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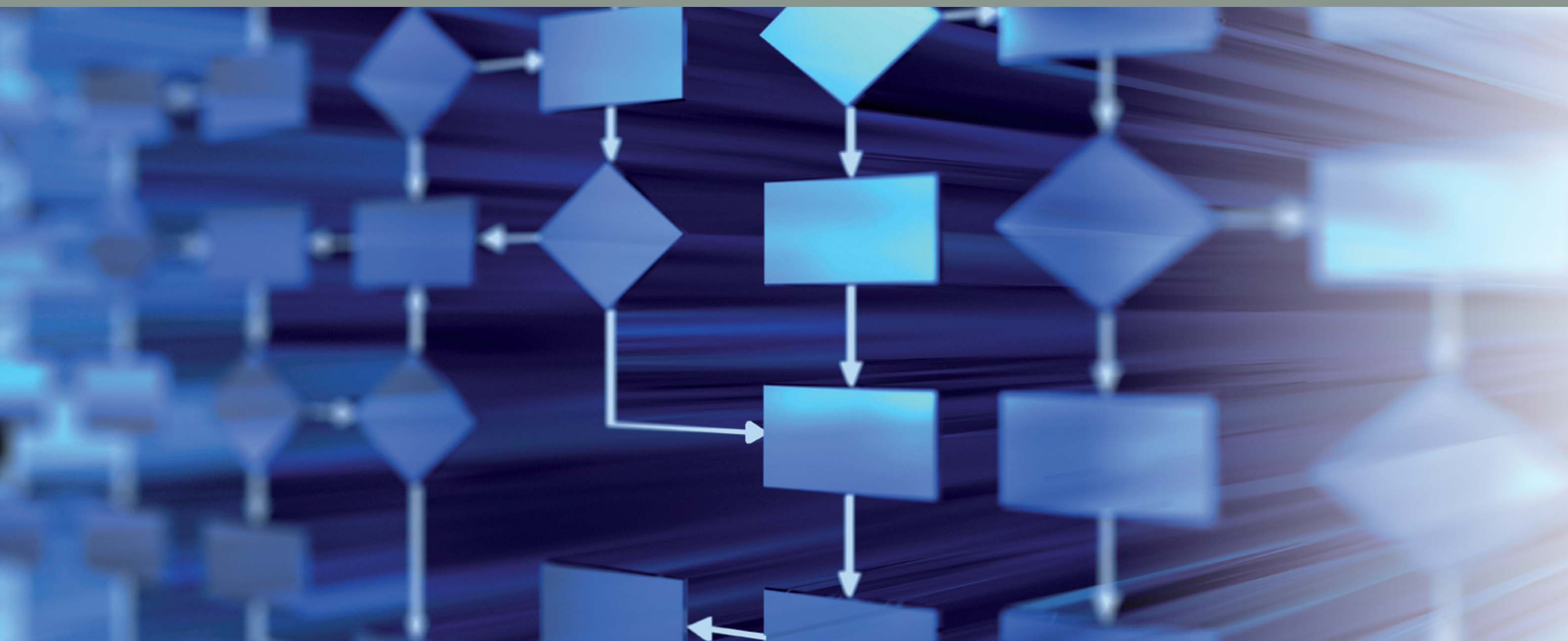

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Enhancing innovation in the Ugandan agri-food sector:
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Abstract

Uganda's innovation performance in recent years has consistently outpaced other low-income and Sub-Saharan African countries. Though encouraging, this nascent progress will benefit the broader Ugandan population if policy makers address specific constraints in the innovation systems of the critical agri-food sector, which is hampered by low productivity and profitability. We explore these constraints using an agricultural value chains framework with particular focus on two important sub-sectors: (i) the Robusta Coffee Planting Material Pipeline (CPMP) and (ii) tropical fruit processing. To understand the current constraints and opportunities in the Robusta CPMP, a detailed survey of Coffee Nursery Operators (CNOs) was designed and implemented. To understand the constraints in the fruit processing sector, primary data was collected via a survey of farm units; structured interviews of food processing clusters were undertaken. Innovation constraints in the CPMP stem from the current policy environment that favours quantity over quality and thereby fails to incentivize investments and upgrading along the pipeline. Constraints in the fruit processing sector also include unfavourable and disconnected policy, but extend to inferior and unpredictable fruit production and weak financial and organization linkages throughout the value chain. Based on the empirical evidence we present, we offer several specific recommendations for enhancing innovation incentives in each sub-sector.

Keywords: Innovation, Intellectual Property, Agriculture, Coffee, Tropical Fruit, Uganda

JEL classification: O3, Q16, D23, E22, H25

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Introduction

While the agri-food sector plays a crucial role in the development process, the full potential of relevant and often existing technologies in this sector is rarely realized. Constraints along the agricultural value chain commonly curtail the incentives to innovate and adopt new and promising technologies in the agri-food sector. Among these constraints, the influence of innovation and intellectual property (IP) policy, which is typically associated with high-technology sectors, is often under-appreciated.

The need for this study emanates from the vital role in Uganda's economy for agriculture, which employs about 3/4 of the country's labor force, predominantly in rural areas, and accounts for about 1/4 of Uganda's gross domestic product (World Bank 2016). Given that many households in Uganda rely on agricultural production for their livelihoods, innovation in this sector can have direct and potent welfare effects. Consequently, increasing agricultural productivity through improved technology and production practices has been a persistent priority at both national and international levels.

Innovations to increase agricultural productivity may be either technological or institutional and may come from a number of different sources. Uncertainty is of course inherent to innovation, so the precise mix and relative importance of different sources of enhanced productivity in the coming decades is unknown.

- Will higher productivity come from new seed varieties from research institutions?
- Will higher productivity come from institutional changes in agricultural input markets and supply chains trying to improve the quality of agricultural inputs and make input suppliers more responsive to the needs of farmers?
- Will higher productivity come from information and communication technologies improving farmers' access to information on agricultural practices and market prices?
- Will higher productivity come from agri-food processors providing farmers with access to inputs and output markets increasing incentives to invest in agricultural production?

Some combination of these potential sources of innovation-based improvements in agricultural productivity and profitability will emerge in the next decade. The precise mix of these sources and the magnitude of the resulting productivity gains will depend importantly on the incentives and constraints imposed by policy.

This report addresses these broad questions by exploring the role of innovation in the agri-food sector in Uganda. We first offer a conceptual framework that draws on agricultural value chains and innovation systems and situations policy and other constraints in this context. We identify relevant innovation barriers to agricultural value chain innovation, in general, and in Africa and Uganda in particular. We then dive into two studies in order to generate insights related to the challenges, opportunities and possible policy priorities related to innovation in the agri-food sector.

- First, we study the Robusta coffee planting material pipeline in Uganda as a critical link between upstream research and development of improved coffee varieties and downstream coffee farmers that shapes the benefits flowing to consumers through international coffee value chains, the returns on upstream R&D investments and the incentives faced by the agricultural innovation system.
- Second, we study the tropical fruit processing sector and consider the specific evolution of technology adopted, modified and improved by key actors in this sector.

To conclude, we explore potential implications for innovation and innovation policy.

1 Agricultural value chains in Uganda, inefficiencies and obstacles to innovation

For purposes of this study, we conceptualize the agri-food sector as "agricultural value chains", ranging from the supply of agricultural inputs such as seeds by input suppliers, wholesalers and retailer agro-dealers, to farming activities such as planting, farming and harvesting, to post-harvest activities such as bulking and processing of raw output, branding and marketing of value-added agri-food products that reach end consumers (Larsen et al. 2009; Pichot and Faure 2011, Lybbert et al., 2017 and Dutta et al., 2017).

In this section, we describe key elements of agricultural value chains and then use this conceptual framework to frame the focus of the WIPO-Uganda Agri-Food Study. The WIPO-Uganda Agri-food Study aims to build on the conceptual framework of value chains and agricultural innovation systems to explore the underlying research questions.

The initial scope of the study is depicted heuristically in Figure 1. The study will begin with a broad view of these value chains and the role various constraints and distortions play in impeding the translation of benefits from innovation in this sector to Ugandans. We will then focus our attention on two value chain links, namely, (1) improved and high-quality coffee germplasm and the coffee planting material pipeline (CPMP) that disseminates this material, specifically for Robusta coffee, to farmers throughout Uganda and (2) post-harvest tropical fruit processing.

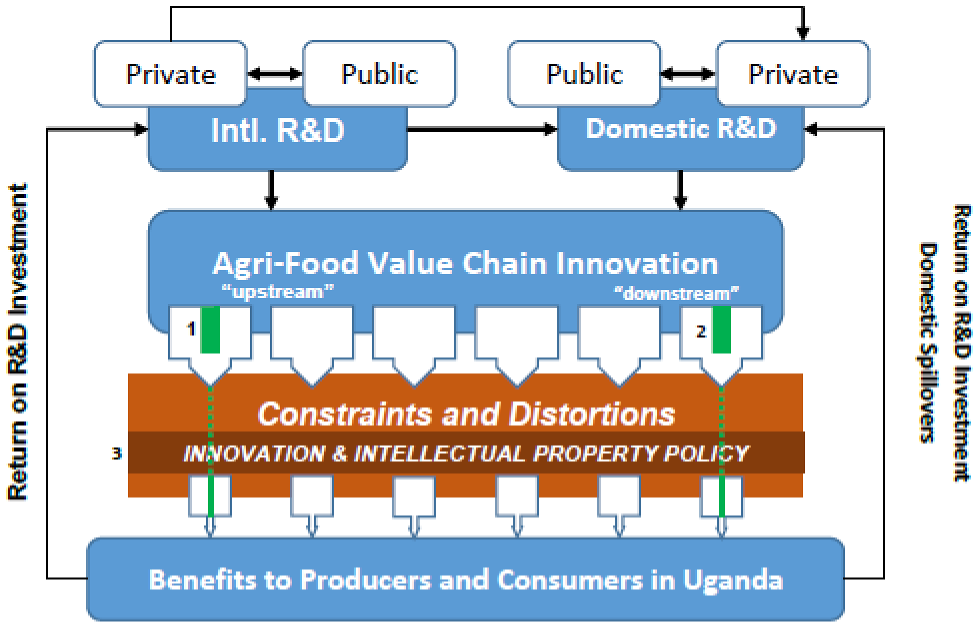

Figure 1: Heuristic depiction of scope of the WIPO-Uganda-Agri-food Study: (1) focal link – Coffee Planting Material Pipeline, (2) focal link – tropical fruit processing, and (3) focal constraints – innovation and innovation policy and associated constraints

By focusing on these two links, we aim to understand how specific firms and organizations make strategic decisions in response to the constraints, distortions and incentives they face and how these strategic decisions influence the development and diffusion of technologies that improve the productivity and profitability of the agri-food sector. Among the relevant constraints and distortions, the study will primarily focus on innovation and intellectual property policy and on others that are associated with these policy instruments and institutions.

1. For the first focal link in the coffee case study – improved Robusta germplasm and the associated CPMP – we concentrate on supply-side issues, while providing discussion of interdependencies between relevant supply- and demand-side constraints, e.g., credit constraints, uninsured risk. The study explores and evaluates how specific features of agricultural input supply chains in Uganda limit the availability of improved inputs and transmit production potential to producers and value to consumers. In many cases, upstream innovation in inputs (e.g., improved germplasm) involves significant public sector support, but the ultimate return on this public R&D investment is constrained by the efficiency and resilience of the input supply chains that deliver these inputs to producers. We consider features such as the role of institutional incentives, logistics, regulation, and other policies from the perspective of innovation policy. Constraints to public and private innovation in the agricultural input supply chain remain a bottleneck to improving the output of Uganda agriculture. On the one hand, access to high quality inputs remains a significant challenge. Issues of quality and suitability prevail. On the other hand, the rise of new hybrid seed varieties and other germplasm sometimes developed domestically, along with organizational innovations and improved distribution of agricultural inputs offer novel possibilities.

2. For the second focal link in the fruit processing case study– we focus mainly on private sector firms that procure primary products from Ugandan farmers and cooperatives and add value in the form of processing, packaging or distribution. The study explores and evaluates how specific features of the agro-processing sector in Uganda constrain the returns to public R&D and other investments in agriculture. By investigating the structure, competitive advantage and constraints of firms, we aim to identify opportunities for enhancing these value chains and improving the profitability of agricultural production in Uganda.

A variety of specific questions emerge throughout the course of the study. For example, how can policy stimulate domestic research and innovation to enhance productivity and address local problems in the agri-food sector? How might public and private sector use local brands, local techniques, local inputs, and local IP to improve the efficiency and dynamism of the agri-food sector? How might promising research, innovation, products, and even services that emerge from the Ugandan agri-food sector best be transferred to neighboring markets in the East African region? While a full treatment of these important questions is beyond the scope of this study and the specific aims of this report are in comparison modest, we are confident that the detailed and concrete explorations of the Robusta CPMP in Uganda and the tropical fruit processing sub-sector will generate insights and stimulate thinking about the challenges, opportunities and policy priorities related to innovation in the Ugandan agri-food sector – and thereby set the stage for broader and more ambitious dialogues in the near future.

1.1 Applying the Value Chain Framework to Agriculture

The concept of value chains originally came to prominence in the 1980s as a framework for improving business management and strategy.[3] For our study, we rely primarily on Trienekens (2011), which focuses on agricultural value chains in developing countries.
The objective of a value chain is “to produce value-added products or services for a market, by transforming resources and by the use of infrastructures – within the opportunities and constraints of its institutional environment” (Trienekens 2011).[4] As supply chains become more intricate and sophisticated, adding value increasingly hinges on successful integration into complex logistical networks: A firm with a great product or service to offer, but without the capacity to seamlessly integrate into these networks may find itself marginalized.

The Trienekens (2011) value chain framework relies on two primary components: (1) constraints, and (2) analysis and upgrading. Each of these components is fleshed out in detail. The constraints component includes three primary constraint elements: (1a) market access and orientation, (1b) limited resources and infrastructure, and (1c) weak institutions. Market access and orientation (1a) relate to the ability to serve a particular market. Market access is achieved through producer capabilities, available infrastructures, bargaining power, and market knowledge. Market orientation is defined as knowledge accumulation and application (Grunert et al. 2005). It is, thus, conditional on market access.
On its own, market access is likely insufficient to ensure the viability of a value chain. Supporting resources, infrastructure, and institutions (1b) are also crucial. Resources are typically defined as input factors, including physical inputs, human capital, and technological capital (Porter, 1990). A shortage in any of these areas could constrain value added. Moreover, poor infrastructure hampers efficient product and information flows through a value chain. Weak or absent institutions (1c) may also obstruct efficient value chains. Government policies and regulations can create trade barriers, legislate unfavorable taxes, and cause information restrictions.

Through an analysis of these various constraints, Trienekens (2011) proposes a variety of upgrading options (2).[5] Upgrading refers to improvements in value chain competitiveness and may be categorized by (2a) value addition through innovative products, processes, or marketing activities, (2b) network structure that enables a firm to tap its best market and market channels, and (2c) chain governance to establish the correct organizational form, oversight and incentives among stakeholders (Webber & Labaste 2010).
In this context, innovation in the agri-food sector can play a critical role in addressing some of the challenges and constraints described above. Upgrading of agri-food value chains, like other sectors, is often enabled by technology and innovation in the sector (Webber & Labaste 2010). Indeed agricultural value chains and their supporting elements can act as an incubator for innovation.

[3] Since that time, it has become an increasingly common analytical tool in development. Reports and papers on the topic and underlying theoretical constructs abound (see for example Gereffi 1999, Kaplinsky et al. 2002).
[4] Value added is defined as the difference between the value of the output less the value of intermediate inputs; it is dictated by the end-customer’s willingness to pay. Essentially, value chains describe how inputs produce an output; how the output progresses from producer to customer; and how value accumulates (Webber & Labaste 2010).
[5] Gereffi (1999) defines upgrading as “a process of improving the ability of a firm or an economy to move to more profitable economic niches.”

1.2 Agricultural Value Chains in Africa: Unique Features and Challenges

In addition to these general constraints, agricultural value chains in Africa encounter unique challenges. African businesses are subject to uncertainties caused by poor enabling environments, barriers to entry, and coordination failures (Poulton & Macartney, 2012). Producers are saddled with poor infrastructure, weak institutions, and unfavorable social and political conditions (Trienekens, 2011).

Coordination failures often result from a trust deficit or asymmetric relationships. Due to a poor track record, many value chains do not engender trusting relationships resulting in excessive risk mitigation, inefficiencies and reduced value add (Webber & Labaste, 2010). For commodities with low value added, such as raw agriculture staples, the terms of trade with Western countries are typically asymmetric (Kaplinsky et al., 2002). Information asymmetry and power balance favors Western partners, who capture the high-value portion of the chain. Moreover, small-scale farmers lack access to larger markets.

With these important dimensions in mind, it is easy to appreciate the marked heterogeneity that characterizes agricultural value chains in Africa. Indeed, this heterogeneity is often so pronounced that it results in three distinct and parallel systems of value chains (see Figure 2). In the A-System, local value chains consist of low value-added staple foods, low income and low productivity farmers, and local, low value-added spot markets. In the B-System, larger local farmers with access to improved inputs and markets product higher value crops and tap into higher value-added domestic agri-food markets. In the C-System, much larger (often, plantation-style) farms produce specialized products (often under production contracts) for high value export markets and must therefore satisfy high sanitary and phytosanitary standards. In developing countries, the A-, B-, and C-Systems typically operate in parallel often with little interaction, further isolating the most vulnerable and least productive producers in the A-System. These realities are key to understanding how value chains operate in Uganda and what upgrading options exist.

In this setting, barriers to entry disadvantage small-scale producers that have little capital to invest, use traditional techniques, and depend on family labour (De Janvry & Sadoulet, 2005) (Daviron & Gibbon, 2002). Such an environment causes difficulties in meeting product standards and makes it difficult to compete with larger-scale, more efficient, and more technologically sophisticated multinational corporations. Without market knowledge or competitive products, many small-scale producers fail to take advantage of larger markets or the techniques that could help them do so.

Furthermore, coordination failures are typically the result of a trust deficit or asymmetric relationships. Because of poor past performance, many value chains do not engender trusting relationships. This can lead to excessive risk mitigation, causing inefficiencies and reduced value addition (Webber & Labaste, 2010).

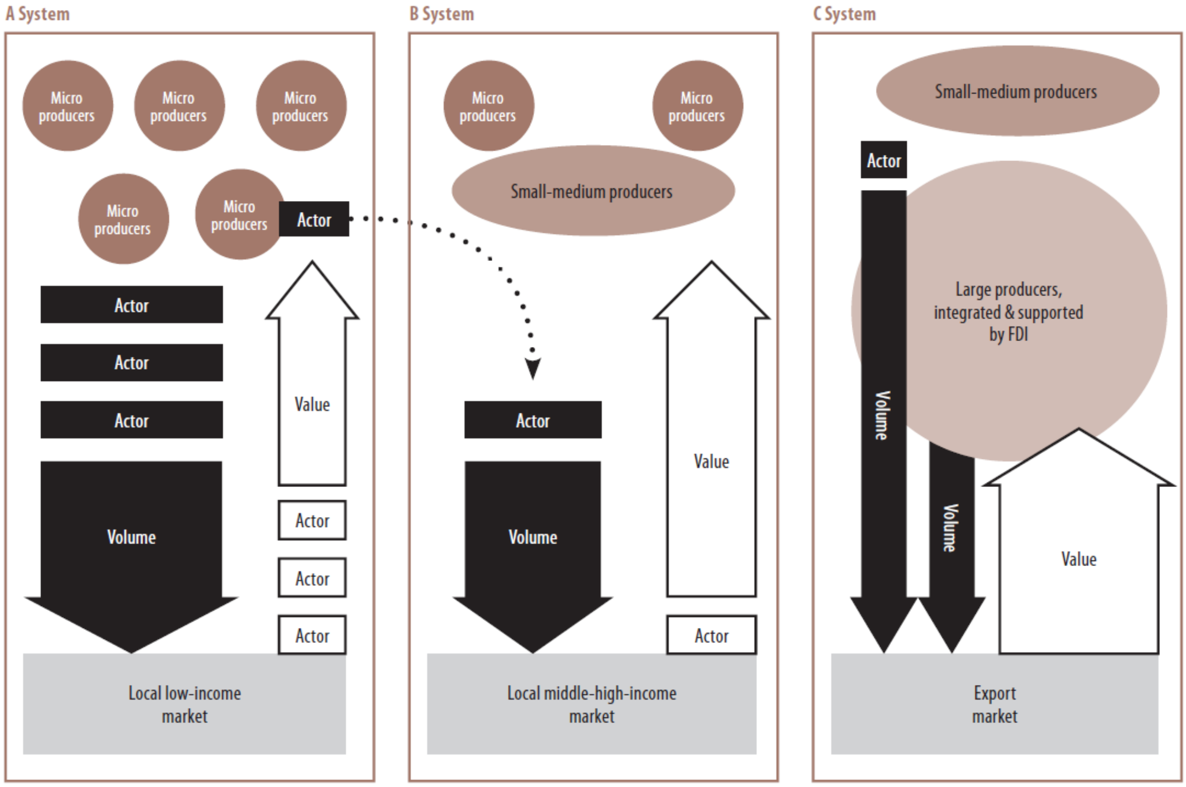

Figure 2: Parallel value chains in African agri-food sectors. (Source: See Lybbert et al 2017, adapted from Trienekens 2011 and Ruben et al. 2007).

For commodities with low value added, such as raw agriculture staples, the terms of trade with Western countries are typically asymmetric. In such circumstances, Western partners capture only the high-value portion of the chain, thereby excluding small-scale farmers from participating in larger markets (Kaplinsky et al., 2002).

These obstacles constrain the ability of lower-end chain actors from innovating in a way that increases agricultural productivity and upgrades the broader system through complementarities and dynamic interlinkages.

- **(Direct) Innovation constraints in the Ugandan agri-food sector:** Some specific limitations and innovation constraints can be identified in the Ugandan agricultural context. First, Ugandan farms are typically small: roughly half of Ugandan farmers own less than three acres of land, a quarter own three to five acres of land, and a quarter own more than five acres of land (LSMS-ISA, 2012) . The total area of both arable land and land under permanent crops has increased at an annual rate of over 2 percent over the past 20 years (FAOSTAT, 2014b). This increase in crop area, however, was outpaced by population growth, and crop area per capita declined nearly 25 percent during this period as a result FAOSTAT 2014). These trends have contributed to an annual decline in both food and agricultural production per capita of about 2 percent in since 2002 (FAOSTAT, 2015b). Thus at both the national and household levels there is a pressing need to increase agricultural productivity in Uganda.

  Moreover, mirroring the above challenges, Ugandan farmers face a host of constraints that limit both their ability and their incentives to invest in their productivity. Among these constraints are unreliable growing conditions; natural disasters; liquidity constraints; uninsured production and market risk; lack of access to or poor quality of agricultural inputs; lack of training, information, and awareness; limited output market opportunities; and a lack of spillovers from public agricultural research and development (R&D). To the extent that farm-level constraints discourage farmers from adopting new technology, they also discourage private-sector investments in the development, distribution, and marketing of improved agricultural inputs and other technologies. Downstream markets for agricultural outputs are similarly suppressed by low on farm productivity and concerns about the stability and quality of outputs. As a result, only one-third of agricultural production reaches domestic and export markets (World Bank, 2015). Key Ugandan agriculture innovation constraints at the value chain level are discussed in the next section.

- **The low quality of agricultural inputs:** The low quality of agricultural inputs in Uganda has been documented in several recent studies (Ashour et al., 2015, Benson et al., 2012, Bold et al., 2015). Thirteen percent (9/67) of the fertilizer retailers surveyed by Benson et al. (2012) reported receiving low-quality supplies from wholesalers. In practice, the 'low quality' appears to be a problem of counterfeited or adulterated or generic versions of the supplies. The widespread adoption of low-quality inputs seems to be more a result of weak enforcement of guidelines and regulations on input producers and dealers than the lack of technology to produce high-quality supplies. Better enforcement and the adherence to higher standards would help overcome this bottleneck. Additionally, institutional changes aimed at improving the quality of agricultural inputs, markets, and supply chains are central to the innovation process. Importantly, such institutional changes make input suppliers more responsive to the needs of farmers because they increase competition in the market. In many cases, upstream innovation in inputs (e.g., improved germplasm) involves significant public-sector support, but the ultimate return on this public R&D investment is constrained by the efficiency and resilience of the input supply chains that deliver appropriate improved inputs to producers.

  Constraints to public and private innovation in the agricultural input supply chain—in particular in the area of seeds, crops, and fertilizers—remains a bottleneck to improving the output of Uganda agriculture. On the one hand, access to inferior inputs (e.g., counterfeit or ineffective fertilizer) remains a significant challenge where issues of quality and suitability prevail. On the other hand, the rise of new, sometimes domestic, hybrid seed varieties along with organizational innovations and improved distribution of agricultural inputs might offer novel possibilities.

- **Imperfect financial markets:** In Uganda, the majority of rural households do not have access to credit. At the time of the 2005/06 Uganda National Household Survey, 24 percent of rural households had applied for credit from informal sources compared with 4.4 percent and 1.8 percent that had applied to micro-finance institutions and banks, respectively; only 15 percent and 12 percent of household heads have the capacity to borrow from micro-finance institutions and banks, respectively (Kasirye, 2007) . Of non-borrowers in the 2009/09 Uganda Census of Agriculture, about half were credit unconstrained, meaning that—given their production opportunities—they did not need a loan, did not borrow because of high interest rates, or could not profitability pay back the loan (Munyambonera et al., 2014). The other half of non-borrowers were credit constrained as a result of lack of collateral, lack of information about credit sources, negative past experiences with receiving credit, or unavailability of lending facilities (Munyambonera et al., 2014). Thus financial markets in rural Uganda should not only be equipped to provide finance to individual households in a community experiencing hardship but should also to look critically at the demand for start-up capital or insurance against risk that is common across households in a community. Prices and market uncertainties contribute to low investment by making borrowing more uncertain and therefore less attractive. This environment of uncertainty inevitably affects household liquidity.

Hybrid seeds and inorganic fertilizers that must be purchased each season are two technologies that are most likely to be affected by liquidity constraints at the household level. Furthermore, imperfect financial markets also impact the way labour is allocated across crops. The poorest households, which are less able to insure themselves against price risk, would tend to allocate less labour to high-return cash crop production, such as coffee production (Vargas Hill, 2009).

- **Information constraints and a weak knowledge base:** Information constraints and also, sometimes, a weak knowledge base among famers are further bottlenecks. Information constraints reduce productive investments by farmers by imposing constraints on (1) information about inputs/products and (2) information about practices/processes. Addressing this lack is the focus of public- and private-sector initiatives as well as research and policy recommendations (Benson et al., 2012) (Jansen et al., 2013).

  Limited information on inputs and products, in turn, negatively affects decisions about what practices and processes to adopt. For example, researchers found that only 2 percent of farmers in their sample correctly identified the variety of maize that they were growing (Stevenson et al., 2016.). If farmers believe they are growing a different variety than the one they are actually planting, they may apply practices and technology appropriate to the wrong variety; this can affect their productivity, as has been shown among cowpea producers in Tanzania (Bulte et al., 2014.).

  Often farmers also lack the capabilities to assess the potential and practical use of new technology or innovation, leading to underinvestment and limited adoption of new technologies.

- **Output markets, processing, and marketing:** Agricultural output markets (e.g., markets for coffee, maize, or mangos) can play an important role in facilitating agricultural innovation. They are the first and the most important link through which the farmers can access domestic agro-processors, neighboring countries, or global markets via processor-exporters. However, output sold by farmers is often purchased by middlemen in the village or at the farm gate shortly after harvest (World Bank, 2015).

  The interdependence between actors along this chain implies that downstream costs of market imperfections may be transferred upstream to farmers themselves. Because farmers make input investment decisions with an eye on the ultimate output markets, reforming agricultural output markets is an important way to increase farmers' use of improved inputs such as fertilizer (Benson et al., 2012). The nascent rice value chain in Uganda provides a concrete example of this dynamic. Since upland rice has only recently been introduced in the country, there are few rice mills and only one industrial agro-processor of rice in Uganda (World Bank, 2015). The costs of transporting rice between farmers and these mills was one of the main factors driving over half of farmers to dis-adopt NERICA rice among those who had initially adopted this crop two years prior.[6]

  Relatedly, low levels of investment in Uganda's agricultural sector are in part due to coordination problems between producers and purchasers of agricultural products. Smallholder farmers face uncertain demand for output, which reduces their incentives and ability to invest in agricultural production. Agro-processors face

[6] New Rice for Africa ("NERICA") is a cultivar group of interspecific hybrid rice developed by the Africa Rice Center (AfricaRice) to improve the yield of African rice cultivars (Kijima et al., 2011).

uncertain quantity and quality of supply, which is exacerbated by potential suppliers' side-selling opportunities on agricultural spot markets. In this way, uncertainty about demand and supply of commodities facing farmers and agro-processors, respectively, reduces their investment incentives. This agricultural investment trap results in only one-third of agricultural production reaching domestic and export markets (World Bank, 2015).

- **Lacking spill overs from public agricultural R&D:** The public sector conducts the vast majority of agricultural R&D in Uganda, as in many least developing and low-income countries. These investments focus primarily on technologies to improve agricultural productivity and sustainability. Yet a number of factors, including the lack of complementary investments and capacity, hamper spillovers from public research to private enterprises. These spillovers and the interactions and processes that generate them are complex and dynamic. It is critical that researchers and policy makers better understand the drivers and challenges inherent in generating R&D spillovers, as well as the levels and direction of agricultural R&D.

1.3 Agricultural Innovation Systems and Innovation Policy

Innovation in the agri-food sector can play a critical role in addressing some of the challenges and constraints described above. Upgrading of agri-food value chains, like other sectors, is often enabled by technology and innovation in the sector (Webber & Labaste 2010). More broadly, both innovation and improved agricultural productivity are potent drivers of economic development (Murphy 2007, Larsen et al. 2009). When these two drivers join forces, they can unleash especially dynamic forces in the process of economic development and poverty alleviation. Understanding these dynamics requires an appreciation for agricultural innovation systems and the potential role innovation policy, including intellectual property policy, plays in these important competitive dynamics.
Elliot (2008) enumerates two basic principles of innovation systems, namely, innovation is (i) context-specific and (ii) holistic. That is, it occurs within a dynamic system of diverse actors, where value chains are an important organizational form. Through this lens, the Agricultural Innovation System (AIS) recognizes that innovation occurs through many different channels.

The system encompasses all potential actors and inputs and assumes innovations derive from a dynamic process reliant on collective action. In this context, agricultural value chains and their supporting elements act as an incubator for innovation. As depicted in Figure 3, the bridging institutions and other enabling policies and norms can directly or indirectly shape how well upstream R&D and educational investments translate into value to producers and consumers and thereby influence incentives for both innovation and technology adoption (for more details see Grovermann et al. (2017).

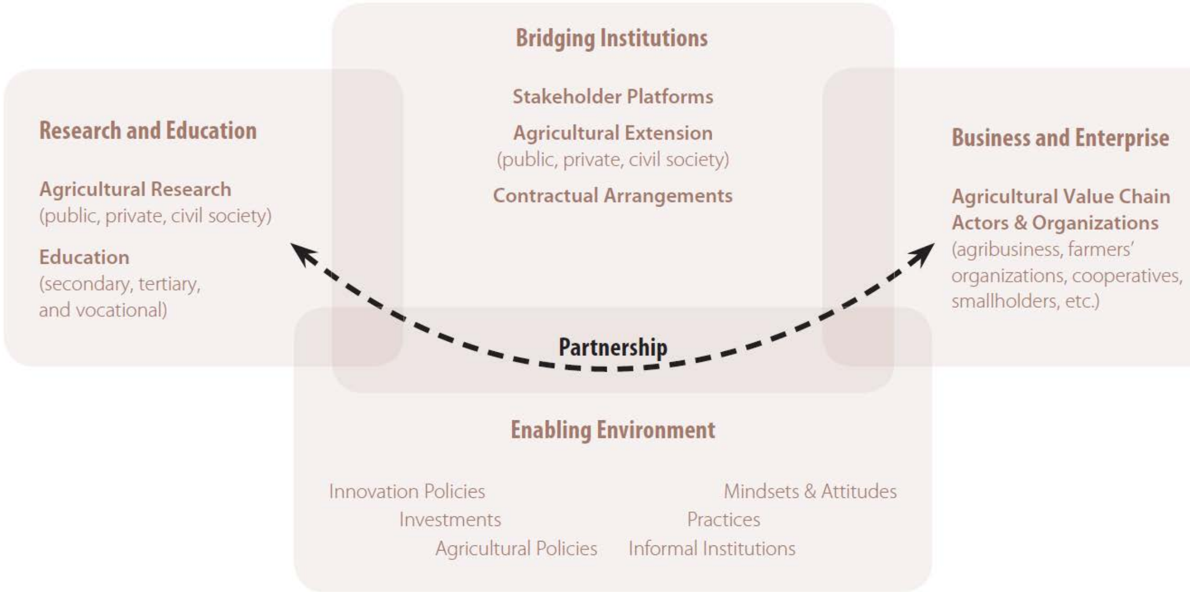

Figure 3: The agricultural innovation system. (Source: Grovermann et al. (2017) adapted from TAP, 2016, with permission from CAB International 2016.)

Government institutions, agencies and officials can directly shape the enabling environment and incentives that encourage or discourage innovation. This influence can be direct and explicit as in the case of funding basic or applied science through competitive grants programs or indirect and subtle as in the case of regulation or education policies. The role of the public sector in innovation systems includes process as much as existing policies or programs. Since innovation is inherently novel, it pushes the frontiers and challenges the status quo. This disruptive nature of innovation raises dilemmas for both private and public sector actors (Christensen 1997). If the processes that govern the emergence of new policies, regulations or enforcement are static and unresponsive, innovation may be stifled or slowed. If instead the policy processes are dynamic and responsive, government is more likely to successfully create an enabling environment that encourages innovation and stimulates innovation-based growth.

One of the explicit tools governments wield to influence innovation is establishing intellectual property rights (IPR) and maintaining the institutions that enable these rights to be used and enforced. An IPR regime encourages innovation by allowing inventors to recoup their investments through monopoly rents. The agricultural industry typically relies on patent protection, plant variety protection (PVP), and trademarks along with associated policies. Governments also engage in the direct funding of agricultural research and development (R&D). Public-private partnerships (PPPs) also support R&D, education, technology transfer, and incremental problem solving (Hall 2006).

Indirect methods for supporting innovation include fostering an enabling environment and collective action. The former typically relates to the provision public goods to address market failures in transportation, communication, and processing. Although, it can also focus on the small produces by aiming to integrate them into the market economy. This relies on a combination of service provision, as mentioned above; facilitation of the private sector, through financial services and fiscal policy; and an appropriate regulatory environment, through standards, regulations, and enforcement. Collective action offers the possibility of lower costs, a more reliable network, and potentially higher profits (Dorward, Kydd, and Poulton 2008). Umbrella organizations play a major role in marketing agricultural produce, providing access to training, and service delivery from external organizations

(Larsen et al. 2009). They also provide an ideal environment for knowledge transfer and innovation as they link farmers with similar interests.

With the full background and motivation for this study set, we present two detailed studies that explore constraints and innovation opportunities in Uganda's agri-food sector. In the next section, we focus our attention on Uganda's Robusta Coffee Planting Material Pipeline and describe the collection, analysis and interpretation of primary data from coffee nursery operators. In the subsequent section, we use case study methodologies to explore the tropical fruit processing sub-sector. These detailed studies provide a concrete basis for extracting policy recommendations that leverage innovation policy to enhance productivity and profitability in the Ugandan agri-food sector.

2 Constraints & Innovation Opportunities in Uganda's Robusta Coffee Planting Material Pipeline

Coffee has always been an important cash crop in the Ugandan agri-food sector and is a primary export commodity. It has endured the booms and busts of the global coffee market as well as a devastating coffee wilt disease (CWD) outbreak in the late 1990s. Coffee yields continue to be low by international standards. Robusta coffee yields in Vietnam, for example, are on average 3-4 times larger than in Uganda. Although there are several reasons for this, including the prevalence of intercropping in Uganda, the quality, suitability and disease-susceptibility of the Robusta coffee varieties grown by Ugandan farmers play a central role in stifling productivity in this key sector.

This study focusses on the Coffee Planting Material Pipeline (CPMP) in Uganda as a source of both productivity constraints and innovation policy opportunities. Ideally, the CMPM would convey high quality planting material from upstream research institutes to coffee farmers while retaining as much as the production potential as possible. In practice, much of this production potential leaks out of the current CPMP in Uganda before reaching farmers. The resulting lost value in the coffee sector is considerable for several reasons. First, with each newly-transplanted seedling, farmers lock in lower production potential for decades to come. Second, farmers rationally underinvest in newly-transplanted seedlings that are weak, low yielding and disease-prone seedlings. There are clear complementarities, for example, between input investments (i.e., fertilizer, pesticides, agronomic practices, etc.) and the innate production potential of new coffee trees: vigorous trees with disease-resistant germplasm can catalyze other investments in productivity whereas weak, disease-susceptible trees can lower the return on and increase the risk of such investments.
In this study, we explore the current CPMP in Uganda for Robusta coffee in order to showcase specific leaks in this pipeline that limit the impact of upstream innovation in coffee planting material. We use this detailed characterization as the basis for discussion of innovation policy implications and priorities that might help to fix these leaks and retain greater value in the Uganda coffee sector. The time for seriously considering these innovation opportunities has never been better given the current agricultural agenda of the Government of Uganda and its ambitions to increase national coffee production by over 500 percent by 2030.

2.1 Motivation for the Coffee Planting Material Pipeline Study

Coffee is crucial to the Uganda economy and to the livelihoods of millions of smallholder farmers, processors and intermediaries. As Africa's largest coffee exporter, Uganda also ranks among the top coffee exporters in the world with record exports of 4.2 million 60kg bags in 2016/17.[7] These coffee exports are a matter of national macroeconomic importance as they generate nearly 20 percent of all foreign exchange in the economy (AMA 2015). Uganda has a history of investing in upstream coffee research and in the broader coffee sector. For the purposes of this study, two institutions figure most prominently among these public investments: the National Coffee Research Institute (NaCORI)[8] and the Ugandan Coffee Development Authority (UCDA).[9] In response to the devastating coffee wilt disease (CWD) outbreak in the 1990s, NaCORI developed seven lines of CWD-resistant (CWD-r) Robusta planting material. These lines were identified, developed and partially approved for

[7] UCDA as cited in http://allafrica.com/stories/201710300123.html.
[8] NaCORI is one of 16 Public Agricultural Research Institutes (PARIs) formed under the National Agricultural Research Organization (NARO). Although coffee research has long been a mainstay of NARO, NaCORI was created in its current institutional form in 2014 as part of the National Coffee Policy (2013) (see http://www.nacori.go.ug/). For simplicity, this report will refer to its predecessors as NaCORI even though the official name of the institute has changed over time.
[9] UCDA was established by the Ugandan Parliament in 1991 and charged with promoting and overseeing the coffee industry in Uganda (see https://ugandacoffee.go.ug/about-ucda).

distribution by 2006. In the past decade, NaCORI has continued to develop pest and disease resistant coffee varieties and recently constructed its first tissue culture laboratory to be used to propagate clean plantlets for both coffee and cocoa. While resource constraints, including both funding, staffing and technical capacity, continue to limit NaCORI's potential impact, the research institute appears to be successfully and effectively pursuing its mandate to support the Ugandan coffee industry through upstream science, research and development.

UCDA is responsible for coordinating, overseeing and promoting the entire coffee value chain in Uganda. A complete description of all these activities is beyond the scope of this study. Instead, we focus on the important roles UCDA plays in structuring the CPMP. In particular, UCDA disseminates coffee planting material through a vast network of Coffee Nursery Operators (CNOs); trains, registers and periodically inspects these CNOs; and directly procures the planting material produced by these CNOs and coordinates the distribution of this material to coffee farmers via the National Agricultural Advisory Services (NAADS), most recently through the Presidential initiative entitled "Operation Wealth Creation" (OWC). Among the many roles and responsibilities of UCDA, we concentrate on its crucial influence on the CPMP as a meta-intermediary that ultimately aims to link NaCORI planting material to Uganda coffee farmers.

In October 2015, the President of Uganda, Y.K. Museveni, issued an ambitious directive to rapidly expand coffee production in the country by 500 percent – from 3.5 million (60kg) bags in 2015 to 20 million bags by 2020.[10] This Coffee 2020 plan with its fivefold increase in coffee production in five years was physically impossible to achieve given that coffee trees only begin yielding viable harvests after 4-5 years, but it had a dramatic effect on the coffee industry and institutions in Uganda – and on UCDA in particular.

Since that announcement, the Government of Uganda has contracted with McKinsey to create a comprehensive medium-to-long term roadmap for achieving this goal – an initiative called the "Coffee Lab." This goal has also been more realistically modified to achieve this fivefold increase in production by 2025[11] and, more recently (and realistically) still, by 2030.[12] The Coffee Lab has identified nine "key transformative initiatives" to enable this massive expansion of coffee production as shown in Table 1.

Among these transformative initiatives, one directly (#7) and two indirectly (#5 and #6) relate to the CPMP. The directly related initiative #7 suggests a clear recognition of the importance of a CPMP that supplies high quality planting material of improved coffee varieties. The indirectly related initiatives both invoke "extensive margin" increases in coffee production by bringing "underutilized" land into production. These extensive margin initiatives could be supplied with planting material by simply scaling up the current CPMP to generate a greater volume of planting material, but they would be far more effective if they were combined with initiative #7 so that this expansion in area devoted to coffee was paired with significant "intensive margin" gains due to improved planting material.

[10] For many years prior to this announcement, Uganda seemed to pin its hopes for transformational industrial development on the exploitation of its recently-discovered oil resources. Lackluster oil prices in 2009-2010 and especially 2015 seems to have shifted the governments focus back to its current biggest foreign currency earner: coffee.

[11] See https://ugandacoffee.go.ug/genesis-coffee-roadmap.

[12] See http://allafrica.com/stories/201710300123.html.

Pillars	Key Transformative Initiatives
Demand & Value Addition	1. Building structured demand through country to country deals, especially with China
	2. Branding Ugandan coffee to drive demand and improve value by up to 15 percent
	3. Supporting local coffee businesses for value addition, including primary processing and a soluble coffee plant
Production	4. Strengthening farmer organisations and producer cooperatives to enhance commercialisation for smallholder farmers and ensuring broad access to extension, inputs, finance and aggregation
	5. Support joint ventures between middle-class owners of underutilised land and investors to develop coffee production
	6. Providing and promoting concessions for coffee production on large underutilised tracts of land
Enablers	7. Improving the quality of planting material (seeds and seedlings) through strengthened research and multiplication of improved varieties
	8. Improving access to quality inputs by reducing counterfeiting (fertiliser, pesticides, herbicides) from current 40-60 percent
	9. Developing a coffee finance programme with the Central Bank and Treasury to provide financing to farmer organisations (including on-lending) to smallholders), coffee businesses and investors.

Table 1: Uganda Coffee Lab Initiatives

Source: McKinsey (2017)

The McKinsey Coffee Lab specifically articulates several potential impacts of these initiatives. It anticipates a 20 percent expansion in land devoted to coffee production and a 3-4x increase in yields. It envisions 1.5 million households benefiting from the initiative as coffee farmers and a requirement of USD 1 billion to USD 1.5 billion in new financing and investment in the next three to five years. It's hard to overstate how massive these desired impacts are.

In summary, our focus on Uganda's CPMP and on understanding the constraints and innovation opportunities that apply to the coffee subsector is motivated by:

i. the general importance of coffee to Uganda's economy and to the livelihoods of an estimated three million households whose incomes derive from the coffee subsector as farmers, processors and other intermediaries in the subsector (AMA, 2015),

ii. the considerable public investments that Government of Uganda has made in recent decades to upstream research and development (NaCORI) and in the development of the coffee industry more generally (UCDA, 2018; etc).

iii. the ambitious "Coffee 2020 Plan" that seeks to expand total coffee production in Uganda fivefold by 2030.

This study, which is narrowly focused on the CPMP for Robusta coffee in Uganda, is essentially a stress-test of the pipeline that is tasked with delivering planting material to farmers. Specifically, we ask a series of questions related to this pipeline. Based on what we can know or infer about the current CPMP, is this pipeline up to the task? What major leaks in the pipeline prevent the full production value of coffee planting material from being delivered intact to farmers? Having identified these leaks, what role could or should innovation policy play in fixing leads in order to retain greater production value in the coffee subsector? The biggest leaks represent the biggest policy opportunities to retain value and achieve the dramatic expansion of productivity envisioned in the coming years.

2.2 Essential Background: The Ugandan Coffee Planting Material Pipeline

The UCDA issues detailed monthly reports for the Uganda coffee industry. According to its November 2017 report,[13] there are currently a total of 2,089 coffee nurseries in Uganda – a dramatic expansion from the 1,138 nurseries reported in a 2015 report prepared for AMA (AMA, 2015). This November 2017 UCDA report estimates that this network of 2,089 nurseries have over 157 million seedlings available for transplanting, 118.3 million of which have been planted. In stark contrast, in 2011/12 total seedling production in Uganda stood at 18.6 million. This massive, nearly 10 fold expansion in the volume of planting material moving through the Ugandan CPMP began before the 2015 launch of the Coffee 2020 Plan, but was fueled by this plan in recent years.

Table 2 provides an overview of key historic events in the Uganda coffee subsector, especially as related to the CPMP (see AMA, 2015). By far the most notable event in the modern history of the CPMP in Uganda was the CWD outbreak of the 1990s, which decimated 45 percent of all coffee trees in Uganda and sent shockwaves through the subsector.

Year	Major Events
1982-87	Coffee rehabilitation program after trees were abandoned during the war, most of the fields had overgrown trees requiring improved management
1987-96	Government (MAAIF) policy was to replace genetically variable materials with genetically pure clonal coffee utilizing assistance from Farming Systems Support Program (FSSP); coffee intercropped with beans, bananas and other crops promoted and input materials like hoes, pruning saws and fertilizers were distributed to farmers. The target was to replace 5 percent of trees per year for the next 20 years i.e. 1993 to 2013 1992: UCDA was formed and built on FSSP work. It supported private sector nurseries to produce more clonal coffee materials. 1993: Coffee Wilt Disease reported in the country. Research into resistant materials started at NaCORI-Kituza.
1997	Rate at which cuttings were being produced to replace CWD attacked trees was realized to be low as a result of high mortality rate during propagation, investment was high, low efficiency of mother garden utilization was recorded and most of them had grown into bushes. 1998: 45 percent of all coffee trees had been killed by CWD.
1999	Moved to production of elite seedlings using seed from the clonal coffee trees that were propagated through cuttings with more coffee seeds supplied from NaCORI. Note: Elite planting material production was very simple, having low mortality rate during propagation, involved low investment and the technology was easy to adopt.
2001	Poverty Eradication Action Plan (PEAP) was introduced with coffee selected as one of the economic empowerment commodities (poverty eradication)
2006	Seven lines of CWD tolerant materials were identified and partially approved
2009	NaCORI-Kituza produced the first lot of tissue culture seedlings to be distributed to private nurseries for multiplication to develop more mother gardens in the country
2009-2014	Farmers receiving free coffee planting materials but not CWD tolerant materials

Table 2: Major historic events in the Ugandan CPMP
Source: AMA (2015)

[13] https://ugandacoffee.go.ug/sites/default/files/monthly-reports/November%202017.pdf

To appreciate the impacts and implications of the CWD outbreak, it is important to first understand the differences between three types of Robusta coffee planting material that co-exist in the Uganda CPMP:[14]

1. "***Seedlings***" are grown from coffee seed. Ideally, this seed is produced as "elite" seed from dedicated seed producers with direct access to approved NaCORI coffee varieties, but it is just as easy to grow seedlings from "local" seed of unknown origin.[15] 95 percent of Robusta coffee planting material in Uganda consists of seedlings (AMA, 2015).

2. "***Clonal Cuttings***" are propagated from nodal cuttings of existing coffee trees. Ideally, these trees are specifically maintained as a "mother garden" based on material provided directly from NaCORI. Cuttings are more difficult to propagate than seedlings and have a lower success rate. They are easily distinguished from seedlings as they look like small sticks growing leaves rather than tender seedlings. Below the soil, these cuttings also look different: They lack the distinct tap root of a seedling, which makes them more difficult to transplant since the root structure takes longer to tap deeper soil moisture. Clonal cuttings have two primary advantages over seedlings. First, as clones, they retain the identical genetic make up of the mother garden tree. If this is improved germplasm, this is a major advantage. Most notably, the seven CWD-r varieties developed by NaCORI in response to the CWD outbreak only retain their disease resistant properties when they are propagated clonally via cuttings. If they are propagated by seed, the genetic purity of these lines quickly erodes and, along with it, the disease resistance. In the case of hybrid coffee varieties, clonal cuttings ensure that the hybrid vigor is fully transmitted to the planting material farmers transplant into their fields; if these are instead grown from seed, farmers end up transplanting F2 (or, worse, F3) material without this hybid vigor. Second, clonal cuttings can mature more quickly into fruit bearing trees, which reduces the time to first harvest for farmers.[16] It is estimated that only 5 percent of the official UCDA-registered Robusta CPMP consists of cuttings (AMA, 2015).

3. "Clonal Tissue Culture ***Plantlets*** propagated in vitro in modern tissue culture laboratories from healthy leaves of a mother plant that has desirable genetic properties. Because these are clones like clonal cuttings, they retain the full CWD-r attributes if drawn from one of the CWD-r lines from NaCORI. But because they are not taken from cuttings, the leaf and root structure of these plantlets is indistinguishable from seedlings. The primary advantage of tissue culture plantlets is that they are propagated in very controlled and clean conditions, which eliminates the risk of contamination through inferior or diseased soil, polybags or water. Ideally, these plantlets would be used as mother gardens to produce superior cuttings to be distributed to farmers. In the current CPMP, only advanced coffee estates have access to plantlets of this type – typically via in-house nurseries with access to private tissue culture facilities via contract.

After NaCORI has developed the seven lines of CWD-r planting material, UCDA shifted its focus to training up a new generation of CNOs that could properly propagate clonal cuttings via mother gardens in order to retain the full CWD-r properties of this material. Since the CWD outbreak and ensuing destruction were clear and painful memories at that point

[14] Note that for simplicity in this report we occasionally resort to the common (implicit) convention of referring to planting material generically as "seedlings" but these more precise terms to identify the propagation technique used to produce the planting material where necessary.
[15] Robusta coffee is endemic to Uganda and so is well-adapted to the local agro-ecological conditions. This means that growing seedlings from seed is remarkably easy.
[16] See, for example, http://www.monitor.co.ug/Magazines/Farming/growing-clonal-Robusta-coffee-paying/689860-2800844-12cibh7z/index.html.

(2006), this push to establish a new, more sophisticated, more resilient CPMP was natural – but frustrations ensued. In particular, NaCORI did not yet have in-house tissue culture facilities and instead focused on scaling up the CWD-r material via clonal cuttings, which can be a slow process. NaCORI and/or UCDA chose not to partner with private firms with access to tissue culture facilities that could have rapidly produced clonal CWD-r plantlets.[17] In the end, the volume of clonal cuttings distributed across the countries to establish mother gardens was but a trickle of what was anticipated and needed to fill the CPMP with high quality, CWD-r cuttings.

The launch of the President's Coffee 2020 Plan in 2015 came after several such years of frustration that promising CWD-r material was not being disseminated from NaCORI to the wider CPMP. And this ambitious plan set UCDA into overdrive to rapidly expand the volume of seedlings being multiplied and distributed through the CPMP. This seems to mark a clear shift towards quantity and away from quality in the CPMP: Volume quickly became the top priority – and the memory of the CWD devastation of the 1990s seemed to fade.

[17] There is anecdotal evidence that several such private firms both within Uganda and internationally offered to provide this service.

The architecture of the Robusta CPMP in Uganda has been depicted in recent reports in ways that highlights some specific constraints. For example, Swaibu et al. (2014) depicted the ideal CPMP for propagating hybrid coffee cuttings and contrasted this to the actual CPMP. This depiction, replicated in Figure 4 shows how the mother garden capacity constraint that exists at both the Zonal Agricultural Research and Development Institute (ZARDI) and the CNOs leads to a loss of hybrid vigor. Specifically, instead of receiving F1 seedlings with hybrid vigor fully intact, farmers in the CPMP observed by these researchers end up with F2 seedlings that lose much of the hybrid vigor bred into the variety by plant breeders at NaCORI. The recent AMA report on the CPMP in Uganda (AMA, 2015) offered a depiction of the actual and ideal CPMP that is both more general and more detailed (see Appendix C).

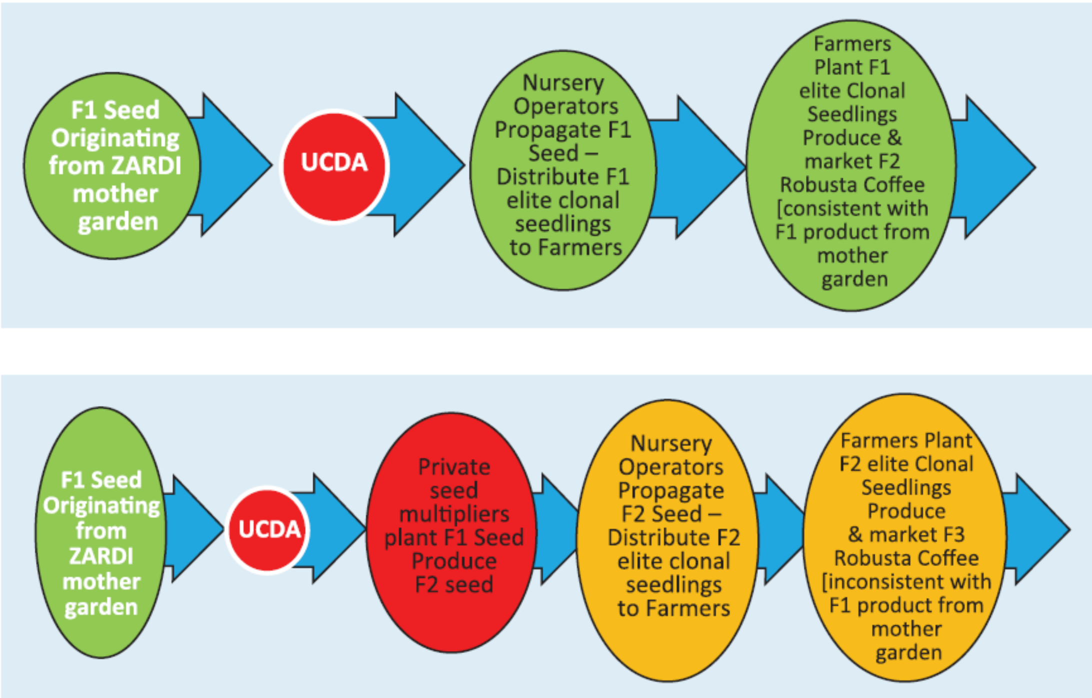

Figure 4: Best practices in coffee seed multiplication (top panel) and observed practices due to limited mother garden capacity at Zonal Agricultural Research and Development Institutes (ZARDI) and among CNOs (bottom panel). (Source: EPRC Policy Brief No. 44 (May 2014).)

2.3 Conceptual Framework & Considerations for the CPMP Study

To frame our investigation into the CPMP, we first layout key assumptions and elements of a conceptual framework to guide this exploration. We focus on Robusta coffee exclusively. We take the upstream research and development at NaCORI, including the seven lines of CWD-r material and other ongoing research into disease resistance and other improved varieties, as given. That is, we do not analyze the institutional structure, incentives or innovation efficiency of NaCORI, but simply take this as the given “headwaters” for the CPMP in Uganda. We focus our attention on the pipeline that links NaCORI to farmers and aim to understand constraints (i.e., “leaks”) that reduce the potential production value delivered to farmers.

Clearly, after farmers receive seedlings from this pipeline many other constraints create additional downstream “leaks” in the coffee subsector. For example, official reports from 2016 suggest that the overall survival rate of seedlings delivered to farmers via OWC was roughly 36 percent with over 40 million seedlings perishing between procurement at the CNO and farmers’ fields. On farm, there is similarly a host of constraints that reduce the productivity of coffee trees, including sub-optimal agronomic and pruning practices, insufficient or non-existent investments in fertilizer, pesticides or other inputs, biotic stresses such as CWD and coffee twig borer, abiotic stresses such as poor soils, and drought (see Wang 2014). Additional constraints arise after the farm-gate – as coffee berries are purchased and processed in the downstream value chain (see AMA Value Chain). While these constraints all matter enormously to the value-added (and retained) along the coffee value chain, they are not our focus in this study. We cite these only briefly to acknowledge their presence and importance, but focus our attention here on the CPMP that delivers planting material from the gates of NaCORI and to Ugandan farmers.

One compelling reason to focus on the CPMP is that the health, vigor and disease resistance of a seedling as it emerges from the pipeline and is transplanted can be “locked in” for the duration of the life of the coffee tree. A seedling that is weak or diseased at the time of transplanting is likely to have reduced productivity for its lifespan of 20 or more years. Although rehabilitation through careful agronomic practices and input investments can partly offset these initial deficiencies, they can nonetheless have large and persistently negative effects on productivity. When it comes to disease resistance, the durable deficiency of a seedling is fully “locked in” and is not amenable to rehabilitation to reconfigure its genetic inheritance.

On the basis of these different types of seedling deficiencies, we conceptualize seedling quality as consisting of two dimensions corresponding roughly to familiar “nature” and “nurture” determinants:

1. **Nature**: Enhanced production potential based on improved germplasm:
    a. Elite seedlings propagated directly from elite seeds from NaCORI planting material.
    b. Clonal propagation of cuttings or plantlets to retain CWD-r and F1 hybrid vigor.
2. **Nurture**: General seedling health and phytosanitary vigor from clean propagation conditions and investments in best practices and quality inputs (soil, water, etc.).

Whereas seedling quality due to “nature” is locked in at the time of initial propagation, seedling quality due to “nurture” reflects investments in clean and favorable propagation conditions.

The flow of information regarding these dimensions of seedling quality shapes how the CPMP functions and how well it is able to retain production value. As always, this flow of information is directed by the incentives faced by players and stakeholders along the pipeline. In the current structure of the CPMP in Uganda, the UCDA orchestrates and influences how and how much information flows through the pipeline as well as the incentives faced by CNOs and other actors. For most CNOs the customer of choice – indeed, the only viable customer for many – is the UCDA. Thus, the procurement policies of the UCDA most directly affect the decisions made by CNOs.

Until recently, UCDA’s official procurement price for elite seedlings was 300 UGX/seedling. In late 2017, UCDA posted updated prices on their website as follows: 350 UGX for elite seedlings, 1000 UGX for clonal cuttings, and 1,500 UGX for tissue culture plantlets.[18] While

[18] See https://ugandacoffee.go.ug/fact-sheet (accessed 8 Jan 2018).

it is not clear how and how many cuttings and plantlets UCDA procures at these prices, it is almost certainly true that 90 percent or more of the material procured and distributed via OWC consist of elite seedlings. Moreover, while UCDA conducts periodic inspections of nurseries, it is not clear what specific information is collected in these inspections and how it is conveyed, if at all, to farmers or other downstream actors in the pipeline. Some characteristics of a seedling are readily observable to a farmer, including number and color of leaves and whether it was propagated from a clonal cutting. Other key attributes are not observable – either to farmers or UCDA inspectors – including CWD resistance, hybrid vigor and whether a seedlings is a tissue culture plantlet or a seedling.

The fact that key seedling quality attributes are not directly observable raises important challenges. As a compounding factor, some claim that smallholder coffee farmers do not know enough about these important attributes to even try to discern these dimensions of quality. While there are surely some discriminating and clever farmers who understand how unwise it is to commit decades of care and maintenance to a new seedling of questionable provenance and quality, it seems likely that the average smallholder coffee farmer is now little more than a passive recipient of a free OWC seedlings procured from nurseries that have passed UCDA's inspection.

At the other end of the spectrum of coffee producers in Uganda, there some very large, sophisticated producer-exporters who understand perfectly the importance of getting high quality planting material. These producers would never consider investing in seedlings of unknown provenance and quality. They remember the devastation of the CWD outbreak of the 1990s. They recognize the magnitude of the risks of procuring seedlings from independent CNOs or from UCDA. Instead, they have chosen to vertically integrate by bringing their nursery operations in-house. This gives them much greater control over both the nature and the nurture of their planting material. Given their persistent concerns about CWD susceptibility, which seems oddly missing from most smallholder coffee producers, they procure CWD-r material directly from NaCORI and propagate tissue culture plantlets or clonal cuttings under carefully controlled and clean conditions.

To illustrate the durability of potential seedling deficiencies and highlight the significant implications of this durability for the expected value of lifetime production of a coffee tree, we construct a simple simulation of expected yields in coffee cherries.[19] We assume a conservative "full potential" yield per tree of 3kg/tree/year.[20] In Figure 5, we compare this "full potential" yield profile to three prototypical yield profiles for seedlings with deficiencies of various kinds. The first deficient seedling is a clonal cutting from a CWD-r mother garden and is therefore resistant to CWD, but was propagated in poor phytosanitary conditions and suffers from a chronic yield deficit of 15 percent. This 15 percent deficit may be due to poor quality soil or water used in the nursery, which makes the seedling and the mature tree weak and susceptible to abiotic stresses.

The second deficient seedling is an elite seedling that was propagated in excellent phytosanitary conditions – and hence suffers from no chronic yield losses due to "nurture" deficits – but is non-CWD resistant because it was not clonal propagated from a CWD-r

[19] Simulating yields in terms of unprocessed harvested cherries, called *Kiboko* in Uganda, simplifies the simulation and focuses this simple analysis on production potential without accounting for post-harvest value addition.
[20] This "full potential" yield of 3kg/tree/year is computed as the average of UCDA's range of 0.55-1.1 kg/tree/harvest (1.1-2.2/kg/tree/year given two harvests per year) (see https://ugandacoffee.go.ug/fact-sheet (accessed 27 Dec 2017)) and other claims that under "average management practices" a Robusta tree can yield 4kg per year (see http://www.monitor.co.ug/Magazines/Farming/How-two-acres-of-coffee-can-earn-you-Shs32m-a-year/689860-2289088-qknjo5z/index.html (accessed 28 Dec 2017)). Note that because this "full potential" becomes the benchmark for what follows, we can easily adjust these assumed yields and the relative yield profiles between different types of planting material will not change.

mother garden. To account for potential CWD losses, we assume that the probability of a CWD outbreak slowly increases from years 4-8 since transplanting to a maximum (and conservative) annual probability of outbreak of 10 percent. Consistent with the scientific literature, we also assume that CWD kills trees and eliminates all future yield from the tree. As stated by Rutherford (2006), "[u]nlike many other diseases of coffee, CWD will rapidly kill an infected mature tree, often within as little as 6 months following the appearance of the first external symptoms, and thus ultimately result in total yield loss." (p.663, Rutherford, 2006) These two assumptions imply that by age 20 the probability that a coffee tree has not been infected and killed by CWD is roughly 20 percent.[21] As shown in Figure 5, non-CWDr imposes a massive expected yield deficit. It is important to note that this is an *expected* yield profile that builds in the probability of CWD infection; for a given tree yield drops to zero once it is infected with CWD.

The third and final deficient seedling is, like the second, non-CWDr but also suffers from chronic yield deficits due to poor propagation conditions and/or inferior germplasm. Specifically, we assume that these chronic yield deficits impose a 25 percent yield penalty – higher than the first deficient seedling above because this seedling is propagated by seed instead of via clonal cutting and is therefore likely to suffer from mixed genetics (cross-pollination) in addition to poor propagation conditions. Relative to the "full potential" seedling, this seedling offers farmers only a fraction of expected yield: During peak production years (say, 10 years post-transplanting), this seedling's expected yield is less than 30 percent of full potential. Unfortunately, the vast majority of seedlings procured from UCDA-registered nurseries are CWD susceptible because they are propagated via seed rather than by clonal cuttings or tissue culture (AMA 2015). If CNOs also fail to adhere to best propagation practices, the seedlings they produce are likely to most closely resemble the third, seriously deficient seedling depicted in this figure.

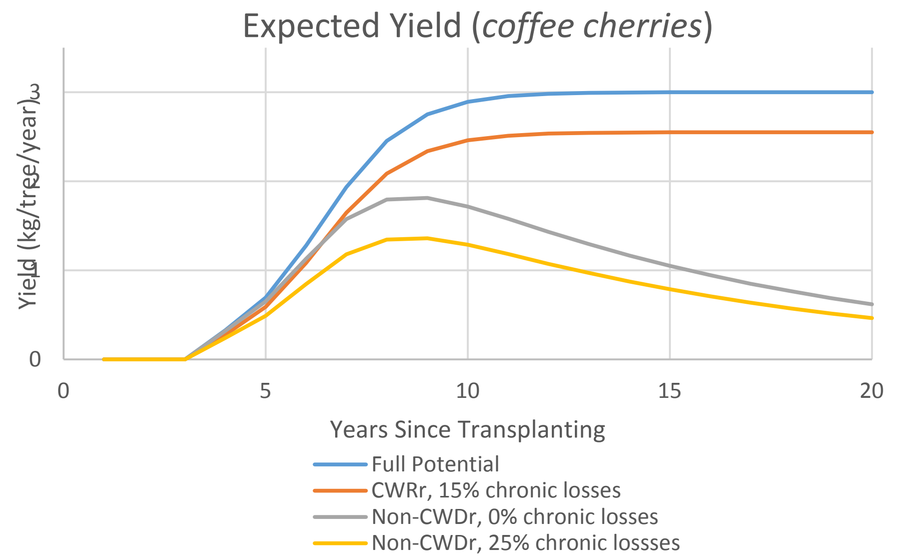

Figure 5: Simulated yield profiles for different planting material

[21] This is calculated as a compound probability where the probability of CWD outbreak in a given year reaches a maximum of 0.10 after eight years since transplanting, implying that the probability of no CWD outbreak and continued production of 0.90. The compound probability of no CWD outbreak and continued production for any two years at this point is given by 0.9*0.9=0.81. After 20 years, the compound probability of no CWD outbreak is 0.207.

In order to directly compare these four types of coffee seedlings, we compute the expected present value of coffee harvests for the lifetime of the tree. To do this, we assume a Robusta coffee berry price of 2050 UGX/kg[22] and a discount rate of 9.5 percent.[23] Figure 6 shows the expected present value of these different types of seedlings at the time of transplanting. The lost value due to nature and nurture deficits is considerable. In particular, Uganda must avoid the risk of flooding farmers with inferior seedlings that reduces the potential value produced by the future Ugandan coffee subsector by more than half as indicated in this simulation. Unfortunately, this risk is very high: As described below, the vast majority of the planting material distributed by the current CPMP is non-CWD and likely to most resemble the fourth and most deficient seedling depicted in Figure 6.

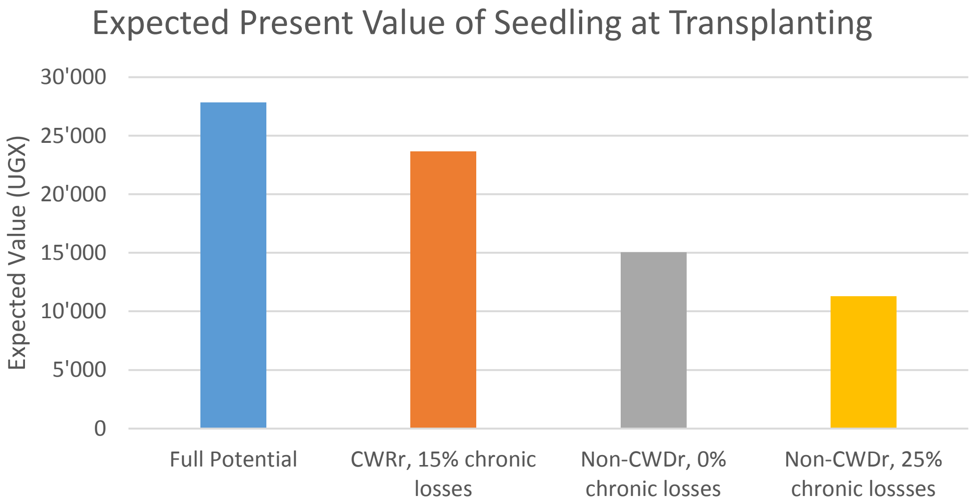

Figure 6: Expected present value of different planting materials at time of transplanting assuming a price of Robusta coffee cherries of 2,050 UGX/kg (https://ugandacoffee.go.ug/statistics Accessed 29 Dec 2017) and a discount rate of 9.5 percent (https://www.bou.or.ug/bou/home.html Accessed 29 Dec 2017).

2.4 Coffee Nursery Operator Sample & Survey

To understand the current constraints and opportunities in the Robusta CPMP, we conducted a detailed survey of CNOs. To finalize the sampling frame and questionnaire, we first conducted a series of key informant interviews with actors throughout the CPMP and collected and reviewed relevant pre-existing studies from the Ugandan coffee industry. This broader set of research activities are described in the research design included as Appendix A. In this section, we describe the sampling frame and questionnaire we used to collect data from CNOs.

[22] See https://ugandacoffee.go.ug/statistics (accessed 29 Dec 2017)
[23] This is taken from the Bank of Uganda (https://www.bou.or.ug/bou/home.html (accessed 29 Dec 2017).

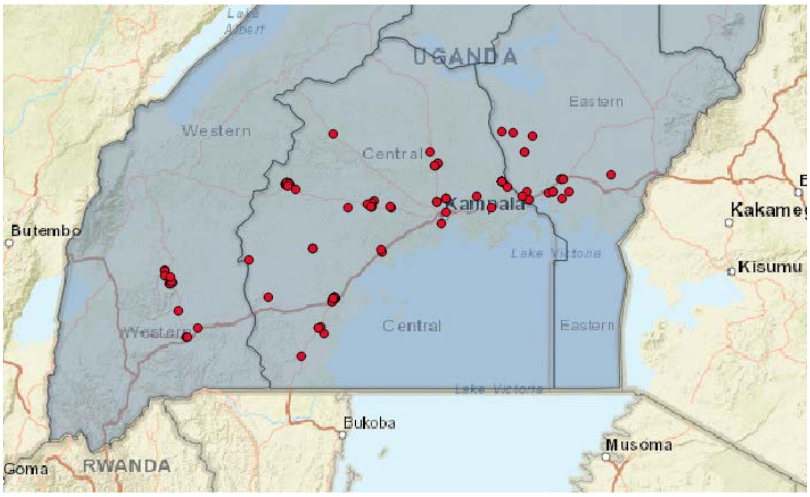

Figure 7: Location of sampled CNOs across three regions and 14 districts

We constructed our sampling frame around three regions of Uganda with significant Robusta coffee production: Western, Central and Eastern. In each of these regions, we consulted with local UCDA representatives to select four Robusta coffee growing districts. For each of these four target districts, we then acquired a list of all UCDA registered CNOs. From these lists of CNOs, we randomly selected CNOs to interview. To complement this sample of UCDA-registered CNOs, our research team specifically sought unregistered CNOs to include in the survey. There were very few such "informal" CNOs in these target districts, so we ended up with only 13 such unregistered CNOs in our sample. Our final sample consists of 178 CNOs spread across 14 districts. The location of these sampled CNOs is depicted in Figure 7. Roughly 75 percent of these sampled nurseries are individual operations; the remaining nurseries are a mix of family, group and association operations. About two-thirds of our respondents are owners of the operation, and the remaining third are managers and employees of the nursery.

The questionnaire was designed to capture important dimensions of heterogeneity among CNOs, including the size, age, cost structure, planting material sources, and customers of the nurseries. It also included several questions about "best practices" to serve as a proxy for both the knowledge of the CNO and the quality of the planting material they produce. We asked several questions about financing of nursery operations and the personal wealth level of the CNO. The full questionnaire is provided in Appendix B. This research was approved by the University of California, Davis Institutional Review Board[24] and was granted research authorization from Uganda National Council for Science and Technology.

2.5 Heterogeneity among Registered UCDA Robusta Coffee Nurseries: Analysis & Results

One of our primary objectives in conducting this CNO survey is to better understand the heterogeneity among CNOs in order to more clearly identify potential "leaks" in the CPMP that reduce the potential production value delivered to farmers. With this objective in mind we describe a series of analyses in this section. We begin by exploring responses to the "best practices" module, which we use to construct a best practices index to help characterize nurseries. We then combine this best practice index with several other relevant characteristics of CNOs and conduct a cluster analysis in order to identify groups of CNOs in our sample that share important structural features. With these clustered identified and defined, we then contrast and compare these clusters along several dimensions.

[24] Upon review of the application for IRB approval, the UC Davis IRB designated the research "exempt" as the questions were considered to be non-invasive, non-threatening and non-sensitive.

The "best practices" module (Section F-1 in the questionnaire, included in Appendix B) contains 29 questions, which were formulated and vetted with assistance from coffee agronomists. We use a subset of these questions to formulate a factor analytic index of best practices.[25] The resulting index provides a data-weighted index of best practices for each CNO that serves as a useful proxy for the general propagation conditions of the nursery and for the phytosanitary health and vigor of planting material produced by the nursery. By construction, this index has a mean of zero across all CNOs in the sample. Figure 8 shows the distribution of this best practices index across these nurseries. The mass of nurseries follow very few of the best practices embedded in this subset of questions and, consequently, have best practice indexes below zero. Among those that adopt some of the practices, there is a range of best practice adoption that spans the right side of the distribution, with a clear and distinctive group of CNOs that maintain relatively good practices. In our continued analysis in this section we aim to identify these nurseries as they are much more likely to produce quality seedlings. That is, they are less likely to lose

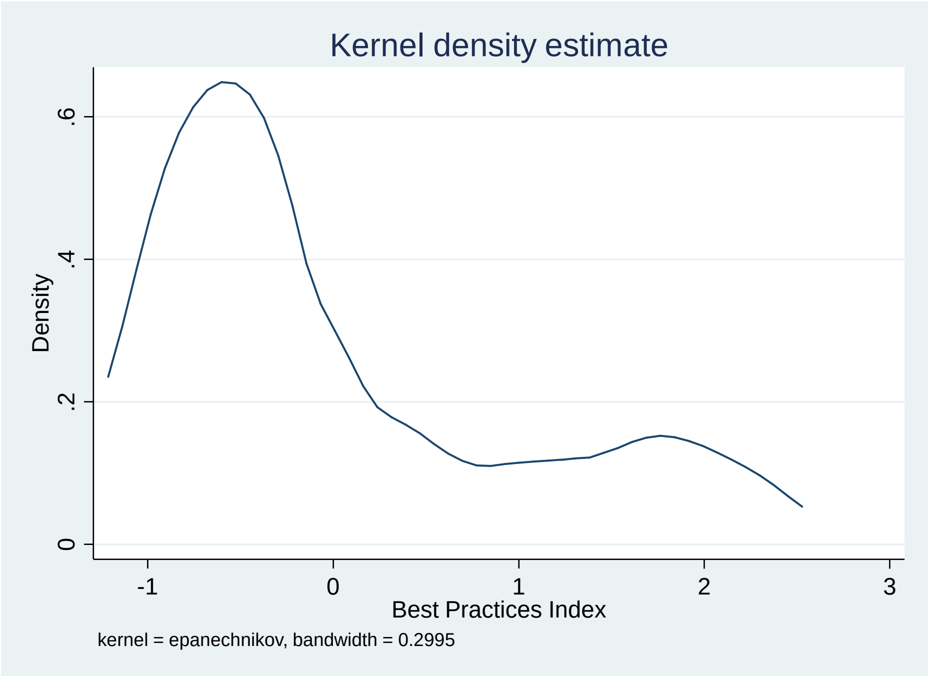

Figure 8: Distribution of Best Practices index for all surveyed nurseries

potential production value via inferior propagation practices.

[25] Specifically, we selected responses to questions 7-21 and 23-25 to include in this index. This subset of questions includes some that are relevant for nurseries propagating via cuttings and therefore captures best practices for a wide range of nursery types.

Table 1 Median across seven clustering variables for each of the three distinct clusters of nurseries

Cluster	Best practice index	Support from other CNOs index	Percentage of total labor hired	Percentage of total labor done by women	Nursery size (normalized)	Total use of water (normalized)	Expenditure in chemicals and fertilizers (normalized)
1	-0.67	0.09	23.9	42.0	0.09	0.16	0.13
2	-0.44	0.09	92.0	34.9	0.19	0.23	0.21
3	1.67	0.15	94.1	34.5	0.23	0.17	0.41

To explicitly identify clusters of like nurseries, we use cluster analysis, which is a standard exploratory data analysis methodology for grouping observations based on similarities along multiple pre-defined dimensions. In our case, we chose to conduct cluster analysis using seven pre-defined characteristics of nurseries:[26] (1) best practices index, (2) the degree of technical and other support from and interaction with other CNOs (constructed as an index of relative engagement with other CNOs), (3) the percentage of total labor that is hired (as opposed to non-hired family labor), (4) the percentage of labor done by women, (5) the size of the nursery (constructed as an index of relative size), (6) the amount of water used in the nursery (constructed as an index of relative water usage), and (7) total expenditures on chemicals and fertilizers (constructed as an index of relative input investment). We extract three distinct clusters from this analysis as shown in Table 1.

The spatial distribution of these three types of nurseries is shown in the map in Figure 9. Based on the observable differences across these groupings of nurseries, we describe these three clusters as follows:

- **Cluster 1 "Small, low-input nurseries using family labor and very poor practices"** These nurseries score very low on the best practices index and employ family labor for the majority of the work around the nursery. They are slightly more likely to use female labor. They are the smallest of the three clusters and invest only lightly in chemical and fertilizer inputs. These nurseries appear to correspond quite well to the low-input low-cost nursery model describe in Mbwoa (2014). Cluster 1 nurseries produce 11 percent of the total seedlings in our sample.

- **Cluster 2 "Larger, medium-input nurseries using poor practices"** These nurseries score slightly better on the best practices index, but still do poorly in this regard. They are no more likely to be connected to other CNOs than Cluster 1 nurseries, but are much larger, employ hired labor and invest more in chemical and fertilizer inputs. Overall, these nurseries appear to be larger and more formal versions of Cluster 1 nurseries. Cluster 2 nurseries produce 60 percent of the total seedlings in our sample.

- **Cluster 3 "Largest, high-input, well-connected nurseries using good practices"** These nurseries clearly stand out from their cluster 1 and 2 counterparts. In particular, they score much higher on the best practices index, are much more integrated into local CNO networks, invest much more in purchased inputs, and produce more seedlings than the other two clusters. If high quality planting material is likely to emerge from the current CPMP via UCDA-registered nurseries, it is almost certainly going to emanate from these Cluster 3 nurseries, which produce 29 percent of the total seedlings in our sample.

[26] We conduct this using a comparison of median values of these seven variables rather than of mean values to limit the influence of potential outliers in the data.

The assessment of propagation practices is central to how the heterogeneity in the CPMP translates into the retention of production value potential. The cluster analysis only uses relative differences in these best practices between different CNOs. We also care about the absolute extent of best practice adoption. In Table 2, we show the average “yes” response to a selection of best practices. While cluster 3 nurseries clearly have better propagation practices, adherence with best practices falls well short of complete even among these higher quality CNOs.

Table 2: Selected average responses to “best practices” questions by cluster

Nursery Practice	"Yes" by Cluster 1	2	3
Do you use an agricultural shade net or greenhouse net in your nursery?	16.7%	34.7%	86.1%
Does your shade net have a height of 3 meters?	20.8%	31.6%	88.9%
Do you use polypots of size 4-6 inches in diameter and height?	29.2%	48.4%	94.4%
Do you roast potting soil to kill pathogens?	8.3%	10.5%	27.8%
Do you sieve potting soil?	58.3%	64.2%	83.3%
Do you use clean and clear water without sedimentation (i.e., filter water if not from the tap)?	83.3%	82.1%	77.8%
Is this nursery supervised by well qualified nursery supervisor (e.g., with a degree in Agronomy)?	33.3%	35.8%	36.1%
Does this nursery have a proper disposal of polypots (i.e., not littered all over the nursery and its surrounding?	58.3%	53.7%	88.9%
Does this coffee nursery has a footbath?	4.2%	5.3%	16.7%
Do you use separate sprayers (knapsack) for fungicides and herbicides?	62.5%	62.1%	83.3%

Now that we have well-defined clusters of nurseries that share essential characteristics, we can delve deeper into these dimensions of heterogeneity. Although descriptive and exploratory in nature, this analysis provides some key insight into the functioning and structure of the current Robusta CPMP. Since so much of planting material quality – including, CWD-r – hinges on clonal propagation of cuttings from a mother garden, we first look at the prevalence of established mother gardens by cluster.

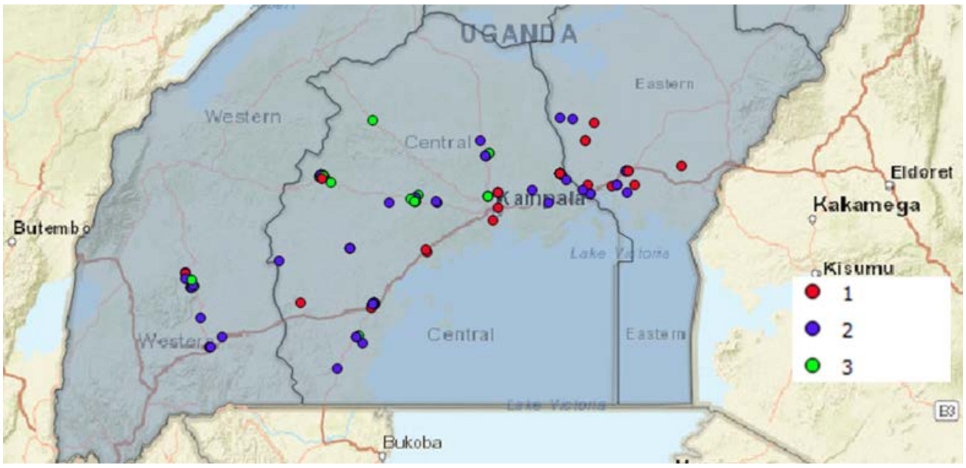

Figure 9: Map of surveyed CNOs by cluster

The top panel in Table 3 shows that while 42 percent of nurseries in cluster 3 have a mother garden, very few in clusters 1 and 2 have one. The lower panel of Table 2 shows a clear (and related) pattern in the age of the nursery: Cluster 3 is the most established of the three types. Taken together, these patterns seem to corroborate the evolution of UCDA priorities with respect to the CPMP over the past decade. As mentioned above, at about the time that cluster 3 nurseries were being formed, UCDA was trying to expand the capacity of the CPMP to create clonal cuttings in order to ensure the diffusion of CWD-r planting material. As frustration set in over the difficulty of this approach and the pressure to dramatically expand coffee production mounted, UCDA shifted its focus to volume of coffee seedlings produced by the CPMP. While other explanations may also have merit,[27] this shift is apparent in the clusters of nurseries in our sample. Without disaggregating by cluster we find that nurseries with mother gardens are on average older (11.4 years in operation) than those without mother garden (4.6 years in operation), which is consistent with UCDA training and registering CNOs under different objectives and criteria a decade or more ago.

Table 3: Median water usage per seedling per day by water source and cluster

Cluster	Percentage of CNOs that have a mother garden
1	5.9
2	8.1
3	41.7

Cluster	Years open (mean)
1	3.5
2	5.5
3	9.6

Not surprisingly, cluster 3 CNOs who are more likely to have a mother garden are more likely to pay attention to the source material they use in their nursery. Specifically, we find that while 94 percent of cluster 3 CNOs always seek out specific source material, only 74 percent of cluster 2 CNOs do (with the other 26 percent taking whatever they can get). As a result of these mother garden capacity constraints and related differences between these clusters, less than 13 percent of the planting material produced in our sample are clonal cuttings. This implies that *at most* 13 percent of the planting material from our sample

27 In particular, one explanation could be that cluster 3 CNOs are further along a learning curve and that cluster 2 and 1 CNOs will follow suite if given sufficient time to mature and learn best practices, etc. As addressed below, we do not think this is as credible an explanation and believe instead that the selection of CNOs being drawn into nursery management has changed substantially with UCDA priorities.

nurseries is resistant to CWD, leaving an astounding 87 percent of the CPMP susceptible to this devastating disease.

Next, we consider the quality of the water source used to irrigate the planting material in the nursery – disaggregated by cluster. Since the two most important sources of contamination and disease in a coffee nursery are soil and water, this has a direct and important effect on phytosanitary health and vigor of the planting material. As shown in Table 4, there is a clear difference in water source and usage across our three clusters. We find that cluster 3 CNOs use significantly less water than their cluster 1 and 2 counterparts and that the water they use is much more likely to be from a high quality source. More specifically, 58 percent and 65 percent of water used by cluster 1 and 2 nurseries, respectively, comes from low quality sources (i.e., stagnant or open water sources). In contrast, 43 percent of water in cluster 3 nurseries is low quality.

Table 4: Savings and loans as a source of capital for investment in nursery

Cluster	High quality source	Low quality source
1	0.151	0.212
2	0.073	0.132
3	0.038	0.028

Median usage of water per seedling by type of source.
High quality source includes: Tap, tank, borehole and well
Low quality source includes: River and stagnant sources

Table 5: Savings and loans as a source of capital for investment in nursery

Cluster	Used savings for nursery	Used loan for nursery
1	77.1	29.4
2	86.6	36.1
3	87.5	41.7

We next consider the source of financing for nursery operations and the cost structure of the nurseries in our sample by cluster. Table 5 shows that all three clusters tap personal savings with considerable frequency to finance their operations. While nearly 90 percent of cluster 3 nurseries use personal savings in this way, cluster 1 nurseries are not far behind at 77 percent. Although fewer rely on formal loans from banks or other credit institutions to finance their nursery operations and cluster 3 nurseries use credit with greater frequency, they are not that different than their cluster 1 and 2 counterparts.

Since these nurseries tend to be individual operations, the wealth level of the CNO can have a significant impact on how well capitalized the nursery is. For the two-thirds of respondents who are CNOs we collected detailed asset data and other wealth indicators (e.g., access to remitances). We use these variables to construct a factor analytic wealth index (similar to the best practices index above). We graph the distribution of this wealth index for each cluster separately in Figure 10. There are two noteworthy patterns in this figure. First, it is generally true that cluster 3 CNOs are wealthier than cluster 2 CNOs, who are wealthier than cluster 1 CNOs. This includes some cluster 3 CNOs who are quite wealthy in relative terms (e.g., wealth index>2). Second, cluster 2 CNOs include some quite poor individuals – CNOs who are poorer than even their cluster 1 counterparts. Below we explore two possible explanations for these clear differneces between the CNOs in different clusters – explanations with important implications for the policy and structure related to the CPMP.

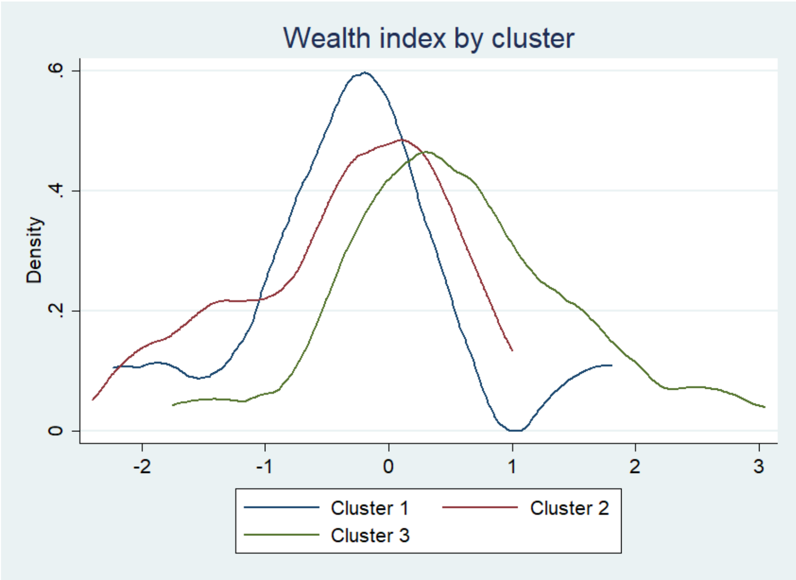

Figure 10: Distribution of CNO wealth index by cluster

Figure 11 depicts the cost structure of nurseries by cluster. In the left panel, we see that the general breakdown of costs is remarkably similar across the three clusters. In the right panel, we see were all the differences emerge: in the composition of "other" costs. Interestingly, cluster 2 nursuries make up nearly all of the transportation expenses.[28] The next pattern that stands out in the composition of "other" costs pertains to water bills: cluster 3 nursuries invest relatively heavily in improved water sources (as opposed to stagnant but free or cheaper water sources). The composition of the laborforce employed by these different nurseries is quite distinct in cluster 1, which relies more heavily on family labor than either cluster 2 or 3 (see Figure 11).

[28] While it is unclear why this is, it may be that UCDA requires them to transport their seedlings to collection points but directly procures from cluster 3 nurseries.

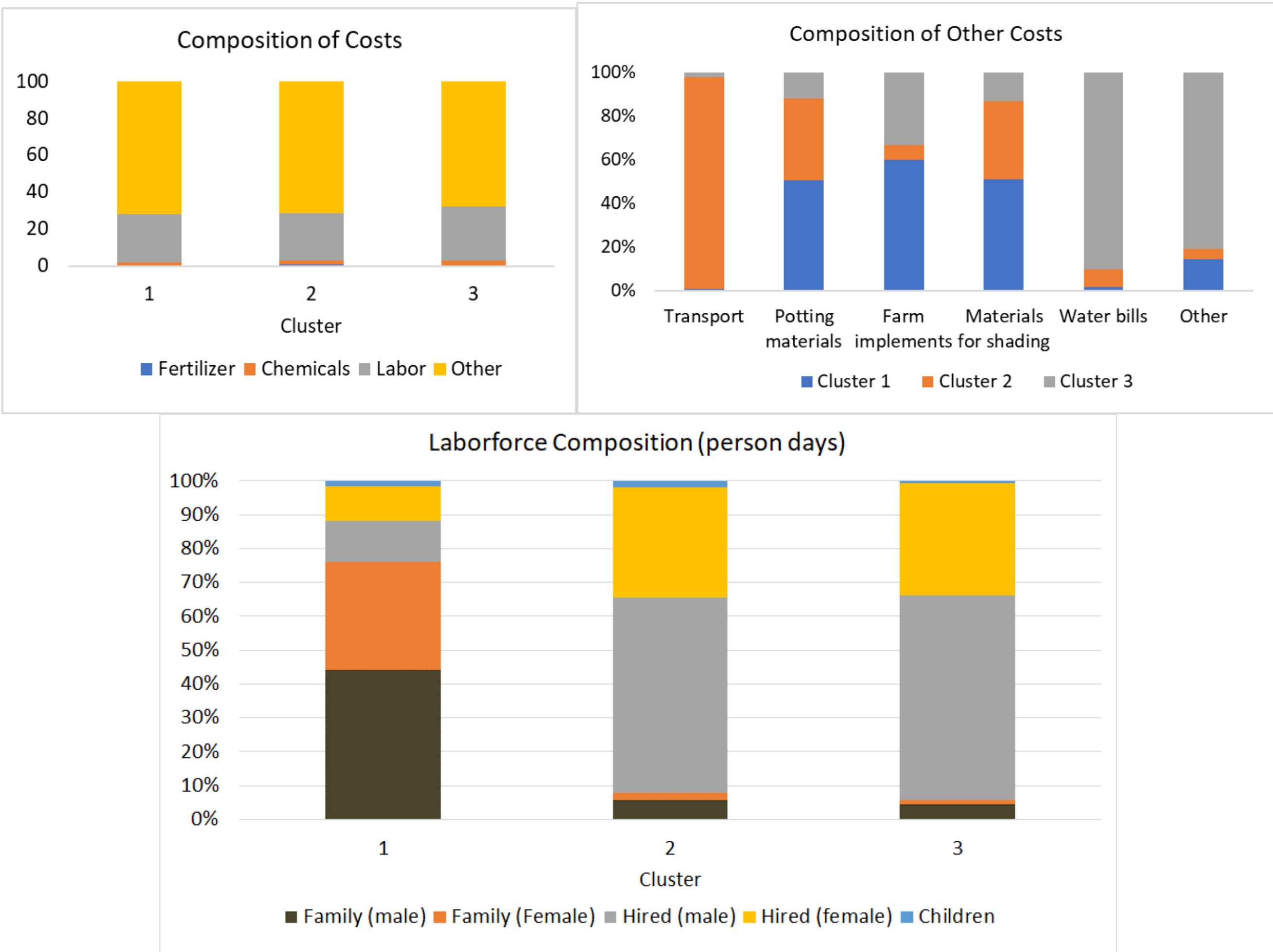

Figure 11: Cost structure and composition by cluster

To understand the economic viability of these different clusters we combine measures of input usage and revenue to gauge overall profitability of these operations. Carefully constructing profit measures is a painstaking process that is beyond the scope of this study and the subject of the AMA (2015) report for AMA,[29] so we aim instead to gauge the relative profitability of nurseries in the different clusters.

[29] For more details on the return on investment of different types of nurseries, see AMA (2015).

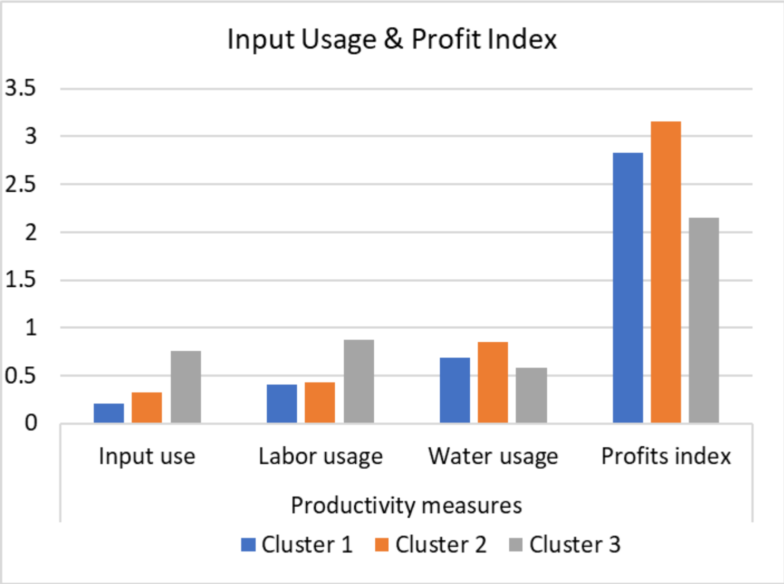

Figure 12: Input use and profit indices by cluster

As seen in Figure 12, which confirms many of the patterns we have already seen, cluster 3 nurseries stand out as using more inputs and labor, but they earn lower profits according to our measured profit index. With all the standard caveats and potential problems with self-reported cost and revenue measures in mind,[30] this pattern may suggest that in the current Robusta CPMP the additional investments made by cluster 3 nurseries, which almost surely enhance the quality of the planting material they produce, do not generate additional profit for the operation. If this is true, the most likely explanation has to do with the rigid pricing scheme that UCDA uses to procure seedlings from CNOs.

We find that 92 percent of all seedlings sold to UCDA/NAADS as part of the OWC distribution activities were sold at the standard price of 300 UGX per seedling. A few cluster 3 CNOs claimed to receive prices of 500, 700, 1000, 1200, and 1500 UGX for clonal cuttings, but these higher prices among a select few nurseries do not appear to offset the generally higher input costs associated with better practices. If procurement prices are not sufficiently responsive to improvements in planting material quality, they may not enable these higher quality nurseries to reap a return on investment in improved practices. UCDA appears to have recently updated its stated procurement prices, as mentioned above, but there is not yet evidence that these stated prices will be implemented and offered to CNOs in a way that meaningfully enhances their incentives to produce invest in producing higher quality planting material. This has important implications for incentives to innovate and retain value throughout the CPMP and clearly deserves more attention in follow-on research.

We have explored in detail the heterogeneity in observable characteristics and nursery structure and performance between these three distinct nursery clusters. It is clear from this analysis that cluster 3 nurseries are very different than the other two clusters. Since cluster 3 nurseries are more likely to turn out quality seedlings that retain more production potential than those produced by cluster 1 and 2 nurseries, it is important to distinguish between two possible explanations for these systematic differences. First, it could be that these differences are evidence of nurseries and CNOs becoming more sophisticated and adopting

[30] Since we are most interested in a measure of relative profits rather than the absolute profit level, we are most concerned with potentially systematic differences in self-reported costs and revenues across these three clusters. In particular, if cluster 3 nurseries are more inclined to underreport revenues, then our comparison between clusters would be partly misleading. We acknowledge these concerns and, with these in mind, have strived to construct these profit measure as carefully and completely as possible.

better practices over time; after all, cluster 3 nurseries are much older and more established than their counterparts. Second, it could be that these differences are due instead to a self-selection effect at the time these nurseries were established. For example, these differences may simply reflect the evolution of UCDA priorities as they recruited and trained different cohorts of CNOs. Cluster 3 CNOs may have been established when UCDA was actively recruiting would-be CNOs who were wealthier and better able to finance their nursery operations and to establish improved production practices, including establishing mother gardens. Since over 70 percent of all seedlings in our sample are produced by cluster 1 and 2 nurseries, decyphering between these two competing explanations is very important: If differences are due to learning and maturing over time, then perhaps the quality of material produced by clusters 1 and 2 will steadily imporve in the coming years.

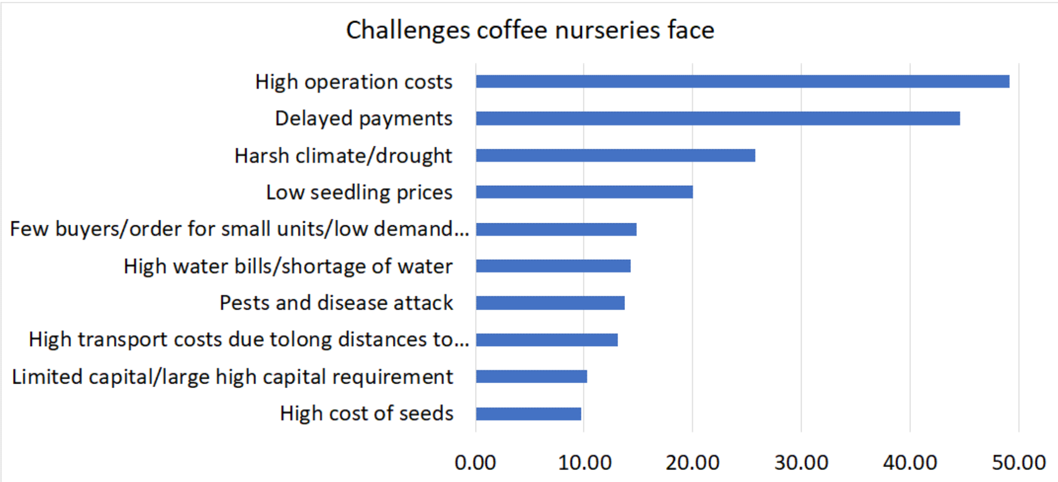

Figure 13: Frequency of responses to open-ended question about the challenges of operating a coffee nursery

If, however, differences are due to initial selection, then these observable differences may not improve naturally over time with experience in the nursery business – and quality improvements for the majority of seedlings in the official UCDA CPMP may be harder to come by. Our cross-sectional survey data does not allow us to analzye the evolution of cluster 3 nurseries, so we cannot conduct a rigorous test of the learning and maturing explanation. One simple test we can conduct, however, is to see whether there are structural, time-invariant differences between these clusters: We find that cluster 3 CNOs have 2.5 years (25 percent) more education than their cluster 1 and 2 counterparts. This evidence favors the selection explanation.

We conclude this section with a summary of the challenges nurseries face as stated by CNOs and managers, namely high operation costs, delayed payments, harsh climate / drought, low seedling price, few buyers and orders, high water bills or water shortage, pests and disease attach and other barriers. Figure 13 shows the frequency of responses to an open-ended question about the biggest challenges of operating a coffee nursery. As is evident, the two biggest concerns by far have to do with high operation costs and delayed payments (from UCDA). While high operation costs may simply reflect the costs of doing business (indeed, there is no indication that these high costs are artificially inflated due to any policy-induced market distortions), the delayed UCDA payments are an artifact of the way UCDA operates. This concern has been raised by others beyond the CNOs in our sample (e.g., AMA 2015) and has important implications for the transmission of incentives for quality in the CPMP.

2.6 Vertical Integration of In-House Coffee Nurseries and Innovation in "Cluster 4"

While the vast majority of coffee planting material is produced and distributed via the CPMP described above and characterized in the preceding section, the past 15 years or so have seen some important innovation in private nurseries that provide a high quality alternative to the UCDA CPMP. These in-house nurseries for Robusta coffee provide a stark contrast to the heterogeneity we explore using CNO survey data above. Whereas we identify three distinct clusters in the UCDA CPMP, the private in-house nurseries constitute a separate cluster altogether. For the purposes of this report, we refer to this set of high quality nurseries as "Cluster 4" nurseries, but hasten to clarify that this cluster is not represented in our CNO survey data and therefore does not emerge from the cluster analysis described above. Instead, we describe two such vertically-integrated firms using mainly qualitative, anecdotal information about the existence and structure of these nurseries. Specifically, building on the information provided in the AMA (2015) report, we directly contacted a selection of large coffee producers and exporters in Uganda with potential in-house nursery capacity to conduct brief interviews.

Before delving into what we learned about these "cluster 4" nurseries and discussing two cases of vertically-integrated firms with in-house nursery facilities, we elaborate briefly on the insight mentioned earlier: According to a well-known economic theory originally postulated by Ronald Coase as the "Theory of the Firm," firms exist when transactions costs make production, processing or service provision via market mechanisms, including contracts, prohibitively costly or inefficient. In such cases, a firm can find it profitable to internalize the transaction so that it need not rely on specialized market intermediaries for these inputs or services. This seems to describe very well the emergence of private, in-house coffee nurseries, especially in the wake of the CWD outbreak in the late 1990s. Large producers and exporters realized that there were risks of receiving inferior quality planting material from independent nurseries. Given the long-term investment riding on this planting material, there was simply too much riding on the vitality, vigor and resilience of the seedlings they transplanted to trust seedlings of unknown provenance, genetic potential and phytosanitary quality. From the perspective of these large, high quality producers, this form of excessive transaction cost to procuring seedlings from the market because especially untenable when NaCORI released the seven lines of CWD-r material. At that point, the risk of not benefiting from this material and being fully exposed to another CWD outbreak was unacceptable – and they opted instead to vertically integrate the propagation of planting material via private, in-house nurseries with CWD-r material procured directly from NaCORI.

The companies we contacted for information about engagement in private, in-house nursery production of coffee planting material are listed in Table 6. This collection of major private actors in the coffee sector in recent years represent a wide range of private approaches to procuring planting material. The first four listed in this table have full and direct control over the production of planting material. Some offer this material to UCDA, but seem to rely more heavily on demand from individual farmers and, in the case of the Neumann Gruppe GmbH, from their own estates, making this the only company that is fully vertically-integrated. We offer more details about this company and Kyagalanyi Coffee, Ltd.

Table 6: Major coffee producers and exporters in Uganda with nursery details

Company Name & Contact Information	No. of seedlings produced/year	Source of Planting Material	Degree of nursery control	Customers
Agromax (U), Ltd. Plot 92, Lutette, Gayaza Road Kampala, Uganda. Phone: +256 (0) 756 622465 / +256 (0) 414 666030 Fax:+256 (0) 414 343632 Email: info@agromaxug.com	500,000 seedlings	• Procure coffee seeds from UCDA or other seed suppliers certified by UCDA • Cuttings purchased directly from NaCORI • All material is verified as CWD-r	Full, direct control	• UCDA • Individual farmers
Kyagalanyi Coffee, Ltd Address P.O Box 3181 Kampala Location Kampala Industrial Business Park, Namanve Telephone +256 414 344021/ 251447 Fax +256 414 230145	About 160,000 seedlings	• Has a mother garden for Robusta coffee where they get the cuttings for propagation • UCDA certifies its nurseries • Also procure coffee seeds from UCDA or its certified suppliers	Full, direct control	• UCDA • Individual farmers
Neumann Gruppe GmbH Coffee Plaza · Am Sandtorpark 4 20457 Hamburg, Germany Tel: +49 (40) 808112 436 Fax: +49 (40) 808112 433 info@hrnstiftung.org	About 30,000 seedlings	• Cuttings from own mother garden • Cuttings purchased directly from NaCORI • Seeds from UCDA or certified suppliers • All material is verified as CWD-r	Full, direct control	• Own use in coffee estates on leased land • Individual farmers
Ankole Coffee Producers Cooperative Union, Ltd. Address P.O Box 172, Bushenyi. Location Bassaja Ward, along Mbarara-Kasese Road. Telephone 0772461876	N/A	Buy seeds from UCDA and raise both CWD-r and hybrid seedlings	Full, indirect control	• Farmers in Ankole region • Other farmers and companies in other regions
UGACOF, Ltd. Address P.O Box 7355 Kampala Location Plot 246 Kireku, Bweyogerere Telephone +256 414 250024/25 Fax +256 312 250020 Email reception@ugacof.com	About 300,000 seedlings	• Procures seed from a coffee farmer in Masaka. • Procures seed to raise coffee seedlings and seed to plant a mother garden	Partial control	• UCDA • Individual farmers
Hima Cement	Distributed 4.2 million per year to farmers in Kasese and Kamwenge districts (2012-17)	UCDA-registered CNOs	Limited/no control	Farmer associations (farmers paid 5UGX per seedling; Hima paid 300UGX per seedling)

Newmann Gruppe GmbH: This producer is a major international player in the coffee sector, with operations in Brazil, Mexico and Uganda. Their operations in Uganda started in 2001 - in the wake of the CWD outbreak and devastation. In a 2013 report, they claim about 2,500 hectares of coffee production area based on land they acquired via long-term lease.[31] They aim to produce 3,500 tons of green coffee a year. They also have their own nursery capacity to produce (in 2013) 120,000 coffee seedlings a year. These seedlings are reportedly produced using the full suite of best-practices with the best available germplasm, including CWD-r material directly procured from NaCORI. Presumably, this means they maintain their own mother gardens for clonal cutting propagation, although it is likely that they also have access to tissue culture plantlets – possibly via contract with private tissue culture labs in the Kampala/Entebbe area.

Kyagalanyi Coffee, Ltd: This is a leading coffee procurement, processing and exporting company in Uganda. In 2009, its total exports constituted roughly 16 percent of total coffee exports from Uganda. This firm works directly with farmers and farmer groups to procure their supplies of coffee berries and beans. Given its clear stake in the productivity of these farmer-suppliers, Kyagalanyi invested heavily in propagating CWD-r material at a large private nursery facility in Mukuno District. Conveniently – and not coincidentally – this facility is located in the same district as the main NaCORI facilities. After adhering to strict propagation practices, which may include access to tissue culture plantlets but surely consists of clonal cuttings from CWD-r mother gardens, Kyagalanyi makes this planting material available to farmers at no cost. It is not clear how farmers are selected to participate in this production network and under what contractual terms, but farmers who are selected as Kyagalanyi producers have access to superior planting material with much greater production potential.

2.7 Summary of Results and Implications for Innovation Policy in the Ugandan CPMP

Several findings emerge from this exploration of the Robusta CPMP in Uganda. We summarize seven key results in this section and use our conceptual framework to provide a perspective on these findings.

1. The CPMP in Uganda is subject to a host of constraints and challenges that characterize rural life in Uganda for the many actors in the pipeline between NaCORI and farmers, including the smallholder farmers themselves. These constraints and challenges make it difficult to retain the full value of potential production of coffee planting material. Remedies to these general constraints extend well beyond the specifics of the CPMP (e.g., infrastructure, credit and liquidity constraints, technical training and skills, uninsured risk, etc.).

2. The Coffee 2020 Plan seems to have prompted UCDA to sacrifice quality of the planting material produced by nurseries in order to dramatically expand the quantity of seedlings produced by the CPMP. This has created significant new "leakage" of production potential and jeopardizes the productivity and resilience of smallholder coffee farmers in Uganda for decades to come.

3. The official UCDA pipeline for Robusta planting material consists of three distinct clusters of nurseries. While adherence to best practices is low across all three clusters, it is particularly low among the smaller, newer and low-investment CNOs that were recently recruited and registered with UCDA. These poor propagation practices likely compromise the vigor and phytosanitary health of seedlings. Since

[31] See http://www.nkg.net/userfiles/Documents/2013-01-30-facts-figures-ng-kaweri-en.pdf (accessed 2 Jan 2018).

each seedling comes with its own soil and poly-pack, these poor practices may even contribute to the spread of CWD and other pests or diseases.

4. Only some of the cluster 3 nurseries are equipped to clonally propagate CWD-r cuttings from a mother garden. This explains why 95 percent or more of the seedlings distributed via the UCDA are not CWD-r. This inferior germplasm in seedlings produced with poor practices is being “locked-in” for decades to come. Consequently, the expected present value of the seedlings produced in the current CPMP is therefore considerably lower than it might otherwise be.

5. We find evidence that the clear differences between the older CNOs in cluster 3 and the newer CNOs in cluster 1 and 2 are due to selection of different types of CNOs over the past 12 or more years – likely as UCDA has changed its objectives and priorities in recruiting and training CNOs. While these differences do not appear to be due to the older CNOs learning and upgrading their practices over time, we cannot rule out this explanation entirely.

6. In addition to directly shaping the structure of the CPMP via recruiting and training, the UCDA indirectly and importantly shapes the incentives to invest in quality and to innovate by the way it governs the pipeline. At the time of our survey and from the perspective of the CNOs in our sample, seedling procurement prices appeared to be relatively non-responsive to quality. As a result, cluster 3 CNOs seem to invest more, but have lower profits than their cluster 1 and 2 counterparts. Recent changes in procurement prices may change this. With UCDA as an intermediary, there is little scope for CNOs to convey information about the quality of the seedlings they produce directly to farmers. Finally, consistent with many other reports, CNOs cite delayed payments from UCDA as a top concern. These features of the UCDA pipeline effectively discourage CNO investments in quality practices and seedlings.

7. The highest quality planting material in Uganda is produced outside the UCDA CPMP in private, in-house nurseries that we refer to as “cluster 4.” These nurseries seem to have formed in the wake of the CWD outbreak of the late 1990s as firms realized the importance of procuring high quality, CWD-r planting material with certainty and vertically integrated to internalize these benefits. We know less about these cluster 4 nurseries given that they are private and were not in our sample, but they seem to source CWD-r material directly from NaCORI and thereby retain as close to full production value as possible.

As a heuristic summary of these results, we offer Figure 14. This simple diagram abstracts from some of the complexity of the CPMP as we have describe it in this report, but captures essential elements of the heterogeneity in the capacity of CNOs along the pipeline. There are a few pieces of the CPMP that we have not been able to verify in full detail, including whether there are sources of germplasm beyond that provided by NaCORI and whether “cluster 4” nurseries provide high quality CWD-r planting material to the UCDA/NAADS distribution channel. Overall, however, the picture that emerges is one where the vast majority of planting material that is currently flooding areas with a history of or potential for coffee cultivation is inferior quality and CWD susceptible.

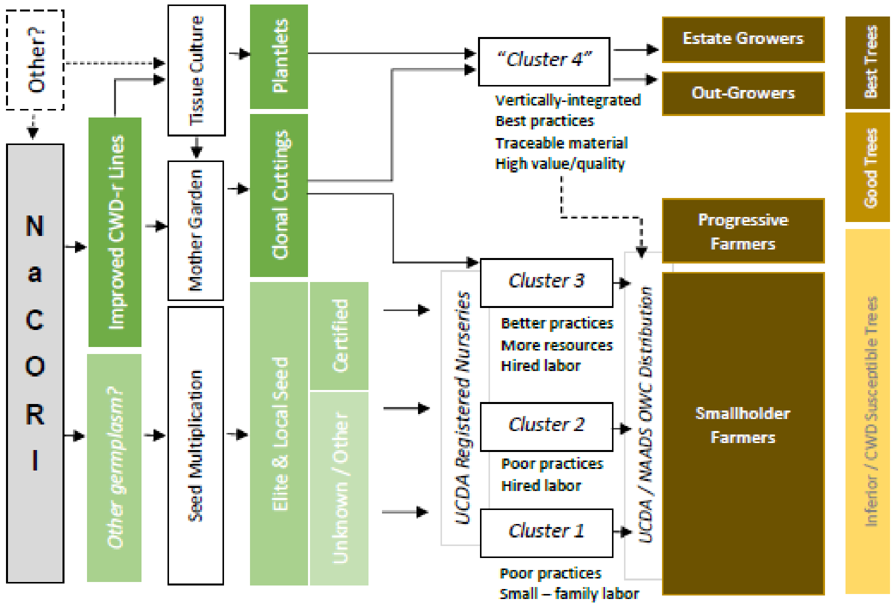

Figure 14: Heuristic summary of results emphasizing the heterogeneity in CPMP and associated implications for farm-level planting and material quality.

These seven key findings and this heuristic summary map directly into the "constraints and distortions" component of the conceptual framework for the broader project shown in Figure 1 above. In this figure, the CPMP is the "upstream" study. A confluence of domestic and international R&D funds, mainly public funds, have supported the work of NaCORI to generate improved Robusta varieties, in particular the CWD-r varieties released in 2007. These improved technologies have vast potential in the Ugandan agri-food sector given the preeminence of the coffee sub-sector in Uganda. As a direct consequence of the seven findings described above, however, only a trickle of this value emerges from the CPMP as realized benefits to coffee farmers and to the coffee sub-sector more generally. These severe constraints limit not just the production value of new coffee plantations, but also limit the return on the original investments. This almost certainly hampers subsequent R&D investments, including would-be private sector investments in the Ugandan coffee sub-sector (e.g., from companies such as Xclusive Cuttings, the Neumann Gruppe, etc.).

What does this exploration of the Robusta CPMP in Uganda and the seven key findings summarized above mean for innovation incentives and innovation policy? Innovation typically entails investment – and the CPMP in Uganda is no exception: Real investments of resources will be required to upgrade the CPMP to (i) generate higher potential production value at the upstream plant breeding stages and (ii) retain more of this production value as the material is propagated and multiplied and ultimately delivered to farmer as Robusta seedlings. It is important to recognize, however, that the current CPMP also entails significant investments in resources, but, as discussed above, these investments have increasingly been aimed at scaling up the volume of seedlings produced rather than their quality.

To illustrate this point, consider the official records on the 2016 seedling distribution campaign coordinated by UCDA/NAADS under the OWC initiative. As shown in Table 7, the 64.5 million seedlings distributed in this campaign (REF) entailed an estimated seedling procurement cost of 19,350 million UGX (USD 5.7 million), excluding all costs of procurement beyond the direct purchase of seedlings. Based on official reports, approximately 64 percent of these seedlings died before being successfully transplanted, which represents a direct loss (not accounting for all other costs of procurement and distribution) of 12,390 million UGX (USD 3.64 million). With this very low survival rate, the effective direct cost per seedling (excluding all other costs) is 834 UGX, nearly triple the official procurement price at the time of 300 UGX. To demonstrate an alternative allocation of these direct procurement funds, consider the counterfactual depicted in Table 7. Suppose that instead of prioritizing quantity of seedlings, the UCDA coordinated the CPMP to prioritize seedling quality with high survival rates and was able to achieve a survival rate of 85 percent. In this scenario, the UCDA could have offered CNOs 709 UGX per seedling with the same direct procurement budget. If we were to account for all the indirect costs of procurement, they could have offered considerably more than this given all the other savings with distributing less than half as many seedlings throughout the country.

Although this exercise is meant only to be suggestive, it is not hard to imagine a different scenario where, without increasing its investment in the CPMP, UCDA might have achieved the same number of new established coffee trees (23.2 million) with seedlings with an expected production value profile like the "Full Potential" in Figures 4 and 5. Instead, the new coffee trees are, on average, lower potential and non-CWD-r.

Table 7: Actual 2016 allocation of seedlings versus a counterfactual allocation that prioritizes quality over quantity

		Value (UGX)	**Value (USD)**
UCDA seedling procurement price in 2016 (UGX)		300	0.09
Exchange rate in 2016 (UGX/USD)	3400		
Actual Procurement Record in 2016			
Total seedlings procured	64,500,000	19,350,000,000	5,691,176
Seedlings survived to transplanting	23,200,000		
Seedlings lost between procurement and transplanting	41,300,000	12,390,000,000	3,644,118
Effective cost per transplanted seedling		834	0.25

Counterfactual			
To achieve the same total number of seedlings transplanted in 2016 but with an improved survival rate of 85 percent, how much could UCDA have offered CNOs for seedlings on average?			
Seedlings procured to match total transplanted in 2016 at counterfactual 85 percent survival rate.	27,294,118		
"Budget neutral" seedling procurement price		709	0.21

Based on this rough approximation, it is clear there are resources in the current CPMP that might be allocated in a different way to more directly incentivize innovation and to amplify the return on investment in upstream innovation. Of course, there are limits to what this kind of a "budget neutral" counterfactual can achieve as large improvements in innovation outcomes will almost surely demand real increases in investment in the CPMP. We find some evidence that the cluster 3 CNOs are investing their own resources in improved production practices in general, but did not discover specific cases of true innovation on their part. This is not entirely surprising given that the UCDA is the intermediary for the vast majority of the planting material emerging from the official UCDA CPMP. This appears to leave little room for market incentives to produce high quality planting material to transmit directly to CNOs (although the recently announced prices for improved seedlings may improve these incentives).

The most striking evidence of innovation in the propagation of planting material instead comes from the "cluster 4" private nurseries that almost surely produce the most uniformly high quality seedlings in Uganda. Tellingly, these nurseries have emerged where vertically-integrated firms have fully internalized their return on investments in improved practices. Outside of these in-house nurseries, there appears to be only weak incentives at best for CNOs to make similar investments. Consequently, there are two distinct and parallel futures for Ugandan Robusta coffee: Farmers fortunate enough to have access to "cluster 4" seedlings are investing in quite a different productivity future as coffee farmers than their counterparts who rely on the UCDA CPMP. Because they are working with higher potential material from the time of transplanting, these fortunate farmers are more likely to invest coffee production for the life of the tree due to productivity synergies in inputs (i.e., high quality initial inputs raise the returns on subsequent high quality inputs).

The presence and success of "cluster 4" nurseries in Uganda will continue to shape the ongoing dynamics of the CPMP, including any attempts to upgrade this pipeline. Consider two extreme paths that might emanate from these "cluster 4" nurseries in the coming decade. First, the official UCDA CPMP may function for years to come independently of the more advanced "cluster 4." Second, "cluster 4" nurseries may scale up rapidly and outcompete on quality the existing UCDA CPMP. Based on the analysis in this study, the next decade will almost surely look more like the first path than the second. There is simply very little evidence that "cluster 4" nurseries aspire to dominating the planting material pipeline. This likely path raises upgrading opportunities and provides a few clear policy recommendations. First, demonstrated successes in "cluster 4" offer valuable opportunities to learn how to upgrade the UCDA CPMP. Such demonstration effects are likely to be especially powerful among the more capable and more entrepreneurial cluster 3 CNOs.

These learning spillovers need not be confined to technical aspects of nursery management; much could be learned from these private nurseries about the form and level of incentives needed to instigate UCDA CNOs to upgrade their practices and investments, including access to higher procurement prices for higher quality material. Second, there are surely opportunities to engage "cluster 4" firms and other service providers more directly in the CPMP via private-public partnerships. UCDA already sources some material from these nurseries, but more could be done to aggressively and strategically leverage this capacity to upgrade the public CPMP as described more below. Finally, "cluster 4" has succeeded in large part by internalizing the benefits of high quality planting material via vertical integration. UCDA should explore ways to replicate these successes through enhanced property rights along the CPMP, including the implementation of PVP as described in greater detail below. In order to induce greater investments in upgrading the CPMP in order to tap the full potential of upstream innovation and to incentivize further innovation investments, it is critical to improve the transmission of information about planting material quality to farmers and other actors in the pipeline. While UCDA presently conducts periodic inspections of registered CNOs,[32] there is a real need for independent and rigorous verification of propagation conditions. Such services are already offered elsewhere in the agricultural inputs sector in Uganda: AgVerify[33] is scaling up quickly to provide such verification services with other crops. UCDA should issue a request for proposals from firms like AgVerify to explore the possibilities for independent verification and even certification so that farmers can have greater confidence that their planting material is high quality, CWD-r that is

[32] Despite repeated requests, we were unable to learn the details of these inspections.
[33] See https://www.agverify.net/ (Accessed 10 January 2018).

worth their time and investments. Relatedly, DNA fingerprinting technologies and techniques are advancing quickly. It may soon be possible to cost-effectively determine key genetic features of both seedlings and established coffee trees. Conducting a representative inventory of these traits should be a top priority and the possibility of continued monitoring with DNA fingerprinting tests might provide greater incentives for compliance with best propagation practices. These tests may be particularly useful as UCDA introduces a multi-price menu for procuring seedlings from CNOs.

To further incentivize investments in the CPMP and in upstream innovation, UCDA should experiment with new ways of educating smallholder farmers and giving them greater choice and greater influence over CNOs. Among such "demand pull" options are improved agricultural extension and a voucher system that gives farmers greater voice in the CPMP. In order to reap the benefits of upgrading the CPMP, farmers must be more aware of quality and understand why they should be more discriminating when choosing planting material. In this sense, an effective agricultural extension system for coffee farmers is a critical component to upgrading the CPMP as a means to stimulating demand of quality planting material. To give farmers greater choice over material, UCDA should consider piloting a voucher system for seedlings in which farmers can choose whether to receive generic UCDA seedlings as usual or to receive vouchers that directly subsidize their purchase of seedlings from CNOs. This would enable farmers to self-select into the market for higher quality seedlings and would incentivize the more entrepreneurial and innovative CNOs to respond with better seedlings and new ways of signaling quality to their customers. These CNOs might quickly realize how much they could learn from the "cluster 4" nurseries about producing the highest quality planting material. Voucher systems can be challenging to implement, but the time is ripe for modest experimentation with such pilots to incentivize greater investment as Uganda aims for 20 million bags produced in 2030.

In the context of the agricultural innovation systems heuristic (see Figure 1) and in the Ugandan CPMP, public-private partnerships can play an especially important role encouraging greater innovation and productivity investments. There may be several places throughout the CPMP where such partnerships would be worth pursuing, but the potential impact is no where greater than with tissue culture laboratories. One constraint that has prevented the improved CWD-r material from circulating widely to mother gardens throughout Uganda is the limited capacity of NaCORI to produce clonal cuttings or tissue culture plantlets of their seven CWD-r lines. Apparently, over the past decade several private tissue culture labs have offered their services to quickly multiply these plantlets, but the details of both the offer and the response by Ugandan officials are unclear. What is clearly true is that there is now sufficient tissue culture capacity in the private sector in and around Kampala (see AMA 2015) to propagate millions of plantlets in a matter of months. Negotiating a partnership with these labs should be a top priority for NaCORI and UCDA jointly. With a full pipeline of CWD-r plantlets to deliver to CNOs with mother gardens throughout the country, combined with improved UCDA procurement practices and prices, many more CNOs may be induced to invest in mother garden facilities. More generally, there are likely many other opportunities for the "cluster 4" capacity in Uganda could be tapped more strategically through such partnerships to upgrade the CPMP.

How does IP policy specifically relate to this exploration of the Ugandan Robusta CPMP? While utility models, patents and trademarks may be relevant to the Uganda coffee sector in the upstream and downstream (e.g., for processing equipment, branding, etc.), in the upstream planting material pipeline, other areas of IP, notably geographic indicators (GIs) are more relevant. It is possible that GIs could help to differentiate downstream demand for coffee beans in ways that shape the CPMP upstream since GIs apply to specific geographic areas and might thereby alter the investment and innovation incentives throughout the pipeline in favored areas, but this is much more likely with Arabica coffee that is more likely to carry a market premium. The IP form that is most likely to be relevant to the Robusta

CPMP in Uganda is plant variety protection (PVP), which is the subject of a Plant Variety Protection Law in Uganda that was signed in 2014. Since this law has yet to be operationalized in a way that enables it to be implemented and enforced, it currently has no direct effect on the CPMP. Moreover, investing in the institutional capacity needed to effectively implement PVP protection is a long-term commitment. Only such a long-term commitment is likely to create incentives for innovation in coffee variety breeding programs in both the public and private sector. In that future development, the enforcement of PVP over clonally propagated planting material and the associated collection of royalties or licensing payments to PVP holders will surely pose considerable challenges. Among the challenges and opportunities created by a functional and enforced PVP system will be germplasm imported from the international public and private sector. It is beyond this study to conduct a complete inventory of promising Robusta germplasm, but it is likely that a functional PVP system and a more responsive and incentivized CPMP would naturally attract and experiment with potentially important planting material from abroad.

In the short- to medium-term, however, there may be a more promising potential way forward with PVPs. Specifically, the dominant role that UCDA plays in coordinating and orchestrating the Ugandan CPMP and the dominate role that NaCORI currently plays in breeding improved coffee varieties suggest some possible paths to leveraging PVP to improve coffee productivity. Imagine, for example, that PVPs were enforceable in Uganda and that NaCORI received PVPs for its seven CWD-r lines (or some future improved variety that has yet to be released). The fact that UCDA acts as a near perfect monopsonist (single buyer) of planting material in the open (non-private) CPMP could dramatically simplify the enforcement of these PVPs and the collection of royalties for clonal cuttings of CWD-r mother gardens of the lines protected by PVP. Instead of being subject to the complexities of a competitive market with many small CNOs (sellers) and even more and smaller smallholder farmers (buyers), this reduces negotiations around these PVPs to two parties. Although it is not clear how such a benefit sharing arrangement would be negotiated between NaCORI, UCDA and private tissue culture labs (see above) - or even if such an agreement would be permissible under Ugandan law – it is nonetheless easier to envision this scenario of PVP shaping incentives and investments along the CPMP than one that entails a competitive market for planting material. The existing variety release committee of MAAIF could facilitate this coordination of PVP enforcement and associated royalty payments. With so few players, versions of this scenario for PVP-based incentives shaping the CPMP could even resemble a prize-based system in which UCDA issues a lump-sum prize to breeding research institutes (including, but not limited to NaCORI) to produce a new variety with specific attributes. Alternatively, the Uganda Government could streamline publicly funded research to leverage the IP resulting from that research. In that environment NaCORI is part of a competitive research environment involving public and private researchers who receive public funds to conduct research. In this case, IP incentivizes private and public companies that receive public funds to continuously pursue superior plant varieties.

The issues and opportunities raised in this report hinge crucially on seeing the coffee sub-sector in general and the CPMP in particular through a “systems lens” that appreciates the heavy influence and critical dynamics of linkages between upstream R&D, downstream farmers and markets, and the important institutions in-between that shape the enabling environment and bridge actors in this innovation system. To maintain our focus on the CPMP in this study, we have intentionally ignored the coffee value chains that links farmers to markets and ultimately to coffee drinkers around the world – value chains that raise many more innovation and innovation policy issues (e.g., Samper et al. 2017). Within the Robusta CPMP in Uganda, NaCORI link through UCDA and NAADS to millions of smallholder farmers. Among larger and more progressive coffee farmers, “cluster 4” nurseries and, perhaps, an ever expanding set of private tissue culture laboratories play a role in this pipeline. In all cases, there are potent complementarities at the production stage that feedback into this pipeline. Coffee farmers with high quality planting material face stronger incentives to invest in a host of complementary inputs and agronomic practices. The opposite is unfortunately also true, and the inferior quality seedlings delivered by the current CPMP will likely hamper coffee productivity for decades to come. This deleterious effect of inferior planting material comes both as a direct effect of lower production potential and as an indirect effect of diminished incentives to invest in improved complementary inputs and practices.

The dominant institutional role of UCDA in the CPMP offers an opportunity to upgrade the innovation systems that link importantly to the CPMP, but tapping this opportunity may first require broad willingness in the Uganda political economy to prioritize seedling quality over sheer numbers of seedlings distributed via OWC. Given how aggressively and quickly the CPMP has seemingly responded to the Coffee 2020 Plan, it is not difficult to imagine how a modest modification to this plan that sets specific goals for the share of seedlings transplanted that are CWD-r could dramatically tip the scales in favor of higher quality planting material.

3 Constraints & Innovation Opportunities in Uganda’s Tropical Fruit Processing Sub-Sector

The production and processing of tropical fruit form an important subsector of Uganda’s economy and contributes to household income and food and nutrition security in both the rural and urban areas of the country. Given Uganda’s favorable climate and production conditions, the list of tropical fruit produced in this subsector is long and diverse, including pineapples, oranges, passion fruits, mangoes, paw paws, tangerines, jack fruit, avocados, lemons, apple bananas, guavas, lemons, apples, berries and tomatoes. The subsector is also one of the fast-growing sources of foreign exchange in Uganda. Available statistics show that the value of fruits exported has generally trended upwards over the past two decades, increasing from USD 0.58 million in 1995 to USD 16.88 million in 2015 before dropping to about USD 10.86 million in 2016 (see Figure 15).[34]

Better performance of Uganda’s fruit sector is hampered by seasonal supply of fruits, fruit pests, e.g. fruit flies and high post-harvest losses. These constraints can be relaxed by developing and promoting innovations and appropriate technologies for fruit production and processing. Fruit processing reduces post-harvest losses and waste, especially during seasons with bumper harvests. Improved processing can also increase and conserve produce/product shelf-life, increase value of the more perishable produce, create employment more especially for the youth, reduce produce bulkiness, and stabilize and increase income and market value of fruits. Because fruits are widely produced in most parts of Uganda, innovations that add value to fruits can increase their productivity, and can contribute to improved household income, food and nutrition security in both rural and urban households in the country. Innovations are generated through interactive processes involving interactions among a wide array of public and private sector actors including individuals, firms, and organizations or associations that demand and supply technical, commercial and financial knowledge and competencies (World Bank, 2007)-- the public sector provides the enabling economic, social and institutional conditions for innovative processes.

[34] UNCTAD stats, downloaded on January 11, 2018.

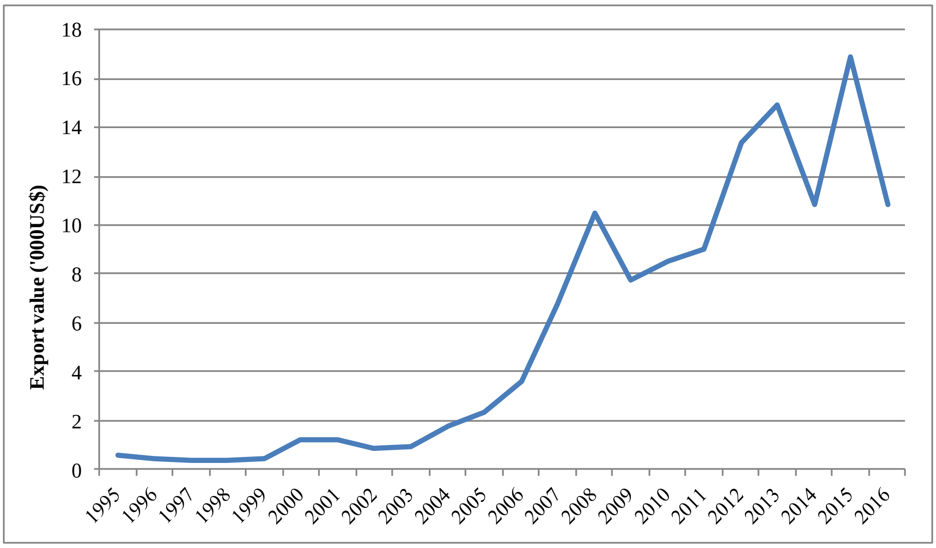

Figure 15: Estimated value of Uganda's exports (1995-2016)

Source: United Nations Conference on Trade and development, 2018

In that line, the Government of Uganda (GOU) has engaged in partnership with the private sector to implement research and development programs that promote innovations and technologies for fruit processing in the country. Examples of fruit processing innovations used by farmers and fruit entrepreneurs range from fruit drying, extraction of juice, wine making, and bottling, labelling and packaging. A better understanding of the dynamics of these innovations can guide for formulation and implementation of more effective innovation policies and interventions for increasing competitiveness and sustainability of the fruit subsector in Uganda. This section uses case studies of fruit processing enterprises in Uganda to identify and explore fruit processing innovations and constraints faced by agribusiness fruit processors. This study relies on information collected from selected key informants in the fruit subsector (Appendix C), and other relevant secondary sources including reports, websites of relevant institutions, and datasets.

3.1 Uganda's Institutional and Policy Initiatives for Promoting Tropical Fruit Processing

Over the years, the GOU has refined its approach to strengthening agro-processing within the framework of its national poverty reduction strategy. Currently, the Government is implementing the second phase of the National Development Plan (NDP II), a holistic framework for poverty eradication in Uganda. The NDP II aims at propelling the country towards middle-income status with a per capita income of USUSD 1,033 by 2020 (National Development Plan II (NDPII), 2015/16-2019/20). The NDP II recognizes value addition in agriculture as a major driver of economic growth and development. Specifically, the plan aims at improving agricultural markets and value addition for 12 prioritized commodities, including fruits, through:

1. Promoting value addition, agro-processing and storage as a means to increase access to domestic and regional markets;

2. Promoting appropriate technologies and practices for minimizing post-harvest market losses along the commodity value chains; developing and expanding a sustainable market information system;

3. Developing, maintaining and improving physical agricultural market infrastructure;

4. Developing and improving food handling, marketing and distribution systems; and

5. Strengthening national capacity for quality assurance, regulation and safety standards to promote increased trade at all levels (NDP II, 2015/16 -2019/20).[35]

In line with the current overarching development strategy, there are value addition strategies and initiatives. Below we summarize some of the important strategies including the Agriculture Sector Strategic Plan (ASSP) (NDP II 2015/16-2019/20), the Uganda development corporation (UDC), the Uganda Industrial Research Institute (UIRI), and the Food Technology and Business Incubation Centre.

The Agriculture Sector Strategic Plan (ASSP) for the period 2015/16 to 2019/20 is implemented by the Ministry of Agriculture Animal Industries and Fisheries (MAAIF), and has set improving access to markets and value addition and strengthen the quality of agricultural products as one of the four strategic objectives for achieving the goal (MAAIF 2016).[36] The ASSP lists the fruit production and processing as a priority enterprise for strategic investment. The ASSP strategic interventions for improving access to agricultural markets and value addition include: promoting private sector investment in value addition for the priority enterprises; building capacity of capacities of farmers, traders and processors in quality standards and market requirements; and supporting of individual farmers or farmer groups to acquire necessary processing equipment and facilities.

The Uganda Development Corporation (UDC) is under ministry of trade industry and cooperatives (MTIC). The UDC is implementing the construction of two fruit processing facilities: The Soroti Fruit factory in the Eastern region and the Luwero fruit factory. These factories are however not yet operational, in part due to delays from funding constraints. The Food Technology and Business Incubation Centre (FTBIC) established at the School of Food Technology, Nutrition and Bio engineering Makerere University to develop new value addition businesses based on research. The purpose of FTBIC is to develop new value-addition food businesses based on research conducted at Makerere University and to support students to gain practical and entrepreneurial skills as well as contribute to the further development of the agro-food processing industry. Trainees (mostly new graduates) at FTBIC are offered access to processing facilities and provided with technical support in production, marketing and business management. Other food industry clients also benefit from the services which include product development, training in food processing, contract processing, food analysis and technical advice; especially on aspects of quality management, processing and packaging. The FTBIC has facilitated the development of more than 20 new food processing enterprises and expanded the variety of agro-based food products on the market. It has also helped to strengthen the linkage between food science and technology research, training and business within the university.

3.2 Actors in the Tropical Fruit Processing Sub-Sector in Uganda

The components of the agribusiness fruit processing value chain in Uganda range from the supply of fruit (by farmers), wholesaling and retailing of fresh fruits to processors (by whole fruit intermediaries), fruit processing, packaging and branding agencies, and distribution of value-added fruit products that reach end consumers (by retailers and wholesalers), and

[35] (1) Sustainable production, productivity, and value addition in key growth opportunities; (2) increasing the stock and quality of strategic infrastructure to accelerate the country's competitiveness; (3) enhancing human capital development; and (4) strengthening mechanisms for quality, effective, and efficient service delivery.

[36] The other three objectives of the ASSP are: (1) To increase production and productivity of agricultural commodities and enterprises; (2) to increase access to critical farm inputs; and (3) to strengthen the agricultural services institutions and the enabling environment.

research and development institutions (see Figure 16). Fruit farmers include individual farmers or farmer groups who produce and supply fruits to traders and fruit processors. Fresh produce intermediaries include local wholesalers or local open markets of fruits and act as middle men between farmers and processors of fruits. Fruit product traders include wholesalers and local open markets. Local wholesalers buy from farmers or local small-scale traders and sell it to local processing factories with preliminary agreed prices and amounts. They also deliver the product to local markets. Aggregators include farmer organizations and companies that establish collection points for fruits during the harvesting season.

Primary processors of fruits include individuals, companies and food service caterers (such as restaurants and hotels) involved in the first fruit processing to produce fresh fruit juices and smoothies, fruit salads, fruit based deserts (by hotels and restaurants), pulp, and dried fruits (e.g. sliced dry pineapples by Kayunga ACE). Secondary processors are firms or individuals engaged in advanced processing to produce more refined products such as packaged juice, fruit wine, and fruit yoghurt. Examples of secondary processors include Jakana foods, Siligad investments limited etc. The fruit processors are supported by research and development institutions that generate and disseminate better processing technologies; regulatory institutions such as the Uganda National Bureau of Standards (UNBS) that enforce safety and quality standards of fruit products and technologies; manufacturers of packaging materials and processing equipment (local artisans and international manufacturers); branding agencies and distributers such as supermarkets; and transporters of fruits and fruit products to end-users.

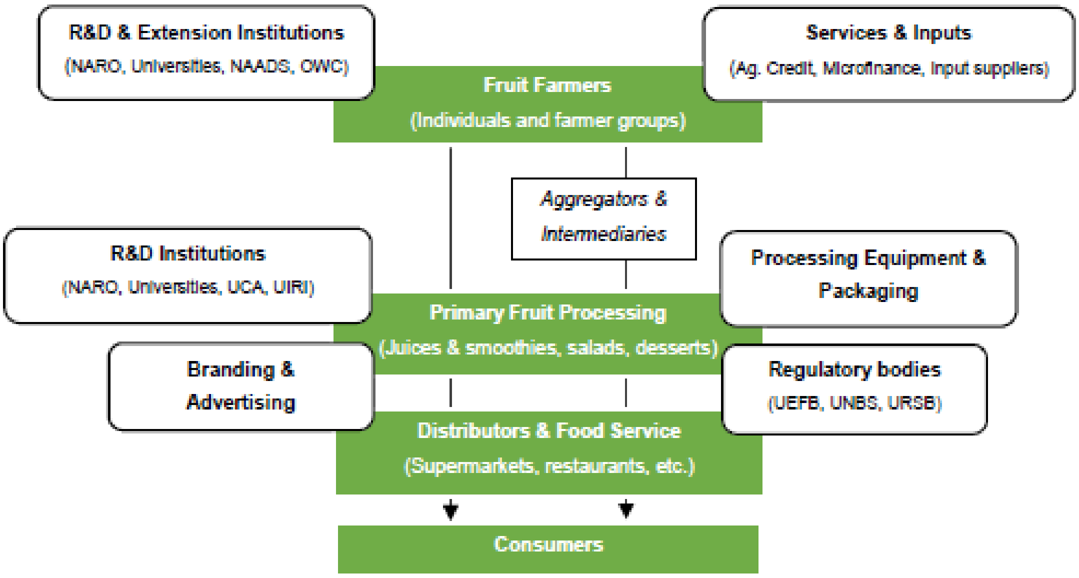

Figure 16: Value chain actors in the fruit processing in Uganda

3.3 Agribusiness Innovation & the Evolution of Technology in Tropical Fruit Processing

In this section, we highlight several specific fruit processing innovations that have appeared in the Uganda fruit processing subsector in recent years, according to the discussions we had with selected key informants. We begin with the acquisition of improved equipment and constantly upgrading the production technology to improve production processes. There has been a steady evolution of technology innovations in the fruit processing subsector, which were aimed at increasing productivity of the agribusinesses. Below are three examples of technological improvements in fruit drying, juicing and wine production.

Evolution of Fruit Drying Technologies: Improvements in fruit drying include upgrading from wooden solar drier which entirely depended on the sun, to durable metallic solar driers, to walk-in high capacity driers with a secondary heat source (e.g., wood burning stove with smoke diversion pipe) and to imported electric controlled fruit driers.
Figure 17 illustrates the evolution of pineapple drying technologies at Kangulumira ACE.

These driers have been developed through participatory research involving farmers, agro-processors and researchers from institutions such as Makerere University and NARO. Based on information from the key informant at KACE, the wooden solar drier was constructed in 1998, with technical support from the Department of Food Science and Technology (FST) at Makerere University in collaboration with local artisans. The metallic driers were then acquired in the year 2014 using funding from the Agricultural Business Initiative (aBi) trust and finance. The metallic driers are fabricated by local artisans in Kayunga district, supported by experts from Makerere University and directed by a technician trained at Mississippi State University.[37] The metallic solar drier helped to improve hygiene and thus quality of the dried pineapples. The metallic driers where followed by walk in solar driers with secondary heat source. KACE have since upgraded from a metallic drier to the walk in solar drier a secondary heat source developed by Makerere University. The walk in solar drier is more efficient and limits chances of contamination of the products. It also allows one to control temperature and humidity for proper drying. Figure 17d is the old generation of electric drier which did not have timer. According to the production manager Jakana foods, upgrading to a more automatic drier allows more planned drying, and has increased efficient use of labor resources.

[37] Mr. Charles Naluwailo (256789463830) is the local artisan who fabricates solar driers. He is based in Kayunga district and has been in fabrication business for the past three decades. He acknowledges the technical training he has received from Mississippi State University in 2000 and the continued support from Makerere University and the National Agricultural Research Organization.

a) Wooden fruit driers at Kanqulumira ACE

b) Metallic driers at KACE in Kayunga

c) Walk-in drier with secondary heat source

d) Old model drier at Jakana foods Ltd

e) Imported electric fruit drying ovens at Jakana Foods Ltd

Figure 17: Evolution of Fruit Drying Technologies

Evolution of Juice Extraction and Processing Technologies: Fruit processors have acquired and installed more efficient power-driven juice extractor, pasteurizers, bottler fillers and equipment for packaging juice. Panels (a) through (f) of Figure 18 show the initial evolution of these juicing technologies at KACE. By contrast Figure 18g shows the more precise, higher capacity and imported juicing equipment at Jakana Foods, Ltd. The improved juice extracting and processing equipment has enhanced productivity and quality of the products that are more appealing to consumers.

The FTBIC at Makerere University recently developed a mobile fruit processing (juicing) unit (**Error! Reference source not found.**). Mobile fruit processing model such as the Makerere university mobile fruit processor, a truck with the necessary equipment to process fruit at the farm, that takes processing to the source of production by travelling around rural areas. The unit traverses the country during the peak harvesting season to buy fruits from farmers, process the fruits on site before transporting the processed product, mostly juice and pulp, to the processing centre at Makerere University.[38] This has helped fruit farmers to reduce post-harvest losses and improved access to market.

a) Manual juice extraction at KACE

b) Charcoal based boiler **at KACE**

c) Improved juice extractor **at KACE**

d) Juice mixer at KACE

[38] The Food Technology and Business Incubation Centre (2017). College of Agricultural and Environment science, School of Food Technology, Nutrition and Bio-engineering, Makerere University. http://ftbic.mak.ac.ug/index.php/72-about-us/1860-welcome-to-ftbic.

e) Juice pasteurizer **at KACE**

f) Bottle filler at KACE

g) Imported fruit juicing equipment at Jakana Foods, Ltd

Figure 18: Evolution of Juice Extraction and Processing Technologies

Figure 19: Mobile fruit (juice) processor prototype developed by the FTBIC at Makerere University

Evolution of Fruit Wine Production Technologies: Siligad Investments, Ltd. (located in Mbarara town) has invested in several equipment upgrades that demonstrate the importance of technological innovation in fruit wine making, an emerging value-added industry in Uganda. Siligad Investments started processing wine using traditional plastic drums to ferment the fruit. The company has since acquired improved fermenting drums and improved packaging materials (Figure 20). According to the director, improved fermenting drums have reduced spoilage and wastage of fruit during processing, and led to increased quality and quantity of wine produced. This enhanced increased more wine sales enabling the company to invest in boxes to distribution of wine easier.

a) Original fermentation drum

b) Improved fermentation drum

c) Improved packaging and branding materials

Figure 20: Evolution of Wine Production Technologies at Siligad investments limited

To supplement these three specific examples of technological evolution in fruit drying, juicing and wine making, we describe other innovations that facilitate and enhance productivity in the fruit processing subsector in Uganda, including a list of more general innovations. Near-farm factories established to increase smallholder fruit farmer's access to higher-tech fruit processing equipment. An excellent example of this form of innovation, which is in the same vein as the mobile FTBIC processing unit described above, is the fruit processing plant established by the Uganda development corporation in Luwero and Soroti districts (Uganda Development Corporation, 2018).

Luwero Fruit Processing Factory: This factory, which is still under construction, is a multi-purpose fruit processing facility with modern production systems and processing technology for fruit chopping, pulp extraction, evaporation, pasteurization, fruit drying and production of fresh juice. The facility will also consist a fruit sorting, grading, drying, storage and packaging center to prepare and process fresh fruits for consumption in the local, regional and international markets. The factory was established to provide an accessible market and fair price for fruit farmers' produce in Luwero Triangle by adding value to their produce. The aim being the reduction of postharvest losses during the peak seasons, extraction of a larger portion of the value in the fruit production and processing chain, and to increase and diversify the incomes of fruit farmers.

The Teso Fruit Factory in Soroti: This factory was set up by the GOU with support from the South Korean International Cooperation Agency (KOICA) has set up fruit the under the Uganda Development Cooperation (UDC) (see Figure 21). The Factory will process orange and mango into concentrates for mainly supply to the region's processing facilities and, ready to drink juice for the local market. The Factory has a processing capacity of 6 metric

Figure 21: Teso Fruit Factory

tons per hour for orange and 2 metric tons per hour for mango, and targets to source fresh fruit from farmers organized under Teso Fruit Cooperative Union (TEFCU). Fruit farmers in the region are trained in modern agronomic practices, proved agribusiness, value addition and value chain to insure improved quality and quantity of fruits supplied to the factory. The fruit processing subsector in Uganda has enhanced its productivity and profitability in several other ways in recent years, including:

(i) Advertisement and promotional activities to widen markets (through sponsorships, advertise through print and electronic media—such as social media, websites
(ii) Making major improvements on the existing products including product differentiation to suit customer requirements
(iii) Improvements in packaging such as production of pasteurised juice products, vacuum packaging in stand up doy pack pouches (shelf life of up-to 12 months instead of 4 days for plastic bottles).
(iv) Certification, Branding, and product registration. Most fruit processors have acquired local certification from the Uganda National Bureau of Standards (UNBS). Some fruit processors such as Jakana foods Ltd has acquired international certification. For example, Jakana foods Ltd has produced certified organic products (NOP USDA Organic and EU 834/2007 Certified Organic dried fruits). Fruit processors in Uganda have also acquired brand names for their products. For instance, Uhuru fruit juice produced by Tursam, Jakana products by Jakana foods ltd, Minute maid by Century Bottling Company, Diama juice by Sameer, Kanywe fruit juice by Delish enterprise. Some processors have registered trademarks but this is mostly true for large scale companies such as Jakana foods Ltd, Sameer and Century bottling company Ltd.
(v) Form marketing companies, marketing units or engage marketing agencies to market new products & services. For example, the. Exit marketing agency for Dawn fruits charged with distributing the final products to consumers.

3.4 Case Studies of Selected Fruit Processors

In Table 10, we present case studies of selected fruit processors in Uganda, highlighting their innovations in the subsector. The data presented here were collected through expert interviews with an employee of the respective processing companies.

Table 10: Innovation and challenges among selected secondary fruit processors in Uganda

Company	***Fruit Product Produced***	***Source of Raw Materials***	***Innovations***	***Market for Products***	***Support to Farmers***	***Challenges***
Kangulumira Area Cooperative Enterprise (KACE) in Kayunga district KACE is registered with the ministry of industry trade and cooperatives. The cooperative was established in 2003, and it comprises seven rural farmer organisations in Kayunga district.	Dry sliced pineapples using solar technology. Extraction of pineapple juice has been stopped because of lack of appropriate technologies for juice extraction and packaging. Most solar driers are purchased from local artisans, with a few imported from Kenya.	Farmers from member associations, and Individual pineapple farmers	-Has acquired improved pineapple driers Packaging of sliced pineapples, -Certification of sliced pineapple product -Market linkages with exporters and other large scale processors	It sells both fresh and dried pineapples in the local and regional markets. The local market accounts for 75% of the annual supply. The major buyers include Jakana foods ltd, AHAP investments ltd, FON Company, FLONA Company, TROFP Company, located in Kampala- Uganda and Mavubi in Rwanda.	-Provides ready markets for pineapple fruits -Adds value to pineapples (dry sliced pineapples and pineapple juice) which fetch better prices -Trains farmers from member groups in pineapple processing Provides affordable credit members, -Provide farmers with quality pineapple suckers.	-Lack of capital to purchase equipment for juice extraction and packaging to diversify and expand -Poor perception about cooperatives -High inflation rates -High taxes on packaging materials
<u>Jakana foods ltd</u> Mainly deals in production of juice and dry fruits. Though much effort is on dried fruits unlike juice fruits which are mostly seasonal. http://www.jakanafoods.com/	- Mango juice - Pineapple juice - Dried mangoes - Dried pineapples - Died apple - Dried banana - Dried jack fruit - Dried banana (Gonja) - Dried pawpaw	Procures dry fruits (organically produced) from certified farmer groups in Kangulumira in Kayunga district, Ntungamoand Luwero district. For example, Jakana procures about 10% of fresh fruits and 15% of dry fruits from Kangulumira ACE; Works with over 100 farmers in the Kayinka banana farmers association in Luwero district.	-Packaging (pasteurised juice products), some products are vacuum packed in stand up pack pouches and have a shelf life of up-to 12 months. The rest of products are in plastic bottles with shelf life of 4 days. -Branding -Certified organic products (NOP USDA Organic and EU 834/2007 Certified Organic dried fruits)	About 95% of their dried fruits are exported about 70% of the juices produced is supplied to the local market	- Trains in organic fruit production through demonstration farms. - Ensure fruit quality through farm inspections - Promotes fairness along the entire fruit value chain (ensures all actors benefit). Fair For Life Social and Fair Trade program to ensure protection for our environment, fair wages for our workers, and fair trade for our	- Seasonality in production of fruits - Stiff competition from soft drinks - Lack of improved technologies for drying and fruit extraction. - High taxes

Company	*Fruit Product Produced*	*Source of Raw Materials*	*Innovations*	*Market for Products*	*Support to Farmers*	*Challenges*
			-Inspection of farmers -All our juice products are pasteurised. The product is The rest is packed in plastic bottles and have to be refrigerated. They have a shelf life of 14 day		farmers -	
Dawn company, Makerere University Kampala	Pineapple juice	Used to buy from farmers in Kayunga but stopped because they are small and expensive Currently buy pineapple fruits from farmers in Luwero district	Have registered a distribution company (Exit marketing agency) charged with distributing the final products to consumers.	Supermarkets and shops around Kampala		- High pineapple prices -Pineapples have very low acidity and low sugars
Superior organic food processors	*Mango juice* *Passion fruit juice* *Orange juice*	traders in city markets such as Nakasero Market and Kalerwe. Traders sources mangoes from Yumbe district, and oranges from farmers in Soroti and Rakai districts, and passion fruits are mainly supplied Mukono, Luwero and Kayunga districts.		They distribute their fruit juice supermarkets around Kampala city.		
Molly enterprises Located at the school of food sciences and technology Makerere University.	They extract and package hibiscus juice.	The source fruits from Hibiscus farmers in Mbarara in western Uganda.		They mainly supply their juice in supermarkets around Kampala city		
Delish enterprise also located at the school of FST at Makerere University.	They are involved in production and packaging of mango juice under the brand name “Kanywe fruit juice”.	Buys fresh fruit from city markets	*Fruit extraction, Packaging and branding*	They supply their products to university canteens and restaurants around the university		

Company	Fruit Product Produced	Source of Raw Materials	Innovations	Market for Products	Support to Farmers	Challenges
Tursam investments limited An Agribusiness-Food processing enterprise founded in 2009.	Produces 100% Natural fruit *juice from* mangoes, bananas, pineapples, passion fruits.	Buys locally grown fruits from farmers and traders	*Juice extraction* *Packaging and marketing* *Has a brand name, Uhuru fruits*	Exports to Rwanda and DR Congo, with potential demand in Kenya and Sudan	*Provide market to over 1000 farmers who supply the factory*	
AHAP investments ltd It's located along Kiwatule Najjera road. All 100% of its exports are from Kangulumira. The quality of the pineapples is good	fresh pineapples	Buys from Kangulumira monthly	- Packaging - Branding - Certification. -	exports fresh pineapples to Iran.		
Jessa Farm Dairy Limited It mainly deals in production of dairy products including fruit yogurt (Regarding milk production, 6% is produced by Jessa farm and 94% is outsourced) and its products like yogurt, butter, fresh cream. 80% is marketed locally and 20% exported.	- Passion fruit yogurt with Passion fruits - Straw berry	Imports fruits from south Africa and Egypt. Does not use local fruits because they are of poor quality and not preserved well.	- Branding - Advertising - Sorting - packaging			
House of Dawda (Britannia Allied Industries Limited) juice products— Splash and Yojus.	- Mango juice, pineapple juice, orange juice, apple juice, passion fruit juice, guava juice	Appear to import pulp, with limited purchase from local fruit farmers	- Branding - Advertising - Sorting - packaging			
Sameer Agriculture Livestock Ltd (SALL). Invested Shs5.2 billion in a juice plant.	- Produces fruit juices under the brand Daima, comes in six flavours: mango, apple, pineapple, guava, orange and mixed fruit.	Use pulp imported from Holland, Brazil and India before water and sugar is added from Uganda.	-			

3.5 Innovation Constraints in Agribusiness Fruit Processing in Uganda

Key informant interviews of selected actors of the fruit processing revealed several constraints that discourage innovation in tropical fruit processing. These include liquidity constraints, market constraints, production constraints, risks and uncertainties, seasonal and unstable fruit supply, inferior quality of fruits supplied, and lack of access to more efficient and appropriate processing equipment and spare parts. While these constraints affect many dimensions of agribusiness and enterprise in this subsector, they also have important and direct implications for innovation and technology adoption.

Liquidity constraints, including lack of access to capital and credit facilities at reasonable terms, severely hinder investments in innovation and technology modification, adaptation and adoption. For example, high interest rates on credit and the high collateral requirements during loan application hamper access to credit. These restrict potential entrants in agribusiness fruit processing, and hampers adoption and investment in better agro-processing technologies and innovations.

High cost of production including prohibitive cost of equipment and high operation costs restrict potential entrants in agribusiness fruit processing, and hampers adoption and investment in better agro-processing technologies and innovations efforts. This is aggravated by lack of appropriate and more efficient processing equipment and their spare parts on the local market, as most of these are imported. For example, Jakana foods limited has not been able to fix the new improved juice extractor that broke down recently because the spare parts are too expensive and also do not have the expertise to fix the problem. This underscores the need to support the capacity of local artisans and manufactures of agro-processing equipment and of improved locally manufactured equipment and packaging materials. Furthermore, strong linkages are needed between the NARO, agricultural engineering units in academic institutions, the local artisans, processors and farmers to model and develop suitable low cost machinery for fruit processing.

Innovation in the agro-processing subsector in Uganda is also possibly constrained by absence of IP protection by most of agribusinesses. Only a few agribusinesses in Uganda formally register their innovation as IP, leaving many innovators unprotected mainly due to lack of awareness of IP, and high transaction costs associated with IP acquisition. Newer agribusinesses have not yet bothered formulating or even conceptualizing an IP strategy simply because they are still dealing with more pressing constraints to their core business (e.g., securing a stable supply of quality fruit as described below). A few initiatives such as the Innovation Systems and Clusters Program Uganda (ISCP-U) at Makerere University are currently facilitating the process of acquiring IP but lack adequate resources to provide support to entrepreneurs and firms that need assistance.

Unstable and inferior quality of fruit supply is a major production constraint in the subsector and, by extension, diminishes incentives to invest in innovative, high-volume processing equipment. The supply of fruits in Uganda is highly seasonal leading to surplus during the harvesting season (mainly December to March) and worrying shortages during the off-season. Fruit processors also receive fruits of inferior quality, which are generally small, irregularly sized, and occasionally diseased or otherwise infested with pests. These factors hamper innovation effort as they make it difficult for fruit processors to meet the market demand and satisfy standards required for high value markets needed to justify the upgrading of processing capacity.

Agro-processing actors in Uganda are also very vulnerable to market risks and they do not have access to effective mechanisms for management and mitigation such market risks. Agricultural insurance markets in the country are still underdeveloped, and many processors especially those located in the rural areas lack awareness on insurance markets.

Limited access to market opportunities (local, regional and international market opportunities) especially the small-scale processors and the new entrants, hamper sales and profits of the firms and negate their investment in better innovations. Strong networks and associations among agribusiness fruit agro-processors can facilitate collective action and drive the innovation system, but such linkage are currently very limited and weak. For instance some fruit processing companies have formed associations with the aim of increasing bargaining power and increasing market access; however, internal conflicts prevent smooth functioning of the associations.

Another important constraint to innovation in agro-processing is the low level of entrepreneurship and management training of those directly engaged in agro-processing. For instance, a large majority of agro-processors including the local manufacturers (artisans) of agro-processing equipment have had little or no formal training in the technical aspects of the operations and less in agribusiness management and marketing. There are many local potential local manufacturers of agro-processing equipment but are not well linked to agriculture engineering units in academic institutions for skill development. Business incubation R&D is a good step toward linking between R&D with the markets but this needs to be further strengthened with mechanisms that link and support all actors in the innovation system. There may be need to provide business incubation services to assist innovation actors with not only business case development but also helping them to find affordable financing, and providing IP advice. Furthermore, business incubation services need to be expanded in the country by establishing regional or district satellite incubation service centres.

Lack of more specific regulatory policies also hampers innovation in agro-processing. For example whereas Uganda has a national science, technology and innovation (STI) policy framework, it may be too general to support sectoral specific innovations. Similarly, the draft national IP policy, which links the different important development policies such as the national agricultural policy, is not been adopted and implemented by the Government. When fully implemented, the policy will help streamline the management and administration of the IP landscape in the country.

Government institutions, agencies and officials can directly shape the enabling environment and incentives that encourage or discourage innovation. This influence can be direct and explicit as in the case of funding basic or applied science through competitive grants programs or indirect and subtle as in the case of regulation or education policies. The role of the public sector in innovation systems includes process as much as existing policies or programs. Since innovation is inherently novel, it pushes the frontiers and challenges the status quo. This disruptive nature of innovation raises dilemmas for both private and public sector actors (Christensen 1997). If the processes that govern the emergence of new policies, regulations or enforcement are static and unresponsive, innovation may be stifled or slowed. If instead the policy processes are dynamic and responsive, government is more likely to successfully create an enabling environment that encourages innovation and stimulates innovation-based growth.

3.6 Summary of Results and Implications for Innovation Policy in the Ugandan fruit processing sector

Several fruit processing innovations are evident in the Uganda fruit processing subsector, with the main one being technological improvement in fruit drying, juice extraction and wine making. Key technological improvements include upgrading from wooden solar fruit driers to more efficient solar powered driers with a secondary source; upgrading from traditional plastic drums for fermenting to the improved fermenting drums in wine production; and upgrading from manual juice processing (i.e. extraction and packaging) to more efficient power-driven juice extractors, pasteurizers, bottler fillers and equipment for packaging juice. Other important specific innovations include advertising and promotional activities, making improvements in existing products, improvements in packaging, and certification, branding, and product registration to enhance profitability and productivity.

However, several constraints hamper establishment of a vibrant innovation system in the fruit processing subsector in Uganda. These include: severe lack of access to financing and credit at reasonable terms, high cost of processing equipment and their spare parts, limited and weak linkages between processors and other fruit value chain actors including development institutions, lack of coherent association of innovators to foster collective action, unstable and inferior quality of fruit supply to sustain the market demand, low level of training among agro-processors in entrepreneurship and agribusiness management, weak markets and ineffective or absent market incentives including lack of implementation of the PVP which is supposed to enhance innovation effort, and unfavorable and disconnected policy regimes.

4 Conclusions and Policy Suggestions

Uganda has been taking several measures that would be expected to improve its innovation performance, including in the agri-food sector. However, for Uganda to translate this success to economy-wide gains, it needs to address constraints hampering innovation and productivity improvements in its agriculture sector. This study has outlined several factors that impede value addition and upgradation of its agriculture value chains. It has also highlighted some possibilities that could improve the country's agri-food innovation. The policy measures required for Uganda to improve its current innovation standing focus on enhancing its institutions to promote and protect IPR, foster innovation, and provide an enabling environment to cultivate collective action.

4.1 Innovation policy suggestions

Uganda's performance in previous editions of the GII attests to its growing focus on innovation as a driver of development in some of its key sectors. Within the agriculture sector, Uganda is prioritizing investments in modern biosciences, with a particular focus on disease diagnostics, vaccine development, crop productivity improvement, and value addition (Ecuru & Kawooya, 2015). The government is also taking steps (though small) to improve institutional capacity, as evident through the growing importance of work of R&D institutions such as NaCORI and others within NARO.

The growing focus and recent measures taken by the government for promoting innovations and value addition in agro-based industries is definitely a step in the right direction. However, to truly stimulate growth, the government needs to create an enabling environment for agri-food innovations by addressing obstacles that impede value addition and innovation in agri-food systems . Policies for supporting innovation should include fostering an enabling environment and collective action. The former typically relates to the provision of public goods to address market failures in transportation, communication, and processing. However, such policies can also focus on the small producers by aiming to integrate them into the market economy. Indeed, a strong agro-processing sector, which is linked to farmers, is an incentive for small producers to invest more to increase the productivity of their farms. This relies on a combination of service provision, as mentioned above; facilitation of the private sector through financial services and fiscal policy; and an appropriate regulatory environment achieved through standards, regulations, and enforcement. Collective action offers the possibility of lower costs, a more reliable network, and potentially higher profits.[39] Umbrella organizations play a major role in marketing agricultural produce, providing access to training, and service delivery from external organizations (Larsen et al., 2009). They also provide an ideal environment for knowledge transfer and innovation as they link farmers with similar interests. Finally, governments can also engage in the direct funding of agricultural R&D. Public-private partnerships also support R&D, education, technology transfer, and incremental problem solving.[40]

As depicted in Figure 3 the bridging institutions and other enabling policies and norms can directly or indirectly shape how well upstream R&D and educational investments translate into value to producers and consumers and influence incentives for both innovation and technology adoption (for more details see Grovermann et al. 2017). Consistent with this innovation systems view of the agri-food sector, we extract three overarching policy recommendations aimed to address opportunities that are specific to the Ugandan context. While these recommendations emerge from the two studies we conducted in this work, they are relevant to much of the agri-food sector, so we discuss them before proceeding to the subsector specific recommendations in the next subsections.

1. **Improved policy and institutional integration:** Uganda has an active, engaged and – judging from the amount of legislation created – productive policy environment across many sectors of the economy, including agriculture, health, education, etc. The institutional and policy landscape often appears disjointed, however, with different jurisdictions, agencies and units claiming overlapping sets of responsibilities with different, sometimes contradictory, directives and objectives. Such disconnections are clearly on display in the coffee sector, but surely relevant in many other agri-food sub-sectors.

   RECOMMENDATION: Greater vertical and horizontal integration (or at least coordination) of responsibilities, authority and expertise is needed to provide more coherent, responsive and strategic policy action and implementation. For policy topics with central innovation dimensions, it is possible for the Ministry of Science, Technology and Innovation to have clear jurisdiction and offer clear direction so that innovation efforts across sectors and ministries are coordinated to leverage synergies.

[39] Dorward et al., 2008.
[40] Hall, 2006.

2. **Prioritize, streamline and structure new public R&D funding mechanisms and institutions**: In the agri-food sector, the flow of public R&D funding is relatively functional within the NARO system, but outside of NARO's mandated areas of research (e.g., fruit production and processing) public funding is unpredictable and short-term, which prevents serious strategic planning of innovation investments.

   RECOMMENDATION: Establish a policy framework for institutionalizing publicly funded research and for tracking the development and diffusion of new technologies produced by these investments. Such a framework in the agri-food sector should prioritize engagement with the private sector and the use of public-private partnerships, particularly in domains that fall outside of the NARO mandate.

3. **Expand URSB capacity to facilitate the creation and use of IP in the agri-food sector:** URSB has improved its operations in recent years in many respects and now takes a distinctly business-like approach to public service. In contrast to most bureaucracies in Sub-Saharan Africa, it is accessible, dynamic and generally service-oriented. URSB conducted effective nationwide training and awareness campaigns among other innovative activities. Still, URSB might require more personnel resources to manage the entire IP portfolio.

   RECOMMENDATION: Invest in expanded URSB capacity with strategic coordination of IP with the Ministry of Science, Technology and Innovation and the Ministry of Agriculture, Animal Industry, and Fisheries. URSB already has capacity to administer other areas of IP. Adding agri-food related IP areas like the Plant Variety Protection (PVP) Act of 2014 to URSB's portfolio could save resources, leverage existing expertise, and avoid duplication that inevitably results from creating parallel structures for administering IP in different government departments. Moreover, the draft national IP policy document vests the implementation of that policy with URSB. The study agrees with that recommendation and recommends that IP management, whether in agri-food sector or other sectors, be under the management of URSB. For agri-food sector, with additional administrative resources, URSB could develop specialized and quasi-independent units to manage different areas of IP with a special focus on branding and trademarks and the new PVP system.

4.2 Robusta Coffee Planting Material Pipeline

Several obstacles to innovation and associated opportunities emerge from our study of the Robusta coffee planting material pipeline. Here we summarize the key innovation (and innovation-relevant) policy opportunities that emerge from this specific study.

1. Re-evaluate current focus on quantity over quality of planting material and re-allocate existing resources towards improved quality of planting material. Upgrading the CPMP to more effectively leverage and stimulate innovation will demand additional investment from both the public and private sector, but optimizing the use of existing CPMP resources should be an immediate priority.

2. Facilitate the transfer of technologies and practices from advanced private nurseries ("cluster 4") to the public CPMP coordinated by UCDA. Public-private partnerships may be especially useful as a mechanism for bridging the public and private nursery systems, including upstream tissue culture laboratories.

3. Enhance property rights in germplasm along the CPMP by operationalizing the existing PVP. The current dominant role played by UCDA in the CPMP may simplify efforts to offer and enforce PVP, although it may also discourage private sector involvement and competition as a source of innovation. Operationalizing the PVP system entails significant investments in both institutional and personnel capacity, but is a critical bridge to more effective engagement of both private and public sectors and to enhanced incentives for improved innovation and technology adoption.

4. Establish independent and rigorous verification of the propagation conditions in nurseries to supplement UCDA inspections with publicly-available nursery quality information. Private sector options are rapidly emerging in Uganda (e.g., AgVerify), as are complementary technologies such as DNA fingerprinting that could be used to track and monitor key dimensions of germplasm.

5. Stimulate farmer demand for improved planting material and transmit this demand upstream to nurseries. Many smallholder farmers lack sufficient awareness about planting material quality to insist on quality attributes. Improved agricultural extension in the coffee sector, including the use of scalable information and communication technologies (e-extension), should prioritize knowledge of seedling quality. UCDA should pilot as soon as possible and potentially in conjunction with farmer education a voucher program that gives farmers a more direct choice in procuring planting material directly from nurseries.

4.3 Fruit processing

There are several policy options that emerge from this study of the fruit processing sector in Uganda. Among these options are several priorities that should be considered seriously as a means of stimulating the innovation system in this important subsector of the agri-food sector in Uganda. These include the following:

1. Integrate IP policy with the national agricultural policy and support IP protection among innovators in agro-processing to develop incentive mechanisms to reward innovators.

2. Mainstream incubation initiatives and approaches with the current development policy and programs implemented by the relevant ministries to support agribusiness development.

3. Expand business incubation initiatives to assist the emerging innovation actors with not only product and enterprise development but also financing options and IP assessment and advice.

4. Establish a comprehensive financing mechanism framework to enable development and uptake of improved technologies among actors; these may range from small incubation grants, matching grants, soft loans, venture capital, and commercial loans.

4.4 Intellectual property

On the specific issue of intellectual property (IP), more innovation in the agro-processing subsector in Uganda could result from more active use of IP by agri-businesses.

- Only a few agribusinesses in Uganda formally register their innovation as IP, leaving many innovators unprotected mainly due to lack of awareness of IP and its innovation, and high transaction costs associated with IP acquisition.

- Newer agribusinesses have not yet bothered formulating or even conceptualizing an IP strategy simply because they are still dealing with more pressing constraints to their core business (e.g., securing a stable supply of quality fruit as described in this study).

- Generally speaking, there is a low awareness and use of IP, limiting innovation incentives in particular among fruit processors.

- A few initiatives such as the Innovation Systems and Clusters Program Uganda (ISCP-U) at Makerere University are currently facilitating the process of acquiring IP but lack adequate resources to provide support to the many entrepreneurs and firms that need assistance.

In addition, the government could leverage IP policies and maintain effective IP institutions to foster increased agri-business innovation. The execution of the draft Ugandan national IP policy, which links the different important development policies such as the national agricultural policy, will contribute to such favorable innovation conditions. When fully implemented, the policy will also help streamline the management and administration of the IP landscape. It will then be important to integrate IP policy with the national agricultural policy and, where appropriate, to facilitate the use of IP among innovators in agro-processing. Addressing the lack of implementation of the PVP is also a priority.

With support from WIPO, the Government of Uganda is finalizing a new National Intellectual Property Strategy. The substantive work behind this initiative was completed in 2017 as document that outlines strategic considerations and best practice guidelines for managing IP in the Ugandan economy and context (see Kamugasha, 2017). This strategy document – like much of Ugandan national policy – is motivated by the plans and goals articulated in the Uganda Vision 2040 initiative, which aims for "a transformed Ugandan society from a peasant to a modern and prosperous country within 30 years." The innovation-related efforts that specifically relate to this study include the National Science, Technology and Innovation Policy, the National Agriculture Policy and the Draft National Agricultural Seed Policy. The report laments the lack of any mention of IP issues in the National Agriculture Policy:
"It is...a great paradox that the policy that underpins the national economy is completely silent on both IP and innovation. This disconnect must be urgently and seriously addressed, if Uganda is to achieve its national development objectives. The integration of IP into agricultural policy, objectives and strategies is likely to result in a step change in the rate at which sector goals are realized." (p.21, Kamugasha, 2017)

The present study was commissioned at least in part as an attempt to fill this void and to offer an innovation perspective on the agri-food sector that might provide a specific point of departure for discussions around the critical but underappreciated links between innovation and innovation policy, including IP policy, and the productivity and profitability of the agri-food sector. The vision and mission proposed by this document are of particular interest as part of the broad conceptual and motivating framework for this research Table 11.

The Ugandan National Intellectual Property Policy	
Vision	“A Uganda where creativity and innovation are stimulated by Intellectual Property for the benefit of all; a Uganda where intellectual property promotes advancement in science and technology, arts and culture, traditional knowledge and biodiversity resources; a Uganda where knowledge is the main driver of socioeconomic development, and knowledge owned is transformed into knowledge shared.”
Mission	“Stimulate a dynamic, vibrant and balanced intellectual property system in Uganda that: (a) fosters creativity and innovation thereby promoting entrepreneurship and enhanced social, cultural and economic development, and (b) focuses on enhancing agriculture, industry, health, education and other sectors of the economy that are of vital social, economic, scientific and technological importance.”

Table 11: The core motivation and purpose of the draft Ugandan National IP Policy as articulated in the Vision and Mission. Source: p.52, Kamugasha 2017.

Although a functional and dynamic agricultural innovation system in Uganda could provide ample opportunities for a broad range of IP to achieve this mission in the agri-food sector, one distinct and important form of IP in this sector is the protection of plant variety rights. In this regard, the report briefly discusses the emergence of the Plant Variety Protection Bill in 2010. As with most such pieces of legislation, this bill aims to balance the rights and incentives of plant breeders with “fair and equitable sharing of IP benefits,” including with farmers and ultimately consumers. This discussion concludes with the simple observation that “the development of regulations for operationalization of the Act still remains to be done.” (p.46, Kamugasha, 2017). Implementing this new Plant Variety Protection Bill ought to be a top priority for the Government of Uganda. The coffee planting material pipeline study below highlights the importance of incentives and innovation in the upstream generation and dissemination of improved planting material and serves to underscore this priority.

In the past decade, Uganda has taken some major strides towards establishing a well-functioning IPR regime in agriculture. The country recently introduced its Plant Variety Protection Act 2014 and became a signatory to the International Treaty on Plant Genetic Resources for Food and Agriculture, to which it acceded in 2003. It also enacted its Geographical Indications Act 2013, which provides protection and promotes the value of its indigenous and traditional agricultural produce. Enhancing the instruments available to both private and public players in the agri-food sector to create viable business opportunities based on innovation could be a policy priority. At the most basic level, firms will invest in innovation only if they have a defensible strategy for building and maintaining a reputation that attracts customers and differentiates high-quality products and services. The effective use of trademarks may therefore play a role in improved branding and longer-term investments in innovation. Uganda also enacted its Trademark Protection Act in 2010. Since then, compared with other forms of intellectual property (IP) protection—such as patents—the use of trademarks has increased rapidly. Furthermore, this approach is emerging as the preferred form of protection in the agricultural, food and beverage sectors because the majority of trademark fillings occur within these sectors (WIPO, 2017).

In the near future, Uganda can draw on this basic framework to promote formal agricultural investment in innovation.

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List of Acronyms

Agri-food	Agriculture and food
AMA	Agribusiness Management Associates, Ltd
ASSP	Agriculture Sector Strategic Plan
CAADP	Comprehensive Africa Agriculture Development Programme
CDIP	Committee on Development and Intellectual Property
CNOs	Coffee Nursery Operators
CPMP	Coffee Planting Material Pipeline
CWD	Coffee wilt disease
CWD-r	CWD-resistant
EU	European Union
FSSP	Farming Systems Support Program
FTBIC	Food Technology and Business Incubation Centre
GI	Geographic Indications
GII	Global Innovation Index
GOU	Government of Uganda
INSEAD	European Institute of Business Administration
IP	Intellectual Property
IPR	Intellectual property rights
KACE	Kangulumira Area Cooperative Enterprise
KOICA	South Korean International Cooperation Agency
MAAIF	Ministry of Agriculture, Animal Industry, and Fisheries
MTIC	Ministry of trade industry and cooperatives
NAADS	National Agricultural Advisory Services
NaCORI	National Coffee Research Institute
NARO	National Agriculture Research Organization
NDP II	National Development Plan Second Phase
NERICA	New Rice for Africa
NGO	Non-governmental organization
NOP USDA	National Organic Program, United States Department of Agriculture
OWC	Operation Wealth Creation
PEAP	Poverty Education Action Plan
PPPs	Public-private partnerships
PVP	Plant variety protection

R&D	Research and development
S&T	Science and technology
TEFCU	Teso Fruit Cooperative Union
UCDA	Ugandan Coffee Development Authority
UDC	Uganda Development Corporation
UGX	Ugandan Shillings
UNBS	Uganda National Bureau of Standards
UNCST	Uganda National Council for Science and Technology
UIRI	Uganda Industrial Research Institute
URSB	Uganda Registration Services Bureau
USD	United Sates Dollars
WIPO	World Intellectual Property Organization
ZADI	Zonal Agriculture Development Institutes
ZARDI	Zonal Agricultural Research and Development Institute

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Appendix A: Coffee Nursery Operator Research Design

1. Focused background research. To more specifically inform our deeper dive into the coffee sector, we will review all the existing analyses in this sector with a particular focus on coffee production, input quality and input supply chains – especially seedlings. Some additional insights from the broader international coffee market – both production and consumption – will be relevant. There have been several efforts in recent decades to identify and understand key actors and dynamics in the coffee value chain in Uganda. While we do not need a comprehensive synthesis of this work, we do need a nearly comprehensive survey of the work related to seedling quality, varieties, multiplication, and distribution. Among the topics that will be addressed in this background research are the following:

    a. Map the seed coffee supply chain and actors using existing sources, reports and data and by consulting sector exports. This will include the structure of the Operation Wealth Creation channel. This map will aim to represent what we would see if we could "trace each coffee tree" in Uganda back to its genetic origins (at NaCORI or elsewhere).
    b. Learn what we can about the seed supply chain in other coffee producing countries (e.g., Vietnam). How do they preserve information about varieties? How do they transmit incentives?
    c. Document the role of agricultural extension services. How effective have they been in the coffee sector in general? How do they add-value to the seed supply chain and help ensure that higher quality seedlings are delivered to farmers?
    d. Identify promising sources of data related to the objectives of this study, including UCDA 'administrative' data (e.g., distribution of seedlings by year and spatial location), any existing surveys of coffee nursery operators (CNOs), any surveys of coffee farmers, etc.

2. Key informant interviews of large, upstream actors in the coffee seed supply chain. Using the map and other details from the background research in #1, we will identify key organizations and individuals to interview.

    a. Respondents will be selected to be qualitatively representative of the public sector (NaCORI, UCDA, OWC), private sector (exporters, estates, transporters), and NGOs. While many are in the Kampala area, some are in outlying coffee regions.
    b. Research and development conducted at NaCORI produces aims to produce new and improved coffee trees that are specifically tailored to the Ugandan growing conditions. The release of new varieties marks the beginning of the seedling supply chain. These releases are overseen and approved by the variety release committee at NARO/MAAIF. The institutions and individuals involved in this most-upstream point in the supply chain and those charged with organizing the release and dissemination of new germplasm (e.g., UCDA) should be represented in some way in these interviews.
    c. While CNOs will not be the main target for these interviews, we aim to talk with one or two CNOs to help refine our thinking about the CNO survey described below.
    d. These interviews can be semi-structured: there are some questions we definitely want to ask all/most of the respondents, but the interview can also include several open ended and freeform questions as the conversation takes shape.

3. Survey of actors in the coffee seed and seedling supply chain. We will design a sampling frame and a survey instrument that will enable us to collect primary data from CNOs to better understand the current structure, dynamics, constraints and incentives that shape the efficiency and performance of the supply chain from NaCORI and UCDA through Zonal Agricultural Development Institutes (ZADIs) and CNOs to Ugandan coffee farmers.

    a. This structured survey of a statistically representative sample will focus entirely CNOs for two reasons:

        i. this is the critical "last mile" link in the planting material pipeline – the interface with producers – and so plays an important role in seedling quality and information about quality dimensions.

        ii. This is the only link in the pipeline with sufficient actors to justify a survey. The interviews described in #2 will help us understand the "upstream" structure of the chain.

    b. Research Questions. Several questions may guide this survey of CNOs.

        i. How exactly do CNOs fit into the 'coffee planting material supply chain' in Uganda? Where do they source their material and on what terms? Who are their clients? What costs, volume and risks are implied by their position in the supply chain?

        ii. What specific roles do CNOs play in coffee productivity in Uganda? How much of the NaCORI germplasm potential is lost at the nursery stage due to CNO management decisions that introduce disease or otherwise compromise seedling vitality (phytosanitary hygiene, shade netting, manure, etc.)?

        iii. How and how effectively do CNOs convey information about coffee varieties and quality (e.g., CWD resistance)? This a potentially important asymmetric information problem, especially if farmers know that there are quality dimensions about seedlings that they cannot directly observe.

        iv. Based on a careful accounting of CNO costs and revenue, how profitable are coffee nurseries as a business? Amidst the many that are unlikely to be profitable, are there any stand-out examples of innovative and profitable nurseries? If so, what do these CNOs do differently?

        v. How does OWC affect the incentives, management and productivity of CNOs? How much does OWC distort the germplasm quality passed through the CNOs? How specifically do CNOs interact with OWC (contract, delayed payment, etc.)? Do CNOs require explicit/formal or implicit/informal approval before they can serve as an OWC supplier? How does OWC change the productivity and profitability of CNOs as independent business operations?

vi. How heterogeneous are CNOs with regards to these questions? How does this heterogeneity interact with farmer heterogeneity? To the extent that different types of farmers source their seedlings from different types of CNOs, there may be specific productivity implications. These implications would affect how innovation in improved coffee germplasm disseminates through the seed supply chain.

To make these research questions more concrete, consider the following scenario. Suppose NaCORI succeeded in breeding a much better coffee variety. How would it disseminate it to growers? There is presently no system for tracing a given variety with any reliability through the nursery chain to farmers. Among other things, we could consider what implementing PVP might mean in this case. For example, if NaCORI was able, in principle, to earn royalties on its coffee varieties via PVP, they would earn nothing in the current system because of free seedlings distributed via OWC and the inability to trace varieties.

b. Dimensions to Capture in Sampling Frame and Survey: Based on what we understand about the structure of the coffee seed supply chain, there are several promising dimensions that we would consider reflecting in our sampling frame and in the design of the survey instrument.

1. The seed supply chain includes both formal and informal actors, as well as public and private actors. For example, there are many small-scale nurseries involved in propagating the seedlings that are distributed to farmers in a particular region. These small nurseries appear to be informal. In contrast, larger nurseries further upstream or in especially important coffee regions are managed as formal entities. Similarly, the interaction between the public sector actors and the private sector nurseries will be important to capture in the sampling frame and in the design of the survey instrument.

2. The survey will seek to understand the incentives that motivate actors in the supply chain as it is currently structured. Many of the seedlings distributed to farmers through official channels are subsidized completely by the Ugandan government. This obviously and directly shapes the incentives that cascade through the supply chain. Since farmers are not typically paying customers, nurseries and multipliers may have little incentive to adhere to protocols that are intended to preserve the integrity and performance of coffee germplasm. This can lead to inferior seedlings ultimately being supplied to farmers. The survey instrument will seek to understanding the incentives that exist for different actors in the current system.

3. According to recent official reports and longstanding informal reports and anecdotes, the current seedling distribution system – much of which is part of Operation Wealth Creation – is plagued by a host of logistical constraints that undermine the efficiency and value-added of the seed supply chain. For example, farmers often receive more seedlings than they can plant and commonly receive them during the dry and hot season that is not the optimal time for transplanting. Consequently, only a minority of the distributed seedlings are transplanted and survive for more than a few weeks. While the survey will have to address this crucial logistical constraint in the supply chain, it must be not overpowered by this dimension.

4. Finally, there are reports that more sophisticated coffee growers, including a handful of big coffee estates, frequently bypass the nursery chain altogether and source their seedlings directly from NaCORI. By moving it all in-house with their own nurseries, they know exactly what they are planting. They may be the only growers who do. Vertical integration like this is typically motivated by high transactions costs in the absence of integration. In this regard, the information void is a form of a transactions cost – one that has large dynamic costs in the form of lower lifetime coffee productivity. The sampling frame and survey will aim to document the extent of such alternatives to the official public seed supply chain.

Appendix B: Coffee Nursery Operator Questionnaire

Available here.

Appendix C: Supplementary Tables & Figures

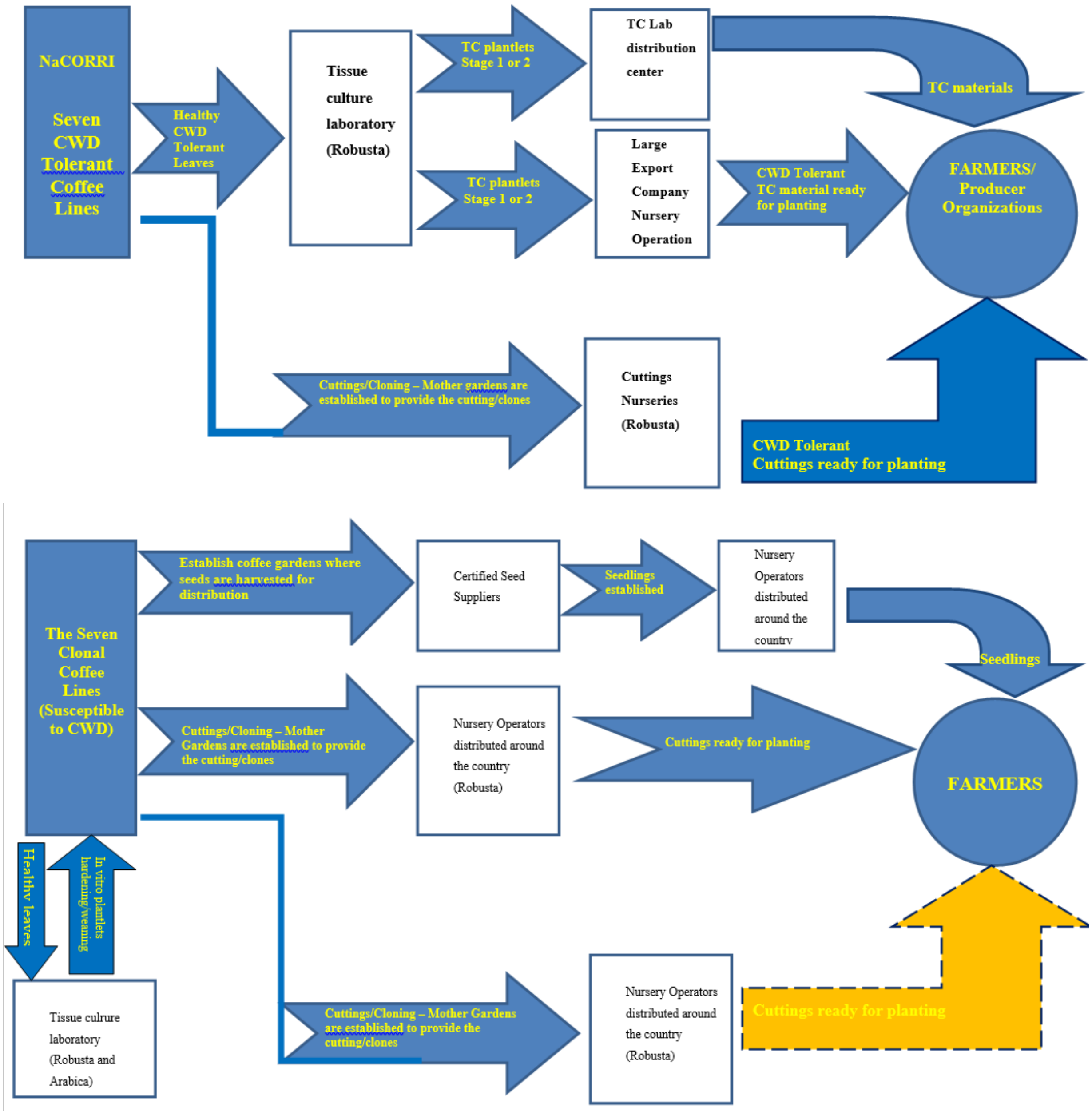

Figure A1 Current (top panel) versus observed (bottom panel) CPMP as depicted in the AMA Coffee Nursery Report (Feb 2015)

Table A1: Stakeholders interviewed for tropical fruit processing study

#	Name	Title	Institution	location	contact
1	Mr Yahaya	Secretary	Kangulumira ACE	Kayunga	0754909460
2	Mr Amir Hossein	Director	AHAP investments ltd	Kampala	0782727591
3	Mrs Kembabazi Stella	Research Assistant-Product development dept.	PIBID	Bushenyi	0779207252
4	Mr Musoke Philip	Manager production	Teso fruit factory	Soroti	0704938378
5	Mr Mugula	Production Manager	Jakana Foods ltd	Kampala	0706262787
6	Mrs Hadija	Head fruit and vegetable dept.	UIRI	Kampala	0759766168
7	Mr Allan. N	Technician	Makerere University Incubation centre	Kampala	0782392739
8	Mr Karim	Quality controller	Jessa Farm Diary ltd	Wakiso	0775669702
		Director			