPro

This session was held as a panel discussion. Over 820 million people worldwide are hungry and two billion suffer from micronutrient deficiency[1]. Hence, it is important to not talk about food production in isolation but link it to healthy dietary outcomes. Climate change is putting strain on our food systems. When we talk about the fourth industrial revolution it is important to recognise that much of the African continent has not seen the second one – there is a need to leapfrog. There is a difference between feeding people and nourishing people – the latter ensures child growth and productive populations. Undernourishment, micronutrient deficiencies and obesity are a triple crisis. High salt and sugar foods have become industry norms. The challenge is that nutrition is a cross-sectoral issue and needs policy coherence and interdisciplinary programmes.

The session co-chair Mangani agreed that the shift to healthy diets globally is multidisciplinary in nature. For the shift to be successful, there is a need for:

- Production of food in a healthy environment
- Post-harvest management to reduce loss in quality and quantity
- Ensuring nutrient availability in food and their maximisation
- Microbial health from food.

The speakers then introduced themselves and their work. In her introduction, Rojee Suwal from Hellen Keller International highlighted that no country is free from malnutrition problems. Food security and nutrition is a concern of every citizen as food is key determinant of malnutrition. We need to focus on the 'one health' approach and need to consider human, plant, animal, and planetary health at the same time. Rojee presented the aims of the Suaahara II programme run by the Nepal government, which consists of a nutritional plan and an agricultural strategy. Although Nepal has made remarkable progress in terms of decreasing rates of stunting, wasting and underweight children, there is much work still to do to end hunger and malnutrition. The focus of the Suaahara II project is on implementing 'nutrition sensitive agriculture' over a five-year period in 42 districts to reach over 900,000 households. It is multi-sectoral and emphasises collaboration and coordination across sectors – agriculture and livestock, water, sanitation and hygiene, health, social inclusion, local governance, and behaviour change. The project improved access to diverse and nutrient-rich foods by women and children improving their dietary diversity and thus their nutritional status.

2 https://globalnutritionreport.org/reports/2017-global-nutrition-report/

Some of the programming principles for nutrition sensitive agriculture include:

- Prioritising production diversity
- Low-cost but easy to adopt climate smart technologies
- Year-round access to quality foods
- Developing local extension capacity on resilient food
- Targeting 1,000 days period.

The programme was implemented on three levels: household, community and structural. Although the project was successful and there is evidence to support these intuitive pathways, we need to be careful because pathways are complex, context-specific and do not operate in the same way. Hence, we need to analyse drivers of food systems, which are associated with nutritional outcomes such as seasonality, climate change, natural disasters, socio-cultural factors such as food taboos (for example poultry rearing and egg consumption), socio-economic aspects (limited risk bearing), and access to infrastructure.

The following speaker, Trust Beta, described her work on nutrient phytochemical and non-nutrient phytochemical interactions and identifying them. She focuses on characterising the metabolites (for example digested forms) of foods and their bioactivities within the body, exploring which are healthier than others. What are the identities of plant chemicals following digestion and gut fermentation of food? Do mechanisms differ between digested and undigested forms?
Her motivation for the work on plant-based foods is to optimise release of nutrients and to better understand the impact of phytochemicals for health promotion. Identifying the phytochemicals and mechanisms by which they act can then lead to assessing and redressing nutrient claims. The next step is looking to link the promotion of optimum production systems to maximise the health-promoting phytochemicals. This research is not without its limitations – even identifying phytochemicals poses a major challenge, let alone the many metabolites. Additionally, there is a lack of standard approaches to documenting efficacy of nutrients and it is challenging to study interactions of nutrients when we consume mixtures of foods together.

Over 820 million people worldwide are hungry and two billion suffer from micronutrient deficiency[1].

Following her presentation, Trust was asked to give examples about some of the processes she has examined and the impact. She focused on the example of maize, which can be processed in various ways – roasted or boiled, dried and boiled, grinded and cooked as a thick porridge. Interestingly, when assessed for certain vitamins, if children were given roasted maize, the vitamin content was much lower than if given in boiled or porridge form. This example highlights the importance of understanding the food processes that deliver the bioavailability of nutrients. There should be more focus not only on eating certain foods but also on eating these foods processed in certain ways.

The third speaker, Kahit Hien, shared his story of setting up an enterprise aimed at caterpillar production as a food resource. Kahit wanted to start a business that would make a difference for his community. He realised there might be a business opportunity in scaling up the consumption of caterpillars, which have been a part of his own diet since he was five years old. To make sure that the local population could generate income, he was determined to find a market for the caterpillars that were collected by the community. Since 2014, 200 women have been trained in caterpillar collection and the production has increased from 2 tonnes per year to 12 tonnes. Caterpillars are high in protein and rich in fatty acids like Omega 3. These nutritional benefits need to be recognised and more attention should be given to how we can use these resources to improve our food systems. In addition, insect farming is low-carbon, which could contribute to decarbonising agriculture.

Delegates asked Kahit about marketing insect-based protein to people who are sceptical – what strategy can we take towards changing taboos around eating food that is perceived as 'unacceptable'? Kahit highlighted the importance of communicating the nutritional value of caterpillars. People are unaware they can get the most important nutrients from other types of food than the ones they are used to – changing this requires nutritional education. Design of the product needs to be appealing and diversity of products – for example biscuits, protein bars, powders – can be very helpful. The target audience should be younger generations as they are not only bolder and more willing to try new products but can also convince their parents.

Several cross-cutting issues were then highlighted by the delegates in the lively discussion. For example, there is a need to change retail practices in terms of less emphasis on homogeneity, which often does not allow for the variety of products that can offer better nutritional outcomes.

2 https://globalnutritionreport.org/reports/2017-global-nutrition-report/

The need for recognition of investing in nutrition was also highlighted – for every $1 invested in nutrition there is a return of $16-$18[2].

More attention needs to be given to the role and relevance of indigenous biodiversity in food systems across the world as there is a lot more variety than the common staples of rice, maize and similar crops. There is a lot of emphasis on climate change in relation to food in the West and moving to more plant-based diets but how does this translate into contexts of malnutrition and food scarcity? The need for recognition of investing in nutrition was also highlighted – for every $1 invested in nutrition there is a return of $16-$18[2].

The delegates were then asked what crops or food products within their countries might be commercialised. The answers included Andean potatoes from Peru, which have lots of colours and functional properties that need more research. Several individuals mentioned seawater farming and plants such as sea wheat, sea lavender and samphire. An added value of these plant species is that they sequester carbon when they grow, which could contribute to lowering carbon emissions. Other answers included indigenous fruits, sweet potato leaves, black soldier flies, traditional rice varieties, and other insects such as larvae.

The second question asked delegates to share their own experiences of barriers to accessing healthy diets in their individual countries. Consumer perception and decision-making based on appeal (often defined by marketing and driven by large advertising budgets of multinational corporations) rather than nutritional values were highlighted. However, the lack of appealing healthy and highly nutritious products could be a barrier from the consumer perspective. Socio-economic and socio-cultural factors such as lack of family spending power, lack of information in schools, cultural perceptions, and the increasing rate of urbanisation, which changes diets for the worse, were mentioned. There are also challenges related to food production such as seasonal availabilities and contamination with micro-toxins and pesticides. Finally, non-standard produce can pose processing challenges and novel foods might require novel preservation and processing techniques, which might negatively affect uptake by individuals.

To sum up, intervention to improve diets need to:

- Be context-specific
- Address perceptions
- Enable policy development and policy coherence
- Equip and empower people
- Understand agriculture to nutrition pathways.

Food loss and waste

How do we tackle losses and waste of foods already produced?

Session co-chairs

Annie Chimphango, Stellenbosch University, and Isa Kabenge, Makerere University

Presentations

1. Quantification of food loss and waste in different regions in sub-Saharan Africa and innovation of bio-waste processing technology

   Tilahun Seyoum, University of Kwazulu-Natal

2. How can we generate money from lost and wasted food?

   Duncan Mbuge, University of Nairobi

3. Tackling food waste with bio packaging

   Julien Lepine, Université Naval

4. Nourish and re-nourish: circular nutrition for nutrition security?

   Madalina Neascu, University of Aberdeen

Food loss and food waste (FL&W) represents food that is produced for consumption but never arrives or reaches the consumer in a state too poor to consume. Globally, over one-third of the food produced for consumption is lost or wasted at different points in the food value chain from farm to fork[3]. This can be during production, post-harvest, processing, distribution, and/or consumption. The problem is caused by many complex factors that emanate from within, as well as outside, the value chain. Consequently, FL&W exacerbates food insecurity and poverty in poor communities because of the reduction in real income for all consumers. This is especially true for the poor, who devote a high percentage of their disposable income to staple foods.
In addition, FL&W is one of the major contributors to greenhouse gas emissions in developed countries. Mitigation measures have been less effective and inefficient because factors that constitute FL&W are poorly defined. Furthermore, there is lack of in-depth understanding of the contributing factors and their synergetic effects, which affects accurate quantification of FL&W and systematic implementation of appropriate measures. There is a need for a comprehensive assessment of the contributing factors, such as the effectiveness and efficiency of technical and non-technical FL&W interventions at various stages in the value chain. Both socio-economic and environmental point of views should be considered.

The presentations in this session considered FL&W causes from different perspectives, including economic, nutritional, environmental, and engineering. They also looked at current mitigation measures and barriers and the opportunities for further research.

The first presentation from Tilahun Seyoum focused on the issue of quantification of FL&W and how to create value from what is currently wasted. Food loss in the food chain is caused by agricultural production or post-harvest losses caused most likely by transportation and storage or processing. On the other hand, food waste is caused during distribution or consumption, for example by poor storage or transportation

3 www.fao.org/3/mb060e/mb060e.pdf
4 www.fao.org/3/mb060e/mb060e.pdf

Globally, over one-third of the food produced for consumption is lost or wasted at different points in the food value chain from farm to fork[3].

facilities, poor packaging, lack of consumer planning or best before dates. There is massive (1.3 billion every year) FL&W globally[4] due to different factors, such as technical issues, economic factors, business considerations, and human behaviours and attitudes. Tilahun presented graphs showing trends of increasing losses (exponential trend from the 1990s) caused mostly by the expansion of land under cultivation. Losses in higher income nations across the world seem to have stabilised relative to losses in Africa. He also touched on his research on bio-refinery in food industry plants for the valorisation of food waste. Some of the potential bioprocessing technologies include biocatalyst and innovative bioreactors, ultra-filtration and nano-filtration, membrane processes to recover natural compounds, and food SMEs integration to chemical industry. The potential value-added products from wasted food could include cosmeceuticals and nutraceuticals, functional ingredients as foods, bioactive components, production of natural antioxidant extracts, and recovery of water from food.

Next, Duncan Mbuge offered a deep dive into evaporative charcoal cooler technology as an example of a solution to reduce food losses. His work is based in Kenya. These low-energy, evaporative coolers are being used to reduce post-harvest FL&W. The coolers' walls include charcoal, which absorbs water and can retain it for some time. These units can be wetted and can then reduce temperatures with evaporative cooling. Duncan showed an example of a cooling unit that was 4x4 metres wide and 2 metres high, constructed through modular frames and a roof that allows for mass production. Solar energy runs a fan with lighting within the unit. This solution could be used by supermarkets as it would allow them to keep their produce cool. Duncan is now looking to move this technology forward – the materials used have already been improved after finding that wood, steel mesh and chicken wire developed rust so aluminium and perforated fibre glass are now used. Additionally, charcoal is a highly political material; in Kenya, it is prohibited to transport charcoal because of environmental issues so there is a need to look into alternatives, such as pumice, vermiculite, synthetic materials, and coconut coir. Optimisation of unit size and air flow is the next item on the list of potential improvements.

Julien Lepine's presentation focused on tackling food waste with bio packaging. Transport is a critical component of food waste, especially in developing countries where up to 50% of the food can be wasted. This means that half of the farming inputs used to produce it, such as water, fertilisers and labour, are also wasted. Fruits and vegetables are often transported from farm to market on poorly maintained roads or vehicles, which can cause damage and accelerate spoilage and waste. Julien's research proposes to use agricultural waste and by-products to create bio packaging to protect produce from transport hazards. The key challenges are to use resources easily available at smallholding farms and develop manufacturing processes that can be used locally at low expense. Using plant-based material also reduces the negative impact of packaging on the environment and eases its integration in circular economy schemes.

Madalina Neascu started her presentation with an interesting fact: if food waste was a country, it would be the third largest contributor of greenhouse gas emissions after China and the US[5]. Moreover, the world lost a great number of food crop varieties, which resulted in nutrients loss: in 100 years from 1900 to 2000, the world lost 75% of agrobiodiversity[6]. High processing of foods leads to lots of nutrients being lost in empty calories. Different processes lead to different nutrient losses and it is key that we start refining and processing food less. It is also crucial to diversify our sources of protein and fibre. Madalina then presented a transformative idea of moving from linear food systems and linear nutrition to circular food systems and nutrition. This idea is based on sourcing food grown regeneratively and locally where appropriate, making the most of food already available and designing and marketing healthier food products. One example of a better circularity would be taking retailer-rejected produce, freeze drying and reformulating it to

5 www.fao.org/3/a-bb144e.pdf

6 Davies, et al 2004,J Am Coll Nutr, Vol. 23, No. 6, 669–682

then reintroduce it back to the food chain. By adding food additives, we can create new food formulations that can then diversify our protein intake, boost fibre and increase shelf life. This process would ultimately limit the food waste and contribute to the green economy.

The interactive part of this session assigned the same crop to different groups of delegates, asking them to evaluate food loss and waste along the value chain from developed and developing countries perspectives, respectively, highlighting the contrasts. The delegates were also asked to come up with potential interventions and to establish information gaps that require innovations or further research. Two different crops were selected: maize and tomatoes.

For maize in developing countries, delegates highlighted the challenge of storage and the difficulty to get good data on where in the value chain losses are occurring to address them. The potential interventions to help with these challenges included improving storage sites and developing on-farm processing, such as freezing, although this could have an impact on the quality of the produce. Improving packaging solutions specially to address moisture levels would also help reduce food loss and food waste along the maize value chain.

Maize value chains in high-income countries face the challenge of retailer policies that turn down suppliers if more than 2% of the product is rejected. This then increases the pressure on farmers and leads to them sorting the produce very conservatively, often leaving lots of produce on the farm, which eventually ends up being wasted. It was also highlighted that different strains of maize face different challenges and have different losses. Interventions should focus on proximity and time – earlier interventions closer to point of production are likely going to be more effective. Since maize does not usually go straight into consumption but is processed to a specification, better data mining might allow processors to take produce that they might have otherwise rejected if they modify processing.

Quantifying harvest losses of tomatoes in low- and middle-income countries is a real challenge. Mobile applications for farmers that would allow to image detect and gather data on the product as well as identify the sources of losses were suggested as a potential solution. To help achieve accurate quantification, education on visual assessment for producers should be rolled out. Innovations to allow delayed ripening either in-transport or through genetic modification were also suggested. To avoid spoilage risks in transport, improving cooling and packaging as well as on-farm processing into different products (for example juice) could be used.

Production of tomatoes in developed countries faces the challenges of financial, physical and nutritional loss. Climatic factors are a variable too. The ‘integrated losses’ concept whereby unproductive land is considered a loss also poses a challenge. Interventions suggested focused on consumer campaigns on food waste as well as around climate change. Encouraging consumers to love ‘ugly’ fruit and vegetables was recognised as a powerful idea. Genetic modification could also play a role.

Transport is a critical component of food waste, especially in developing countries where up to 50% of the food can be wasted.

Frontiers insights

The Frontiers insights session was designed and run by the event's co-chairs, Dr Tahrat Shahid and Professor Noble Banadda. They asked delegates to brainstorm on a set of key questions /topics, building on the conversations from the sessions and encouraging them to consider some crucial issues that have not been discussed yet.

Professor Banadda started off by encouraging delegates to think of **practical solutions** that would make a difference to rain-fed, rural agriculture in low- and middle-income countries. The need to diversify farmers' income was highlighted first while suggesting to always consider the following rule: if you are using a piece of land for only one source of income then you are not extracting most value from it. What contributes to this problem is that smallholder farmers are often encouraged to produce only food they can eat rather than grow crops they could sell. If they were able to do this, they could then use the income on food and move away from growing mostly subsistence crops to high-value crops.

Another suggested solution for these communities was increasing uptake of low-cost preservation technologies, such as low-tech affordable coolers. The technology has been available for a while, but the uptake is very low. What contributes to this challenge is that policymakers often champion technology that cannot be easily taken up by farmers.

However, it was also raised that technology is not enough – skills development is crucial in developing the individual working in the agricultural sectors.

There is a need to recognise the importance of developing those skills and get the right infrastructure to develop and foster knowledge and resourcefulness in farmers. This process needs to start with having a two-way conversation giving the farmers a chance to say what skills they would like to learn. To get the buy-in, the conversation needs to start by making a link to improving well-being of the individuals, their families and the community. Establishing the practical constraints and needs of producers needs to be the starting point rather than any technologies.

Supply chains are incredibly complicated, and individuals can often only see what is in their immediate horizon, so it is also important to help people understand the broader agricultural opportunities and the various processes and mechanisms along the value and supply chains. Supply chains often have middlemen with a lot of power to drive down the prices, but they lack the knowledge of how to look after the produce. Poor last mile infrastructure and poor quality of feeder roads means that often it is only the middlemen who are willing to take the risk to access rural areas. This then gives them the power to bargain down the prices and make a huge mark-up.

However, this is not within the farmers' powers to act against, it is a policy issue. At the same time, it is difficult to find the people who oversee and are 'in charge of' the supply chains. Policies need to be aimed at targeting corruption to reduce extra costs to farmers. It is also necessary to introduce price controls on the prices that collectors of the produce are paying and the level of mark-up they can sell at. However, policymakers are often the bottleneck.

Dr Shahid then asked delegates to consider how best to resolve the dilemma between preserving traditional foods that are valuable to people and producing crops that can feed the most people at the lowest cost (for example genetically modified organisms that can survive disasters and other shocks). What tends to happen is that often with the roll out of the latter, peoples' traditional crops and their varieties are steamrolled. This links to another problem where farmers who produce 'super foods' cannot actually afford to eat them as selling brings in most income. Additionally, once strong markets for these products have been established, the poorer communities are then priced out of the market.

An example from Uganda was shared: only poor people used to eat silver fish but after a publication came out showing its nutritional benefits, it became popular across the middle class and now poorer communities can no longer afford it.

Balancing the need to produce for and grow external markets versus producing food for oneself is key to these issues. Building on protocols such as the Nagoya protocol could be helpful, but more conversation is needed to ensure these protocols are explicit in advance.

Improving traceability as a potential solution was discussed at length. Consumers are often convinced to pay a premium for produce that is not in fact premium or will not deliver the benefits the consumers are convinced it will (for example labels such as 'organic' or 'virgin oil from Italy').

Better traceability would also help with capturing food loss – an area where it is desirable to get a better picture of the status quo. Although tracing is a complex issue, this is where engineers can help the policymakers to introduce technologies to simplify some of the existing complexities.

An idea to better inform consumers was then suggested – sharing farmers' stories and more information about their livelihoods and the hurdles they encounter across the supply chain could convince consumers to pay extra. Understanding how the produce links to individual families and their livelihoods could make a difference.

The next big issue discussed was food loss from a variety of perspectives. Food loss is loss of economic value, nutrition value, loss of nutrients from the soil, and loss of energy. It was suggested that we should stretch our thinking even further and think of food loss as loss of people since that food lost could have been tackling malnutrition and lowering mortality rates.

Careful planning of meals is where the solution could start – planning meals ahead of time can lead to appropriate levels of produce purchasing. Across the globe, these activities are dominated by women, which means that women need to be involved in tackling this issue, but more work should be done to get more men involved in nutritional planning too. Encouraging consumers and big sellers to buy produce that is crooked or off colour or in general does not meet the standard in appearance would help reduce losses, especially in the global North.

Improving transport and packaging to reduce FL&W was also highlighted – there are a lot of simple solutions that can be deployed. There is more investment needed to improve this and governments need to get more involved as the private sector is unlikely to resolve this. On-farm processing technologies would also help farmers to turn current losses into farming inputs. Harnessing solar technologies could be an appropriate way to enable more on-farm and local food processing, for example solar-powered refrigeration and drying technologies.

Building on the local knowledge and working with farmers associations is crucial. A good example showcasing the role for indigenous knowledge is farmers digging holes and storing cassava underground as they know this is a suitable method to store it. Scientific observations of existing indigenous techniques for evaporative cooling triggered scientists to develop it further through the application of technology and scientific analysis, which has led to very effective technologies. To make sure this continues, there needs to be more work to improve knowledge sharing – better communications and data services such as mobile phones could play a part. More work also needs to be done to ensure any research and/or innovations are easy to understand and to access for farmers. Including social scientists and anthropologists as well as farmer associations could be very beneficial.

Any long-term solutions will require a systems approach with appropriate stakeholder assessment in the planning and design of solutions and involve the end-users as well. A lesson learnt can be taken from Uganda where the World Bank funded the government to set up cold chain support along major highways across the country. This resulted in every major market having a refrigerator. However, none of the refrigerators are working – they forgot to consider covering the cost of electricity, which no one can afford. Now the concern is how the government can cover the electricity bills. This is an example of a solution that was invested in without engaging reality on the ground.

The event chairs wrapped up the discussion by emphasising the importance of local knowledge. It is impossible to suggest solutions without knowing how they fit into the local context. This is where interdisciplinarity comes in and where programmes such as Frontiers can make a difference by encouraging interdisciplinary research between practitioners across the globe.

Vincent Doumeizel

Lloyd's Register Foundation's Foresight review on food safety

Access to adequate food and freedom from hunger was recognised as a human right by the UN's Universal Declaration of Human Rights in 1948. Despite this, there are still individuals who experience hunger. To help avoid this, the Lloyd's Register Foundation (LRF) commissioned a Foresight review of food safety[7], gathering insights from experts and providing information for a societal debate about food safety challenges. Vincent Doumeizel is the Director of the Food Programme at LRF and lead author of the review. In his presentation, Vincent highlighted the main findings of the Foresight review.

The review outlines key trends affecting the food sector such as: population growth; lack of food production; food fraud; low level of traceability and lack of transparency; environmental and social impacts; low income and low profit margins; and social media exposure. The ambition is to focus on food safety as there are an estimated 600 million cases of foodborne diseases per year. To address some of the key challenges and explore opportunities that lie ahead, LRF will focus on three main areas:

1. Food safety education and training

- Delivering appropriate training in the food supply chain leads to improvement in food safety and traceability.
- Educating the public on food safety can lead to healthier eating choices both for individuals and the planet based on facts. Social media could play a key role in this.
- This requires high levels of collaboration across sectors and countries, especially to deliver impact in low- and middle-income countries. Food safety should be included in the school curriculum and there is a need to train more specialists in food safety.

2. Traceability to enable a safer food supply chain

- Life science and data science innovations offer solutions to address challenges in traceability – LRF will focus on 'phygital' solutions, which relate to the connection between physical food stuffs and digital records.
- Some examples of innovative solutions in this space include smart packaging, satellite monitoring, open platforms, online auditing, new markers for food such as stabilised isotopes, microbiomes, DNA and genomics.

3. Ocean of (safe) food

- Scaling up aquaculture could address the global increasing demand for food. Using offshore areas is the obvious choice considering their low current use.
- Although there are various challenges in developing more offshore aquaculture, such as higher levels of investments required, increased risk because of exposed conditions, potential consequences for the eco-system, the benefits outweigh the risks.

7 https://www.lrfoundation.org.uk/en/publications/foresight-review-of-food-safety/

Project site visit

On the second day of the symposium, all delegates visited a project site in Ambohitrimanjaka, outside of Antananarivo. The project was run by Action Intercooperation Madagascar (AIM) and had two main focuses:

- To help the women in the community start raising poultry and to generate income this way
- To sustainably improve the periurban producers' and traders' income as well as the people's access to regular supply in fresh produce.

To achieve the first goal, the project helped to develop a process for rearing the chickens more quickly and with as greater success rate as well as helped to move away from chemical inputs to organic inputs and composting. It also provided support to source customers for the chickens with the focus to sell the meat. Although the women spoke about the project positively and highlighted how the additional income helped to pay for education of their children, the income was precarious as it was vulnerable to market and price fluctuations. It also relied on the chickens being healthy but there were frequently disease outbreaks, which meant that they could lose anywhere from 20 to 100% of the flock. Because of these reasons, there was an agreement that there is a need to diversify income sources to minimise the vulnerabilities.

To improve production, the project focused on professionalisation of the production through dissemination of agroecological systems and practices. The interventions were aimed to improve:

- **Quantity** – increasing productivity and ecological intensification systems
- **Quality** – improving the products' life span, reducing the pesticide residues
- **Diversity** – diversification within highly specialised production areas
- **Regularity** – seasonal adjustment of production using varieties and methods.

The project also focused on supporting the producers to access agricultural services and markets, mainly by building capacity and helping set up structures for farmers' and producers' groups. More specifically, this includes consolidating their operation, governing, and strengthening their technical capacity to provide quality services and meet market's expectations.

Seed funding awards

Enhancing food security through urban farming systems in Jordan

This project primarily aims to increase the resilience of poor urban communities in Jordan to any unexpected external shocks by testing and piloting two locally based food systems, for example vertical agriculture and rooftop hydroponics in Jordan.

- Jonathan Cooper, Harper Adams University
- Almoayied Assayed, Royal Scientific Society Jordan
- Mohammed Mashatleh, Royal Scientific Society Jordan
- Rana Ardah, Royal Scientific Society Jordan

Evaluating deployment of mobile phone Apps in smallholder fertiliser management

The aim of this project is to assess suitability of mobile phone App technology to implement precision fertiliser management on vegetable crops grown by smallholder farmers in Madagascar and Pakistan.

- Ruben Sakrabani, Cranfield University
- Harinaivo Ramanantoanina, Engineers Order of Madagascar
- Lina Raharasoavelohanta, AIM – Action Intercooperation Madagascar
- Afia Zia, Peshawar Agricultural University

Fostering nutrition security through cash crops/indigenous food crops systems in Madagascar

The project will look at how to increase the productivity and sustainability of selected value chains through nutrition-specific interventions, which also have an impact on the management of genetic crop diversity in the field and on natural resources, in particular in terms of soil quality and water resources management.

- Martina Bozzola, Queen's University Belfast
- Harinaivo Ramanantoanina, Engineers Order of Madagascar
- Aurel Clyde Rabehanta, WaterAid Madagascar
- Trust Beta, University of Manitoba
- Hernan Alfredo Manson, International Trade Centre (UN/WTO)
- Lameck Fiwa, Lilongwe University of Agriculture and Natural Resources (LUANAR)
- Jean Gabriel Rakotondrabe, Consultant
- Kenlee Randrianarisoa, Soanamad Madagascar

Identification of sensor targets for low-cost soil fertility assessment

This project will be used to define a technological solution to the challenge of poor soil fertility within Kenya by identifying key biological and chemical markers that could be implemented in a low-cost sensor platform for use by smallholder farmers.

- Andrew Ward, University of Strathclyde
- Ruben Sakrabani, Cranfield University
- Ezeiel Njeru, Kenyatta University
- Charles Knapp, University of Strathclyde
- Damion Corrigan, University of Strathclyde

Multi-scale zero-waste smart protein

Building on their cross-disciplinary expertise, this project aims to advance the understanding of the potential of multi-scale protein technologies (including insect protein, microbial protein and waste-derived feed protein) in Africa and Asia (focusing on Madagascar and Indonesia).

- Miao Guo, King's College London
- Ai Karawati, Noveltindo Eiyo Tech Ltd
- Geoffrey Knott, New Foods Ltd/University of Surrey
- Felamboahangy Rasoarahona, University of Antananarivo/SUN Madagascar
- Miguel Entrique Malnati Ramos, Bio Natural Solutions Company

For more information about these projects, please visit raeng.org.uk/frontiers

Prototype drink from Amazonian plants based on community's nutritional needs

Combining the expertise of human nutrition and food technology, this six-month-long project aims to help decrease the levels of malnutrition in Amazonian Peru by introducing a low-cost, ready-to-drink beverage that is high in nutrients commonly lacked in local communities.

- Katharina Kessler, University of Cambridge
- Miguel Entrique Malnati Ramos, Bio Natural Solutions Company
- Claudia Carol Zavaleta Cortijo, Universidad Peruana Cayetano Heredia
- Magaly Blas, Universidad Peruana Cayetano Heredia

Single-cell Protein for sustainable shea caterpillar farming in Burkina Faso

The goal of this project is to develop a sustainable insect feed for large-scale farming of shea caterpillar (Cirina butyrospermi).

- Tuck Seng Wong, University of Sheffield
- Kahitouo Hien, FasoPro
- Kang Lan Tee, University of Sheffield
- Bepio Herve Bama, Institut de l'Environnement et Recherches Agricoles (INERA)

Towards online monitoring for microorganisms in water systems

This project seeks to address the challenge of providing clean water through a multi-sector, multidisciplinary team by developing a low-cost sensor that could be used as an early warning of microbial contamination in distributed water systems.

- Andrew Ward, University of Strathclyde
- Harry Chaplin, Tatirano Social Enterprise
- Tsiry Angelos Andriamanampisoa, University of Antananarivo
- Damion Corrigan, University of Strathclyde

Z-lab: co-designing sustainable livelihoods in rural Zambian refugee resettlements

Building on a developing relationship with the United Nations Development Programme (UNDP) in Mayukwayukwa Refugee Settlement and an understanding of the real-life issues faced by resettled farmers, the overarching aim of Z-lab is the creation of a multi-stakeholder platform that will enable connecting, sharing and facilitating the co-development and co-design in-situ of innovative long-lasting solutions to the challenges faced by the local community.

- Olwenn Martin, Brunel University London
- Ximena Schmidt Rivera, Brunel University London
- Prof Tilahun Workneh, University of Kwazulu-Natal
- Harry Chaplin, Tatirano Social Enterprise
- Lameck Fiwa, Lilongwe University of Agriculture and Natural Resources (LUANAR)
- Xiaojun Yin, Swansea University
- Justin Munyaka, UNDP
- Julien Lepine, Université Laval
- Sheila Etam, Ukulima Tech Ltd
- Mary Richards, Brunel University London

For more information about these projects, please visit raeng.org.uk/frontiers

Annex A

Attendee list

Name	Organisation
Afia Zia	University of Agriculture, Peshawar
Ai Karwati	Noveltindo Eiyo Technoprima Ltd
Allyson Lawless FREng	South African Institution of Civil Engineering
Almoayied Assayed	Royal Scientific Society Jordan
Andrew Ward	University of Strathclyde
Annie Chimphango	Stellenbosch University
Anongnat Somwangthanaroj	Garden Fresh
Bibi Giyose	African Union – NEPAD/UN Food and Agriculture Organisation
Bruce Grieve	University of Manchester and Fotenix LTD
Charles Adetunji	Edo University
Daniel Hefft	University of Birmingham
Daniel Taylor	Dent Agrisystems
Duncan Mbuge	University of Nairobi
Earnest Bbaale	Vertical Farm
Esther Nwanna	Federal University of Technology Akure
Ezekiel Njeru	Kenyatta University
Geoffrey Knot	University of Surrey/HOP
Harinaivo Ramanantoanina	Engineers Order of Madagascar
Harry Chaplin	Tatirano Social Enterprise
Hasina Rafamantanantsoa	National Office of Nutrition Madagascar
Henintsoa Felambohangy Rasoarahona	MIKASA – SUN Madagascar
Isa Kabenge	Makerere University
Jessica Enright	University of Glasgow
Jocelyn Zarate	University of the Philippines Los Baños
Jonathan Cooper	Harper Adams University
Julien Lepine	L'Université Laval
Kahit Hien	FasoPro
Katharina Kessler	University of Cambridge
Kerry Brown	London School of Hygiene and Tropical Medicine
Kok Siew Ng	University of Oxford

61 participants

Based in
20 countries

Name	Organisation
Lameck Fiwa	Lilongwe University of Agriculture and Natural Resources
Lawrence Okettayot	Sparky Dryer
Lisa Boden	University of Edinburgh
Madalina Neascu	University of Aberdeen
Mangani Katundu	University of Malawi
Martina Bozzola	Queen's University Belfast
Mehroosh Tak	University of Edinburgh
Miao Guo	King's College London
Miguel Malnati Ramos	Bio Natural Cover
Neeraj Moher	Ministry of Agro-Industry and Food Security, Mauritius
Netalie Shloim	University of Leeds
Noble Banadda	Makerere University
Olwenn Martin	Brunel University London
Reggie Annan	Kwame Nkrumah University of Science and Technology (KNUST)
Rojee Suwal	Hellen Keller International
Ruben Sakrabani	Cranfield University
Sheila Etam	Ukulima Tech LTD
Simon Pearson	University of Lincoln
Stella Lignou	University of Reading
Tahrat Shadid	UK Research and Innovation
Temitope Alade	University of Worcester
Tilahun Seyoum	University of Kwazulu-Natal
Trust Beta	University of Manitoba
Tsiry Andriamanampiosa	University of Antananarivo
Tuck Seng Wong	University of Sheffield
Vincent Doumeizel	Lloyd's Register Foundation
Wirulda Nik Pootakham	HybridSure
Xiaojun Yin	Swansea University
Ximena Schmidt Rivera	Brunel University London

Event feedback

In the post-event survey completed by 35 respondents, 100% of respondents said they would recommend attending a Frontiers of Engineering for Development event. 86% rated the overall event ‘excellent’ and the remaining 14% rated it ‘good’.

“It was a very well-coordinated symposium that presented me with the perfect opportunity to meet and establish cross-disciplinary networks. The trip to the farms enables me to focus my research agenda towards activities that would have beneficial impact on society. It was very well done.”

“The event organisation and preparation was remarkable. I have never been to such a well organised event. Huge thumbs up!”

“This is the first event where I truly found interaction among participants at its best.”

“It was for me an excellent event to create new collaborations!”

“As a non-engineer I deeply enjoyed the multidisciplinary angle of the event and I think it was extremely well organised!”

“It was brilliant all through. Thank you.”

“I learned a lot during this event. Very interesting, rewarding event.”

Royal Academy of Engineering

The Royal Academy of Engineering is harnessing the power of engineering to build a sustainable society and an inclusive economy that works for everyone.

In collaboration with our Fellows and partners, we're growing talent and developing skills for the future, driving innovation and building global partnerships, and influencing policy and engaging the public.

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Our 2025 ambition

Talent & diversity

We'll grow talent by training, supporting, mentoring and funding the most talented and creative researchers, innovators and leaders from across the engineering profession – with an aim to help over 7,500 professionals to enhance their leadership skills.

We'll develop skills for the future by identifying the challenges of an ever-changing world and developing the skills and ideas we need to build a resilient and diverse engineering profession. We've set ourselves a target to work with over 500 engineering businesses and organisations to champion diversity and inclusion in the workplace.

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