# Technology Needs Assessment - Uganda

Uganda

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# List of acronyms

| | |
|---|---|
| ADSIP | Agriculture Sector Development Strategy & Investment Plan |
| ASSP | Agriculture Sector Strategic Plan |
| AU | African Union |
| CA | Conservation Agriculture |
| CCM | Cold Chain Management |
| CSA | Climate Smart Agriculture |
| CSOs | Civil Society Organisations |
| CURAD | Consortium for Enhancing University Responsiveness to Agribusiness Development |
| DAP | Draft Animal Power |
| ESTs | Environmental Science Technologies |
| FAO | Food and Agriculture Organisation |
| GDP | Gross Domestic Product |
| GHGs | Greenhouse Gases |
| GIAB | Genetically Improved Animal Breeds |
| GMP | Good Manufacturing Practices |
| GoU | Government of Uganda |
| H&S | Hides & Skins |
| Ha | hectare |
| HACCP | Hazard Analysis and Critical Control Point |
| HFCs | Hydrofluorocarbons |
| ICT | Information Communication Technology |
| IP | Intellectual Property |
| IPR | Intellectual Property Rights |
| ISO | International Organization for Standardization |
| LDCs | Least Developed Countries |
| M&E | Monitoring & Evaluation |
| MAAIF | Ministry of Agriculture, Animal Industry & Fisheries |
| MCA | Multi-Criteria Analysis |
| MCDA | Multi-Criteria Decision Analysis |
| MoSTI | Ministry of Science, Technology and Innovation |
| MRL | Maximum Residue Limit |
| MSIPS | Multi-Stakeholder Innovation Platforms |
| mt. | metric tonnes |
| MWE | Ministry of Water & Environment |
| NAES | National Agricultural Extension Strategy |
| NAP | National Agriculture Policy |
| NARO | National Agricultural Research Organisation |
| NDCs | Nationally Determined Contributions |
| NDP | National Development Plan |
| NEMA | National Environment Management Authority |
| NIMP | National Irrigation Master Plan |
| NIS | National Innovation System |
| R&D | Research & Development |
| SD | Sustainable Development |
| SDGs | Sustainable Development Goals |
| SDP | Sector Development Plan |
| SLM | Sustainable Land Management |
| STI | Science, Technology & Innovation |
| TAP | Technology Action Plan |
| TIMPs | Technologies, Innovations & Management Practices |
| TNA | Technology Needs Assessment |
| UBOS | Uganda Bureau of Statistics |
| UIRI | Uganda Industrial Research Institute |
| ULAIA | Uganda Leather and Allied Industries Association |
| UN | United Nations |

| | |
|---|---|
| UNCST | Uganda National Council for Science & Technology |
| UNCTA | United Nations Conference on Trade & Development |
| UNESCO | United Nations Educational, Scientific and Cultural Organization |
| UNFCCC | United Nations Framework Convention on Climate Change |
| UNIDO | United Nations Industrial Development Organization |
| US$ | United States Dollar |

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# CHAPTER 1
## Introduction

This is a report on the technology needs assessment (TNA) for Uganda's agricultural sector. The report has been developed by the Ministry of Science, Technology and Innovation (MoSTI) in collaboration with key local stakeholders in the agricultural sector, as illustrated in the "Stakeholders" section below, and with the technical and financial support of the United Nations Technology Bank for Least Developed Countries. The report also benefitted from the United Nations Conference on Trade and Development (UNCTAD) – supported Science, Technology and Innovation (STI) Policy Review as well as the TNA process under the United Nations Framework Convention on Climate Change (UNFCCC).

The report identifies key technologies that can bring about transformational change in the country's agricultural sector, barriers that would hinder their effective and successful deployment as well as measures to address those barriers.

## 1.1 Background of the TNA Process and the UN Technology Bank for Least Developed Countries

The United Nations Technology Bank for Least Developed Countries (or simply the "UN Technology Bank" or the "Bank" in this report) is a United Nations (UN) organisation with a core mandate of bridging technology gaps in the Least Developed Countries (LDCs) for sustainable development (SD). Established in 2018, the UN Technology Bank delivers on this core mandate by working with LDCs and former LDCs (the latter for up to five years after their graduation from the LDC category) and other stakeholders (national, regional and international partners) on initiatives that enhance the contribution of science, technology and innovation (STI) for sustainable development.[1]

The history of the UN Technology Bank dates back to 2011 with the adoption of the Istanbul Programme of Action for the Least Developed Countries for the Decade 2011–2020 at the Fourth United Nations Conference on the Least Developed Countries, which called for the establishment of a technology bank dedicated to the least developed countries.[2]

UN Technology Bank's establishment is premised on the challenges by LDCs such as Uganda in meeting their technology needs in pursuit of sustainable development, including mitigating and adapting to the impacts of climate change. As a result, they (LDCs) significantly lag behind the more-advanced developing countries that are closing socio-economic divides through more developed knowledge-based economies. The institution's establishment also addresses Goal 17 (Target 17.8) of the Sustainable Development Goals (SDGs), which calls for the institution's establishment by 2017.[3]

Among the key activities of the UN Technology Bank are STI Reviews and Technology Needs Assessments. The reviews and assessments, being conducted in collaboration with UNCTAD, the United Nations Educational, Scientific and Cultural Organization (UNESCO) and relevant national organisations, aim to identify technological gaps and priority needs, as a first step towards developing coherent and integrated strategies that are tailored to the specific situation of the country under review.[4]

According to the Bank's 3 Year Strategic Plan (2016-2019), TNAs comprise:[5]

1. Identifying the core area of focus for each LDCs (such as public health, agriculture, industry, environmental science technologies (ESTs), sustainable energy, and information and communication technology) and preparing specific initiatives to maximize the impact of technology as an instrument to foster structural transformation, reduce poverty and promote sustainable development.

1 UN Technology Bank. (n.d.). *Who We Are.* Retrieved from https://www.un.org/technologybank/content/who-we-are
2 UN Technology Bank Council (2018). *Technology Bank for the Least Developed Countries: budget and programme of work for 2018.* First Meeting of the Council held on 20-21 November, 2017 in New York, USA
3 Ibid
4 UN Technology Bank. (n.d.). *Current Activities*. Retrieved from https://www.un.org/technologybank/content/current-activities
5 UN Technology Bank (2016). *Supporting the operationalization of the Technology Bank for the Least Developed Countries – a 3 Year Strategic Plan.* Retrieved from http://unohrlls.org/custom-content/uploads/2016/08/Strategic-Plan-of-the-Technology-Bank-for-the-LDCs-8-August-2016.pdf

2. Providing expertise to interface with donors, UN agencies and international organizations to articulate LDC priority needs, prepare proposals, and communicate with providers of Intellectual Property (IP)-related support.

3. Assessing STI policies, the innovation ecosystem and technology commercialization capacity of the LDCs to identify gaps and appropriate interventions.

4. Identifying opportunities to strengthen R&D infrastructure, providing a platform to coordinate with existing capacity building programmes to improve access of LDCs.

5. Promote collaboration at the regional level and among group of LDCs sharing common characteristics/challenges and explore synergies and complementarities.

6. Collaborate with relevant UN system entities and other international organizations in identifying data gaps and fostering statistical capacities needed for STI policy-making.

## 1.2 The Uganda Technology Needs Assessment Project

Uganda is among the beneficiaries of UN Technology Bank's first round of support, owing to the country's development needs and its own initiative in addressing its technology gaps. In Uganda, MoSTI, working with other stakeholders, identified the agricultural sector as the first of the TNA priority sectors for support by the UN Technology Bank. Other priority sectors for TNA are tourism, minerals, oil & gas, infrastructure and human capital development.[6]

These six sectors –agriculture, tourism, minerals, oil & gas, infrastructure and human capital development – are also the priority sectors of the third National Development Plan (NDP) 2020/21 – 2024/25, whose focus is accelerating resource-led sustainable industrialisation.[7] Value addition in these key growth sectors will trigger structural change and eventual movement of labour from low-paid peasant agriculture to relatively better-paid industrial employment, thereby increasing household incomes and improving the quality of life of Ugandans. This envisaged economic transition will require deployment of various technologies across the priority sectors, hence the importance of TNAs for the sectors.

The choice of agriculture as the first sector among the priority TNA sectors was pegged primarily on the overriding role of agriculture and its linkages with other sectors in Uganda's development priorities in the short to medium term, as illustrated in detail in Chapter 2 of this report. Vision 2040, the country's long term development blueprint, best illustrates the special place of the sector in Uganda's long-term development agenda. The Vision *aspires to transform Uganda from a predominantly peasant and low-income country to a competitive upper middle-income country by 2040*, indicating that agriculture is a priority sector in this envisaged transformation.

In addition, NDP III forecasts an increasing demand for agricultural exports due to the increasing global population, rising levels of urbanisation and rising incomes, hence better prospects investments in the sector including agro-industrialization.

The first and primary element of this TNA is therefore the identification of technologies that would ensure that the transformation of the sector, as envisaged in the Vision 2040 and its implementation tools such as the National Development Plans (NDPs), is environmentally benign, socially responsive and yields economic growth, i.e., that a transformation that contributes to Uganda's sustainable development.

The TNA also lays a special emphasis on climate change given its impact on agriculture as a sector that is primarily rain-fed and very minimally mechanised. The priority technologies are therefore those that will help the sector mitigate and adapt to climate change as well as contribute to the attainment of Uganda's international climate change obligations such as its mitigation targets and adaptation goals in its first Nationally Determined Contribution (NDC) to the UNFCCC.

6 Government of Uganda (n.d.). *Uganda Technology Needs Assessment Concept Note.* Kampala: Ministry of Science, Technology and Innovation

7 Government of Uganda (2020). *Third National Development Plan (NDP) 2020/21 – 2024/25.* Kampala: National Planning Authority

A third element of the TNA is the linkages between the agricultural sector and information, communication and technology (ICT) and energy sectors. The report thus explores these two sectors in the context of industrialisation of the agricultural sector, which will be instrumental in bringing about its envisaged transformational change.

### 1.2.1. Goals of the Technology Needs Assessment

The objectives of the Technology Needs Assessment are:

1. To contribute to transformational change of Uganda's agricultural sector and its sustainable development;
2. To identify a portfolio of technologies that could be implemented to create the desired transformational change of the agricultural sector for Uganda's sustainable development;
3. To analyse and prioritise technologies that could the basis for agricultural sector environmental sound technologies (ESTs) from the portfolio of identified technologies;
4. To identify human, institutional and systemic capacity needs to ensure smooth development, transfer and acquisition of agricultural sector ESTs; and
5. To interest key stakeholders and forge partnerships to support investment or remove barriers in order to enhance the commercialisation and/or the diffusion of high priority technologies.

### 1.2.2. Expected Outputs

Based on the above goals or objectives of the TNA, its expected outcomes then are:

1. Priority agricultural sector ESTs identified;
2. Human, institutional and systemic capacity needs that can enable smooth development, transfer and acquisition of agricultural sector ESTs identified; and
3. Key stakeholders and partnerships for the implementation of the TNA identified (development of a Technology Action Plan for the agricultural sector).

### 1.2.3. Key Stakeholders

TNAs are country-owned and led processes, with a national institution leading the process of a country's TNA development as well as its implementation. The Ministry of Science, Technology Innovation (MoSTI) led this TNA process, and will play an instrumental role in its implementation. The overarching role that the Ministry played in the formulation of the TNA, and will play in its implementation, is line with the Ministry's core mandate of providing overall *policy guidance and coordination for scientific research and development and the whole National Innovation System in Uganda.*

In addition to identifying the sector for the TNA, the Ministry was also instrumental in identifying other stakeholders for the TNA, which stakeholders included players in the National Innovation System, e.g., research institutions, private sector players, and development partners. A full list of the stakeholders engaged in the process is annexed to this report.

The expected roles of each of these key stakeholders in the implementation of this TNA are similar to related to those prescribed by the STI Sector Development Plan 2019/2020 -2024/2025[8]:

**Ministry of Science, Technology and Innovation (MoSTI)** - In its capacity as the Ministerial level champion and sector lead for STI, MoSTI will spearhead necessary technological policy changes and creating a conducive STI policy environment necessary for effective execution of this TNA. A number of technologies such as drone and its application in agriculture (e.g., delivery of pesticides and other farm inputs to remote places) and biotechnology applications that were identified by stakeholders for this TNA will require certain policy interventions.

**Research and Development (R&D) institutions** - in the agricultural sector, the National Agricultural Research Organisations (NARO) and the 16 research institutions under it as well as non-agricultural sector R&D institutions will undertake R&D necessary on various aspects of this TNA's priority technologies.

8 Government of Uganda (2019). *Science, Technology and Innovation (STI) Sector Development Plan 2019/2020 -2024/2025*. Kampala: MoSTI

**Academic institutions** - will undertake research and training on necessary technological innovations, in line with their core mandate

**Farmers and farmer groups** - their key role will be adoption of the priority technologies. The success of the programme will depend on early adopters, the so-called “champions”, who will be the critical agents of change by enabling others to practically understand and appreciate the benefits of particular technologies.

**Private sector** - Some private sector institutions have in-house research and development units that could contribute to the identified technologies’ R&D. They are also the primary consumers of technology innovations, and are expected to play an important role with respect to technology production and diffusion.

**Civil society groups and other not-for-profit organisations** - Uganda has a number of CSOs including the Uganda National Academy of Sciences and foundations that support science and technological innovations across different fields of science, constituting part of the wider STI sector. Through working farmers and farmer groups, CSOs could help break the technology barrier through technology demonstrations.

**Development partners** - Key functions include provision of R&D financing, technical assistance, and facilitating technology transfer.

**Uganda Industrial Research Institute (UIRI)** - UIRI is mandated by the Uganda Industrial Research Institute Act 2003 to undertake applied research, develop and acquire appropriate technology in order to create a strong, effective and competitive industrial sector for the rapid industrialization of Uganda. The institution provides basic and applied research, R&D, and promotes technology transfer and business incubation in various industrial value chains. Its research and development activities focus on new product development and process improvements in industrial value chains linked to natural resource exploitation, hence its critical value to this agricultural sector TNA. It also provides technology up grading for existing indigenous technologies. UIRI operates technology demonstration and value addition centres to promote technology transfer in different regions.

**Uganda National Council for Science and Technology (UNCST)** - formed under Statute No.1 of 1990 (CAP 209 of the Laws of Uganda) initially to coordinate the development and implementation of policies and strategies for integrating science and technology into the national development process, a role that has since been assumed by MoSTI. UNCST’s key mandate thus remains accreditation of research institutions, issuing research permits and servings as a clearinghouse for information on research, experimental development and innovation activities in scientific institutions and enterprises.

## 1.3. Linkages between the Technology Needs Assessment Project and other STI related Initiatives

This TNA is aligned with a number of STI related policies, strategies and initiatives in Uganda. These include the UNFCCC’s TNA process, the STI policy review under UNCTAD and the implementation of the recently developed and launched STI Sector Development Plan 2019/2020 -2024/2025.

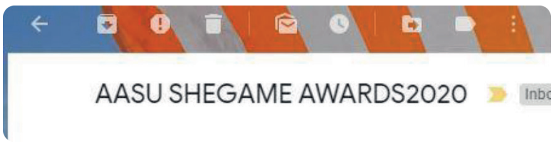



**Figure 1. TNA Institutional Implementation Framework.**

### 1.3.1. The Uganda UNFCCC’s Technology Needs Assessment

Within the context of the United Nations Framework Convention on Climate Change (UNFCCC), developed country parties are required to cooperate with developing country parties in the area of technology transfer for addressing climate change. Technology transfer is further defined as “a broad set of processes covering the flows of know-how, experience and equipment for mitigating or adapting to climate change among different stakeholders such as governments, private sector entities, financial institutions, non-governmental organisations, and research/

education institutions".[9]

The UNFCCC's TNA helps a country determine its priority technological needs for reducing its greenhouse gases (GHGs) emissions and adapting to the adverse impacts of climate change. A TNA thus supports national sustainable development, builds national capacity and facilitates the implementation of prioritized climate technologies.[10]

The UNFCCC indicates that more than eighty (80) developing countries have conducted TNAs since the initiative began in 2001, with Uganda among the twenty-three (23) beneficiaries of the initiative's third phase that was rolled out in 2018.

This agriculture sector TNA process engaged with the UNFCCC TNA process, which, among other things, informed how it (the former) was conducted and identified areas of synergy between the two processes.[11] The methodology used for this TNA, for instance, borrows heavily from the UNFCCC TNA process. The key difference between the two is that this TNA is a much shorter process (3 months) than the longer (often 2 years or more) UNFCCC TNA process (see Section 1.4 on Assessment Methodology).

For this reason, the process omitted the third step in the conventional (UNFCCC) TNA process, i.e., prioritisation of technology barriers in the development of the Technology Action Plan (TAP). The report thus recommends that the ongoing UNFCCC TNA process take up this third element.

### 1.3.2. The Uganda STI Policy Review

Science, Technology and Innovation (STI) policy reviews are a key undertaking of the United Nations Conference on Trade and Development (UNCTAD) in its capacity as the STI focal point within the UN system. The UNCTAD's STI Review Programme provides tailored technical support to countries in assessing national STI systems and designing or reframing national STI policies and plans.

The STI Policy Review is conducted on the request of the Ministry of Science, Technology and Innovation. The process has an overall goal of conducting a diagnosis of the Ugandan national innovation system (NSI) and a review of STI related policies. The aim of the review, according to the draft report, is *to assess the overall functioning of Uganda's innovation system and to recommend STI policies and actions that would enhance its performance and positively impact growth and development with consideration of challenges of inclusiveness and sustainability.*[12]

The draft review report defines a national system of innovation as the sum of linkages, relationships and information and knowledge flows among STI stakeholders, which when are pervasive, extensive, and of high quality, enable innovators in the private and public sectors, in academia and among citizenry, to test their competencies and create wealth and welfare.[13] The creation of that enabling national innovation system, as the STI review process envisages, will create an enabling environment for the implementation of this TNA.

The STI policy review makes a set of recommendations on:

1. Improving STI policy formulation and implementation in Uganda;
2. Creating stronger linkages and more effective partnerships among the players in the NSI space; and
3. Identification of measures that can enhance the absorptive capacity of the various actors in the (NSI) space as well as facilitate the transfer of technology through international trade, investment and other channels of transfer of technology.

9 IPCC, 2000. IPCC Special Report – Methodological and Technological Issues in Technology Transfer – A Summary for Policy Makers. Retrieved from https://www.ipcc.ch/site/assets/uploads/2018/03/srtt-en-1.pdf
10 UNFCCC (n.d.). *Technology Transfer Overview: Technology Needs Assessment*. Retrieved from https://unfccc.int/ttclear/tna
11 Ibid
12 Government of Uganda (2019). *Science, Technology and Innovation (STI) Policy Review Draft Report*. Kampala: Ministry of Science, Technology and Innovation.
13 Ibid

This TNA process will inform outcomes 2 (creating stronger linkages and partnerships) and 3 (enhancing absorptive capacity) above given that two of its goals/objectives are related to the same, i.e., identification of barriers to technology absorption and measures to address those gaps as well as creating partnerships among the various STI players.

A particular area of convergence between the two processes is the linking of digital services (information and communication technology) with the agriculture sector and the accelerated moving of the agriculture economy into the sphere of manufacturing and industry, with the TNA process borrowing from the work already undertaken in the STI policy review.

### 1.3.3. Uganda's STI Sector Development Plan 2019/2020 -2024/2025

The Uganda STI Sector Development Plan (SDP) 2019/2020 -2024/2025 is the first STI sector development plan whose aim is to ensure alignment and coordination of STI activities, with a view to creating a vibrant national science and technology innovation system, as a critical ingredient of the Vision 2040's delivery menu.

The SDP thus *maps out the sector development strategy, priorities and interventions for realizing the transformational impact of STI on the economy in pursuit of NDP II and Vision 2040 goals.*[14]

**Key areas of collaboration between MosTI and the Ministry of Agriculture, Animal Industry and Fisheries (MAAIF)**

1. Advancement of biotechnology research
2. ST&I infrastructure usage
3. ST&I Policy and legislative proposals coordination
4. M&E of national agriculture research Programmes
5. Resource mobilization for scientific research & technology development
6. Technology generation & diffusion (including improved technology development in water for production promotion)
7. Registration & regulation of agriculture research & institutions
8. Research in animal breeding, nutrition and health
9. Research in generation of adaptable cost-effective agriculture technologies (e.g. in mechanization & water for production)

**MoSTI's areas of focus**

1. Scientific research and technology development in value added product development
2. Scientific research and technology development in areas of agricultural machinery and equipment
3. Research and technology development for post-harvest management
4. Research in acquisition of new adaptable technologies in animal breed characterization
5. Research in nanotechnology in livestock semen processing
6. Research & technology development in embryo transfer in cattle

## 1.4. Assessment Methodology

Uganda is among the pioneer beneficiaries of the UN Technology Bank's TNA support, as indicated in Section 1.2 of this report. With the UN Technology Bank still in its formative stages and in the process of developing various guidelines including a guideline on how to conduct sectoral TNAs and technology reviews in LDCs, this TNA had to rely on existing guidelines and methodologies for conducting similar TNAs.

This TNA employed three such existing guidelines developed for the UNFCCC TNA process. These were the *Handbook for Conducting Technology Needs Assessment*

14 Government of Uganda (2020). *STI Sector Development Plan (SDP) 2019/2020 -2024/2025*. Kampala: Ministry of Science, Technology and Innovation

*for Climate Change (UNDP, 2010); Identifying and Prioritising Technologies for Mitigation – a Hands on Guidance to Multi-Criteria Analysis (MCA) (DTU Partnership, 2015); and Evaluating and Prioritizing Technologies for Adaptation to Climate Change – a Hands on Guidance to Multi Criteria Analysis (MCA) and the Identification and Assessment of Related Criteria (DTU, 2015).*

The TNA process however took full cognisance of the fact that a complete replication of the methodologies in the three related guidelines would have replicated the UNFCCC TNA process. The TNA's relatively short timeframe (3 months) in comparison to the UNFCCC process (often about 2 years) further meant that a complete replication could not have been possible, while still yielding credible and useful results. It is on this basis that only two steps in the handbooks, that is, technologies **identification** and **prioritisation**, were applied.

### 1.4.1. TNA Assessment Steps – A Summary of the Applied Guidelines

The applicable steps in the three guidelines may be summarised as follows, with an explanation on how each was conducted. What is worth re-emphasising is that a TNA is a highly participatory process, with the guidelines and the Uganda TNA Concept Note that were applied to this TNA recommending multi-stakeholder engagements at every step of the process.

1. Identification of development priorities and priority sectors. This particular step was not undertaken in this TNA since the TNA sectors – agriculture, tourism, minerals, oil & gas, infrastructure and human capital development – had been pre-selected by the Ministry of Science, Technology Innovation (MoSTI) in consultation with other STI stakeholders and stakeholders in the agricultural sector.[15]

2. Identification of technologies for the priority sector/s (agriculture) – undertaken through a stakeholder engagement (interviews and workshops) process, with stakeholders drawn from the public, private sector, research, academia, and civil society groups. Extensive literature was used to complement and concretise information from the stakeholder engagements.

3. Prioritisation of technologies – this was done using a multi-criteria decision analysis (MCDA) tool that was designed for the assignment (details immediately below). The tool was validated at a stakeholder workshop held on December 27th, 2019 at the Golden Tulip, Kampala, and used to prioritise the identified technologies.

4. Barrier identification – a broad set of barriers to technology development, transfer, diffusion and adoption in the agricultural sector were identified through stakeholder engagements and literature review. The technology-specific barriers' identification and prioritisation process using an MCDA approach, as specified in the three guidelines, was not undertaken for reasons of time and resource constraints, as has been indicated elsewhere.

5. Technology Action Plan development – similar to the Barrier Identification process, a broad set of measures to address potential technological barriers in the agricultural sector were identified through stakeholder engagements and literature review.

It is worth reiterating that in the guidelines applied for this assignment, steps 4 and 5 are highly iterative and consultative processes that could not have been undertaken in the manner they are prescribed in the guidelines within the assignment's short timeframe (3 months) and limited consultations (a round of expert interviews and a one-day consultative workshop). The information presented on the same in this report should ideally be used as basis for further deeper technology-specific barrier analysis and action plan development.

### 1.4.2. Multi-Criteria Decision Analysis Tool for Prioritising Technologies

A multi-criteria decision analysis (MCDA) is defined as a *technique used to support decision making, which enables evaluation of options on criteria, and makes trade-offs explicit. It is used for decisions with multiple stakeholders, multiple and conflicting objectives, and*

15 Government of Uganda (n.d.). *Uganda Technology Needs Assessment Concept Note.* Kampala: Ministry of Science, Technology and Innovation

*uncertainty*.[16] MCDAs help make the process of conducting TNAs more practical and facilitate informed decision making in an easy-to-follow intuitive manner.

The practice is to involve a wide range of stakeholders in the decision making process so as to reach informed opinions or decisions on what actions to take or technologies to advance, in this case. The Handbook for Conducting Technology Needs Assessment for Climate Change (UNDP, 2010) makes a recommendation on the use of an MCDA tool at every stage of the TNA process. This TNA, however, applied an MCDA in only one stage – the technology prioritisation stage – for reasons that have already been discussed.

The MCDA tool used for the assessment comprised a set of eight (8) high-level criteria pertaining to national development goals, each of which was then sub-divided into a number of evaluative low-level sub-criteria, as illustrated in Table 1. The criteria and sub-criteria were chosen based on the national context, with the needs of the agricultural sector being a key factor for consideration. Another key factor for consideration was attribution, that is, the extent to which the technologies being evaluated could attribute to the chosen sub-criteria, in particular. As an example, in the validating of the tool, "health outcomes" was dropped as a sub-criterion under the "socio-economic" criterion for its multi-factorial nature.

## 1.5. National Development Context

Key contributors to Uganda's economy as per the 2016/17 financial year are agriculture (23.5 percent of the Gross Domestic Product (GDP)), industry (26 percent of the GDP) and services (43.5 percent of the GDP).[17] Agriculture is particularly important to, and a priority for, Uganda because of its several linkages with the two other sectors (industry/manufacturing and services). Agro-processing (that is, the processing of dairy products, processing and preservation of meat and fish, grain milling and starch products and coffee processing),

16 United Nations Development Programme (2020). *Handbook for Conducting Technology Needs for Climate Change*. New York: UNDP

**Table 1. Explanation on the MCDA tool used for Technology Prioritisation.**

| Criteria | Sub-criteria | Comments |
|---|---|---|
| Socio-economic | Potential to avoid economic losses and / or boost farmer income & improved livelihoods | Assesses whether the particular technology has the potential increase productivity and production, and assumes availability of ready market. |
| | Improvement in food security | Assesses the effect of the technology on crop yields (productivity and production) and assumes existence of other food security factors |
| | Potential to create jobs | Measured in terms of the number of direct and indirect jobs likely to be created. A tractor, for instance, is not likely create as many jobs as solar drip irrigation can. |
| | Extent of contribution to climate change adaptation goal | Climate change a socio-economic issue, and is a particular challenge to agriculture, among other vulnerable sectors, in developing countries like Uganda. This sub-criterion measures the impact of technology such as drip irrigation in adapting the sector to climate change. |
| Ecological/ Environment | Possibility of synergy with other interventions | Looks at whether the technology being introduced has a multiplier effect on the impact on other environmental interventions, e.g. drip irrigation on the impact of water conservation measures. For this reason, such a scenario may require weighting (multiplication by 2) to take care of the multiplier effect. |
| | Possibility of trade-offs with other interventions | Looks at whether the technology being introduced has a negative effect on the impact on other environmental interventions in addition to its own positive impact for which it is being introduced, e.g. the impact on agrochemicals on potable water. For this reason, such a scenario may require weighting (multiplication by 0.5) to take care of the negative effect. |

17 Government of Uganda (2019). *Rebased GDP Estimates-2016/17 Reference Period*. Kampala: Uganda Bureau of Statistics

| | | |
|---|---|---|
| | Possibility of maladaptation | Looks at whether the technology being introduced results in maladaptation, that is, reinforces climate change impacts. For instance, a large scale irrigation may result in communities lacking water, and thus increases their vulnerability to climate induced water shortages. May require weighting (multiplication by 0.1) to take care of the maladaptation effect |
| | Contribution to climate change mitigation | Assesses whether the technology results in a net increase or decrease in GHG emissions |
| Enabling Framework | Appropriate Infrastructure Available | The availability of supportive infrastructure, e.g., mobile telephony network that can support a number of ICT based technologies ranging from weather information dissemination to extension services |
| | Research and Development | The maturity of research and development in particular technologies, which could support their generation locally |
| | Existence of Enabling Policy/ies | For some technologies such as drones and biotechnology, there might not be an enabling policy |
| | Appropriate Technical Capacities Available | Technical capacity particularly at the local level where the technology is being used to use, troubleshoot and undertake necessary repairs, if need be |
| Financial | Availability of finance to implement the technology/Affordability | Looks at potential sources of finance (financial institutions, own sources, etc.) to finance the technology |
| | Country's financial capacity | A country's state of economy/financial capacity may determine the rate of its adoption of technology, e.g. Uganda may not finance large scale irrigation at the same rate as it could small-holder irrigation |
| | Readiness of the sector to finance the technology | Assesses whether the agriculture sector itself has the capacity to finance and absorb the technology |
| Technology Specific | Minimum cost of set-up | Lower costs favour adoption |
| | Minimum maintenance & operational costs | Lowe costs favour adoption |
| | Farmer acceptance | Cultural and other factors may determine the are |
| | Efficiency compared to other alternatives (maturity, effectiveness), e.g., has it been tried | Mature technologies that have been tested, used and proven may be easily adopted as opposed to novel technologies (resistance to technology) |
| Equity (No. and groups of people likely to benefit) | Gender considerations (extent of coverage) | The extent to which the technology is pro-women, e.g., there are technologies that due to cultural beliefs and other factors, may not benefit women as they would men |
| | Marginalized group considerations (extent of coverage | The extent to which technologies can address the need of the unreached/marginalised, e.g., communities in the country's marginal areas, special groups, etc. |
| Partnership | Availability of private sector players | Private sector players can both finance and help deliver technologies at the grassroots where these are needed |
| | Availability of community level supportive networks | Community networks such as women groups can be a strong voice for technology diffusion |
| | Availability of development partner support | Availability of finance from development partners, and whether the technology falls within their support area |
| Policy Alignment | Alignment with national priorities e.g. Vision 2040 & NDP III | Does the technology address any of national development objectives as outlined in the Vision 2040 and its implementation instruments such as the NDP and sectoral plans? |
| | Alignment with international priorities e.g. SDGs, climate action | The extent to which the technology helps meet Uganda's international obligations such as the SDGs and climate goals |
| Key: The tool employs the use of simple perception scale 0,1 and 2 where | 0 | Zero or negligible probability |
| | 1 | Low Probability |
| | 2 | High probability |

for instance, dominates the manufacturing sub-sector of the industrial sector at over 80 percent.[18]

The following section provides the development context of Uganda's agricultural sector and the envisaged contribution of this TNA to the same.

### 1.5.1. Uganda Vision 2040[19]

Uganda's long-term development agenda is defined by its Vision 2040, which aims at transforming the country from a predominantly peasant and low-income country to a competitive upper middle-income country. The Vision 2040 builds on the progress that has been made in addressing bottlenecks that have constrained Uganda's socio-economic development, which include an underdeveloped agriculture sector.

It identifies opportunities in key sectors including agriculture whose exploitation could lead to the desired transformation. Specifically in agriculture, the Vision aspires to transform the sector from subsistence farming to commercial agriculture, with agro-processing being a priority action in this regard. This is intended at making agriculture profitable, competitive and sustainable to provide food and income security.

Among priority actions intended to deliver this transformation, which also align with this TNA, include investing in the development of all major irrigation schemes in the country; ensuring continued investment in technology improvement through research for improved seeds, breeds and stocking materials; and invest in the development of the phosphates industry in Tororo to reduce the cost of fertilizer. Others are reforming the extension system in the country to increase information access, knowledge and technologies to the farmers; ensuring that land fragmentation is reversed to secure land for mechanization; collecting adequate agricultural statistics; and improve weather information and its dissemination and intensify environmental control measures to halt the decline in soil fertility.

Priority actions to enhance market access and value addition are improving capacity for regulation and enforcement especially in safety standards and quality assurance; attracting private sector participation in value addition activities and investments; and improve access to credit through the development of rural financing schemes and markets. Other are expanding the network of market infrastructure including appropriate structures to reduce post-harvest losses as well as strengthening cooperatives in order to build capacity of farmers in management, entrepreneurship and group dynamics.

### 1.5.2. Uganda's Third National Development Plan 2020/21 – 2024/25[20]

National Development Plans (NDPs) are the primary means of implementing the Vision 2040. In this regard, NDP III for the period 2020/21 – 2024/25, whose implementation this TNA will contribute, has singled out agriculture as the sector of focus. The *overall development strategy of the plan is hinged on the need for rapid industrialization based* ***on increased productivity and production in agriculture****, while nurturing the potential of the tourism, minerals, oil and gas sectors.*

**Agro-industrialisation programme**, as one of the eighteen (18) programmes of NDP III, aims to increase commercialisation and competitiveness of agricultural production and agro processing, with key results being increasing export value of selected agricultural commodities, increasing the agricultural sector growth rate and increasing labour productivity in the agro-industrial value chain. Others are creating jobs in agro-industry and increasing the proportion of households that are food secure.

Other programmes with close linkages with this TNA are:

1. **Climate Change, Natural Resources, Environment, and Water Management** whose overall aim of stopping and reversing the degradation of Water Resources, Environment, Natural Resources as well as the effects of Climate Change on economic growth and livelihood security this TNA's

18 Ibid

19 Government of Uganda (2013). *The Vision 2040 – a transformed Ugandan society from a peasant to a modern and prosperous country within 30 years.* Kampala: National Planning Authority

20 Government of Uganda (2020). *Third National Development Plan (NDP) 2020/21 – 2024/25.* Kampala: National Planning Authority

proposed technologies such as efficient (drip) irrigation systems, improved seeds and eco-friendly pest control methods could contribute to.

2. **Manufacturing Programme** whose aim of increasing the product range and scale for import replacement and improved terms of trade this TNA will contribute to through its focus on agro-processing related technologies.

3. **Energy development Programme**, which aims to increase access and consumption of clean energy. One of its expected results – an increase in primary energy consumption – is particularly aligned with this TNA given that the TNA aims to increase agricultural sector's consumption of energy as a means of improving the sector's production and productivity.

4. **Innovation, technology development and Transfer Programme**, which aims to increase development, adoption, transfer and commercialization of Technologies & Innovations through the development of a well-coordinated STI eco-system.

### 1.5.3. Uganda National Agriculture Policy of 2013[21]

The overall objective of the agriculture policy is to achieve food and nutrition security and improve household incomes through coordinated interventions that focus on enhancing sustainable agricultural productivity and value addition; providing employment opportunities; and promoting domestic and international trade. The NAP is to be pursued through the following six inter-related strategic objectives:

1. Ensure household and national food and nutrition security for all Ugandans;

2. Increase incomes of farming households from crops, livestock, fisheries and all other agricultural related activities;

3. Promote specialization in strategic, profitable and viable enterprises and value addition through agro-zoning;

4. Promote domestic, regional and international trade in agricultural products;

5. Ensure sustainable use and management of agricultural resources; and

6. Develop human resources for agricultural development

With respect to technology in the sector and therefore the alignment of the policy with this TNA, the policy's proposed actions are:

1. Generate, demonstrate and disseminate appropriate, safe, and cost-effective agricultural technologies and research services to enhance production and increase quality of products through access to high quality agricultural technology, agribusiness and advisory services for all categories of farmers;

2. Promote strategic partnerships between technology development research and advisory services at all levels;

3. Promote agricultural mechanization through the application of appropriate machinery and expansion of animal traction;

4. Develop and implement a policy and regulatory framework for biotechnology in agriculture;

5. Promote and facilitate the construction of appropriate agro-processing and storage infrastructure at appropriate levels to improve post-harvest management, add value and to enhance marketing;

6. Promote and support the dissemination of appropriate technologies and practices for agricultural resources conservation and maintenance among all categories of farmers, including Sustainable Land Management (SLM) and Conservation Agriculture (CA);

7. Develop capacity to harvest and utilize rainwater for agricultural production;

8. Work collaboratively with the sector responsible for environment to strengthen the capacity for collection, analysis and dissemination of agricultural meteorological data at all levels; and

21 Government of Uganda (2013). *National Agriculture Policy*. Kampala: Ministry of Agriculture, Animal Industry and Fisheries

9. Provide vaccination services for animal vector disease control.

### 1.5.4. Uganda Agriculture Sector Strategic Plan[22]

The Agriculture Sector Strategic Plan (ASSP) for the period 2015/16 to 2019/20 is a successor of the Agriculture Sector Development Strategy and Investment Plan (ASDSIP) for the period 2010/11 to 2014/15. It was consultatively developed following a comprehensive review of DSIP in 2015. ASSP articulates the national agricultural development priorities documented in the National Development Plan (NDP) II and the National Agriculture Policy (NAP) of 2013.

Implementation of the ASSP will spur growth in the agriculture sector through the establishment of effective linkages to, and exploitation of, existing and potential local, regional and international markets. This will in turn contribute to national wealth creation and increased employment along the agricultural value chains, support economic growth and transformation of the country to an upper middle-income status.

ASSP's proposed technology interventions are:

1. Develop and promote technologies and protocols for value addition in agriculture and agro processing;
2. Develop and implement a policy and regulatory framework for biotechnology in agriculture;
3. Up-scaling uptake of existing and new appropriate technologies, innovations and management practices (TIMPS);
4. Accelerate Research and Technology Development of the selected twelve priority/strategic commodities (maize, banana, beans, fruits, rice, oil, tea, coffee, palm oil, cocoa, cassava, and cotton);
5. Accelerate the development and commercialisation of the prioritised agricultural commodities;
6. Promote agricultural mechanisation;
7. Improve the use of appropriate pests, vectors and diseases control technologies;
8. Improve access to high quality seeds, planting and stocking materials;
9. Increase access to water for agricultural production (irrigation, water for livestock, aquaculture);
10. Enhance access and use of fertilizers by all categories of farmers; and
11. Strengthen institutional capacity in research and development.

### 1.5.5. National Climate Change Policy of 2015[23]

The National Climate Change Policy was developed in response to Constitutional provision on the right of every person in Uganda to a clean and healthy environment and the huge burden of climate change on the country. Article 245 states that "Parliament shall, by law, provide for measures intended: (a) to protect and preserve the environment from abuse, pollution and degradation; (b) to manage the environment for sustainable development; and (c) to promote environmental awareness". To this end, the constitution caters for climate change both directly and indirectly, hence the need for instruments to respond to climate change such as the Climate Change Policy.

On agriculture, the Policy's two recommendations are:

1) Promote climate change adaptation strategies that enhance resilient, productive and sustainable agricultural systems; and

2) Promote value addition, improve food storage and management systems in order to ensure food security at all times as a factor of resilience

These two are to be achieved by the implementation of a number of strategic actions including the following agricultural technologies:

22 Government of Uganda (2016). *Agriculture Sector Strategic Plan 2015/16-2019/20 (draft of April 2016).* Kampala: Ministry of Agriculture, Animal Industry and Fisheries

23 Government of Uganda (2015). *National Climate Change Policy of 2015.* Kampala: Ministry of Water and Environment

1. Promote and encourage highly adaptive and productive crop varieties and cultivars in drought-prone, flood-prone and rain-fed crop farming systems;
2. Promote and encourage highly adaptive and productive livestock breeds;
3. Promote irrigated agriculture by encouraging irrigation systems that use water sustainably;
4. Promote and encourage agricultural diversification, and improved post-harvest handling, storage and value addition in order to mitigate rising climate related losses and to improve food security and household incomes; and
5. Promote biological engineering and restoration of stress-tolerant organisms.

### 1.5.6. Uganda National Adaptation Plan for the Agriculture Sector[24]

The Paris Agreement recognises that adaptation to climate change is a global challenge faced by all with local, sub-national, national, regional and international dimensions, and that developing country Parties, especially the small-island developing states and LDCs such as Uganda are particularly vulnerable to the adverse effects of climate change.

Climate sensitive sectors such as agriculture are the most affected. Indeed, NDPs I, II and III recognise climate change as a main threat to Uganda's overall development and that of the agricultural sector, with changing rainfall patterns and rising temperatures noted as severe threats. Trends and projections are indicating even a grimmer future. Average temperatures are likely to rise by 1-3°C by 2050. Rainfall patterns are expected to be more erratic, affecting the social and economic growth and development of Uganda. Agricultural production, ecosystems and the livelihoods of rural agrarian communities will be under more severe threats than is currently being experienced.

It is against this backdrop that the National Adaptation Plan (NAP) for the Agriculture Sector of 2018 was developed. The Plan aims to enhance the adaptive capacity of the agricultural sector for enhanced food security, improved livelihoods and contribution to the development of other sectors. The Plan also responds to Article 7 of the Paris Agreement, which calls on Parties to formulate and implement national adaptation plans.

The National Adaptation Plan (NAP) for the Agriculture Sector identifies gaps and measures that should be addressed in the implementation of the agriculture sector priority actions identified in the National Climate Change Policy of 2015.

### 1.5.7. Nationally Determined Contribution to the UNFCCC[25]

With all Parties to the UNFCCC expected to undertake actions to implement the Paris Agreement, Nationally Determined Contributions (NDCs), provided for under Article of the Paris Agreement, are the primary instruments of achieving this goal. Uganda's first NDC was submitted to the UNFCCC in October 2015, and has both adaptation and mitigation objectives. It is biased toward adaptation for reasons pertaining to the country's high vulnerability to climate change and negligible greenhouse gases (GHGs) emissions.

The NDC notes that agriculture, water, health and human settlements are particularly affected, giving an example of the 2007-08 fiscal year when climate change caused or was linked to damages equivalent to 4.4% of the national budget, which exceeded the budget allocation for the Environment and Natural Resource Sector.

Priority actions in the agriculture are expanding extension services, expanding climate information and early warning systems, expanding Climate Smart Agriculture (CSA), and expanding diversification of crops

24 Government of Uganda (2018). *National Adaptation Plan for the Agricultural Sector.* Kampala: Ministry of Agriculture, Animal Industry and Fisheries

25 Government of Uganda (2015). *Uganda's first Nationally Determined Contribution (NDC) to the UNFCCC.* New York: UNFCCC. Retried from https://www4.unfccc.int/sites/ndcstaging/PublishedDocuments/Uganda%20First/INDC%20Uganda%20final%20%2014%20October%20%202015.pdf

and livestock, all of which have technology implications. Others are expanding value addition; post-harvest handling and storage as well as access to markets, including micro-finances; expanding rangeland management; expanding small-scale water infrastructure; expanding research on climate resilient crops and animal breeds; and extending electricity to the rural areas or expanding the use of off-grid solar system to support value addition and irrigation.

### 1.5.8. Uganda National Agricultural Extension Strategy 2016/17 – 2020/21[26]

The National Agricultural Extension Strategy (NAES) seeks to implement the National Agricultural Extension Policy of 2016. NAES is also aligned with the second National Development Plan (NDP II) for the 2015/16-2020/21. The strategy responds to four strategic objectives of the policy, which are:

1. To establish a well-coordinated, harmonized pluralistic agricultural extension delivery system for increased efficiency and effectiveness;
2. To empower farmers and other value chain actors (youth, women and other vulnerable groups) to effectively participate and benefit equitably from agricultural extension processes and demand for services;
3. To develop a sustainable mechanism for packaging and disseminating appropriate technologies to all categories of farmers and other beneficiaries in the agricultural sector; and
4. To build institutional capacity for effective delivery of agricultural extension services.

### 1.5.9. Uganda National Irrigation Policy[27]

The Uganda National Irrigation Policy was developed to address the Vision 2040's objective of transforming agriculture from subsistence to commercial agriculture through both mechanization and introduction of modern irrigation systems. The Policy's goal is to ensure sustainable availability of water for irrigation and its efficient use for enhanced crop production, productivity and profitability that will contribute to food security and wealth creation. It outlines a target of achieving an additional one Million, Five Hundred Thousand Hectares (1,500,000 Ha) under irrigated agriculture (constituting 50% of irrigation potential) by 2040.

26 Government of Uganda (2016). *National Agricultural Extension Strategy – 2016/17 – 2020/17 – Knowledge driven Agricultural Revolution*. Kampala: Ministry of Agriculture, Animal Industry and Fisheries
27 Government of Uganda (2017). *National Irrigation Policy – Agricultural Transformation through Irrigation Development*. Kampala: Ministry of Agriculture, Animal Industry and Fisheries and Ministry of Water and Environment

# CHAPTER 2

## The role of the agriculture sector in uganda's sustainable development

Selecting a sector (or sectors) for a TNA is the first step in a TNA process and primarily a consideration of the various sectoral contributions to a country's national development agenda. It is also a multi-criteria decision analysis process, with economic priorities, social priorities and environmental priorities as the key criteria for consideration in deciding the sector/s to work with. For this particular TNA, however, the sector (agriculture) had been pre-selected by the relevant national stakeholders led by the Ministry of Science, Technology and Innovation (MoSTI). The choice was pegged on agriculture's high priority in Uganda's development agenda, as illustrated in Sections 2.1 and 2.2 below.

## 2.1 Agriculture in National Development

The role of agriculture in Uganda's economy and the livelihoods of her people cannot be gainsaid. 68.9 percent of Ugandan households are wholly dependent on the sector.[1] A large proportion of them are smallholder farmers who live on fragmented pieces of land, rely on peasant farming for home consumption, and hardly realise any surplus for the market/income generation.[2] The development of the sector and that of the Ugandan economy in general as envisaged in NDP III aims at transforming agriculture from *a low-wage sector to one that is industrialised, offering high quality jobs, increased incomes and demand for agricultural output, quality education and health services and hence improvement in the quality of life of Ugandans.*[3] The potential socio-economic impact of this transformation of Uganda's economy is captured in Section 2.3 below, which has looked at the impact of agriculture on the Sustainable Development Goals (SDGs). In all these, technology has a crucial role to play.

This TNA also lays special emphasis on industrialisation, and the role that agriculture has to play in the same. In Uganda's context, these two are particularly inter-linked, as has been indicated in the preceding paragraph and elsewhere in this report. The focus of the TNA in this regard is the role of technology in agro-industrialisation.

## 2.2. Agriculture and Sustainable Development: Uganda's Context

Improving sustainable agricultural production and productivity, which is the main aim of this TNA, has the potential to contribute to all the 17 sustainable development goals (SDG); this according to stakeholder consultations under-taken and literature review for the TNA. Table 2 below illustrates this. The respective colour coding indicates the extent to which agriculture can contribute to a particular SDG, considering Uganda's context.

**Table 2. The Impact of Developing Uganda's Agriculture Sector on the SDGs**

| Sustainable Development Goal (SDG) | Impact on the SDG | Comments |
|---|---|---|
| No Poverty | | Agriculture employs about 68% of the Ugandan labour force. More than 80% of Uganda rural population, most of them smallholder farmers, rely on subsistence agricultural production. Sustainable development including agro- industrialisation as envisaged in the Vision 2040 and its implementation plans such as NDP III has the potential to lift many out of poverty. |
| Zero Hunger | | Improved agricultural production and productivity will enhance and ensure food sufficiency, especially for smallholder farmers who are dependent on subsistence. |
| Good Health & Wellbeing | | Food sufficiency will improve nutrition, which is a factor of good health and wellbeing. Other factors with no (direct) linkages to agriculture are state general of the economy and investment in the health sector (infrastructure, human resource, etc.). |

1 Government of Uganda (2020). Third National Development Plan (NDP) 2020/21 – 2024/25. Kampala: National Planning Authority
2 Ibid
3 Ibid
4 Government of Uganda (2015). Uganda's first Nationally Determined Contribution (NDC) to the UNFCCC. New York: UNFCCC

| Sustainable Development Goal (SDG) | Impact on the SDG | Comments |
|---|---|---|
| Quality Education | | Provision of nutritious food is critical to learning, and studies have shown that school feeding programmes in poor and resource-constrained developing countries such as Uganda improve school enrollment and completion rates. |
| Gender Equality | | Rural women play a pivotal role in Uganda's food production systems. Depending on how it is practised, agriculture has the potential to empower women, enabling them to feed, educate and clothe their families. |
| Clean Water & Sanitation | | Agriculture is a large consumer of water. Thus, the envisaged increased mechanisation of agriculture in Uganda (1,500,000 Ha under irrigated agriculture by 2040), coupled with increased use of agro-chemicals, is likely to have a negative impact on water resources. |
| Affordable & Clean Energy | | Agriculture has the potential to drive development of particularly off-grid renewable energy in rural areas to support value addition and irrigation. This is one of the priority actions for the agricultural sector in Uganda's first NDC and other related plans. |
| Decent Work & Economic Growth | | Expanding agricultural production and particularly, particularly mechanisation and value addition, will create additional decent jobs and spur economic growth. |
| Industry, Innovation & Infrastructure | | Mechanisation of, and value addition in, agriculture will bring about opportunities for technological innovation in the sector and the growth of agro-based industry. |
| Reduced Inequalities | | Improved incomes and increased job opportunities especially for peasant farmers and youth (the latter through employment in agro-industries) will reduce income inequalities and inequalities in general. Innovation such as aggregation platforms with associated ICT systems can also open new markets for smallholders. |
| Sustainable Cities & Communities | | Expanding agricultural production including value addition/agro-manufacturing can grow rural economies, create jobs and stem rural-urban migration and urban sprawl |
| Responsible Consumption and Production | | Globally, one third of the food produced is either lost or thrown away, together with the natural resources (water, energy and nutrients) used for its production. In developing countries such as Uganda, food losses hit smallholder farmers the hardest given their limited capacity for storage and processing, with almost 65 percent of these food losses happening at the production, post-harvest, and processing stages. New technologies, better practices and coordination, and investments in infrastructure and storage equipment (e.g., cold storage facilities) can significantly reduce food waste and create responsible consumption and production by eliminating the need to produce that, which ends up being wasted. |
| Climate Action | | Nationally, agriculture is one of the high GHG emitting sectors, and expanding the sector will lead to higher sectoral GHG emissions. According to Uganda's first NDC, agricultural soils and enteric fermentation had a combined contribution of 55 percent, and are projected to increase with the expansion of the sector. |
| | | Uganda's contribution to global emissions is negligible. Its per capita emissions is estimated at 1 .39 tons carbon dioxide, far below the global average of approximately 7.99 tons of carbon dioxide.[4] The country's contribution to the total global GHG burden is less than 1 percent. Any increase in the sector's GHG emissions as a result of its envisaged expansion, even without considering climate smart agriculture (CSA) that the country plans to undertake, will still have a negligible impact globally. |

| Sustainable Development Goal (SDG) | Impact on the SDG | Comments |
|---|---|---|
| Life Below Water | | Diverting water for irrigation may reduce river volumes, thereby affecting aquatic life. However, with abundant rainfall in areas where irrigation is likely to be developed, this will be a negligible impact. The main threat to aquatic life will stem from increased application of agrochemicals in farms, with these being washed down by floods to rivers and lakes. Eutrophication is already a challenge in Uganda and the wider East African region. |
| Life on Land | | Expanding agriculture will destroy critical natural habitats for both flora and fauna, and particularly impacting communities that are highly natural resource dependent. |
| Peace, Justice & Strong Institutions | | Ending hunger can create peace and stability. Instability in northern Uganda, for instance, is a multifaceted challenge, but one of those dimensions is conflict over resources – water and pasture for animals, in particular – upon which the communities' livelihoods depend. |
| Partnerships for The Goals | | Transforming agriculture in developing countries for sustainable development will require partnerships between and among different stakeholders (public, private, civil society, academia, etc.) at local, national, regional and international levels. |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Key: | | Significantly Positive | | Positive | | Moderately Positive | | Somewhat Positive |
| | | Significantly Negative | | Negative | | Moderately Negative | | Somewhat Negative |

Source: FAO (n.d.); Uganda's first NDC; Uganda's Vision 2040; NDP III and Uganda's ASSP

## 2.3. The Role of Technology in Sustainable Agriculture

Technology is critical for the transformation of all sectors of the economy, and will be an evitable component of the solutions for challenges such as low productivity and production as well as climate change that continue to plague Uganda's underdeveloped agricultural sector. Technology played a vital role in the Green Revolution in Latin America and Asia in the 1950s, and African countries such as Uganda can take advantage of the advances in science, technology and engineering to similarly and fundamentally transform their agricultural sectors for sustainable development.[5]

According to the Agriculture Sector Strategic Plan (ASSP) 2015/16-2019/20, among technology-related constraints of Uganda's agricultural sector include:

1. Limited availability of quality (improved/ certified) seeds and planting materials -
2. Limited extension services;
3. Climate change and climate variability with its effects such as unreliable growing seasons that affect many crops and livestock;
4. Value addition constraints due to limited knowledge on post-harvest handling and value addition;
5. Limited use of pesticides;
6. Weak monitoring and evaluation (M&E) systems and statistics; and
7. Limited application of mechanisation technologies.

5 Juma C. (2011). The New Harvest - Agricultural Innovation in Africa. London: Oxford University Press

# CHAPTER 3
## Priority technologies for the agricultural sector

Priority technologies for the agricultural sector were identified through stakeholder engagements (primarily interviews), which were complemented by literature review. Table 3 below shows the complete list of the technologies that were identified for each of value chain component.

**Table 3. Priority Technologies for the Agricultural sector as identified by stakeholders**

| Value Chain Component | Identified Technology |
|---|---|
| Distance learning | • (Genetically) Improved seeds and planting materials<br>• (Genetically) Improved livestock breeds<br>• Draught animal power and implements<br>• Hand-held motorised cultivators and weeding machines<br>• Hand jab planters<br>• Drip irrigation<br>• Modern Fishery technologies (Aquaponics, Fish-Rice Culture)<br>• Adoption and promotion of Synthetic Fertilizers<br>• Animal Fodder production<br>• Animal feeds development<br>• Integrated pest management<br>• Greenhouse systems<br>• Vertical systems<br>• Rain-water harvesting (rooftop) – for agriculture<br>• Rain-water harvesting (surface runoff) – for agriculture<br>• Precision farming (Use of aerial technologies and sensors)<br>• Computational agriculture (Big |
| Post-Harvest Management | • Solar driers<br>• Biomass driers<br>• Electric driers<br>• Harvesters<br>• Motorised crop processing (Threshers, Balers)<br>• Bulk Storage solutions (Grains and cereals storage)<br>• Milk coolers<br>• Cold Chain technologies (for fruits and vegetables)<br>• Pest control<br>• Refrigerated Motorised Transport<br>• Fish nets<br>• Ice machines for fisheries<br>• Trawlers<br>• Smoking chambers |
| Access to equipment | • Food processing technologies<br>• Textile processing<br>• Leather Processing<br>• Market price discovery platforms<br>• Mobile processing plants<br>• Produce aggregation platforms<br>• Food nutrient improvement technologies<br>• Laboratory Infrastructure for standard controls |

**Table 4. Priority and Strategic Agricultural Commodities**

| Priority Commodities | Statistics and Challenges (including Technological Barriers) |
|---|---|
| Banana | • Production in 2014 amounted to 4.6 million metric tonnes (mt), of which 3,070 mt were exported, earning the country US$ 587,000<br>• Projected production by 2020 – 13 million mt<br>• Production challenges include declining soil fertility, pressure from pests and moisture stress |
| Beans | • Production in 2014 amounted to 1.011 million mt, of which 31,796 mt were exported, earning the country US$ 26.19 million<br>• Targeted annual production by 2020 – 10 million mt, with projected annual export value of US$ 63 million<br>• Production challenges include low quality seeds, pests and diseases, inadequate extension services |
| Maize | • Grown by all smallholder farmers food and income<br>• It has also become an increasingly important non-traditional export crop and industrial crop for producing animal feeds<br>• Production in 2014 amounted to 2.9 million mt, of which 134,903 mt were exported, earning the country US$ 43.567 million<br>• 2020 target is 10 million mt annually, with projected export increase to US$ 105 million annually<br>• Challenges include low yields (2.2-2.5 mt/ha, compared to the potential of 5 mt/ha) and high post-harvest losses (up to 15%), which often lead to low farm gate prices due to poor quality. The prevalence of pests and diseases has also affect production in maize |
| Rice | • Has become an important strategic cereal staple and cash crop in the last two decades, particularly with the introduction of upland rice in 2002<br>• Production in 2014 amounted to 237,000 mt, of which 57,053 mt were exported, generating USD28.7 million in export revenue<br>• The sector targets to produce 680,000 mt by 2020 and generate at least USD73 million worth of exports<br>• Challenges include inadequate availability and distribution of improved seeds, limited mechanisation including irrigation, pests and diseases and limited extension services |

## 3.1 Technology Selection and Prioritisation

Prioritisation of the identified technologies using the aforementioned multi-criteria decision analysis (MCDA) tool yielded the technologies priority technologies for each component of the agricultural sector value chain. These technologies are prioritised based on their ability to fundamentally and sustainably transform the agricultural sector in Uganda.

Sections 3.1.1, 3.1.2 and 3.1.3 below provides the local contextual application/s of each of the priority technologies.

### 3.1.1 Primary Production

Primary production is the first stage in the agricultural value chain, and encompasses agricultural (crop cultivation) activities, livestock rearing, aquaculture, fisheries and similar processes that yield raw food materials. The Government has **prioritized 12 commodities** and **four strategic commodities** based on their contribution to household income, food security, and export values, among other socio-economic benefits.

| Priority Commodities | Statistics and Challenges (including Technological Barriers) |
|---|---|
| Cassava | • Recognised as a major crop for poverty alleviation, increasing food and nutrition security, animal feed production and bio-fuel (ethanol) industries<br>• 2014 production amounted to 2.813million mt<br>• 2020 production target is 3.5 million mt<br>• Challenges include<br>• Challenges are limited extension services, pests and diseases, limited mechanisation and limited value addition initiatives |
| Irish potatoes | • 2014 demand was estimated to be over 850,000 mt per annum, and growing, driven largely by increasing urbanisation and its eating habits (chips consumption)<br>• Challenges include limited use of improved varieties, lack of market support, lack of organised production, marketing and processing and lack of an enabling policy framework |
| Tea | • Production in 2014 amounted to 61,376 mt, of which 60,504 mt were exported, generating US$ 84.7 million in export earnings<br>• The sub-sector targets to produce 112,000 mt by 2020, with exports valued at approximately US$ 155 million<br>• Challenges include limited research and extension services, inadequate tea farmer associations and credit facilities, underutilised land with high potential for tea and lack of processing facilities in tea growing areas |
| Coffee | • Uganda's principal export commodity<br>• 2014 production amounted to 211,872 mt, of which 206,831 mt were exported. This generated US$ 410.064<br>• 2020 projected production is 595,890 mt , valued at approximately US$1.153 billion<br>• Challenges include inappropriate agronomic practices, limited use of high quality genetic materials at farm level, underutilisation of the coffee growing potential areas, limited agro extension and business development services and limited support for farmer organisations |
| Fruits and vegetables | • The main fruits cultivated are citrus fruits, apples and pineapples, while vegetables comprise traditional and exotic vegetables produced mainly for local consumption<br>• Challenges are limited quality seeds and seedlings that are tolerant to pests and diseases, limited extension and poor storage, leading to significant post-harvest losses |
| Dairy | • Total milk production in 2014 amounted to 1.55 billion litres, with exports from milk and its products earning Uganda US$ 28.684 million<br>• Only thirty three percent of the marketed milk in Uganda is processed<br>• The processing capacity of milk was 1.304 million litres in 2014<br>• The sub-sector production target by 2020 3.35 billion litres annually, with exports worth US$ 92 million<br>• Challenges are inadequate local capacity in conserved feed production, marketing and on-farm water harvesting infrastructure, lack of a national animal feed quality analysis laboratory, poor pasture and rangeland management practices, absence of a National Dairy Herd Information Management System and limited availability of improved heifers |
| Fish | • Total fish production in 2014 amounted to 461,726 mt, of which 17,597 mt were exported. This generated US$ 134,791million for the country<br>• The sub-sector's annual target production by 2020 is 674,028 mt, with export Earnings of US$ 238.80 million<br>• Challenges are depletion of fisheries, underdeveloped pelagic fisheries, limited commercial aquaculture, inadequate infrastructure and technology to support the fisheries value chain, weak monitoring of water bodies and environmental challenges such as the water hyacinth menace |

| Priority Commodities | Statistics and Challenges (including Technological Barriers) |
|---|---|
| Meat and animal/ insect based products | • Beef production in 2014 stood at 202,929 mt and is projected to increase to 360,000 mt in 2020, valued at US$ 1.636 billion<br>• Mutton and chevon (goat meat) production in 2014 stood at 34,289 mt, and is projected to increase to 39,775 mt in 2020, valued at US$ 421 million<br>• Poultry production in 2014 stood at 54,868 mt, and is projected to increase to 63,647 mt in 2020<br>• Honey production in 2014 stood at 24,000 mt<br>• Challenges are persistent and wide adoption of poor quality breeds (goats, sheep, and cattle), limited extension services, lack of a ready market, poor market linkages, inadequate investment in infrastructure and poor agronomic practices |
| Cocoa | • Cocoa is ranked among the high value export commodities that offer great economic opportunities for increasing farmers' incomes and foreign exchange earnings for the country<br>• Production of cocoa and export earnings from the commodity have steadily increased from 16,478 mt worth US$ 35,121 million in 2010 to 25,720 mt worth US$59,429 million in 2014<br>• Fourth highest foreign exchange earner after coffee, fish and tea in 2014<br>• Key challenges are inadequate research and technology development and poor extension services |
| Cotton | • Cotton lint production in 2014/15 amounted to 17,275 mt, of which 12,674 mt were exported, generating US$21.918 million for the country<br>• The sector targets to produce 64,750 mt annually by 2020<br>• Key challenges are limited research in cotton value chain development and inadequate as well as lack of capacity building of farmers associations |
| Oil seeds | • Oil seeds production in 2014 was 758,500 mt. Projected growth by 2020 is 2,027,800 mt, more than the 2014 figure<br>• Exports from vegetable oils are projected to increase from US$102 million registered in 2014 to US$281 million by 2020<br>• Challenges in the sub-sector include limited availability and distribution of quality seeds, limited use of fertilisers to boost productivity, limited mechanisation and extension services, inadequate and lack of capacity building of farmer organisations and limited access to credit facilities. Others are post-harvest losses, poor market linkages and weak coordination and implementation of various sub-sector policies. |
| Oil palms | • The economy of scale favours nucleus commercial production, although there is a growing interest by smallholder farmers in the sub-sector<br>• Challenges that must be overcome in this regard include knowledge building, skills transfer, input distribution and bulking of produce. Others are inadequate research and development, identification and acquisition of additional land, plantation establishment and development and weak institutional coordination. |

*Source: ASSP 2015/16-2019/20 (draft of April 2016)*

Of these priority and strategic commodities, ten are prioritised in the third National Development Plan (NDP III) for their export earnings, and in line with the Plan's overall focus are on sustainable agro-industrialisation of Uganda. The ten are coffee, tea, fish and fish products, dairy, horticulture, tea, cocoa, maize, cotton, vegetable oil and bananas. In addition, fish, maize and dairy have significant benefits for nutrition and food security. Cassava is also prioritised due to its large-scale production potential, drought resistance, and potential for multi-industrial use and food security.[1]

Uganda's current agricultural production is way below its potential and threatens its agro-industrialisation plans, owing to a number of challenges, some of which have been highlighted in Table 4. For instance, about 80 percent of Uganda's land is arable, but currently, only 35 percent is being cultivated.[2] Limited mechanisation and the application of technology in general is a critical factor underpinning Uganda's underdeveloped agriculture.

This TNA prioritises five technologies aimed at addressing these challenges. These are improved seeds and planting materials, improved livestock breeds, drip irrigation, mechanisation (hand-held motorised cultivators and weeding machines) and synthetic fertilisers (shaded in colour green in Table 5).

**Table 5. Ranking of Priority Technologies for Primary Production**

| Technology | Score | Ranking | Comments |
|---|---|---|---|
| Drip Irrigation | 1.30 | 1 | Ranked #1; considered a priority technology for Uganda on the basis of its socio-economic context (priority on increasing productivity and production by small-holder farmers, who constitute the largest proportion of Ugandan farmers |
| (Genetically) improved seeds and planting materials | 1.26 | 2 | Ranked #2; considered a priority technology for Uganda on the basis of its socio-economic context (priority on increasing productivity and production by small-holder farmers, who constitute the largest proportion of Ugandan farmers |
| (Genetically) improved animal breeds | 1,22 | 3 | Ranked #3; considered a priority technology for Uganda on the basis of its socio-economic context (priority on increasing productivity and production by small-holder farmers, who constitute the largest proportion of Ugandan farmers |
| Synthetic fertilisers | 1,22 | 3 | Ranked #3; considered a priority technology for Uganda on the basis of its socio-economic context (priority on increasing productivity and production by small-holder farmers, who constitute the largest proportion of Ugandan farmers |
| Handheld motorised tillers and weeding machines | 1.00 | 4 | Ranked #4; considered a priority technology for Uganda on the basis of its socio-economic context (priority on increasing productivity and production by small-holder farmers, who constitute the largest proportion of Ugandan farmers |
| Rain-water harvesting (rooftop) – for agriculture | 1.37 | 5 | Scores highly, but is considered a practice (rather than a technology) that supports the implementation of certain technologies, in this case, irrigation |

1 Government of Uganda (2020). Third National Development Plan (NDP) 2020/21 – 2024/25. Kampala: National Planning Authority
2 Ibid

| | | | |
|---|---|---|---|
| Rain-water harvesting (surface runoff) – for agriculture | 1.33 | 6 | Scores highly, but is considered a practice (rather than a technology) that supports the implementation of certain technologies, in this case, irrigation |
| Conservation agriculture Animal fodder production | 1.19 | 7 | Scores highly, but is considered a practice (rather than a technology) that supports the implementation of certain technologies |
| Animal fodder production | 1.11 | 8 | Scores highly, but is considered a practice (rather than a technology) that supports the implementation of certain technologies |
| Animal feeds development | 1.11 | 8 | Scores highly, but is not prioritised since inadequate animal fodder production is not considered to be (one of) the most important barrier to improving livestock productivity and production |
| Draught animal power and implements | 1.00 | 9 | Scores highly; but not considered a priority technology for its poor performance with respect to gender considerations (socio-cultural context), i.e., its low rate of adoption by women, who constitute the largest proportion of small-holder farmers and therefore the key targets of the TNA's interventions |
| Integrated pest management | 1.00 | 9 | Scores highly, but is not prioritised since it is considered to be a practice rather than an application of a particular technology |
| Hand jab planters | 0.93 | 10 | Scores highly, but not considered a priority technology as planting is not considered to be a significant barrier to improving agricultural productivity and production |
| Greenhouse systems | 0.89 | 11 | A well developed technology in Uganda, but not considered a pro-poor technology, hence limited contribution to food and nutrition security |
| Modern Fishery technologies (Aquaponics, Fish-Rice Culture) | 0.67 | 12 | A novel technology in the context of Uganda, with significant implementation challenges and therefore, not a priority technology for this TNA |
| Computational agriculture (Big Data) | 0.52 | 13 | A novel technology in the context of Uganda, with significant implementation challenges and therefore, not a priority technology for this TNA |
| Vertical farming systems | 0.48 | 14 | A novel technology in the context of Uganda, with significant implementation challenges and therefore, not a priority technology for this TNA |
| Precision farming (Use of aerial technologies and sensors) | 0.44 | 15 | A novel technology in the context of Uganda, with significant implementation challenges and therefore, not a priority technology for this TNA |

***Note:** Ranking and therefore prioritisation of technologies, is not necessarily based on the scores; other factors, as indicated in the comments section, also play a critical role in the final selection of the key or priority technologies.*

### 3.1.1.1. Drip Irrigation

**General Description of the Technology**

Irrigation is an agricultural operation involving supplying the need of a plant for water. Irrigation is necessary in a dry climate where natural rainfall does not meet plant water requirements during all or part of the year. In Uganda agriculture, which is predominantly rain-fed, is increasingly adversely affected by the climate change and variability manifested in unpredictable rain patterns, prolonged dry spells, and floods[3]. This has led to a farm-level productivity, which is far below the attainable potential for most crops (Fermont and Benson 2011). Under these existing conditions, irrigation is critical in helping farmers against climate change and plays an integral role in transitions from subsistence to commercial farming by ensuring year-round production and farm employment.[4, 5, 6]

Uganda's national policy framework for the development of irrigated agriculture guided by the National Water Policy, 1999, which is anchored on poverty alleviation and economic growth. The draft National Irrigation Master Plan (NIMP) for 2010–2035 identifies drivers of irrigation development in Uganda, which include:[7]

1. Vision 2050, which calls for "a transformed Uganda society from a peasant to a modern and prosperous country within 30 years";
2. climate change and variability;
3. New markets; and
4. An increasing number of major international investors looking to establish commercial agricultural assets in the region.

Despite previous efforts by the Government of Uganda (GoU) to promote irrigation, less than 1% of Ugandan farming households practice irrigation.[8] The area equipped for irrigation is less than 3% of the total potential irrigable area of 567,000 ha.[9] There is, therefore, an opportunity to exploit the country's irrigation potential, which would ensure that Uganda is not only food secure but also an exporter of agricultural products.

Information on irrigation development is scant and segmented in various documents, and a comprehensive assessment has not be done, thus undermining consensus on how to build on what already exists.[10] Be that as it may, irrigation practices are defined by the size of the irrigated area: large-scale (>500 ha), medium-scale (100–500 ha) or small-scale (<100 ha). Large-scale irrigation currently dominates functional irrigation schemes in Uganda or those under rehabilitation, accounting for 76% of the total area under irrigation (about 8,500 ha of the total 11,200 ha).[11] The Central Government constructed most of the large-scale irrigation schemes under the Water for Production programme. Other smaller systems such as the solar mini irrigation systems are planned and implemented at the three regional levels countrywide. The water is channelled through canals, sprinkler irrigation system, drip irrigation system and spot – on irrigation system to the gardens. In some cases, fertigation1 is done to improve production and productivity.

Drip Irrigation is a technique of application of specific and focused quantities of water to crops. The system uses pipes, valves and small drippers or emitters transporting water from the sources to the root area and applying it under particular quantity and pressure specifications. Drip irrigation can provide as much as 90 per cent water-use efficiency in contrast to surface irrigation and sprinkler systems, which provide 60 per cent 75 per cent efficiency respectively, and can therefore enable

3 Joshua Wanyama et al. (2017) Irrigation Development in Uganda: Constraints, Lessons Learned, and Future Perspectives
4 Haile, G. G., and Asfaw, K. K. (2015). *Review paper irrigation in Ethiopia: A review* Acad. J. Agric. Res., 3, 264–269.
5 Kadigi, R. M. J., Tesfay, G., Bizoza, A., and Zinabou, G. (2012). *Irrigation and water use efficiency in Sub-Saharan Africa.* Global Development Network Agriculture Policy Series-Briefing Paper Number, Global Development Network (GDN), New Delhi, India, 1–8
6 Megersa, G., and Abdulahi, J. (2015). *Irrigation system in Israel: A review.* Int. J. Water Resour. Environ. Eng., 7(3), 29–37.
7 Ministry of Water and Environment (2011). *Irrigation Master Plan (2010–2035).* Kampala, Uganda: MWE
8 Uganda Bureau of Statistics (2010). *Summary report on Uganda census of agriculture 2008/2009.* Kampala: UBOS
9 Ministry of Water and Environment (2011). *Irrigation Master Plan (2010–2035).* Kampala, Uganda: MWE
10 Joshua Wanyama et al. (2017) *Irrigation Development in Uganda: Constraints, Lessons Learned, and Future Perspectives*
11 MWE (2017) *Irrigation Development in Uganda: Constraints, Lessons Learned, and Future Perspectives.* Kampala: MWE

farmers to adapt to climate change in crop production under erratic rainfall conditions.[12]

A wide range of components and system design of drip irrigation are available. Types of drip irrigation technologies include bucket and drum or mini-tank drip, Chapin (types of bucket), dream drip kits, captain brand and gravity.[13] With low-head drip irrigation the over sophisticated and over engineered control elements used in the conventional drip systems are minimized and replaced by simple do-it-yourself equipment— low-head drip irrigation technologies.[14] Small reservoirs such as oil drums can be used as header water tanks. These are supported on blocks so that the water pressure falls within the required range. Perforated flexible plastic piping conveys water to the plants.[15]

Drip irrigation provides:

- Maximum efficiency in water use
- Reliable heavy duty lines and high quality drippers with wide water passage
- Easily filled and drained
- Enables fertilization through the system
- Simple in installation and maintenance
- Gravity fed or low-head drip irrigation technologies

The bucket kit is a small-scale drip irrigation system with high water use efficiency that operates at low-pressure heads of 0.5 to 2.0 m (0.05-0.2 bar). It consists of a 20-liter bucket or a 200-liter drum, drip tape, filters, rubber washers, male and female adapters, two supply tubes and barb fittings. A screen filter and flow regulator is usually used with the drip kit. The bucket is mounted on a stand, which holds it one meter above the ground. The drip lines are supplied in lengths of 15 m, and, for best results, they are laid on level ground.[16]

Water for drip irrigation systems may come from wells ponds, lakes, harvested water (roof and surface run off), piped water and rivers. Drip irrigation zones can be identified based on factors such as topography, field length, soil texture.

Drip irrigation can be categorized as market consumer good, capital or public good depending on the level of application; whether undertaken by small or large scale farmers. It is a consumer good when it involves small-scale households and becomes capital good if undertaken by large institutions. It can also be a public good through research by public institutions.[17]

Market Characteristics for Small Scale Drip Irrigation are:

- It is relatively adaptable to small scale farmers including women.
- Requires importation of pumps.
- Local manufacturing of pipes, tanks
- Can be used in green houses or open garden
- Awareness on the technology is carried out by the relevant government institutions) private sector and civil society organizations.
- Though some of inputs for drip irrigation are available locally. Some components are imported. Barriers exist in the supply chain, which hinders wide adaptation and diffusion of the technology at local levels.

**Economic Impacts**

- Ensures water use efficiency compared to conventional flood and furrow irrigation methods
- Reduces on the use of other inputs e.g. fertilizers
- Enhances crop yield without additional costs
- Eliminates water stress for crops even under severe water scarcity conditions

12 Quezada et al. (2011). *Water requirements and water use efficiency of carrot under drip irrigation in a haploxerand soil*. J. Soil Sci. Plant Nutr. 11 (1): 16 – 28
13 Alam, M.M., Bhutta, M.N., Azhar, A.H. (2006). *Use and Limitations of Sprinkler and Drip Irrigation Systems in Pakistan:* Pakistan Engineering Congress, 70th Annual Proceedings Session.
14 Gilead et al. (1985). In S.N. Ngigi, J.N. Thome, D.W. Waweru, H.G. Blank (2000). *An evaluation of low-head drip irrigation technologies in Kenya*. International Water Management Institute
15 Ibid
16 S.N. Ngigi, J.N. Thome, D.W. Waweru, H.G. Blank (2000). *An evaluation of low-head drip irrigation technologies in Kenya*. International Water Management Institute
17 Ibid

- Operational costs remain constant
- Reduces the cost associated with operations like irrigation, weeding, ploughing and preparatory works
- huge savings in the costs towards weeding, inter-culture
- Improved income

**Environmental Impacts**

- Since drip irrigation supplies water directly to the root zone that does not allow weeds to grow hence prevents the use of chemicals to control weeds
- Saves water in comparison to conventional irrigation technologies (90 per cent water-use efficiency in contrast to surface irrigation and sprinkler systems, which provide 60 per cent 75 per cent efficiency respectively)

**Social Impacts**

- Improved food and nutrition security
- Energy saved can be used to light up homes
- Water saved can be diverted to households
- Improved living standards due to improved income

#### 3.1.1.2. Synthetic fertilisers

Nitrogen (N) and potassium (K) and phosphorus (P) are essential nutrients for living organisms. These three constitute plant macronutrients, all of which are essential for plant life. Phosphorus plays a major role in the growth of new plant cells and tissues, photosynthesis and related complex energy transmissions, and in the development of plant's roots as well as hastening of growth.

The criticality of any of these three elements (N, K and P) in agricultural production is that with respect to their respective functions in plant health and growth, none is substitutable.[18, 19] Without each of them, plant growth would be very limited, if possible at all.[20] This is also true of micronutrients such as iron, copper, sulphur, manganese and others, although these are often required by plants in much lower quantities that are sufficiently available naturally in nearly all arable soils.[21]

In general, the use of mineral fertilisers such as phosphorus (or in its combination with the other two macronutrients, N and K) in crop production is linked to higher agricultural productivity and increased per capita food availability, holding constant all other factors. Low fertilizer use is one of the factors behind the low agricultural productivity growth in Africa compared to the rest of the world. A World Bank report indicates that in 2002, the most recent year for which such data are available, the average intensity of fertilizer use in sub-Saharan Africa was only 8 kilograms per hectare of cultivated land, much lower than in other developing regions.[22] Phosphorus was in fact, the main driver of the 20$^{th}$ Century's Green Revolution (in Latin America and Asia).[23]

It is therefore not surprising that limited synthetic fertiliser use in Uganda, amidst declining soil fertility, has been identified as a critical factor in the country's low agricultural productivity and production. Average fertiliser use is estimated at 1 kg $ha^{-1}$ $yr^{-1}$ of applied nutrients compared to estimated nutrient depletion of over 80 kg $ha^{-1}$ $yr^{-1}$.[24]

The three main factors driving low and inappropriate fertiliser usage are access (including affordability), availability and knowledge gaps. On the latter, issues such as erroneous perceptions about the 'fertility' of Ugandan soils (the

18 Cordell D., 2010. The story of Phosphorus: Sustainability implications of global phosphorus scarcity for food security. Linköping University Press. Linköping: Linköping University Press

19 Elser, 2012. In Heckenmüller M., Narita D. and Klepper G., 2014. Global Availability of Phosphorus and Its Implications for Global Food Supply: An Economic Overview. Kiel Working Paper No. 1897

20 Smit et al., 2009. In Heckenmüller M., Narita D. and Klepper G., 2014. Global Availability of Phosphorus and Its Implications for Global Food Supply: An Economic Overview. Kiel Working Paper No. 1897

21 Dawson and Hilton, 2011. In Heckenmüller M., Narita D. and Klepper G., 2014. Global Availability of Phosphorus and Its Implications for Global Food Supply: An Economic Overview. Kiel Working Paper No. 1897

22 Morris M. et al., 2007. Fertiliser use in African agriculture: lessons learned and good practice guidelines. The World Bank. Washington DC: The World Bank

23 Ashley et al., 2010. In Heckenmüller M., Narita D. and Klepper G., 2014. Global Availability of Phosphorus and Its Implications for Global Food Supply: An Economic Overview. Kiel Working Paper No. 1897

24 Government of Uganda (2016). Agriculture Sector Strategic Plan 2015/16-2019/20 (draft of April 2016). Kampala: Ministry of Agriculture, Animal Industry and Fisheries

common narrative is that Ugandan soils are very fertile); limited information on soil fertility management and the potential yield increment from fertilisers use on crop production; and out-dated and blanket fertiliser recommendations that do not correspond to changes in soil fertility still persist. Others are inadequate information about fertiliser types and their use and access to soil analysis tools by farmers and agro-dealers.

The most disadvantaged with respect to fertiliser usage are smallholder farmers, a majority of whom remain subsistence-orientated, using few intermediary inputs and rudimentary technology to produce low-value crops.[25] For such farmers, profligate application of fertilisers is not an option – simply because they cannot afford it in the first place. This TNA thus recommends a technique called fertiliser micro-dosing that involves applying small quantities of fertiliser (about 6 grams) in the hole where the seed is placed at the time of planting.

Research undertaken elsewhere (in Zimbabwe, Mozambique and South Africa) shows that using fertiliser microdosing, smallholder farmers can increase their maize and millet yields by between 50 and 200 percent compared to the conventional methods. Similar results were obtained in West Africa (Mali, Burkina Faso, and Niger), with millet and sorghum yield increases of between 44 and 120 percent.[26]

Micro-dosing would be an appropriate technology for Ugandan small-holder farmers for whom fertiliser cost is a barrier to accessing and adequately using fertiliser to improve productivity and production.

**Economic Impacts**

- Improved farmer income
- Improved national growth as measured by the GDP
- Increased agricultural commodities' export earnings
- Increased employment opportunities across the entire value chain, but in agro-processing (value addition) in particular

**Environmental Impacts**

- Eutrophication in aquatic environments owing to nutrient loading from agricultural soils run off (and municipal wastewater discharge)
- Potential reduced deforestation from avoided clearance of virgin, fertile land
- Ecological impacts of mining of phosphorus rocks for making fertilisers (upstream impacts)

**Social Impacts**

- Improved food and nutrition security
- Improved quality of life from improved income levels
- Potential negative health impacts due to the increasing levels of cadmium and uranium in the remaining phosphate reserves that get mined, processed into fertilisers and shipped to the developing world

#### 3.1.1.3. Improved seeds and planting materials

**General Description of the Technology**

The close to 70 percent of Uganda's farming households that are engaged in subsistence rain-fed agriculture rely largely on farmer-saved seeds of low quality for their agricultural activities. Certified seed contributes to only about 15% of seed requirement.[27] This results in low productivity and production. For instance, yields of beans, a major food crop, range between 300 kg and 500 kg per acre per season against a potential of up to 900 kg per acre per season. Maize yields are below 2,000 kg per hectare per season compared to 7,000 kg per hectare per season for hybrid maize. Rice is currently at less than 1,000 kg (on average) per hectare compared to an expected potential of 3,000 - 4,000 kg per hectare per season.[28]

25 Ibid
26 ICRISAT (n.d.). Fertiliser microdosing – boosting production in unproductive lands. Retrieved from http://www.icrisat.org/impacts/impact-stories/icrisat-is-fertilizer-microdosing.pdf
27 MAIF (2018). *Uganda National Seed Strategy 2018/19- 2022/2023.* Kampala: Ministry of Agriculture, Animal Industry and Fisheries
28 MAIF (2018). *Uganda National Seed Policy.* Kampala: Ministry of Agriculture, Animal Industry and Fisheries

The primary factors behind the heavy reliance on farmer-saved seeds are insufficient availability of affordable high-quality seed and lack of trust in the certified seeds available in the market. The lack of trust in certified seeds in the market is driven by the inability of seed companies to supply the required quantities of certified seeds and the limited capacity in the regulatory system. This has created a counterfeit seed market, with an estimated 30-40 percent of the seeds traded in the market being counterfeits.[29]

With the National Seed Policy launched in 2018, Uganda seeks to address this challenge. The policy seeks to improve the use of improved and certified seeds and planting materials for food and nutrition security, increased household incomes and enhanced production of raw material for agro-industrialisation.

While these two terms – certified seeds and improved seeds – are often used interchangeably including in the Uganda National Seed Policy of 2018, they, in fact, differ in their practical meanings. A certified seed is defined as the progeny of basic-seed produced according to the standards prescribed for the crop being certified, where basic seed is seed produced by a multiplication unit that is one or two generations after pre-basic seed but will be multiplied one more time to produce seed that to be sold to farmers.[30] In other words, a certified seed is seed produced according to certain prescribed certain standards and certified accordingly.

On the other hand, an improved seed (and planting material)3 is seed that is produced for certain desirable traits, which often include high yields, fast maturity, resistance to pests and diseases, and increasingly, tolerance to adverse weather owing to the importance of climate change to agriculture in developing countries. In the modern world, biotechnology is the primary means of producing transgenic products of such desirable traits, and there are several applications of biotechnology in modern agriculture.

**Economic Impacts**

- Improved farmer income (because of fast maturing, high yielding varieties
- Improved national growth as measured by the GDP from improved agricultural production
- Increased agricultural commodities' export earnings
- Increased employment opportunities across the entire value chain, but in agro processing (value addition) in particular
- Reduced costs of farm inputs particularly for pest and disease tolerant species

**Environmental Impacts**

- Reduced use of pesticides for pest and disease resistant and/or tolerant crop varieties, which has positive ecological impacts
- Reduced water use for drought tolerant species
- Reduced application of fertilisers for fast maturing varieties, which has positive ecological benefits
- Persistent concerns over the safety of biotechnology for human health and the environment for transgenic products of genome engineering

**Social Impacts**

- Improved food and nutrition security
- Improved quality of life from improved income levels
- Persistent concerns over the safety of biotechnology for human health and the environment for transgenic products of genome engineering

### 3.1.1.4. Improved livestock breeds

**Background Information and General Description of the Technology**

Similar to transgenic improvements in plants for certain desirable traits, animal breeding can deliver livestock varieties that are fast maturing, high yielding, tolerant to pests and diseases and generally increase livestock productivity, while delivering climate change (resilience and GHG reduction) benefits. Further, it can yield permanent and cumulative

29 Ibid
30 Ibid

improvements in the population because the selected traits are directly transferred from generation to generation.

Farmers have traditionally bred animals for increased production, disease resistance, successful reproduction, and resilience to climate stresses, most often heat and drought. Breeding, including cross-breeding between indigenous and imported species, can improve resilience to diseases and heat stress and increase reproductive performance. Biotechnology and its tools only provide better and enhanced means of delivering these same traits.

**Economic Impacts**

- Improved farmer income (because of fast maturing, high yielding varieties
- Improved national growth as measured by the GDP from improved agricultural production
- Increased agricultural commodities' export earnings
- Increased employment opportunities across the entire value chain, but in agro processing (value addition) in particular
- Reduced costs of farm inputs particularly for pest and disease tolerant species

**Environmental Impacts**

- Reduced use of pesticides for pest and disease resistant and/or tolerant animal varieties, which has positive ecological impacts
- Reduced water use for drought tolerant species
- Reduced application of fertilisers for the production of animal feeds for fast maturing livestock varieties, which has positive ecological benefits
- Persistent concerns over the safety of biotechnology for human health and the environment for transgenic products of genome engineering

**Social Impacts**

- Improved food and nutrition security
- Improved quality of life from improved income levels
- Persistent concerns over the safety of biotechnology for human health and the environment for transgenic products of genome engineering

#### 3.1.1.5. Handheld Motorised Tillers, Planters and Weeding Machines

**Background Information and General Description of the Technology**

Cultivation, planting and weeding are necessary tasks to ensure farms yield desirable produce. Typically, farmers in Africa use an implement, such as a hand hoe to accomplish these tasks. The hand hoe is indeed the most widely used farm implement in Africa, employed by nearly all subsistence farmers. It is also associated with drudgery and inefficiency. Its continued use in a world laden with agricultural technologies that are more sophisticated is a principal factor in the underperformance of Africa's agriculture.

In Uganda for instance, only an estimated 10 percent of the farmers employ some form of mechanisation, with about 8 percent using draft animal power (DAP) and another 2 percent using tractors. This is a major factor contributing to low levels of production, productivity, commercialisation and value addition.[31] This is why, along with farm inputs and support to improve agricultural production and productivity, mechanisation of agriculture is a priority for the Government of Uganda. Replacement of the hand-hoe is actually an African-wide programme under an initiative of the African Union (AU) dubbed, "Retiring the Hoe to the Museum".[32]

This TNA proposes the introduction of handheld motorised tillers, planters and weeding machines, as suitable replacements of the hand-hoe. These could come as three separate implements – tillers, planters and weeding

31 Government of Uganda (2016). *Agriculture Sector Strategic Plan 2015/16-2019/20 (draft of April 2016).* Kampala: Ministry of Agriculture, Animal Industry and Fisheries

32 African Union (2019). *African Union Unveils a statue "Retiring the Hoe to the Museum" to Launch a Continental Agenda to Improve Agriculture Mechanization among Women Farmers.* Retrieved from https://au.int/en/pressreleases/20191021/african-union-unveils-statue-retiring-hoe-museum-launch-continental-agenda

machines – although in many instances, it is essentially one device with three (or four) separate and removable heads – tiller, slasher, weeder and planter. Their sizes also vary depending on the intended scale of application, with perhaps the biggest size being what could be described as a walking tractor in that the person operating such a device often has to walk behind it.

The hand-held motorised implements are more efficient than traditional implements (the hand-e). A 2010 New Vision article indicates that a walking tractor takes a week to cultivate an area that would take a month with a hand hoe, in addition to digging much deeper.[33]

**Economic Impacts**

- Reduces the cost of labour and saves time (as against traditional hand cultivation, planting and weeding)
- Increases production since mechanization increases the rapidity and speed of work with which farming operations is performed
- Increased efficiency of labour and enhances the farm production per worker
- Increased yield of land per unit of area –
- Results in lower cost of work
- Leads to commercial agriculture due to the need for more land and capital to be associated with farmer in order to reap the full technological benefits
- Job creation (operators, maintenance and increased agricultural productivity and production that supports agro-processing/value addition)
- Increased earnings/GDP

**Environmental Impacts**

- Improved agricultural productivity and incomes for smallholder farmers results in exploitation of natural resources, e.g., trees for charcoal, and therefore reduces deforestation and forest degradation.
- Mechanisation may lead to over-cultivation and associated soil and land degradation

**Social Impacts**

- Modification of social structure in rural areas since it frees the farmers from much of laborious, tedious, hard work on the farms
- Releases man-power for non-agricultural purposes since surplus manpower may be available for other social activities
- Significant gender benefits given the disproportionally larger role of women in peasantry
- Time saving
- Improved health from reduced drudgery
- Improved food and nutrition security
- Improved standards of living from increased income (better education, improved health from reduced drudgery and improved food and nutrition security and general living standards)

### 3.1.2. Post-Harvest Management

Food loss and waste has recently become a prominent global topic with the release in 2011 of a Food and Agriculture Organisation (FAO) report that estimated that indicated that a third (1/3) of the world's food was lost or wasted every year. FAO further defines food loss and waste, in a 2019 report, as the *"decrease in quantity or quality of food along the food supply chain"*.[34] The 2019 report attempts to delineate the two concepts (food loss and food waste) by defining food losses as *occurring along the food supply chain from harvest/slaughter/catch up to, but not including, the retail level while food wastes occur at the retail and consumption level.*[35]

Food losses occur particularly in developing countries such as Uganda due to poor post-harvest handling primarily due to inadequate harvesting time, climatic conditions, practices applied at harvest and handling, inadequate storage conditions, challenges in marketing produce, and decisions made at earlier stages of the supply chain, which predispose products to a shorter shelf life.[36]

33 New Vision (2010). You Need a Walking Tractor. Retrieved from https://www.newvision.co.ug/new_vision/news/1279659/walking-tractor
34 FAO (2019). *The State of Food and Agriculture 2019. Moving forward on food loss and waste reduction.* Rome: FAO
35 Ibid
36 Ibid

These challenges can be addressed by adoption of appropriate technologies. To this end, Ugandan stakeholders proposed solar dryers and cold-chain technologies as the priority technologies for implementation.

**Table 6. Ranking of Priority Technologies for Post-Harvest Management**

| Technology | Score | Ranking | Comments |
|---|---|---|---|
| Solar dryers | 1.33 | 1 | Ranked #1 on the basis of the critical role of drying as a preservation method for grains and pulses, and the technology's huge potential in the same. |
| Cold Chain technologies (for fruits and vegetables) | 1.23 | 2 | Ranked #2; a critical technology for vegetables and fruits processing, which remains an untapped opportunity for Uganda. |
| Milk coolers | 1.15 | 3 | Ranked #3; but has already been widely adopted and is therefore likely to be a game changer in the milk processing industry. Not prioritised. |
| Biomass driers | 1.15 | 3 | Ranked #3; but not prioritised because of its potential maladaptation potential – the use of non-renewable biomass. |
| Smoking chambers | 1.11 | 4 | Ranked #4 and primarily on the basis of its wide adoption, but not prioritised as it is unlikely to be a game-changer |
| Motorised crop processing (Threshers, Balers) | 1.07 | 5 | Would be a game changer, but is still a novel technology in Uganda's context, and is therefore unlikely to be widely adopted. Not prioritised. |
| Pest control | 1.07 | 5 | Already being implemented, and is unlikely to be a game changer in post-harvest management. Not prioritised |
| Ice machines for fisheries | 0.93 | 6 | Already being implemented, and is unlikely to be a game changer in the fishing industry. Not prioritised |
| Trawlers | 0.89 | 7 | Already being implemented, and is unlikely to be a game changer in the fishing industry. Not prioritised |
| Fishing nets | 0.89 | 7 | Already being implemented, and is unlikely to be a game changer in the fishing industry. Not prioritised |
| Mobile refrigerators and processors | 0.85 | 8 | A novel technology in Uganda's context, and is therefore unlikely to be widely adopted; not prioritised |
| Electric driers | 0.85 | 8 | Cost of electricity would hinder its wider adoption; and therefore not prioritised |
| Bulk Storage solutions (Grains and cereals storage) | 0.81 | 9 | Not prioritised due to likely very low rates of adoption in a majority smallholder/peasantry system |
| Harvesters | 0.63 | 10 | Not prioritised due to likely very low rates of adoption in a majority smallholder/peasantry system |

***Note:*** *Ranking and therefore prioritisation of technologies, is not necessarily based on the scores; other factors, as indicated in the comments section, also play a critical role in the final selection of the key or priority technologies.*

### 3.1.2.1. Solar Dryers

**General Description of the Technology**

Farmers in Africa rely almost exclusively on natural drying of crops by combining sunshine and movement of atmospheric air through the produce, and direct solar drying has been used since antiquity for processing and preserving food, vegetable, fruits crops and other products by laying products out in the sun to dry. It is this principle upon which solar dryers are built.

The Solar Dryer technology entails conversion of sunlight to heat energy, which the device traps and uses to absorb moisture from produce, making it dry.[37] This prevents food from decay and spoilage, as the produce retains moisture below the level required to support the growth of moulds. Grains, the targeted agricultural produce in this particular case, should have a moisture content of 13 – 15 percent for long-term storage.

Based on capacity, there are broadly three different types or categories of solar dryers:[38]

1. Individual family units are those systems designed to dehydrate small quantities of agricultural produce (grains, vegetables or herbs) at a family/household level. Due to the dominance of peasantry in Uganda, this is the category targeted for widespread adoption. These easy-to-fabricate and easy-to-operate dryers can be suitably developed in small-scale (cottage) industries. Such low-cost drying technologies can be readily introduced in rural areas to reduce spoilage, improve product quality and overall processing hygiene.

2. Medium scale systems are meant to meet the need of individuals and groups, cooperatives or associations to supply a greater quantity of product to reach more markets.

3. Large-scale commercial applications require greater capitalization, and are designed to dry very large quantities of product for village cooperatives as well as large commercial farming operations.

**Economic Impacts**

- Cost savings in comparison to electric or fossil-fuel powered dryers
- Improved income from improved quality and quantity of produce
- Reduced poverty (from cost savings and increased volumes of produce for sale)
- Job creation (fabrication, sales, maintenance)
- Foreign exchange savings (from reduced fossil fuel imports)

**Environmental Impacts**

- Reduced GHG emissions (as compared to business as usual – fossil fuel powered and electric dryers and from avoided production that would be required to offset food losses often incurred without the technology)
- Reduced water consumption and pollution (from avoided production that would be required to offset food losses often incurred without the technology)
- Other ecological benefits associated with avoided production that would be required to offset food losses often incurred without the technology

**Social Impacts**

- Improved quality and hygiene as opposed to drying cereals on tarmac roads (in some cases)
- Improved food security
- Reduced levels of aflatoxins and its associated negative health consequences
- Avoided air pollution
- Time savings

### 3.1.2.2. Cold Chain technologies

**General Description of the Technology**

The technology is based on refrigeration, which is the removal of unwanted heat from a selected object, substance, or space and its transfer to another object, substance, or space. Heat removal from an object

37 Government of Kenya (2013). Barrier Analysis and Enabling Framework for Climate Change Technologies – Mitigation. Nairobi: National Environment Authority (NEMA)
38 Ibid

lowers its temperature. This process may be accomplished by use of ice, snow, chilled water or mechanical refrigeration.[39] The latter, which is the targeted technology in this TNA, employs the use of refrigerants. Refrigerants are chemical compounds that are alternately compressed and condensed into a liquid and then permitted to expand into a vapour or gas as they are pumped through the mechanical refrigeration cycle.

In 2012, Uganda had less than 6,000 cold storage facilities, all located at Entebbe Airport to handle exports. This is according to an assessment by the International Institute of Refrigeration assessment.[40] The low rate of cold chain storage adoption was also evident in the dairy sector, with only 170 milk coolers installed and operating mainly in South West Uganda.[41]

These statistics indicate Uganda's low rate of adoption of cold chain technologies, which is a significant impediment to combating post-harvest losses and enhancing the productivity as well as efficiency of the agricultural value chain. Most importantly, they also indicate that there exists an opportunity for investment in this component of the agricultural value chain, particularly by targeting smallholder farmers in rural communities who incur significant post-harvest losses owing to lack of immediate markets for their fresh produce.

A mix of three cold chain technologies – cold storage facilities, refrigerated trucks and domestic and small commercial refrigerators – will be targeted for this TNA.

**Economic Impacts**

- Improved earnings/income from increased quality and quantity (reduced spoilage) of agricultural produce for sale
- Increased foreign exchange earnings from increased food exports
- Job creation (operation and maintenance cold chain facilities as well as increased outputs from the agricultural value chains)
- Other economic benefits associated with power installation in previously unserved or underserved areas

**Environmental Impacts**

- Potential increased GHG emissions depending on the types of refrigerants used (may be offset by reduced agricultural production that would be required in business as usual scenario)
- High power consumption/combustion of fossil fuels
- Non-recyclable packaging
- Cold chain sterilisation with chemicals
- Refrigerants such as hydrofluorocarbons (HFCs) used in cold chains are some of the most GHGs, responsible for climate change
- Reduced water consumption and pollution (from avoided production that would be required to offset food losses often incurred without the technology)
- Other ecological benefits associated with avoided production that would be required to offset food losses often incurred without the technology.

**Social Impacts**

- Improved standards of living for farmers
- Improved quality and safety of food
- Improved food security – more safe food is available for consumption

### 3.1.3. Value Addition

Agricultural value addition is at the heart of Uganda's overall growth strategy, as underpinned in the Vision 2040, which aims to transform the country from a predominantly peasant and low-income country to a competitive upper middle-income country. Every successive NDP has consequently prioritised agro-industrialisation, which is, for instance, one of the (18) programmes of NDP III. The aim of NDP III's agro-industrialisation programme

39 Berg (undated). What is a chiller? The Principles of Basic Refrigeration. Retrieved from https://berg-group.com/engineered-solutions/the-science-behind-refrigeration/
40 James Ssemwanga, P. (2012). Presentation made at the Regional Workshop on the Use of the Cold Chain to Promote Agricultural and Agro-industry Development in Sub Saharan Africa. June 4-6, 2012. Yaoundé, Cameroon. Retrieved from http://www.fao.org/fileadmin/templates/ags/docs/I3950F/4_uganda.pdf
41 Ibid

is to increase commercialisation and competitiveness of agricultural production and agro processing, with key results being increasing export value of selected agricultural commodities, increasing the agricultural sector growth rate and increasing labour productivity in the agro-industrial value chain. Others are creating jobs in agro-industry and increasing the proportion of households that are food secure.

Making value addition a reality will require massive deployment of technology, which is not the case in present day Uganda. At the same time, financial and other constraints also mean that Uganda must prioritise what it can undertake in the short to medium term. It is on this basis that Ugandan stakeholders prioritised food and leather-processing technologies for this TNA, as indicated in Table 7 below.

**Table 7. Ranking of Priority Technologies for Value Addition**

| Technology | Score | Ranking | Comments |
|---|---|---|---|
| Food processing | 1.15 | 1 | Ranked #1 and prioritised based on Uganda's development priorities for the agricultural sector (value addition/food processing) |
| Leather processing | 1.15 | 1 | Ranked #1 and prioritised based on Uganda's development priorities for the agricultural sector (value addition/increasing agricultural sector's output) |
| Textile processing | 1.00 | 2 | Scores highly, but not a priority in the short to medium given competition from second-hand imports and exiting agreements |
| Produce aggregation platforms | 0.96 | 3 | A novel technology in Uganda's context that is unlikely to be widely adopted |
| Market price discovery platforms | 0.89 | 4 | A novel technology in Uganda's context that is unlikely to be widely adopted |
| Mobile processing plants | 0.74 | 5 | A novel technology in Uganda's context that is unlikely to be widely adopted |
| Food nutrient improvement technologies | 0.37 | 6 | Faces a significant barrier in the form of technical capacity. A relatively novel technology in Uganda's context that is unlikely to be widely adopted |
| Laboratory Infrastructure for standard controls | 0.33 | 7 | Faces a significant barrier in the form of technical capacity; low rates of adoption. Also considered a component of other technologies, e.g., food processing, rather than a standalone technology |

***Note:*** *Ranking and therefore prioritisation of technologies, is not necessarily based on the scores; other factors, as indicated in the comments section, also play a critical role in the final selection of the key or priority technologies.*

### 3.1.3.1. Food preservation and processing technologies

**General Description of the Technology**

Agro-processing is defined by FAO as the subset of the manufacturing sector that processes raw materials and intermediate products derived from agriculture, fisheries and forestry.[42] The sector is taken to include manufacturers of food, beverages and tobacco, textiles and clothing, wood products and furniture, paper, paper products and printing, and rubber and rubber products.[43]

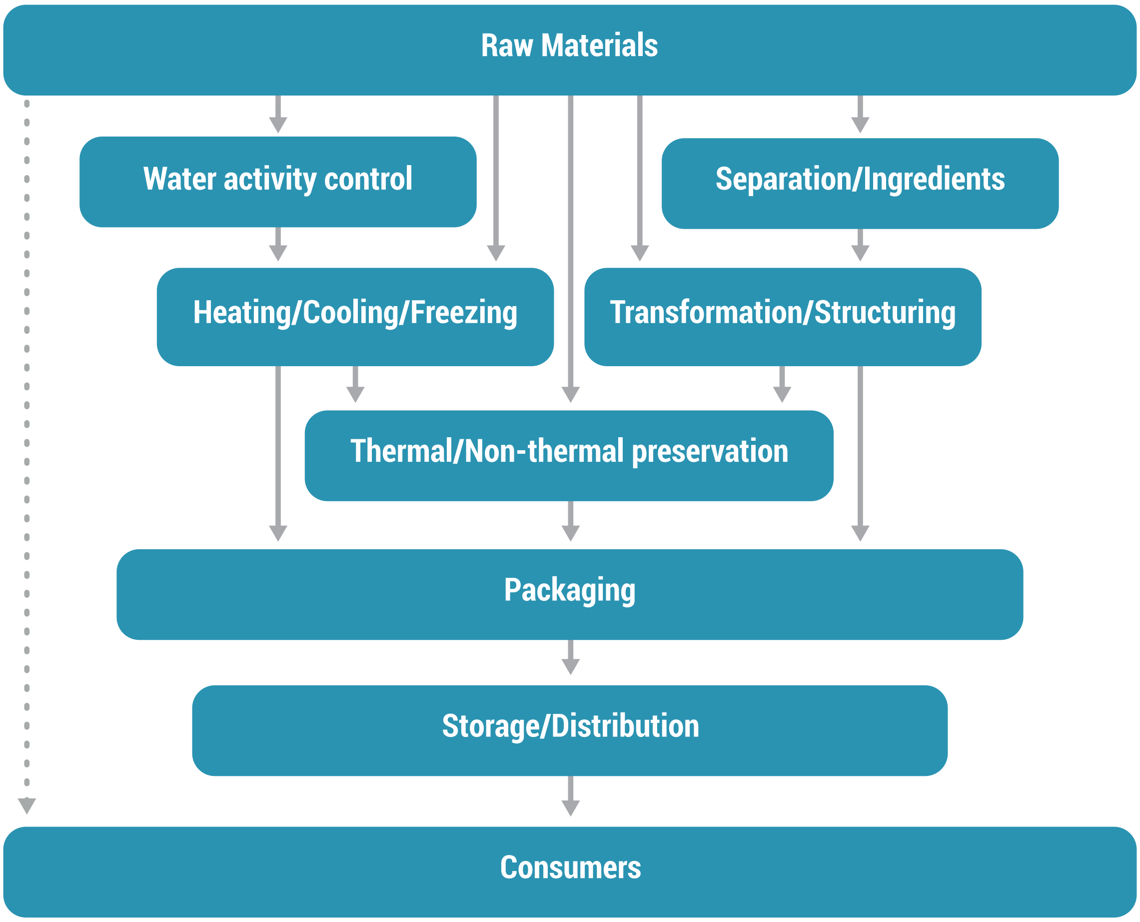
42 FAO (1997). *The State of Food and Agriculture 1997.* FAO Agriculture Series No. 30. Rome: FAO
43 FAO, UNIDO and CAB International (2009). Agro-industries for development. Rome

A combination of technologies of technologies are used in agro-processing and include:

1. Preservation technologies, that is, those that slow down food degradation (as described under the 'Post-Harvest' section above). Preservation methods employed in food processing include as canning, pickling, drying and freeze-drying, irradiation, pasteurisation, smoking, and the addition of chemical additives.
2. Technologies that transform agricultural produce from its original state to a more valuable state. This process involves fabricating foods by mixing, transformation and structuring technologies.

Most foods consumed in industrialised nations and developing countries' large urban centres (cities) undergo some form of storage, mixing, transformation and packaging before distribution. Figure 3 illustrates the complex combination of technologies involved in these processes.[44]

**Figure 3. An Illustration of Food Processing Process and Technologies**




**Generic technologies**

- Biotechnology
- Bioinformatics
- Nanotechnology
- Energy - saving technology
- Waste- conversion technology
- Sensor and analytical technology
- Robotic and automation technologies
- Information technology

44 Source: FAO, UNIDO and CAB International (2009). *Agro-industries for development*. Rome: FAO. Retrieved from http://www.fao.org/3/a-i0157e.pdf

**Economic Impacts**

- Improved GDP
- Improved export earnings
- Job creation
- Improved earnings for farmers

**Environmental Impacts**

- increases and transformations in agricultural production that accompany agro-industrialization have profound implications for land usage about deforest (deforestation, desertification and loss of biodiversity (among others)
- Competition for land (increased demand for increased agricultural production and setting up of industries)
- Negative ecological and health impacts of increased use of agro-chemicals (may be offset if more advanced and safer active ingredients are used, i.e., application of Green Chemistry principles)
- Water pollution from application of chemical fertilisers and pesticides to increase productivity and production (may be offset by the use of organic manure and integrated pest management principles)
- Reduced water availability for other uses due to increased water demand for agro-processing and irrigation to meet the demand of agro-processing (may be solved by introducing less water-intensive and higher-value crops for water-intensive cereals, thus presenting scope for water conservation)
- Increased GHG emissions from increased production to meet agro-processing demand
- Air and water pollution associated with the actual processing and distribution factory processes)
- Post-farm-gate solid waste management challenges (methane emissions, local air pollution, reduced aesthetics, etc.)
- Increased energy demand (competition with other uses and potential increase in fossils based generation, which has associated negative impacts such as GHG emissions and climate change, local air pollution and respiratory diseases).

**Social Impacts**

- Capital-for-labour substitution may reduce employment opportunities
- Potential increase in fossils based generation, which has associated negative impacts such as GHG emissions and climate change, local air pollution and respiratory diseases) to meet increased energy demand
- Post-farm-gate solid waste management challenges (local air pollution, reduced aesthetics, etc.)
- Increased employment opportunities
- Improved standards of living

### 3.1.3.2. Leather processing

The leather industry value chain comprises four broad stages with by-products of each phase being sellable as they are. In the first stage, raw hides and skins (H&S) are obtained. In the second stage, raw H&S are converted to semi-processed products including pickled and tanned leather. The third stage produces fully processed/ finished leather. In the fourth stage, leather products are manufactured, for example, footwear, garments, accessories such as watch straps, handbags and notepad covers, and automotive or furniture upholstery. This process is illustrated in figure 4.[45]

Between 2008 and 2012, Uganda exported more than 40 percent of its hide and skins (H&S) produced in raw form. During this period, the country produced on average 1.6 million hides and 4.7 million skins annually with an estimated loss in terms of foregone revenue (taxes, foreign currency earnings and jobs, etc.) and other indirect benefits resulting from the lack of value addition was estimated at $271.2 million per year.[46]

45 FAO (n.d.). Description of the tanning process. Retrieved from http://www.fao.org/3/X6114E/x6114e05.htm

46 International Trade Centre (ITC) (2018). *Leather value chain investment profile Uganda*. Retrieved from https://www.ugandainvest.go.ug/uia/images/Download_Center/SECTOR_PROFILE/Leather_Sector_Profile.pdf

To capture this foregone revenue and improve the Ugandan livestock value chain, the leather industry in Uganda requires technical assistance in technological transfer including machinery and maintenance skills to be able to fully tap the huge potential of the market that exists.

### Economic Impacts

- Employment opportunities (youth employment creation opportunities)
- Increase in income and economic (GDP) growth
- Improved earnings for livestock keepers
- Improved export revenues
- Reduced foreign exchange due to reduced importation of leather products

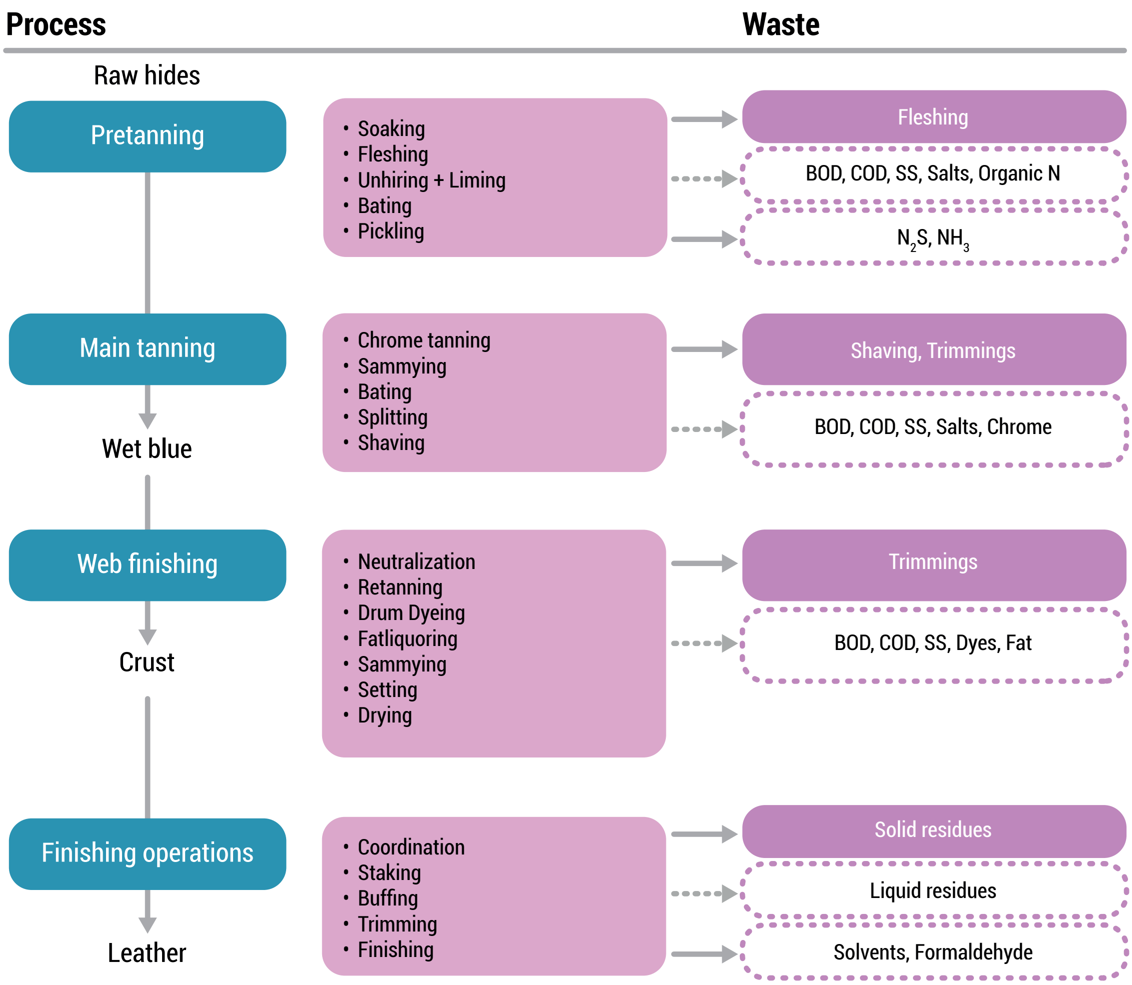
### Environmental Impacts

- Air pollution with toxic fumes (e.g., ammonia and hydrogen sulphide) from tanneries
- Pollution of water sources with effluent discharge from tanneries

### Social Impacts

- Potential respiratory related problems for workers and neighbours as a result of pollution air with toxic fumes such as ammonia and hydrogen sulphide
- Pollution of water with effluent discharge from tanneries rendering it unsafe for consumption and/or could cause long term health problems (cancer risks) if consumed
- Potential displacement of persons to create room for factories and other facilities

**Figure 4. Leather Processing**




*Source: FAO (undated).*

## 3.2. Linkages with ICT and Energy

Table 8 below shows how each of the nine priority technologies across the three components of the value chain are linked to the ICT and energy sectors, whose own growth will be critical to fully realising the potential of the agricultural sector.

**Table 8. Linkages of the Priority Technologies with the ICT and Energy Sectors**

| Piority technology | ICT linkages and actions | Energy linkages and actions |
|---|---|---|
| Drip Irrigation | • Development of ICT networks, particularly, mobile telephony, in rural areas to connect users with equipment providers and technicians (for troubleshooting and repair) | • Will spur rural electrification, and in particular, the development of off-grid solar systems (or hybrid systems) to power the systems<br>• Local development of some kits and components could spur the development of cottage industries, which would in turn spur development of the energy sector, particularly rural electrification |
| Synthetic fertilisers | • A critical gap in the present fertiliser market is lack of information on availability and market prices, which could be solved by an ICT platform (such as mobile apps) that links fertilisers traders with farmers/consumers<br>• An ICT platform can link financial institutions, smallholder farmers, retail providers and agricultural product buyers through a cashless microcredit programme. Farmers gain access to fertilisers (and other inputs) from local input providers by using a pre-established line of credit from banks, where the app provides a bank with a credit rating score for each farmer, e.g. DrumNet in Kenya | • If Uganda chooses to invest in local capacity for fertiliser production (fertiliser blending), substantial investment in energy will be required to meet the demand |
| Improved seeds and planting materials | • An ICT based platform (e.g., mobile apps) that links farmers with providers with genuine certified seeds and planting materials. This could be a part of the solutions for the counterfeit seed market that has created distrust in certified seeds<br>• A combination of mobile and web services and advisory call centres to improve access to extension services, e.g., Esoko (Africa-wide) and Community Knowledge Workers in Uganda<br>• Sharing of best practices to improve productivity, and price benchmarking to increase sales prices, e.g., e-Choupal in India<br>• ICT platforms provide better information on markets signal opportunities to producers, consumers, and traders – such as when excess demand is creating more profitable opportunities to sell or when excess supply leads to cheaper deals, e.g., Reuter's RML Information Services in India | No strong linkages with the energy sector |

| | | |
|---|---|---|
| Improved livestock breeds | • An ICT based platform (e.g., mobile apps) that links farmers with livestock breeders<br>• A combination of mobile and web services and advisory call centres to improve access to extension services, e.g., Esoko (Africa-wide) and Community Knowledge Workers in Uganda<br>• Sharing of best practices to improve productivity, and price benchmarking to increase sales prices, e.g., e-Choupal in India<br>• ICT platforms provide better information on markets signal opportunities to producers, consumers, and traders – such as when excess demand is creating more profitable opportunities to sell or when excess supply leads to cheaper deals, e.g., Reuter's RML Information Services in India | No strong linkages with the energy sector |
| Handheld motorised tillers, planters and weeders | • No strong linkages, but ICT based platforms could provide information on market (availability and prices) of devices as well as link farmers with technicians/ service providers | Some of these devices are being (could be) locally fabricated and/or assembled, which requires/would require investment in energy to grow the industrial sector |
| Solar dryers | • Development of ICT networks, particularly, mobile telephony, in rural areas to connect users with equipment providers and technicians | • Local manufacturing would spur the development of cottage industries, which would in turn spur development of the energy sector, particularly rural electrification |
| Cold chain technologies | • ICT platforms enabling produce aggregation, which enables economy of scale that large-scale cold chain storage technologies require<br>• Increasing sophistication of cold chain storage technologies will require ICT related training for operation and maintenance | • Will spur rural electrification, and in particular, the development of off-grid solar systems (or hybrid systems) to power the systems |
| Food processing technologies | • ICT platforms enabling produce (raw materials) aggregation, which enables economy of scale that agro-processing requires<br>• Increasing sophistication of food processing technologies will require ICT related training for operation and maintenance | • Agro-industrialisation will require significant investment in the energy sector, including rural electrification to enable mechanised agriculture |
| Leather processing | • ICT platforms enabling produce (hides and skins) aggregation, which enables economy of scale that large-scale leather processing requires<br>• Increasing sophistication of leather processing technologies will require ICT related training for operation and maintenance | • Growth of leather-based cottage industries will spur rural electrification, and in particular, the development of off-grid solar systems (or hybrid systems) to power the industries |

*Source: FAO (2017). Information and Communication Technology (ICT) in Agriculture*

# CHAPTER 4
## Identification and Prioritisation of Technologies' Barriers

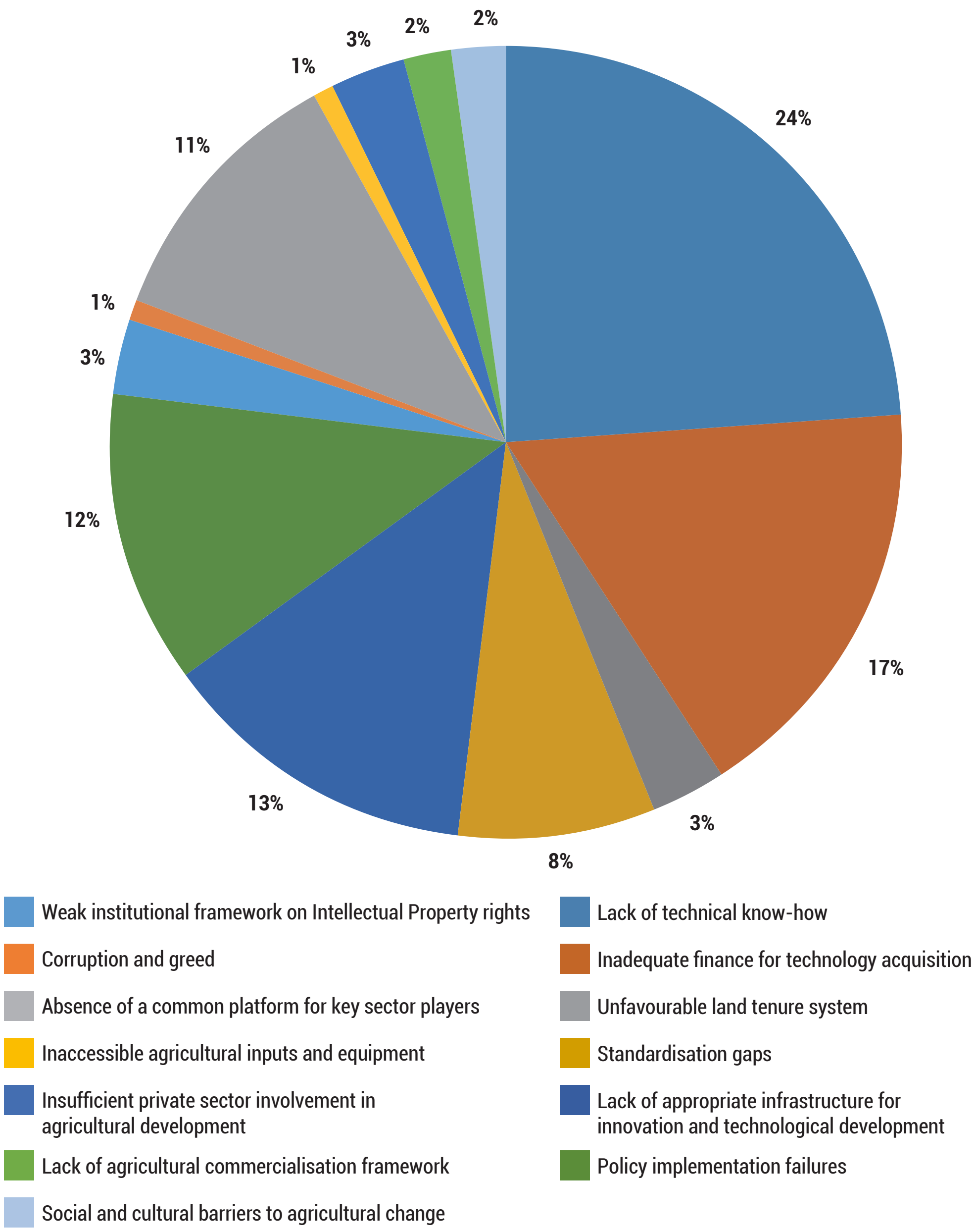
This chapter details some of the barriers to technology diffusion in the agricultural sector and measures to address the barriers. It is divided into three sections, with the first section being the listing of barriers, as identified by stakeholders that the assignment engaged. The second section touches on barriers specific to particular priority technologies, as identified in Chapter 3. The last section is an action plan for the priority barriers as pertains to priority technologies.

## 4.1 Identification of Key Barriers and Measures

### Barriers

In consultations with local stakeholders, a number of barriers hindering agricultural technology development and/or transfer, acquisition and adoption were identified. These are summarised in Figure 4 below, which is an analysis of the barriers in terms of their perceived importance (the frequency with which the stakeholders highlighted individual barriers).

**Figure 4: Main barriers hindering technology application in Uganda's agriculture**



The top five barriers are:

1. Lack of technical know-how or capacity;
2. Inadequate finance to acquire needed technology (owing to low purchasing power);
3. Lack of or insufficient infrastructure for local innovation and technological development;
4. Incoherent policies and policy implementation failures; and
5. Absence of a common platform for key sector players to deliberate on sectoral challenges and potential solutions including technological solutions.

**Lack of or inadequate technical know-how -** There is generally limited technical capacity in [agricultural] machinery and technology handling and operation. The implication of this barrier is that even technologies that are readily available, in terms of cost and proximity to end-users, are not widely adopted by particularly smallholder farmers, as they lack the technical capacity to operate and maintain them. They also lack the resources to employ the services of technicians. Examples of technologies facing, or likely to face, this type of barrier, are simple solar powered irrigation systems, hand-held cultivators and hand-held weeding machines, all of which are all available in the local market. The downtime associated with these technologies' breakdown and the lack of local capacity for diagnosis and repair has prevented many farmers from adopting them. ICT-based platforms or technologies (e.g., technologies that offer agricultural e-extension services) are another form of technology, which presents a particular challenge to last-mile farmers, many of whom are barely literate.

**Lack of finance for relevant technology acquisition -** was highlighted as the second barrier, and concerns the low purchasing power of smallholder farmers in particular. The baseline (2010) data used for the Vision 2040 indicates that more than 24.5 percent of Ugandans live below the poverty line of less than 2 dollars a day. Considering that a large proportion of this group relies solely on subsistence agricultural production with no surplus for the markets (income generation), upfront acquisition of even the simplest modern agricultural technology is often an insurmountable challenge for them. Yet this group is the most technology constrained and can substantially improve their agricultural productivity, livelihoods and general socio-economic wellbeing with the application of simple agricultural technologies. Lack of finance is a main hindrance to the agricultural sector's long-term plan of replacing the hand hoe, whose continued widespread use is major factor in low agricultural productivity and production. Suitable replacements in the form of hand-held motorised cultivators and weeding machines cost between USD 1000 and 3000, a cost that is simply beyond the reach of the target group.

**Lack of or insufficient capacity and/or infrastructure for local innovation and technological development -** there is some capacity for local innovation and technology development with a number of agricultural innovations and technologies having been produced locally (e.g., a locally produced winnowing machine and several IT-based platforms or tools). However, this capacity including related infrastructure is still quite limited for the scale of technology deployment required to bring about the desired transformational change in the agricultural sector. Lack of Infrastructure may also inhibit deployment of existing technologies or innovations. This is the case with e-extension services whose widespread application is constrained by inadequate investment in information & communication technology (ICT) infrastructure. Similarly, lack of roads in certain parts of the country, particularly rural access roads, inhibit access to such places, which thus remain cut from the rest of the world in all aspects including access to modern agricultural technologies.

**Incoherent policy landscape and policy implementation failures -** concerns the incoherence in, and/or non-implementation of, the existing policy and legal framework on the use of agricultural technologies. Three particular technologies that stakeholders mentioned in this regard are biotechnology, drones and blockchain (for commodity payment systems). On the first, there is an existing regulatory (legal) framework for biotechnology research, but none to support its commercial application, with attempts to overcome this policy gap facing several bureaucratic hurdles. On drones, the regulatory framework is quite obscure, with many stakeholders indicating the difficulty of importing drones into the country given that as flying objects/devices, they are associated with a national security risk or threat. Yet at the same time, some organisations such as the Consortium for Enhancing University Responsiveness to Agribusiness Development (CURAD) have been able to import drones for their pilot projects (e.g., spraying of pesticides). This scenario makes it difficult to understand the exact policy landscape with respect to the technology.

**Absence of innovation platforms -** for key sector players to deliberate on sectoral challenges and potential solutions including technological solutions. A platform bringing together the innovation triple helix[1] – government, private sector (industry) and academia (universities) and other research and development (R&D) institutions – is presently lacking. This is major hindrance to innovations in all sectors of the economy, as innovations that are generated by universities and other (R&D) institutions do not necessarily meet the needs of industry (broadly defined in this case to include farmers). A starting point could be the resuscitating, strengthening and institutionalising of the Multi-stakeholder Innovation Platforms (MSIPs) that were established during NDP I, as the main drivers of knowledge sharing, learning, joint demand-driven needs assessments and implementation.[2]

Other notable barriers that were highlighted included:

1. Lack of standards to enforce quality on both locally produced and imported technologies (or a weak standards enforcement regime that sees sub-standard technologies get into the market). This erodes confidence in the affected technologies.
2. Unfavourable land tenure systems such as land fragmentation that render mechanisation economically non-viable.
3. A weak regulatory framework on intellectual property rights (IPR).
4. Inaccessibility to agricultural inputs and equipment owing to non-cost related factors such as distance and lack of access roads.
5. Insufficient private sector involvement in the agricultural sector, particularly service to the last-mile farmers.
6. Social and cultural barriers, i.e., social and societal norm by which one is expected to live may prevent them from adopting certain technologies. An example is the culture of keeping large herds of cattle by some communities (e.g., the Ankole), which could prevent them from adopting improved breeds that zero-graze.
7. Awareness, especially by last-mile communities, on the existence of certain technologies.

**Measures**

The following are some of the indicative measures for addressing the above barriers, as identified by stakeholders in the agricultural sector:

1. Innovation of different financial models for agriculture
2. Capacity building for sustainable agriculture including mobilisation of resources locally
3. Development of enabling regulatory frameworks for farming
4. Increased government support through the Innovation Fund and related funds
5. Infrastructural development to accelerate agricultural production
6. Sensitization/awareness creation among the key stakeholders in agriculture
7. Building partnerships for sustainable agriculture
8. Development of agriculture sector investment plans
9. Modernizing the agricultural education and training curriculum
10. Provision of technical backstopping for the establishment of conservation agriculture

1 A triple helix is defined as a set of: (i) components (the institutional spheres of University, Industry and Government, with a wide array of actors; (ii) relationships between components (collaboration and conflict moderation, collaborative leadership, substitution and networking); and (iii) functions, described as processes taking place in 'Knowledge, Innovation and Consensus Spaces'. For more details, please refer to https://triplehelix.stanford.edu/images/Triple_Helix_Systems.pdf

2 Government of Uganda (2016). *Agriculture Sector Strategic Plan 2015/16-2019/20 (draft of April 2016)*. Kampala: Ministry of Agriculture, Animal Industry and Fisheries

11. Creation and adoption of market-focussed agricultural production
12. Restructuring of the agriculture support systems including adoption of appropriate technologies
13. Creation of agricultural research fund to provide strategic and predictable funding for agricultural research activities and support
14. Development a cluster farm model with large farms offering support to smaller farms in the way of technology adoption and support
15. Development of formalized off take agreements to see the purchase of farm produce by larger buyers or institution of contract farming structures to support small holder farmers and assure them of market and fair prices
16. Perform extensive training and engage communities from the onset of technology identification and adoption to create ownership

## 4.2. Technology-Specific Barriers

Improving the rate of use of modern technology in agriculture in Uganda will require addressing both the general barriers that plague the (agricultural) technology landscape as identified in Section 4.1 above, but also the technology-specific barriers that hinder widespread use of specific technologies.

Applicable TNA methodologies require the use of stakeholder engagements in determining and prioritising technology-specific barriers. However, this assignment used literature review as an alternative approach, given the aforementioned time and resource constraints. In this respect, the following are some of the barriers associated with the priority technologies identified in this TNA.

### 4.2.1. Primary Production

The barriers associated with each of the three priority technologies under primary production are highlighted in Tables 9 to 13 below.

**Table 9. Barrier Categorisation and Description – Drip Irrigation**

| Barrier Category | Barrier | Barrier Description |
|---|---|---|
| Economic and Financial | • High cost of initial installation<br>• Inadequate access to credit and loan facilities for smallholder farmers in particular<br>• Apprehension by smallholder farmers of loans/external financing<br>• Lack of collateral especially among women due to gender based disparities in land ownership<br>• High maintenance cost<br>• Inadequate incentives in the agriculture sector | • Implementation of this technology is constrained by high upfront cost of the equipment and kits.<br>• Training needs (of technicians) for installation and maintenance further increase the costs<br>• The country's low manufacturing capacity also means most of the materials and components have to be imported, further increasing the costs |
| Technical/ Infrastructure | • Water quality - High suspended sediments in water, which lead to frequent constriction/blockage of the system<br>• Water quality - Salty borehole water, which damages the piping system over time<br>• Inadequate water harvesting and storage<br>• Potential damage of pipes by rodents (squirrels and porcupines in particular)<br>• Brittleness of the plastic pipes and plugs – prone to frequent damages<br>• The plastic equipment easily punctured by objects<br>• Lack of spare parts and inadequate extension services<br>• Frequent system clogging (due to sedimentation)<br>• Leakage of water through improperly fitted connections, punctures and cracks<br>• Uneven water distribution especially on slopping land, which affects yields due to water shortage in some sections of the land and water clogging in others | • Limited technical know-how and high costs for lowering suspended solids and water desalination Limited technical know-how for repair and maintenance of the kits and dealing with pests and animal menace Shortage of kits and spare parts at both farmer as well as at the national level Difficult to combine with mechanised production like tractors and other farm machinery, which can damage pipes, tubes or emitter. Pest attraction: being the only green spot, especially during the prolonged dry spells, insects, rodents (squirrels and porcupines) and aphids find refuge in the drip gardens |
| Socio-Cultural | • Resistance to change (adoption of new technologies; ways of doing things) by the generally conservative communities<br>• Preference to other irrigation methods especially the sprinkler and furrow technologies<br>• Insecurity – inhibits investment<br>• Gender biases<br>• Poverty | • Some communities such as pastoral communities tend to resist sedentary life of mixed farming (crop cultivation and animal husbandry).<br>• Other irrigation methods such as sprinkler and furrow are easier and cheaper to adopt/use<br>• Fear of theft and/or vandalism is the system is installed far away from home<br>• In many communities, women (and girls) bear the burden of fetching water, yet do not have the (financial) resources to make investment decisions<br>• Resource-poor smallholder farmers do not have the capacity to undertake upfront investment in the technology |

| | | |
|---|---|---|
| Information and Awareness | • Inadequate awareness of the existence of the technology<br>• Inadequate networking and information sharing<br>• Inadequate market and market information | • Awareness of the existence of the technology is lacking especially in remote, unserved (underserved) parts of the country<br>• Inadequate networking and information sharing among the few users of the technology, hindering faster and wider adoption<br>• Limited involvement of the private sector especially in remote places |
| Human Skills | • Low education levels<br>• Low technical capacity for appropriate use of the technology<br>• Inadequate training of a majority of farmers | • Low levels of education among many smallholder farmers hinders technical skills acquisition<br>• The technology is associated with skills to accurately manage and maintain water flow control, carefully maintained for maximum efficiency. This includes issues of proper maintenance in order to avoid leaking or plugging. Emitters must also be regularly cleaned to avoid blockage from chemicals. This capacity is usually not available and requires heavy investment<br>• There is general lack of skills in installation, operation, maintenance and repair of drip system |
| Environmental Issues | • Water scarcity (availability) | • Water scarcity especially during droughts/dry spells when rivers and springs that provide water for irrigation dry up proves to be an incentive for investing in the technology (where there is inadequate water storage, as is often the case) |
| Policy | • Inadequate policy support | • Inadequate provision of relevant extension services |

**Table 10. Barrier Categorisation and Description – (Genetically) Improved Seeds and Planting Materials**

| Barrier Category | Barrier | Barrier Description |
|---|---|---|
| Economic and Financial | • High costs associated with animal breeding (particularly genetic engineering infrastructure<br>• High cost of improved seeds and planting material<br>• High cost of farm management and maintenance<br>• High cost of supporting machinery | • Genetic improvement programs require significant investments, which Uganda, as a least developed country, may not be able to afford<br>• The use of improved seeds and planting material is costly for small holder farmers who have been accustomed to using saved seeds and planting material<br>• To ensure a productive crop the purchased seeds and planting materials are meant to be complemented with additional inputs of fertilizer and crop pesticides to ensure optimal results<br>• Some improved seeds and planting materials require the use of specialized machinery to plant or transfer into the farm. This high initial cost of either purchase or renting of this machinery is a barrier to its implementation |
| Technical | • Inadequate extension services<br>• Inadequate machinery and equipment<br>• Inadequate capacity in improved seed quality control and certification (SQCC) | • Improved seeds and materials in some instances require specialised processes and equipment not used with traditional crops<br>• The lack of adequate extension support and trained farmers limits the ability of farmers to maximize output<br>• Seed companies lack capacity in SQCC, with the market being dominated by informal seed providers who lack the requisite knowledge and resources<br>• NARO seed distribution to the informal system not optimally used |

| | | |
|---|---|---|
| Socio-Cultural | • Resistance to change<br>• Poverty<br>• Trust issues | • Farming communities have long practiced seed saving as their main source of seeds for planting. This gives them the advantage of obtaining seeds at little to no cost. Their willingness to purchase expensive seeds and planting material is something new and has encountered challenges due to set behaviours and patterns<br>• Negative connotations associated with some forms of biotechnology such as genetic modification or engineering that prevent their adoption. For example, concerns such as the transfer of GM genes to wild relatives and the development of resistance to pests persist<br>• Even where farmers willing to purchase improved seeds, they may not be afford to<br>• Infiltration of the seed market with counterfeit seeds marketed as certified seeds that has created distrust in certified/improved seeds |
| Information and Awareness | • Low levels of awareness<br>• Limited use of relevant networks<br>• Low levels of market penetration | • Awareness of the existence of the technology is lacking especially in remote, unserved (underserved) parts of the country. An example of a biotechnology product that would immensely women farmers who spend most of their time in farms is herbicide-tolerant maize, which reduces the need for weeding. Awareness of the existence of such technologies is limited<br>• Inadequate networking and information sharing among the few users of the technology, hindering faster and wider adoption<br>• Limited private sector engagement especially in remote areas |
| Human Skills | • Lack of technical skills<br>• Inadequate training in biotechnology and related studies<br>• Information exchange | • Considerably more care and attention may be required to use and produce crop from improved seeds.<br>• Limited capacity to produce improved seeds and planting materials in large varieties and quantities<br>• There is currently limited regional and international networks for mobilizing, sharing and using existing scientific and technological capacities in biotechnology that hinders its growth |
| Environmental Issues | • Perception of environmental and health risks | • Persistent concerns over the safety of biotechnology for human health and the environment for transgenic products of genome engineering |
| Policy | • Lack of a policy and regulatory framework for biotechnology in agriculture<br>• Insufficient legislation<br>• Lack of appreciation of the role of an effective biosafety framework in supporting safe advancement of biotechnology applications | • Restrictive national biosafety policies that impose excessive regulatory barriers to the adoption of agricultural biotechnology, e.g., the policy limbo with regard to biotechnology use<br>• Lack of laws and standards of GMOs production and utilization<br>• Existing laws are not explicit on biosafety or regulation of GE techniques and products and this can cause conflicting mandates in different regulatory institutions<br>• Most of the existing laws and policies were formulated before Uganda ratified the Cartagena Protocol on Biosafety<br>• Delays in the passage of the national biosafety law is a major set-back in mainstreaming biosafety across sectors |

**Table 11. Barrier Categorisation and Description – (Genetically) Improved Animals Breeds**

| Barrier Category | Barrier | Barrier Description |
|---|---|---|
| Economic and Financial | • High costs associated with animal breeding (particularly genetic engineering infrastructure)<br>• High investment costs (for livestock farmers)<br>• High operational and maintenance costs | • Genetic improvement programs require significant investments, which Uganda, as a least developed country, may not be able to afford<br>• High cost of improved breeds in comparison to conventional breeds hinders many farmers from adopting them<br>• Improved livestock breeds may sometimes specialised care (e.g., feeding) that can increase a farmer's costs of operations |
| Technical | • Supply chain and network failure<br>• Lack of advisory/extension services<br>• Lack of infrastructure in marginal areas<br>• Lack of capacity for implementing research guidelines and procedures on biotechnology use and biosafety | • Little incentive for breeders to use and promote GIAB<br>• Rivalry between traditionalists and modernists that interfere with uptake<br>• Economic concerns – a fear of loss of income<br>• Weak advisory support available to farmers with regard to genetic selection and improvements of breeds<br>• Poor infrastructure in marginal areas where local breeds are found may impair the introduction of genetic improvement programs |
| Socio-Cultural | • Livestock complex syndrome<br>• Misconceptions<br>• Activism against biotechnology advancement by selected groups | • Cultural views about what constitutes a good farmer/ food<br>• Breaking the link between stock numbers and productivity<br>• Biosafety system is not clearly understood by many as the subject is often associated with advancement of genetically modified organisms (GMOs) that is a divisive subject yet the purpose of a biosafety system is regulation |
| Information and Awareness | • Low levels of awareness<br>• Too few well-informed science journalists<br>• Inadequate biosafety awareness building efforts | • Inadequate simple, translatable materials;<br>• Low level of farmer literacy<br>• Inadequate farmers' organisations<br>• Lack of GE products |
| Human Skills | • Inadequate capacity building in various regulatory institutions and research centres<br>• Inadequate training in biotechnology and related studies<br>• Information exchange | • Limited capacity to produce improved livestock breeds<br>• There is currently limited regional and international networks for mobilizing, sharing and using existing scientific and technological capacities in biotechnology that hinders its growth |
| Environmental IssuePolicy | • Perception of environmental and health risks | • Persistent concerns over the safety of biotechnology for human health and the environment for transgenic products of genome engineering |

| | | |
|---|---|---|
| Policy | • Lack of a policy and regulatory framework for biotechnology in agriculture<br>• Insufficient legislation<br>• Lack of appreciation of the role of an effective biosafety framework in supporting safe advancement of biotechnology applications | • Restrictive national biosafety policies that impose excessive regulatory barriers to the adoption of agricultural biotechnology, e.g., the policy limbo with regard to biotechnology use<br>• Lack of laws and standards of GMOs production and utilization<br>• Existing laws are not explicit on biosafety or regulation of GE techniques and products and this can cause conflicting mandates in different regulatory institutions<br>• Most of the existing laws and policies were formulated before Uganda ratified the Cartagena Protocol on Biosafety<br>• Delays in the passage of the national biosafety law is a major set-back in mainstreaming biosafety across sectors |

**Table 12. Barrier Categorisation and Description – Hand-held motorised tillers, planters and weeding machines**

| Barrier Category | Barrier | Barrier Description |
|---|---|---|
| Economic and Financial | • High costs of purchase<br>• High maintenance costs | • The initial cost of acquiring these technologies is beyond reach to many farmers<br>• Training needs (of technicians) for installation and maintenance further increase the costs |
| Technical/ Infrastructure | • Inadequate technical know how<br>• Lack of spare parts | • Given limited education by most smallholder farmers, they may face challenges with operating the motorised equipment and diagnosing simple problems<br>• Lack of availability of spare parts particularly in remote areas may hinder adoption of the technology |
| Socio-cultural | • Displacement/redundancy of human labour<br>• Poverty | • Resistance to change given the attachment to the hand-hoe; apparent complexity of the technology further reinforcing this attachment to the hand hoe<br>• Low purchasing power of the smallholder farmers limiting their ability to acquire the technology |
| Information and awareness | • Inadequate awareness<br>• Limited information sharing | • Awareness of the existence of the technology is lacking especially in remote, unserved (underserved) parts of the country<br>• Inadequate networking and information sharing among the few users of the technology, hindering faster and wider adoption<br>• Limited involvement of the private sector especially in remote places |
| Human skills | • Low education levels<br>• Low technical capacity for appropriate use of the technology<br>• Inadequate training of a majority of farmers | • Low levels of education among many smallholder farmers hinders technical skills acquisition<br>• There is general lack of skills in installation, operation, maintenance and repair of motorised technologies in rural areas |
| Environment | • Topography and landscape characteristics | • The inherent topography and landscape characteristics may limit the technology's applications |
| Policy & Legal | • Lack of a supportive regulatory framework | • Inadequate policy support especially financial instruments that can enable smallholder farmers to acquire the technology |

**Table 13. Barrier Categorisation and Description – Synthetic fertilisers**

| Barrier Category | Barrier | Barrier Description |
|---|---|---|
| Economic and Financial | • High costs | • Relatively high costs of synthetic fertilisers make them costly to smallholder farmers |
| Technical/ Infrastructure | • Lack of local blending<br>• Knowledge of soil fertility<br>• Lack of knowledge of appropriate fertiliser application methods and practices<br>• Limited extension services | • Lack of local blending that would lower the costs, and make fertilisers affordable to more smallholder farmers<br>• Farmers lack the knowledge of the fertility of their soils as well as lack the means of accessing that information<br>• Lack of knowledge by farmers of the various fertiliser application methods and practices that could suit their needs; precipitated by inadequate extension services |
| Socio-cultural | • Perception about the fertility of Ugandan soils<br>• Poverty | • There is widespread misconception among (smallholder) farmers that Ugandan soils are very fertile and therefore, do not require fertilisers<br>• Limited financial capacity to purchase fertilisers even when and where there is willingness |
| Information and awareness | • Limited awareness of the importance of fertilisers<br>• Limited private sector involvement | • Limited awareness by most farmers of the high levels of productivity associated with farmers, precipitated by limited information sharing<br>• Limited involvement of the private sector in the fertiliser market especially in very remote areas |
| Human skills | • Appropriate methods and practices | • Lack of knowledge by farmers of the various fertiliser application methods and practices that could suit their needs |
| Environmental | • Farming practices and topography | • For hills and slopes in general, inappropriate farming methods often lead to erosion of top soil together with its nutrients, which means that fertilisers must be repeatedly applied in such farms |
| Policy & Legal | • Inadequate regulatory/policy environment | • Lack of a conducive regulatory framework particularly on pricing and quality of fertilisers |

### 4.2.2. Post-Harvest Management

**Table 14. Barrier Categorisation and Description – Solar driers**

| Barrier Category | Barrier | Barrier Description |
|---|---|---|
| Economic and Financial | • High costs purchase, installation, repair and maintenance<br>• High interest rates<br>• Lack of government subsidies | • High acquisition costs is a central barrier to transfer and diffusion of solar dryer technology<br>• High bank interest rates are a disincentive to those willing to borrow money from banks to acquire solar dryers since they cannot afford loan repayments.<br>• The government of Uganda does not provide subsidies for purchase of solar dryers |
| Technical/ Infrastructure | • Lack of quality control and warranties<br>• Lack of maintenance and aftersales services<br>• Lack of technical infrastructure<br>• Assurance of durability | • Persistent quality concerns of solar products hindering their widespread adoption; precipitated by an immature market that lacks self-regulatory mechanisms and weak policies<br>• Limited number of trained personnel to offer aftersales services and their non-availability in rural areas in particular<br>• Limited investment in local capacity for manufacturing solar modules, which hinders technical skills development |
| Socio-cultural | • Resistance to change<br>• Misuse | • Target consumers are used to the traditional means of drying their produce (cereals and pulses) and are likely to be reluctant to adopt new methods/technologies.<br>• Where the technology is communally owned and is to be used as such, there is a tendency for it to be misused |
| Information and awareness | • Inadequate awareness | • Lack of knowledge of the technology and its benefits<br>• There is absence of good information about solar dryer technology – lack of knowledge on products, benefits, costs, financing sources and market potential |
| Human skills | • Inadequate skilled manpower among the local community | • There are not adequate personnel to install and operate the technology<br>• Limited technical know-how for repair and maintenance of the solar dryers |
| Environment | • Availability of sunshine | • Limited sunshine such as during wet weather limits the application of the technology, and may lower its rate of adoption in regions that are wet throughout the year |
| Policy & Legal | • Insufficient policy and legal framework<br>• Lack of institutional and regulatory framework | • Lack of government commitment in promoting solar dryers by formulating necessary policies and legislations in the agricultural sector<br>• A critical policy inadequacy is in the areas of quality and standards of solar products, with sub-standard products getting into the market and proving a hindrance to solar market development in the long run |

**Table 15. Barrier Categorisation and Description – Cold storage (for fruits and vegetables)**

| Barrier Category | Barrier | Barrier Description |
|---|---|---|
| Economic and Financial | • High costs of installation and operation<br>• Cost of energy consumption | • The initial cost of installation in CCM is beyond reach to many small scale framers<br>• High operating costs, especially the cost of power makes these technologies quite unaffordable to smallholder farmers |
| Technical/ Infrastructure | • Lack of sufficient capacity among the local communities<br>• Poor cold storage infrastructure<br>• Poor cold chain network<br>• Out dated technology<br>• Lack of reverse logistics<br>• Uneven distribution of capacity<br>• Time temperature abuse<br>• Sensitive links in food chain | • Temperature fluctuations can easily be encountered in the entire cold chain. Temperature control problems occur due to lack of compliance with the temperature specifications for refrigerated foods |
| Human skills | • Lack of skilled manpower | • Lack of skilled manpower especially in rural areas where these are required the most |
| Information and awareness | • Inadequate information | • Lack of knowledge of the technology and its benefits |
| Environmental | | |
| Policy & Legal | • Lack of government policy and regulatory support<br>• Lack of government support<br>• Lack of industry standards of implementation<br>• Lack of overall integrated planning throughout the value chain | • The industry is fragmented and will require heavy investment in building technology enabled cold chain storage facilities to cover entire value chain from procurement to transportation |

### 4.2.3. Value Addition

**Table 16. Barrier Categorisation and Description – Leather Processing**

| Barrier Category | Barrier | Barrier Description |
|---|---|---|
| Economic and Financial | • High investment costs<br>• Inadequate access to credit facilities<br>• High taxation rates<br>• Lack of readily available local market<br>• Inadequate incentives for investment in leather processing<br>• Cheap imports of wet blue leather<br>• High operation and maintenance costs | • Implementation of this technology is constrained by high upfront costs of investment<br>• Lack of or inadequate credit facilities to meet the high upfront investment costs; unpredictable investment climate lowers the risk appetite of capital owners<br>• High taxation rates that discourage investors<br>• Competition from imported second-hand leather products and low-cost footwear produced in offshore markets that make locally produced products uncompetitive<br>• Incentives such as tax rebates, government subsidies and lower taxation rates on machinery currently lacking<br>• The cost of imported wet blue leather, the primary raw material, is significantly lower than that produced locally<br>• Costs of raw materials, chemicals, effluent treatment and utilities in particular prohibitively high |
| Technical/ Infrastructure | • Poor quality wet blue leather<br>• Challenges with effluent treatment to international standards<br>• Destruction of moulds and fungi on tanned leather<br>• Poor quality of skins and hides<br>• Good practices and standards<br>• Transport network<br>• Poor state of tanning facilities and related infrastructure | • Poor animal husbandry and skinning at local abattoirs resulting in poor quality wet blue leather (primary raw material requirement for leather products manufacturers)<br>• Good Manufacturing Practices (GMP) demand that effluent treatment, a major challenge in the leather industry, must meet stringent standards for the products to be internationally competitive, and this is a challenge for local firms<br>• The growth of moulds and fungi on locally tanned leather due to the treatment method is a challenge that affects the quality of finished leather products<br>• A number of natural defects (scratches, diseases, ecto-parasitic defects) and man-made defects (ripping and flaying, preservation methods, transportation, storage and general bad handling) contributing to low quality hides and skins<br>• Capacity building of the Uganda Leather and Allied Industries Association (ULAIA) required to help it ensure good practices and standards in the industry<br>• Poor state of roads in some animal corridors that could negatively impact on the collection of hides and skins<br>• Most tanneries rely on old and outdated technologies that cannot meet the demands of the projected industry growth |

| | | |
|---|---|---|
| Socio-cultural | • Resistance to change<br>• Poverty<br>• Social stigma | • Perceived low quality of locally produced leather products driving away would be buyers<br>• High poverty levels that make the products unaffordable<br>• Trading in skins and hides is, in some communities, considered an inferior occupation and looked down upon |
| Information and awareness | • Inadequate awareness of the industry potential<br>• Inadequate networking and information sharing<br>• Inadequate market and market information<br>• Data and information gaps | • Lack of awareness of the value of the leather industry particularly among livestock keepers, hence no priority on the quality of skins and hides<br>• Poor linkages among the players in the industry, e.g., lack of networking among traders and dealers in hides and skins that limit the growth of the industry<br>• Limited private sector involvement in the leather value chain<br>• There is currently no reliable data and information on the industry, e.g., on the value of the market that would inform private sector engagement |
| Human skills | • Lack of relevant technical skills<br>• Limited research & development (R&D) in leather development<br>• Inadequate training in leather sector development | • Inadequate technical skills in leather design, technology and marketing<br>• There are far too few leather-related R&D institutions and undertakings in place to serve the industry's projected growth demands<br>• Current universities' and tertiary institutions' courses/programmes in leather sector development are inadequate in several respects, not least product design and machine/technology handling |
| Environment | • Water scarcity (availability)<br>• Effluent treatment and discharge<br>• Occupational health hazards<br>• Land and soil pollution<br>• Noise problems | • Leather processing is a water intensive industry that has the potential to cause water shortages and result in depletion of surface and underground water<br>• Wastewater treatment is costly, tedious and effluent water must meet the standards set by the National Environment Management Authority (NEMA) before being discharged into municipal waste water systems<br>• Chemicals used in the tanning process may cause dermatitis and skin colour. Inhalation of the polluted air in factories/tanneries may cause respiratory diseases<br>• Discharge of effluents and solid waste may cause soil pollution and an unsightly environment<br>• Hearing impairment during to noise pollution within the processing facilities |
| Policy & Legal | • Outdated policies | • Most veterinary regulatory frameworks are old and are thus being reviewed or entirely reformulated to meet the new economic policies and to harmonise with WTO Agreements and measures as well as other international agreements and obligations |

**Table 17. Barrier Categorisation and Description – Food Processing**

| Barrier Category | Barrier | Barrier Description |
|---|---|---|
| Economic and Financial | • High investment costs<br>• Inadequate access to credit facilities<br>• High taxation rates<br>• Lack of readily available market<br>• Inadequate incentives for investment in food processing<br>• Limited availability of raw materials<br>• Cost of compliance with standards<br>• Competition from global brands | • Implementation of this technology is constrained by high upfront costs of investment<br>• Lack of or inadequate credit facilities to meet the high upfront investment costs; unpredictable investment climate lowers the risk appetite of capital owners<br>• High taxation rates that discourage investors<br>• Preference for non-processed foods by Ugandans limits the size of the market<br>• Incentives such as tax rebates, government subsidies and lower taxation rates on equipment currently lacking<br>• Due to seasonality of certain crops, food processing often faces delays in production resulting in low supply. Low yields due to inadequate inputs such as fertilisers especially by small-holder farmers further exacerbate shortages<br>• Economic cost of compliance with standards and regulations a key barrier to smallholder farmers<br>• Local food manufacturers (entrants into the food processing industry) must contend with stiff competition from global food brands |
| Technical/ Infrastructure | • Poor storage<br>• Standards and regulations<br>• Quality control<br>• Transport network<br>• Outdated technologies/methods of inspections | • Lack or inadequacy of storage infrastructure – warehousing and cold storage in particular – lowers the quality and availability of the final product<br>• Challenges with meeting the stringent standards and practices regarding food product safety, environmental impact and the health, safety and welfare of workers and animals (Global GAP standards, Codex standards, ISO Food Safety Management Standards, Hazard Analysis and Critical Control Point (HACCP) and others)<br>• Inadequate laboratory facilities and human resources to provide sufficient quality control relating to microbial limit tests, pesticide maximum residue limit (MRL) tests, contamination tests and all other aspects of food quality and safety, as specified in various standards and regulations<br>• Poor road network causing delays in delivery and expiry of fresh produce; significant losses and potential quality gaps. Perishable food items must be shipped with proper packaging to avoid breakages and damages during transportation. Also, timely delivery is important to avoid spoilage – certain food items do not last long even if stored in climate-controlled facilities<br>• The manual inspection of agricultural and processed food products (by human evaluators) is time-consuming, labour intensive and prone to human error |

| | | |
|---|---|---|
| Socio-cultural | • Resistance to change<br>• Social standards and responsibilities | • Preference for non-processed foods by Ugandans limits the size of the market<br>• Food exporters are required to meet certain social responsibilities such as worker compensation and work place safety measures to be able to access external markets |
| Information and awareness | • Low levels of awareness by farmers on standards and regulations | • Low levels of awareness by smallholder farmers on the Global GAP and other standards' requirements as pertains to standards and quality of produce for processing for international markets |
| Human skills | • Lack of relevant technical skills | |
| Environment | • Water demand (availability)<br>• Environmental standards | • Water demand by the food processing industry may place pressure on water and result in its scarcity for other uses<br>• Food exporters are required to adhere to certain standards such as resource efficiency and pollution control to be able to access external markets |
| Policy & Legal | • Policy conflicts and implementation<br>• Weak institutional linkages | • Low coverage of inspection services due to limited resources and personnel<br>• Fragmented laws and regulations with institutions having conflicting mandates on implementation of the same<br>• There are no proper linkages between the various institutions in the agricultural and food sectors |

# CHAPTER 5
## Conclusions And Recommendations

## 5.1. Conclusions

In recognition of the pertinent role of technology in the desired transformational change of Uganda's agricultural sector, which is required to meet both the country's short and long-term development goals, a technology needs assessment (TNA) for the sector (agricultural sector) was undertaken. This is a report of the TNA. The TNA report identifies key technologies that, if implemented, can bring about the desired transformational change, barriers that would hinder their effective and successful deployment as well as measures to address those barriers.

### 5.1.1. The Process

The TNA employed a multi-stakeholder engagement process that involved engaging with stakeholders from the public, private sector, academia and research organisations and civil society groups. These engagements were complemented by an in-depth desk review of available literature on technology transfer and related subjects. Materials reviewed the United Nations Framework on Climate Change (UNFCCC)'s guidelines on TNA, Uganda's technology regulatory (legal and policy) framework, the Vision 2040 and its National Development Plans, and a host of sectoral development plans, among others.

### 5.1.2. Key Technologies for the Agricultural Sector

The process identified forty technologies across the three segments of an agricultural value chain, that is, primary production, post-harvest management and value addition. A multi-criteria decision analysis tool (MCDA) was used to prioritise the technologies for implementation. This process yielded a total of nine technologies across the three segments or components of the value chain.

The MCDA used for the assignment comprised a set of eight (8) high-level criteria pertaining to national development goals, each of which was then sub-divided into a number of evaluative low-level sub-criteria. The criteria and sub-criteria were chosen based on the national context, with the needs of the agricultural sector being a key factor for consideration. Another key factor for consideration was attribution, that is, the extent to which the technologies being evaluated could attribute to the chosen sub-criteria, in particular. As an example, in the validating of the tool at national workshop held in Kampala in December 2019, "health outcomes" was dropped as a sub-criterion under the "socio-economic" criterion for its multi-factorial nature.

Table 18 illustrates the TNA nine priority technologies. A critical consideration for each of the nine priority technologies is their direct impact on productivity and production, which is the overall aim of the TNA.

**Table 18. Technology Action Plan for the Agricultural Sector**

| Component of Value Chain | Technology | Key consideration factor |
|---|---|---|
| • Primary production | Drip irrigation | • Relatively low cost, making it relatively affordable to smallholder farmers<br>• Simplicity<br>• Suitability in dry areas – less water consumption |
| | Artificial Fertiliser | • Current low rates being a major impediment of improving agricultural productivity and production<br>• A single factor that could substantially transform the agricultural sector in Uganda |
| | (Genetically) improved seeds and planting materials | • Limited use of improved/certified seeds and planting materials – low productivity and production |
| | (Genetically) improved livestock breeds | • Limited use of improved/certified seeds and planting materials – low productivity and production |
| | Handheld motorised tillers, planters and weeders | • The need to replace the hand hoe with a cost effective option that removes drudgery and is gender |

| | | |
|---|---|---|
| Post-harvest management | Solar dryers | • Significant post-harvest losses of grains and pulses, necessitating a cost friendly technology applicable even in remote communities |
| | Cold chain storage technologies | • Significant post-harvest losses of fruits and vegetables, necessitating a range of cold chain technologies |
| Value addition | Food processing | • The premium that the third National Development Plan places on agro-industrialisation |
| | Leather processing | • The premium that the third National Development Plan places on agro-industrialisation |

### 5.1.3. Barriers to Technological Deployment in the Agricultural Sector

Further, an assessment of the barriers to adoption of technology in the agricultural sector was undertaken at two levels – a "global" level that looked at overarching barriers that generally hinder the use of technology in the agricultural sector, and a technology-specific barrier analysis. The latter is detailed in Section 4.2 of this report and may be not easily reproducible in this section, while still maintaining relevance.

On the former, a range of technological barriers in the agricultural sector identified by Ugandan stakeholders was subjected to a statistical analysis in order to understand which of these is/are the most important. The five most important barriers are:

**Lack of or inadequate technical know-how -** There is generally limited technical capacity in [agricultural] machinery and technology handling and operation. The implication of this barrier is that even technologies that are readily available, in terms of cost and proximity to end-users, are not widely adopted by particularly smallholder farmers, as they lack the technical capacity to operate and maintain them. They also lack the resources to employ the services of technicians.

**Lack of finance for relevant technology acquisition -** was highlighted as the second barrier, and concerns the low purchasing power of smallholder farmers in particular. Considering that a large proportion of the poor relies solely on subsistence agricultural production with no surplus for the markets (income generation), upfront acquisition of even the simplest modern agricultural technology is often an insurmountable challenge for them. Yet this group is the most technology constrained and can substantially improve their agricultural productivity, livelihoods and general socio-economic wellbeing with the application of simple agricultural technologies.

**Lack of or insufficient capacity and/or infrastructure for local innovation and technological development -** there is some capacity for local innovation and technology development with a number of agricultural innovations and technologies having been produced locally (e.g., a locally produced winnowing machine and several IT-based platforms or tools). However, this capacity including related infrastructure is still quite limited for the scale of technology deployment required to bring about the desired transformational change in the agricultural sector. Lack of infrastructure may also inhibit deployment of existing technologies or innovations. Similarly, lack of roads in certain parts of the country, particularly rural access roads, inhibit access to such places, which thus remain cut from the rest of the world in all aspects including access to modern agricultural technologies.

**Incoherent policy landscape and policy implementation failures -** concerns the incoherence in, and/or non-implementation of, the existing policy and legal framework on the use of agricultural technologies. Three particular technologies that stakeholders mentioned in this regard are biotechnology, drones and blockchain (for commodity payment systems).

**Absence of innovation platforms -** for key sector players to deliberate on sectoral challenges and potential solutions including technological solutions. A platform bringing together the innovation triple helix – government, private sector (industry) and academia (universities) and other research and development (R&D) institutions – is presently lacking. This is major hindrance to innovations in all sectors of the economy, as innovations that are generated by universities and other (R&D) institutions do not necessarily meet the needs of industry (broadly defined in this TNA to include farmers).

### 5.1.4. Measures

Addressing the five overarching barriers and the technology-specific barriers (section 4.2) forms the premise of this TNA. The TNA's recommendations (Section 5.2) are also drawn around the same. On the overarching barriers, a technology action plan identifies the following as some of the measures necessary to overcome the key technological barriers in the agricultural sector:

## 5.2. Recommendations

This TNA recommends two key follow-up activities, which are linked to its methodology, and the limitations of this assignment with respect to the said methodology. The TNA employed three existing UNFCCC guidelines for conducting TNAs. These are *the Handbook for Conducting Technology Needs Assessment for Climate Change (UNDP, 2010); Identifying and Prioritising Technologies for Mitigation – a Hands on Guidance to Multi-Criteria Analysis (MCA) (DTU Partnership, 2015); and Evaluating and Prioritizing Technologies for Adaptation to Climate Change – a Hands on Guidance to Multi Criteria Analysis (MCA) and the Identification and Assessment of Related Criteria (DTU, 2015).*

A complete replication of the methodologies in the three related guidelines would have replicated the UNFCCC TNA process. The TNA's relatively short timeframe (3 months) in comparison to the UNFCCC process (often about 2 years) further meant that a complete replication could not have been possible, while still yielding credible and useful results. It is on this basis that only two steps in the handbooks, that is, technologies identification and prioritisation, were applied.

Based on the foregoing, the TNA makes the following recommendations as the next two logical steps for its implementation:

1. Linking the process with the UNFCCC TNA process for purposes of prioritisation of the technology-specific barriers, as identified in Section 4.2 This will enable the development of technology-specific Technology Action Plans (TAPs), as recommended in the applicable methodologies.
2. Development of the Project Idea Report (PIR) for the nine priority technologies. A Project Idea Report is a project document (PD) on the implementation of a selected technology or a combination of technologies.

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