AfroAgEng
PAN AFRICAN SOCIETY FOR AGRICULTURAL ENGINEERING

Agricultural Engineering in Africa

A Key Driver for Transforming Agriculture to Deliver Food Security and to Support Economic Prosperity

Let’s Mind the GAEAP and Grow Agricultural Engineering to Transform Africa

A Report and Call to Action by the Pan African Society for Agricultural Engineering

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The Pan African Society for Agricultural Engineering (PASAE) dedicates this report and call to action to the memory of PASAE Council member, report contributor and eminent Agricultural Engineer, Professor Noble Banadda (14 May 1975 — 1 July 2021) who was a Ugandan biosystems engineer, researcher and academic, and a Professor of Biosystems Engineering at Makerere University, Uganda's largest and oldest public university. PASAE hopes that his passing as a result of the Covid Pandemic acts a reminder of the terrible fragility of the world we inhabit and that his legacy, along with all those who have been lost to the pandemic, will be a revitalised Agricultural Engineering profession across Africa.

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This production of this report and provision of evidence for review has been supported by a broad range of universities, commercial organisations and individuals. We have listed these in **Appendix A** and gratefully acknowledge all contributions made, including any we may have inadvertently not listed in **Appendix A.**

We thank and gratefully acknowledge the UK Royal Academy of Engineering (RAEng) for funding a project titled *"Growing Agricultural Engineering in Africa: Supporting the Operations and Implementation of the Strategic Plan for AfroAgEng"* through which this document has been produced as one of the deliverables of the project. We are indebted to the project team, the South African Institution of Agricultural Engineers (SAIAE), the UK Institution of Agricultural Engineers (IAgrE), Harper Adams University in the UK, and PASAE for undertaking the RAEng funded project. We also acknowledge the contributions from made other national professional societies of Agricultural Engineers in Africa – for being part of the mission to highlight the critical role and grow Agricultural Engineering in Africa.

We would like to extend our particular thanks to members of the Agricultural Engineering in Africa Project Team and the PASAE Council, for their dedication, hard work and unparalleled commitment. PASAE thankfully acknowledges Mr Alastair Taylor, former CEO of IAgrE, for his enthusiasm and commitment to promoting the Agricultural Engineering profession and for leading the compilation and successful completion of this document.

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Foreword

Let's Mind the GAEAP and Grow Agricultural Engineering to Transform Africa

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Past President – International Commission of Agricultural and Biosystems Engineering

In June 2014 at the African Union Summit in Malabo, Equatorial Guinea, Heads of State and Government adopted an extraordinary set of concrete goals for agriculture to be attained by 2025. The Malabo Declaration on Accelerated Agricultural Growth and Transformation for Shared Prosperity and Improved Livelihoods articulates a new set of goals showing a more targeted approach to achieve the agricultural vision for the continent which is shared prosperity and improved livelihoods for the African Continent. In effect, the Malabo Summit reconfirmed that agriculture should remain high on the development agenda of the African Continent, and that it is a critical policy initiative for Africa's economic growth and poverty reduction.

To achieve its 'Commitment to Halving Poverty by the year 2025, through Inclusive Agricultural Growth and Transformation', the leaders agreed on the need to sustain annual agricultural GDP growth of at least 6%, and to create job opportunities for at least 30% of the youth in agricultural value chains. Similarly, while committing to ending hunger in Africa by 2025, African leaders resolved to facilitate, among others, sustainable and reliable production; supply of appropriate knowledge, information, and skills to users; efficient and effective water management systems notably through irrigation; suitable, reliable and affordable mechanization and energy supplies; and to halve the current levels of postharvest losses, by the year 2025.

Speaking on the theme of the 2015 "Year of Women's Empowerment and Development towards Africa's Agenda 2063", the then African Union Commission Chairwoman – Dr Nkosazana Dhlamini-Zuma – challenged Africans that despite their critical role, rural African women continue to work the land with archaic working methods such as the handheld hoe! She concluded that African women made this clear when they said:

> **'This hoe, we do not want it anymore!! It must henceforth be confined to the museum as an artifact! A subject of art for future generations!'**

To meet these lofty and ambitious aspirations and commitments of African leaders to transform and modernize African agriculture for inclusive growth and sustainable development, Africa needs Agricultural Engineers and related technical vocations. No other academic discipline and profession is better equipped to lead the mechanisation, digitisation, commercialisation and industrialisation of a knowledge-intensive, profitable and sustainable African agriculture. Africa needs a critical mass of talented young women and men Agricultural Engineers – including their professional bodies, to drive Africa's Green Revolution. To achieve this, we need to grow the talent pipeline, plug some of the brain drain, and foster brain gain. African agriculture needs the best of our talent and access to the best of global innovative engineering technologies.

For far too long, African agriculture has been synonymous with 'subsistence' and 'smallholder' mindsets; lacking both the speed and intensity of modernisation needed to increase productivity and achieve the much-needed industrialisation and widespread rural development. The necessity to increase the efficiency of sustainable agricultural production systems and to reduce environmental damage assures demand for Agricultural Engineers and other related knowledge workers in African agriculture. The impact of climate change on agri-food systems and increasing new threats such as the COVID-19 pandemic underscores the need for continuing search for new knowledge.

Professional societies, such as AfroAgEng – the Pan African Society for Agricultural Engineering (PASAE), have critical roles to play in promoting the development and deployment of modern engineering technologies in agriculture for socio-economic development, including education, research and thought leadership. The Mission of AfroAgEng is to promote and advance the profession of Agricultural Engineering in Africa. Similar regional professional bodies have shown that it is possible to grow Agricultural Engineering for socio-economic impact.

The Indian Society of Agricultural Engineers (ISAE) is credited with spearheading the establishment of agricultural machinery testing centres in India, which is now widely recognised as the precursor to the growth of India's modern-day successful agricultural machinery manufacturing and export industry. ASABE – the American Society of Agricultural and Biological Engineers, is globally recognised for its pioneering role in transforming rural America through the provision of education, research and extension services supporting infrastructure modernisation such electrification and drainage, and the mechanisation of agriculture.

AfroAgEng/PASAE is the apex umbrella network of engineers in African agriculture. AfroAgEng is new and young – it needs to be nurtured, and it needs to grow to serve African agriculture and the world at large.

The impressive impact of Agricultural Engineering in Africa in contributing to new knowledge in Africa, and from Africa to the world, was highlighted in a recent study by Beaudry et al. (2018). Among 86 scientific fields with highest contributions from Africa, Agricultural Engineering and Chemical Engineering were the only engineering disciplines which featured, each contributing 3.9% and 3.02%, respectively, of the World Share of scientific publications during the period 2005-2015. Furthermore, a positional analysis of "all the disciplines in the broad field of the agricultural sciences", shows that two disciplines – Veterinary Sciences and Agricultural Engineering – stand out as having above average impact and strength.

These positive impacts of Africa's Agricultural Engineering need to be translated into real change – transformation and modernisation of Africa's agri-food systems. A vibrant professional body of Agricultural Engineers in Africa – AfroAgEng – with a critical mass of membership and programmes, is needed to lead, sensitise and mobilise action for quality life-long education, research and innovation, and policy for impact to support the commercialisation of agricultural value-chains and integrated rural development.

This Growing Agricultural Engineering in Africa Project (GAEAP) report is an output of a project funded by the UK Royal Academy of Engineering (RAEng) – "Growing Agricultural Engineering in Africa: Supporting the Operations and Implementation of the Strategic Plan for AfroAgEng". This report highlights the challenges and opportunities in African agriculture, makes a strong case for supporting the professional body of engineers in African agriculture, and charges Africans and our partners to embrace a paradigm shift necessary to realise The Africa We Want.

We thank the UK Royal Academy of Engineering (RAEng) for funding and supporting this project. We are indebted to our partners – the South African Institution of Agricultural Engineers (SAIAE), the UK Institution of Agricultural Engineering (IAgrE), Harper Adams University in the UK, and other national professional societies of Agricultural Engineers in Africa – for being part of the mission to highlight the critical role and grow Agricultural Engineering in Africa. I thank my colleagues in the Project Team and PASAE Council, for your dedication, hard work and unparalleled commitment.

I invite you to read and widely share this GAEAP report – among your colleagues, students, partners, policy experts, and business partners. Post it on your Social Media networks – Facebook, Twitter handle, Instagram, LinkedIn, and cite it in your publications. It is my hope and prayers that this historic GAEAP report becomes the reference source of information for fresh ideas and motivation to Grow Agricultural Engineering to modernise and truly transform smallholder agriculture to achieve our collective vision of The Africa We Want – "An Integrated, Prosperous and Peaceful Africa, driven by its own citizens and representing a dynamic force in the global arena".

Distinguished Professor Umezuruike Linus Opara CEng FIAgrE FSAIAE FNIAE
President – Pan African Society for Agricultural Engineering
Past President – International Commission of Agricultural and Biosystems Engineering

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Overview

This report focusses on Agricultural Engineering and highlights its crucial role in Africa as a key driver for transforming agriculture to deliver food and water security, sustainable agricultural production, and thus to support economic prosperity. The harsh facts which face Africa are well known and well documented by a broad range of organisations. The role of Agricultural Engineering in helping to address these is less well known and this report articulates and highlights the contributions and impact the profession makes towards sustainable food production, post-harvest handling and processing systems, both now and in the future.

The specific key development challenges such as low agricultural productivity, shifting demographics, poor infrastructure and the image of the Agricultural Engineering profession is reviewed in this document. As well as exploring the profession and interpreting what it means for society, the concept of promoting a professional approach is encouraged. As engineering and technology evolves, including the growing importance of developing and applying technology for Agriculture (Agritech), the roles and associated career opportunities present an exciting future for those people wishing to pursue a future in this vitally important development area.

However, these opportunities are generally not known or recognised by the public, institutions and government. Hence, one of the objectives of this document is to highlight the need for Engineers working in agriculture and the natural environment and the contributions Agricultural Engineers are making, and can expand on, in developing the **Africa We Want** vision. This requires recognition for and growing the demand from industry and government and meeting this demand by the training and production of engineers, technologist and technicians who can contribute to solving the many challenges Africa is currently facing.The UN Sustainable Development Goals (SDGs) are analysed in this document in terms of how Agricultural Engineering can contribute to their realisation and it is evident that for many of the SDGs, the profession has an important role to play in conjunction with all engineers, regardless of their discipline, who need to work together and thus contribute to meeting the SDGs. Multi-disciplinary and systems engineering approaches, well developed in other industries and parts of the world, need to be harnessed to help progress the African agenda and especially **Agenda 2063: The Africa We Want.**

None of this is possible without a vibrant education system and this report investigates the shape of provision and some of the innovations which are being developed across the different regions of the continent. Some new and innovative practices are starting to emerge, and these are reviewed together with some of the ambitions of those working in education and associated research.

Without a doubt, a paradigm shift is needed, and this report explores some emerging ideas and thoughts on how this will look. Drawing on international and commercial ideas, this report puts forward a new proposition to tackle the challenges we face in an innovative and coherent way. Please read on to find out more details!

We would like to thank those professionals in Agricultural Engineering from across the African continent and beyond for their enthusiasm and support for this report. Without your insight and sources of information, the compilation of this report would not have been possible.

Professor Jeff Smithers
Secretary-General
PASAE

Alastair Taylor
Report Editor, Agricultural Engineer,
former CEO of IAgrE, UK

Recommendations

I Raise the Profile

1. The widespread lack of knowledge and awareness of Agricultural Engineering and the role the profession can play in sustainable development needs to be addressed by increasing knowledge of Agricultural Engineering in industry, government and the general public. This is necessary to grow the demand for Agricultural Engineers and for young people to see the exciting opportunities afforded by Agritech and innovative technology-based sustainable solutions and thus attract new students and graduates to the profession.

2. Agricultural Engineering should feature more in the media. Universities, research institutions and professional bodies should do more to showcase the positive impact of all aspects of Agricultural Engineering and develop a higher profile of the discipline with the press and other media outlets including social media, on-line news feeds and television.

3. Professional bodies, universities and other influencers should use this report, and the examples highlighted herein, to identify and commence dialogue with government departments, ministers, non-governmental bodies, foreign aid agencies and other relevant stakeholders to raise the profile of Agricultural Engineering and associated disciplines, and the positive benefits they offer.

4. The Pan African Society for Agricultural Engineering should identify key professional partners and other influencers across the African continent and beyond who can act as key advocates and patrons for the Agricultural Engineering cause and use them to further the voice and raise the profile of the profession.

II Reform and Modernise

5. Educational institutions on the African continent should review the Agricultural Engineering related curriculum in terms of its suitability for promoting the development and use of technology in food and water security and environmental sustainability in the twenty-first century, thus ensuring it is appropriate and relevant for current and future needs and is adapted for new and emerging technologies.

6. Governments and education policy makers should review the provision of curriculum with a Science, Technology, Engineering and Mathematics (STEM) content as it relates to food and water security and environmental sustainability to ensure that there are sufficient progression routes and a suitable balance between the production of engineers, technologists and technicians, with a current specific focus on developing the number and capacity of engineering technologists and technicians.

7. Engineering education curriculum should be modernised and continuously updated to identify gaps and to keep abreast of new technological developments and to be relevant to society. For example, the extent to which curriculum covers the UN Sustainable Development goals should be mapped to ensure real contributions to society by the Profession.

8. At University level, curriculum should be aligned to the requirements of international standards (e.g., The Washington Accord) in order that it conforms to the same standard as widely used around the world. All degrees should be independently accredited by a relevant independent professional body as meeting the standard and to facilitate the transition of graduates into professional engineers.

9. Tertiary institutions should review the way in which the curriculum is delivered including the pedagogy used, links and collaboration with employers and industry stakeholders through Industry Advisory Boards, a shift towards a more student-centred approach with more practical experience and the development of teamworking, solving complex open-ended problems and the harnessing of the skills and unique knowledge of Africans. This approach should encompass more multi-disciplinary approaches and with a focus on systems thinking. AfroAgEng should continue to facilitate the sharing of best practices in this area.

10. Across Africa there should be more joint working of education providers including the sharing of common resources including specialist staff, teaching, and learning resources, and pedagogical approaches. A new and reinvigorated African Model for Training and Education in Agricultural Engineering should be established which draws upon best practice used internationally with, where relevant, international partners used to support developments.

11. Leaders and managers of Agricultural Engineering should engage in a new leadership programme – the Agricultural Engineering Leadership Development (AELDP) programme. This programme should include industry professionals as part of the development of dual professionalism which brings together pedagogical excellence with subject specific expertise. The concept of “Teach Too” should be considered whereby industry specialist make a commitment to routinely providing input to education provision.

12. Education partners should continue to collaboratively engage in international programmes such as those arranged by the Royal Academy of Engineering. They should actively engage more with international research partners and activities, especially those being offered by international university partners.

III Grow the Profession

13. AfroAgEng should work closely with professional bodies to identify a clear value proposition (Agricultural Engineering for Africa) which can be used to promote their role in further developing Agricultural Engineering excellence.

14. Professional bodies should use this report as a basis for engaging in discussion with national and regional stakeholders as a means of promoting the concept of professionalism. The value proposition should include the concept of more rigorous contracting and procurement so that over time, professionally registered Agricultural Engineers are the expected minimum requirement when contracts are awarded.

15. Key professional Agricultural Engineers from across the African continent should be identified and given the tools which allow them to act as advocates and, where appropriate, as patrons for the sector.

16. All technical and academic education in Agricultural Engineering and allied technological disciplines should be identified and added to a central database of provision. Over time this should be subject to a staged accreditation process staring with a basic listing of identified provision through to fully accredited as meeting international standards.

IV Create New Opportunities

17. The role of Agricultural Engineering in supporting the UN Sustainable Development Goals is compelling and, to that end, AfroAgEng, universities, professional bodies and research partners should engage with the UN and the African Union Commission (AUC) to show the important role which the profession has in contributing to meeting these goals. Agricultural Engineering "touches" every part of the process and such the discipline is a natural systems integrator bringing together different disciplines from different sectors.

18. AfroAgEng should liaise with engineering professions outside of Agricultural Engineering such as Civil Engineering, Mechanical Engineering and Environmental Engineering to identify where collaboration will promote the role and profile of the discipline and to illustrate that there are many more people working in the sector through their associated work, even though they would not identify themselves as an Agricultural Engineer

19. Universities should work collaboratively within their own organisations with faculties, departments and disciplines such as life sciences, environmental studies, management, economics, civil engineering, mechanical engineering, electrical engineering and electronic engineering to develop multi-disciplinary approaches and a more coherent approach for food and water security and environmental sustainability.

20. AfroAgEng, Professional Bodies and Universities should collaborate to show the benefits of working across sectors to deliver supportable mechanisation solutions and technology that generates added value to produce. They need to better identify the barriers which need to be overcome and articulate the potential solutions together with the business proposition which needs to be adopted if innovation is to be funded, moved into the production phase, and sustained.

21. The barriers which stand in the way of innovation and its adoption need to be better understood. AfroAgEng should engage with funding agencies and financial institutions to understand what is expected and how barriers can be overcome. This information needs to be interpreted in a way which helps the food production and processing industry understand what it needs to do in order to secure funding to support its developments.

V Sustain the Contribution

22. All partners should engage with global forces such as machinery manufacturers, civil engineering companies and others to ensure that Agricultural Engineering excellence is always considered when development projects are being planned and delivered.

23. All partners should engage with Non-Governmental Organisations (NGO), charities active across Africa and providers of official development assistance (Foreign Aid) to provide a template for programmes and projects which showcase how these should be planned to deliver long term and sustainable improvements to food and water security and climate change mitigation, as opposed to the traditional "quick fix" or "politically expedient vanity project" approach which characterises many initiatives of the past.

24. All partners should work with their regional governments and administrations to secure funding to support the activities of the Pan African Society for Agricultural Engineering. All development activities must be funded appropriately on the basis that good quality up-front investments lead to more sustainable development in the future.

25. PASAE and the partnering national bodies should embrace appropriate levels of professionalisation in their management/administrative structures in order to provide for continuity and institutional memory. This will allow the leadership to focus on policy matters and development of programmes for the benefit of members, while management/administrative staff ensure that related quality services are delivered to members.

Chapter 1 Introduction

1.1. Harsh Facts

In writing this report, the Pan African Society of Agricultural Engineers believes that Africa is in the eye of a storm. Leading global organisations (United Nations Foundation, 2021) highlight many global challenges and, for most of these, the potential impact on Africa is significant. At a time of great challenge, there is also great hope, and this report will focus on the critical role that the Agricultural Engineering profession can play in mitigating the challenges and contributing to positive solutions. However, we cannot escape from the harsh facts:

- More than half of global population growth between now and 2050 is expected to occur in Africa. At 1.25 billion in 2017, Africa has one of the highest rates of population growth in the world. The population of Africa is projected to double by 2050 (United Nations World Population Prospects, 2017). All these people will need to be fed.
- In 2018 it was estimated (World Bank Open Data 2021) that of the sub-Saharan Africa population, 41% live in extreme poverty, 55% are engaged in agriculture, 61% have access to only basic drinking water, and youth unemployment was estimated to be approximately 13%.
- For the informal economy, a recent study (International Labour Office, 2018) shows that an overwhelming majority of the youth aged between 15-24 (94.9%) are informally employed, with no or little education, are rural based and mainly engaged in subsistence agriculture. All of this leads to increased urbanisation and away from the traditional agrarian economy. The poor supply of skilled labour in rural areas will be a growing threat to food security.
- The water-food-energy nexus is central to sustainable development (UN Water, 2021). Demand for all three is increasing, driven by a rising global population, rapid urbanization, changing diets and economic growth. Agriculture is the largest consumer of the world's freshwater resources, and more than one-quarter of the energy used globally is expended on food production and supply.
- Climate change poses a significant threat to economic, social and environmental development in Africa. Climate change is likely to reduce crop yields, increase water scarcity, accelerate biodiversity loss and contribute to desertification, hence imposing a severe challenge on the continent's drive towards economic prosperity and peace (Niang, et al, 2014).
- Africa is the region with the highest prevalence of undernourishment, at almost 20% of the population. It is reported that 237 million people living in Africa are undernourished which is approaching one third of all undernourished people worldwide (FAO, IFAD, UNICEF, WFP and WHO. 2020)

It is acknowledged that much good work is done to support improvements in food security such as The World Food Programme (WFP) who work with communities and knowledge development, the World Bank whose activities include encouraging climate-smart farming techniques and restoring degraded farmland, breeding more resilient and nutritious crops and improving storage and supply chains for reducing food losses, and the UN Food and Agricultural Organisation (FAO) who focus on eradication of hunger, food insecurity and malnutrition together with better utilisation of natural resources. The International Fund for Agricultural Development (IFAD) funds projects which seek to address the same challenges.

In 2021, the United Nations Educational, Scientific and Cultural Organisation (UNESCO) and the International Centre for Engineering Education (ICEE) under the auspices of UNESCO (2021) reached similar conclusions. It goes on to highlight social issues and a lack of development, environmental deterioration, climate change and natural hazards, and water, food, and energy security as being the specific issues facing Africa. Similarly, the report highlights the role of engineering in addressing these together with the changes which need to take place if engineering and technology is to be part of the solution. It focuses on the role of engineering in addressing the United Nations Sustainable Development Goals. Relevant sections of this report are highlighted below.

Despite concerted efforts by African governments and their development partners over the decades to support agriculture as the engine for rural development and economic growth, the productivity of African agriculture remains very low, and poverty is highest internationally among smallholder farmers. It is well documented (Grow Africa, 2018) that Africa holds the greatest potential for agricultural production in the world, and with vast swathes of arable land available and yields that are often only 20% of those achieved in other regions, Africa has the potential to become the world's breadbasket, supporting global food security and stabilising food prices.

Progress in realising the potential of African agriculture has been slow due to a range of obstacles including limited access to quality inputs, productivity-enhancing technologies, support services, finance, poor infrastructure, high incidence of preharvest and postharvest food losses, and limited value chain development. The obstacles create a barrier for farmers to develop a sustainable business. i.e., one that is financially viable and provides and income for the farmer and their family.

One of the key challenges, and in turn a big part of the solution to transforming and modernising African agriculture, is education and access to knowledge in the agri-food sector. There is unequivocal and historical scientific evidence which affirm the critical role of education in enhancing agricultural development (Shultz, 1964).

Studies carried out in Africa and elsewhere have overwhelmingly shown that education improves agricultural productivity, especially in the case of adopters of modern technology (Young and Deng, 1999; Weir, 1999; Oduro-Ofori et al., 2014; Paltasingh and Goyari, 2018)

It is acknowledged (The Alliance for a Green Revolution in Africa, 2018) that education is a key ingredient to realize Africa's agricultural transformation.

These challenges present unique opportunities for Agricultural and Biosystems engineers in Africa and around the world to come together as a critical mass of educators, researchers and thought leaders to drive the change needed to transform African agriculture. AfroAgEng will stimulate, promote and shape the education, research, policy and practice of agricultural and biosystems engineering in Africa (Opara, 2012).

The role that the Agricultural Engineering profession and discipline can make in meeting the above challenges, both globally and particularly in Africa, is not widely known, understood, or appreciated. This report will provide evidence and make the assertion that a vibrant and progressive Agricultural Engineering sector will be a pivotal contributor in transforming and sustaining agricultural production and environmental sustainability across Africa and illustrates how this helps in delivering food security and supporting economic prosperity. It showcases the positive and growing potential contribution which Agricultural Engineering can make and explores the very broad footprint it has and the way in which the profession already contributes to solving many of the socio-economic challenges which Africa faces.

In the context of this document, the term Agricultural Engineer refers to engineers from all disciplines who develop and apply technical solutions for food production, processing and associated logistical systems, and for sustainable environmental and bioresources management. Agricultural Engineering, therefore, is the discipline and profession of engineers who, through education, training and practice, apply engineering skills to solve problems in agriculture and other biological industries, including resource and environmental management. This includes variants to the name Agricultural Engineering, including combinations of Bioresources, Biosystems, Biological, Environmental and Food Engineering.

The Agricultural Engineering profession and the technical skills it brings has an important role to play in providing the solutions needed for delivering **Agenda 2063: The Africa We Want** and, implicit in this, goes a long way towards providing realistic solutions to the United Nations Sustainable Development Goals.

Appendix B of this report contains explicit links which highlights the contribution of Agricultural Engineering to the delivery of a wide range of relevant Agenda 2063 and associated UN Sustainable Development Goals. There are critical and essential contributions to many of these goals, and with a significant contribution to many others. This route map provided in Appendix A could be adopted by stakeholders to help move the agenda forward.

This report seeks to be founded on information derived from credible literature. We have reviewed literature including reports from: The United Nations, The World Bank, The Royal Academy of Engineering, The UN Food and Agriculture Organisation as well as Universities, professional bodies and research organisations from Africa and more widely, including those from the UK and the USA with expertise in the subject of economic and technological developments in Africa. We have drawn on real field practice from a range of practitioners including from African food supply systems, Non-Governmental Organisations (NGOs), agricultural machinery manufacturers, and innovative university initiatives. We sought to be inclusive and open minded and to look to the future as well as drawing on established sources of information.

With regards to Africa, there are a plethora of facts relating to food security and land use. It is beyond doubt that, although there may be some disagreement over precise facts and figures, the underlying messages remain the same as summarized below.

The Charity Farm Africa (Farm Africa, 2021) points out that "Today, almost half of the world's extreme poor live in sub-Saharan Africa. The vast majority work in agriculture". They go on to ask the question "What's the most effective way to reduce poverty in Sub-Saharan Africa?" The report goes on to say:

> *'Agriculture dominates all other sectors, whether the comparison is within or between countries. Half of the world's extreme poor live in sub-Saharan Africa, that is almost 400 million people. The vast majority live in rural areas and work in agriculture. With a rapidly growing population, the IMF predicts that Sub-Saharan Africa will need to create about 18 million jobs per year until 2035 to absorb the growing workforce.*
>
> *The region has the fertile land and water resources available to invest in agriculture, however it also faces important threats like soil erosion, deforestation and destruction of grazing lands. Boosting agriculture in a sustainable way, while ensuring good access to markets for farmers are key aspects to reducing poverty in Africa'.*

Our findings suggest that here are many other NGOs, charities and others who would state much the same.

The need to provide sufficient food to a rapidly growing population in Africa emphasises the major role that Agricultural Engineers can play in providing and applying technology for sustainable food production and processing which includes efficient water use and management, conservation of natural resources and contributing expertise to environmental rehabilitation/regeneration.

The following summary of key facts and figures highlight some of the challenges which Africa faces. This information is summarised from publications by a range of highly reputable organisations and is therefore accepted.

Agriculture

- Agriculture employs 70% of the population in eastern Africa (Foresight Africa, 2017)
- Smallholders manage 80% of the farmland in sub-Saharan Africa (FAO, 2012)
- Agriculture contributes between 27 and 42% of total GDP in the countries where Farm Africa works (Farm Africa, 2021)
- Growth in agriculture is 2.5 times more effective than any other sector in decreasing poverty (Farm Africa, 2021)

Whilst most of this information is presented as factual rather than judgemental, the readers eye should be drawn to projections related to the environment which present some very harsh projections.

Environment

- A 1.5°C - 2°C temperature rise will contribute to farmers losing 40% to 80% of the cropland in the 2030s and 2040s (World Bank, 2013)
- Between 2001 and 2009, East Africa lost approximately 9.3% of it's forest cover. The region's critical deforestation crisis is driven by population growth, unscrupulous timber extraction, and conversion of millions of hectares of forest to agricultural production (Rainforest Alliance, 2020).
- In the Ethiopian highlands, 1.5 billion tons of topsoil are lost to erosion each year (Tamene and Viek, 2008)

It is well recognised across the world and in Africa that many agricultural production practices degrade the environment. This has a negative impact for future generations who go on to inherit less productive land. This is a topic that has been the subject of much research with a range of relevant publications exploring the subject. For example, Lal and Stewart (2019) investigate soil degradation and restoration in Africa and suggest the following:

> *Soil degradation is a widespread problem in Africa resulting in decreased agricultural productivity while demand for food continues to increase. Degradation is caused by accelerated erosion, acidification, contamination, depletion of soil organic matter and plant nutrients, and salinization. The major cause of soil degradation in Africa is uncontrolled and excessive grazing in the savanna regions followed by deforestation and the use of inappropriate and extractive farming practices.*

Connectivity

According to the African Centre for Economic Transformation (ACET) agriculture remains the backbone of most African economies (ACET, 2014), for example contributing 24% of gross domestic product in Tanzania, and about 30% in Burkina Faso. It also accounts for a significant proportion of exports, for example, about 65% in Kenya and 49% in Uganda. Yet most African economies have so far failed to leverage this advantage and it is time to take this bold step if they are to transform their economies.

Furthermore, (ACET 2021) believes that farmer's voices are the missing link in the quest for agricultural transformation. It goes on to suggest that the process of agricultural transformation will lead to higher productivity on farms as it gives more commercial orientation to farming and that will strengthen the link between farming and other sectors of the economy. ACET suggests that small scale farmers are frequently marginalised from the formulation of policy and are frequently on the periphery of the decision-making process. This has led to mistrust and, if addressed, will be pivotal in transforming agricultural productivity.

All of the above suggests that agricultural productivity is facing a very stark future which can be summed up as three key challenges in Africa:

- A high rate of population growth and associated need for food, water, energy and employment.
- Unprecedented environmental threats impacting upon future production.
- The lack of a vibrant and coherently interconnected agricultural industry which makes a positive contribution to solving the challenges.

This report asserts that Agricultural Engineering is a key driver for transforming agriculture and sustaining the environment and is able to contribute significantly to food and water security and sustaining the environment, and thus supporting economic prosperity.

It is worthwhile exploring how others have studied the same agenda. In 2011, the UK Government Office for Science produced a far-reaching report 'The Future of Food and Farming: Challenges and choices for global sustainability'. Known as the Foresight Report (HM Government UK, 2011), this work was intended for policy makers and a wide range of professionals and researchers whose interests relate to all aspects of the global food system, including governance at all scales, food production and processing, the supply chain, and also consumer attitudes and demand. It is also relevant to policy makers and others with an interest in areas that interact with the food system, for example, climate change mitigation, energy and water competition, and land use.

The author of the report, Professor Sir John Beddington CMG, FRS Chief Scientific Adviser to HM Government, and Head of the Government Office for Science made the following opening remark:

> *'The case for urgent action in the global food system is now compelling. We are at a unique moment in history as diverse factors converge to affect the demand, production and distribution of food over the next 20 to 40 years. The needs of a growing world population will need to be satisfied as critical resources such as water, energy and land become increasingly scarce. The food system must become sustainable, whilst adapting to climate change and substantially contributing to climate change mitigation. There is also a need to redouble efforts to address hunger, which continues to affect so many. Deciding how to balance the competing pressures and demands on the global food system is a major task facing policy makers, and was the impetus for this Foresight Project.'*

The report explores a range of challenges which are as relevant to Africa as they are any other part of the world, namely:

A. Balancing future demand and supply sustainably – to ensure that food supplies are affordable.

B. Ensuring that there is adequate stability in food supplies – and protecting the most vulnerable from the volatility that does occur.

C. Achieving global access to food and ending hunger. This recognises that producing enough food in the world so that everyone can potentially be fed is not the same thing as ensuring food security for all.

D. Managing the contribution of the food system to the mitigation of climate change.

E. Maintaining biodiversity and ecosystem services while feeding the world.

These last two challenges recognise that food production already dominates much of the global land surface and water bodies and has a major impact on all the Earth's environmental systems. These challenges have grown in stature over the past decade. More focus should be place on rehabilitation and regeneration.

1.2. The Agricultural Engineering Proposition

Few would disagree with the Foresight Report and least of all Agricultural Engineers. Specific reference to the discipline and the role it plays in global food security is more implicit than it might have been, and this elicited a response from the UK based Institution of Agricultural Engineers (IAgrE)[1], a professional engineering institution of eighty years standing and a recognised authority.

This report on Agricultural Engineering in Africa is founded on the same principles as an earlier report produced by IAgrE titled Agricultural Engineering: *A Key Discipline for Agriculture to Deliver Global Food Security (Institution of Agricultural Engineers, 2012).* This status report was developed by IAgrE in response to the UK Government's Foresight Project: Global Food and Farming Futures.

Writing in the forward, IAgrE Presidents at the time, Peter Leech and Andrew Newbold, wrote:

> *'The Foresight Report 'The Future of Food and Farming: Challenges and Choices for Global Sustainability' concluded that 'the global food system faces formidable challenges today that will increase markedly over the next 40 years. … Much can be achieved immediately with current technologies and knowledge, given sufficient will and investment. But coping with future challenges will require more radical changes to the food system and investment in research to provide new solutions to novel problems.'*

They concluded the following:

> *'The American Society of Mechanical Engineers identified agricultural mechanisation as one of the top ten achievements in mechanical engineering in the 20th century. Agriculture was a gruelling and laborious business, but mechanisation reduced the drudgery, increased outputs and allowed operations to be carried out at the right time. The advances in the last 100 years in drainage and irrigation, in tractors, tillage and crop protection, and in harvesters and cool chain management all derive from agricultural engineering innovation. Now we have a new revolution in information and control technologies, and in engineering science to understand the performance of highly complex systems and provide routes to optimised operations from farm to fork. These advances can provide similar benefits in the 21st century, not just to the farmer but also to the environment, the food chain and the global consumer.'*

These assertions are as relevant to the African agenda as they are anywhere else in the world and, to that end, this report on Agricultural Engineering in Africa will put into context, how this discipline will be a key driver in transforming African agriculture to deliver food security and to support economic prosperity.

[1] https://iagre.org/

1.3. The Pan African Society for Agricultural Engineering *(PASAE and/or AfroAgEng)*

This report has drawn upon the specialist expertise of the Pan African Society for Agricultural Engineering[2] (PASAE). In this report the name is shortened to either PASAE and/or AfroAgEng. The objective is to produce a definitive overview of the potential the discipline has in addressing the food and water security and environmental sustainability challenges of the continent.

This report seeks to maintain a positive and 'solutions driven' approach to solving problems and meeting the challenges. It outlines a range of potential strategies and solutions which can be harnessed to move the discipline forward such that it makes an even great contribution to delivering the aspirations set out in **Agenda 2063: The Africa We Want.**

AfroAgEng was formed in 2012, as the network of professionals in academia, research, industry and policy, as well as companies and private individuals with interest in the application of engineering principles in agriculture, food and related land-based industries and is the umbrella organization connecting national and regional associations and societies of Agricultural and Biosystems Engineering in Africa. AfroAgEng is a member of CIGR[3], the global organization for Agricultural and Biosystems Engineering.

The Mission of AfroAgEng is to promote and advance the profession of Agricultural Engineering in Africa. The Society seeks to become a key knowledge partner and visible policy advocate on the role of engineering and technology in the transformation and industrialization of agriculture in Africa towards Agenda 2063 and beyond – **The Africa We Want.**

The International Food Policy Research Institute (IFPRI) explored Agricultural Productivity in Africa Trends, Patterns, and Determinants (International Food Policy Research Institute, 2016). According to this report, agricultural productivity in Africa remains the lowest in the world, but recent concerns about food security, water security, rapidly expanding global population, rising food prices and unsustainable resource utilisation have focussed world-wide interest on the role of agricultural production in feeding Africa and the world.

Currently most of the world's uncultivated agricultural land is in Africa, yet the capacity to harness this resource remains limited due partly to very low application of innovative technologies which are necessary for improved and sustainable food production. Postharvest loss remains high in Africa due to inadequate infrastructure, limited agro-processing and other value addition activities, and the lack of favourable policies.

These challenges present unique opportunities for Agricultural Engineers in Africa and around the world to form a critical mass of educators, researchers and industries to create the required leadership to drive the change needed to transform African agriculture. AfroAgEng aims to stimulate, promote and shape the education, research, policy and practice of Agricultural and Biosystems Engineering in Africa.

In essence, The Africa We Want will be inhabited by a widely recognised, vibrant, progressive and valued Agricultural Engineering profession who works in unison with local and national governments, industry, commerce, education, research, other disciplines and wider society across the African continent. This will be essential if there is to be improved agricultural production, food and water security and environmental sustainability.

Beyond the subject of this report, the Objectives of AfroAgEng include the following:

- Raise awareness about the critical role of engineering and technological innovations in agriculture and related bio-based industries in Africa.
- Promote curriculum reform and academic mobility among Agricultural Engineering programs.
- Facilitate the exchange and sharing of information on the different aspects of Agricultural, Biosystems and Bioresources Engineering.
- Assist individual members to develop their professional knowledge, skills and network through information exchange.
- Promote and support a network of young Agricultural Engineers as the pipeline for future leadership in the discipline and profession.
- Promote greater engagement between the academic discipline, professional practice and industries serving agriculture, including manufacturers.
- Represent the profession at continental and global levels.
- Participate in the affairs and promote the activities of the CIGR in Africa.
- To achieve these, the Society will be active in organising and supporting networking events such as conferences, workshop, seminars and symposiums on current and emerging issues facing engineering and technology in agriculture, and related publications.

Since its creation in 2012, PASAE has offered a range of conferences, workshops and events to promote its cause. The reports from these conferences can be found at

http://www.pasae.org.za/Events.html.

[2] Pan African Society for Agricultural Engineering (PASAE). http://pasae.org.za/index.html
[3] International Commission of Agricultural and Biosystems Engineering (CIGR). https://cigr.org/

To date, PASAE events have included:

March 2018	1st PASAE Conference, Nairobi, Kenya held in conjunction with KeSEBAE
September 2018	PASAE Workshop on Growing Agricultural Engineering in Africa, KwaZulu-Natal, South Africa
September 2019	2nd PASAE Conference, Rabat, Morocco held in conjunction with ANAFIDE
September 2020	PASAE Workshop, held online, on Modernising Agricultural Engineering Programmes to meet Africa's Agenda 2063: The Africa We Want
April 2021	3rd PASAE and the Nigerian Institution of Agricultural Engineers (NIAE) Conference on Engineering Africa's Agro-Industrial Transformation for Economic Prosperity and Sustainable Development

Chapter 2 Key Development Challenges

2.1. Agricultural Productivity

The dynamics of agriculture are good – the growing human population must eat! Therefore, there are many opportunities to develop better solutions that deliver food security.

The subject of Agricultural Productivity and Environmental Sustainability in Africa is a very well researched subject with a plethora of research bodies, Non-Governmental Organisations, universities and others producing a very broad range of reports.

It will add no value to this report if any particular report is highlighted so the focus here will be to link findings to the role of Agricultural Engineering in applying modern and appropriate technology to the solutions. However, the UNESCO and ICEE report on Engineering for Sustainable Development (UNESCO, 2021) is worthy of being highlighted as an example of how wider engineering has an important role to play.

The harsh facts are that food and fodder production on the African continent is not meeting the growing demand and this is mainly attributed to low productivity. This is exacerbated by very high post-harvest losses and excessive waste.

Speaking at a Centre for Global Development event in 2017, President of the African Development Bank (AfDB), Akinwumi Adesin and a former Nigerian Agriculture Minister stated (Shaban, 2017) the following:

"Africa's annual food import bill of $35 billion, estimated to rise to $110 billion by 2025, weakens African economies, decimates its agriculture and exports jobs from the continent. To rapidly support Africa to diversify its economies, and revive its rural areas, we have prioritized agriculture. The Bank has committed $24 billion towards agriculture in the next 10 years, with a sharp focus on food self-sufficiency and agricultural industrialization,'

In one example, an event report on Raising Agricultural Productivity in Sub Saharan Africa (Development and Economic Growth Research Programme, 2015) is helpful in highlighting some of the Africa specific issues where Agricultural Engineers may support solutions.

This report highlights at least five potential reasons for low productivity including:

- returns from more productive technologies on farms are lower than expected,
- the risks of adoption are too high,
- markets for inputs, credit and insurance work imperfectly,
- insecure rights over land deter investment, and
- technical knowledge is not getting to farmers.

2.2. Rising Population and Shifting Demographics

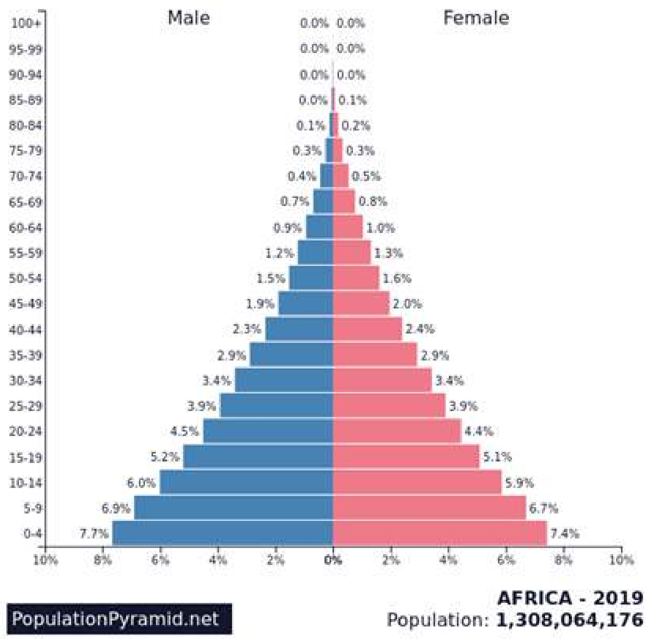
Across Africa, research into shifting demographics is widespread (United Nations, 2018; United Nations Economic Commission for Africa, 2018) For the African context, this can be captured in three broad areas.

African Population

- 1 billion people in 2010
  (representing around 15% of 6.9 billion globally)
- 2.3 billion people in 2050
  (representing around 25% of 9.6 billion globally)

Age Groups in Africa

The number of young people is very high as illustrated by this chart. (Population Pyramid,2021)



Urbanization in Africa

Globally

- 54% of population living in urban areas in 2014
- Projected to be > 60% by 2030 and 70% by 2030

Africa

- 40% of population in urban areas
- 50% increase by 2030

In addition to urbanisation, the rising number of middle-class people is expected to double by 2030, which will add to the demands on agricultural productivity, and in the demand for a wider range of food. Across Africa migration from rural to urban areas is likely to have a negative impact on the number of people available for agricultural work. Technological solutions will be an essential component in addressing this challenge as is illustrated in the next part of this report.

2.3. The Water, Food and Energy Nexus

The facts and figures relating to the relationship between food production and associated water and energy use make for stark reading:

- Globally, 72% of all water withdrawals are used by agriculture, 16% by municipalities for households and services, and 12% by industries. (UN Water, 2021)
- In sub-Saharan Africa, irrigated areas are expected to more than double by 2050, benefiting millions of small-scale farmers. However, it has been estimated that 41% of current global irrigation water use occurs at the expense of environmental flow requirements (Food and Agriculture Organisation (FAO), 2020a).
- Africa's growing demand for resources are estimated as a 283% growth in water consumption between 2005 and 2030, a 60% increase in food demand between 2015 and 2030, and a 70% growth in electricity demand between 2016 and 2030 (Food and Agriculture Organisation (FAO), 2020b)

2.4. Infrastructure Deficit

The technology requirements for Africa are very diverse as illustrated in figures 1 & 2:

From this ...

Fig. 1

To this ...

Fig. 2

The infrastructure in rural areas is often poor and challenging making distribution difficult as illustrated in figures 3 & 4

Fig. 3

Fig. 4

A lack of systems integration, training and local support mean that appropriate technology is not always used to best effect as illustrated in Fig 6 & 7.

Fig. 5

Fig. 6

The result of this infrastructure deficit is that agricultural production in Africa generally utilises low-technology and is underdeveloped. At present it is predominantly one of subsistence farming as illustrated in Fig7 & 8 which needs to be transformed into small and larger scale commercial enterprises. Overcoming this challenge will unlock productivity.

Fig. 7

Fig. 8

(All images supplied by Mark Moore FIAgrE)

A report from the Southern Africa Development Community (SADC, 2018) on Engineering Numbers and Needs in the SADC Region highlights a range of general recommendations in relation to engineering. It also maintains a good focus on engineering as it relates to agricultural production and highlights some stark truths which need to be addressed by stakeholder and policy makers. In summary:

- The percentage of rural communities eking out a living is alarming and does little to encourage people to remain on the land.
- Given the large percentage of young people, this must be addressed to prevent mass migration to the cities which is unsustainable.
- In many countries, agricultural extension capacity has declined, and where young people are being trained, they have had limited hands-on experience, hence their advice is not valued by mature farmers.
- Where comprehensive extension support has been in place, there are many success stories of improved output using improved seed, fertilisers, controlled watering and other techniques.

- To expand the areas that families can farm effectively, the introduction of small-scale mechanisation has proved successful.
- Many innovations require engineering skills or input of some sort.
- There are limited postharvest facilities for processing, packing and storing excess crops.
- Transport network development plans are normally based on the needs of the mining and manufacturing sectors. Agricultural production should be factored into these plans.

There is much to take on board from the above list. In a later section, this report will explore the provision of undergraduate education and training from across the African continent and highlight some of the emerging best practices which exist.

These are complex topics and difficult to resolve. In the next section, the profession of Agricultural Engineering will be explored in detail. This is vital in that food and water insecurity and environmental degradation are so widespread across Africa. This demonstrates the need for relevant engineers, technologists and technicians to engage more broadly to find solutions.

These solutions are likely to revolve around improved food production, harvesting, processing systems and logistics, including soil conservation and management, irrigation and water supply, sustainable mechanisation, technical knowledge transfer, management of risk associated with technology adaptation, reducing post-harvest, storage and processing losses, and transport logistics to move the product from the field to point of sale. The important task here is for Agricultural Engineers to be recognised and to contribute to the debate. They have a lot to contribute through the development, adaptation, and efficient use of appropriate technologies.

2.5. The Image of Agricultural Engineering

Speaking in 2020 to the South African publication Engineering News (Engineering news 2020), Thabo Mavundza, Vice President of the South African Institute of Agricultural Engineers[4] (SAIAE) at the time and current President of SAIAE said:

> '*The agricultural industry remains key to the development of South Africa and addressing the country's prevalent unemployment issues, but local Agricultural Engineers are a scarce breed'.*
>
> *'Agricultural Engineers are at the centre of the food, water and energy nexus and are, thus, vital to ensuring food security and sustainability for the future.'*

Although referring to the situation in South Africa, there is evidence that these comments relate to much of the continent. Although the take up of engineering programmes is often strong, Agricultural Engineering has an image problem. It is generally unknown or much misunderstood with many incorrect perceptions as to what it is, perhaps drawn from traditional views of the discipline.

To many people Agricultural Engineering is perceived to be an old-fashioned industry and not worthy of a modern career. At the same time, migration from rural to urban areas is indicative of a view that work on the land and with agriculture is of the past. This could not be further from the truth and later in this report, some of the new opportunities will be explored. The challenge for the profession is to change prejudices so that Agricultural Engineering is perceived to be 'of the future'.

At its biennial symposium in KwaZulu-Natal during September 2018, SAIAE explored this matter further. The aims of this four-day symposium were to:

- to present and discuss technical challenges and solutions in the broad fields covered by Agricultural Engineering.
- to host a workshop on growing the Agricultural Engineering profession in Africa.

This event attracted professionals involved in Agricultural Engineering, not only from South Africa but from all over the continent (and beyond). The workshop element of the symposium was organised by the Pan-African Society for Agricultural Engineering through a project funded by the Royal Academy of Engineers in the UK. The qualitative data gathered represents a rich source on which to base analysis of stakeholder perceptions of Agricultural Engineering in Africa and from which to make conclusions about the discipline's future on the continent. Five questions were discussed by delegates at the workshop:

- What are the opportunities of growing Agricultural Engineering in Africa?
- What are the challenges of growing Agricultural Engineering in Africa?
- What are the barriers to overcoming these challenges?
- What prioritised strategies should be undertaken to grow and strengthen Agricultural Engineering in Africa?
- What additional activities should PASAE/AfroAgEng undertake to grow, service and support members?

[4] South African Institute of Agricultural Engineers (SAIAE). http://saiae.co.za/index.html

In **Appendix C**, the responses to these questions are discussed in more detail but they are highly relevant to this report and will be explored in more detail where they arise. In summary, the following solutions were considered.

Question	Key Responses
What are the opportunities of growing Agricultural Engineering in Africa?	• Some of the key threats to humanity such as population growth, food insecurity and global warming are an opportunity for Agricultural Engineers. • The opportunity to further develop and enhance mechanisation as a solution, and particularly as computers and automation takes hold.
What are the challenges of growing Agricultural Engineering in Africa?	• Addressing the poor perception of Agricultural Engineering as an exciting and rewarding career option. • Employment opportunities through making better links with employers to broaden access to good quality jobs.
What are the barriers to overcoming these challenges?	• The lack of collaboration and the way in which the "silo mentality" pervades in a world where a multi-disciplinary approach is needed. • The lack of professional bodies prevents the cross fertilisation and sharing of knowledge.
What prioritised strategies should be undertaken to grow and strengthen Agricultural Engineering in Africa?	• More partnerships are needed between employers and universities, private and public sectors, business and government. • More mobility should be prioritised for students, graduates and academics, as well as the profession and industry, as a vehicle for knowledge transfer.
What additional activities should PASAE/AfroAgEng undertake to grow, service and support members?	• Facilitating engagement with academia and industry is seen as a key development. • Marketing the profession and helping to show case examples of great engineers doing great things.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Chapter 3 Defining the Profession

3.1. What is Agricultural Engineering

Agricultural Engineering is an often-misunderstood sector where observers, including the media, education professionals and career advisors have no knowledge or hold a narrow view of its function. In too many cases it is perceived to be about the design, service, and repair of farm machinery such as tractors and harvesters. This is a narrow viewpoint which undermines the very broad range of activities and job roles that Agricultural Engineers undertake. In fact, agricultural engineers play a vital role in the food production system. They "touch" every part of the process, unlike for example soil science for example, which is only focused on soil. Agriculture Engineers are therefore natural systems integrators and bring many different disciplines together from different sectors.

Agricultural Engineering is a unique discipline and stands out from other engineering disciplines through the way in which it connects the living world of plants, soil, water, animals and people with engineering and technology, i.e., systems, structures, and machines.

A key organisation is the International Commissions of Agricultural and Biosystems Engineering (International Commission of Agricultural and Biosystems Engineering (CIGR), who represents a global network of relevant societies with the collaborative aim:

> *'… to serve - on a world-wide basis and through its members - the needs of humanity by fostering mutual understanding, improvement and rationalisation of sustainable biological production systems while protecting nature and environment and managing landscape through the advancement of engineering and allied sciences...'*

The American Society of Agricultural and Biological Engineers (ASABE, 2021), an educational and scientific organization dedicated to the advancement of engineering applicable to agricultural, food, and biological systems founded in 1907 asserts:

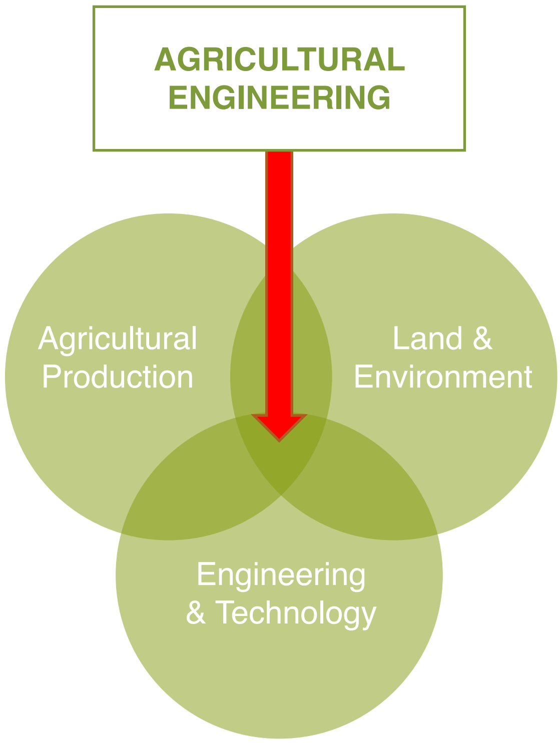
> *Agricultural, food, and biological engineers develop efficient and environmentally sensitive methods of producing food, fibre, timber, and renewable energy sources for an ever-increasing world population.*

These definitions are helpful and identify the important contribution that Agricultural Engineers make along the whole food chain, from field to fork. It also highlights the extent to which an Agricultural Engineer needs to understand the impact of their work on plants, animals land and environment. The crucial reference to environmentally sensitive methods of production and an ever-increasing world population have particular relevance and importance when applied to the African context.

It is important to note that the traditional use of the term Agricultural Engineer has been expanded by many institutions to focus on the biological aspects and which include combinations of agricultural, biological, bioresources, biosystems and environmental engineers in order to better define the scope of the graduates. Identities are important, particularly if the discipline of Agricultural Engineering is to be perceived as a 'go to' career option for future scientists, engineers and technologist.

It is essential therefore, that society, policy makers and other stakeholder understand what Agricultural Engineering is about. As such these engineers need to have an appropriate understanding of biology, chemistry and environmental sciences in addition to core engineering functions.

The diagram below put this nexus into context with Agricultural Engineering at the centre.



It is not uncommon to find graduates from many other engineering disciplines and science disciplines working in this sector. In some respects, this presents an opportunity in so far as graduates in agriculture, land, and environmental subjects, or those who have studies a more general aspect of engineering, can be found working across Agricultural Engineering. For example, those working in soil science, or the application of pesticides, with a background founded in science, particularly biology and chemistry often make a vital contribution to Agricultural Engineering.

3.2. The Importance of Professionalism

The importance of professionalism is well developed across many disciplines: engineering through to accountancy, law making and the health sector. In Agricultural Engineering there is a strong history of participation in those traits commensurate with the professional approach.

Across the world and Africa there are a range of professional bodies and membership associations of which AfroAgEng is just one. These are founded around the principle of promoting professionalism and professional registration through an appropriate regulatory body.

According to the United Kingdom Engineering Council (EngC) who act as the regulatory body for the UK engineering profession and is well respected across the globe, including Africa, this is defined as:

> *'Professional registration provides a benchmark through which the public, employers and their clients can have confidence and trust that registered engineers and technicians have met globally recognised professional standards'.*

These definitions imply that professionalism encompasses several different attributes, and, together, these attributes identify and define a professional. The same attributes are common across most professional bodies, including those with an environmental focus such as the UK Society for the Environment (Society for the Environment (SocEnv). 2020) and include:

- Specialized knowledge.
- Competency.
- Honesty and integrity.
- Accountability.
- Self-regulation.

Through this report, AfroAgEng asserts that anyone working with food security, environmental protection, water supply and irrigation, food processing and distribution, and everything else that constitutes the discipline, should adopt a professional approach.

The UNESCO/ICEE report on Engineering for Sustainable Development (UNESCO, 2021) highlights that 'Professional engineering organisations are playing an increasingly important role in engineering capacity building through interregional partnerships. Hence, AfroAgEng and its development is a vital component in developing engineering across Africa, and especially in terms of engineering and technology solutions for the Sustainable Development Challenges.

Professional societies, whether that is AfroAgEng covering all of Africa, or those in individual countries such as the Kenya Society of Environmental, Biological and Agricultural Engineers (KeSEBAE) or SAIAE, together with their partners across the world, offer an important foundation for the promotion of a professional approach as well as a means by which expertise can be shared, policy decided, and future thinking established.

By way of illustration, the professional approach (American Society of Agricultural and Biological Engineers (ASABE) is helpful in showing how the people of the world benefit from the work of the professional body and how that positively impacts on food, water, energy and the environment. This report seeks to unleash the same benefit for the good of the people of Africa and as part of Agenda 2063: The Africa We Want.

The image below (ASABE, 2021) is courtesy the American Society of Agricultural and Biosystems Engineers and is equally applicable in the African context.

[5] Engineering Council (EngC). Professional Registration. https://www.engc.org.uk/professional-registration/
[6] Society for the Environment (SocEnv). Championing and Registering Environmental Professionals. https://socenv.org.uk/
[7] Kenya Society of Environmental, Biological and Agricultural Engineers (KeSEBAE). https://www.kesebae.or.ke
[8] American Society of Agricultural and Biological Engineers (ASABE). https://www.asabe.org/About-Us

3.3. Careers in Agricultural Engineering

In addition to the earlier definitions made by CIGR and ASABE, the USA Environmental Science and Education Careers (Environmental Science, 2021) service expands on the wider job roles found in Agricultural Engineering and in the context of this report and as far as Africa is concerned, offers a helpful expansion of the various roles and opportunities available to those looking for a career in this sector:

> *'Agricultural engineers integrate technology with farming. For example, they design new and improved farming equipment that may work more efficiently or perform new tasks. They design and build agricultural infrastructure such as dams, water reservoirs, warehouses, and other structures. They may also help engineer solutions for pollution control at large farms. Some agricultural engineers are developing new forms of biofuels from non-food resources like algae and agricultural waste. Such fuels could economically and sustainably replace gasoline without jeopardizing the food supply.'*

This highlights the broad range of skill sets needed by Agricultural Engineers who generally need to display the ability to work in a multi-disciplinary way by integrating engineering and science systems. However, as the profession evolves, this description it is already outdated. The changing face of agriculture and associated technology now encompasses environmental, biological, computational, and other wider factors must be included in any future definitions.

In addition, Agricultural Engineering is the only engineering discipline focussed on working with plants and animals. This makes it unique. Use of the term 'Biosystems' in some circles introduces the concept of interconnected systems and an approach which has to draw from a broad nexus of learning and understanding. This will be explored further when this

Table 1 – An overview of the broad range of Agricultural Engineering Jobs

Agricultural Engineering jobs focus on the science behind food production and processing systems and sustainable farming operations, and application of this technology to develop systems to help today's agricultural methods and products meet global and national food demands while sustaining/regenerating the environment. While tasks vary significantly from job to job, the following list includes standard duties that an Agricultural Engineer could encounter:

- Plan, design, maintain and supervise the construction of irrigation, drainage, and flood- and water-control systems
- Design and supervise the construction of agricultural buildings, food processing systems and storage facilities in order to engineer a system that is the most efficient while also the most cost effective
- Design equipment and machinery used for field preparation, seeding, spraying, harvesting, and transporting agricultural products
- Ensure equipment design is consistent with local codes and farming culture as well as catering to the resources available in the region
- Design and manage all aspects of the production and delivery of agricultural products from seed to table
- Prepare and present technical reports, meet with clients, and communicate technical concepts to internal and external stakeholders
- Advocate for sustainable agriculture on a local and national level.
- Research to develop technologies to support new and more efficient ways of agricultural production, harvesting, processing, transport and storage in an environmentally friendly and sustainable manner
- Undertake research and development for the design of new structures and systems
- Conduct research in the field and laboratory to develop practices for food production and processing that protect the environment

Senior Agricultural Engineer jobs often have an added level of managerial tasks to facilitate the scheduling, budgeting, and communications needs of various projects. Some common tasks may include:

- Analysing data, and preparing reports for external stakeholders
- Drafting and implementing computerized construction and management plans
- Planning projects, administering and managing budgets
- Participating in longitudinal safety analyses
- Communicating with internal and external clients, stakeholders, and government departments
- Researching and collecting contextual information for case studies
- Supervise the construction of flood- and water-control systems

report examines the subject of **Systems Engineering.**

The USA Environmental Science and Education Careers Service expands further and in doing so suggests that those employed in mechanisation and with the maintenance, service and repair of farm machinery and tractors, as crucial as that role is, form a small part of the wider Agricultural Engineering discipline.

This overview is summarised in **Table 1** for the African context, and specifically for some of the goals set out in **Agenda 2063: The Africa We Want;** and this demonstrates the range of job opportunities and roles available to those who pursue a career in this discipline.

At the same time as espousing these graduate level roles, it is important to emphasise the importance of Agricultural Engineering Technicians. These perform an essential role in installing and maintaining the complex mechanisation systems, tractors and machinery, irrigation systems and soil and water conservation structures found in modern agriculture. Across Africa, whilst university provision is well understood and regarded, the more technical and vocational provision is less well defined.

The sector is facing an exponential growth in the complexity and sophistication of the equipment, machinery and processes used. The growth in skills and knowledge of those technicians who maintain and repair these complex machines, equipment and systems is increasingly lagging behind.

Writing in the UK Institution of Agricultural Engineers (IAgrE) professional journal, Landwards, former President Peter Leech, Hon FIAgrE, who spent 42 years with John Deere, charts the march of progress (Leech 2018). This is summarised in **Table 2**.

Table 2 – The growth in skills and competence requirements

Skills and Competence	Pre 1900 Blacksmith	1900 to 1940 Journeyman	1940 to 1970 Fitter	1970 to 1990 Mechanic	1990 until Today Technician	The Future: Tomorrows Tech
Practical common sense and logic	✓	✓	✓	✓	✓	✓
Ingenuity to solve problems	✓	✓	✓	✓	✓	✓
Adaptability to invent solutions	✓	✓	✓	✓	✓	✓
Self-sufficiency (working alone)		✓	✓	✓	✓	✓
Customer relationship management	✓	✓	✓	✓	✓	✓
An understanding of farming operations	✓	✓	✓	✓	✓	✓
Work with steel and welding	✓	✓	✓	✓	✓	✓
Work with spanners and hand tools		✓	✓	✓	✓	✓
Internal combustion engines			✓	✓	✓	✓
Transmissions			✓	✓	✓	✓
Complex transmission systems PST, IVT				✓	✓	✓
Hydraulics and hydrostatics				✓	✓	✓
Air conditioning systems					✓	✓
Electro-Hydro systems					✓	✓
Electronics, CAN bus systems					✓	✓
Emissions systems					✓	✓
Telematics					✓	✓
Robotics						✓
Use of intelligent diagnostic systems						✓
Electric/Hybrid vehicle technology						✓
Autonomous/self-driving vehicles						✓

It can be seen that Agricultural Engineering demands a broad range of knowledge and skills from engineering, science and technology to support its many subject specialisms as well as offering technicians and graduates an impressive array of career opportunities.

Table 3 illustrates the various aspects of Agricultural Engineering in terms of technical and support roles through to professional practice. In terms of this report and its assertion that this discipline should be viewed as a key driver for transforming agriculture to deliver food security and to support economic prosperity, it can be concluded that this discipline should be viewed as a vital component in delivering many aspects of Agenda 2063: the Africa We Want and contributing to food, water and energy security and a sustainable environment and thus improving livelihoods.

Table 3 – Subject Specialisms in Agricultural Engineering

Technical and Support	Professional Practice
Service engineer	Machine designer
Diagnostics technician	Engine and power engineer
Welder	Electrical engineer
Fabricator	Electronics engineer
Fitter	Field test and development
Electrician	Irrigation engineer
Workshop supervisor	Water storage and dams
Field engineer	Flood and drainage engineer
Pump engineer	Water distribution engineer
Machine operator	Post-harvest storage
Skills trainer	Post-harvest processing
Refrigeration technician	Refrigeration application
Milking machine technician	Energy utilisation and supply
Construction and plant engineer	Transportation and supply
Autonomous systems technician	Soil and water engineer
Controlled environment technician	Waste management
Soil and Water Engineering	Pollution control
Food Engineering	Systems integration engineer
Power and Off-Road Engineering	Knowledge transfer and extension
	Efficient resource utilisation
	Precision Farming specialist
	Robotics engineer
	Computer code
	Animal welfare
	Livestock housing
	Rural roads and bridges
	Forestry engineering

3.4. The Rise of Precision Agriculture and Agritech

Across the developed world, and increasingly Sub-Saharan Africa, the concept of Precision Farming has taken hold. For many agricultural machinery manufacturers and agronomists advising farmers and growers, it has become a vital aspect of their work. The growth in start-up companies across the world and associated research activity is testament to the vital importance Precision Agriculture will have in the future.

A large number of web-based definitions exist for Precision Agriculture, although the International Society of Precision Agriculture (ISPA, 2021) who seek to advance the science of Precision Farming provide a helpful definition:

> *'Precision Agriculture is a management strategy that gathers, processes and analyzes temporal, spatial and individual data and combines it with other information to support management decisions according to estimated variability for improved resource use efficiency, productivity, quality, profitability and sustainability of agricultural production.'*

This approach to agricultural production has a vital role to play across Sub-Saharan Africa. The environmental benefits, together with great efficiency gained through this approach should be the focus on all stakeholders across the continent. In turn, this is leading to an emerging focus on African led research and innovation and the publication of associated papers such as Precision Agriculture and Food Security in Africa (Ncube et al., 2018).

In the rest of the world, there are many ongoing government led developments to support Precision Agriculture. For example, in launching a United Kingdom Strategy for Agricultural Technologies (Agritech), the UK government (add ref) stated the following:

> *'The challenges facing the food industry are well documented. From adapting to the effects of climate change, to feeding a growing global population with dwindling resources, it is very clear that the degree of change that is required within food and agriculture systems, and the pace with which that change needs to be delivered, requires us to adopt new ways of doing things.'*

This comment is as relevant to the African Continent as it is to rest of the world.

In the context of this report, The Beddington Report (add ref) cited earlier highlights that Agritech solutions are concerned with Global Food Security and, in that context, there is much useful synergy with **Agenda 2063: The Africa We Want.**

The UK based professional engineering body, the Institution of Agricultural Engineers (IAgrE) produced a status report in response to Foresight Report called Agricultural Engineering: a key discipline enabling agriculture to deliver global food security (Institution of Agricultural Engineers, 2012). In responding to this report, Beddington said:

'The Foresight Report 'The Future of Food and Farming: Challenges and Choices for Global Sustainability', which I launched last year, highlights major challenges to global food security. Deploying new and existing technologies, processes and knowledge that help make farming methods and practices more sustainable, while having less impact on the environment, will be important. I welcome this report in highlighting the importance of agricultural and biosystems engineering in contributing to these advances.'

The rise in the importance of Agritech which was born from this report may well have taken place anyway and it is interesting to note a new cadre of engineers and entrepreneurs taking forward development in Agritech on the back new developments in mobile phone technology, communication networks and the provision of 'big data' to support technology platforms. The emerging Internet of Things (IoT) and the new concept of the Internet of Agri Things have encouraged a new enthusiasm toward the application of science and technology to food production. Technologies and applications associated with Agritech include the following:

- Drones
- Satellite photography and remote sensing
- Geographical Information Systems (GIS)
- Sensor networks
- Weather forecasts
- Automated precision irrigation
- Light and heat control systems for optimum production
- Intelligent software analysis for pest and disease prediction, soil and water management and other involved analytical tasks
- Machine vision and vehicle automation
- Variable rate application of irrigation, fertiliser and perticides.

The development of Agritech has led to increased involvement from venture capitalists, global corporations and supporting events (Agritech Africa, 2020) who see the value of developing solutions to meet the particular needs of Africa, although a balance needs to be retained in terms of ensuring developments are 'For Africa, By Africa'.

This rise in Agritech is illustrated by a Tanzanian Agritech start-up who won the 2020 MEST Africa Challenge (MEST, 2020). Kilimo Fresh Foods (Kilimo Fresh, 2021) is an online platform that distributes fresh produce from small farmers to businesses. Through the use of their platform, small farmers are able to showcase and supply their produce including dry foods, vegetables, grains, and fruits to various businesses in Tanzania. The startup enterprise has worked with small farmers from the coastal regions as well as the Northern and Southern Highlands in Tanzania to ensure that only high-quality and organic products are distributed.

Global partners are actively engaged in collaborative research activities with increasing levels of involvement from African institutions and universities. In 2021, these included: Cassava Brown Streak Virus early disease sensing for delivering clean planting materials to Tanzanian small holder farmers; Sentinel wheat rust fungal pathogen mapping through Internet-of-Things (IoT) networked biomimetic sensors in Ethiopia; and Delivering low-cost subsoil imaging for roots so as to help breed cowpea crops that can survive on low-phosphate Nigerian soils. Each of these are at varying levels of TRL (Technology Readiness Level), but all are based on proof-of-concept systems which could be adapted to alternate crops and regions.

Similarly, the Royal Academy of Engineering Africa Prize for Engineering Innovation continues to attract a wide range of Agritech proposals. Some of these developments are explored later in this document.

3.5. Education, Research and Innovation

All of these developments in Precision Agriculture and associated Agritech will demand a new cadre of engineers and technologists who have the knowledge and skills to deal with the emerging technologies.

Whilst across Africa, the university training of traditional Agricultural Engineers appears broadly well founded and well understood with a long history, there is little reference to vocational and applied education and training and especially at technician level. This is a significant deficit which needs to be addressed.

Investment in research is similarly low. The UNESCO/ICEE report on Engineering for Sustainable Development (UNESCO 2021) highlights the challenge and compares the expenditure on Research and Development (R&D) as a percentage of Gross Domestic Product (GDP) and the number of researchers per million inhabitants. For most African countries, these numbers are so low that they do not appear in the data. South Africa is cited with around 500 R&D researchers per million inhabitants and a R&D spend of around 0.8% of GDP. By comparison, European nations typically have 4500 R&D researchers per million inhabitants and a R&D spend of between 2-5%. Clearly, the area of spend on R&D is a challenge which needs to be addressed, including the work which goes on outside of the continent which could be adapted to have a positive impact in Africa.

In Chapter 6, this report considers the Future Farm Initiative as an example of one potential solution combining education, research and innovation as illustrated in Fig 9 & 10 below. This integrated approach could be pursued more widely across Africa.

Fig. 9

Fig. 10

Chapter 4 Sustainable Development Goals

4.1. A Vision for the Future

Both Agenda 2063 – Africa's blueprint and master plan for sustainable development and economic growth of the continent, and the United Nations Sustainable Development Goals (SDGS, 2021) set a very clear vision for the future and the terms of the **Agenda 2063: The Africa We Want** brings this together in a way which is appealing to a range of stakeholders. Clearly agricultural productivity and sustainable food supply is implicit across all of Agenda 2063 (African Union 2021: Overview) although is particularly relevant to the first aspiration listed below:

Aspiration 1: A prosperous Africa based on inclusive growth and sustainable development

We are determined to eradicate poverty in one generation and build shared prosperity through social and economic transformation of the continent.

Goals:

1. A high standard of living, quality of life and well-being for all
   - ending poverty, inequalities of income and opportunity; job creation, especially addressing youth unemployment; facing up to the challenges of rapid population growth and urbanization, improvement of habitats and access to basic necessities of life – water, sanitation, electricity; providing social security and protection;
2. Well educated citizens and skills revolutions underpinned by science, technology and innovation
   - developing Africa's human and social capital (through an education and skills revolution emphasizing science and technology)
3. Healthy and well-nourished citizens
   - expanding access to quality health care services, particularly for women and girls;
4. Transformed economies and jobs
   - transforming Africa's economies through beneficiation from Africa's natural resources, manufacturing, industrialization and value addition, as well as raising productivity and competitiveness
5. Modern agriculture for increased proactivity and production
   - radically transforming African agriculture to enable the continent to feed itself and be a major player as a net food exporter;
6. Blue/Ocean Economy for accelerated economic growth
   - exploiting the vast potential of Africa's blue/ocean economy;
7. Environmentally sustainable climate and resilient economies and communities
   - putting in place measures to sustainably manage the continent's rich biodiversity, forests, land and waters and using mainly adaptive measures to address climate change risks

In the same way, the Flagship Projects (Africa Union 2021, Flagship Projects) set out for the first ten years of Agenda 2063 are ambitious and point towards developments that will improve food supply and security.

One of these projects, around the establishment of an African Virtual and E-University which aims to use ICT based programmes to increase access to tertiary and continuing education in Africa by reaching large numbers of students and professionals in multiple sites simultaneously may be of value to those involved with providing extension services to support the development of technological solutions which address agricultural productivity and food security.

Clearly, the Agricultural Engineering discipline has a lot to offer Agenda 2063 and the challenge facing the profession is in getting its message across to those who will influence the agenda as it progresses. Of particular interest, and especially useful for Agricultural Engineering in Africa are the SDGs set out by the United Nations General Assembly in 2015. These are a collection of 17 interlinked goals designed to be a "blueprint to achieve a better and more sustainable future for all". This is an ambitious agenda by any measure and when explored in detail, it is clear that Agricultural Engineering, together with other science, technology and engineering professions have a huge role to play in realising the agenda. The next section will explore this in more detail.

The report on Engineering for Sustainable Development (UNESCO, 2021) shows that the role of engineering in addressing sustainable development goals is gathering pace as an area for increased emphasis. It is helpful to highlight what is being said at this high level with regards to the specific second goal of Zero Hunger (SDGS, 2021).

> *'Engineering has already mechanized agriculture and food production, and increased productivity through the use of fertilizers and pesticides. These advances are the work of agricultural, mechanical and chemical engineers.'*
>
> *'Future technological innovations by electronics and agricultural engineers for sustainable development include automated sensors for soil moisture and condition monitoring to optimize the delivery of scarce water and fertilizers, robotics for the application of pesticides and fertilizers and for weeding and planting, and communications technology for weather monitoring, forecasting and natural disaster warnings, as well as providing farmers with accurate, up-to-date information on harvest potential, which is crucial to achieving global food security' (GEO, 2020).*
>
> *An example of a global-scale approach to improving food security with technology is the Famine Early Warning Systems Network (FEWS 2021), a network of satellite and Earth-based monitoring and remote sensing technologies that provide early warning and analysis on food security. Funded by the US Agency for International Development (USAID), it links the National Aeronautics and Space Administration (NASA), the National Oceanic and Atmospheric Administration (NOAA), the US Department of Agriculture (USDA) and the US Geological Survey (USGS).*

Satellite and ground-based monitoring and advanced data management are used to monitor the climate and therefore food security in 34 countries in Africa and Asia, enabling relief agencies to plan for and respond to humanitarian crises (FEWS, 2021).

Technologies are also being deployed by engineers to assist farmers at a local level. For example, one initiative is Farmer Link, an innovative mobile-based farmer advisory service that links poor coconut farmers to an early warning system and market buyers in the Philippines, providing access to vital agricultural training and financial services (Gatti, G. 2018).

4.2. The Role of Agricultural Engineering

The Agricultural Engineering profession and the technical skills it brings have an important role to play in critically contributing to the solutions needed for delivering **Agenda 2063: The Africa We Want** and implicit in this, goes a long way towards providing realistic solutions to the United Nations SDGs.

Appendix C suggests some specific examples of how Agricultural Engineering can contribute, in a very positive manner, to these goals. The approach used in the Appendix B seeks to build on work by the United Nations (Agenda 2063 Linkages 2021) which links Agenda 2063 goals with individual SDG. Clearly some SDGs are related to several different Agenda 2063 goals but are contextualised in a different way.

For all of these Goals and SDGs, different stakeholders will have a role to play as they represent their own discipline and agenda. **Appendix C** shows this from the perspective of an Agricultural Engineer. An important task as the agenda progresses will be to ensure that the different contributions complement each other and avoid duplication of effort.

The flowchart below seeks to illustrate one example of how the Agricultural Engineering discipline will make a very positive impact.

Agenda 2016 Goal

Environmentally sustainable and climate resilient economies and communities

Associated Sustainable Development Goals

(6) Ensure availability and sustainable management of water and sanitation for all.
(7) Ensure access to affordable, reliable, sustainable and modern energy for all.
(13) Take urgent action to combat climate change and its impacts.
(15) Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss.

The Agricultural Engineering Contribution

- The wider Agricultural Engineering profession encompasses a very broad range of knowledge and understanding. They have the unique understanding of the way in which geography, physical resources, biology and chemistry connects with more traditional engineering and technology applications.
- Agricultural Engineers have a detailed understanding of dams, lakes, water storage and distribution networks together with irrigation systems, desalination, and waste water management. In recent years, they have become specialists in energy utilisation, wind and solar power, electricity storage and distribution.
- They are heavily engaged in sustainable land use, management and regeneration, and design and implementation of systems for sustainable intensification.
- Agricultural Engineers have the expertise to develop and apply technology for sustainable intensification of agricultural production, processing, transport and storage systems thus contributing to improved agricultural productivity and food and water security. They understand the need for a strong infrastructure and now harness 4G networks to support the concept of Precision Agriculture, something which is starting to have more and more influence across Africa. As such Agricultural Engineers will be the experts needed to influence the shape of the agricultural production and post-harvest processing and distribution infrastructure.

4.3. Harnessing the Energy of Young Africans

With population growth projections suggestion that there will be 2.3 billion people living in Africa by 2050 with a very high proportion of young people, a significant challenge for Africa is to harness the energy of this group. There is a great deal of energy and enthusiasm amongst this group and the quality of their thinking is espoused by the various international projects which draw on their work activities.

The Africa Prize for Engineering Innovation (Royal Academy of Engineering (RAE) Africa Prize, 2021) is one good example which illustrates this. The Africa Prize is Africa's biggest prize dedicated to engineering innovation. It awards crucial commercialisation support to ambitious African innovators developing scalable engineering solutions to local challenges, demonstrating the importance of engineering as an enabler of improved quality of life and economic development.

Between 2015 and 2020 there have been approaching 100 successful entrepreneurs who have reached the final stages of the competition. All submissions are required to demonstrate how their proposal will assist in delivering against relevant SDG and this focus is an important element of the prize.

Proposals cover a broad range of subjects such as water, Agri-tech and renewable energies and, as such, various aspects of Agricultural Engineering have featured in the initiative. For example, for in Agri-tech there have been 17 shortlisted proposals and three finalists. For Renewable Energy there have been 9 shortlisted and three finalists. For water, five shortlisted and one finalist were topped in 2015 by the Africa Prize winner Dr Askwar Hilonga and his team from Tanzania with their Nanofilter product which according to the company:

'The Nanofilter integrates cutting-edge nanotechnology with sand-based water filtration to provide clean, safe drinking water. The process is affordable and sustainable and highly relevant in rural settings across Africa where access to clean water remains a huge challenge. Custom built per region, it gives communities access to existing bodies of water that were previously too polluted to use'.

This is an excellent example of an engineering and technological solution which harnesses African people in developing innovative solutions. Although these winners would not always identify themselves as Agricultural Engineers, it is clear that their work is part of the wider Agricultural Engineering discipline.

The following table illustrates a selection of Agri-tech related activities which have featured as shortlisted and finalists in the Africa Prize between 2016 and 2020. For further details, there is an Interactive Tool (Royal Academy of Engineering (RAE) Africa Prize, Interactive Map 2021).

Finalists

On Spot Fertiliser Applicator

Small-scale farmers in Zambia typically apply commercial fertiliser to their crops by hand, which not only results in inconsistent application but is labour intensive and time consuming. Designed to mimic a walking stick, the On-Spot Fertiliser Applicator is an efficient and consistent device that allows farmers to apply fertiliser directly to their crops with one simple action. It is light and affordable and eliminates wastage, making it environmentally friendly.

Farmz2U

A digital platform that prevents food waste by helping farmers plan their crops. Farmers tell the application how much land they have, what crops they want to grow, what their budget is, and even their target profit. Farmz2U calculates how many seedlings the farmer should get, what fertiliser and pesticides to use, and provides training guides and videos for certain crops. Farmers can also find out where there is demand for their product, track orders and invoices, and find storage locations. Farmz2U even allows users to access financing, insurance, and receive weather reports and warnings.

Draadsitter

Mounted to the wiring posts of a fence, the Draadsitter (Afrikaans for 'fence sitter') is a fence security alarm system. The innovation detects tampering on fences of up to 800 metres and can also detect fires. Using sensors, the device warns owners of the location and nature of tampering on their fence, allowing them to react before security is breached.

Shortlisted

SolarKoodo

This is a movable solar water pumping system that helps smallholder farmers to pull water from boreholes in off-grid regions where water tables drop very low. SolarKoodo, which means 'solar crops' in Mooré, can also be used to electrify homes.

HWESOMAME

A low-cost, smart sensor which farmers can use to accurately measure soil conditions. HWESOMAME - which means 'look after it for me' in local language Twi - consists of a sensor which is stuck into the ground. The sensor measures the soil moisture, temperature, salinity and levels of organic matter. The data is converted into an easy-to-understand format and sent to the farmer via text or a voice-automated phone call in a local language.

Mechanical Cassava Harvester

The labour intensity of cassava harvesting is the biggest constraint to its commercial production. The Mechanical Cassava Harvester is an affordable tractor-mounted mechanical tool which turns up the soil to expose the root vegetable without damaging it. It takes five to ten minutes to harvest one cassava plant by hand, depending on the softness of the soil. The mechanical harvester can uproot one plant every second.

Kitovu

An online platform which helps rural and remote smallholder farmers triple their crop yields, and sell their produce. The app links the farmer's location to a soil database to determine the soil types found on a particular farm. Using that information plus the crop type determines the fertiliser the farmer should use.

3-D-3-P

The 3-D-3-P dryer is a simple system that dries grains and cereals using conduction rather than hot air, conventionally used in industrial dryers. This system, developed over more than six years in conjunction with students of his over the years, is far more affordable than conventional dryers. Based on the same principle as simply heating grain in a pan over fire, a series of three drums are heated to directly dry out the grains travelling through them. Rollers ensure that grains don't burn, and the gas heating the system is adjustable at each stage.

Tryctor

A three-wheeled mini-tractor based on a motorbike. Using low-cost local components, it is easy to maintain, efficient and simple to operate. The Tryctor is manufactured in Nigeria and provides affordable mechanisation to smallholder farmers and cooperatives. Its size-to-power ratio makes it a multipurpose vehicle which can be used to transport goods, and can even generate power.

Sparky Dryer

This is a low-tech dehydrator which dries fruits and vegetables to extend their shelf life from two days to two years. The dryer, which looks like a filing cabinet, is powered by organic waste like leaves and branches. Agriculture is the main source of income in large parts of Africa. In Uganda, poor preservation and storage, and time-consuming, unhygienic dehydration methods means that 45% of produce is lost post-harvest. Sparky Dryer will reduce this to below 20%, while maintaining the nutrients in the food.

DryMac

A containerised drying system that uses biomass to dry crops without using electricity. Biomass waste products, like maize stalks, grass or wood chunks, are burnt to create heat and gas. The drier has ducts, which control airflow to and from the furnace. This ensures that heat is distributed evenly throughout the drier, so that the product – which is fed through the container on rollers – is dried uniformly.

Drylobag

The Drylobag is a heavy-duty plastic bag designed to dry and store grain, without the need for expensive silo infrastructures. The Drylogbag prevents loss of stock from grain going mouldy by reducing the grain temperature and drying it evenly, even in the high humidity typical of Africa's most fertile regions. This enables farmers to harvest earlier, which reduces the risk of weather damage and crops being eaten by wildlife, and helps farmers get crops to market sooner.

Smart Brooder

This is an intelligent energy management system to automate chicken coops, giving farmers more freedom and peace of mind. Pre-programmed to understand the needs of chickens at every stage of their development, the Smart Brooder system controls heating, measures temperatures and humidity, and advises farmers and workers when physical intervention is required.

UjuziKilimo

UjuziKilimo meaning knowledge farming, measures soil characteristics to help farmers understand and quantify soil qualities. Information is collected by an electronic sensor in the ground, and sent for analysis to a central database, which collects agricultural information from research institutions, universities, and financial markets. Farmers receive a text message with a guide on the soil, and personalised advice on preferred crop breeds, pest control, current market value of crops, tools required and where to find them.

Illuminum

These greenhouses use solar panel and sensor technology to create a controlled environment for growing crops. The sensors collect data on temperature, humidity and soil moisture and send this to farmers via text message, allowing them to monitor and regulate their greenhouse, including turning irrigation on and off, without having to be on the farm. The system works on all types of phones and the use of solar power makes Illuminum ideal for rural areas with poor access to energy.

Best Practices in the Application of Agricultural Engineering in Africa

Some of these examples from the Africa Prize for Engineering Innovation (RAE Africa Prize, 2021) have gone on into commercial production with some great success. Some examples, and others from across the industry are shown in Appendix D and are excellent case studies demonstrating the role of Agricultural Engineering and the work of the profession in meeting the needs of Africa through innovative solutions.

Such a list of examples can never be representative of the whole of the agricultural engineering and Agritech sector but needs to be considered, firstly as examples of the great energy and innovation of Africans but also as an indicator of where the profession contributes to these developments through its multi-disciplinary approach. The table below show give details of a selection of relevant cases studies:

Appendix	Company	Website
D (a)	Coldhubs	https://www.coldhubs.com/
D (b)	Dent Agrisystems	https://www.facebook.com/dentagrisystems/
D (c)	Farmz2U	https://www.farmz2u.com/
D (d)	Sparky Dryer	https://sparkydryer.com/
D (e)	ZZ2	https://www.zz2.co.za/

The work of the company highlighted in Appendix D(e) is important to highlight. This company has gone further by working with AfroAgEng to produce a detailed report (ZZ2, 2020) which investigates how Agricultural Engineering contributes as a "key enabler: Connecting the living world of plants, soil, water, animals and people with engineering technology i.e. systems, structures, machines and energy". Such an approach might sensibly be adopted by other companies to showcase the important role played by the Agricultural Engineering discipline.

In another example from commerce, a global agricultural engineering corporation set the vision of "Sustainable high-tech solutions for farmers feeding the world". As part of this, the "Martin Richenhagen Future Farm" (AGCO, 2021) was developed from a vision to impact and empower farmers across Africa. It commenced activities in Zambia in 2012 when the farm started its mission to give all African farmers access to modern agriculture solutions.

By educating people on modern farming techniques, the Future Farm team are empowering local communities, helping people develop sustainable food production systems and increasing productivity.

The Future Farm which seeks to showcase a range of best practices and provide knowledge transfer to the farming community. Selected examples are expanded on below.
A study on tillage and traffic management where the objective is to determine the effect of tillage and traffic systems on growth and yield of maize and wheat. The trial split the field in four blocks both under irrigation and dryland cropping. The treatments under controlled traffic farming is where all machinery movement is confined to permanent wheel tracks in the field and random traffic where machinery is driven at random without designated wheel tracks. Higher yields were obtained in the controlled trafficked plots compared to average yields for the random trafficked plots during the same period.

A study of impacts of tillage in wheat production where the objective is to show the effect of tillage treatment on wheat yield. During the chosen cropping season, a seed drill was used to plant wheat in a cultivated field and in a no till field and the yield was compared at maturity. Overall grain yield was lower than average due to very low precipitation in this region during the chosen cropping season. Research at the Future Farm determined that planting wheat with no till resulted in a 20% increase in grain yield.

A key aspect of the Future Farm is that the agricultural engineering profession is at the heart developments on accounts of their strong knowledge or soils, compaction, tillage, mechanisation and harvesting.

Chapter 5 Education and Training

5.1. Education for Agricultural Engineering

In 2018, the Southern African Development Community (SADC) commissioned a report on 'Engineering Numbers and Needs in the SADC Region' (SADC, 2018). This is informative in terms of showing the relative profile of education provision relating Agricultural Engineering when compared to other engineering disciplines. This report is helpful in defining Agricultural Engineering as one of the main engineering disciplines and provides a very helpful definition together with the areas of practices which are associated with it.

An agricultural engineer performs and supervises engineering work concerned with planning, design, development, operation and maintenance of agricultural land, buildings, infrastructure, machinery, equipment, mechanisation, production and processing. Agricultural engineering practitioners generally concentrate on one or more of the following areas:

- Agricultural energy and renewable energy
- Agricultural product processing engineering
- Agricultural structures and facilities
- Agricultural waste handling and management
- Aquaculture engineering
- Mechanisation and refrigeration
- Hydrology, irrigation and water use management
- Natural resource and environmental engineering
- Post-harvest processes and food engineering
- Rural infrastructure engineering.

The SADC report points out that establishing the actual numbers and future requirements with any degree of accuracy is very difficult, however, it suggests the following proportions currently exist between engineering disciplines:

Agricultural	5%
Chemical	7%
Civil	32%
Electrical, Electronics, Systems and Telecommunications	27%
Mechanical, Mechatronics, Aeronautical, Marine and Industrial	24%
Mining, Quarrying, Metallurgy, Oil and Gas	5%

The table below from the SADC Report (SADC 2018) suggests the estimated number of engineering practitioners per discipline.

COUNTRY	Agriculture	Chemical	Civil	Electrical, Electronics, Systems & Telecomms	Mechanical, Mechatronic, Auronauti-cal, Marine & Industrial	Mining, Quarrying, Metallurgy & Oil annd gas	Total
Angola*[1]	552	368	4770	1718	944	649	9000
Botwana	30	100	2600	1650	1270	350	6000
DRC	6270	550	2600	3370	3400	1750	18000
Eswatini	120	35	685	520	230	10	1600
Lesotho	25	20	500	350	195	60	1150
Madagascar	1110	400	2900	3040	2700	850	11000
Malawi	301	25	1255	1079	508	31	3200
Mauritius	20	150	2200	1550	1070	10	5000
Mosambique *[1]	989	747	5103	2401	1760	*[2] See note	11000
Namibia	20	55	1200	840	520	165	2800
Seychelles	-	3	143	178	184	2	510
South Africa	900	10175	30950	32350	31325	4300	110000
Tanzania	1550	1475	12350	7400	6375	850	30000
Zambia	350	700	3800	3300	2600	1250	12000
Zimbabwe	180	400	2360	1850	1810	1000	7600
TOTAL	**12417**	**15203**	**73476**	**61596**	**54891**	**11277**	**228860**

*[1] Only engineers are reported on in these countries
*[2] The Ordem dos Engenheiros de Moçambique reports civil and mining engineering as one total which is reflected under civil

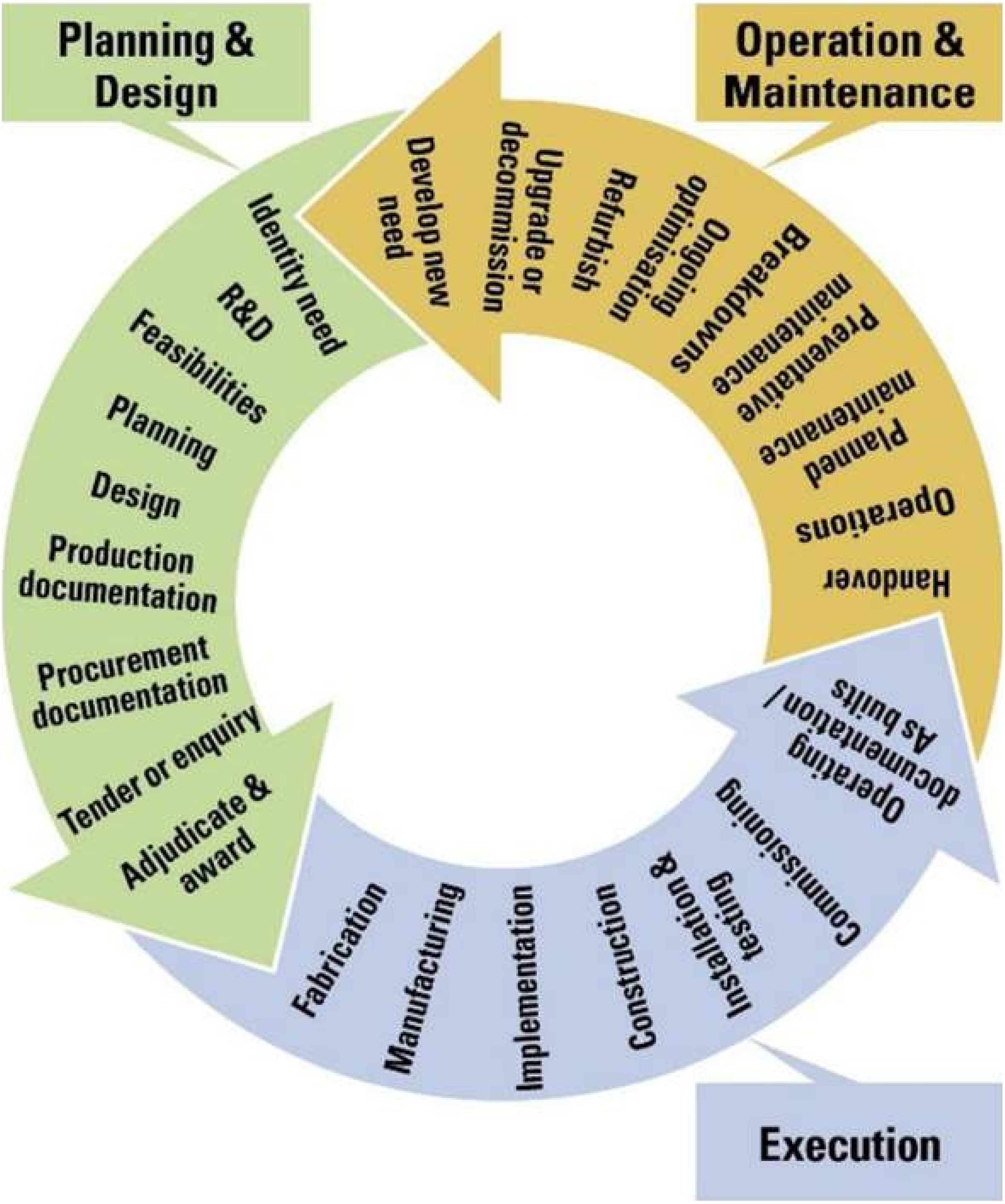
Although Agricultural Engineers represents a small proportion as suggested earlier, the raw number of approximately 12 500 reinforces the view that this a significant industrial sector yet at the same time, this is just over 5% of the total. The limitation of this data is that it does not show the extent to which, for example, when Civil Engineering is applied in the agricultural context.

The SADC (2018) report also added:

> *"The extent of the use of agricultural engineers was difficult to gauge as there are few voluntary associations dedicated to agricultural engineering and agricultural engineers were not found in many registering body datasets. In the French and Portuguese speaking countries, agronomy qualifications also include engineering subjects hence agronomists are classified as engineers, which is reflected in the higher numbers in those countries".*

"In many countries the number of agricultural engineers and extension officers is low and has been reducing over the years. Given the need to support millions of rural farmers to achieve sustainability, a rethink of national policy with respect to food security, developing sustainable villages and developing agricultural engineers, scientists and extension officers could well add more numbers of engineers to the workforce. Agricultural engineers lament never having been involved in the formulation of the agricultural policy in their countries and have many ideas to share".

Another aspect of the SADC report is the way in which it highlights the whole engineering life cycle, as illustrated below (SADC, 2018):



Of particular relevance to this report on Agricultural Engineering is the need for engineers and technologists who have the training and education to fulfil roles throughout the whole of the engineering lifecycle. The SADC report points out that in too many countries there is an oversupply of graduates for the planning and design stage with a lack of adequate provision for operation and maintenance.

The SADC (2018) Report looks as the role of engineers, technologists and technicians and suggests that the different education and training should be viewed of equal value in an engineering team, as shown in figure below.

The "Engineering Numbers and Needs in the SADC Region" report makes many helpful recommendations and there would be good sense developing some of these in relation to the Agricultural Engineering sector. In addition to recommendations for each country, at a regional level, there are several areas in which harmonisation and collaboration to ensure quality service delivery and that appropriate capacity is developed. Of the twelve areas highlighted, two of these are very specific to the Agricultural Engineering discipline, namely:

> ***Agricultural engineering solutions***
> *Regional solutions need to be researched and shared to support countries with innovative ideas on how to assist smallholders to become more productive and contribute towards national food security.*
>
> ***Rural development***
> *Infrastructure development has largely been focused in urban areas and industrial centres. Rural development programmes and support for rural communities is essential to grow rural e*conomies and encourage de-urbanisation.

As well as reinforcing the importance of Agricultural Engineering, these findings also highlight the aims of the Pan African Society of Agricultural Engineering (PASAE) in terms of promoting solutions to address these challenges.

5.2. Engineering Education and Capacity Building for Sustainable Development

The findings and recommendations made in the report on Engineering for Sustainable Development (UNESCO, 2021) echoes many of the findings which have been identified by AfroAgEng. This makes the important point that:

"Engineering is a problem-solving profession and requires a problem-based approach to learning. From early school education and throughout the educational system, science subjects will benefit from a more inquiry-based approach combined with design thinking and interdisciplinary collaboration with other school subjects.

Engineering students need to learn how to analyse and solve the problems facing by society and to develop technologies that will improve sustainable living. These needs are reinforced by major trends shaping engineering education, like emerging technologies and the employability agenda, as well as diversity issues such as gender balance."

This represents important thinking from a high-profile organisation, hence an increased pace of change in educational development should be anticipated. The same report refers to the educational approaches which have proven most effective in driving a more effective curriculum as outlined below:

How do engineering institutions respond to these challenges and what emerging trends can be identified for future curriculum models? Accreditation institutions respond to this by referring to the professional competencies such as those identified in the Washington Accord of International Engineering Alliance (IEA), and the American Board of Engineering and Technology (ABET) criteria for American engineering education, along with Australian engineering competencies (attributes).

During the last 20 years, educational institutions have moved from a teacher-driven system towards a student-driven learning environment, which involves the following.

- Active learning in the classroom (the 'flipped classroom') and problem and project-based learning (PBL).
- Practice-related learning with the inclusion in the curriculum of elements devoted to later work situations, such as internships, industry projects, entrepreneurship and innovation hubs, and learning professional competencies.
- An increased number of institutions changing to a more system-oriented approach where entire institutions change their curriculum instead of single courses (Graham, 2018).

5.3. The Modernisation of Agricultural Engineering Programmes

Earlier in this report, the role, function, aims and objectives PASAE were discussed. As part of these, PASAE plays an important role in bringing together a range of education and university partners from across the African continent and beyond.

Education is at the heart of the PASAE mission, specifically:

- To promote and advance the profession of Agricultural Engineering in Africa.
- Seek to become a key knowledge partner and visible policy advocate.
- Promote the role of engineering and technology in the sustainable transformation and industrialisation of agriculture in Africa.

As part of this, PASAE have focused on raising the esteem of education for Agricultural Engineering through a workshop focusing on Modernising Agricultural Engineering Programmes to meet Africa's Agenda 2063. In the context of this report, this workshop is very helpful in pointing towards the actions which need to be put in place if that ambition is to be realised.

The workshop, held in September 2020 set the following aims:

- Showcase/provide an overview of Agricultural Engineering curricula offered at various institutions to learn from best practices.
- Capture an assessment of the impact of Agricultural Engineering programmes on sustainable food production in response to regional needs.
- Promote Agricultural Engineering curriculum transformation to support engineering and the use of modern technology in the transformation and indus trialisation of agriculture in Africa towards Agenda 2063 and beyond.
- Share accreditation and quality assurance practices in Agricultural Engineering programmes.
- Share good pedagogical practice to equip Agricultural Engineers to meet the current and future needs of industry.
- Promote engagement between Agricultural Engineering degree programmes offered in Africa and internationally.
- Establish a Technical Section of PASAE focussed on Agricultural Engineering Education and Training in Africa.

An overview of Agricultural Engineering education in a range of Sub-Saharan Africa countries including South Africa, Nigeria, Ghana and Uganda as well as an overview from Morocco in North Africa were presented at the workshop. This was complemented by a vision for the future based upon a North American perspective. This report highlights the key findings and perceived challenges from each presentation in terms of how they will help drive the transformation of agriculture to deliver food security.

A more detailed overview from each country, together with links to presentations is available in **Appendix E – Pan African Agricultural Engineering Provision – Features of Education Provision.**

In addition, an important view of the future education requirements for the African context as recommended by the Food and Agricultural Organisation of the United Nations (FAO, 2021) was included in this workshop. This will be explored, and priorities identified in the next section of this report which focusses on the Paradigm Shift that will be needed if Agenda 2063 is to be met.

The workshop gathered expertise from across the continent and offered the opportunity to explore thinking around the future agenda and its implementation. The following questions were discussed in break-out groups and reported back to the plenary session:

- Are the Agricultural Engineering curricula offered at various institutions meeting the needs of industry? If not, what needs to change?
- What transformation of Agricultural Engineering curriculum is necessary to support the transformation and industrialisation of agriculture in Africa towards Agenda 2063 and beyond?
- How can quality assurance in Agricultural Engineering programmes be improved to facilitate accreditation?
- What good pedagogical practice should be adopted to meet the needs of current and future students?
- What needs to be done to promote engagement and collaboration between Agricultural Engineering degree programmes offered in Africa?
- What matrices/milestones are needed to progressively measure/assess the impact of enhanced Agricultural Engineering Curricula on the journey towards the Africa we Want?

The outcomes of these discussions are summarised in **Appendix E** and will contribute significantly in developing recommendations around setting the future agenda towards **The Africa We Want**.

The Key Features of Pan African Agricultural Engineering Provision

The following snapshots are based on the various presentations on Agricultural Engineering education in South Africa, Nigeria, Morocco, Ghana, and Uganda. As such they will showcase a range of practices and approaches from across the continent with many lessons and conclusions which can be applied more broadly.

South Africa

This snapshot was presented by Professor Jeff Smithers, Professor of Agricultural Engineering and Director of the Centre for Water Resource Research at the University of KwaZulu-Natal, South Africa.

South Africa provision represents an excellent model in terms of its content and approach with a good focus on preparing graduates for employment and progression. However, provision is currently limited to one university and, when combined with the low number registrations for the Agricultural Engineering degree programme, there is an overall undersupply to industry of appropriately qualified graduates. In addition, the challenges of the degree programme, and first year students less prepared for tertiary studies than in the past, means that improving retention is important. The South African model offers good practice through external professional accreditation of the Agricultural Engineering degree programme, recognised internationally under the Washington Accord, meaning that graduates are linked to a professional body with all of the benefits associated with accreditation.

Further details are available in **Appendix E(a).**

Nigeria

This presentation from Professor Kehinde Taiwo from Obafemi Awolowo University, and Professor Emmanuel Ajav from the University of Ibadan focused on the development of Outcome Based Education (OBE) for the Mobility of Agricultural Engineers.

It is clear that quality and consistence of Agricultural Engineering degrees will benefit from this approach. The model is aligned to international standards and has included a very good focus on the needs of the industry served by the university. This may well be uncomfortable for some academics, but the overall aim of this approach has been to afford better outcomes for graduates. That has been identified as a very positive attribute. The focus on assessment and quality assurance is strong throughout this process. The impact of this is anticipated as being better recognition by employers that graduates are suitable equipped for the rigours of professional practice.

Further details are available in **Appendix E(b)**

Ghana

This presentation from Professors Emmanuuel Bobobee and Ahmed Addo, and Drs Eric Asante and Enoch Bessah from the Department of Agricultural and Biosytems Engineering, Kwame Nkruma University of Science and Technology in Ghana covered the subject of Agricultural Engineering Education in Ghana.

The balance of academic and technical university provision across a range of levels offers undergraduates with a good range of access points and progression opportunities. The research focus is strongly related to the wider Agricultural Engineer discipline. The link to the nation's professional engineering society is a strong feature. The growth in numb ers joining programmes suggests that there is positive acknowledgement of the importance of this discipline area.

Further details are available in **Appendix E(c)**

Uganda

This presentation from Professor Noble Banadda of the Department of Agricultural and Biosystems Engineering, Makerere University, Kampala, Uganda provided an overview of Agricultural Engineering Training and associated research at the university.

The range of research streams is impressive and well-focused in the interactions with wider Biosystems engineering. There is an interesting parallel with some wider research initiatives which bring together science and engineering with socio-economic work streams. The collaboration with universities around the world for academic delivery as well as research presents a useful model from which other educational institutions in Africa could benefit.

Further details are available in **Appendix E(d)**

Morocco

This overview of Agricultural and Biosytems Engineering Education in Morocco was presented by Dr El Houssine Bartali from IAV Hassan II, Rabat, Morocco.

Agricultural Education degree programmes have a very clear focus on the needs of North Africa and in the case the subject of irrigation. To some extent, this is a specialist sub-set of wider Agricultural Engineering and is a model which has value across the whole of the continent. There is no reason why the excellence developed in Morocco cannot be replicated elsewhere and PASAE has a potential role in this respect.

Further details are available in **Appendix E(e)**

Agricultural Engineering Programmes to meet Africa's Agenda 2063

The on-line workshop offered an opportunity to bring together in excess of 100 stakeholders from across the continent to consider a range of question and to help form a view on what needs to be addressed if we are to move towards **Agenda 2063: The Africa We Want.**

In this section, the findings are summarised in terms of six key questions and as such, these set some very clear thoughts on the actions which policy makers and stakeholders need to consider if the aspiration of **"The Africa We Want"** is to be realised.

Are the Agricultural Engineering curricula offered at various institutions meeting the needs of industry? If not, what needs to change?

The following points were noted:

- Linkages between academia, industry and policy need to improve. It is important to define who "the industry" is - the end-users of knowledge. Understanding this will help foster the much-needed synergy between knowledge creation and its application.
- The need to have the buy-in of policymakers was also noted together with the need to overhaul the current industry training schemes. A good example is the Student Industrial Work Experience Scheme (SIWES) established in Nigeria.
- It is recommended that the current curricula and program structure requires a complete overhaul. Three contextual changes were given particular prominence: (i) many of the curricula were outdated, (ii) the current heavy credit load was not relevant to current times, and (iii) the program structure was not efficient.
- More generally, the view was expressed by many that there was a need to include practical applications in the curricula and expose students to modern technologies and advanced applications such as digitalisation, data science, drone technology, machine learning, artificial intelligence and robotics.
- There is also a need to provide the necessary facilities and equipment for practical trainings. It is argued that the current Agricultural Engineering program provides little connection between engineering principles and engineering inclined agricultural systems knowledge. For example, in Nigeria, the first three years are spent learning other engineering principles; only in the fourth and fifth years do students start learning about applications in agriculture. This means there is no proper grounding or solid foundation in agricultural systems knowledge.
- The direct impact of the stereotypes associated with the name "Agricultural Engineering", and that graduates find it difficult to find employment because of the name, was noted. This is due to competition between Agricultural Engineering and other engineering disciplines. This led to the recommendation to consider a name change and or the need to make the name more attractive.
- Any future paradigm shift should include the integration of local knowledge and custom-made approach to solving Africa's problems. There is a need to embrace 'Africa-technology' by integrating local knowledge and a focus on how local solutions could be improved or optimised to solve local problems. This will encourage adoption of technology in the industry and also promote African knowledge transfer systems.
- The need to train students on critical thinking ability is also important as this will enable students to provide customised solutions to problems in local industries.

What transformation of Agricultural Engineering curriculum is necessary to support the transformation and industrialisation of agriculture in Africa towards Agenda 2063 and beyond?

The following points were noted:

- An important requirement is to adopt and adapt curricula which acknowledges that we are on a journey of transformation from a traditional approach, and this needs to be accelerated.
- Specific focus is needed to change to a 'systems thinking' approach and break silo-thinking in the minds of those currently involved. There is a need to develop soft skills while keeping hard engineering at heart of the programmes.
- Soft engineering skills to function and work in the new environment are deemed to be as essential as core engineering. A challenge is to get buy in from accreditation bodies and these need to be pursued to confirm adaptations and changes required in curricula.
- There are many constraints to transformation which need to be addressed. These include the logistics which allow students to use new learning platforms, and the approach of lecturers themselves who are often outdated and use traditional teaching approaches which the lecturer experienced as a student.
- Agricultural Engineers need to learn how to talk to stakeholders (politicians, policy & decision makers, and development partners) in order to sell their services.
- Specific modules need to be developed to prepare graduates in Agricultural Engineering to function in national and international spaces, as current engineering training puts an excessive focus on hard

engineering with students lacking the necessary soft engineering skills.

- A holistic and systems approach is needed in the transformation of the curricula, and overall, Africa needs to leave the colonial type of training experienced in the past.
- The overall objectives of transformation have been influenced following the Covid 19 pandemic which has illustrated that we need hands-on experience to change ourselves
- In terms of provision, there needs to be a shift to a mixed mode system of training with perhaps 75% soft and 25% hard (brick and mortar).
- In addition, there are more and more young lecturers with little practical hands-on experience and there is a need to upscale the academic staff and arrange upskilling and training to upscale their knowledge.
- There is scope to share a system of accreditation at sub-regional level to allow mobility of students and lecturers, and as part of this we need to harmonise and have uniformity of standard curriculum.

How can quality assurance in Agricultural Engineering programmes be improved to facilitate accreditation and intra-Africa mobility of skills and talent?

The following points were noted:

- Industry and university linkage should be encouraged to improve the quality of teaching and thereby improve accreditation based on clear input from industry to shape provision. There should be industry advisory board to Agricultural Engineering programs to ensure quality.
- The involvement of a professional body at the curriculum development phase of the Agricultural Engineering program could be helpful.
- There is a need to improve technical report writing skills of students since the industry is complaining about the lack of adequate skills and knowledge in technical report writing – industry has a role to play here.
- Work should be undertaken to ensure the production of standard quality graduates from Agricultural Engineering programs and to improve facilitation of accreditations and maintain the same quality graduate outcomes over a given period, which facilitates accreditation.
- Maintain fixed minimum entry requirements to an agricultural engineering program. Promote gender equality in Agricultural Engineering curriculum to give all genders a voice in the profession. There should be a policy for credit transfer between institutions across Africa.
- Maintain an acceptable staff-student ratio and ensure that external examiners are well qualified and should not serve for more than 3 years. External examination of assessed materials must be in place.
- The linking of training to the industry for practical training that ensures quality and thereby facilitates accreditation and standards. There have been issues where the budget for practical training have been reported as a limiting factor.
- Upgrade teaching and learning facilities parallel with the growth in the modernisation of agricultural technologies.
- Student and staff exchange between universities within the regions in Africa and the rest of world should be encouraged and implemented.
- A large number of students in a classroom of agricultural engineering curriculum leads to compromising the quality of teaching and learning and thereby brings challenges with facilitation of accreditation.
- Qualified and experienced technicians should be in charge of student practical sessions.
- Full external examiner reports should be requested immediately after examination of assessment materials and that facilitates processing accreditation. The accreditation body to evaluate the contents of the curriculum and subjects on regular bases, example 5-year interval.
- Teaching staff should engage in research activities to keep the teaching and to learn up to date and thereby maintain quality that can facilitate the accreditation.

What good pedagogical practice should be adopted to meet the needs of current and future students?

The following points were noted:

- There are already some innovative practices being used across the continent and there is scope to build on the best of these to develop excellence in pedagogical practice.
- The need for 'soft skills' e.g. communication skills to deal with a broad range of professionals and have your concepts understood has been introduced.
- Entrepreneurship – graduates need to 'hit the ground running' – young engineers need to be called to lead experienced staff if this is to add value.
- In South Africa – new department in Agro-Engineering acknowledged the need for more than knowledge and the need for application. It is identified that current lecturers are not always adept at applying core knowledge into real-world applications.

- In another Nigeria example, industrial training is used to offer real experience in working with others with workshops on actual hands-on technological skills with real equipment, for example, the National youth service corp in Nigeria.
- Other examples from across the continent include a move to more 'hands on' outside the classroom and the lengthening of the industrial placement. In one case, greater direct university and industry collaboration is used to place students in industry during holiday periods.
- The Covid-19 pandemic has led to a faster pace of change in pedagogical approaches through necessity. For example, the virtual classroom with shared lecturers, facilitation of learning instead of teaching (chalk and talk). Technology has advances at a pace and made all of this more possible.

What needs to be done to promote engagement and collaboration between Agricultural Engineering degree programmes offered in Africa?

The following points were noted:

- The current way of working as a consequence of the Covid-19 Pandemic may have some legacy as collaborative working is much easier, for example, online workshops and seminars.
- Collaboration across the continent is very important but maybe we need to start with regions first, e.g. in East Africa. Exchange of tutors/lecturers, capacity building ofr staff and students and sharing of resources in necessary. There is scope to tap into the RAENG programme for partnering universities such as research partnerships, capacity building, etc.
- Scope for the engagement and collaboration to go beyond Africa so that universities from around the world can contribute. Online content sharing using both commercial and non-commercial avenues from universities around the continent could be a good way forward. There is much good quality newly prepared content.
- The forum established by PASAE is a good way forward and the way in which our current circumstances has driven a less insular approach.
- Opening doors for different nations from across Africa to discuss and share the same issues is an important way forward and will lead to positive outcomes.
- Curriculum needs to be changed to make it more future proof and to facilitate more collaboration. The European 'Erasmus' programme could be a model for students to gain experience from different places.
- We need to take advantage of what we have learnt from the 'New Normal'. Start with some regions and facilitate connections, e.g, heads of faculties seeking to collaborate at both macro- and the micro-levels.
- Engage industry to help shape the curriculum and the university 'offer' and open up opportunities for placements and work experience.
- Lever connections from national bodies in countries (Professional Engineering Institutions, etc). Focus on issues of particular importance.
- Establish short, medium and long terms aims and objectives in respect of this agenda. Introduce task and finish groups or Action Learning Sets to focus on particular issues with a sharply focused agenda. Involving industry viewed as a key element to all of this.
- Tap into the past alumni. Use these as guest lecturers either on-line or in person. All contributes to the building of relationship.
- Ask industry for challenges and problems and involve students in arriving at suitable solutions. This helps industry to see the value of universities.

What matrices/milestones are needed to progressively measure/assess the impact of enhanced Agricultural Engineering Curricula on the journey towards the Africa we Want?

The following points were noted:

- There are a range of methods which could be adopted. These include a move from the more conventional metrics to the more relevant metrics such as outcome and impact, i.e. more than just input measures.
- Another method could be an annual survey of graduate outcomes. Feedback from employers is also an essential matrix.
- Consider measures such as the quality of outcomes, the percentage of graduates placed in industry, in government, etc Retention in the industry, avoiding wastage to other sectors. Research addressing industry requirements.
- The most significant measure will be the increase in agricultural productivity and ultimately the extent to which there is an improvement in Sustainable Development Goals including those which address global poverty, zero hunger and the role of women, etc.
- There is scope to integrate reference to Sustainable Development Goals in the curriculum so that the curriculum and its delivery continually focuses on these. This could be an important matric by which provision is judged.

Chapter 6 The Paradigm Shift

6.1. A Systems Approach

This section contains a review of a range of innovative ideas and approaches for future education and training provision drawing upon a number of perspectives. The purpose of this is to highlight some potential solutions which, if implemented, might leapfrog Agricultural Engineering education, training, and application, through to knowledge transfer and traditional extension.

This will draw on perspectives from the Food and Agriculture Organisation of the United Nations, international universities who have addressed the paradigm shift in providing a new model for the education and training of graduates, and an approach taken by a global agricultural machinery manufacturer who has designed a bespoke approach for Africa and introduced this in one region. It will go on to challenge the approach taken by Non-Governmental Organisations (NGO) whose past approaches to addressing social and political issues could be more sustainable.

6.2. Viewpoint of the Food and Agriculture Organization of the United Nations

This viewpoint is drawn from the work of Dr Joseph Mpagalile, an Agricultural Engineer specialising in Sustainable Mechanisation based at the Food and Agricultural Organization (FAO) Regional Office for Africa in Accra, Ghana.

The FAO recognises and reiterates the same contextual challenges for Agricultural Engineering in Africa as defined in the earlier chapter on the Key Developments Challenges facing Africa and at the same time highlights the important role of the sector, and everything that wraps around it, in meeting those challenges.

The following key points are stressed:

- The need for Agricultural Engineering professionals in Africa is still high (e.g. for irrigation, agricultural production, postharvest handling, agro-processing etc.).
- Countries and stakeholders need Agricultural Engineers with excellent practical skills and adequate competencies, who are innovative and open to the digitalization age.
- Improvement in Agricultural Engineering Education is required to address technological innovation, socio-economic changes and finance models for Agricultural Engineering in Africa.
- Training institutions need to align their curricula with the present needs, including those of those in industry and commerce who are driving innovation in Agricultural Engineering.
- The training of Agricultural Engineering technical skills is still needed at different levels among Graduates, Technicians, Farmers, Entrepreneurs etc.
- There are not enough mid-level hands on technicians in many countries, creating a significant gap in the Agricultural Engineering profession.
- While we have seen an increase in agricultural investment in infrastructure, machinery, equipment etc, Agricultural Engineering technology management on the continent remains a weak point.
- Gender, agribusiness and finance aspects still need to be adequately mainstreamed in the Agricultural Engineering education programmes.
- On-job training for graduate engineers, instructors, technicians is missing resulting in a lag in innovation, digitalization etc.

This identifies the need to position and align Agricultural Engineering Education such that the profession features much more prominently across sub-Saharan Africa and beyond. In making this assertion, it stresses the key roles where the discipline has a role to play. These include the conclusions that Agricultural Engineering is:

- An essential pillar for Africa's agricultural transformation and job creation (including attracting the youth back to agriculture)
- A key profession in linking agriculture to manufacturing, hence, leading to the economic transformation in Africa and in job creation
- A key pillar in reducing the yield gap for Africa to reach its goal of Zero Hunger by 2025 through its ability to enhance productivity and increases safety, quality and the value of food i.e. value addition along the value chain
- Playing an important role in delivering logistics and food security during the pandemics e.g. COVID-19.

The FAO makes some specific recommendations in relation to the development of Agricultural Engineering provision and these can easily be related to the challenges surrounding Agenda 2063. If we are to move towards the Africa we Want, the following challenges need to be addressed:

- Capacity development is essential at all levels, from farmers through to artisans, technicians and professional engineers, in addition to policy and planning experts.
- Revision of curricula of programmes offered by higher education and training institutions is necessary:
    1. New areas of knowledge such as precision farming, automated systems, robotics, and conservation agriculture are emerging and need to be mainstreamed.
    2. Refresher courses for lecturers and instructors should be considered in the wake of fast development in innovations including robotics, digitalization etc.

- Engage key Agricultural Engineering stakeholders and manufacturers of machinery to develop education provision including organizing joint practical oriented training, revising curricula, planning refresher courses etc.
- Implement targeted training programs, designed to build the capacity of stakeholders such as the mechanization hire service providers. These could be vocational training, short courses etc.
- Support the establishment of the Centres of Excellence (Regional and sub-regional levels) to carry out capacity development, research, innovation and technology transfer.
- Agricultural Engineering education in Africa should consider gender issues and help to build competency towards sustainability (Commercial, Environmental & Socio-economic) and skills on agribusiness and finance models
- Produce a cadre of highly competent Agricultural Engineers to drive appropriate technical developments, policy and strategic decisions that propel the profession - we need Agricultural Engineers to sit at tables where future decisions are made.

International Perspectives

This viewpoint is from Dr Thomas Lee who is the Chief Education Officer for a private sector company who are working in collaboration with the Obafemi Awolowo University in Nigeria on a project around the 'Localised Engineering Education Paradigm' which is concerned with the pedagogy for producing the engineering for the Africa we Want.

This sets the vision of 'empowering engineering heroes by giving them the tools to help them reach their potential' and to 'provide a modern framework for engineering education through a physical grounding of mathematical theory, manifested in a way that lets students see and feel how the mathematics flow out from the theory and into the physical world.'

In highlighting recent transformations, be that in transport where the move is towards autonomous vehicles, in agriculture where the move is from hand working to drones and robots, and energy where the move is from coal power to wind and solar energy, the key point is that all of these have an impact on agriculture and those engineers who support its transformation.

This presents challenges for modern universities and around the world and these have started to be addressed. The same challenges are faced by the university community in Africa. Traditional lectures are moving to a more 'hands on' experience, traditional theory is being translated into engineering systems and application, and isolated research activities are being converted into a more compete experience with the best of these drawing on inputs from industry and commerce.

The challenge is how to develop these future engineering skills within the African economic context. This could involve the concept of 'Localised Engineering Education Paradigm' which is expressed as follows:

- Localized = regionally relevant challenges and solutions
- Engineering = modern, rigorous, sophisticated innovations
- Applications = regional industry-ready contexts
- Paradigm = academically effective and efficient experiences

It is with great optimism that this approach can be developed. History would suggest that the digital revolution of the past 50 years has led to exciting and often disruptive new systems. The shift from microcomputers to the internet, and to mobile telephone technologies has been matched with the growth of technology platforms.

With a move to the Internet of Things (IoT), a new generation range of entrepreneurs are emerging, and Africa is well placed to be up there among the most innovative. The need for a new generation of regional entrepreneurial engineers is recognised, and the Royal Academy of Engineering Africa Prize demonstrates this well with many Africa related Agricultural Engineering solutions under the auspices of the Agritech agenda being listed amongst nominees.

In exploring this, the point is made that with new IoT capabilities, everything can be measured, treated and refined and new technology accelerates creativity everywhere. To achieve this, consideration needs to be given to:

- Advanced engineering applications on modest technology platforms
- Advanced mechatronics, IoT, 'Cyber Physical (Imperial College London 2021) systems engineering, and Artificial Intelligence so that it is available to everyone.
- Emerging pedagogical frameworks applied with regional guidance

A key message for Agricultural Engineering education and training is the need to re-imagine learning methodology and to adopt the learning platforms to support these. What is clear is that the traditional classroom approach is no longer appropriate and that a much more blended and technology supported approach is needed.

At the heart of this is the need to establish new skills to enhance progression. This celebrates the systems engineering approach although this will always be founded on good underpinning knowledge and practical abilities.

According to Dr Thomas Lee, this is an example of progressive skills development and the associated technological development platforms:

Mechatronic integration of physical systems

- Physical system characterization, modeling
- Dynamic control systems
- Sensor and processor integration
- Networks of physical systems
- Cloud and data applications

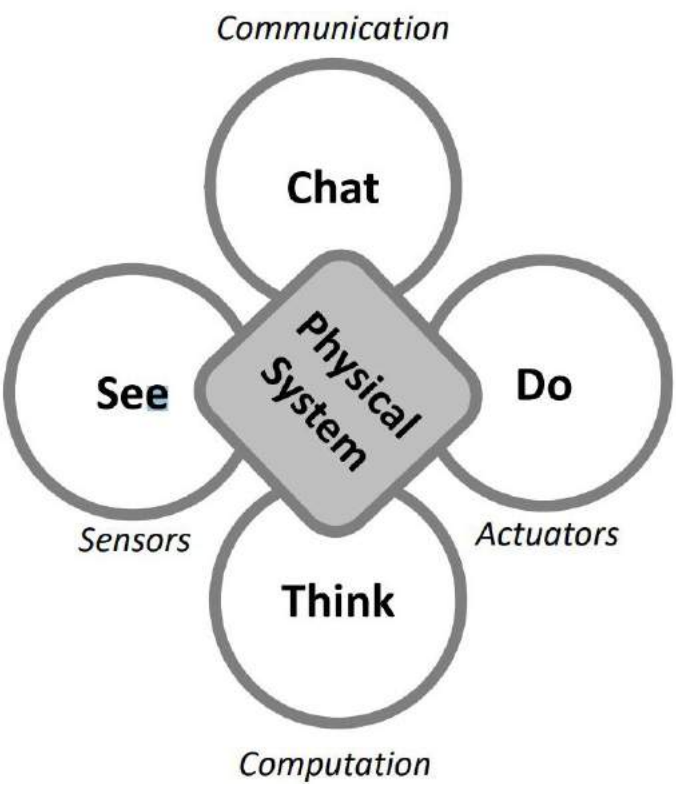
Essential autonomous robotics

- Fundamental mobile robotics programming
- Machine vision and image processing
- Advanced sensor integration
- Machine learning and collaborative robotics

Advanced Cyberphysical System applications

- Complete, research and applications studios
- High performance, high-fidelity, open architecture
- Rapid development of complex multi-device applications

At the heart of this debate and is an abject example of the paradigm shift towards the need for a physical systems engineering approach to be captured in the provision of future education and training. This is captured in the diagram below, again from the work of Dr Thomas Lee:



New Paradigms in Action

There is evidence from around the world that traditional approaches are no longer fit for purpose. Some universities are starting to consider how they deliver degree programmes and how they can promote a more systems thinking and multi-disciplinary approach. They are identifying that the engineering subject knowledge is only part of the role of education and training, and that the development of thinking skills, problem solving, and other 'soft' skills are as important.

Appendix F explores the rationale for a UK initiative called the New Model Institute for Technology and Engineering which seeks to provide university provision through a new paradigm. **Appendix F(a)** explores the Olin College in the USA which is adopting a similar approach.

These two models present an innovative approach which Pan African universities might consider as part of their future developments. It is encouraging that some of the ideas explored in **Appendix F(b)** show that the Pan African university sector is capable of innovation.

Similarly, one major agricultural machinery manufacturer has made a significant investment to introduce a new farming system in Africa which integrates mechanisation with the various agronomical supply chains to create horizontal integration. Called the Future Farm, this is explored in **Appendix F(c).**

Rethinking the Role of NGOs in Agricultural Engineering for Development

Over the years, Non-Governmental Organisations (NGOs) have played an important role in supporting the African continent through the provision of resources such as tractors and machinery. In too many circumstances, the long-term legacy of this support could be much more sustainable. For example, too many tractors remain underutilised as they await spare parts and technical support.

It is important that NGOs develop partner relationships, rather than acting as a supplier. This will allow project partners to step in and take over activities to ensure sustainability once NGO funds end or are diverted elsewhere. This approach will make the important contributions made by NGOs more sustainable.

In addition, the application of systems thinking by NGOs would help their support to be more long term and with a greater legacy. Short term fixes should be avoided. If NGOs work alongside Agricultural Engineers and other systems thinkers, they are more likely to design solutions which not only provide tractors and machinery but also the technical support and service as well as the training for operators and those farmers and contractors who are integrating this technology into their routine farming practices.

The Future Farm model described earlier combined with improved provision of knowledge transfer and on-farm extension, including input from Agricultural Engineers, has an important role to play in this respect.

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Notes

PAN AFRICAN SOCIETY FOR AGRICULTURAL ENGINEERING

Agricultural Engineering in Africa

A Report and Call to Action by the Pan African Society for Agricultural Engineering

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Appendix A

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About the Editor

Alastair Taylor HonFIAgrE, CEnv, IEng

Honorary Fellow of the Institution of Agricultural Engineers (IAgrE), Alastair is an Incorporated Engineer (IEng) and Chartered Environmentalist (CEnv) and following retirement from his role as CEO of the Institution of Agricultural Engineers continues as a freelance specialist in engineering and technology for agriculture. As part of this, and through his association with the Royal Academy of Engineering, Alastair has travelled extensively across Southern Africa and as such has a comprehensive understanding of the context and challenges of agricultural engineering in the region.

Alastair was bought up on a farm in the eastern part of England and originally trained as an Agricultural Engineer. He spent over forty years immersed in the agriculture, engineering and emerging Agritech industries. He spent 20 years working in front line education where he undertook various roles within the teaching and management of agriculture and mechanisation, including irrigation, farm buildings, waste management and financial management.

In 2000, Alastair joined UK national inspectorate for vocational education becoming well known as an inspector of the subject and leader of inspection teams. From 2013 to 2019, Alastair was the Chief Executive of the Institution of Agricultural Engineers, the professional body for professional engineers working in the industry.

Alastair is the editor of the report for the Pan African Society of Agricultural Engineering titled: Agricultural Engineering in Africa: A Key Driver for Transforming Agriculture to Deliver Food Security and to Support Economic Prosperity. Alastair is active in the developments of professional engineering standards for Engineering UK and Europe and acts as Chief Licence Reviewer for the UK Society of the Environment.

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- Sparky Dryer, Kampala, Uganda
- ZZ2, Mooketsi, South Africa
- The AGCO Corporation, Stoneleigh, United Kingdom
- Nigerian Society of Agricultural Engineers
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- South African Institute of Agricultural Engineers
- Institution of Agricultural Engineers (UK)
- The American Society of Agricultural and Biological Engineers

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- John Magnay, Director at Nakifuma Farming Company Ltd, Uganda

Appendix B

The contribution of Agricultural Engineering in delivering a selection of relevant Agenda 2063 and associated UN Sustainable Development Goals

Agenda 2063		UN Sustainable Development Goals		Agricultural Engineering Contribution
Goals	Priority Areas			
1. A high standard of living, quality of life and well-being for all citizens.	• Incomes, jobs and decent work • Poverty, inequality and hunger • Social security and protection, including persons with disabilities • Modern, affordable and liveable habitats and quality basic services	1 2 8 11	End poverty in all its forms everywhere in the world End hunger, achieve food security and improved nutrition and promote sustainable agriculture. Promote sustained, inclusive and sustainable Economic growth, full and productive employment and decent work for all. Make cities and human settlements inclusive, safe, resilient and sustainable.	• In many countries, hunger has been virtually eliminated and food security secured through the work and application of Agricultural Engineers. • The mechanisation and automation of farming processes such as cultivation, sowing and harvesting has taken away the drudgery of these traditional activities and has led to great efficiency and higher work rates. • Agricultural Engineers have developed improved irrigation systems to optimise the application of water to crops resulting in improved production and economic returns for farmers. • Agricultural Engineers are using evolving technologies such as precision agriculture, remote sensing and monitoring, which when combined with developing mobile phone networks and Apps, has facilitated the use of mobile technologies to provided farmers and growers with real time information on climate, markets and optimisation. • In some African countries, the "systems engineering" approach of Agricultural Engineers, combined with their multi-disciplinary approach has facilitated a better integration of production systems such as mechanisation, fertiliser application, harvest, post-harvest storage and marketing. This presents an important move toward horizontal integration of production systems. • The development and application of precision application technologies by Agricultural Engineers has reduced the environmental impacts of agricultural production systems.

Appendix B - *continued*

Agenda 2063		UN Sustainable Development Goals		Agricultural Engineering Contribution
Goals	Priority Areas			
2. Well educated citizens and skills revolution underpinned by science, technology and innovation.	• Education and science, technology and innovation (STI) driven skills revolution	4	Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all.	• Agricultural Engineering brings together science (particularly chemistry and biology) with engineering and technology solutions is a unique way which makes it unique from other engineering disciplines. • Agricultural Engineering is involved with traditional engineering skills and knowledge as much as it is wider factors such as plants, animals and the land, including the environment and land masses. • The future needs "systems engineers" and those who are able to apply technical knowledge and skills in a "multi-disciplinary" approach to solving problems and finding solutions. • Agricultural Engineering education and training presents a fine example of a more inclusive approach which could be an excellent model for the future which could in turn transform the traditional approach to education provision which has a tendency to operate in exclusive and non-connected silos – an approach which is of the past.
3.Healthy and well-nourished citizens.	• Health and nutrition	2	End hunger, achieve food security and improved nutrition and promote sustainable agriculture. Ensure healthy lives and promote well-being for all at all ages.	• Agricultural Engineers are an integral component of international initiatives to address the challenge of sustainable food production, resilient supply chains, improved nutrition and public health. One example, which could be adopted as a pan African solution is shown at: https://www.n8research.org.uk/research-focus/n8-agrifood/ • Improved yields and the reduction of post-harvest losses area as a result of the contribution of Agricultural Engineers. • The contributions shown against Goal 1 apply here

Appendix B - *continued*

Agenda 2063		UN Sustainable Development Goals		Agricultural Engineering Contribution
Goals	Priority Areas			
4.Transformed economies	• Sustainable and inclusive economic growth • STI driven manufacturing, industrialization and value addition • Economic diversification and resilience	8 9	Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all. Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation.	• Agricultural Engineers (and technologist in general) have overseen a revolution in transforming economies through the implementation of agricultural mechanisation. This has transformed economies around the world and African should benefit from the same. • Well developed economies have worked hard to integrate the systems of food production, distribution and supply. Any work to transform economies across African can harness the "systems engineering" approach espoused by Agricultural Engineers. • Engineers and technologies can help Africa to leap frog many economies if it harnesses 21st century mechanisation which now includes automated systems together with the infrastructure needed to support and sustain it. There is a natural fear that technology makes jobs redundant when in fact it creates jobs which demand a higher level of skills with better work conditions. • Agricultural Engineers have a role to play in developing the resilient infrastructure needed to support agricultural production and food security. It is well recognised that post-harvest storage and distribution is a challenge across much of Africa and improvements to this will be pivotal in delivering these goals.

Appendix B - *continued*

Agenda 2063		UN Sustainable Development Goals		Agricultural Engineering Contribution
Goals	Priority Areas			
5. Modern agriculture for increased productivity and production.	• Agricultural productivity and production	2	End hunger, achieve food security and improved nutrition and promote sustainable agriculture.	• Agricultural Engineers are a component part of international initiatives to address the challenge of sustainable food production, resilient supply chains, improved nutrition and public health. One example, which could be adopted as a pan African solution is shown at: https://www.n8research.org.uk/research-focus/n8-agrifood/ • The mechanisation and automation of farming processes such as cultivation, sowing and harvesting has taken away the drudgery of these traditional activities and has led to great efficiency and higher work rates. • Agricultural Engineers have developed improved irrigation systems to optimise the application of water to crops resulting in improved production and economic returns for farmers. • Agricultural Engineers are using precision agriculture and evolving technologies such as remote sensing and monitoring which when combined with developing mobile phone networks and Apps has facilitated the use of mobile technologies to provided farmers and growers with real time information on climate, markets and optimisation. • In some African countries, the "systems engineering" approach of Agricultural Engineers, combined with their multi-disciplinary approach has facilitated a better integration of production systems such as mechanisation, fertiliser application, harvest, post-harvest storage and marketing. This presents an important move toward horizontal integration of production systems. • The development and application of precision application technologies by Agricultural Engineers has reduced the environmental impacts of agricultural production systems and hence sustains production into the future.

Appendix B - *continued*

Agenda 2063		UN Sustainable Development Goals		Agricultural Engineering Contribution
Goals	Priority Areas			
6. Blue/ocean economy for accelerated economic growth.	• Marine resources and energy • Port operations and marine transport	14	Conserve and sustainably use the oceans, seas and marine resources for sustainable development.	• In some countries, Agricultural Engineers have been involved with off-shore activities such as intensive fish farming including the design of storage, feeding and harvesting. Agriculture and Fisheries are often overseen by the same government departments which illustrates the way in which these will co-exist. • The wider geographic and environmental knowledge of Agricultural Engineers gives them a unique understanding of how land based activities impact on marine life, and vice versa.
7. Environmentally sustainable and climate resilient economies and communities	• Bio-diversity, conservation and Sustainable natural resource management • Water Security • Climate resilience and natural disasters preparedness	6 7 13 15	Ensure availability and sustainable management of water and sanitation for all. Ensure access to affordable, reliable, sustainable and modern energy for all. Take urgent action to combat climate change and its impacts. Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss.	• The wider Agricultural Engineering profession encompasses a very broad range of knowledge and understanding. They have the unique understanding of the way in which geography, physical resources, biology and chemistry connects with more traditional engineering and technology applications. • Agricultural Engineers have a detailed understanding of dams, lakes, water storage and distribution together with irrigation systems, desalination, and waste water management. In recent years, they have become specialists in energy utilisation, wind and solar power, electricity storage and distribution. • The development and application of precision application technologies by Agricultural Engineers has reduced the environmental impacts of agricultural production systems and hence sustains production into the future. • They are heavily engaged in land use and reclamation, the care of forestry, soil science and sustainable intensification.

Appendix B - *continued*

Agenda 2063		UN Sustainable Development Goals		Agricultural Engineering Contribution
Goals	Priority Areas			
8. World class infrastructure	• Communications and infrastructure connectivity	9	Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation.	• In the 21st century, the Agricultural Engineers is the expert in Sustainable Intensification when it comes to agricultural productivity and food security. They understand the need for a strong infrastructure and now harness 4G networks to support the concept of Precision Agriculture, something which is starting have more and more influence across Africa. As such Agricultural Engineers will be the experts needed to influence the shape of the agricultural production, processing and post-harvest distribution infrastructure.
9. Capable institutions and transformative leadership in place	• Institutions and leadership • Participatory development and governance	16	Promote peaceful and inclusive societies for sustainable development, provide access to justice for all and build effective, accountable and inclusive institutions at all levels.	• Agricultural Engineering is a profession with those employed in senior positions often being associated with a professional or learned society. Through this engagement, they subscribe to professional codes which encompass matters of good design principles, ethical approaches, the promotion of equality, diversity, high professional standards, environment and sustainability. • These professionals can make a positive contribution to sustainable development and wider leadership across Africa. They can contribute to the design of educational programmes and support the promotion of high standards.

Appendix C

Stakeholder Perceptions of Agricultural Engineering in Africa

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1.Introduction

The South African Institute of Agricultural Engineers (SAIAE) held its biennial symposium in KwaZulu-Natal during September 2018. The aims of this four-day symposium were twofold: to present and discuss technical challenges and solutions in the broad fields covered by Agricultural Engineering; and to host a workshop on growing the agricultural engineering profession in Africa. This event attracted professionals involved in Agricultural Engineering, not only from South Africa but from all over the continent (and beyond). The workshop element of the symposium was organised by the Pan-African Society for Agricultural Engineering (PASAE), also referred to as 'AfroAgEng'. This short report presents findings from the workshop and makes conclusions on their relevance for the future growth of agricultural engineering in Africa.

2. Method

One element of the workshop involved the formation of ten focus groups, each composed of between five and twelve individuals, to discuss topics related to Agricultural Engineering in Africa. Each focus group was assigned a facilitator who moderated discussion in order to cover each of the topics of interest; scribes were appointed to record agreed responses. In total there were 82 participants, each of whom is professionally engaged in Agricultural Engineering in some capacity; a range of sub-sectors and levels of experience was represented. The vast majority of participants were professionally active in Africa; a minority were from other parts of the world but had a professional interest in Agricultural Engineering in Africa.

Although the workshop's venue meant that there was a natural over-representation of participants from South Africa, there was representation of participants from other parts of the African continent and overseas.

Qualitative data was gathered through two means: responses agreed through group discussion were recorded on flip-chart paper by the facilitator or scribe; and responses from individuals within each group were recorded on hard-copy questionnaires in a free text format.

The qualitative data gathered represents a rich source on which to base analysis of stakeholder perceptions of Agricultural Engineering in Africa and from which to make conclusions about the discipline's future on the continent.

Five questions were discussed:

i) What are the opportunities of growing Agricultural Engineering in Africa?

ii) What are the challenges of growing Agricultural Engineering in Africa?

iii) What are the barriers to overcoming these challenges?

iv) What prioritised strategies should be undertaken to grow and strengthen Agricultural Engineering in Africa?

v) What additional activities should PASAE/AfroAgEng undertake to grow, service and support members?

The first four questions were designed to stimulate discussion among professionals about their own discipline in general. The fifth question pertains to the organisation which hosted the workshop and which seeks to promote and advance the profession of Agricultural Engineering in Africa; this final question was designed to inform the organisation's activities for the benefit of its members and other stakeholders. The responses to these questions were analysed using a thematic approach.

Thematic analysis is a standard method for the analysis of qualitative datasets of this type and is used to identify patterns. Although, as with other qualitative methods, some have concerns about the trustworthiness and/or subjectivity of thematic analysis, it was used for this report because it was deemed to be the most suitable technique for the qualitative data that was available.

3. Limitations

No data is available to allow for a breakdown of the participants' nationalities or sub-sectors within the Agricultural Engineering discipline; neither is demographic data available. Although such data might have given more granularity to the findings presented below, its usefulness for a sample of this size would have been limited. This report adopts a qualitative approach to present the findings of the workshop. Although a quantitative approach could have been adopted, it would have limited statistical significance with a sample of this size. This report does not discuss the findings of this workshop in the context of existing literature on the Agricultural Engineering discipline in Africa. Rather, it presents these findings on a stand-alone basis. This report is aimed primarily at a general audience rather than an academic one.

Findings

The following findings are based on the identification of key themes which emerge repeatedly through qualitative analysis of the dataset. Each question is discussed in turn. The themes identified are not presented in any particular order but have been grouped for structure. Quotations are used (anonymously) throughout to illustrate the themes which were identified during analysis of the qualitative data. Unorthodox formatting used in manuscripts has been retained for accuracy in direct quotations.

4.1 What are the opportunities of growing Agricultural Engineering in Africa?

Responses to the first question can be split into two key themes: turning threats into opportunities and mechanisation. The first broad theme which emerged repeatedly through analysis of responses can be encapsulated by the idea that several threats which humanity faces at large are in fact opportunities for the Agricultural Engineering profession. For example, the increased demand for food due to population growth was mentioned by several participants: 'need for food [is] main driver – population growth'; 'increase in population – need for efficient and effective farming'; 'a lot of opportunities due to the demand for food'; 'main driver is [the] need for food'. Increasing demand for basic needs such as food are, of course, seen by many as a threat but this could be interpreted as an opportunity for the profession as the importance of meeting such demand is obvious.

Other threats such as climate change were noted by several participants as opportunities. For example, one noted: 'there is a need for engineering with the growing demand for irrigation'. The increasing prevalence of drought in many regions, including parts of Africa, is associated with climate change and necessitates greater irrigation for agricultural production systems.

The second theme which emerged repeatedly as an opportunity was that of mechanisation. Many participants identified mechanisation as an obvious opportunity for the discipline and a number of respondents specified that smallholder mechanisation was a particular opportunity. Others went beyond traditional ideas of mechanisation and identified the increasing uptake of information and communications technologies and artificial intelligence in agricultural production as an opportunity. Although mechanisation is certainly not a new idea in agriculture, its ongoing importance may be overlooked by some. Of course, many other opportunities were identified by individual participants but these two stood out during analysis as being referred to repeatedly.

4.2 What are the challenges of growing Agricultural Engineering in Africa?

Responses to the second question can be split into two key themes: education and misunderstanding. Education was identified as a challenge from a variety of perspectives. First, the challenge of attracting students was identified: 'lack of awareness about the degree'; 'students' unwillingness to take Agricultural Engineering as a course of study'; 'poor / lack of promoting Agric Eng as a rewarding and contributing career to the future'; 'lack of Universities/facilities teaching Agricultural Engineering'.

Secondly, the challenges of employability were identified: 'lack of knowledge of employment opportunities'; 'lack of industry exposure; need to focus much more in depth on career development and after-study support; creating opportunities via private sector'; 'lack of sufficient employers for entry level engineers'; 'lack of employer engagement in supporting development [of graduates]'.

Thirdly, the challenges of accreditation were identified: 'accreditation of programs: ONE standard' (emphasis in the original manuscript); 'synergy between the accreditation body & universities'; 'lack of collaboration among accreditation bodies in country; it is important to have a unified standard to recognise Eng'; 'need to recognise professionals from other countries i.e. accreditation & recognition of Eng from other countries'.

Beyond education, another key theme which emerged as a challenge was that of the misunderstanding about agricultural engineering that seems to exist among the general population. This can be exemplified by the following responses: 'misunderstanding of what an Agricultural Engineer is'; 'world don't see / recognise Ag Eng – awareness'; 'lack of knowledge to the public about Agric. Eng.' This perennial problem is not unique to Agricultural Engineering and it is not confined to Africa. However, it has been identified as a major challenge to the growth of the profession.

Other themes which emerged repeatedly through analysis included the challenges posed to logistics by limitations in infrastructure (e.g. roads) and the idea of inertia as illustrated by one participant: 'many farmers are doing the same things for the past 50 years, thus no innovative solutions, no need for Ag. Eng.'.

4.3 What are the barriers to overcoming these challenges?

Responses to the third question can be split into two key themes: insufficient collaboration and the inadequacy of professional associations. It may be a cliché to say that the 'silo mentality' is a barrier and this is certainly not a problem exclusive to the Agricultural Engineering profession; nonetheless, this was identified as a key barrier by participants on a range of levels: 'working in silos – no interaction between disciplines'; 'co-ordination and communication between disciplines'; 'not enough collaboration between African institutes'; '[lack of] collaboration between countries'; 'no "continental" co-operation'.

Participants made several suggestions for how this particular barrier could be overcome: 'break silos'; 'better communication and collaboration between bodies, example between ag and civil for roads'; 'co-ordination between departments/disciplines; appointment of engineers in technical posts; politicians don't listen to engineers; communication by engineers – poor'; 'agricultural engineers must be put in government positions'; 'better mutual relations with other countries, with regards to agricultural engineering'.

Another key barrier identified by participants was the inadequacy of professional associations. This can be exemplified by the following comments: 'lack of active professional bodies […] lack of institutional stability/sustainability'; 'lack of Ag. Eng. societies/professional bodies' 'lack of active professional Agric. Eng. bodies' (emphasis in the original manuscript); 'lack of active professional bodies'.

Of course, much good work is done by professional associations for agricultural engineers across the continent but it is also true that some are inactive or non-existent in several African countries.

Another theme which was identified by a large number of participants was lack of funding. Of course, a lack of investment is a barrier to many activities – not just in Africa but all over the world. As one participant put it, a key problem is: 'to convince investors that Agric Engineering can make investments in agriculture more profitable'.

4.4 What prioritised strategies should be undertaken to grow and strengthen Agricultural Engineering in Africa?

Responses to the fourth question can be split into two key themes: partnerships and mobility/mentoring programmes. First, the idea of partnerships (of various types) came out strongly through analysis. For example, participants called for the following: 'partnerships with university, combined with possible private sector involvement'; 'link between industry and tertiary institutes'; 'establish entities that promote communication across disciplines.

Other respondents sought partnerships between research institutions, between universities and private enterprises, between agricultural engineers and policy-makers, and between countries both within the continent and overseas. It is clear that there is a link between the strategy of partnerships and the barrier of the 'silo mentality' (see above).

Secondly, the establishment of mobility/mentoring programmes was identified as a strategy by several participants. Mobility programmes were suggested for students, graduates and academics. Mentoring programmes were suggested between recent entrants into the profession and more experienced Agricultural Engineers as a means of knowledge transfer and development. Another theme which was identified by a number of participants can be illustrated by the following comment: 'Africans must solve their own African problems'.

4.5 What additional activities should PASAE/AfroAgEng undertake to grow, service and support members?

Responses to the fifth question can be split into two key themes: engagement with academia and marketing. First, activities were suggested for greater engagement with higher education and research institutions as typified by the following comments: ‘strategy to attract young people e.g. scholarships’; ‘link the private sector and the university students’; ‘integration with industry/academia’; ‘universities and industry – integration to foster publicity and awareness’; ‘share quality standards between agric. engineering schools’; ‘PASAE should promote continental journal in Ag Eng in Africa’.

As a number of the workshop participants were academics and PASAE membership also includes academics, it is perhaps unsurprising that engagement with academia has been put forward as a set of priority activities. Secondly, activities were proposed for promoting the ‘brand’ of Agricultural Engineering; participants suggested: ‘marketing the Ag. Engineering profession’ and ‘improving the agricultural engineering brand (making sure what we do is known)’.

This set of activities is linked to the challenges associated with the misunderstanding of the nature of Agricultural Engineering (see above). Additionally, several participants referred to a desire to see activity in lobbying both national governments and the African Union.

5. Conclusions

The findings presented above represent the views of 82 individuals engaged in agricultural engineering in Africa. Through the workshop process, these individuals had the opportunity to discuss in depth their own discipline and its growth on the continent.

Although it is not necessarily the case that the findings presented above represent the stakeholder perceptions of all Agricultural Engineers in Africa, it is intended that the themes identified during analysis of the qualitative data gathered during the workshop will be useful for two main purposes.

First, the themes which emerged from the first four questions give insights into the opportunities and challenges of growing Agricultural Engineering in Africa, as well as the barriers to overcoming these challenges and the strategies which could be adopted to do so.

Secondly, the themes which emerged from the fifth question could be used by the Pan-African Society for Agricultural Engineering (PASAE) to inform its activities for the benefit of its members and other stakeholders.

Opportunities include the idea of turning threats into opportunities and that of mechanisation. Challenges include those posed by educational systems and those caused by a misunderstanding of the nature of the profession. Barriers to overcoming these challenges include insufficient collaboration and the inadequacy of professional associations. Potential strategies for the growth of the discipline include partnerships and mobility/mentoring programmes.

As for the activities which could be undertaken by the PASAE, stakeholders identified a desire for greater engagement with academia and suggested activities which would market the profession to a wider audience.

Appendix D (a)

Best Practice in the Application of Agricultural Engineering in Africa

This information has been sourced through discussions with the company and is published here with their full agreement. Please note that AfroAgEng has no commercial relationship and/or endorsement arrangements with the company and therefore accepts no liability whatsoever in this regard.

The Nigerian organisation ColdHubs was formed to address the problem of food waste. In developing countries, 45% of food spoils mainly due to lack of cold storage. This means that around 470 million small farmers can lose up to a quarter of their annual income.

Perishable food especially fresh fruits and vegetables start to deteriorate as soon as they are harvested because they are cut off from their source of water and nutrition. They lose weight, texture, flavour, nutritional value and appeal. Cooling significantly slows down the rate of deterioration, thereby increasing the storage life of the produce. The Cold Hubs solution is a walk-in, solar-powered cold stations for 24/7 storage and preservation.

ColdHubs Innovation

ColdHubs, is a "plug and play" modular, solar-powered walk-in cold room, for 24/7 off-grid storage and preservation of perishable foods. It adequately addresses the problem of post- harvest losses in fruits, vegetables and other perishable food. ColdHubs, is installed in major food production and consumption centres (in markets and farms), farmers place their produce in clean plastic crates, these plastic crates are stacked inside the cold room.

This extends the freshness of fruits, vegetables and other perishable food from 2 days to about 21 days. The solar powered walk-in cold room is made of 120mm insulating cold room panels to retain cold. Energy from solar panels mounted on the roof-top of the cold room are stored in high-capacity batteries, these batteries feed an inverter which in turn powers the refrigerating unit.

Coldhubs offers farmers with a flexible pay-as-you-store subscription model. In preparation for storage, farmers transfer their perishable foods into reusable crates, which fit neatly onto the shelves. Farmers pay a daily flat fee for each crate of food they store.

It is claimed that in 2020, the 54 operational ColdHubs saved 42,024 tons of food from spoilage, serving 5,250 farmers, retailers, and wholesalers using it's 54 installed cold rooms in 32 farms, aggregation centres, and markets within the Southern and Northern Regions of Nigeria.

The Agricultural Engineering Profession includes specialist in post-harvest technologies and the use of technologies such as refrigeration and rapid cooling to help reduce food waste.

For more information, visit:
http://www.coldhubs.com/

Appendix D (b)

Best Practice in the Application of Agricultural Engineering in Africa

This information has been sourced through discussions with the company and is published here with their full agreement. Please note that AfroAgEng has no commercial relationship and/or endorsement arrangements with the company and therefore accepts no liability whatsoever in this regard.

DENT Agrisystems from Ghana are specialist in product design, software and hardware engineering, marketing, agriculture and business development. They focus on providing low-cost sustainable agricultural technology solutions to smallholder farmers in Africa.

With diverse backgrounds and perspectives DENT Agrisystems include professionals in STEM to create a "think tank" where skills and knowledge are used to provide solutions to the many problems in the Agricultural sector. DENT Agrisystems have established two key products using the Hwesomame (which literally means "look after it for me" in Ghanaian local language Twi).

Hwesomame Smart Soil Sensor

This smart soil sensor aims at taking guesswork out of farming. Soil Parameters like moisture, temperature, salinity, pH and the nutrient contents are measured by the sensor and the data is cross-referenced against an extensive database of plants and soil. Farmers then receive personalized predictive insights on their plants and soil via a text message and voice call in a local language. This allows farmers to make informed decisions which will increase their yield and profit and improve crop quality.

The Agricultural Engineering Profession includes soil scientists and systems integration engineers who can link this information to management decision making through software and remote sensing platforms.

Hwesomame Weather Update Service

With climate change, farmers and farm communities around the world will be increasingly challenged. Through the Weather Update Service, farmers receive accurate weather information on atmospheric humidity, temperature, precipitation and wind speed. This information helps farmers make irrigation event schedules, set pest alarms, plan times for sowing and harvesting. Farming based on weather data is crucial to successful farm management. It ensures sustainable farming, thus protecting the environment.

The Agricultural Engineering Profession includes water management experts and irrigation engineers who can help use this data to make better use of precious water resources

dent AGRISYSTEMS

For more information, visit:
https://www.facebook.com/dentagrisystems/

Appendix D (c)

Best Practice in the Application of Agricultural Engineering in Africa

This information has been sourced through discussions with the company and is published here with their full agreement. Please note that AfroAgEng has no commercial relationship and/or endorsement arrangements with the company and therefore accepts no liability whatsoever in this regard.

Located in Nigeria, Farmz2U has worked towards the primary objective of reducing global food waste and enhancing food nutrition. They seek to ensure that farmers adopt sustainable production methods that ensure high nutritional content of produce.

This is aligned with the United Nation's SDG 3. For the second objective Farmz2U achieves this by promoting responsible production among farmers and this is aligned with United Nations' SDG 12.

The vision of Farmz2U is founded in forming an engineering and technology solution to address the disconnected market, and farmers poor access to capital, quality assured inputs and adequate technical expertise. Farmz2U aims to use technology to empower farmers with data analytics that can support core operational processes and key decisions, with access to relevant stakeholders in the value chain. This is founded in the application of Agricultural Engineering to the value chain.

Agronomy Research

Working with academia and agricultural experts to support the provision of expertise to farmers. Addressing threats such as soil degradation and climate change this seeks to develop a more efficient farming process and promote techniques such as fertiliser micro dosing and swarm robotics.

The Agricultural Engineering profession includes soil scientists, fertiliser application technologists and robot engineers.

Farmz2U

Soil Testing

Using on-farm data including like soil composition and weather, this allows detailed analysis of the resources the farmer needs like. With farm specific data Farmz2U provides tailored expertise that can increase yields.

The Agricultural Engineering profession includes systems engineering and data integration engineers.

Precision Agriculture

Using farm data and hardware such as soil sensors and drones, decision making can be automated. With historic data and regression analysis the user can view trends in a location or value chain and make better decisions.
The Agricultural Engineering profession includes agri-tech specialists and drone experts.

Sales Aggregation

Farmz2U's aim is to help the increase sales and get to commercial scale. With partnerships with buyers and distributors, they seek to guarantee the sale of produce and to ensure harvested products quality assurance tests.

The Agricultural Engineering profession includes post-harvest processing and storage technologists.

For more information, visit:
https://www.farmz2u.com/

Appendix D (d)

Best Practice in the Application of Agricultural Engineering in Africa

This information has been sourced through discussions with the company and is published here with their full agreement. Please note that AfroAgEng has no commercial relationship and/or endorsement arrangements with the company and therefore accepts no liability whatsoever in this regard.

The Sparky Dryer is founded from the fact that although agriculture is the main source of livelihood in Uganda and across Africa, typically some 40% of harvested produce (mainly fruits and vegetables) are lost before consumption. The post-harvest losses are due to poor handling and preservation, particularly for small scale farmers.

The loses not only means less food available for consumption, increasing food insecurity but also less profitability for the farmers, reducing their earnings and keeping them in the cycle of poverty. This challenge is affecting over 15 million households in Uganda, according to the Uganda Bureau of statistics (2015).

Growing up in the northern part of Uganda that experienced a two-decade civil war, the creators observed the realities of food insecurity. Local communities struggled to grow food and frequently half is lost due to poor handling and preservation. These experiences inspired the Sparky Dryer, a multi-disciplinary team of young innovators, engineers, entrepreneurs to solve the problem for Uganda and also for Africa.

The Sparky Low-Tech Food Dryer

Sparky is a low-tech food dryer that reduces the current 40% post-harvest losses in fruits and vegetables to less than 20%, by extending the shelf-life of the produce from just 2 days to more than 6 months through dehydration. It is powered by harvest waste from the gardens as clean biofuel (briquettes) with the help of solar-powered energy to dehydrate food in typically 5 hours.

SPARKY preserve today to feed tomorrow

It dehydrates 5 times faster than solar dryers and 10 times faster than the open sun drying method while maintaining all the nutrients in the food.

With the Sparky Dryer, a farmer can dry up to 50 kg of produce within a day with only 5kg of biofuel through the gasification process with zero CO2 emission despite whether it is raining or shining.

This makes the Sparky dryer not only reliable but also very convenient for use and environmentally friendly.

The Agricultural Engineering profession brings together through a multi disciplinary and systems engineering approach a range of post harvesting and energy saving technologies to reduce food waste

For more information, visit:
https://sparkysocialenterp.wixsite.com/sparkydryer

Appendix D (e)

Best Practice in the Application of Agricultural Engineering in Africa

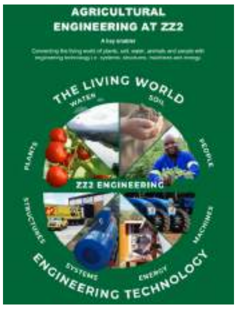
This information has been sourced through discussions with the company and is published here with their full agreement. Please note that AfroAgEng has no commercial relationship and/or endorsement arrangements with the company and therefore accepts no liability whatsoever in this regard.

The ZZ2 Group of companies started their farming operations more than a hundred years ago. ZZ2 farms mainly in the Limpopo Province in South Africa growing tomato es and avocados. They also operate in the Western Cape, Eastern Cape, Gauteng, North-West Province, Mpumalanga of South Africa and Namibia growing mangoes, onions, dates, cherries, apples, pears, stone fruit, almonds and blueberries. ZZ2 put Agricultural Engineering at the heart of their work and to that end, have produced a report which illustrate the extent to which the discipline is:

"A key enabler: Connecting the living world of plants, soil, water, animals and people with engineering technology i.e. systems, structures, machines and energy."

The number of engineers in ZZ2 grew from 1 in 2005 to 17 in 2020. The engineering disciplines in 2020 include:

Mechanical	9
Industrial	3
Agricultural	2
Civil	1
Electrical	1
Cooling	1



The following list of some of the functions performed by engineers working at ZZ2.

Packhouse and process optimisation	IoT Systems
Water supply	Electro-mechanical systems
Irrigation and drainage	Farm Structures
Protected cultivation	Dams
Mechanisation	Roads and Rails
Cooling	Product development and improvement
GEO information systems	Eskom and electricity
Surveying	Management and project management (Packhouses, Logistics, Technical, Strategy and Corporate governance)
Energy (including renewables)	
Computer and automation	

The report goes on to illustrate the role engineering ahs to play and assert the need for multi-disciplined engineers. It goes on to list of some of the projects where Engineers of ZZ2 and other Engineers are involved and for each of these there is a project summary of each project on the next pages. For example:

- Forced aeration compost production.
- Water extraction from sand riverbeds.
- Dealing with Eskom's load shedding to ensure sustainable farming.
- The possibility to farm without Eskom.
- Increased transport efficiency.
- Increased transport efficiency through higher payloads.
- Using LIDAR to enable surveying, planning and design of large-scale avocado developments.
- The development of a unique sprayer for open field tomatoes.
- The development of a unique sprayer combination for net house tomatoes.
- Back to the basics with biomass water heating.
- Retaining product quality.
- "smAvo" and "smaTo": For a smoother ride from field to the table.
- Engineering 4.0 & Innovation Africa: Research in the #4IR Era.
- Road condition.
- Investigating various pollination methods inside tomato net houses.
- Precision agriculture, including IoT, a reality at ZZ2:
    - Blue berry growth data capturing.
    - Weather station overhaul.
    - Lysimeters.
    - Variable fertilizer application.
- Integration of all engineering disciplines to create a state-of-the-art packing facility.
- Considerations when building a structure to house a packing facility to handle future avocado and tomato production.
- To perform calibration & constant rate tests on 150 Boreholes.
- Preventing of stage skipping and dry fruit during harvesting season of Medjool palm dates.

This report is helpful in showcasing the valuable role played by Engineers. Moreover, it makes the point that there is a shortage of suitable qualified and experienced Agricultural and Biosystems Engineers. To overcome this challenge, ZZ2 provides support for training of agricultural and other engineers through the provision of professional development schemes, a bursary scheme, post graduate training courses and various other strategies.

It is working with specific universities to ensure sufficient future supply of appropriately qualified engineers and technologists.

AfroAgEng views this as good practice from which others could learn.

Appendix E (a)

Snapshots of Pan African Agricultural Engineering Provision
(a) South Africa

This snapshot was presented by Professor Jeff Smithers, Professor of Agricultural Engineering and Director of Centre for Water Resource Management at the University of KwaZulu-Natal, South Africa.

The full presentation is available at:
http://pasae.org.za/Events.html

Key Features

- Against a population of approximately 60 million, Agricultural Engineering is available at one university (The University of KwaZuli-Natal). There are under 20 graduates each year. Recruitment at around 30 undergraduates a year is steadily declining. Retention for the duration of the programme is poor.
- The purpose of the programme has real clarity, namely:
  - o Prepare engineers, with the necessary knowledge, understanding, abilities and skills
  - o Required for further learning towards becoming innovative practicing professional engineers
  - o Competent to address the needs of society
  - o Field of engineering applied to the production, management, processing and storage of biological resources
- The general structure of the programme is clear including fundamental and basic sciences, application of sciences, problem solving.
- The knowledge area are well distributed to offer a balance curriculum:
  - o Mathematical sciences: 19-21%
  - o Natural sciences: 14-18%
  - o Engineering sciences: 34-37%
  - o Design and synthesis: 15-17%
  - o Complementary studies: 11-15%
- The curriculum seeks to maintain a broad focus with core knowledge areas covering farm machinery and implements, hydrology, irrigation and food processing.
- Elective modules area offered across the broad spectrum of agricultural engineering including soil and water conservation engineering, water quality, food engineering, electrical applications, environmental control and sustainable energy.
- Quality is assured through standard university procedures and Engineering Council South Africa accreditation. This assures the quality of graduates when compared to other programmes. Standards are linked to the International (Washington) Accord.
- Provision seeks to deliver a range of graduate outcomes to aid employability and career progression including: Problem solving, Application of scientific and engineering knowledge, Engineering design, Investigations, experiments and data analysis, Engineering methods, skills and tools, Professional and technical communication, Sustainability and impact of engineering, Individual, team and multi-disciplinary work, Independent learning ability, Engineering professionalism, Engineering management.

Challenges

- Covering the breadth required in the time available – Agricultural Engineering is a very broad subject.
- Human and physical resources, constrained by the breadth of the programme and the relatively low number of experts available to teach
- Keeping up with the pace of technological change together with the breadth of technologies encountered by graduates.
- Growing the student intake and maintaining performance.
- Public perception of the industry with a lack of knowledge, poor perception of opportunities and a negative attitude towards agriculture
- Industry demand negatively influenced by a poor economic climate and pressure on prices in a global economy.

Conclusion

The provision in South Africa represents an excellent model in terms of its content and approach with a good focus on preparing graduates for employment and progression. The low take up of degree programmes is a challenge to be overcome together with improving retention on the programme. It is good practice to have external accreditation of degree programmes.

Appendix E (b)

Snapshots of Pan African Agricultural Engineering Provision
(b) Nigeria

This presentation from Professor Kehinde Taiwo from Obafemi Awolowo University, and Professor Emmanuel Ajav from the University of Ibadan focused on the development of Outcome Based Education (OBE) for the Mobility of Agricultural Engineers.

The full presentation is available at:
http://pasae.org.za/Events.html

Key Features

- The provision of Agricultural Engineering across Nigeria presents a positive pictures with 27 active universities, 12 Federal, 10 State and 5 Private. These are well distributed across the country.
- The nomenclature of Agricultural Engineering programmes is divers and include:
  - o Agricultural and Environmental Engineering
  - o Agricultural and Biological Engineering
  - o Agricultural and Bio-Resources Engineering
  - o Agricultural and Biosystems Engineering
  - o Agricultural and Food Engineering
  - o Biosystems Engineering
  - o Bioresource Engineering
- The introduction of an Engineering Register is viewed as the gateway to liberalisation and professional services with mobility cited as an important aspect.
- Due importance is given to international benchmarking as and external recognition of quality and as a symbol of assurance to a broad range of stakeholders.
- A range of well-established mobility forums are cited such as the Association of South East Asian Nations, International Professional Engineers Agreement.
- The value of engineering accreditation agreement is espoused such:
  - o Washington Accord
  - o European Network for Accreditation of Engineering Education
  - o Sydney Accord for Engineering Technology
  - o Dublin Accord for technician engineering.
- It is acknowledged that prior to 2002, the Washington Accord was based on the conventional education system – input based so the adoption of an outcome based approach was welcomed as an improvement to standards.
- OBE focuses on what students can actually do after they are taught with the following key questions:
  - o What do we want the students to learn or be able to do? (Outcomes and Motivation)
  - o How best can we help students to learn or achieve it? (Delivery and Resources)
  - o How will we know whether the students have learnt or achieved it? (Assessment and Evaluation)
  - o How do we close the loop for further improvement? (Continuous Quality Improvement (CQI)
- The approach is to use the concept of Outcome Based Education to define Programme Education Objectives (PEO)
- PEOs are statements that describe the expected achievements of graduates in their career and professional life a few years after graduation (say 5 years).
- A key element in developing PEO is the need to take on board the needs of stakeholders and use these to inform the development activities of the academics designing the degree programme
- Program Outcomes (PO) are developed based on the PEOs. These will:
  - o Describe what students are expected to know
  - o What students are able to perform or do by the time of graduation
  - o POs address Knowledge, Skills and Attitudes to be attained by students
  - o There must be a clear linkage between Objectives and Outcomes.
- Course Outcomes (COs) are statements that describe what students are expected to know and be able to perform or do upon completion of a course.
- Every learning outcome is intentional and therefore the outcomes must be assessed using suitable performance indicators.
- Course outcomes (COs) must satisfy the stated programme outcomes.

Appendix E (b *continued*)

- Course Outcomes are essential as they:
  - o Define the breadth and depth of learning that students are expected to achieve
  - o Provide a benchmark for formative and summative, assessment
  - o Clearly inform expectations to students
  - o Clearly communicate graduates' skills to the stakeholders
  - o Define coherent units of learning that can be further subdivided for classroom or other delivery modes
  - o Guide and organize the lecturer and the student
- Reasons for careful specification of outcomes:
  - o They enable better planning of instruction and since they are end points they ensure lecturers know where they are going
  - o If the student knows where the lecturer is going they can direct their attention and effort to this goal a point
  - o They can improve performance assessment through between test construction
  - o They provide clearly defined parameters for evaluation

Assessment & Evaluation

- In education, assessment is the process of gathering, interpreting, recording and using information about pupils' responses to an educational task.
- Both Formative and Summative assessments are used.
- Formative assessment takes place during the course of teaching and is used essentially to feed back into the teaching and learning process. E.g. assignments, tests, quizzes.
- Summative assessment is the "sum" of teaching/learning assuming a finality status and happens at the end of a course. E.g. Exam.
- Assessment Tools for Programme Education Objectives (PEO) include:
  - o Employers' Survey on Employment Satisfaction
  - o Input from Industrial Advisory Committee
  - o Program Educational Objectives Alumni's Survey
  - o Faculty Annual Self-Assessment
- Assessment Tools for Programme Outcomes (PO) include
  - o Course-based Embedded Assessment
  - o Student Course Satisfaction Survey
  - o Cumulative GPA (CGPA) Index for Each Course
  - o Senior Design Projects -- Index of Excellence
  - o Programme Accreditation
  - o Academic Review – External Examiner
  - o Graduate Employment Statistics
- Formative Assessment Tools for Course Outcomes (CO) include:
  - o Written tests linked to course outcomes
  - o Oral presentation and assessment
  - o Student surveys, individual and focus group interviews
  - o Written project reports
  - o Assignments, and reports in capstone design subject
  - o Demonstration and simulation
  - o Student portfolios
  - o Peer-evaluations and self-evaluations
  - o Behavioural observation
- Summative Assessment Tools for Course Outcomes (CO):
  - o Written examination and tests linked to course outcomes
  - o Oral presentation and assessment
  - o Student surveys, individual and focus group interviews
  - o Written project reports
  - o Demonstration
  - o Employer survey

Appendix E (b *continued*)

- A new roles of students in OBE
  - o Know the required Programme Outcomes and Programme Objectives
  - o For each course, review the Learning Outcomes at the beginning of each semester.
  - o This gives them an idea of the knowledge and skills expected from a particular course.
  - o Be more proactive in the learning process to acquire the Learning Outcomes of subjects
  - o Demonstrate through the assessment methods that the required skills and knowledge have been acquired.
  - o Attain the Programme Outcomes and Programme Objectives as a whole during the entire programme.
  - o Give constructive feedbacks on the programme/course/academic staff to obtain accreditation through active participation in Online Teaching Evaluation, Academic Advisory System, dialog sessions, etc.
- External Accreditation Criteria
  - o Academic Curriculum:
  - o Mission and Programme Objectives,
  - o Programme Outcomes and Teaching Processes
  - o Students
  - o Teaching Staff & Support Staff
  - o Facilities
  - o Quality Management System: Institutional
- Qualifying Criteria
  - o Minimum 120 credit hours of which 80 credit hours must be engineering courses
  - o Offered over 5/6 years
  - o Final year project
  - o Industrial training
  - o Minimum of 8 full-time academic staff
  - o Staff: student ratio is 1:20 or better
  - o External examiner's report
  - o Programme Objectives
  - o Programme Outcomes

Conclusion

It is clear that quality and consistence of agricultural engineering degrees across the country will benefit from this approach. The model is aligned to international standards and has included a very good focus on the needs of the industry served by the university. This may well be uncomfortable for some academics but the overall aim to afford better outcomes for graduates and in itself, that has to be a very positive attribute. The focus on assessment and quality assurance is strong throughout this process.

Appendix E (c)

Snapshots of Pan African Agricultural Engineering Provision
(c) Ghana

This presentation from Professors Emmanuuel Bobobee and Ahmed Addo, and Drs Eric Asante and Enoch Bessah from the Department of Agricultural and Biosytems Engineering, Kwame Nkruma University of Science and Technology in Ghana covered the subject of Agricultural Engineering Education in Ghana

The full presentation is available at:
http://pasae.org.za/Events.html

Key Features

- Ghana talks in terms of Agricultural and Biosystems Engineering (ABE) for the tertiary sector as covering engineering sciences, agriculture and humanities.
- There are four traditional (academic) universities and five technical universities distributed around the country.
  - o Traditional universities award BSc, MSc, MPhil, PhD degrees
  - o Technical universities award HND, BTech, MTech and DTech degrees
- Ghana as the aim to become national and international centres of academic excellence, providing leadership through study, research and extension work in Agricultural and Biosystems Engineering appropriate to the tropical and Ghanaian conditions.
- Programmes are available across the broad range of levels suggesting good opportunities for progression and a range of entry points
- All technical universities except one run a 3-year HND programme with one having introduced a 2-year BTech Top-Up for HND holders and another runs a 4-year BTech programme.
- The research focus of most agricultural engineering Departments in Ghana is to improve agricultural productivity in the following areas:
  - o Post-harvest loss reduction of crops, meat and fishery products,
  - o Farm Animal Traction Technology and Farm Power,
  - o Mechanised farming and land and water management practices,
  - o Precision agriculture,
  - o Agro-chemical use and environmental pollution,
  - o Wastes treatment and biogas generation, and
  - o Productive uses of electricity for agro-based industries in rural areas.
- To enhance Agricultural and Biosystems Engineering practices for the development of Ghana and Africa, departments in Ghana seek to:
  - o Provide the enabling environments to suitably qualified applicants of all nationalities and gender and to produce industry-ready graduates,
  - o Educate future scientists and engineers, industrialists, farmers and policy-makers to be compliant with continental agenda 2063 and global sustainable development goals.
- Agricultural Engineering programmes generally comprise of:

o Humanities <9%,
o Mathematics 8-17%
o Basic Engineering Sciences 36-46%
o Agricultural Engineering 39-52%.

- There is an increasing trend of prospective applicants since the inception of the programme with one student in 1971 at KNUST, Kumasi.
- All agricultural engineering and mechanization graduates belong to the Ghana Society of Agricultural Engineers (GSAE) and they will be encouraged to join PASAE.

Conclusion

The balance of academic and technical university provision across a range of levels offers undergraduates with a good range of access points and progression opportunities. The research focus is strongly related to the wider Agricultural Engineer discipline. The linked to the nations professional engineering society is a strong feature. The growth in numbers joining programmes suggests that there is positive acknowledgement of the importance of this discipline area.

Appendix E (d)

Snapshots of Pan African Agricultural Engineering Provision
(d) Uganda

This presentation from Noble Banadda of the Department of Agricultural and Biosystems Engineering, Makerere University, Kampala, Uganda provided an overview of Agricultural Engineering Training at the university.

The full presentation is available at:
http://pasae.org.za/Events.html

Key Features

- The development of Agricultural Engineering provision over the past 100 years presents and interesting history.
  - Department of Ag. and Biosys. Eng. was formerly the Department of Agricultural Engineering
  - From 1922 to 1956, Makerere University ran a British model that focused on faculties rather than departments
  - In 1957, changed to departments & 1st tractor model was well known in East Africa as the Kabanyolo Tractor
  - In 1973, there was terrible trauma on account of the regime at the time and this set developments back
  - In 1990, an independent B.Sc. Ag. Engineering programme
- At present there are 16 academic staff, 120 undergraduates, and 10 post graduates following:
  - BSc. Agricultural Engineering
  - BSc Water and Irrigation Engineering
  - BSc Bioprocessing Engineering
  - M.Sc. and Ph.D. program in Agricultural Engineering
- The University engages with five international staff from USA Universities.
- The broad teaching load of the university includes:
  - Agribusiness and Natural Resource Economics
  - Agricultural and Biosystems Engineering
  - Agricultural Production
  - Environmental Management
  - Extension and Innovations
  - Food Technology and Human Nutrition
  - Forest Bio-diversity and Tourism
  - Geography, Geo Informatics and Climatic Sciences
  - Adult and Community Education
- Themes of Research at the University include
  - Sustainable Agriculture
  - Land and Water Resources Engineering
  - Post-harvest Handling Engineering
  - Biological and Process Engineering
  - Machinery & Equipment Engineering
  - Renewable Energy Engineering
  - Wastewater and Sanitation
  - Simulation and modelling (EDEM and CFDs)
- The Publication record and rankings suggests a strong position. Subjects include:
  - Agricultural Production
  - Forest Bio-Diversity and Tourism
  - Extension and innovations
  - Agricultural and Biosystems Engineering
  - Women and Gender Studies
  - Agribusiness
  - Disease Control
  - Food Technology

Appendix E (d *continued*)

- Collaborations are viewed as a key aspect of research with partnerships across the world including:
  - o North America
  - o Europe
  - o South America
  - o Wider Africa
  - o Middle East
  - o Asia Pacific

Conclusion

The range of research streams is impressive and well-focused in the interactions with wider Biosystems engineering. There is an interesting parallel with some wider research initiatives which bring together science and engineering with socio economic work streams. The collaboration with universities around the world for academic delivery as well as research presents a useful model from which other could benefit.

Appendix E (e)

Snapshots of Pan African Agricultural Engineering Provision
(e) Morocco

This overview of Agricultural and Biosytems Engineering Education in Morocco was presented by Dr El Houssine Bartali from IAV Hassan II, Rabat, Morocco.

The full presentation is available at:
http://pasae.org.za/Events.html

Key Features

- Agricultural Engineering development in Morocco is very much focused on the needs of the North African context and includes the following strands:
  - o Support Moroccan Economy through modernisation of Agriculture
  - o Dams contruction policy
  - o National structuring Plans
  - o Develop irrigation reach target of 1 million ha irrigated land by 2000 (the irrigated area has reached nowadays 1,6 million ha)
  - o Supply drinkable water to urban and rural communities
  - o Develop waste water treatment network and plants
  - o Develop rural roads
- The Mediterranean type climate of Morocco is characterized by considerable spatial and temporal irregularity of rainfall. 80% of the country receives less than 400 mm per year.
- Agriculture in Morocco is an important economic sector. It is the largest employer in the country with about 40% of the nation's workforce.
- Due to population and industrial growth, irrigated agriculture, urbanization, tourism, climate change, Morocco's water resources are becoming exposed to increasing pressure with 730 cubic meter/capita/year.
- The characteristics of Moroccan education provision focus on the application of science with tight links to the field and farm. This deals with:
  - o Water mobilisation and management, irrigation development,
  - o Water valorisation and agricultural productivity
  - o Rain fed agriculture,
  - o Rural infrastructure
  - o Water supply and waste water treatment and networks
  - o Sustainable food supply chains
  - o Environment protection
- In Morocco, the role of the future Agricultural Engineer, encompasses the ability to answer or solve future problems that are not yet known to us today. In other words, an engineer must be resourceful (creative and imaginative), and to be so, he must be prepared during his training.
- In view of the present and future challenges already known for which the agricultural and biosystem engineer must have capacities, in various fields as listed in the following:
  - o Environment and Water scarcity
  - o Water Governance, Integrated Water Resources Management and Sustainable Development Goals (SDGs)
  - o Climate Change, Sustainable Value chains
  - o Management, Information and Communication
- The approach taken by Hassan II Institute of Agronomy and Veterinary Medicine is as follows:
- A six semester degree in Agricultural Engineering focusing on:
  - o Basic science and technology
  - o Management
  - o Languages, communication, sports and cultural activities
  - o A final semester completing a project
- The programme includes three internships, on a farm, diagnosis and development at irrigation scheme level and professional integration.

Appendix E (e *continued*)

- The Moroccan provision views itself as having a role to play in extending this training to wider Africa and as such they can be found in:
  - o Main departments in charge of agriculture, Water, energy, equipment, environment
  - o The professional sector: major boards of engineering , contractors
  - o Supporting innovative projects in dams construction, irrigation design and management
  - o Water saving systems in agriculture
  - o Design and implementation of non-conventional water projects for irrigation and drinking water
  - o PPP projects, including desalinisation of sea water
  - o Upgrading and maintenance of rural and agricultural infrastructure

Conclusion

Agricultural Education degree programmes have a very clear focus on the needs of North Africa and in the case the subject of irrigation. To some extent, this is a specialist sub sector of wider agricultural engineering and is a model which has value across the whole of the continent. There is no reason why the excellence developed in Morocco can't be replicated elsewhere and PASAE has a potential role in this respect.

Appendix F

(a) NMITE – New Model Institute for Technology and Engineering

This is an initiative backed by the UK government, educators, the Olin College in the USA, and industry, to transform higher engineering education in Britain.

The NMITE[1] project is essential to Britain's competitive future. Engineers are key to resolving major world challenges but the UK is critically short of them. Practical problem-solvers will be the innovators of the future and this is crucial for global development.

The objective of NMITE is to change all this.

> *"We don't have enough engineers; we don't have enough women engineers; and employers tell us that too many engineering graduates lack the right industry skills for the future".*

NMITE plans to be different! It will be changing the way engineers are selected. Looking to the future it intends to have an application process where candidates will impress through their curiosity, ingenuity and passion as much as by a set of starred grades. NMITE hopes to make engineering come alive as the creative, problem-solving and inspiringly worthwhile discipline it is.

NMITE plans to change the way undergraduates learn as Elena Rodriguez-Falcon, President & CEO says, 'you won't come here to study engineering; you'll come here to be an engineer.' NMITE future learner engineers will work collaboratively in small groups, on real-world engineering challenges set by real-world organisations. Once approved, it will be a unique curriculum model that will enable learners to gain an MEng in three (46-weeks) years and will place learning-by-doing over lectures, and learning-by-results over exams.

The aim is to change the route into employment as the future learning experience of NMITE is being designed solely to align the skills and talent of our engineers with the needs of employers. This will reflect technological developments and help to develop a mindset that is open to change.

(b) Olin College in the USA

Olin College[2] was founded to radically change engineering education with the goal of fuelling the technical innovation needed to solve the world's complex future challenges.

In 1997, the F.W. Olin Foundation established the college with a visionary and unprecedented grant "to be an important and constant contributor to the advancement of engineering education in America and throughout the world." From day one, Olin had no departments or tenured faculty, allowing for true collaboration and integration of efforts.

Olin instils passion and ignites innovation by focusing engineering students on the needs of people in the real world. This broad perspective in the hands of creative and motivated students inspires technical mastery for a purpose. Olin "engineer-innovators" envision and deliver products, services and systems that transform the way people live on this planet.

The academic approach

- At Olin College of Engineering we want our students to experience learning not just in formal and technical ways, but also as explorers and creators who design their own path. Learning happens everywhere:
- In group experiences like faculty-led classes, student-led independent studies, and co-curriculars (where students, faculty and staff come together around common interests)
- In student clubs and organizations, ranging from highly structured engineering competition teams to service organizations, social clubs and sports teams
- In exploring the boundaries of knowledge and innovation working on research projects with faculty
- By pursuing new ideas and passions through independent studies and Passionate Pursuits.

Learning in all of these contexts is fun and inspiring, and it lets students work on things they are excited about. These activities inspire creativity and equip students to use what they've learned to make a positive impact on the world. The campus culture values engagement and learning, no matter where it happens. Each semester we celebrate student work at the Olin Expo[3], where students share the project they are most excited about.

(c) The AGCO Corporation Future Farm

Agricultural Engineering and systems thinking is at the heart of this initiative. The original vision came from an AGCO employee of African origin. This presents a very good example of a project which is "for Africa, by Africa"

The AGCO Future Farm[4] was developed from a vision to impact and empower farmers across Africa. It all began in 2015 when the AGCO Future Farm started its mission to give all African farmers access to modern agriculture solutions. The Future Farm is located in Zambia

[1] https://nmite.ac.uk/
[2] https://www.olin.edu/
[3] https://www.olin.edu/our-community/events/expo/

Appendix F (*continued*)

By educating people on modern farming techniques, the Future Farm team are empowering local communities, helping people develop sustainable food production systems and increasing productivity. The Future Farm team are dedicated to helping farmers to understand how to use agricultural resources more efficiently.

The cutting edge facilities at the farm can support both small and large commercial farming operations across Africa. Day to day the Future Farm seeks to provide aspiring African farmers with the knowledge and resources that they need for their business to succeed. Online and classroom based courses teach users how to increase yields and maximise resources.

The specific detail and illustrations in this report have been Dr Mark Moore, an Agricultural Engineer with over 25 years' experience in applying Technology in Agriculture and an expert in Precision Farming. He has worked with farmers and research organisations around the world on the application of technology.

The Future Farm proposition is founded on the principal that traditional technology solutions have been to "vertically integrated" predicated by a tendency for them to be supplied and supported by one organisation with a focus on specific elements of technology. The assertion is that there should be more integration of systems and this is more "horizontally integrated". This is illustrated by the following deliverables:

- Systems integration: Work with partners to confirm there are no technical issues and solutions work at farm level
- Value proposition: Integrate mechanisation & technology with agronomy to demonstrate the value of AGCO solutions
- Education & training: Provide the foundation for training on agricultural solutions and the value proposition they provide
- Distribution & support: Provide opportunities for dealers to grow their business by providing additional products and services

In understanding the impact this approach might have, we need to compare the current approach with how it might look when systems thinking is applied.

Under most current circumstances, it is the end user, the farmer, who has the task of integrating all of the information and inputs to reach a decision. The approach is very much driven by a "top down" approach as illustrated here:

Appendix F (*continued*)

In the Systems Integration approach espoused by the Future Farm, the is a focus on ensuring that the solutions work before they are exposed to the local supply network and for farm level application, under these circumstances, the farmer has the role of agronomic integration which is better suited to their expertise. This "systems" approach is illustrated here:

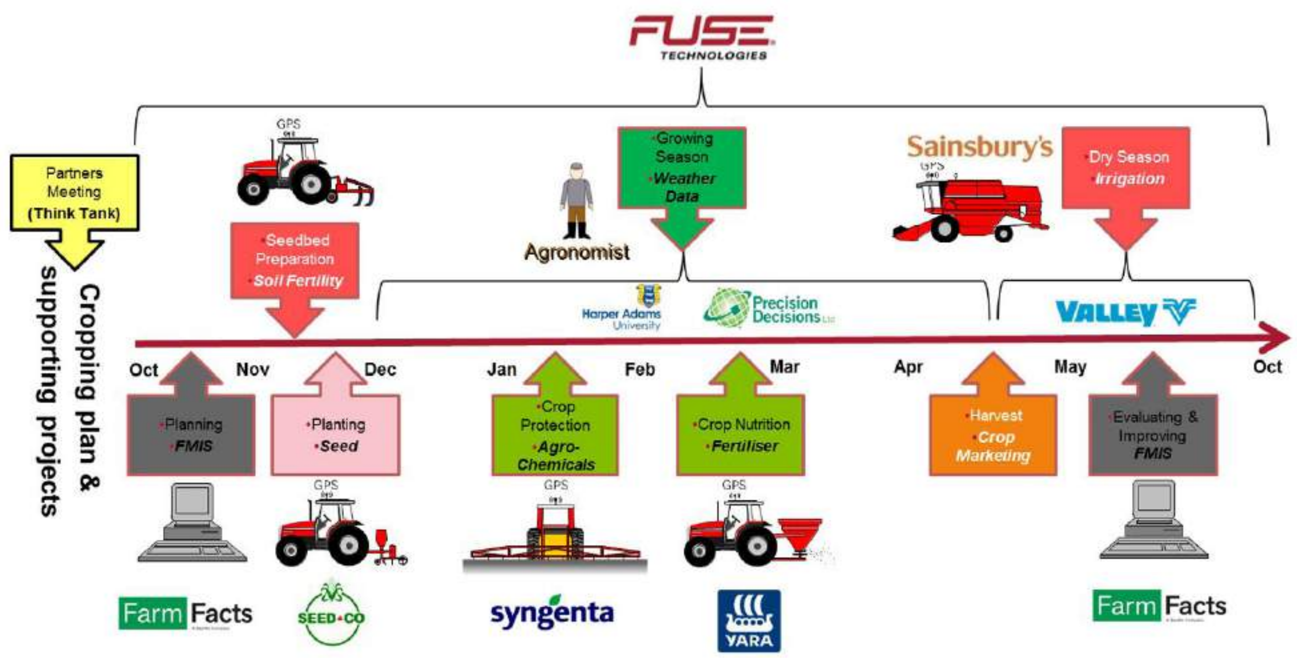
GLOBAL: The suppliers of tractors, machinery, seed, fertliiser, irrigation, harvesters, etc offer a range of solutions and choices

TECHNICAL INTEGRATION: Drawing on the provsion of machinery, seed, fertiliser and chemical solutions and choices, the **FUTURE FARM** undertakes the Technical Integration drawing upon available technology and offering training and support to key partners and stakeholders

LOCAL: The supply of machinery, fertiliser, seed and chemicals is a more informed process based on science and research

FARM LEVEL: The farmer uses the Technical Integration information and along with the Agronomist deals with Agronomic Integration

In the case of the Future Farm, the illustration visualises the Systems Approach (this illustrates the Northern European context but can be applied to Sub Saharan Africa). Agricultural Engineering is at the heart of this thinking.



Notes