WFP EVALUATION

Innovative Pilot Evaluation: Aflatoxin Reduction in the Rwanda Maize Value Chain from October to December 2021

Decentralized Evaluation Report

WFP Regional Bureau of Nairobi

WFP World Food Programme

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Executive Summary

1. The subject of this decentralized evaluation is AflaSight, an innovative pilot activity for aflatoxin reduction in the maize value chain of Rwanda. The evaluation was commissioned in November 2020 by the Regional Bureau of Nairobi (RBN) of the World Food Programme (WFP) in collaboration with the WFP-led Farm to Market Alliance (FtMA) and the WFP Rwanda Country Office (CO). It serves the dual purpose of learning and accountability. Changes in the timeline increased the focus on learning, with relatively more weight on forward-looking elements than on accountability and past performance.

2. Rwanda has a large workforce of smallholder farmers (SHFs) but who have limited access to premium markets for maize. One barrier to market access is aflatoxin, a carcinogen produced by Aspergillus fungi which thrive in a variety of crops and grains when stored in humid conditions due to poor post-harvest handling and storage, and lack of efficient drying facilities. There is no currently available way to recognise kernels affected with aflatoxin and screen it out. Maize grain with high levels of aflatoxin is rejected by premium buyers adhering to regional and national aflatoxin standards, producing income losses for SHFs. WFP's work on smallholder market integration and aflatoxin control in Rwanda (much of which is implemented through FtMA) aims to address these issues.

3. In this context, AflaSight (operated by a start-up firm based in Rwanda) uses an innovative aflatoxin reduction technology developed by a multinational plant equipment manufacturer (Bühler). The technology (LumoVision) removes aflatoxin from already infected maize kernels at industrial scale. The direct users of AflaSight are agro-processors and traders that source maize from smallholder cooperatives.

4. The installation and calibration of the processing line in the Special Economic Zone of Kigali was finalised with substantial delay in October 2021. This delay, and time constraints related to the evaluation budget, shifted and shortened the originally planned evaluation period (February to August 2021, main agricultural seasons A and B) to October to December 2021 (the first three months of the pilot, minor season C). The geographic and value chain scope of the evaluation includes processors, aggregators and other food system actors based in Kigali, as well as four 'pilot cooperatives' active in season C in the Southern Province of Rwanda. The main users of the evaluation are WFP CO and RBN, FtMA, Government institutions involved in agricultural production and food standards, AflaSight, Bühler and private entities (including cooperatives) forming parts of the maize value chain.

5. The evaluation followed a theory-based mixed methods approach to answer the nine main evaluation questions (EQs). Primary data was collected in November and December through key informant interviews in Kigali, as well as interviews, focus groups, direct observation, and a large-scale survey with SHFs in the Gisagara and Nyanza districts. The main methodological limitations were related to the timing of the evaluation (beyond control of the evaluation team) which substantially limited stakeholder's (especially SHFs') experiences with AflaSight at outcome and impact levels. Uncertainty about the future course of the pilot and its effects remain. Moreover, given that AflaSight has so far only worked with a limited set of four cooperatives – all in one region, already supported by FtMA, and only active in season C –, the external validity of results on SHFs is limited.

FINDINGS

EQ 1 – Relevance: To what extent is the pilot activity appropriate for the realities and needs of the targeted beneficiaries, including smallholder farmers, specifically women, as well as other value chain actors?

6. The pilot offers a solution to the widespread problem of aflatoxin. It complements existing approaches to aflatoxin reduction, such as adequate post-harvest handling and storage (PHHS) practices promoted by FtMA. The pilot is closely aligned with the relevant policies and strategies of WFP and Government to ensure safe food and support for SHFs. SHFs and all other members of the maize value chain have an opportunity to benefit from the technology.

EQ 2 – Relevance: To what extent is the introduction and use of the technology accepted, understood by, and accessible for smallholder farmers (especially women) and other stakeholders?

7. Smallholder farmers were only being made aware of the technology at the end of evaluation period and processing of smallholder grain began thereafter. Traders, processors and government are generally positive about the potential value of the technology.

EQ 3 – Efficiency: Is the pilot activity cost-effective in terms of higher-level outcomes (reduction in aflatoxin levels, smallholder integration in maize value chains)?

8. For agro-processors, AflaSight is the least costly solution for aflatoxin reduction if they choose to offset the additional costs of the process by buying contaminated grain from coops at sufficiently low prices. Cost-effectiveness calculations suggest that the required price discount is only half of the current price difference between premium and local markets – sharing of profits from the technology between buyers and coops is thus in principle possible.

EQ 4 – Effectiveness: How well does the LumoVision technology and its related processes perform in the local context, and what factors influence its effectiveness in achieving the technical objectives?

9. The technology has shown its ability to reduce aflatoxin levels. The average reductions so far are 72 percent for grain from season B stored by traders and 55 percent for fresh harvest from season C while weight loss from optical sorting is typically below 5 percent. Results for season A may be different. The first batches of commercial grain from a cooperative have been converted from low to high quality by the technology with no failures.

EQ 5 – Effectiveness: To what extent will the technology help smallholder farmers (especially women) to connect with premium buyers, why and how, and what enabling or disabling factors are present?

10. The technology allows agro-processors to source a larger share of their demand for high-quality maize domestically. This additional demand will increase connections between coops and premium buyers. Premium buyers might want to first 'test' the technology with coops that already apply sound PHHS practices before connecting with coops that face larger aflatoxin problems. FtMA support (PHHS, information on AflaSight, etc.) plays an important role in creating the conditions for linking coops to premium buyers. No major disadvantages from the technology have been identified for farmers.

EQ 6 – Impact: What effects, or emerging effects, are being realized for smallholder farmer livelihoods, especially for women?

11. Any grain that would previously have been rejected (but can now reach premium markets) can bring additional income for smallholder farmers, provided that premium buyers share their gains from the technology with farmers. This requires cooperatives to connect with direct users of AflaSight and be sufficiently informed about the technology and the aflatoxin levels of their harvest to negotiate their profit share. These conditions that are not fully met yet. While it is too early to know the magnitude of the income effect on farmers, AflaSight will make the biggest income difference for farmers with contaminated grain that would otherwise marginally fail the acceptance threshold. Any income increase, once achieved, is likely to continue in the future and increase farmers' investment in agricultural production and livestock, human capital, and savings/insurance management.

EQ 7 – Impact: What are the likely outcomes within the wider market systems and maize value chain?

12. Increased domestic high-quality grain production should reduce input costs for processors and may contribute to improved profitability, lower food prices, and increased exports of food products. Smaller unregulated mills and food producers will produce less contaminated food.

EQ 8 – Sustainability: Is the pilot activity based on realistic assumptions, is it technically and financially viable, and should it be scaled up – and if so, what could be scaled, how, and why?

13. The business model for AflaSight seems realistic but the high fixed costs attached to the machine mean that the throughput for each machine must be high to support the costs. It is too early to assess demand but if it is sufficient, then the pilot should be scaled-up.

EQ 9 – Sustainability: Are there adequate local capacity and institutional arrangements to sustainably continue the operations?

14. There are adequate aggregation and storage facilities in the country to allow for the scale-up. Government has been very supportive of the pilot so far and this is likely to continue.

CONCLUSIONS

Conclusion 1: Aflatoxin is a major problem in Rwanda and optical sorting has the potential to make a big contribution and generate direct or indirect benefits for all members of the maize value chain.

15. Contaminated grain is widespread due to poor storage and drying facilities combined with high rainfall. The Buhler LumoVision is the first technology to offer effective sorting of high volumes of grain to

remove aflatoxin. The main direct users and beneficiaries of the technology are likely to be agro-processors and traders while the potential benefits for coops and SHFs are indirect.

Conclusion 2: The machine's performance in the pilot so far is likely to be sufficient to reduce aflatoxin levels in grain and provide a cost-effective solution for increasing the volume of domestic grain available to processors.

16. After only two months of operation – not including the main agricultural season A –, the machine is able to remove 80-90 percent of affected grains from the most contaminated stocks. The operating costs are sufficiently low for processing to be financially worthwhile with current grain prices.

Conclusion 3: AflaSight should enable farmers to sell a larger quantity of grain to premium markets, and increase their income, provided that they are able to connect – and negotiate higher farmgate prices for aflatoxin-affected grain – with the direct users of AflaSight.

17. Farmers will not use the process directly but will benefit whenever they can sell moderately contaminated grain that would otherwise have been sold to informal markets to buyers use AflaSight and gain a premium price. Whether buyers will share the profits from the technology with farmers will depend on the negotiation capacity of farmers, which is currently limited by information gaps related to AflaSight and the aflatoxin levels of their produce.

Conclusion 4: Women and men have equal access to the technology, but they may benefit from it somewhat differently although it is too early to tell with certainty.

18. Women are reported to be more diligent at looking after their crops and better at following coop guidelines and rules for PHHS and aflatoxin prevention. If this causes lower rejection rates their grain will not need to use the AflaSight process.

Conclusion 5: There are many potential advantages for consumers and the economy.

19. An increase in Rwandan maize that meets the aflatoxin standards means that more domestic grain will be used for food and the benefits will also trickle down to small millers and producers, who will eventually receive higher quality maize also and so produce safer food.

Conclusion 6: FtMA will play an important role in the introduction of AflaSight to guide farmers and coops as to how they maximise their chances to sell to processors and share the value added from the technology.

20. FtMA already work closely with coops and can ensure that farmers use their bargaining strength to receive back part of the benefit attached to upgrading the seed.

Conclusion 7: The pilot clearly needs to continue for several more months to gain more experience with the process itself, learn how value chain members make use of it, and make decisions on scaling up.

21. The technology has only been running for a short time and needs probably six months more to generate sufficient results to make decisions about scaling up. Potentially high fixed costs mean that AflaSight will need to ensure that there is a strong (demand driven) market before scaling up to ensure sufficient throughput.

RECOMMENDATIONS

Recommendation 1 (high priority – to be implemented immediately until the end of 2023):

22. WFP/FtMA should support (throughout the life of the FtMA programme) coops whose grain passes through the AflaSight process, as a means of increasing the income of SHFs (and women in particular) and continuing the shift from subsistence to commercial farming. This should include: further development of the food systems approach in Rwanda in relation to the project; further extension of FtMA support to coops and farmers in terms of production and PHHS skills to connect with premium buyers; and fostering the availability of aflatoxin testing to coops and farmers, for example through AflaKiosk.

Recommendation 2 (high priority – to be implemented immediately until early 2023):

23. WFP/FtMA should continue to monitor and support the engagement of SHFs with the AflaSight pilot to maximise its value for them and to maximise the access of coops to the technology. This should include: support to coops in terms of market links, negotiations and contract arrangements with premium buyers; support to AflaSight for awareness events; and provision of information about AflaSight to farmers.

Recommendation 3 (high priority – to be implemented immediately until late 2022):

24. The Innovation Hub for Eastern Africa, with support of the Rwanda CO, should mobilise innovation funding for AflaSight until the results are better understood and can inform the decision on scale-up (while already exploring funding options for scale-up). This should be for at least the three agricultural seasons. Work should begin to explore means of funding the scale-up, for example through the Innovation Hub, international development banks, and private investors.

Recommendation 4 (medium priority – to be implemented from mid-2022 to early/mid-2024):

25. WFP should explore opportunities to work with RICA to support their efforts to widen the enforcement of aflatoxin standards and to carry out market surveys to understand better the extent of aflatoxin contamination in grain and flour on the market in Rwanda.

Recommendation 5 (medium priority – to be implemented from mid-2022 to early/mid-2024):

26. WFP should work with the authorities and key stakeholders such as East Africa Exchange to explore the opportunity to further develop a warehouse receipt system in Rwanda in the context of the quality "insurance" provided by AflaSight. Warehouse receipt systems allow farmers to partially monetise their crop while retaining ownership in order to sell when prices are most favourable. Initial exploratory meetings should be held within the next three months.

Recommendation 6 (medium priority – to be implemented from mid-2022 to early/mid-2023):

27. WFP (RBN) should commission a study to identify which countries in East Africa would most benefit from access to the Bühler LumoVision technology. The results of the study (on market size, aflatoxin levels, smallholder benefits, etc.) can be used to guide WFP's support for regional scaling-up of AflaSight or other partners.

1. INTRODUCTION

1.1. EVALUATION FEATURES

1. The subject of this decentralized evaluation is **AflaSight, an innovative pilot activity for aflatoxin reduction in the maize value chain of Rwanda**. The evaluation was commissioned in November 2020 by the Regional Bureau of Nairobi (RBN) of the World Food Programme (WFP) in collaboration with the WFP-led Farm to Market Alliance (FtMA)[1] and the WFP Rwanda Country Office (CO). It was implemented by a consortium of Particip (lead company) and the Center for Evaluation and Development (C4ED). Annex 1 includes the Terms of Reference (ToR) for the evaluation.

2. AflaSight, the activity and start-up firm of the same name, has been financially supported by the WFP Innovation Hub for Eastern Africa, a regional hub of the global WFP Innovation Accelerator. The activity uses an optical sorting technology of a third-party manufacturer (Bühler) to remove aflatoxin-infected kernels from batches of maize grain. It also provides drying and cleaning services and engages in market operations with traders (and potentially other value chain actors in the future). While the service model of AflaSight is, in principle, open to users across the country, the evaluation focused on pilot operations in the Special Economic Zone of Kigali, with maize from previous seasons stored by traders, as well as four FtMA-supported maize cooperatives in the Gisagara and Nyanza districts of Rwanda as potential 'pilot' suppliers of newly harvested grain.

3. Originally expected to cover agricultural seasons A and B from February to August 2021, the evaluation period was substantially shifted by the delay in the installation of the optical sorting machine in Rwanda (October 2021) and shortened by the expiration of the evaluation budget in December 2021. The evaluation thus covers only the first three months of the AflaSight pilot from October to December 2021 (agricultural season C). It serves the dual purpose of learning (why certain results occurred, or may occur, or not; and lessons and good practices for operational and strategic decision-making) and accountability (performance measurement and assessment). The changes in the timeline further increased the focus on learning, with relatively more weight on forward-looking elements than on accountability and past performance. Dimensions of Gender Equality and Women's Empowerment (GEWE) have been mainstreamed across the evaluation objectives.

4. The primary users of the evaluation report and its findings comprise:

- FtMA, WFP Rwanda CO, AflaSight, Bühler, and the Rwandan Ministry of Agriculture and Animal Resources (MINAGRI), which seek evidence to decide on further support and scale-up of the pilot
- WFP RBN, which seeks strategic guidance, programme support, and oversight, especially related to nurturing and scaling up new innovation projects
- WFP Headquarters, for wider organizational learning and accountability, and the Office of Evaluation, for evaluation syntheses and reporting to the Executive Board.

5. The detailed evaluation timeline is presented in Annex 2. In-country data collection for this evaluation was carried out from 15 to 23 November and 13 to 16 December 2021 (interviews, focus groups, and field visits), and from 29 November to 13 December 2021 (quantitative smallholder survey). The evaluation and survey teams included in-house and external experts of Particip and C4ED.

[1] FtMA is an alliance of six global agri-focused organizations (the Alliance for a Green Revolution in Africa, Bayer, Rabobank, Syngenta, WFP, and Yara International). FtMA forms private and public sector partnerships to deliver products and services tailored to the needs of farmers. The objective is to sustainably improve smallholder farmer incomes and resilience and to develop commercial viability for all value chain stakeholders. FtMA currently operates in Kenya, Rwanda, Tanzania and Zambia.

1.2. CONTEXT

6. In 2019, the real gross domestic product of **Rwanda** grew by 9.5 percent. As a result of the Covid-19 pandemic, it dropped by 3.4 percent in 2020[2] but is estimated to have rebounded by 10.2 percent in 2021.[3] The international **poverty rate** of Rwanda stood at 55.4 percent in 2019, and is estimated to have increased by more than 3 percentage points in 2020 and have decreased by 0.7 percentage points in 2021.[4] In relation to Sustainable Development Goal **(SDG) 2**, **access to food** is determined mainly by seasonal patterns, commodity prices and people's purchasing power and is influenced by socio-economic norms and structural inequalities. Prior to the Covid-19 pandemic, in 2018, two thirds of households reported difficulties with access to food at some point in the previous year. In the same year, 38.6 percent of the population was identified as marginally food secure, 17 percent as food insecure, and 1.7 percent as severely food insecure. [5] Female headed households were more prone to be food insecure or severely food insecure than male-headed households (23 versus 17 percent). Low crop yields and animal productivity hamper food security improvements, especially among subsistence farmers. In 2020, maize has the third largest harvested crop area after beans and bananas with an average yield of 1.5237 metric tons (MT)/ha and a total production of 448,633 MT in the country.[6]

7. Rwanda has a large workforce of smallholder farmers, mostly **women** (76 percent and 54 percent of the total female and male workforce, respectively, worked in agriculture in 2018).[7] While women have (formally) equal rights regarding agricultural land,[8] they still experience discrimination as a result of social norms and power imbalances which tends to prevent them from contributing to their own livelihoods and limits their access to credit, extension services and farming inputs. Cultural practices leave lower-value subsistence crops to women and attribute cash crops to men. Women also have limited power in negotiations with buyers over sales and prices, and they lag behind in some capacities and skills. Compared with men, there are fewer women in the formal and bigger agriculture business. While women participate in cooperatives, they rarely occupy executive positions.[9]

8. Despite the relatively small geographical area of Rwanda, many **smallholder farmers** cannot access commercial markets. Quality requirements of big processors are not well understood by farmers, especially in relation to **aflatoxin levels in maize**. Aflatoxin is produced by Aspergillus fungi, which thrive in a variety of crops and grains when stored in humid conditions.[10] Aflatoxin (a by-product of the infection) is a carcinogen and thus endangers the health of consumers. Smallholders rarely have access to efficient drying facilities and the stored crop is not protected from further rainfall.

9. Measures to control aflatoxin include post-harvest practices and biological controls (such as 'Aflasafe' tested by the International Institute of Tropical Agriculture (IITA)) exist in Rwanda, but these have (so far) not reduced the level of aflatoxin in maize crop at a larger scale. The contamination of already infected maize cannot be removed at commercial scale using current technology, and government promotion of aflatoxin reduction measures, regulations on aflatoxin levels in food – maximum values of 10 and 5 parts per billion (ppb) are allowed by the East African Community for total aflatoxin and aflatoxin B1 respectively[11] – and combined private/public efforts have not contained the problem. A 2019 study of nine flours in local

[2] World Bank. 2022. Open Data.

[3] International Monetary Found. 2021. Rwanda: Staff Concluding Statement of the 2021 Article IV Mission and Fifth Review of the Policy Coordination Instrument.

[4] World Bank. 2021. Macro Poverty Outlook for Sub-Saharan Africa, Annual Meetings 2021.

[5] WFP. 2018a. Rwanda: Comprehensive Food Security Analysis 2018.

[6] FAO. 2022. Food and Agriculture Data.

[7] National Institute of Statistics of Rwanda. 2018. Labour Force Survey Trends, February 2018.

[8] The Succession Law of 1999, the 2004 Land Policy and 2013 Land Law, and other related legal and policy reforms, provide women with equal rights to inheritance and all aspects of land acquisition, registration and management.

[9] FAO. 2020. Financial Services for Women: Case study on Women's Participation in the Maize and Bean Value Chains in Rwanda.

[10] The problem is thus most acute for the crop harvested in January/February as this is infected in storage during the long rains in March/April.

[11] World Trade Organization. 2013. East African Standard: Maize Grains – Specification for East African Community.

Rwandan markets still found mean aflatoxin levels of over 60 ppb.[12] Similarly, 2021 data from unprocessed maize samples of more than 80 traders in 15 locations, screened through mobile testing facilities ("AflaKiosk") supported by the International Finance Corporation (IFC), found that 50 percent of the maize samples tested had above 10 ppb and 25 percent above 40 ppb.[13] In line with these results, aflatoxin handling rules in Rwanda were tightened in April 2021, requiring all warehouse operators, wholesalers, and other companies dealing with maize and a range of other commodities to have aflatoxin testing facilities prior to purchasing, storing or processing the grain.[14]

10. Persistently high aflatoxin levels in the maize produced by smallholder farmers prevents them from selling their grain at higher prices to premium buyers (producers of flour and animal feed) adhering to aflatoxin regulations. Premium buyers must then import most of their demand at higher cost, and farmers sell their contaminated maize crops at price discounts to informal networks, which reduces their income and livelihoods.[15]

11. **WFP's work** on smallholder market integration and aflatoxin control in Rwanda aims to address these issues and is based on its Country Strategic Plan (CSP, 2019–2023). Specifically, Strategic Outcome 4 of the CSP is: "*Smallholder farmers, especially women, have increased marketable surplus and access to agricultural markets through efficient supply chains by 2030*".[16] CSP Activity 4 supports this Strategic Outcome by focusing on smallholder support (including gender), value chain development and food safety.[17] Many of these activities are implemented through the Rwanda branch of FtMA. As per December 2021, FtMA Rwanda supported 101,335 smallholder farmers organised in 298 Farmer Service Centres,[18] with the aim to bridge the last-mile gap between these farmers and other value chain players. The majority of Farmer Service Centres are run by cooperatives that aggregate input buying and output sales and provide agricultural know-how. FtMA Rwanda operates as the (de facto) coordination platform of the maize value chain, bringing together off-takers and agro-processors, financial institutions, input providers, logistics, post-harvest equipment suppliers, government institutions and development partners to ensure predictable income for farmers.

12. The previous work of WFP and FtMA Rwanda forms part of the wider **WFP food systems approach** in the East Africa region as outlined in the Strategic Approach Paper (2021) of RBN. Among other opportunities, the paper identifies smallholder support and market access as frameworks for the formulation of context-specific, integrated value chain development projects. It also acknowledges that a broad range of private sector actors – from farmers to multinational corporations – can be potential collaborators, especially those with increasing emphasis on social values. Moreover, the strategy highlights the potential role of WFP in fostering innovation and incubating new food systems 'offerings' (such as AflaSight) with existing WFP clients and leveraging them with new audiences.

13. In line with **SDG 17** and the 2018-2023 United Nations Development Assistance Plan, WFP Rwanda partners with **other United Nations (UN) agencies**, MINAGRI, the Rwanda Agricultural Board (RAB, an autonomous body with the mission of championing the agricultural sector development in the country), and the Rwanda Standards Board (RSB) in the areas of food and nutrition security, crop production, value chain development, private sector investment and food standards.

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[12] Grosshagauer, S., et al. 2020. Inadequacy of Nutrients and Contaminants Found in Porridge-type Complementary Foods in Rwanda.

[13] IFC. 2021. Aflatoxin Testing kiosks – Rwanda: September Report.

[14] RICA. 2021. Announcement Meant to Prevent Spread of Aflatoxin in Some Traded Agricultural Commodities.

[15] Less than 15,000 tons of farmer production of maize reaches premium buyers, out of an estimated 350-450,000 tons of national production per year. The premium buyers import most of their demand (>100,000 tons) at higher cost while farmers sell their contaminated maize at significant reduced prices. Source: WFP. 2020a. Terms of Reference for the Evaluation of an Innovative Pilot Activity on Aflatoxin Reduction and Smallholder Farmers Market Integration and Income Generation in Rwanda.

[16] WFP. 2018b. Rwanda Country Strategic Plan (2019–2023).

[17] Activity 4 i) supports the government to build capacity for quality assurance, post-harvest handling and storage; ii) uses agriculture value chains as a platform for addressing gender inequalities; iii) builds national capacity for the distribution of post-harvest equipment; iv) integrates local smallholder farmers into the value chain; and v) provides capacity strengthening to enable the Rwanda Standards Board to develop laboratory facilities for testing critical food safety parameters, including for fortified blended foods.

[18] FtMA. 2022a. Rwanda Country Profile.

14. Among other UN agencies, IFC is a key player in value chain strengthening, smallholder support and (more recently) aflatoxin control. Under the Private Sector Window of its Global Agriculture and Food Security Programme (GAFSP),[19] IFC holds a share in African Improved Foods (AIF – a partnership between the Government of Rwanda, several development finance institutions and a private company)[20] and has established off-taker contracts for low-aflatoxin maize with smallholder farmers in the country. More recently, IFC has supported mobile grain testing facilities ("AflaKiosk") in major grain trade hubs of Rwanda under the GAFSP – see Section 1.3 for details.

15. UN agencies also deliver wider support in related areas. The Food and Agriculture Organization (FAO) in Rwanda focuses on food security and nutrition, agricultural productivity, value chain development and private sector investment. The World Bank has many initiatives for the development of sustainable land, and crop production, to tackle issues of food insecurity and low livelihood income levels among rural communities in Rwanda. The African Development Bank supports the rural development sector in Rwanda through various development investments. The World Health Organization has a focus area to promote a safer and healthier environment, improved nutrition and food safety.

16. Besides UN agencies, many non-governmental organizations contribute to the improvement of food security in Rwanda, and international research and technology transfer. Organizations such as CGIAR[21], the Alliance for a Green Revolution in Africa, and Harvest Plus play a significant role in bridging research and knowledge gaps (as well as disseminating technology) on various areas of food security in Rwanda.

17. Relevant **government policies include:**

- The National Food and Nutrition Policy (2013-2018)[22].
- The Revised Gender Policy (2021)[23], which contains a number of strategies across various sectors of gender mainstreaming. Within agriculture, the policy recognizes the need for "*Mobilize and build the capacity of women to participate in more productive agricultural value chains (agro-processing, post-harvest process, irrigation among others) through cooperatives and agri-businesses.*"
- The Rwanda Private Sector Development Strategy (2013-2018)[24], which aims for entrepreneurship development, with a specific focus on commodity chain development. National agro-processors promote the availability and access of nutritious food products on Rwanda's domestic market – and are the main buyers of premium maize in the country.
- Regulations of the Ministry of Trade and Commerce (MINICOM) regarding domestic trade of maize to maintain minimum quality standards and incomes for farmers. Since 2015, MINICOM also sets the seasonal minimum farmgate prices for maize.

1.3.SUBJECT EVALUATED

18. This evaluation covers the first three months of **AflaSight**, a **pilot activity** that combines an innovative technology – an optical sorting machine ("Sortex A LumoVision")[25] – for **aflatoxin reduction in infected maize grain** with ancillary processes and market operations. AflaSight is operated by a start-up company with the same name (part of Kumwe, a group of companies that provide post-harvest services in Rwanda[26]), while the **LumoVision** technology has been developed by Bühler, a multinational plant equipment manufacturer based in Switzerland. The AflaSight office and plant are located at the premises of Kumwe in

[19] Subject to an ongoing impact evaluation: NORC at the University of Chicago. 2020. Impact Evaluation of Rwanda Projects, Global Agriculture and Food Security Programme Private Sector Window (GAFSP PrSW): Midline Assessment.

[20] AIF. 2021. The role of AGRA in national systems development in developing countries: the case of AIF's ' On Cob model' in post-harvest handling and marketing in Rwanda.

[21] Formerly, the Consultative Group on International Agricultural Research.

[22] Government of Rwanda. 2014a. National Food and Nutrition Policy

[23] Ministry of Gender and Family Promotion. 2021. Revised National Gender Policy: Accelerating the Effectiveness of Gender Mainstreaming and Accountability for National Transformation.

[24] MINICOM. 2013. Rwanda Private Sector Development Strategy 2013-2018.

[25] The fact that AflaSight uses the LumoVision technology in Rwanda is public information. See, for example: WFP. 2021a. WFP Rwanda Country Brief, November 2021; WFP. 2020a. Terms of Reference for the Evaluation of an Innovative Pilot Activity on Aflatoxin Reduction and Smallholder Farmers Market Integration and Income Generation in Rwanda.

[26] AflaSight, Kumwe Trade, and Kumwe Harvest. The latter was acquired by AIF in October 2020.

the Special Economic Zone (SEZ) of Kigali. The AflaSight processing line includes a drier leased from RAB, two seed cleaners, the LumoVision machine provided by Bühler under a research and development agreement, short-term warehouse facility, and quantitative aflatoxin testing equipment (see sub-question 4.2 for a detailed description).

19. In contrast to existing solutions that focus on aflatoxin prevention, LumoVision removes kernels that are already infected by aflatoxin from batches of maize at industrial scale. The technology uses cameras to detect spectra of emissions from maize grains under ultraviolet (UV) light. The grains passed through the machine fluoresces under the UV light causing a weak emission of light (non-infected grains in blue, infected grains in green). Colour-classified contaminated grain is then removed from the batches passed through the machine. In the process, the machine collects data on each batch of grain and stores it on a cloud-based platform of Bühler.[27]

20. The **strategic objective** of AflaSight is to solve the aflatoxin problem in maize in Rwanda (and Africa more broadly) and establish the quality link that enables smallholder farmers to connect with premium buyers of locally produced maize. For WFP, the pilot activity contributes to Strategic Outcome 4 (market access for smallholder farmers) of the current (2019-2023) CSP for Rwanda. The pilot activity is based on a **partnership** between the WFP Innovation Hub for Eastern Africa[28] and RBN (financiers of the starting grant and this evaluation respectively), AflaSight (operator of the activity), Bühler (technology provider), FtMA (expertise on smallholder support and value chain development), MINAGRI and RAB (support to the import and operation of the technology).

21. The AflaSight pilot has been financially supported by the WFP Innovation Accelerator/Hub through its "Sprint Programme" with a grant of 100,000 USD.[29]

22. AflaSight was accepted into the Sprint Programme in November 2020, and the installation of the LumoVision machine was originally expected by late January/late February 2021. However, the setup of the processing line was only completed in early October 2021 due to extensive administrative procedures, the unexpected announcement of the Cabinet of Rwanda in mid-April that the originally foreseen AflaSight location (at the RAB seed plant in Masoro, SEZ) would be privatized and no longer be available, and delays in the import of the individual components of the processing line. While the **pilot phase** of AflaSight is expected to last one year – the initial period (until August 2022) in which Bühler provides the LumoVision machine to AflaSight, without leasing fees, for research and development purposes –, the **evaluation period** had to be limited to the first three month of the pilot (October to December 2021), coinciding with the minor harvest season C in the second half of November. The methodology section (1.4) provides the rationale and more details on the evaluation period.

23. **Key activities** during this period included the setup of the AflaSight processing in the SEZ of Kigali, as well as processing of maize from different domestic sources:[30]

- 130 MT of grain processed for the calibration of the machine in October 2021
- 112.5 MT of grain from previous seasons A (January-February 2021) and B (June-July 2021) stored by traders in their warehouses and processed in November and December 2021
- 30.1 MT of new season C harvest bought by a premium buyer from one of the FtMA-supported cooperatives in December 2021 and processed in early January 2022.

24. AflaSight and WFP/FtMA implemented information campaigns and market operations with different value chain actors. In the evaluation period, AflaSight has mainly informed and operated with actors further 'downstream' the maize value chain – traders and agro-processors. Traders and agro-processors bring truckloads of maize grain to the AflaSight plant, where the grain is unloaded and tested for aflatoxin and moisture content to determine the required services in the processing line. The grain is subsequently dried, cleaned and/or optically sorted, and AflaSight charges service fees for each of these steps to the **direct**

[27] Bühler. 2018. Bühler LumoVision: Saving Lives and Improving Livelihoods with Revolutionary Data-driven Grain Sorting Technology; Microsoft. 2018. New Bühler Machine Uses the Cloud to Find the Needle in the Haystack – or the Poisonous Kernel in a Truckload of Corn.

[28] A regional hub of the global WFP Innovation Accelerator.

[29] 5 out of 100 project applications presented to the WFP Innovation Hub for Eastern Africa were selected for the Sprint Programme, one of them being AflaSight.

[30] In addition, AflaSight also processed imported maize.

users/beneficiaries (traders and agro-processors). The range of direct AflaSight users may potentially be widened in the future, also depending on whether additional units of the LumoVision machine will be installed in other locations of the country.

25. AflaSight-specific activities in the 'upstream' part of the value chain – with **smallholder farmers (SHFs) and cooperatives as indirect beneficiaries** – have mainly been implemented by WFP and FtMA Rwanda. At the end of November, FtMA informed the leaders of four selected 'pilot' cooperatives, located in the Gisagara and Nyanza districts of Rwanda, about the technology. FtMA has also provided technical advisory to AflaSight. Within its wider mission in Rwanda (not limited to AflaSight), FtMA and its implementing partners[31] offer training on aflatoxin awareness and control through post-harvest handling and storage (PHHS), digital solutions, access to financing for smallholder, other capacity strengthening and support to market access to cooperatives and their members (see the previous context section).

26. The exact **number of indirect beneficiaries** is not well defined but essentially depends on how many cooperatives chose to sell on grain – thus 'connecting' – to direct users of AflaSight. In the four pilot cooperatives, for example, about 4,000 members have been involved in season C production of maize grain. However, only 5.6 percent of their total season C harvest purchased by a premium buyer in late 2021 (in fact, only 13.2 percent of the harvest of only one of the cooperatives) has been processed by AflaSight in the evaluation period.[32] The other three pilot cooperatives ultimately decided to sell in the cob model to their buyers (explained further below in this section), rather than on grain.

27. The **geographic scope** of this evaluation, which includes the locations of the AflaSight plant and the season C 'pilot' cooperatives selling to premium buyers, is shown in Annex 3.

28. The original assumptions and viability statement of the AflaSight business model predict income gains for direct and indirect users. These income gains depend on the effectiveness parameters of the machine reflected in the **planned outputs** of the pilot activity (also see the Theory of Change in Annex 4):

- Aflatoxin infection in maize is reduced, depending on starting levels, to grade 1 safe limits (<5 ppb) or to 5-20 ppb for other markets, by removing 90 percent of the infected kernels.[33]
- Volume loss from optical sorting is limited to 5 percent.
- A sufficiently large throughput of grains in the machine is achieved (5-20 tons per hour, and approximately 10,000[34]-50,000[35] tons over one year).
- Increased knowledge of AflaSight and aflatoxin levels among value chain actors.

29. The first parameter has been achieved in trials of the machine in Asia. AflaSight has tested the machine for the first time in Africa. Results (i.e. the comparison of planned vs. actual outputs) are presented in evaluation question 4 in the findings section (2.4).

30. Relative to its original plan[36], **key changes in the pilot** included the following:

- The operating site is different from the originally planned location (see above).
- The pilot has started in (and the evaluation only covers) season C rather than seasons A and B (see section 1.4), and the pilot has also processed grain stored from previous seasons rather than only fresh harvest.

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[31] Such as the Rwanda Rural Rehabilitation Initiative (RWARRI).

[32] The four cooperatives sold a total of 539 MT of grain (or grain equivalent on cob) to a premium buyer in 2021 season C. The only cooperative selling on grain (Coamanya Nyanza) sold 227 MT, of which 30 MT were processed by AflaSight.

[33] Assuming a 90 percent reduction in aflatoxin, maize with an initial aflatoxin level <50 ppb would be reduced to access the top-premium market (<5 ppb). If the initial aflatoxin level is >50 ppb or the reduction by the machine is below 90 percent, some of the processed grain may end up in the range of 5-20 ppb but could still be sold in markets that are more favourable than traditional (status-quo) markets for AflaSight users. Some off-takers can accept maize with aflatoxin levels <10 ppb, and others (e.g. animal feed producers) accept 10-20 ppb.

[34] WFP. 2020a. Terms of Reference for the Evaluation of an Innovative Pilot Activity on Aflatoxin Reduction and Smallholder Farmers Market Integration and Income Generation in Rwanda.

[35] AflaSight. 2020. Application Form for the Sprint Programme of the WFP Innovation Accelerator.

[36] Outlined in; AflaSight. 2020. Application Form for the Sprint Programme of the WFP Innovation Accelerator; WFP. 2020a. Terms of Reference for the Evaluation of an Innovative Pilot Activity on Aflatoxin Reduction and Smallholder Farmers Market Integration and Income Generation in Rwanda.

- Unlike the AflaSight application for the Sprint Programme, the current business and revenue model no longer estimates income gains for smallholder farmers as indirect users but is consistent with the fact they can only access the machine through other agents (traders, aggregators[37], and agro-processor). Rather than directly benefiting from the machine, the gains of SHF cooperatives in the new setup depend on their knowledge about AflaSight and their bargaining power in claiming that the direct users of AflaSight share some of their income gains with the cooperatives.
- The service fee and revenue models have been fully formulated but predict less income gains per kilogram (kg) for direct users than the original model.
- AflaSight has temporarily waived optical sorting fees for a premium buyer in the evaluation period in exchange for access to the processing data of that buyer.

31. **No formal logical framework** or Theory of Change (ToC) has informed AflaSight. However, most of its activities, key assumptions, expected results (and the result chain) are described in project documents, such as AflaSight's application for the Sprint Programme. Based on these documents and interviews, the Evaluation Team has **reconstructed the ToC** shown in Annex 4. The core mechanism of this ToC is the result chain, which flows from the previously described key activities and outputs (which lead to, or are the direct results of, the processing of grain respectively) to outcomes and higher-level impacts for value chain agents. The ToC also states the key assumptions underpinning these mechanisms, as well as the key contextual factors affecting results. The ToC reconstructed in the inception phase has been updated by the evaluation team based on the previous changes in the pilot, in particular the fact that cooperatives are not directly connected to AflaSight.

32. The **planned outcomes** (and higher-level impacts) of the pilot are depicted in the ToC as well. While the planned *outputs* essentially describe the effectiveness of the LumoVision machine,[38] *outcomes and impacts* capture the benefits along the value chain, as well as learning aspects of the AflaSight business model. Specifically, the expected outcomes and impacts are:

- Smallholder farmers (especially women) and their cooperatives increase their market access to premium buyers of maize and consequently enhance their income (by 15 percent),[39] livelihoods and food security (upstream part of the value chain).
- Premium buyers increase their share of locally sourced grade 1 maize and thus reduce their dependency on imports, and the population consumes less contaminated food (downstream part of the value chain).
- The viability of the AflaSight business model is confirmed and its scalability assessed.

33. **Related interventions,** besides FtMA activities, include the IFC AflaKiosk and the AIF/Kumwe cob model. In July 2021, IFC started establishing mobile grain testing facilities ("**AflaKiosk**") in major grain trade hubs of Rwanda under the GAFSP. By offering quantitative tests for aflatoxin, moisture content, pests, and other measurement, AlfaKiosk provides data on maize quality that informs farmers, traders and other users to decide whether grain can be directly sold to premium buyers or requires prior treatment such as aflatoxin reduction, drying, etc. AflaSight uses AflaKiosk facilities in its processing line.

34. Prior to AflaSight, AIF and Kumwe pioneered the "**cob model**" which takes maize direct from the field to the processor without dehulling and storage on farm – reducing the opportunity for contamination (prevention). The cob model started in February 2017 as a series of two pilot projects. AIF purchased the cob

[37] For example, AflaSight has signed an agreement for Season A 2022 with One Acre Fund, which will aggregate on behalf of SHFs who are not organized in cooperatives. One Acre Fund is expected to directly buy from their farmers. AflaSight plans to dry, clean, and sort their maize that will then go to a premium buyer. These activities fall outside the evaluation period.

[38] The outputs stated in paragraph 27 further above, as well as the Theory of Change more generally, focus on the Sortex A Lumovision machine as the key element of the AflaSight processing line. This is consistent with the evaluation scope defined in the ToR, covering "*Lumovision technical efficiency, effectiveness, and acceptance"* and that "*Through the pilot evaluation, WFP seeks to better understand the efficiency and effectiveness of the machine itself*" (WFP. 2020a. Terms of Reference for the Evaluation of an Innovative Pilot Activity on Aflatoxin Reduction and Smallholder Farmers Market Integration and Income Generation in Rwanda).

[39] AflaSight. 2021. Business model presentations; based on expected net gains from higher market prices for grade 1 maize, minus quantity losses and sorting and drying costs.

from Kumwe in October 2020.[40] AIF buys maize 'on cob' directly at the farmgate and shells it immediately (wet shelling) at central facilities (as opposed to the standard processes of SHFs shelling their cobs, by hand or using mobile shelling facilities of agro-processors, in decentralised locations). Field trials established the average weight loss after shelling and drying per kg of wet cob (and its inverse, the 'grain equivalent' of cob). The quantities and prices of cobs bought from coops are adjusted accordingly. The cob model is part of an ongoing impact evaluation with results expected in 2023.[41]

35. Figure 1 below shows the different configuration of domestic maize value chains (ignoring imported maize) considered in this evaluation. The cob model – one form of direct sourcing at the farmgate – is displayed in column C. Alternatively, agro-processors may directly source on grain at the farmgate (model B) or through traders (model A). The corresponding grain models with AflaSight are depicted in columns D and E respectively.

Figure 1: Alternative configurations of local maize value chains in Rwanda

	A Grain model with traders; no AflaSight	B Grain model with direct sourcing; no AflaSight	C Cob model	D Grain model with traders and AflaSight	E Grain model with direct sourcing and AflaSight
Milling and final processing	Agro-processors	Agro-processors	Agro-processors	Agro-processors	Agro-processors
Optical sorting				AflaSight	AflaSight
Drying and cleaning (grain)	Agro-processors	Agro-processors	Agro-processors	AflaSight	AflaSight
Aggregation from coops	Traders/ aggregators	Agro-processors	Agro-processors*	Traders/ aggregators	Agro-processors
Shelling	Coops/SHFs	Coops/SHFs	Agro-processors*	Coops/SHFs	Coops/SHFs
Harvest and drying (cobs)	Coops/SHFs	Coops/SHFs	Coops/SHFs	Coops/SHFs	Coops/SHFs

* These two stages are inverted in the cob model.

Source: Evaluation team.

36. Given its pilot character, there are no **past evaluations or reviews** of AflaSight or the LumoVision technology (other than the LumoVision trials in Asia and Italy; no results published)[42]. A range of evaluations on the effectiveness and adoption by farmers of other aflatoxin control practices/technologies in Africa exist. These include biocontrol at pre-harvest stage – notably Aflasafe, a microbial soil treatment that reduces Aspergillus infections (e.g. by 82-89 percent in maize and groundnut in Senegal and Nigeria) –, as well as PHHS practices to prevent aflatoxin by reducing moisture in storage and avoiding grain contamination.[43] Different evaluations suggest that market incentives may have the potential of increasing the uptake of aflatoxin control technologies. In Kenya, for instance, an impact evaluation led by the International Food Policy Research Institute (IFRPI) showed that the uptake of PHHS practices and technologies among market producers increased when they had the opportunity to sell aflatoxin-safe maize at a premium a few months

[40] AIF. 2020. Press release, 15 October 2020.

[41] Feed the Future Innovation Lab for Markets, Risk and Resilience at the University of California, Davis. 2020. The Value of Linking Farmers to Maize Value Chains in Rwanda. This document describes the research that is being conducted over the period from 2020 to 2023.

[42] LumoVision builds on a previous optical sorting technology of Bühler also tested in Italy. The results of that trial are reported in: Pascale, M., et al. 2020. Aflatoxin Reduction in Maize by Industrial-Scale Cleaning Solutions. Results of the current LumoVision trial in Italy have not been published yet.

[43] See, for example, the evidence summarised in: Hoffmann, V., et al. 2019. Technologies and Strategies for Aflatoxin Control in Kenya: A Synthesis of Emerging Evidence.

after harvest.[44] The business model and ToC of AflaSight are in line with this evidence, albeit based on a different technology (aflatoxin reduction by removal of infected kernels rather than prevention). While there are no past evaluations commissioned by WFP directly related to AflaSight, the WFP Evaluation of the United Stated Department of Agriculture's Local and Regional Food Aid Procurement Program in Rwanda[45] acknowledges that the AIF/Kumwe cob model was introduced in response to aflatoxin challenges. The evaluation recommended that WFP should conduct an assessment of the different marketing models for SHFs, including grain and cob. The cost effectiveness analysis for the cob, grain and AflaSight models conducted in this pilot evaluation (see EQ 3 below) contributes to the proposed assessment.

37. While the ToR of this evaluation highlight the important role and share (80 percent) of women in the smallholder workforce of Rwanda, no specific gender analysis has been conducted for the pilot activity. AflaSight's grant application does not include any specific reference to female smallholder farmers either. Yet, **gender dimensions** of smallholder farmer support are evident in the monitoring and evaluation (M&E) plan for the Rwanda CSP[46] and the FtMA logframe. The ToR ask the evaluators to identify differential effects of the activity on male and female farmers and to mainstream gender perspectives and considerations through all stages of the evaluation. Details on how this has been considered are given in the following methodology section.

1.4. EVALUATION METHODOLOGY, LIMITATIONS AND ETHICAL CONSIDERATIONS

38. The evaluation has adopted a **mixed methods approach based on theory** to answer the **nine main evaluation questions (EQs)**. The EQs are linked to different thematic elements and result levels of the ToC (see their position in the ToC diagram in Annex 4), and they cover all OECD-DAC **evaluation criteria** except coherence. The chosen criteria correspond to the main questions of interest whether the pilot is appropriate (relevance), cost effective (efficiency), has produced, or is likely to produce, the expected results (effectiveness and impact), and can/should be scaled up (sustainability).

EQ 1 – Relevance:	To what extent is the pilot activity appropriate for the realities and needs of the targeted beneficiaries, including smallholder farmers, specifically women, as well as other value chain actors?
EQ 2 – Relevance:	To what extent is the introduction and use of the technology accepted, understood by, and accessible for smallholder farmers (especially women) and other stakeholders?
EQ 3 – Efficiency:	Is the pilot activity cost-effective in terms of higher-level outcomes (reduction in aflatoxin levels, smallholder integration in maize value chains)?
EQ 4 – Effectiveness:	How well does the LumoVision technology and its related processes perform in the local context, and what factors influence its effectiveness in achieving the technical objectives?
EQ 5 – Effectiveness:	To what extent will the technology help smallholder farmers (especially women) to connect with premium buyers, why and how, and what enabling or disabling factors are present?
EQ 6 – Impact:	What effects, or emerging effects, are being realized for smallholder farmer livelihoods, especially for women?
EQ 7 – Impact:	What are the likely outcomes within the wider market systems and maize value chain?
EQ 8 – Sustainability:	Is the pilot activity based on realistic assumptions, is it technically and financially viable, and should it be scaled up – and if so, what could be scaled, how, and why?

44 Hoffmann, V., and K. Jones 2021. Improving food safety on the farm: Experimental evidence from Kenya on incentives and subsidies for technology adoption.

45 WFP. 2020b. Evaluation of USDA's Local and Regional Food Aid Procurement Program (Rwanda 2017-2019): Endline – Final Report.

46 E.g. one output of Strategic Outcome 4 is "Smallholder farmers (Tier 1), especially women, have improved access to equipment, technical support, and financial services, allowing them to increase their marketable surplus".

EQ 9 – Sustainability: Are there adequate local capacity and institutional arrangements to sustainably continue the operations?

39. Based on discussions with WFP during the procurement stage and the evaluability assessment in the inception phase, the scope of the EQs was slightly reduced in comparison to the EQs originally proposed in the ToR. Annex 5 compares the final EQs with those in the ToR.

40. The **detailed evaluation matrix**, which has constituted the main framework for data collection and analysis, is presented in Annex 6. It breaks down the EQs into more detailed sub-questions and indicators, and presents the different data sources and methods of data collection and analysis for each sub-question.

41. A few additional, very minor adjustments were made to the EQs and sub-questions after the inception phase, following the shift and shortening of the evaluation period (see next paragraph). The formulations of EQs 5 to 8 (and some of their sub-questions) were updated to account for the fact that, at the end of the evaluation period in December 2021, it has still been too early to observe whether higher-level results "*have [actually] been achieved*", but that the timing and data only allow for an evaluative judgement of whether these results "*are likely to be achieved*" in the future. The data sources (and methods of data collection and analysis) in the evaluation matrix have been kept unchanged since the inception phase, although some data sources contain less information than they would have with a longer evaluation period.[47]

42. The **key elements of the evaluation approach** were developed in the inception phase but have been **affected by the change in the evaluation timeline**. The inception report was finalised in April 2021 while the data collection was eventually postponed until November and December 2021. At the time of writing of the inception report, the import and setup of the equipment in Rwanda had already been delayed relative to the initially planned date (early February 2021). Nevertheless, during the inception phase, AflaSight and WFP still expected to initiate the pilot by the end of May. By finalising the inception report before that date, the evaluation team and WFP sought to ensure that the data collection could have started in time to cover agricultural season B. Ultimately, however, the start of the operations was gradually delayed until October 2021 (see Section 1.3). At the same time, the expiration date of the evaluation budget in December 2021 remained unchanged and, in line with WFP procurement and budget regulations, marked the latest date for the evaluation team to finalise all field-based data collection in Rwanda – a key determinant of the timeline.

43. Given these external constraints beyond the control of the evaluation team, the original **evaluation period** (February to August 2021, including the main harvest seasons A and B) had to be shifted and shortened (**October to December 2021)**, covering only the first three months of the one-year pilot. See section 1.3 for the different sources of grain processed during this period.

44. The change in the evaluation period has raised a few additional methodological challenges and limitations, which are outlined throughout the following description of the final evaluation approach. In a nutshell, the original evaluation period would have been long enough to observe most outcomes (albeit only few impacts) of the ToC – whereas **the shortened evaluation period has largely 'cut off' observations beyond the output level**.

45. For example, only 18.9 percent of SHFs interviewed for the survey had heard about AflaSight through their coops at the time they were interviewed.[48] The leadership of the cooperatives were only informed about AlfaSight in the first week of the survey and subsequently briefed their members in general assemblies. Likewise, premium buyer purchases of season C harvest started only towards the end of the data collection. This overlap occurred although the evaluation team had postponed data collection as long as possible under the previous constraints. Only some grain from only one of the cooperatives has been processed by AflaSight in January 2022, also after the end of the data collection.

46. Hence, some of the **evaluability** limitations identified in the inception phase have become more significant. The initial evaluability assessment already anticipated that, besides cost efficiency, the evaluation would generate only limited evidence on higher level-effects on smallholder livelihoods (EQ 6) and the wider market system (EQ 7), as well as some aspects of the sustainability analysis (EQs 8 and 9). Shortening the evaluation period generated some additional uncertainty about the first-order effects on SHFs' connections to premium buyers (EQ 5), their livelihoods (EQ 6), and the AflaSight viability analysis (EQ 8). These results

[47] For example, the smallholder survey has not yet captured many real experiences with AflaSight; and the performance data of the machine have largely been limited to the testing and calibration stage in October 2021.

[48] Table A - 9.

have not been observed yet. The evaluation team has only assessed whether they are likely to be achieved in the future.

47. This pilot evaluation thus contains more formative than summative elements. Rather than focusing on results achieved, it has analysed the setup of the pilot in its very early stage and the perspectives for result generation in the value chain – especially among SHFs – to ultimately assess whether/how AflaSight should be scaled up and supported by WFP.

48. While an attribution analysis had already been discarded at the proposal stage,[49] the previous challenges have also limited the feasibility of other evaluation approaches that rely on actual observation of changes in outcomes and impacts, such as contribution analysis and qualitative comparative analysis. Instead, this evaluation has adopted a **scenario-based approach**, based on **different value chain configurations and AflaSight user models** (see Figure 1 in 1.3), to assess the chances for higher-level results in the future. While the analysis in Section 2 focuses mostly on the trader-based model introduced in the first weeks of the pilot, it also considers the incentives of different value chain actors in alternative configurations that may emerge in 2022. The ToC reconstructed in the inception phase has been adapted to reflect these alternative outcome and impact pathways (see Section 1.3).

49. The analysis of actors and incentives along the possible value chains also introduces a **food systems perspective** in the evaluation. The effectiveness of WFP and AflaSight actions is influenced by – and may itself affect the incentives for – food systems actors, such as agro-processors, traders, cooperatives, SHFs, government authorities, aid agencies, and research institutions. In the findings section, the food systems approach is most visibly reflected in EQs 1.2 (relevance – barriers in the maize value chain), EQ 5 (access of SHFs to premium markets), EQ 7 (outcomes in the wider market system and value chain), 8.3 (scale-up options) and 9.3 (enabling environment).

50. The evaluation approach applied qualitative and quantitative methods of primary data collection and reviewed existing information sources. The **mix of data collection methods** is summarized in Table 1, which also links the data collection methods to the EQs. The specific **data sources** used for each sub-question of the evaluation matrix are indicated in Annex 6. The data collection was not affected by Covid-19. The international and national members of the evaluation and survey teams conducted the primary data collection in Rwanda as foreseen, and there were no travel restrictions.

51. Table 1 and the list of interviews and focus groups conducted in Annex 7 show that the primary data collection involved stakeholders at different levels (national, cooperatives, beneficiary level), and of different types (WFP and implementing staff, AflaSight and other private sector agents, government institutions, other UN agencies, research centres, the leadership of cooperatives, and smallholder farmers).

Table 1: Overview of qualitative (QLI) and quantitative (QTI) data collection methods by EQ

		Method	Data collection format		Evaluation questions								
			Remote/ desk-based	Field/ in person	1	2	3	4	5	6	7	8	9
QLI		Document review	•		■	▒	■	▒	▒		▒	▒	
QLI	Primary	KIIs with regional/national stakeholders	•	•	■	▒	■	■	▒		■	■	■
QLI	Primary	IDIs with local-level stakeholders		•	■	■		▒	■	■	▒	■	▒
QLI	Primary	FGDs with smallholder farmers		•	■	▒			■	■		▒	
QLI	Primary	Direct observation		•	▒			▒	▒				
QTI	Primary	Field survey with smallholder farmers		•	■	■			■	■		▒	
QTI		Review of M&E data	•		▒		▒		▒	▒			
QTI		Review of cost and machine performance data	•				▒	■				▒	▒
KII = key informant interview, FGD = focus group discussion, IDI =in-depth interview					■	*Main source*			▒	*Complementary*			

Source: Evaluation team.

[49] Among other reasons, because (i) the distinction between AflaSight users and users would not have been well defined (e.g. at cooperative level) and (ii) would not have been driven by 'exogenous' differences in exposure to the pilot activity (such as random assignment in an experiment or based on observable characteristics of smallholders or their cooperatives), and (iii) given the expected lack of baseline data for any potential control group.

Compilation and analysis of existing documents and data

52. The evaluation team compiled (with support of the CO and RBN) and reviewed the **documents** listed in Annex 14, which mainly comprised AflaSight and WFP Innovation Accelerator documents, strategy and policy documents of WFP and the national government, and a range of research studies. The evaluation team also compiled, reviewed and analysed **quantitative M&E, performance and cost data** of AflaSight and related interventions (also listed in Annex 14, especially performance data of the LumoVision machine and pricing data of AflaSight services; FtMA data – the sales and contract database, and mobile Vulnerability Analysis and Mapping (mVAM) surveys on PHHS experiences of SHFs; IFC data from the AflaKiosk project; and a premium buyer database of cob model transactions). Due to its pilot character, the overall amount of existing activity-specific documents and data was limited.

Primary data collection and analysis

53. The inception report envisaged primary data collection during season B from cooperatives in a neighbouring district of Kigali. When the start of the pilot was delayed, FtMA selected **four 'pilot' cooperatives** – those active in **season C** – in the **Gisagara and Nyanza districts** in the Southern province of Rwanda (see the map in Annex 3). The four cooperatives are: CCM Muganza, Cojyamugi, Comanya Gishubi (all operating in one sector of the Gisagara district each), and Coamanya Nyanza (operating in two sectors of the Nyanza district). Qualitative and quantitative primary data were collected from all four cooperatives. The data collection instruments were designed after AflaSight operations had started.

54. The primary data were collected in one round.[50] The detailed **field mission schedule** (qualitative: 15 to 23 November and 13 to 16 December 2021, quantitative: 29 November to 13 December 2021) is included in Annex 11. The decision to defer the visit to two of the four cooperatives by three weeks was motivated by the somewhat later start date of their maize harvest. When the evaluation team visited the four cooperatives for qualitative data collection at different points in time, three of them had started harvesting maize in season C (and all four had started at the time of the smallholder survey). In terms of AflaSight awareness, the members of the first two cooperatives visited in November were briefed by WFP about the pilot when the focus group discussions started. The leadership of the other two cooperatives were informed about AflaSight at the end of November and were expected to share the information with the SHFs.

Qualitative primary data

55. **KIIs** refer to interviews with experts in specific thematic, policy or institutional fields about issues within the experts' fields of competence and relevant for the study. In this evaluation, most of the key informants work in the **national offices of stakeholder organizations**. Most KIIs were conducted in Kigali, and a few key informants were interviewed remotely. The full list of KIIs is shown in Annex 7. The instruments (interview guides) are included in Table 10 of Annex 8.

56. **IDIs** covered a wider range of issues with interviewees who, unlikely key informants, are usually not unique 'experts' in a specific field but have been involved in/affected by AflaSight in multiple ways; mainly **traders, and the leadership and technical staff of cooperatives.** The list of IDIs is presented in Annex 7, and the interview guides for IDIs are also included in Table 10 of Annex 8.

57. During the mission in Rwanda, the team leader also participated in a symposium on maize quality organised by IFC in Kigali and conducted short interviews with different stakeholders (KIIs and IDIs).

58. **FGDs**, together with the survey, constituted the main source of primary data from **smallholder farmers.** In each of the four cooperatives, the evaluation team conducted two FGDs with women and two with men. Participants were selected with the support of the WFP Field Office in Huye and the cooperatives. Each FGDs was conducted in Kinyarwanda by one of the two national experts (one woman, one man), sometimes in tandem with one of the international team members. The list of FGDs is shown in the field mission schedule (Annex 11) and the FGD topic guide is presented in Table 11 of Annex 8.

[50] The evaluation approach developed in the inception phase had foreseen two rounds of data collection: remote 'baseline' interviews just before the start of AflaSight operations, and more comprehensive 'endline' data collection in Rwanda a few months later. However, the remote 'baseline' interviews were eventually omitted since the uncertainty about the start date and modality of AflaSight operations was only resolved on short notice. Moreover, it was no longer possible to clearly distinguish between baseline (pre-AflaSight) and endline (post-AflaSight) periods, due to the different origins of the maize processed in the pilot, and uncertainty (until November 2021) about the exact moment in which the cooperatives would be informed about, and connected to, AflaSight.

59. The evaluation team also **directly observed** infrastructure and activities related to the pilot, especially the AflaSight plant and operations in the SEZ of Kigali, and maize harvest and post-harvest activities of the cooperatives in the Southern Province.

Quantitative primary data

60. The **smallholder field survey** collected standardised, large-scale, and statistically representative data from a sample of **members of the four cooperatives**. Box 1 describes the setup (sampling strategy and other key parameters) of the survey. The survey team was composed of researchers from C4ED and enumerators from the Kigali-based Institute of Policy Analysis and Research (IPAR). The survey questionnaire is displayed in Table 12 of Annex 8, and the detailed survey methodology is explained in Annex 9. Box 1 below provides a summary of the key parameters of the survey. The raw data of the survey were cleaned and analysed in Stata, including statistical tests (t-tests) for gender differences in key variables. The full, detailed survey are presented in Annex 10. The tables and figures in this annex are numbered starting with "A- " to differentiate them from those in the main text and the other annexes.

Box 1: Sampling strategy and setup of the field survey with smallholder farmers

Sampling frame:	Member lists of the four 'pilot' coops in Season C beneficiaries (4,038 members)
Sample size:	399 respondents (200 women and 199 men) selected from all four cooperatives
Sampling strategy:	Primary sampling units = sectors Stratification by gender within sectors Random selection of respondents within sectors and gender strata

Cooperative	District	Sector	Number of respondents		
			Men	Women	Total
CCM Muganza	Gisagara	Muganza	49	25	74
Coamanya Gishubi		Gishubi	50	48	98
Cojyamugi		Mamba	50	77	127
Coamanya Nyanza	Nyanza	Ntyazo	25	25	50
		Kibirizi	25	25	50
Total			199	200	399

Interview length:	One hour and a half on average
Language:	Questionnaire in Kinyarwanda (translated from English)
Time period:	Pre-test, supervisor and enumerator training, and piloting: 12-24 November 2021 Data collection: 29 November – 13 December 2021
Survey team:	Ten female and male enumerators, two supervisors, two international survey coordinators/researchers

61. After the analysis by data type/source, the evaluation team **systematically triangulated** the data. The last column in the evaluation matrix (Annex 6) shows the triangulation strategies for some sub-questions, which involved comparing one or more of the following: (i) data collected by different evaluation team members, (ii) qualitative and quantitative data on the same questions; (iii) primary and secondary data on the same questions; (iv) views of different stakeholder types on the same questions (v) data from different individuals of the same stakeholder type on the same questions.

62. **GEWE,** albeit not part of the AflaSight design, has been considered and is reflected in different aspects of the evaluation approach. The evaluation matrix includes several direct references to GEWE issues – mainly at SHF level – in EQs related to relevance, effectiveness and impact. Gender-disaggregated SHF data from the survey and FGDs have been used to inform these EQs. Gender and equity issues are also considered in the conclusions and recommendations of this evaluation.

63. **Ethical considerations** were adequately taken into account in the evaluation, acknowledging that WFP decentralized evaluations must conform to WFP and United Nations Evaluation Group ethical standards and norms. The contractors undertaking the evaluations were responsible for safeguarding and ensuring ethics at all stages of the evaluation cycle. This included, but was not limited to, ensuring informed consent, protecting privacy, confidentiality and anonymity of participants, ensuring cultural sensitivity, respecting the autonomy of participants, ensuring fair recruitment of participants (including women and socially excluded

groups) and ensuring that the evaluation would result in no harm to participants or their communities. Examples of specific measures for these safeguards included:

- *Protecting privacy, confidentiality and anonymity of participants*: All participants in FGDs and the survey were assured that their participation was voluntary and anonymous, and that they could withdraw from the data collection any time without negative consequences (informed consent). The survey data were encrypted for data upload and transfer.
- *Ensuring fair recruitment of participants:* The survey included a random and balanced sample of women and men – all farmers had the same chance of being interviewed. Focus groups had a homogenous composition to ensure that participants felt comfortable with expressing their views in the presence of other community members.
- *No harm to participants or their communities*. All data collection strictly adhered to Covid-19 protocols. The focus groups respected social distancing, and all participants were provided with face masks. FGD facilitators and survey enumerators respected social distancing and wore face masks as well.

64. The main **methodological and data limitations** and corresponding mitigation measures included:

- No logframe – only some of the expected results of the pilot were clearly articulated while others were not yet formulated in the design and pilot stages of the activity. Consequently, the evaluation put more emphasis on learning than on accountability.
- No existing ToC – the ToC was reconstructed in the inception phase and updated in the reporting phase, but it may further change in the short or medium term, depending, for example, on the evolution of AflaSight's business strategy.
- There remains uncertainty about the further direction of the pilot and its results, which are largely driven by the choices of value chain actors on which WFP has limited influence. The pilot evaluation attempted to address this issue by considering different value chain scenarios, as well as the market incentives and enabling environment that influence the decisions of agents in the food system.
- The shortening of the evaluation period meant that observations were 'cut off' at the output level, and that it was too early for the evaluation team to systematically gather real experiences of stakeholders at the outcome and impact levels. This was mitigated through comprehensive primary data collection on stakeholder expectations about outcomes and impacts, and an assessment of the likelihood that these results would be achieved in different value chain scenarios.
- The resulting timing of the data collection – another parameter beyond the control of the evaluation team – overlapped with the roll-out of the pilot activities, which made it sometimes difficult to discern (especially at SHF level) who had what kind of information and experience with AflaSight at the time of her/his participation in the data collection. For different practical reasons, it was not possible to substantially mitigate this problem in the data collection instruments for farmers.
- Even with 'real' AflaSight user experiences in season C, the external validity of the results would be somewhat limited because the aflatoxin problem is more severe in seasons A and B. Other limitations to the external validity of some results on SHFs are linked to the facts that the pilot cooperatives selected by WFP (i) are all in the Southern Province of Rwanda, where maize business is less 'commercialised' than in the Eastern Province (the main region of maize production), and (ii) have benefited from training and market linkages through the WFP FtMA programme, and already sell maize direct to agro-processors, including through the cob model. Within the short evaluation period and the pilot character of the evaluation, it was not possible to increase the external validity.
- Limited availability of some data, e. g. the performance data from the machine and data for the cost-effectiveness analysis. The cost-effectiveness analysis in EQ 3 thus relies on a mix of different data sources to reduce these gaps.
- Some baseline data for selected variables are available for broader samples of FtMA cooperatives and maize batches from traders in Rwanda – but not for AflaSight-specific variables and samples. Therefore, the smallholder survey collected data from season C 2020. Those data ultimately became less important for the analysis since the very limited experiences of farmers with AflaSight at the time of survey meant that an accurate 'endline' for comparison against a baseline would not exist either.

2. EVALUATION FINDINGS

2.1. EQ 1 – RELEVANCE: TO WHAT EXTENT IS THE PILOT ACTIVITY APPROPRIATE FOR THE REALITIES AND NEEDS OF THE TARGETED BENEFICIARIES, INCLUDING SMALLHOLDER FARMERS, SPECIFICALLY WOMEN, AS WELL AS OTHER VALUE CHAIN ACTORS?

Box 2: EQ 1 – key results

- The pilot clearly addresses the widespread problem of aflatoxin contaminated grain that cannot (or should not) be used for human food or animal feed.
- Farmers and traders in Rwanda often lack the resources for preventing aflatoxin development in the value chain. AflaSight offers a solution for the aflatoxin problem in already infected grain.
- FtMA-supported SHFs show high levels of aflatoxin awareness, knowledge, and use of control measures (even if not always effective), meaning that AflaSight meets fertile ground for demonstrating value added to them.
- Women and men farmers face largely the same market access problem, and AflaSight is appropriate for enhancing market links through a reduction of crop rejection by premium buyers.
- All other members of the maize grain value chain – traders, processors, importers, small millers and consumers – have an opportunity to benefit from AflaSight directly or indirectly, which if fully coherent with WFP's global and regional food systems approaches.
- The pilot is closely aligned to different Government and WFP policies and strategies for the production of safe food in Rwanda and the commercial development of smallholder farmers.

Sub-question 1.1: Does the design of the pilot provide an appropriate and affordable solution to the market access problem of smallholder farmers (especially women)?

65. The pilot design is outlined in AflaSight's proposal to the WFP Sprint Programme, which states that "*Farmers, whilst not direct users, are beneficiaries as suppliers to traders and cooperatives".* The document further states that "*Local farmers gain an assured market with a 15% increase in income*". The potential for providing an increase in farm income – despite SHFs not being direct users of AflaSight at the current stage – is discussed under EQs 6.1 and, to a small extent, 3.2. Farmers in FGDs reported that maize production is their only source of cash income; any intervention that can increase the income, or improve the reliability or timeliness of payments, is very significant for them. Many farmers in Rwanda do not have access to high value markets as these markets require low levels of aflatoxin contamination besides other quality characteristics.[51] Almost all farmers in the survey (98 percent) stated that aflatoxin-free maize is sold at a higher price and that a better selling price should be available to the coop.

Existing aflatoxin problem at SHF level

66. Farmers in the season C pilot coops – and even more so, farmers operating in season A and B, and those not supported by FtMA or other programmes – face an aflatoxin problem that weakens their capacity to link with premium buyers.[52] **AflaSight offers a solution for the aflatoxin problem in already infected grain.** Aflatoxin is not visible to the naked eye, although mouldy or discoloured cobs are a sign that it is present. Until now it has been impossible for farmers or processors to remove aflatoxin from maize grain, and so processors are normally unwilling to buy grain from farms or traders. They will only buy crops that are within tolerances when they arrive at the factory. Many loads that are presented by traders at processing factories are rejected after testing, and it would be impractical for farmers or coops to deliver loads to a factory as there are high haulage costs that must be met even if the load is rejected and then sent to a low-value market. [53]

67. Aflatoxin can be controlled by careful post-harvest management, mostly designed to dry the crop as soon as possible after harvest and keep it dry until it is milled. Most farmers in Rwanda do not have the knowledge or the resources needed to produce dry aflatoxin free grain for sale, and few traders have drying

[51] KIIs with processors and WFP/FtMA.

[52] FGD with farmers and KII with WFP/FtMA.

[53] KIIs with processors, traders, and WFP/FtMA.

facilities and so the problem multiplies in their stores.[54] FtMA has been working with many coops to improve knowledge and post-harvest practices so that they are able to produce drier and higher quality grain, but farmers report that it is difficult to avoid aflatoxin when infrastructure (e.g. drying hangars and drying grounds) are not widely available, and equipment (e.g. hermetic bags and tarpaulins) is not readily accessible especially in more remote areas.

68. AflaSight aims to provide an opportunity to bridge the gap between what farms and coops can achieve and what is needed by the premium buyers by ensuring that **crops that are borderline for aflatoxin can be brought within tolerance before being presented to the factory**. The coops visited and surveyed by the evaluation team are part of the FtMA programme and their knowledge and techniques are relatively advanced. The coops have already been linked to premium buyers so that they can already achieve higher prices than from traders.

Aflatoxin awareness, knowledge, and control

69. At least in the pilot coops visited for this evaluation, farmers showed **high levels of aflatoxin awareness, knowledge, and use of control measures. AflaSight thus meets fertile ground for demonstrating value added to SHFs.** In several FGDs, farmers claimed that aflatoxin was not now a severe problem and that they had very few rejections for several years. These were coops that had worked closely with premium buyers for several years and were well trained and equipped to ensure high quality. Growing for season C normally produces better quality crops than season A as harvest is during a drier season. Use of the cob model also normally results in few rejections as the process is supervised by the agro-processor and in any case, cobs are less prone to fungal attack while still on the cob.

The high awareness and good knowledge of aflatoxin, including its causes and effects, was evident in FGDs and the survey. FGD participants were generally aware of aflatoxin (only one coop showed less awareness) and stated to be able to recognise it through discolouration and smell of the grain and cobs. This has been confirmed through survey data. Almost all respondents (96 percent) believe they can identify aflatoxin on maize. Although they are not seeing aflatoxin itself, they are seeing the damage caused by the fungus which produces the toxin and is therefore a proxy for aflatoxin itself. More generally, the survey found that almost all farmers (98 percent) had some knowledge of aflatoxin and achieved a high average score of 4.5 (on a 6-point scale); men are more aware than women (4.7 vs 4.1). [55] Nearly all farmers could describe aflatoxin (as a mould or toxin or both)[56] and 82 percent[57] identified poor drying as the main cause. A smaller number identified poor storage and contact with soil, while 27 percent erroneously said that rain is direct cause (although it is only a major contributory factor). Farmers were aware of health risks and gave a wide range of potential effects, some of which are not correct.[58]

70. Farmers have access to different **aflatoxin control procedures** (as described here), but these are **not always effective** for preventing aflatoxin development in the post-harvest or subsequent stages of the value chain. For this reason, the evaluation team finds that **AflaSight becomes an important intermediary step**. Nearly all farmers in the survey (95 percent) applied control measures against aflatoxin in season C 2021[59]. Figure 2 below shows that thorough drying (96 percent), appropriate drying facilities (communal hangars or on sheets) (57 percent) and proper storage (46 percent) were the most common measures adopted. Fewer farmers used chemicals (22 percent) or sorted grain to prevent aflatoxin (18 percent). More men than women used appropriate storage (69 vs 40 percent) whereas more women used chemicals (28 vs 17 percent).[60] Results for season C 2020 were very similar.[61] Although farmers generally used low-risk means of drying grain, only half could reliably assess when the crop was dry enough (only 40 percent had access to moisture meters)[62] and most used sub-optimal "regular" bags for storage[63]. Men were consistently most likely

[54] KIIs with government institutions and WFP/FtMA.

[55] Table A - 5.

[56] Figure A - 3.

[57] Figure A - 4.

[58] Figure A - 5.

[59] Table A - 10.

[60] Throughout the report, gender differences are only reported where they were found to be statistically significant.

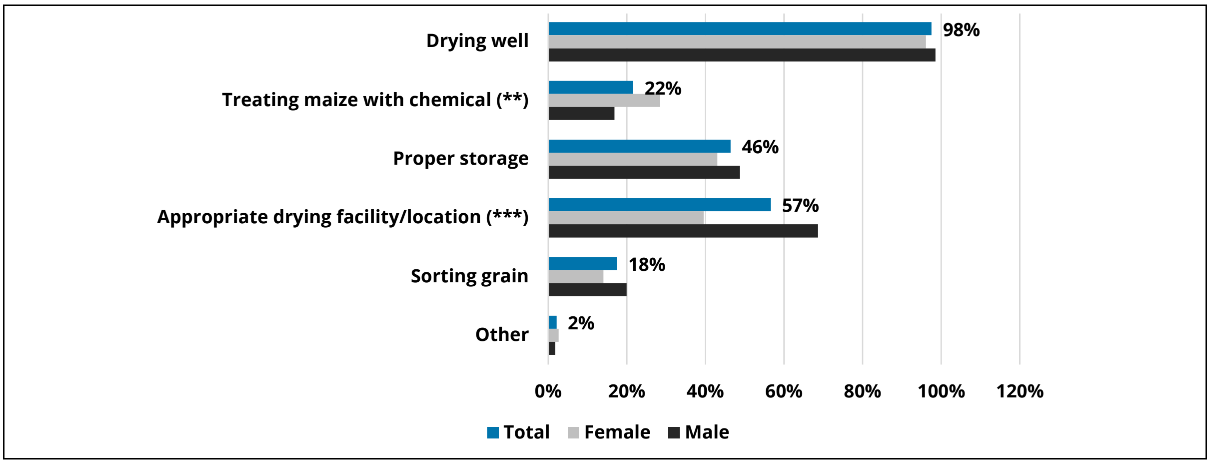
[61] Table A - 2 and Figure A - 2.

[62] Figure A - 8.

[63] Figure A - 7.

to adopt low risk methods to ensure uncontaminated and dry grain.[64] In FGDs farmers stated that they used the appropriate methods when they were able, but they are do not have enough sheets or drying facilities and it is difficult to dry the crop to the correct moisture level.

Figure 2: Aflatoxin prevention measures used by farmers in season C 2021



Note: Number of observations = 374 total, 184 female, 199 male. Percentages next to the bars refer to the total sample. ***, **, * denote gender differences that are statistically significant at the 1, 5 and 10 percent level respectively. t-tests for gender differences were performed with robust standard errors. Observations were weighted using design weights. See Figure A - 17 and corresponding text for additional details.

Source: Evaluation team analysis of smallholder survey data conducted for this evaluation.

71. Aflasafe provides a further means of reducing aflatoxin, based on a microbial culture applied to the growing crop. The microbes are able to limit the spread of the fungus that produces aflatoxin and after it spreads to the plants it "protects" the grain throughout growing, post-harvest treatments, and storage. It is commercially available in several African countries, but in Rwanda, it is still in trials and its effectiveness and cost are not known. For these reasons the report does not compare Aflasafe with AflaSight, but IITA expect that **Aflasafe** will become successful and widely available in Rwanda and provide **complementary benefits to AflaSight**. In particular, according to IITA staff interviewed, it may provide an important means of controlling aflatoxin on smallholder-produced maize that is destined for home use or local sales.

Market links with premium buyers

72. Most farmers and coops in Rwanda sell to traders, but those with links facilitated by FtMA sell to agro-processors.[65] By providing these buyers with direct access to the machine, **AflaSight offers a possible solution to enhance sourcing from coops in Rwanda and enhance their market links with off-takers**. The various options for the value chain are outlined in Figure 1 within Section 1.3 of this report. This shows the options for including traders and by making use of the cob model or AflaSight. Prior to the inception of AflaSight, only the first three options (A to C) have been available to producers. In December 2021, the first coop connected to AflaSight through an agro-processor (option E).

73. Farmers reported in FGDs that, before their involvement with FtMA, they sold this maize directly to traders (model A), which gave farmers immediate cash[66] but a low price. Quality was not usually a major issue in the transaction as traders did not test at the point of purchase. Farmers reported that cheating on weight by traders was common. WFP, government, and other key informants stated that smallholder farmers have been at the mercy of traders for many years and vulnerable to low prices and thus perpetuating low incomes and subsistence.

74. In some cases, farmers or coops try to sell their crops to premium buyers (model B) but they can suffer considerable losses if the crop was rejected by the processor after they had incurred large haulage costs. This can still occur when selling to some large processors. SHFs now sell their consolidated crop through their coops. The coops sell grain or cob to agro-processors (models C and B). **AflaSight provides a**

[64] The reasons for this gender difference were not assessed in the survey but they are probably due to differences in access to equipment and facilities.

[65] IDIs with coops and KIIs with WFP/FtMA.

[66] Timing is critical for many farmers as funds are needed for school fees and inputs for the next season.

means to reduce the risk that crops presented to premium markets by coops will be rejected as AflaSight offers the possibility of "cleaning" them (finding of the evaluation team). Premium buyers pay a higher price and are perceived by SHFs as more reliable than traders despite slower payment (up to one month). Premium buyers oversee post-harvest operations and inspects the crop to ensure quality before final purchase. There are rarely problems as farmers are given instruction on how to avoid aflatoxin,[67] but again, if there are mistakes and a crop is bought by a premium buyer on farm but found to be substandard at the factory, it may be possible to clean it using AflaSight (model E). Other premium buyers do not have the same level of supervision on farm but test for quality (including impurity, moisture and aflatoxin contamination) before purchase;[68] and the evaluation team finds that they are also potential users of AflaSight if crops do not meet standards in later tests. FtMA coops are clearly in a privileged position, receiving support for post-harvest technology and guidance through the process of negotiating contracts with premium buyers.

75. **Gender issues in market access**. There is no evidence from the survey or FGDs that women face systematically larger market access constraints than men, despite some gender division in labour related to maize. **In terms of market access, AflaSight is thus as well adapted to the needs of female farmers as to those of men.**

76. The survey found that female farmers have a somewhat lower socioeconomic status than male farmers. [69] Women tend to be older than the men (by 5 years), their households have fewer children (by 1) and fewer adults (by 1). Women farmers achieve a lower level of education, are less literate and are 8 percent more likely to fall below a poverty index. This latter is probably due to the smaller number in their household. However, neither the survey nor the FGDs suggested that women face larger market access constraints. Female FGD participants said that they were able to join coops and share the decision-making on crop production, post-harvest processing and in the use of income from the crop. In most of the survey answers gender differences were small, indicating an equal participation rate in trainings[70], crop production and involvement with the coop. In FGDs both men and women also stated that most of the work is shared although some heavy work (ground clearing, cutting, spraying and hanging cobs is done by men and weeding, sorting and winnowing is often done by women). However, women were somewhat less knowledgeable about the causes of aflatoxin and tended to dislike the cob model.[71]

Sub-question 1.2: Does the design of the pilot appropriately address the aflatoxin problem of other value chain actors?

77. The technology offers the possibility to mitigate the negative effects of aflatoxin-affected grain at several places in the value chain although its effect may depend on whether/how its introduction will be combined with continued training/awareness building throughout the value chain, investment in post-harvest storage and drying equipment, and progressive enforcement of the official standards (finding of the evaluation team). The relevance of AflaSight across the entire value chain is fully coherent with the WFP global and RBN food systems approaches,[72] and the pilot takes a very comprehensive perspective by linking farmers, coops, traders and agro-processors.

78. **Traders** reported that although many have access to storage, few have drying facilities. This means that they are unable to reduce moisture levels and, for marginal crops, the level of aflatoxin will increase in storage. Although the best options to solve this problem are to buy dry grain or to pass the grain through a drier before storage, this is not always possible. The evaluation team finds that AflaSight provides an opportunity for some of the affected grain to be processed and brought within tolerance for food or feed use and therefore increase the sales value of their stock.

79. EAX operate in several regional countries and have large storage and drying facilities.[73] They act as a trader but also operate a small warehouse receipt system, storing premium quality crops that can later be sold to processors. Apart from the benefit of reducing aflatoxin in their traded stocks, the pilot makes it more

[67] FGDs with SHFs and KIIs with processors.

[68] KIIs with processors.

[69] Table A - 1.

[70] Figure A - 22. PHHP training was equally accessed by men and women, but 27 percent more women did GAP training.

[71] Figure A - 21 and Figure A - 34. This may have been due to the lack of husks to use for cooking fires.

[72] WFP. 2022. Food Systems; WFP 2021b. WFP and Food Systems – RBN Strategic Approach Paper.

[73] Interviews with EAX and other stakeholders, suggesting that this fact is public knowledge.

likely that a warehouse receipt system becomes a more realistic proposition. To be viable the system must have very high reliability that the grain coming out of the store is as valuable as the grain entering the store. With good drying and storage combined with access to the technology, if needed, the quality risk in stored grain should be low.

80. **Large-scale processors** must purchase grain that meets the national standards in order for them to produce healthy food. If they cannot purchase from the domestic market, then they have to import grain. For example, AIF reported that 90 percent of the domestic grain delivered to them in 2017 did not meet the standard and was rejected.[74] AIF introduced the cob model through Kumwe (see Section 1.3) and have significantly improved the volume that they can purchase domestically, with rejections now only being only 5 percent.[75] However, the cob model is not ideal (it is a bulky product and must be transported; it is not liked by all farmers (see EQ 2.1). According to the data of a processor,[76] 77.2 percent of the total volume of grain purchased from coops between season A 2020 and season B 2021 was still sourced through the cob model, and only 22.8 percent through the grain model. The processor stated that it would prefer to move towards grain buying. Buying grain on farm requires higher levels of inspection and control of post-harvest processing on farm and within the coops. AflaSight would provide some insurance against crop loss after purchase.

81. AflaSight claims to offer the possibility of reducing aflatoxin levels below the threshold for the grain that processors purchase from coops. If this is the case, the evaluation team expects that it should also allow them to buy more crops from traders, in a more flexible way, after they have been processed by AflaSight. While other processors are less involved with purchasing directly from farms and coops, the same benefits apply to them regarding volume and flexibility regarding suppliers.

82. **Imports from neighbouring** countries are tested for aflatoxin at the border point but may subsequently fail testing at the central laboratory.[77] These stocks might be suitable for treatment by the AflaSight to allow them to be used for processing and avoid considerable losses for the processors and traders involved.

83. Several interviewees reported that **smaller millers and markets** are not yet controlled closely for aflatoxin standards. When standards are enforced for all products, the same benefits will become relevant.

84. As the ultimate member of the value chain **the consumer** needs to have safe food, but this is not guaranteed for grain saved by farmers, for informal purchases, or for grain or flour from smaller millers and markets.[78] The pilot does not directly attempt to address directly the issue of food safety but if successful, in combination with other interventions on farm and enforcement of regulations, the pilot, when scaled-up, may contribute to the elimination of toxic maize. The pilot is not likely to have any effect on the quality of farm-saved grain or grain sold locally through uncontrolled, informal markets.

85. Standards enforcement by Rwanda Inspectorate, Competition and Consumer Protection Authority (RICA) has only been in place since 2020 (see Section 1.2). The technology should allow it to enforce standards and reject grain. This grain can then be processed by the technology and reach the market following retesting. Without this processing, large volumes of grain may be rejected causing shortages, higher prices and greater imports.

86. Table 2 below shows the major problems associated with aflatoxin in the maize market at present together with the current mitigation measures and the potential mitigation linked to the technology.

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[74] AIF. 2021. The role of AGRA in national systems development in developing countries: the case of AIF's ' On Cob model' in post-harvest handling and marketing in Rwanda.

[75] AIF. 2020. Press release, 15 October 2020.

[76] Evaluation team analysis of Agro-processor X. 2021. Database of farmgate transactions, season A 2020 to season B 2021.

[77] Interview RSB.

[78] IFC. 2021. Aflatoxin Testing kiosks – Rwanda: September Report.

Table 2: Aflatoxin-related barriers and mitigation measures affecting the maize value chain

Barriers in the value chain	Effect on the value chain	Current mitigation measures	Potential mitigation linked to the technology
Lack of **knowledge/ awareness** of traders **about control methods**	Levels of aflatoxin are frequently high, and traders and processors are uncertain what markets the grain can be sold to.	Awareness raising by RAB, FtMA, AflaKiosk and other agencies/projects	The technology could possibly be linked to training/awareness-raising messages of FtMA – albeit not a key role of AflaSight.
Lack of **technology/ facilities to control aflatoxin** in value chain	Farmers/coops and traders unable to control postharvest increase in aflatoxin due to high moisture content.	RAB investment in driers and drying sheds; agro-processor and trader investment in driers	AflaSight provides a new opportunity to reduce aflatoxin levels in grain.
Lack of **knowledge of true aflatoxin levels** in stocks and difficulty of accurate sampling at farm/coop level	Price of grain often not related to true quality. Traders often assume that stocks will not meet processing standards. Testing is often not carried out for farmgate purchases.	AflaKiosk is increasing knowledge; agro-processors and some traders have testing equipment.	AflaSight process measures aflatoxin levels before and after sorting. The stock can then be allocated to the appropriate market at an appropriate price.
High **cost of finance** for maize trading and lack of a large-scale warehouse receipt system	Traders incur high interest costs on working capital especially during the peak season. Farmers needing immediate cash payment receive low prices as traders pass on the cost of financing.	EAX operates a warehouse receipt system, but it is quite small as only high-quality grain can be used as collateral against lower interest bank financing.	The technology reduces the financial risk of marginal quality grain stocks and may enable the expansion of the warehouse receipt system.
Uncertainty whether individual stocks will meet the **quality thresholds for food or feed**, and no means to "clean" stocks	Fixed thresholds for food and feed use currently mean that stocks failing to meet standards are rejected and may become worthless.	Many traders do not attempt to sell to agro-processors. Premium buyers test stocks at coops to ensure quality.	The technology can be used to reduce aflatoxin contamination so that failing stocks can be brought within tolerance.
Lack of **enforcement of permitted aflatoxin levels**	Although large agro-processors must stay within tolerances, small millers are not supervised and contaminated stocks reach local markets. Without enforcement, there is little incentive to improve quality. With strong enforcement, large quantities of grain and flour may be removed from the food and feed market leading to insufficient food availability, higher prices and increased imports.	Government monitors large producers but not smaller mills or maize flour markets. RICA is a new organization, and it is expecting to increase monitoring and enforcement.	The technology will not mitigate the lack of enforcement, but greater enforcement will provide a large opportunity for contaminated stocks to be brought within standards using the technology. This may improve the quality of maize in the market and also allow RICA to reject contaminated stocks of grain as they can be brought up to standard.

Source: Evaluation team based on key informant interviews with different value chain members.

Sub-question 1.3: Is the pilot aligned with relevant government and WFP policies and strategies?

87. The pilot is aligned with the general objective of the National Food and Nutrition Strategic Plan (2013-2018),[79] "*to improve the household food security and nutritional status of the Rwandan people*" as it aims to increase the availability of nutritious (uncontaminated) maize. The pilot also addresses the Government's Revised Gender Policy (2021)[80] through mainstreaming women smallholder farmers as key beneficiaries and to promote their ability to participate in more productive agricultural value chains. As a private-sector operation the pilot is aligned with Rwanda Private Sector Development Strategy (2013-2018),[81] which aims for entrepreneurship development, with a specific focus on commodity chain development. The pilot currently employs several staff and provides commercial services to industrial partners. If successful, it will become an important entity in the maize value chain.

88. The pilot is designed to work closely with the WFP-hosted Farm to Market Alliance (FtMA) which is focussed on "smallholder support (including gender), value chain development and food safety" as part of Strategic Outcome 4 of its CSP 2019–2023[82]: "*Smallholder farmers, especially women, have increased marketable surplus and access to agricultural markets through efficient supply chains by 2030*". The pilot specifically aims to increase the income of smallholder farmers and incentivise investment in farming and improve living standards. As noted in the previous sub-question, it is also is well aligned with the WFP global and RBN regional food systems approaches, by introducing an innovative approach to improving the flow of grain along the value chain from farmer to consumer by reducing the bottleneck of aflatoxin and at the same time contributing to food safety.

89. Finally, the pilot is also aligned with the WFP Gender Policy[83] by aiming to ensure equal access to resources and women's empowerment, and with the WFP global initiatives on smallholder market support[84] aimed at improving the access of smallholder farmers to markets.

2.2. EQ 2 – RELEVANCE: TO WHAT EXTENT IS THE INTRODUCTION AND USE OF THE TECHNOLOGY ACCEPTED, UNDERSTOOD AND ACCESSIBLE BY/FOR SMALLHOLDER FARMERS (ESPECIALLY WOMEN) AND OTHER STAKEHOLDERS?

Box 3: EQ 2 – key results

- Farmers are mostly unaware of the technology so far and only a relatively small number of farmers have had access to the technology during season C.
- From the little information and experience so far, farmers see it as positive and are willing to try it – but have some reservations about losses.
- AflaSight has started the process to encourage traders and agro-processors to carry out test runs.
- Traders, processors, and the Government are positive about the potential of AflaSight to increase the use of Rwandan maize for food production and contribute to improving food in markets.
- The main potential barriers identified are the current uncertainty about the performance and cost, the distance of AflaSight from production areas, and doubts about its capacity to cope with demand during peak periods.

Sub-question 2.1: Are smallholder farmers – especially women – and other stakeholders aware of the technology, do they understand it, and are they willing to try and able to access it?

90. At the time of the survey, **smallholder farmers** had almost no experience with AflaSight – contracts with premium buyers were only closed while the survey was already ongoing, and only one of the four coops sold on grain in season C (without knowing how much of it would subsequently be processed by AflaSight). Some farmers (18 percent) had already heard about AflaSight, but many more (93 percent) were aware of

[79] Government of Rwanda. 2014b. National Food and Nutrition Strategic Plan.

[80] Ministry of Gender and Family Promotion. 2021. Revised National Gender Policy: Accelerating the Effectiveness of Gender Mainstreaming and Accountability for National Transformation.

[81] MINICOM. 2013. Rwanda Private Sector Development Strategy 2013-2018.

[82] WFP. 2018b. Rwanda Country Strategic Plan (2019–2023).

[83] WFP. 2015. WFP Gender Policy 2015-2020.

[84] WFP 2019. Changing Lives for Smallholder Farmers: Beyond the Annual Performance Report 2018 Series.

the cob model.[85] This is consistent with their experience of the cob model in previous years, but also with the late timing (in the first week of the survey) of FtMA information campaigns about AflaSight among coop leaders. More men than women were aware of AflaSight (27 vs. 8 percent) suggesting better attendance by men at the general meetings in which coops informed their members about the technology.

91. After the enumerators had explained AflaSight to those survey respondents who had not heard about it before, most farmers (84 percent)[86] expected the technology to be at least moderately beneficial to them and could be expected be willing to try it. However, significantly more women than men (19 versus 5 percent) were uncertain about the benefits. Given the farmers' lack of experience with AflaSight, it is difficult to tell how these attitudes would change if their coops were direct users of the technology or obtained feedback on the processing results from premium buyers. Only in mid-January 2022 (after the data collection), 30 MT of grain from one of the surveyed coops was processed by AflaSight after being purchased ex farm by a premium buyer. This indirect access to the technology enabled grain that was substandard before AflaSight to be brought within the buyers' aflatoxin standard and used for processing (see EQ 4.1).

92. In contrast, 60 percent of survey respondents stated to have already used the cob model in the past (or expected to use it in season C 2021),[87] but 45 percent of these users reported it to be of very little value to them.[88] This suggests that farmers are potentially willing to change from the cob model to a grain purchase scheme including the pilot technology. Supplying grain to AflaSight does require the cobs to be shelled at the farm/coop; this has the advantage of leaving the husks on farm for use as fuel but requires better storage and drying facilities.

93. While coops and SHFs have been informed about the pilot mainly by FtMA, awareness raising among **other key stakeholders in the value chain** has primarily been the initiative of AflaSight themselves. For example, together with IFC and AflaKiosk, they organised a Symposium on Maize Quality in November 2021 at which there were three government representatives, six processors and industrial consumers, one dozen traders, four coops, and the evaluation team. The AflaSight pilot was well received by stakeholders and further one-to-one meetings have been held to follow up interest.

94. **Processors** interviewed for the evaluation were very positive about the potential benefits of the technology. They saw it a means to upgrade a large tonnage of grain that is not quite good enough to meet aflatoxin standards either for food or feed, and to add flexibility of suppliers and of timing of purchases. They were already starting to use the technology themselves or purchase grain passed through the technology.

95. **Large traders** were also positive about the potential for the technology, mostly to provide a kind of insurance policy for their stocks. Many loads fail when presented to the processing factories and lose much of their value, but with the technology there is a chance that they can be brought back to standard.

96. **Government** interviewees recognised that AflaSight could be important to the value chain for premium maize but also for the quality of maize in other markets. The technology provides an opportunity for government to more strictly enforce standards knowing that failing crops may not need to be destroyed.

Sub-question 2.2: What type of barriers to technology adoption do the different value chain actors face or perceive, and how does the pilot plan to mitigate these barriers?

97. A major barrier to assessing the adoption of AflaSight at present is **uncertainty regarding the effectiveness of the technology and the potential economic value**.[89] The pilot is designed to provide answers to this, and the evidence gained in the first three months of the pilot is discussed under EQs 4 and 3 respectively. When the pilot has completed a major season, this uncertainty should be much reduced.

98. **Location and transport costs.** The pilot is not located in a major maize farming area, so coops and small traders are (and FGD participants confirmed that they are) less likely to use the machine unless the crops are aggregated to fill a 10t truck and the load has been assessed to be likely to benefit from processing (FGDs with farmers). The pilot is located in the Kigali SEZ, close to major plants of the two largest agro-processors (AIF and Minimex) and key stakeholders in Kigali.[90] This location makes it a suitable location for

[85] Table A - 9.

[86] Figure A - 11.

[87] Figure A - 10.

[88] Female farmers with no access to the cob model were much more negative than male farmers (49 vs. 21 percent).

[89] KIIs and IDIs with different value chain members.

[90] Evaluation team observation during stakeholder visits in the SEZ of Kigali.

the pilot phase while the basic technology is being evaluated. If the pilot is scaled up, AflaSight plan to locate future operations in the maize farming regions. In FGDs, farmers also noted that the remoteness of the technology from coops meant a loss of control and potential for cheating. This is a legitimate concern if coops wish to use AflaSight directly, however, it is much more likely that their buyers (traders or agro-processors) will use AflaSight. After scaling-up, larger coops may become direct users of AflaSight.

99. **Capacity of the processing line.** The current plant has a capacity of 12 MT/hour, but this could be brought up to 20 MT/hour with additional grain cleaning capacity (see EQ 4.1).[91] While this capacity should be sufficient for the pilot phase, it is not expected to meet commercial demand if the pilot is successful particularly after season A (finding of the evaluation team). This issue was raised in KIIs and in FGDs with farmers. The AflaSight business plan includes consideration for expansion (see EQs 9.1 and 9.2).

100. Some major buyers and traders of grain noted a potential preference to establish the technology within their own processing plants. This would reduce the potential barrier of bottlenecks at AflaSight during peak grain processing seasons. It would also alleviate the need for additional costs if grain needs to be transported from storage to AflaSight for processing and then returned to the same storage. The high cost of the machines means that this may only be considered by a few organisations such as AIF, Minimex and EAX (finding of the evaluation team).

101. A further potential barrier is **awareness**. While AflaSight has introduced the technology to the major stakeholders, there are many potential users including cooperatives who have not yet been made aware of the pilot. This is further discussed under EQ 2.1 above.

2.3. EQ 3 – EFFICIENCY: IS THE PILOT ACTIVITY COST-EFFECTIVE IN TERMS OF HIGHER-LEVEL OUTCOMES (REDUCTION IN AFLATOXIN LEVELS, SMALLHOLDER INTEGRATION IN MAIZE VALUE CHAINS)?

Box 4: EQ 3 – key results

- The cost effectiveness analysis for an agro-processor compares the total costs for obtaining one kg of low-aflatoxin grain in three different models of direct sourcing.
- Given a realistic set of cost parameters, cost effectiveness depends on the price differential of high- and low-aflatoxin maize. AflaSight is the most cost-effective solution for the agro-processor if, when buying >20 ppb grain, farmgate prices are discounted by at least 36 RWF/kg and 50 RWF/kg relative to <7 ppb grain purchased in the existing cob and grain models respectively.
- For smallholder farmers, cost effectiveness (in terms of access to premium buyers) is reflected in their gross margins from selling maize.
- The cob model yields a higher average margin (195 RWF/kg) for low-aflatoxin maize than the grain model (181 RWF/kg). When selling high-aflatoxin maize, the estimated PHHS costs are low enough for SHFs to gain whenever premium buyers using AflaSight pay more than in informal markets.
- The price discount required to make AflaSight the least costly option for processors is only half of the current price difference between premium and informal markets – sharing of profits from the technology between buyers and coops is thus in principle possible.

Sub-question 3.1: How do the operating and user costs of AflaSight compare to alternative aflatoxin reduction solutions used in the region?

102. In general, the cost effectiveness of an intervention can be analysed from the viewpoint of different stakeholders, e.g. in terms of government/donor sources or user costs for beneficiaries. The focus of the cost effectiveness analysis in this EQ was decided in discussions with WFP when it was confirmed that cooperatives would not have direct access to AflaSight. While the pilot received a grant of USD 100,000 from the WFP Innovation Hub for Eastern Africa, it is expected that, as a private sector start-up, AflaSight will soon achieve financial autonomy. Its cost effectiveness is hence not analysed from a donor perspective, but from the viewpoint of direct users (in this sub-question) and indirect users (in the next sub-question).

103. This sub-question **compares the cost incurred by an agro-processor for obtaining low-aflatoxin (<7 ppb) output grain using AflaSight versus alternative approaches of direct sourcing and processing**. The results are shown in Table 3 on the next page, which also states the key assumption made in the analysis.

[91] KII with AflaSight.

The prices and some costs are the mean values for seasons A and B 2020 and 2021 calculated from databases of the agro-processor. The other cost estimates were largely provided by AflaSight.

104. For both direct and indirect users, the cost effectiveness of AflaSight is strongly influenced by two key parameters: (i) the price difference between grain below 7 ppb vs. above 20 ppb, and (ii) how this 'market premium' is divided between buyers and coops/smallholder farmers.

105. Since prices and premiums are highly variable across seasons and regions, no assumptions have been made on these two parameters in the last column of Table 3. Instead, the analysis first estimates the total sourcing and processing costs per kg of <7 ppb grain in the cob and grain models without AflaSight, showing that the cob model (total costs of 285 RWF) is slightly more cost effective for the agro-processor than the grain model (299 RWF). The last column then calculates the maximum farmgate price for above-limit grain (subsequently reduced below 7 ppb through AflaSight) that the agro-processor could pay for AflaSight to be the most cost-effective solution (≤ 285 RWF).

106. In a nutshell, with realistic cost parameters for cob and grain processing, the calculations show that **AflaSight is the most cost-effective solution for the agro-processor if farmgate prices per kg of >20 ppb grain are discounted by at least 36 RWF and 50 RWF relative to the farmgate prices for <7 ppb grain in the existing cob and grain models respectively**.

107. It is possible, though, that additional savings associated with reduced field staff and lower rejection rates due to AflaSight would lift the 'break-even' price above the minimum price. These two factors are omitted in the calculations. Field staff costs may be reduced by AflaSight if it allows the processor to purchase above-limit grain with potentially somewhat less quality monitoring and control before and after harvest. Table 3 also assumes that post-purchase rejection rates are zero, that is, all maize bought by the processor yields <7 ppb grain after processing. In practice, some of the grain will end up above this limit, which further increases the costs without AflaSight.

108. Prices discounts of the suggested magnitude are, in principle, consistent with estimates of AflaSight that the market premium (in premium quality markets relative to informal markets) is around 100 RWF/kg based on their own observations[92] – and potentially increasing if aflatoxin standards are enforced more widely in the future. Even if up to half of this premium is captured by coops, AflaSight would remain the most cost-effective solution for sourcing <7 ppb maize that is available to the processor – and it allows for a much less 'restrictive' buying strategy than without AflaSight. A potential constraint for processors to lower the price to the 'break-even' level with the cob model could be the minimum price set by the Ministry of Trade and Industry once per year (in season A). In 2020 and 2021, the minimum prices were 223 RWF/kg[93] and 226 RWF/kg respectively but which are not always enforced, especially not for low-quality maize.[94] However, the above calculations (and considering additional saving on field staff not included in them) suggests that paying the official minimum price even for >20 ppb grain would likely be sufficient make AflaSight the most cost-effectiveness solution for the agro-processor.

109. On a different note, a cost comparison of AflaSight with **Aflasafe** was originally considered for the analysis but turned out infeasible due to the very distinct nature of Aflasafe confirmed in key informant interviews with IITA staff.[95]

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[92] The estimates of AflaSight are consistent with the price differences of 101 RWF/kg between grain sold through coops (and eventually to premium buyers) and in local markets reported by farmers for season C 2020. See Table A - 3. Those prices were calculated from dividing reported total income through quantities sold. While the implied price *levels* seem to be slightly inflated (maybe because of some recall bias), the price *differences* should be more accurate.

[93] The New Times. 2020. New maize price set as harvest starts.

[94] The New Times. 2021. Maize farmers count losses as new prices remain unenforced.

[95] Aflasafe is a biocontrol product that farmers spread on their plots during the cropping season. It is largely donor and government-financed in various countries of Africa and requires training from extension officers. Unlike AflaSight, however, it is not possible for agro-processors or users to trace improvements in aflatoxin reduction (and its costs) to Aflasafe. Processors buy grain that has been aggregated from different farmers – some of which use Aflasafe while others do not. Even at the level of individual farmers, Aflasafe is usually applied in combination with other aflatoxin control (PHHS) measures, making it difficult to disentangle the aflatoxin reduction effects (and costs) for the different measures. According to other stakeholders, Aflasafe is also less relevant in Rwanda as aflatoxin develops mainly in the post-harvest stage (rather than during cropping when Aflasafe is applied) – see also: Nishimwe, K. 2021. Situational Analysis of the Legal and Regulatory Framework and Action Plan for Aflatoxin Mitigation in Rwanda (commissioned by MINAGRI). This makes it less interesting for cost effectiveness analysis in this pilot.

Table 3: Estimated sourcing and processing costs per kg of output grain with aflatoxin below 5 ppb, in different models of direct sourcing used by an agro-processor

		Cob model (configuration C)	Grain model without AflaSight (configuration B)	Grain model with AflaSight (configuration E)
	Direct sourcing model and assumed aflatoxin starting levels	Processor buys **on cob** (as long as **<7 ppb)** at discounted price, shells the cob, and processes the grain in-house *	Processor buys **only grain lower <7 ppb** at premium quality price and processes the grain in-house	Processor buys **only grain >20 ppb,** between informal market and premium quality price, and reduces it to <5 ppb through processing at AflaSight
Sourcing	Farmgate price per kg paid by the processor to coops [a]	237.00 RWF (actual price)	251.00 RWF (actual price)	**201.00 RWF** (implied price to break even with cob model)
	Transport costs per kg [b]	20.00 RWF	17.00 RWF	17.00 RWF
Processing (processor)	In-house drying & cleaning costs per kg [c]	23.00 RWF	15.00 RWF	
	Costs (per kg) of weight loss from drying & cleaning		16.00 RWF	16.00 RWF
	In-house shelling costs per kg [e]	5.00 RWF		
Processing (AflaSight)	AflaSight service fees per kg (excl. VAT) [f]			42.00 RWF
	AflaSight costs (per kg) of weight loss from sorting [g]			10.00 RWF
	Estimated total sourcing & processing costs (without field staff costs) per kg of grain with aflatoxin <7 ppb	**285.00 RWF** (actual costs)	**299.00 RWF** (actuals costs)	**285.00 RWF** (set equal to cob model total costs to calculate break-even price)

* In the cob model, the per-kg prices and costs refer to kg of grain equivalent after drying, cleaning, and shelling. Weight losses from these procedures are thus already factored into the farmgate price.

[a] Cob model and grain model without AflaSight: average prices paid by an agro-processor X to coops in seasons A and B, 2020 and 2021 (calculations by the evaluation team based on: Agro-processor X. 2021. Database of farmgate transactions, season A 2020 to season B 2021 ("farmgate database")).
Grain model with AflaSight: calculated max. farmgate price for total costs being lower than in cob model.

[b] Average transports costs (from farmgate to processing sites) incurred by agro-processor X for cob and grain in seasons A and B, 2020 and 2021 (calculations by the evaluation team based on the farmgate database). The grain model with AflaSight assumes the same transport costs as the grain model without AflaSight.

[c] Drying costs: 3.5 RWF per kg and percentage point reduction in moisture (estimates based on AflaSight experience and pre-2020 cob model operated by Kumwe). Starting moisture = average loading moisture content in purchases of agro-processor X from coops in seasons A and B, 2020 and 2021 (cob: 19.01 percent, grain: 16.74 percent, calculated by the evaluation team based on farmgate database). Target moisture = 13 percent.
Cleaning costs: 1.5 RWF/kg (rough estimate by the evaluation team based on: AflaSight. 2022. Internal Revenue Model ("AflaSight revenue model").

[d] Weight loss from drying in percent = (starting moisture - target moisture) / (1 - target moisture). Target moisture content = 13 percent. Starting moisture content for grain model without and with AflaSight = same as in footnotes c and f respectively. Weight loss from cleaning = 2 percent (AflaSight assumption).

[e] Estimate based on pre-2020 cob model operated by Kumwe.

[f] Estimates based on AflaSight revenue model for aflatoxin starting level >20 ppb and output level <7 ppb, and starting and target moisture contents of 20 percent and 13 percent respectively.

[g] Standard rate of 5 percent weight loss (infected kernels) as per Bühler/AflaSight assumptions.

Sub-question 3.2: How cost-effective is the pilot relative to other approaches for smallholder market access and value chain integration (especially those promoted by FtMA)?

111. This sub-question assesses the cost-effectiveness of AflaSight from the perspective of smallholder farmers, the indirect users of the technology. The alternative approaches for SHF market access and value chain integration considered here are the same as in EQ 3.1. All of them are supported by FtMA: connecting to a premium buyer through the cob model or the grain model without or with AflaSight.

112. The **cost effectiveness question for SHFs** is **how to access premium buyers and minimise the loss of profit margin**. This concerns especially high-aflatoxin grain rejected by premium buyers in the conventional grain model, which can only be sold in informal markets or potentially to a premium buyer with access to AflaSight. The main indicator of cost effectiveness for SHFs is the gross (profit) margin per kg of grain. Unfortunately, it is not possible to present reliable estimates of prices and costs of SHFs in the AflaSight model. These figures are more uncertain for SHFs than for processors. Coops tend to be price takers, rather than price setters (confirmed in various IDIs with coop leaders), and their lack of experience with the pilot implies uncertainty whether and how the pilot would alter the PHHS practices and costs of their members.

113. Therefore, the analysis first presents estimates of SHFs' costs and profit margins in the cob and grain models without AflaSight, and then discusses whether AflaSight may increase profit margins for high-aflatoxin maize rejected under the existing models. This distinction of the models in function of aflatoxin starting levels is consistent with the view of various coop leaders and FGD participants that, if anything, AflaSight would make a difference for currently rejected maize, but not for low-aflatoxin maize sold to premium buyers.

114. Table 15 in Annex 12 summarises the **gross margin calculations for SHFs selling on cob versus selling low-aflatoxin grain without AflaSight.** Although this comparison does not measure the cost effectiveness of AflaSight directly, it not only provides an estimate of the PHHS costs of SHFs, but also shows that an innovative aflatoxin solution (such as the cob model) may potentially improve cost effectiveness/gross margins for SHFs. The analysis is largely based on survey data from season C 2021. Season C market and farmgate prices are usually higher and thus differ from those in the previous cost effectiveness analysis for an agro-processor (seasons A and B in 2020 and 2021).

115. Table 15 in Annex 12 shows that the grain model pays relatively higher prices per kg but involves larger PHHS costs due to the need of shelling, drying of grain, and other treatment, while allowing farmers to use the husks as fuel for cooking energy. A 2019 study on the cob model conducted by the Royal Tropical Institute (KIT) undertook a similar comparison with season A 2019 data from coops in Gatsibo and Nyagatare districts.[96]

116. The per-kg gross margins in Table 15 (**195 RWF for cob, 181 RWF for grain**) – not including unpaid (own) labour provided by SHFs – are remarkably close to those estimated in the KIT study (181 RWF for cob, 173 RWF for grain) although prices and costs are both lower in that study. This suggests that the cob model is an improvement in cost effectiveness for SHFs. Yet, these gains are relatively small and only represent an average. Some farmers, depending on their costs, may generate higher margins in the grain model. This explains why the perceived benefits of the cob model widely vary across both survey and FGD participants.[97]

117. However, usually some of the harvest (especially in season A) is rejected by premium buyers due to **high aflatoxin content** and does not directly qualify for either of the two modalities. Without AflaSight, SHFs would have to sell the grain or cob in informal markets at **price discounts of up to 100 RWF/kg** relative to premium quality maize (see previous sub-question), or consume the maize at home. With the discounted price, the gross margin would still be positive even if SHFs face the same PHHS costs (119 RWF/kg) as in the grain model. Therefore, **any increase above the informal market price offered by premium buyers because of AflaSight will increase the gross margin of SHFs**. Even if a premium buyer chooses to offer at its 'break-even' price with the cob model or the minimum price (see previous sub-question), SHFs would gain as well. In addition, it is possible that AflaSight reduces the PHHS costs of SHFs, which would further increase their gross margin.

118. Altogether, however, the analysis shows that there is **no unique cost-effective solution for SHFs**, but that cost effectiveness depends on aflatoxin starting levels at the farmgate (affected by season, PHHS skills and equipment, etc.) and market prices. Coops might make a 'best guess' about the most profitable

[96] KIT. 2019. Understanding the costs and benefits of the cob model for maize farmers in Rwanda.

[97] Figure A - 12 and Figure A - 13.

solution and eventually change in function of their experience with AflaSight and the aforementioned factors. However, being able to choose and negotiate the most cost-effective/profitable solution requires coops and farmers to be able to connect to premium buyers (direct users of AflaSight) and have sufficient information about AflaSight and the aflatoxin levels of their harvest. This is discussed in more detail in EQ 6.1 (potential income effects on farmers).

2.4. EQ 4 – EFFECTIVENESS: HOW WELL DO THE LUMOVISION TECHNOLOGY AND ITS RELATED PROCESSES PERFORM IN THE LOCAL CONTEXT, AND WHAT FACTORS INFLUENCE ITS EFFECTIVENESS IN ACHIEVING THE TECHNICAL OBJECTIVES?

Box 5: EQ 4 – key results

- In addition to the trials for the calibration of the machine, samples of stored season B grain and new season C grain have been processed by AflaSight to remove aflatoxin.
- Although much more testing is needed, the process has managed to reduced contamination levels by on average 72 percent in the season B sample, with weight loss from sorting typically below 5 percent.
- Three crops from season C with 14.4 ppb aflatoxin that would have been rejected by a premium buyer were brought down below the buyer's 7 ppb maximum and were accepted by the factory.
- Results from harvests in wet conditions (season A) may give different results.
- The processing line set up by AflaSight is suitable for the pilot stage when the effectiveness and cost-efficiency of the process are being evaluated and the potential market for its services can be assessed.

Sub-question 4.1: What is the performance of the machine in terms of daily throughput, removal of infected kernels (aflatoxin reduction), and volume loss; and what factors affect the performance?

119. The processing line was set up in October 2021 and therefore the findings in this sub-section are very preliminary and need verification after further calibration of the machine and with the experience of different harvest seasons[98]. The results presented here are data provided based by Bühler and AflaSight until the mid-January 2021.

120. In the pilot proposal[99] Bühler claimed that the capacity of the Sortex A LumoVision machine is up to 20 MT/hour, it eliminates up to 90 percent of contamination and can reduce volume losses to below 5 percent. Published studies using Bühler Sortex and other optical sorting machines have shown aflatoxin reductions of about 80 percent with volume losses of 5-8 percent.[100] During the data collection mission, the evaluation team was able to see the LumoVision machine working and validate that it was removing contaminated grain. The maximum capacity of the machine (20 MT/hour) has so far been limited by the seed cleaners (12 MT/hour, see EQ 4.2); this seems likely to the evaluation team although no supporting data has not been supplied.

121. Data supplied by AflaSight included all three stages/sources covered in this evaluation:

- Grain from different sources for the calibration of the machine in October 2021 (45 trials)
- Grain from season B stored by traders and processed in November and December 2021
- Fresh season C harvest bought by a premium from a coop in Nyanza processed in January 2022.

122. The last two sets of processing data have been supplied to the team based on 13 commercial crops during the period from 7 November 2021 to 17 January 2022.[101] The summary data is included in Table 4

[98] Bühler reported that their technician was only able to spend one day of the first installation and calibration visit (in October 2021) on calibrating the LumoVision. It was planned to return when more recently harvested grain stocks were available.

[99] Bühler. 2020. SORTEX A LumoVision™ Aflatoxin Sorting in Maize.

[100] Pascale, M., et al. 2020. Aflatoxin Reduction in Maize by Industrial-Scale Cleaning Solutions; Pearson, T.C., Wicklow, D.T., and M. C. Pasikatan. 2004. Reduction of aflatoxin and fumonisin contamination in yellow corn by high-speed dual-wavelength sorting.

[101] The performance data includes only those crops processed after the machine was fully calibrated and an additional part was included on the machine that was not available for the early tests. For commercial confidentiality, data on individual lots is not presented in this report.

below. The performance results of the machine are **preliminary, based on a small sample and do not include the main agricultural season A** – and may thus differ in a larger sample from all seasons.

Table 4: Summary performance data for LumoVision Sortex A processing

Origin of crop	Stored crops from traders	Season C from FtMA partner cooperatives
Date	November / December 2021	Mid-January 2022
Number of crops	10	3
Total weight processed	112.5 t	30.1 t
Input aflatoxin	26.3 ppb	14.1 ppb
Output aflatoxin	7.4 ppb	6.4 ppb
Aflatoxin reduction	72 percent	55 percent
Weight loss through LumoVision	4 percent	3 percent

Source: AflaSight.

123. The ten **crops from traders** processed during 2021 were from storage and relatively dry (14.5 percent moisture or less). In total 112.5 MT were processed with an average of 26.3 ppb aflatoxin but with a wide range from 14.1 to 57.8 ppb. After processing the average was reduced to 7.4 ppb, **an average reduction of 72 percent**. These averages mask a wide range from reduction effectiveness from 28 to 87 percent. High levels of reductions (80-90 percent) were achieved for the two crops with initial contamination levels above 50 ppb, while six crops with lower contamination levels were reduced by 69 percent. There were two outliers that achieved reductions below 50 percent. **Losses** through the sorting machine varied from 2 to 6 percent with an **average of 4 percent**.[102]

124. Three loads (totalling 30.1 MT) of **freshly harvested Season C maize** from one of the pilot coops were processed in January 2022. Before processing, the average contamination level was 14.4 ppb. After processing it fell to 6.4 ppb; a **reduction of 55 percent**. There were no major differences between the three crops. The output was tested twice by the premium buyer and met its 7 ppb standard. The average loss during LumoVision processing was 3.1 percent.

125. In summary, although the post-calibration data received so far is limited to 13 samples, the results show that the LumoVision sorter is able to substantially reduce the level aflatoxin. Reduction levels of 90 percent have not been seen in these samples yet but as expected by Bühler, the sorter achieved the greatest reductions (80-90 percent) in crops with the highest contamination. It achieved over 50 percent reduction for all but two of the other crops, including the three 2021 season C crops. AflaSight's standard of <5 percent for losses during LumoVision processing was met by all but one of the 13 crops.

126. On a side note, Bühler has found that the drying method may influence the detection of kojic acid[103]. There have been difficulties detecting kojic acid following wet season harvests in India so it will be important to test the effectiveness of the machine thoroughly on season A crop as this is harvested during the rains.

Sub-question 4.2: What ancillary processing (particularly drying) and requisites (e.g. limits for moisture and infection levels for input samples) are needed for the process to work and reach the desired quality?

127. The processing line set up by AflaSight at the Special Economic Zone in Kigali includes:[104]

- One drier with 20 MT capacity (supplied by RAB)
- Two seed cleaners with capacity of 6 MT/hour each
- The LumoVision machine (with a capacity of 20 MT/hour)

[102] AflaSight is working with a private organisation (https://thebugpicture.com/) to valorise the highly contaminated grain rejected by the Lumovision machine.

[103] Kojic acid is produced by Aspergillus spp. and is used as a proxy for aflatoxin detection in maize grain as it fluoresces in UV light. See Shotwell, O.L., and C. W. Hesseltine. 1981. Use of Bright Greenish Yellow Fluorescence as a Presumptive Test for Aflatoxin.

[104] Evaluation team observation during the visit to the AflaSight plant, and KII with AflaSight.

- Short-term warehouse facility, a loading/unloading ramp small equipment for grain handling between the main processing elements (augers and mobile grain dams)
- Quantitative aflatoxin testing equipment (provided by AflaKiosk).

128. This is the minimum equipment that is needed for the LumoVision to operate effectively under the pilot. The capacity of the line is limited by the cleaning capacity of 12t/hour. In commercial use the capacity of the LumoVision could be increased to near its full capacity with the addition of a third cleaner. Additional storage space will be needed if the pilot starts to trade grain as it will not be returning the cleaned product directly to the customer as it does now.[105]

129. The key cause of high aflatoxin levels is high moisture content. The standard maximum moisture content for traded grain is 13.5 percent requirement for the control of aflatoxin. Crops should be below 18 percent moisture for commercial driers to be efficiently, otherwise the drying process is much slower.

130. Crops need to be effectively cleaned (removal of foreign material, broken grains, chaff, etc.) for the sorter to work most effectively any to meet the standards for sale to high-value market. Commercial equipment to clean crops is readily available for processors but too expensive for cooperatives. At farm and cooperative level, crops are cleaned by hand or using simple winnowing equipment.

131. Because the consistency and effectiveness of process at removing aflatoxin contamination have not yet been determined it is difficult to define the maximum input levels needed to ensure that the output reaches the standard. If 90 percent reduction can be achieved, then input levels of 50 and 200 ppb would allow reduction to the national food and feed tolerances, respectively. However, this performance is an average, so lower input levels would be needed to ensure that even batches with lower-than-average aflatoxin reduction levels fall within the tolerance levels after treatment.

2.5. EQ 5 – EFFECTIVENESS: TO WHAT EXTENT WILL THE TECHNOLOGY HELP SMALLHOLDER FARMERS (ESPECIALLY WOMEN) TO CONNECT WITH PREMIUM BUYERS, WHY AND HOW, AND WHAT ENABLING OR DISABLING FACTORS ARE PRESENT?

Box 6: EQ 5 – key results

- Farmers supported by FtMA, as a result of AflaSight, may potentially further adapt their PHHS practices without lowering their current aflatoxin prevention efforts.
- If the technology reduces the cost of premium quality maize, then the processors will want to increase their domestic grain supply and create new links, or strengthen existing ones, with coops.
- Traders are likely to buy marginal-quality maize if they can use the technology to access premium buyers, and EAX may be able to develop the warehouse receipts system allowing farmers to achieve higher prices off-season.
- FtMA support, including PHHS, plays an important role in connecting coops with direct users of AflaSigh (especially premium buyers), as well as informing farmers about the technology.
- No major risks to adoption have been identified.

Sub-question 5.1: How may the technology lead to a change in the agricultural practices and post-harvest procedures of cooperatives, and what may enable or disable this shift?

132. The farmers who participated in the FGDs and the quantitative survey have previously worked with FtMA and have been assisted to change their agricultural practices. As described under EQ 1.1, they have already adopted most of the practices included in FtMA trainings. Similarly, for a country-wide sample, the latest FtMA PHHS phone survey (August 2021)[106] illustrated the gains made so far: 92 percent of farmers sort out mouldy and insect damaged cobs; 91 percent of farmers dry their grain on tarpaulins or concrete floors; 75 percent measured maize moisture content; and lead farmers stated that 78 percent of farmers are observed applying the PHHS skills learnt during the FtMA provided training.

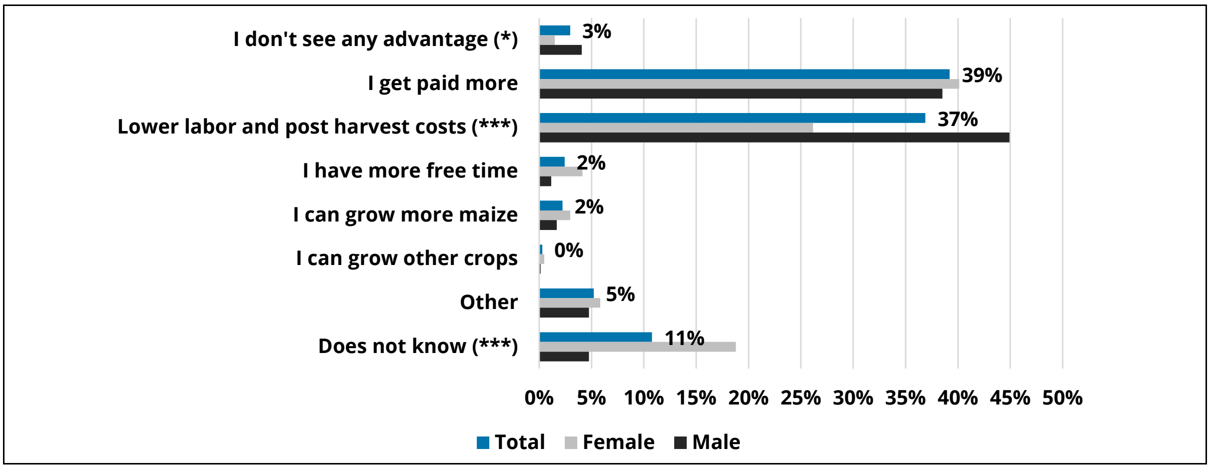
133. In the survey carried out for this evaluation, 83 and 32 percent of farmers expected that they would change their PHHS and agricultural practices, respectively, with AflaSight (although they were not asked for details). Figure 3 below shows that 37 percent of SHFs (i.e. almost half of those expecting some change in PHHS practices) believed that AflaSight would also reduce their labour and other post-harvest costs.

[105] KII with AflaSight and evaluation team analysis.

[106] FtMA. 2021. Do Farmers Retain and Practice what they Learned through PHHS Trainings? mVAM survey August 2021.

Interestingly, this expectation is higher among men (45 percent) than women (26 percent), which may be due to the labour division among women and men in post-harvest work reported in the survey and FGDs (EQ 1.1), e.g. women being relatively more involved in sorting but somewhat less in other PHHS activities (drying etc.) that may potentially be affected by AflaSight.

Figure 3: Farmers' perception of main advantages of AflaSight



Note: Number of observations = 381 total, 189 female, 192 male. Percentages next to the bars refer to the total sample. ***, **, * denote gender differences that are statistically significant at the 1, 5 and 10 percent level respectively. t-tests for gender differences were performed with robust standard errors. Observations were weighted using design weights. See Figure A - 19 and corresponding text for additional details.

Source: Evaluation team analysis of smallholder survey data conducted for this evaluation.

134. The FGDs showed that this **potential change in PHHS practices**, however, **would not imply a reduction in aflatoxin prevention efforts**. Farmers clearly stated that, even if the technology allowed them to submit less high-quality maize (and allow the machine to clean it for them), they would not do this as there was a risk that the crop would be rejected, and they also take pride in the quality of their output and want it to be as clean as possible. To deliberately reduce their efforts to control aflatoxin would clearly be a mistake as it could easily result in rejection by premium buyers despite the use of the AflaSight technology.

135. Examples of potential **enabling factors** for shifts in PHHS practices may include **better knowledge about the use of the machine by buyers** and its effectiveness level as this would help farmers to decide how much they should invest in PHHS practices, and this may lead to an increase or decrease. The provision of improved access to **aflatoxin testing facilities** allows FtMA-assisted farmers to make similar decisions.

136. Examples of potential **disabling factors** are the long distance and therefore **no direct access to the machine** and a lack of information about the machine, its use and effectiveness. Although coops may have a choice of premium buyers, they are currently largely price-takers, and without the support of FtMA are uncertain about price differences/premiums they may get for grain of different aflatoxin levels of from different buyers.

Sub-question 5.2: Is the technology likely to enhance the links of smallholder cooperatives with traders and agro-processors, and are there any barriers?

137. Coop leaders stated in interviews that the introduction of the on-farm technology for controlling aflatoxin has greatly increased their ability to sell to agro-processors. Some also said that the relationships with processors were strong, in part because technical advisors came regularly during harvest and the post-harvest period to advise farmers how to manage their crops to avoid aflatoxin. The process they used to accept or reject crops was also clear so that farmers trust premium buyers. They buyers also provide shelling machines which are much easier and quicker to use than manual methods. This is also in the interest of premium buyers as it shortens the period during which cobs are prone to infection with Aspergillus. In the one-year period between season C 2020 and season B 2021, the FtMA cooperatives signed 238 contracts totalling 12,752 tons with different premium buyers (max. one contract per coop and season). AIF and EAX accounted for the bulk of the total contracts and volume. Other buyers included (in the order of descending

total contract volume) Sarura, Minimex, Gorilla Feed, and the Rwanda Grains and Cereals Corporation (RGCC).[107]

138. Despite the **large numbers of coops that are now selling to premium buyers**, there are many more that are not. Processors or traders looking for crops for the premium market may choose to approach these coops. It is likely that these "**non-connected" coops will have a greater general level of aflatoxin in their crops** as they are less likely to have received the same PHHS training as provided by FtMA. On the other hand, processor or traders may be more willing to buy now, given that AflaSight may be able to reduce aflatoxin levels sufficiently to reach a premium market.

139. If AflaSight enables **agro-processors** to reduce the cost of input grain from Rwandan producers, then it is more likely to further replace imports with domestic production. This will necessitate an **expansion of the number of suppliers (mostly cooperatives)** that it purchases from **and/or buy more marginal-quality grain from their current suppliers** and use AflaSight to ensure that it reaches the standard. The premise of AflaSight is that they will share part of that benefit of the improved cost effectiveness by paying a higher premium for the grain to farmers (see EQ 3.1). In this case it is in the interest of both coops and processors to increase the production of high-quality maize and develop long-term supply relationships.

140. The reduced risk of crop rejection as a result of the ability to remove aflatoxin should encourage more traders to identify and purchase crops that are close to the food/feed tolerance thresholds. This will require an increased level of trust between traders and coops to ensure that quality levels are consistent and that sampling and testing aflatoxin levels is accurate. EAX would be able to increase the volume of stock that is used in their warehouse receipt system and therefore there will be greater access for farmers and co-ops to utilize the system to save stock and sell when prices are high.

141. One potential **barrier** identified in FGDs and interviews with coop leaders is that the **technology is unlikely to be located at farm/cooperative level**, so transport costs would be incurred if farmers/coops wish to make direct use of AflaSight. During the pilot this requires haulage to the current AflaSight location in Kigali. Coops will be reluctant to incur the haulage cost with no guarantee of acceptance by the processor. During scale-up, the technology is likely to be set up nearer the main production areas alleviating this problem to some extent.

142. A second potential barrier is the lack of **awareness** (see EQ 2.1). Those coops linked to FtMA will be introduced to AflaSight in the near future, but other farmers/coops will be less aware. Finally, the widespread lack of aflatoxin testing (except through AflaKiosk, some premium buyers, and very few traders) and the skills required to ensure correct grain sampling, mean that coops and farmers do not know whether their grain is good enough to be sold direct to processors or would benefit from AflaSight processing to reach that standard, or is too contaminated to be treatable.

Sub-question 5.3: To what extent does other FtMA support help smallholder farmers (especially women) to benefit from the technology for enhanced market access?

143. FtMA uses a food systems approach to link farmers to markets, input and PHHS suppliers, financial institutions, insurance providers, digital platforms, extension providers and government and others. As part of this approach, it is linking farmers to the technology indirectly or directly. Since its inception in late 2015 FtMA in Rwanda has connected more than 100,000 smallholder farmers (48 percent women). After one year of operation farmers working with FtMA were reported to be earning 57 percent more on average than other farmers outside FtMA.[108] The help provided by FtMA to help farmers benefit from the technology can be divided into four categories.

144. **FtMA links coops with off-takers, the direct users of AflaSight** – FtMA has worked with coops for several years and is now starting to play a key role in linking coops to the direct users of AflaSight. At this early stage of AflaSight, FtMA are introducing the concept and opportunities of AflaSight to coops while providing the same level of support as in previous years. FtMA provides forecasts of premium buyer demand to coops and then puts the coops in touch with the clients. FtMA does not encourage sales to small traders as it would be a waste of high-quality maize and they are trying to encourage strong long-term relationships with premium buyers. FtMA attend the initial meeting with the client and assist the coops to understand their commitments. Once the price and method (cob or grain) is agreed the coop may arrange to borrow shelling machines (for grain sales only). AflaSight are not part of the negotiation as they are only providing a service

[107] Evaluation team analysis of: FtMA. 2022b. Contract database for cooperatives 2020-2021.

[108] FtMA. 2020. Rwanda Phase Two and Beyond.

to premium buyers so the coops and AflaSight are unlikely to meet in the normal course of business. The role of FtMA in connecting coops with the direct users of AflaSight is thus crucial.

145. **FtMA (not AflaSight itself) explains the technology to coops**. FtMA explains to the coops what options are available to them. This vital knowledge will enable them to ensure that they receive part of the gains obtained through the technology. The sharing of income gains is discussed above under EQs 3.1, 3.2 and 6.1.

146. **FtMA supports PHHS processes and equipment.** FtMA has led a programme to train farmers produce better quality maize. In 2020 FtMA provided PHHS training to 26,549 farmers (48 percent female) [109]and the extension organisation Hinga Weze reached a further 7,089 (49 percent female); 91 percent of the farmers use tarpaulins but only 33 percent had access to modern shelling methods.[110] This illustrates the level of support that FtMA provides and the basis for the improved quality in harvested crops. The PHHS support creates a virtuous circle in that agro-processors are most interested to buy from these coops, which increases the likelihood and volume of market links between coops with direct users of AflaSight. Coops gain from higher prices and farmers, in turn gain more income for their home use and for re-investing in their production. The AflaSight pilot offers premium buyers the opportunity to buy more crops from the best producers, even if they are somewhat over the maximum threshold for aflatoxin as the buyers can expect to reduce the contamination level by passing the crop through the technology. The coops in turn, can expect to sell crops that are above that threshold and receive at least part of the premium price paid normally by the processor.

147. **FtMA support to financial services for farmers.** FtMA has increased access to financial services for farmers and supported the development of savings schemes. The results improve the engagement of farmers in commercial life and allow them to invest more in their crop production and improve their cash income from it. In an FGDs farmers said that they now have that better access to loans and that this reduces the pressure for farmers to offload their high-aflatoxin maize to traders or customers in informal markets, but it allows them to accept waiting longer for the cash if premium buyers buy the grain and pass it through AflaSight.

Sub-question 5.4: Are smallholder farmers (especially women) likely to face any risks from using the technology and shifting to premium markets?

148. **No major potential problems** were raised **specifically about the technology** – 56.2 percent of survey respondents did not expect any disadvantage from AflaSight at all – see Figure 4 below. When the AflaSight system was explained to FGD participants, some were concerned about losing income as weight is lost during the sorting process, so they have less to sell. This grain is highly aflatoxin affected and should be removed in any case. AflaSight is investigating whether the rejected grain can be put to use in order avoid it being discarded. Feeding trials are under way to see whether the grain can be converted to high-protein poultry feed by feeding it to insect larvae.

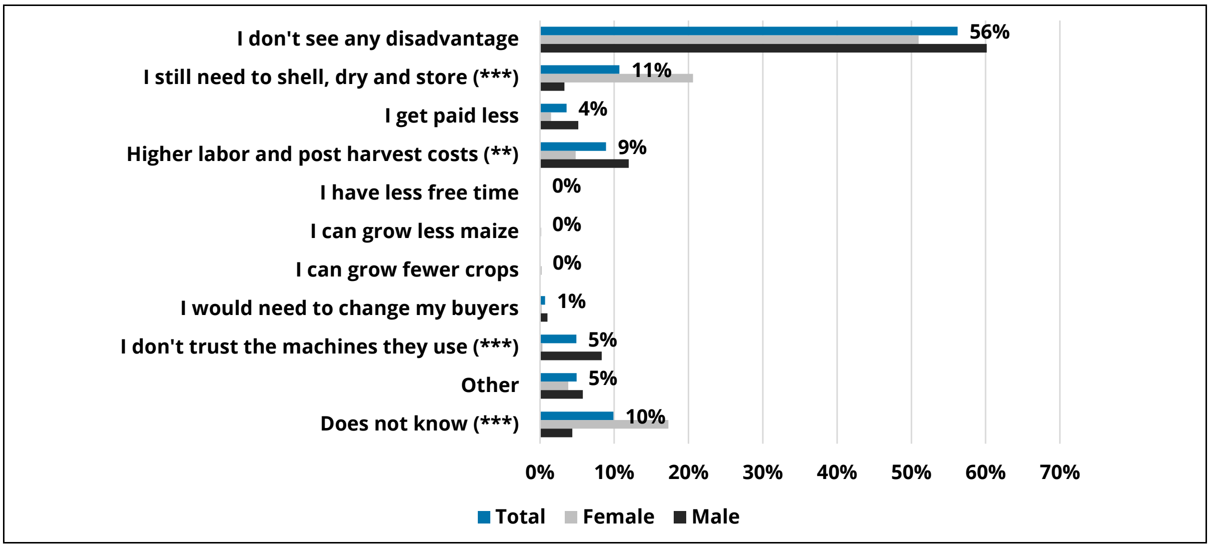
149. Payments from traders are cash on collection at a low price – whereas processors pay within a month (in accordance with their contract). This is an important factor for farmers who need the cash for their immediate needs although interviews with coop leaders and FGDs confirmed that farmers have good access to loans through the coop to cover short term needs throughout the year.

150. No gender differences in technology-associated risks were revealed by the survey or in interviews. This may be because the subject was new, and interviewees had not had the chance to find out if there were gender-based differences.

[109] Despite the equal levels of training participants found in the FtMA PHHS survey (FtMA. 2021. Do Farmers Retain and Practice what they Learned through PHHS Trainings?), there were significant gender differences in the SHF survey conducted with the four pilot coops for this evaluation. 41 percent of men but only 25 percent of women reported having received some support from FtMA, and of these, more women received GAP training (women 72 percent vs. men 46 percent). The few that received contracting support were mostly men. See Table A - 11 and Figure A - 22.

[110] FtMA. 2021. Do Farmers Retain and Practice what they Learned through PHHS Trainings? mVAM survey August 2021.

Figure 4: Farmers' perception of main disadvantages of AflaSight



Note: Number of observations = 381 total, 189 female, 192 male. Percentages next to the bars refer to the total sample. ***, **, * denote gender differences that are statistically significant at the 1, 5 and 10 percent level respectively. t-tests for gender differences were performed with robust standard errors. Observations were weighted using design weights. See Figure A - 25 and corresponding text for additional details.

Source: Evaluation team analysis of smallholder survey data conducted for this evaluation.

2.6. EQ 6 – IMPACT: WHAT EFFECTS, OR EMERGING EFFECTS, ARE BEING REALIZED FOR SMALLHOLDER FARMER LIVELIHOODS, ESPECIALLY FOR WOMEN?

Box 7: EQ 6 – key results

- While AflaSight anticipated that an income increase of up to 15 percent may trickle down to farmers, it is still too early to gauge these income effects.
- Necessary conditions for AflaSight to increase SHF income are market premiums, as well as market links, information about AflaSight and bargaining power of SHFs. WFP support increases the chance that these conditions are met.
- Prices increases due to lower rejection rates for high-aflatoxin maize are the main driver of income gains for farmers. Income effects could differ between men and women if costs or rejection rates do.
- More generally, farmers selling contaminated grain that would marginally fail the acceptance threshold without AflaSight should experience the largest income increase.
- Any income increase, once achieved, is likely to continue in the future but there remains a moderate risk for SHFs that off-takers retain the potential gains from AflaSight as an ‘insurance premium’.
- Survey data suggest that SHFs would invest additional income from maize in agricultural production and livestock, human capital, and savings/insurance management, with only few gender differences.

Sub-question 6.1: To what extent (and how) is the process likely to increase the income of smallholder farmers from maize production, and are these effects likely to differ between women and men?

151. When AflaSight applied for the WFP Innovation Accelerator, they predicted that “*Local farmers gain an assured market with a 15% increase in income*”[111] although they acknowledged that farmers would not be direct users of the technology. The draft business model later specified that this 15 percent income gain would apply to local sellers (rather than farmers) but there would be “trickle-down benefits” to farmers.[112]

152. At this very early stage of the pilot, it is not possible to gauge the magnitude of the potential income effect of AflaSight on SHFs. When SHFs were interviewed for this evaluation (in focus groups or the survey), they had not received payments for season C yet. Some had recently been informed by their coops about the sales modalities (cob or grain) and prices agreed with premium buyers. Farmers’ experience with AflaSight

[111] AflaSight. 2020. Application Form for the Sprint Programme of the WFP Innovation Accelerator.
[112] AflaSight. 2021. Business Model Presentations.

was very limited in the evaluation period. Only 30 MT of grain purchased by a premium buyer from one of the pilot coops in season C was passed through the processing line and successfully brought below the 7 ppb threshold. The contract between the buyer and the coop established a single farmgate price independently of whether some grain would be processed by AflaSight or not.

153. **A systematic trickle-down effect to SHFs has thus not been observed yet.** The **necessary conditions** for such an effect to occur in the future – and ensure that AflaSight is an innovative solution also in terms of income generation for SHFs – include:

- There is a substantial price difference between high- and low-aflatoxin maize, so that processors save on direct sourcing costs when using AflaSight (value chain model E vs. models B and C) and traders receive market premiums for high quality maize (model D vs. model A).
- SHFs connect with direct users of AflaSight (processors or traders).
- Coops/SHFs are informed about AflaSight, its effectiveness and the farmgate aflatoxin level of their grain, and they have enough bargaining power to claim their shares in the income gains of buyers.

154. As discussed in EQ 5.3 for FtMA support, WFP will have a crucial role in engaging with different food systems actors to ensure that the conditions on market links, information, and bargaining power are met. For example, the role that WFP/FtMA can play as 'information broker' for AflaSight is evident from statements of coop leaders and FGDs explaining that farmers (in general assemblies of the coops) take the decision about sales modalities (so far, cob or grain) and thus need to be sufficiently informed about these options. The interviewees also acknowledged that the lack of information of aflatoxin levels undermined their negotiation power – which is currently limited to proposing small adjustments to the bids made by one or few premium buyers –, and that the technology could help them to reduce this information.

155. Given the above conditions, AflaSight can potentially increase the income (gross margins) of farmers through higher prices or possibly lower PHHS costs – but the latter is much more uncertain (see EQ 5.1).

156. **AflaSight has strong potential for increasing average farmgate prices through lower rejection rates for high-aflatoxin crop** (see EQ 5.2). Coop leaders and FGD participants suggested that farmers received much lower prices in local (informal) markets than in premium quality markets. One coop reported that in recent years, they had to sell some maize of poor quality (for aflatoxin and other reasons) at prices of 120 RWF/kg or below.

157. The potential price increase for a farmer depends on the size of her/his aflatoxin problem. The four pilot coops considered in this evaluation are well connected to premium buyers and, with support of FtMA and the buyers, have usually managed to keep rejection rates low. Their members expected to only sell 14 kg of grain in local markets/to middlemen compared to 192 kg through their coops/to premium buyers.[113] This suggests that AflaSight would have increased a farmer's total income from selling grain by less than one percent.[114] Yet, income increases will be higher for farmers with large volumes of aflatoxin-affected crop. Two of the four pilot coops, for example, had experienced high rejection levels in the previous season C 2020 due to mould (30 percent of the total harvest of the first coop, and one of the five sites of the second).

158. **AflaSight may also increase the flexibility of coops in price negotiations.** In past seasons, the grain of some coops was rejected after it had been stored longer than foreseen (either during the negotiation period with potential buyers, or because the buyers picked up the grain later than planned). Some coop leaders mentioned that time pressure (to limit aflatoxin contamination during storage) made them discard potential buyers that would pay higher prices albeit with longer storage periods. AflaSight would possibly allow coops to accept these offers while being 'insured' against aflatoxin contamination in storage.

159. Finally, as an innovative solution for aflatoxin reduction in the grain model, AflaSight could partially replace the cob model and recover some of the on-farm wage labour opportunities in PHHS work that would be lost in the cob model. This would not benefit the farmers directly, but agricultural workers in their

[113] Table A - 16.

[114] Calculations: matching the previous sales volumes with the AflaSight assumption of a 15 percent income increase for affected grain, assuming that this gain is entirely passed to farmers and that prices are 300 and 200 RWF/kg for selling to premium buyers and in informal markets respectively.

communities (mostly men).[115] In comparison with the cob model, the AflaSight model would, however, also require farmers to put back some PHHS work in the process.

160. The potential **income effect** of AflaSight **only differs between women and men SHFs if costs or rejection rates differ**. Coop leadership and FGD participants, both women and men, confirmed that all coop members received the same price per kg if the crop is sold to premium buyers.[116] In the pre-AflaSight grain model, for example, the average gross margin reported in EQ 3.2 (181 RWF) differs between men (167 RWF) and women (205 RWF) only because of differences in PHHS costs,[117] (although this difference is partially driven by the fact that part of these costs were estimated, and men seemed to overestimate the costs, just as they did with their earnings and resulting prices[118]). However, several female and male FGD participants and coop leaders stated that women were taking better care of their harvest and follow more closely the rules/guidance of the coop than men. If this leads to higher rejection rates for crops produced by male farmers, the AflaSight income effect of 'rescuing' grain from informal markets may possibly be larger for men than for women.

Sub-question 6.2: Are any income increases for smallholder farmers (if any) likely to continue in the future, and what income risks remain?

161. **It is likely that income increases – if and once achieved – would continue in the future.** This is also the perception of farmers: less than 5 percent expect to earn less with AflaSight,[119] and almost 90 percent would use AflaSight in the future albeit to a varying degree.[120]

162. The main **remaining income risk** for SHFs is that **off-takers**, due to uncertainty about aflatoxin levels in input grain as well as the performance of the machine, **decide to retain large part the potential gains from AflaSight as 'insurance premium'** rather than sharing it with farmers.

163. In the current value chain configurations without AflaSight (A to C), prices for grain and cob are usually set at the farmgate after visual inspection and possibly qualitative aflatoxin testing of the products. Traders and agro-processors bear the residual risk of higher-than-expected aflatoxin levels found (or developing) after buying the crop. If this practice does not change under AflaSight, it will remain difficult for off-takers to predict the aflatoxin levels of input and output grain sourced from cooperatives. Even if aflatoxin measurement in input grain at the farmgate can be improved (e.g. through AflaKiosk), the current AflaSight data shows variation in aflatoxin reduction levels achieved in output grain (see EQ 4.1). In addition, cooperatives usually cannot trace the aflatoxin levels – and know the final market value – of their harvest beyond the farmgate. Off-takers may thus decide to retain a larger part of their gains/savings from AflaSight – as a de facto insurance premium – when buying maize at the farmgate.

164. This risk would be substantially reduced if coops could directly access decentralised units of the machine close to their production areas. Although FtMA is interested in this option (especially for larger coops), no concrete plans for additional units have been made by AflaSight yet.

Sub-question 6.3: How will female and male smallholder farmers likely use the additional income from the process?

165. The survey data collected from SHFs suggest that **additional income from maize** (generated from AflaSight or other sources) would trigger further income gains in the long-term through **investment in agricultural production and livestock, human capital, and savings/insurance management**. This would be consistent with the statement of AflaSight that "*These [income gains] incentivise greater investment into yield growth, farm commercialisation, and greater family living standards*".[121] While the (actual or expected) additional

[115] For the potential effects of the cob model on local labour markets, see: KIT. 2019. Understanding the costs and benefits of the cob model for maize farmers in Rwanda.

[116] The SHF survey did not ask directly about prices per kg but calculated them from the total earnings and total kg of maize sold (reported by farmers). These quantities vary within coops, and so do the resulting price estimates in Table A - 16, because they were largely based on expectations rather than actual figures (season C 2021) or affected by inaccurate recall (season C 2020).

[117] Table A - 15.

[118] Conclusion from comparing Table A - 16 with actual season C prices reported by FtMA.

[119] Figure A - 25.

[120] Figure A - 33.

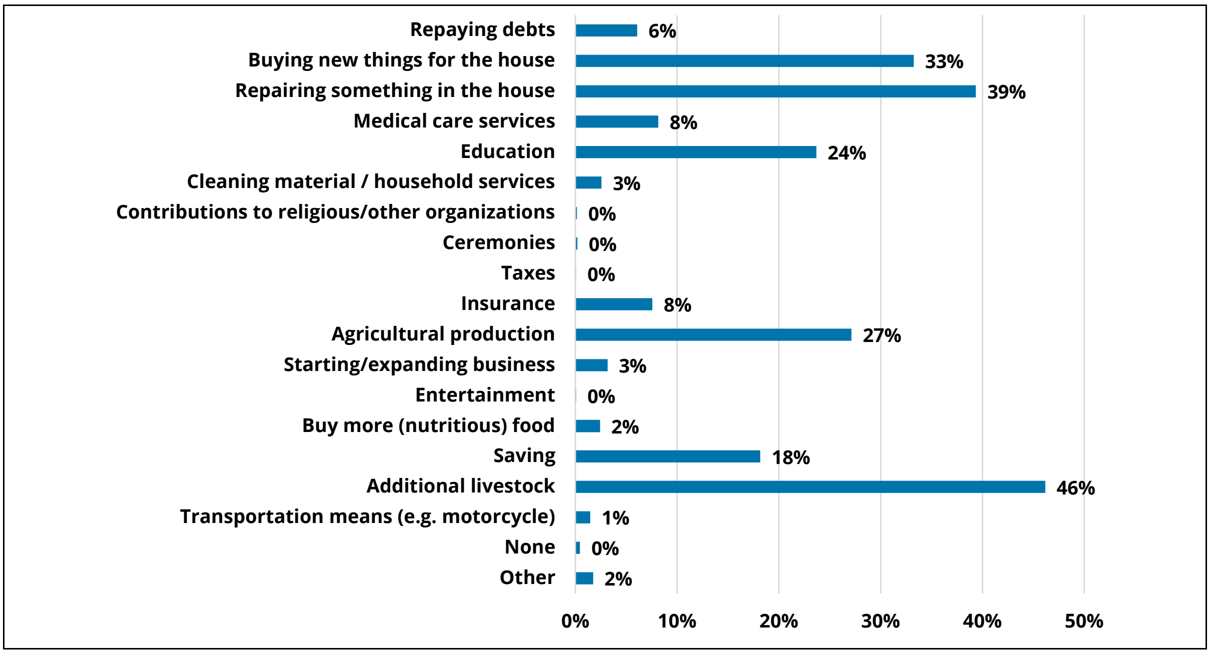
[121] AflaSight. 2020. Application Form for the Sprint Programme of the WFP Innovation Accelerator.

income identified in the survey cannot be attributed to AflaSight yet, there is little reason to believe that its *use* will depend on the value chain configuration that generates the income increase.

166. The survey results on income use focus on the sub-sample of farmers who expected (or already knew) that their income from maize in season C would increase relative to the previous year. A large number of these SHFs would invest, in the short term, at least some of their additional income in agriculture or livestock (multiple uses possible). Specifically, 42.3 percent planned to buy livestock – the main item reported by SHFs. About 10 percent would invest in fertilizer or hand tools. Interestingly, the same data also suggest that female farmers were more likely to undertake productive agricultural investments with their additional income. Only 14.5 percent of women (compared to 32.1 percent of men) would not invest their additional income in agriculture at all. 17.3 percent of female farmers (but only 3.8 percent of male farmers) would invest in improved seeds and seedlings.[122]

167. In SHFs' long-term investment plans for additional income – depicted in Figure 5 below – from maize, livestock and agricultural production rank similarly high. The survey results on investment plans do not differ much between farmers who expect/know that their season C income increases relative to the previous year and those who do not.[123] In the long term, almost half of the SHFs would invest the additional income in buying livestock, and about one quarter would invest in agricultural production, with no significant gender differences. Other frequent investment of additional income includes housing (buying new things, or repairs – both named by around 30-40 percent of SHFs) and education (reported by one quarter of all SHFs, but more frequently by men than women). Savings, insurance, and debt repayment account for 5-20 percent each.

Figure 5: Farmers' future investment plans with additional income from maize



Note: Number of observations = 399. Observations were weighted using design weights. See Figure A - 30 and Figure A - 31 and corresponding text for additional details.

Source: Evaluation team analysis of smallholder survey data conducted for this evaluation.

168. Information on financial decision-making within households captured in some of the FGDs (with both female and male SHFs) revealed that the use of income from maize is usually decided by both spouses together – independently of whether the registered household member who receives payment from the cooperative is the woman, the man, or both. This is consistent with the overall **relatively small gender differences in the use of additional income** reported in the survey. The few gender differences in the survey data (e.g. in agricultural investment) may stem from different plans for – but not actual – use of additional income, or differences between female-headed and male-headed households, for instance.

[122] Figure A - 29.

[123] Figure A - 30 and Figure A - 31 respectively.

2.7. EQ 7 – IMPACT: WHAT ARE THE LIKELY OUTCOMES WITHIN THE WIDER MARKET SYSTEMS AND MAIZE VALUE CHAIN?

Box 8: EQ 7 – key results

- The first grain from cooperatives working with FtMA have been accepted by a premium buyer into the food chain as a result of processing by AflaSight. This is expected to continue as long as input is not too heavily contaminated.
- There is clear data to show that both grain and food products are contaminated with aflatoxin, but most samples fall within the expected cleaning potential of AflaSight treatment.
- Increased domestic high-quality grain production should reduce input costs for processors and may contribute to improved profitability, lower food prices and increased exports of food products.
- The food produced by major processors already meets official standards, but smaller mills and food producers will produce less contaminated food if the general level of aflatoxin in maize is reduced.

Sub-question 7.1: Has there been, or is there likely to be, a reduction in grain rejected by agro-processors, and is treated grain now (or likely to be in future) accepted into the food chain for milling and food processing?

169. AflaSight reports that several loads of grain that do not meet the standards for aflatoxin have been **passed through the processing line** and have then been **accepted by the processor into the food chain**. Although Rwanda has adopted the East African Community (EAC) standard for total aflatoxin of 10 ppb, the processors set their own limits. The limits of two key commercial processors for food are 7 ppb and 4 ppb. If the machine fulfils the expected 90 percent reduction stated by Bühler,[124] then grain with aflatoxin levels of up to 50 ppb should be cleaned to within the 5 ppb tolerance for food. Initial results (see EQ 4.1) show lower levels of reduction but even if the reduction is only 75 percent, then there will be many stocks of grain that can be brought within tolerance and safely used for food or feed.

170. Little is known of the levels of aflatoxin in maize grain at a national level. A survey in 2019 of 227 samples of grain[125] found that aflatoxin levels varied from 0 to 101 ppb with a mean of 9.7 ppb and 90 percent above 10 ppb. The AflaKiosk programme is building up a database of observations since its start in July 2021. The 109 samples tested had an average aflatoxin level of 29.1 ppb. 50 percent of the maize samples tested had above 10 ppb and 25 percent above 40 ppb.[126] These results indicate that **many of the samples are within the expected cleaning potential of the machine** and could be used for food processing, however it should be noted that the samples in both 2019 and 2021 were taken after season B when aflatoxin levels are expected to be at their lowest.[127]

171. Although this study is concerned with aflatoxin, grain may fail to be accepted for processing for many other reasons including high moisture and **other contaminants**. The LumoVision machine removes only aflatoxin-contaminated grain, it does not perform the task of a seed cleaner. AflaSight has set up a drier and standard cleaning machinery to bring the crop to acceptable moisture levels and remove other impurities such as foreign matter, broken grains etc; these contaminants will be removed where it is possible. These machines are included as many crops may not qualify for food processing due to excessive moisture and contamination even though the aflatoxin level is acceptable. Although it is not the purpose of AflaSight it can be used as a standard drying and cleaning line to meet international or processor standards apart from aflatoxin.

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124 Bühler. 2020. SORTEX A LumoVisionTM Aflatoxin Sorting in Maize. Internal presentation slides; Bühler. 2018. Bühler LumoVision: Saving Lives and Improving Livelihoods with Revolutionary Data-driven Grain Sorting Technology.

125 Niyibituronsa M, et al. 2020. Assessment of aflatoxin and fumonisin contamination levels in maize and mycotoxins awareness and risk factors in Rwanda.

126 IFC. 2021. Aflatoxin Testing kiosks – Rwanda: September Report.

127 Furthermore, an older (2017) study of complementary foods (used for children under 24 months) examined 17 samples of ten different commercially available products. The study reported that alarmingly high aflatoxin contamination was found in nine of the 17 samples, with 294 ppb of total aflatoxin the highest detected values. This far exceeds the tolerable limits of 10 ppb limit set by the Rwanda Standards Board in 2016. Detectable amounts of aflatoxins were also present in the remaining samples. See Grosshagauer, S., et al. 2020. Inadequacy of Nutrients and Contaminants Found in Porridge-type Complementary Foods in Rwanda.

Sub-question 7.2: How would an increase in the local production of Grade 1 maize affect the quality, sales and profitability of flour and other maize products in domestic and export markets?

172. The quantity and quality of maize flour and other products depends on the supply and quality of maize that they buy. The major agro-processors buy what grain they can from domestic suppliers to produce flour and other products and import the shortfall that they need to satisfy their customers. [128] An increase in grade 1 maize produced domestically would reduce the need for imports, and, if it were at a lower cost than imports, it **could improve the profitability of the processor and/or reduce the cost of maize products** and it might also increase opportunities for export.[129] Given the large current deficit it is unlikely, however, that Rwanda will become a net exporter of grade 1 maize grain as a commodity in the foreseeable future but there may be greater opportunities for more specialized maize-based food products including those produced for WFP (finding of the evaluation team).

173. An increase in reliable local production of maize that meets Rwandan aflatoxin standards is **unlikely to affect the quality of maize products produced and sold by the major agro-processors** in Rwanda as their production is monitored by RICA (for raw product) and the Food and Drug Authority (for processed foods), and they already meet the official aflatoxin standards using a combination of domestic and imported maize. **Smaller millers and local processors** are less able to monitor and control aflatoxin levels and an increase in high quality maize should result in **improved availability and quality of uncontaminated maize products**. According to interviews with processors, sourcing costs add significantly to the costs and risks attached to imported grain. Processors importing grain require more extensive due diligence, reliance on inspection and testing at source, more complex negotiation, compliance with international trade rules and international payments. All of these are simpler if the supplier is within Rwanda. International prices may also vary unexpectedly due to droughts or other problems within the region. A greater domestic supply would stabilize and probably reduce the cost base for processors.

174. The cob model was introduced in order to combat the large deficit in premium quality grain. Premium buyers report that it has increased the quantity, but it is a complicated system to operate as it involves the expensive transport of whole cobs and deprives farmers of the value of the husks. An alternative system (such as AflaSight) should increase the efficiency and therefore the profitability of processors.

175. In the longer term, control of aflatoxin by farmers and traders through improved post-harvest management and the widespread use of driers and improves storage could be reinforced by AflaSight to ensure that aflatoxin contamination can be greatly reduced. However, it is too early to say whether the volumes and prices will be sufficient to establish export markets.

2.8. EQ 8 – SUSTAINABILITY: IS THE PILOT ACTIVITY BASED ON REALISTIC ASSUMPTIONS, IS IT TECHNICALLY AND FINANCIALLY VIABLE, AND SHOULD IT BE SCALED UP – AND IF SO, WHAT COULD BE SCALED, HOW, AND WHY?

Box 9: EQ 8 – key results

- AflaSight reduces aflatoxin but so far less than planned, especially for samples with low initial levels of contamination. This reduces the number of crops that can be cleaned to the highest standards.
- The business model shows that variable costs are quite low but fixed costs are large, and economic viability of the pilot and the scaling-up proposal will depend heavily on demand (throughput).
- The pilot expires imminently, but there is insufficient data to make investment decisions as the pilot has only recently starting to work commercially.
- No major modifications are needed to the pilot
- There are opportunities to use a food systems approach to bring in other food systems actors.

Sub-question 8.1: From the currently available data, does the pilot indicate whether the technology is likely to be effective for aflatoxin reduction in the specific local setting, and is the pilot likely to be technically viable?

176. Based on the data collected and available to the evaluation team within the evaluation period, the machine has shown that it is **capable of removing aflatoxin** from contaminated grain. Preliminary results from a small sample without season A suggest that for highly contaminated grain (>50 ppb) aflatoxin levels

[128] KIIs with processors.

[129] KIIs with processors.

can be reduced by 80-90 percent but for grain with 15 ppb the reduction is around 55 percent (EQ 4.1). This suggests that to achieve a standard of 7 ppb the input grain needs to be below 15 ppb. In order to meet the 20 ppb feed standard a maximum initial contamination of 100 ppb may be sufficient. Three freshly harvested crops from season C 2021 with an average contamination level of 14.4 ppb were brought within the 7 ppb standard in January 2022. Results may improve as more experience is gained with the machine.

177. Maize harvested in **season A** will have a higher moisture content at harvest and is likely to be the most severely affected by aflatoxin. The effectiveness of the machine under these conditions needs to be assessed. Season B is normally harvested in drier conditions but AflaKiosk results[130] suggest that more than 50 percent of maize samples have an aflatoxin level unacceptable for formal food markets.

Sub-question 8.2: Is the pilot likely to deliver sufficient results (and is the local setting adequate) to test the business model, and is the business model financially viable?

178. WFP support for the pilot is due to expire in January 2022 (including a no cost extension). Unless there is funding for a continuation, the **evidence** gathered to date is **insufficient to be confident that the business model is financially viable**. The number of completed processing contracts to date is quite small and these are all from stored grain and season C.

179. Users (processors, traders and coops) need to have more experience with the pilot in order to be confident that the pilot is economically worthwhile. The pilot needs to work through season A and preferably for a full year to assess whether there are sufficient committed users to assure commercial viability of the current pilot and to develop a case for scaling-up. The pilot also needs to operate during the peak period in order to judge whether the technology and management can cope with the demands at that time.

180. AflaSight has provided a **business (revenue) model**[131] with income, costs and profit/loss calculations for many options. The evaluation team has reviewed the model and made suggestions to AflaSight. The variable costs in the model are derived from their actual costs since the beginning of the project and are expected to be quite accurate. The **major variable cost is drying** (electricity) but this is not always needed; drying cost is calculated as 13 RWF/kg for a reduction from 18 to 13.5 percent moisture. It is clearly less expensive for crops to be air-dried if this is possible. The remaining costs (loading/unloading, electricity for cleaning and LumoVision and aflatoxin testing) are quite small – totally around 6 RWF/kg.

181. The **overhead costs** are more difficult to assess. No allowance is made in the model for the capital costs of the machine (servicing, parts, depreciation, interest charges or leasing). During the pilot these costs have been supported by Bühler (e.g. by waiving the leasing fees in the pilot year), but this is unlikely to continue through the scale-up phase once the proof-of-concept (pilot) phase is complete. Personnel costs have initially been included as a variable cost based on a fixed tonnage per month but have now been treated as an overhead. If the process is running to its 4,200 MT/month estimated capacity[132] the allocation of labour cost would be around 1 RWF/kg but if the plant only processes 600 MT/month, then the labour cost is 7 RWF/kg. If machine costs are included, then it is possible that fixed costs may be larger overall than variable costs. **The throughput of each machine is thus critical to profitability.** Charges need to be established, based on variable costs plus an allowance based on realistic estimates of throughput. If the throughput estimates are too low then the prices charged will be high and possibly deter customers, but if they are too high then AflaSight will not cover its costs.

182. For users, the calculation is simple. Provided that treatment is more-or-less guaranteed to bring a crop under the threshold for a premium customer, the cost of AflaSight treatment is sufficiently lower than the difference between the low-value market and the high-value market (see EQ 3.1). For the user other factors will also be involved in these decisions, such as long-term supply commitments, the risk of insufficient contamination reduction, availability of the machine when needed and other factors that affect the sales such as payment timing and reliability.

183. In summary, the business plan looks very attractive with only the variable costs, but the fixed costs are dependent on throughput. With the assumptions of the business plan – without machine and facilities costs and assuming a throughput of 600 MT/month – the planned charge of around 20 RWF/kg (excluding drying) appears to cover the costs and allow for the expected profit.

[130] IFC. 2021. Aflatoxin Testing kiosks – Rwanda: September Report.

[131] AflaSight. 2022. Internal Revenue Model.

[132] 50,000 MT/year, see: AflaSight. 2020. Application Form for the Sprint Programme of the WFP Innovation Accelerator.

Sub-question 8.3: How should the pilot be scaled up to maximise its benefit, and what parts of the activity should be modified – and why?

184. **Provided that technical performance meets expectations for the season A crop and** the costs and revenue allow for **profitable operations**, then the **pilot should be scaled up**. The national shortfall of high-quality maize for food and feed which is currently met by imports[133] should lead to continuing and expanding market. The application for funding from WFP provided a bold scaling-up process: it was estimated that, with a capacity of 200 tonnes per day and 50,000 tonnes per year per site, one operating location would be able to process 16 percent of national contaminated maize in Rwanda.[134] The capital investment for each site including the machine and additional processing equipment is estimated at 750,000 USD with operating costs of 500,000 USD. The proposal included an additional site in Rwanda in the second year together with one site in Uganda, with further scaling to ten sites in five years. Provided that the technical and business cases have been met and sufficient demand has been established during an extended pilot these targets are reasonable provided that investment or loan funding is available.

185. At present, due to the early stage of the pilot, there are too many unknowns to be able to make detailed calculations and funding proposals for the **scaling-up phase**. That phase will need to be **demand-driven** as processors and intermediaries recognise (or not) the advantages of using the process.[135] Ideally, long-term commitments (including possible investment in the capital costs) should be negotiated with the major users to facilitate funding. The number of sites needs to be tailored to the likely market. If too many machines are imported, then they are likely to operate at below capacity and the interest or leasing payments on the machine will be excessive (see EQ 8.2 above).

186. In order to maximise its benefit to cooperatives the location of **new machines** should be centred in the **main production areas**. This will reduce the risk of high haulage costs being incurred despite the risk that the grain cannot be cleaned sufficiently to meet premium quality standards. It will also increase the availability of high-quality grain to mills and other markets in regional centres.

187. The benefits to smallholder farmers can be maximised indirectly by establishing a reliable system for ensuring that most grain produced in Rwanda – with appropriate PHHS measures to avoid aflatoxin contamination – can achieve the aflatoxin (and other) standards of processors when processed by AflaSight if necessary. Not all grain will be suitable but a much higher proportion than is now used. More directly the coops and SHFs can benefit from direct processing if they have machines located within major production areas and operating reliably and with reasonable costs.

188. No major modifications are required for the pilot to achieve its aims of establishing its technical and effectiveness and therefore its utility to potential customers. Once these questions are answered it would be valuable to look at AflaSight and its position in the grain value-chain through a **food systems perspective**. This is already achieved to some extent through its potential to benefit several different actors (SHFs, traders, processors and the food consumer). It is also achieved through the FtMA work with farmers and coops to produce better crops and linking farmers to markets and to financial services. Other food system actors could also be included, such as providing support to RICA to ensure stronger enforcement or support to RAB to improve the provision of post-harvest equipment. Farmers in surveys noted that good quality tarpaulins are not easy to obtain in the regions – further work could be done to encourage the agricultural input supply chain.

2.9. EQ 9 – SUSTAINABILITY: ARE THERE ADEQUATE LOCAL CAPACITY AND INSTITUTIONAL ARRANGEMENTS TO SUSTAINABLY CONTINUE THE OPERATIONS?

Box 10: EQ 9 – key results

- From the available data it is likely that there is adequate aggregation and storage facilities nationwide to house the proposed scale-up of the AflaSight technology.
- For scale-up AflaSight will need to replicate their pilot facilities with some additional storage. If they start to trade on their own behalf, they will require access to further storage.

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[133] Imports of maize in 2020 = 118,000 MT with value 27.5 million USD; exports of maize in 2020 = 16,000 MT with value 0.2 million USD. Source: FAO. 2022. Food and Agriculture Data.

[134] AflaSight. 2020. Application Form for the Sprint Programme of the WFP Innovation Accelerator.

[135] Evaluation team analysis based on KIIs with AflaSight and other food system actors.

- Government organizations are very supportive of the pilot and are likely to remain so if AflaSight is successful. Progressive enforcement of the aflatoxin standards will reinforce the role of AflaSight.

Sub-question 9.1: Are there sufficient local capacity and acceptable systems for aggregation and delivery of grain to the machine, in the scenarios with one vs. multiple processing units in the country?

189. Aggregation systems require delivery capacity (suitable trucks with drivers and servicing), suitable warehousing/silos, equipment for loading and unloading (or this can be largely manual, and maybe also processing equipment such as driers) and management.

190. Interviewees state that there is no shortage of road **haulage capacity** in the country and labour for loading and unloading is widely available. A study of post-harvest infrastructure in 2020[136] found that there were 518 warehouses and 11 metal silos around the country, about 80 percent of which are operational. The report also stated that the **capacity of warehouses** was 240,150 MT and of metal silos was 56,620 MT. According to the National Strategic Framework (2017-2014)[137] that capacity is planned to be increased to a total of 350,000 by 2024.

191. If AflaSight wishes to set up processing lines with only short-term storage of 2,000 MT to allow for continuous operation of the processing line, then it is unlikely that warehouse capacity would be a limiting factor. According to the same study, total grain production in season B is 30 percent higher than season A indicating that the most serious bottlenecks for capacity nationwide are likely to be after season B. However, season A is harvested during the wet season and the need for storage and processing may be greater.

192. If coops wish to use the processing units directly, they already have aggregation capacity within the coops and can rent local haulage to deliver (and collect) their grains. Traders have existing capacity for aggregation and transport, while most also have storage facilities.

Sub-question 9.2: Is the capacity/management of the processing site likely to be adequate to continue/expand the operation?

193. The **capacity for the LumoVision machine** is up to 20 MT/hour[138]. If it were running 20 hours per day/300 days per year, then the maximum capacity would be 120,000 MT/year. The AflaSight application for the Sprint Programme[139] suggests that more than 50,000 MT will be processed per year by each of six machines making a total of 300,000 MT/year, or approximately the total Rwandan production of contaminated maize. The actual usage of the technology cannot be usefully predicted at this stage but will depend very much on seasonality of demand, the economics of processing, and demand from the agro-processing companies.

194. For the **pilot phase** grain has been brought directly to the machine in full loads (up to 10 MT)[140]. The **processing centre does not need to store the grain** as it is processed within a few hours and collected by its owner; this arrangement is quite adequate for the pilot phase. Input may come from traders' stores or from coops, and, after processing may return to the trader's store or be delivered directly to agro-processors. The location of the store is sufficient for the pilot but discussed earlier under EQ 2.2.

195. If there are multiple units and AflaSight is operating as a service provider, the same arrangements may be sufficient, although it may be advantageous to have storage facilities to keep the machines operating during peak seasons. If AflaSight becomes a trader rather than a service provider, then they would likely need more storage space for their stocks.

196. Current management is sufficient for the pilot phase, but in order to operate the machine at full capacity it is likely that an **additional cleaning line** and more space for grain handling operations would be needed. More warehouse staff may also be needed if the machine is run at full capacity. It is anticipated that Bühler will continue to provide technical support as AflaSight is a development project for them.

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136 European Union. 2021. Technical Assistance to Enhance the Government of Rwanda's Capacities in the Agriculture Sector for the Sustainable Use of Land and Water Resources, Value Creation and Nutrition Security: Postharvest Infrastructure Baseline Survey Final Report.

137 Government of Rwanda. 2017. Rwanda 7 Years Government Programme: National Strategy for Transformation (NST 1), 2017 – 2024.

138 Bühler. 2020. SORTEX A LumoVisionTM Aflatoxin Sorting in Maize.

139 AflaSight. 2020. Application Form for the Sprint Programme of the WFP Innovation Accelerator.

140 Findings under this sub-question are evaluation team analysis following interviews with AflaSight and a visit to the pilot.

197. As the operation is scaled up it is likely that each site will need to have the same facilities as the pilot. Besides the current managing director, a site manager would be needed for each location to manage operations within the site and liaise with customers. If AflaSight starts to trade grain then it will need to have experienced staff to manage the purchases, sales and financing.

Sub-question 9.3: What type of government support is in place or can be expected to support the operations in the long run?

198. The Government of Rwanda has enacted legislation which has adopted the EAC standards for aflatoxin (5 ppb aflatoxin B1 and 10 ppb total aflatoxin in cereal and cereal products). The Government is well aware of the aflatoxin problem and seeks to find ways to reduce the problem through **standards enforcement** and provision of **drying sheds and driers** to avoid aflatoxin build-up. RAB supports measures to improve quality of maize through training programmes for farmers and by providing drying sheds (in the past) and driers (currently).

199. RICA was set up in 2018 to enforce the standards in foods. It issued a directive in April 2021 requiring that dealers in agriculture products to effectively use the facilities to test for aflatoxin – naturally occurring toxic substances – prior to accepting, storing or even processing these agriculture supplies. Although enforcement is applied to imports and foods, smaller millers and local markets are not yet controlled routinely, and aflatoxin levels are generally assumed to be above government thresholds.

200. Until there is better post-harvest control to reduce the prevalence of aflatoxin and/or a means of “cleaning” affected stocks (e.g. AflaSight), it is difficult for the Government to remove and destroy a large proportion of the staple food on sale in markets.

201. Interviews with government stakeholders showed a **strong support** for, and optimism towards the AflaSight initiative. One interviewee stated at the AflaSight/IFC symposium that he would strongly recommend importers and domestic traders with contaminated grain to make use of the AflaSight process. In interviews with government officials, it was clear that the Government of Rwanda will continue to support initiatives that promote the production of safe food and increased use of domestic maize by processors. This is likely to include progressive enforcement of the aflatoxin standards in markets and at the premises of traders and millers.

3. CONCLUSIONS AND RECOMMENDATIONS

202. This section presents a set of seven conclusions and six recommendations. Annex 13 shows how the findings from the EQs have been mapped into conclusions and recommendations.

3.1. CONCLUSIONS

Conclusion 1: Aflatoxin is a major problem in Rwanda and optical sorting has the potential to make a big contribution and generate direct or indirect benefits for all members of the maize value chain.

203. Aflatoxin contamination of maize grain is widespread in Rwanda; storage and drying facilities are lacking, and the problem is aggravated by high seasonal rainfall. The shortage of good quality grain means that agro-processors are only able to source a small part of their needs from domestic growers. Aflatoxin causes short and long-term health problems; the government has set official standards, but these are not yet fully enforced. The Bühler LumoVision optical sorting technology removes maize grains that are contaminated with aflatoxin. It is the first technology that has the capacity to remove a high percentage of affected grain with a high throughput and so it is clearly relevant to test the technology in Rwanda to see if it can be part of the solution to the aflatoxin problem. The main direct users and beneficiaries of the technology are likely to be agro-processors and traders while the potential benefits for coops and SHFs are indirect.

Conclusion 2: The machine's performance in the pilot so far is likely to be sufficient to reduce aflatoxin levels in grain and provide a cost-effective solution for increasing the volume of domestic grain available to processors.

204. With only two months of commercial operations the number of samples processed is limited, but it appears that from initially highly affected grain an aflatoxin reduction of 80-90 percent is possible, and for lower aflatoxin starting levels a reduction of 55 percent has been achieved. The results are from stored grain and from season C; it is not clear if the same results will be obtained in season A. For agro-processors that seek to eventually obtain <7 ppb through direct sourcing from coops, AflaSight is the least costly method if farmgate prices paid for >20 ppb grain are sufficiently below those for <7 ppb maize. For processors and traders, the cash benefit of the improved grain is likely to be greater than the cost of processing, so they are likely to use the process.

Conclusion 3: AflaSight should enable farmers to sell a larger quantity of grain to premium markets and increase their income, provided that they are able to connect – and negotiate higher farmgate prices for aflatoxin-affected grain – with the direct users of AflaSight.

205. The main potential benefit to farmers is increased grain sales to premium markets. AflaSight will not have an effect on unaffected grain that can be sold at premium prices as now, but for moderately affected grain, AflaSight should be able to "create" premium quality maize. Whatever price is paid to SHFs above the informal/local market price is a benefit to them. While AflaSight has a strong potential for increasing farmgate prices for high-aflatoxin crop and consequently farmers' income, it is not yet possible to say how much of the potential income gains/cost savings of the direct users of the technology (processors and traders) will actually trickle down to SHFs. This income effect will crucially depend on the ability of farmers to connect and negotiate higher prices with processors and traders.

206. In the current setup, farmers still face some barriers to fully benefit from the technology:

- Farmers' awareness of AflaSight is still low (as the pilot has only just started to operate).
- The direct access of farmers to the technology is limited in the pilot phase as the machine is remote from farming areas.
- Aflatoxin testing is not readily available to farmers except through AflaKiosk, processors and some traders, which limits them in making informed decisions about marketing their produce.

Conclusion 4: Women and men have equal access to the technology, but they may benefit from it somewhat differently although it is too early to tell with certainty.

207. Men were more aware of the causes of aflatoxin, but women were reported to be more diligent at looking after their harvested crops and following the coop rules and guidance for PHHS and aflatoxin prevention. The potential consequence is that women may face lower rejection rates and AflaSight would make less of an income difference for them. If women receive additional income, they are more likely than men to make productive investments in agriculture with it and buy improved seeds. There is some gender division in PHHS labour, and potential changes in PHHS practices caused by AflaSight (particularly for those currently selling under the cob model) could possibly affect women and men somewhat differently.

Conclusion 5: There are many potential advantages for consumers and the economy.

208. Grain that can be brought within the premium standard will be used by agro-processors for food or feed production. This means that more domestic grain can go into the food chain. The additional grain will also reduce imports. In the longer term AflaSight has the potential to contribute to an increase in the overall quality of grain and food in Rwanda as smaller millers and local processors are able to purchase higher quality grain. Moreover, warehouse receipt systems operate in many countries and enable many SHFs to increase their income through avoiding forced sales at times of surplus, but due in part to aflatoxin causing a large potential loss of value, this has not been introduced widely in Rwanda. With AflaSight it may be possible to remove this barrier.

Conclusion 6: FtMA will play an important role in the introduction of AflaSight to guide farmers and coops as to how they maximise their chances to sell to processors and share the value added from the technology.

209. FtMA are already supporting coops and farmers to foster linkages with premium buyers and ensure that their grain meets the standards needed for direct sale to these processors. In the future coops will need more guidance on their sales, and more knowledge about AflaSight, to increase their chances that the added value of AflaSight to processors is shared in the sales price; FtMA is well-placed to provide this. FtMA is already using a food systems approach in linking all stakeholders in maize production. This will become more important as farmers increase their cash income and become more integrated into the local cash economy.

Conclusion 7: The pilot clearly needs to continue for several more months to gain more experience with the process itself, learn how value chain members make use of it, and make decisions on scaling up.

210. The technology has only been running for a short time and needs probably six months more to generate sufficient results to make decisions about scaling up. The level of reduction of contamination and its consistency for different seed sources needs to be fully assessed. Potential users of the technology will have an opportunity to decide whether it provides financial or other benefits to them and how, and to what extent, they wish to use it. No major changes to the pilot are needed at this stage. AflaSight's business model shows variable costs that can be covered comfortably by their proposed service fees. The model also includes some fixed costs for labour but does not include costs for the machine. The fixed costs may damage the viability of an AflaSight unit if throughput is too low. AflaSight will need to ensure that there is a strong (demand driven) market before scaling up.

3.2. RECOMMENDATIONS

211. The six recommendations are presented in the following text and summarised in Table 5 at the end of this sub-section.

Recommendation 1: WFP/FtMA should support (throughout the life of the FtMA programme) coops whose grain passes through the AflaSight process, as a means of increasing the income of SHFs (and women in particular) and continuing the shift from subsistence to commercial farming.

212. This should include:

- Further developing the WFP food systems approach in Rwanda to engage all relevant stakeholders including financial institutions, insurance companies, extension providers and government agencies. Providers of PHHS equipment, finance for investment in farming, and suppliers of test kits are all potential partners.
- Reaching as many coops and independent farmers (and women in particular) as possible to enable them to gain production and PHHS skills and connect to premium buyers. Processors are more likely

to use/test AflaSight with coops who have knowledge and skills in PHHS. If coops adopt these practices, they are more likely to connect with direct users of AflaSight. The corresponding FtMA strategy may include sharing methodology and knowledge with other organisations providing support to the sector to maximise the gains made by FtMA.

- Extending the availability of aflatoxin testing to coops and farmers through AflaKiosk and through working with kit suppliers and other agencies (including RICA – see recommendation 3). This will help SHFs to understand the market value of their crop, and whether it needs (or qualifies for) AflaSight.

Recommendation 2: WFP/FtMA should continue to monitor and support the engagement of SHFs with the AflaSight pilot to maximise its value for them and to maximise the access of coops to the technology.

213. This should include:

- Supporting the linkages between coops and premium buyers with particular attention to ensuring that coops receive a fair share of the benefits from the AflaSight technology.
- Support AflaSight in the planning and implementation of awareness events/ training/publicity about the technology for coops and SHFs but also for other stakeholders such as government, traders and smaller processors.
- Feeding results of AflaSight back to SHFs so that farmers better understand the market value of their crop.
- Recording contract arrangements made between FtMA-supported coops and premium buyers to be able to assess whether coops are consistently receiving a fair benefit from AflaSight.

Recommendation 3: The Innovation Hub for Eastern Africa, with support of the Rwanda CO, should mobilise innovation funding for AflaSight until the results are better understood and can inform the decision on scale-up (while already exploring funding options for scale-up).

214. This should include:

- WFP RCO/ Innovation Hub should mobilise the innovation funding scheme, before the present funding ends, to ensure that AflaSight has the resources to keep running its operations until it has performance results and a thorough understanding of the likely long-term use of the technology by potential users. This should be for at least the three growing seasons – that is until at least half of harvest B 2022 has been processed.
- Although not yet ready for decision-making on scaling up, work should begin within three months in support of AflaSight to explore means of funding the scale-up. The Innovation Hub is one source but IFC and/or international development banks and private investors may all be willing to invest.
- Ensuring that AflaSight quantifies fixed costs in their business planning if they are applying for scale-up funding.
- Between April and July, WFP should carry out a small study to assess the latest data on the performance of the LumoVision machine and assess (through usage and interviews with key users) the potential for scale-up.

Recommendation 4: WFP should explore opportunities to work with RICA to support their efforts to widen the enforcement of aflatoxin standards and to carry out market surveys to understand better the extent of aflatoxin contamination in grain and flour on the market in Rwanda. This work should commence within the next six months. No immediate additional resources are needed for initial studies although any joint programme may eventually involve a WFP commitment.

Recommendation 5: WFP should work with the authorities and key stakeholders such as EAX to explore the opportunity to further develop a warehouse receipt system in Rwanda in the context of the quality "insurance" provided by AflaSight.

215. These systems are common in other regional countries but have not been possible in Rwanda which has been at least in part due to the aflatoxin problem. Warehouse receipt systems allow SHFs to partially monetise their crop while retaining ownership in order to sell when prices are most favourable. Initial exploratory meetings should be held within the next three months and followed up as appropriate. No additional WFP resources are envisaged for this.

Recommendation 6: WFP (RBN) should commission a study to identify which countries in East Africa would most benefit from access to the Bühler LumoVision technology.

216. Although the results are not conclusive yet, the technical and cost effectiveness are looking positive. In three to six months (provided that AflaSight continues to show good progress) a study should be launched. The results of the study can be used to guide WFP's support for regional scaling-up of AflaSight or other partners. Criteria for judging benefit will include the size of the maize market, the levels of aflatoxin contamination in grain, the potential benefit to SHFs (particularly women) and the suitability of the structure of the value chain for an intervention such as AflaSight. The additional resources needed to launch the study could possibly shared by AflaSight and Bühler.

Table 5: Summary of recommendations

No.	Recommendation (O: Operational, S: Strategic)	Responsibility (lead office)	Other contributing entities	Priority (high/medium)	Timeframe (start/end)
1	**S:** WFP/FtMA should support (throughout the life of the FtMA programme) coops whose grain passes through the AflaSight process, as a means of increasing the income of SHFs (and women in particular) and continuing the shift from subsistence to commercial farming.	WFP Rwanda CO	FtMA (Rwanda), IFC/AflaKiosk, other entities supporting smallholder maize farming, potential food systems partners	High	Immediate/ through life of FtMA (at least until end 2023)
2	**O:** WFP/FtMA should continue to monitor and support the engagement of SHFs with the AflaSight pilot to maximise its value for them and to maximise the access of coops to the technology.	WFP Rwanda CO	FtMA, AflaSight	High	Immediate/ 1 year
3	**S:** The Innovation Hub for Eastern Africa, with support of the Rwanda CO, should mobilise innovation funding for AflaSight until the results are better understood and can inform the decision on scale-up (while already exploring funding options for scale-up).	WFP Innovation Hub	WFP Rwanda CO	High	Immediate/ Late 2022
4	**S:** WFP should explore opportunities to work with RICA to support their efforts to widen the enforcement of aflatoxin standards and to carry out market surveys	WFP Rwanda CO	RICA	Medium	3 months/ 2 years
5	**S:** WFP should work with the authorities and key stakeholders such as EAX to explore the opportunity to further develop a warehouse receipt system in Rwanda in the context of the quality "insurance" provided by AflaSight.	WFP Rwanda CO	EAX and other potential warehouse receipt system operators, IFC	Medium	3 months/ 2 years
6	**S:** WFP (RBN) should commission a study to identify which countries in East Africa would most benefit from access to the Bühler LumoVision technology.	WFP RBN	AflaSight, Bühler	Medium	3 months / 1 year

Source: Evaluation team.

ANNEX 1 TERMS OF REFERENCE

217. The Terms of Reference have been published on the WFP website and can be accessed through the following link: https://www.wfp.org/publications/rwanda-innovative-pilot-activity-aflatoxin-reduction-and-smallholder-farmers-market.

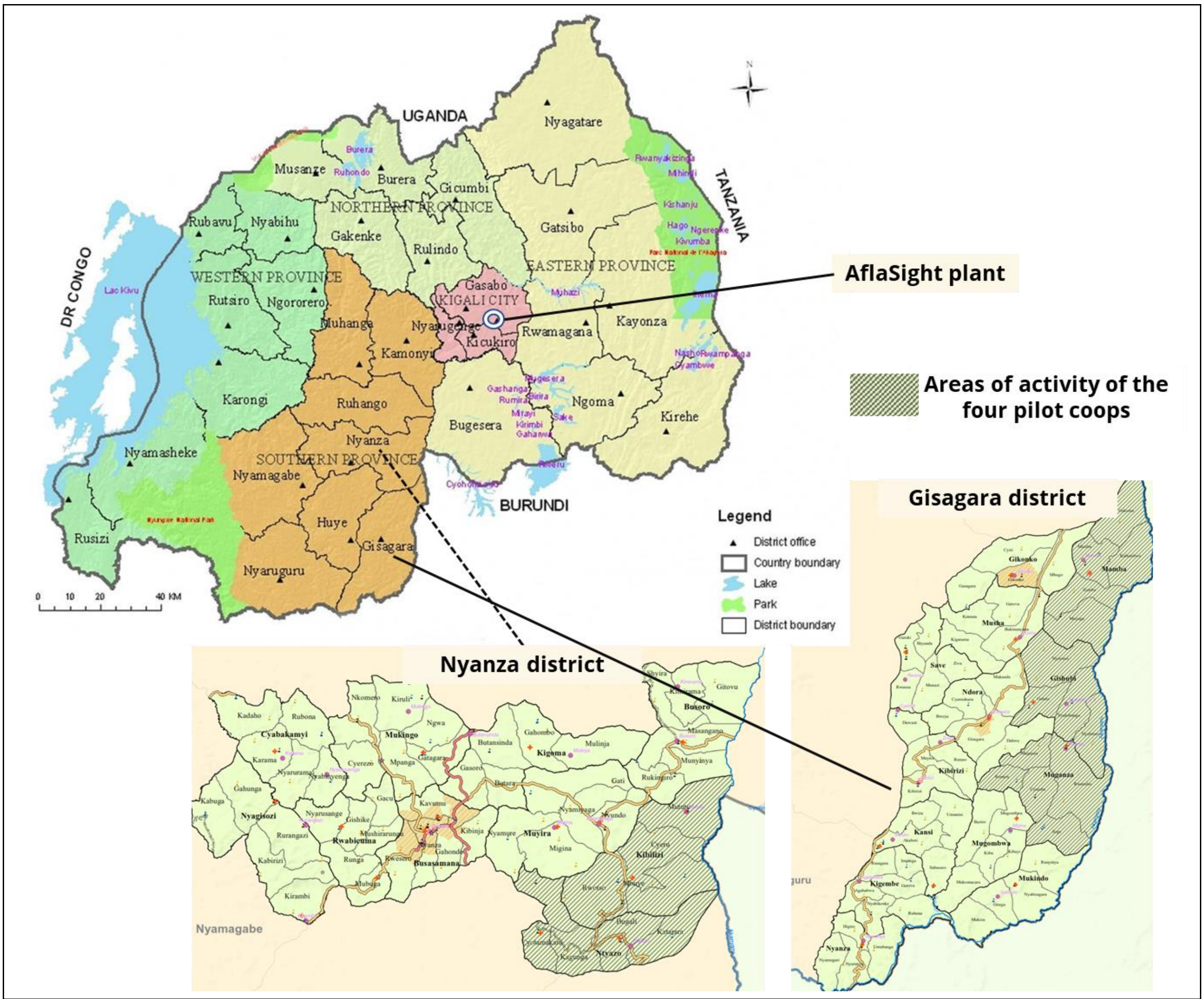
ANNEX 2 EVALUATION TIMELINE

Table 6: Evaluation timeline

Responsible stakeholders	Activities	Key dates
	Inception phase	
RBN, CO, ET	Kick-off meeting	3 Feb 2021
ERG, RBN, CO, ET	Inception report (IR) draft #1 – debriefing with ERG	23 Mar 2021
ET	IR draft #1 – submission	31 Mar 2021
DE QS, RBN	IR draft #1 – DE QS comments	14 Apr 2021
ET	IR draft #2 – submission	18 Apr 2021
ERG, CO	IR draft #2 – ERG comments	29 Apr 2021
ET	IR final – submission	6 May 2021
	Fieldwork	
ET, CO	*Qualitative data collection (focus groups, interviews, direct observation):* Field mission part 1: Kigali and Gisagara district Field mission part 2: Gisagara and Nyanza districts	 15–23 Nov 2021 13–16 Nov 2021
ET, RBN, CO	Qualitative fieldwork debriefing / presentation slides	30 Nov 2021
ST	*Quantitative data collection (smallholder survey):* Pre-test, enumerator training, piloting Survey data collection from SHFs	 12-24 Nov 2021 29 Nov – 13 Dec 2021
	Analysis and reporting	
ET	Evaluation report (ER) draft #1 – submission	30 Jan 2022
ET, ERG, RBN, CO	ER draft #1 – Presentation of main findings to ERG	8 Feb 2022
DE QS, ERG, RBN, CO	ER draft #1 – DE QS, and ERG comments	11 Feb 2022
ET	ER final and 2-page brief – submission	26 Feb 2022
ET = Evaluation Team ST = Survey Team CO = Rwanda Country Office RBN = Regional Bureau Nairobi DE QS = Quality Service for Decentralized Evaluations ERG = Evaluation Reference Group		

ANNEX 3 ACTIVITY LOCATION MAP

Figure 6: Map of AflaSight activities and pilot cooperatives

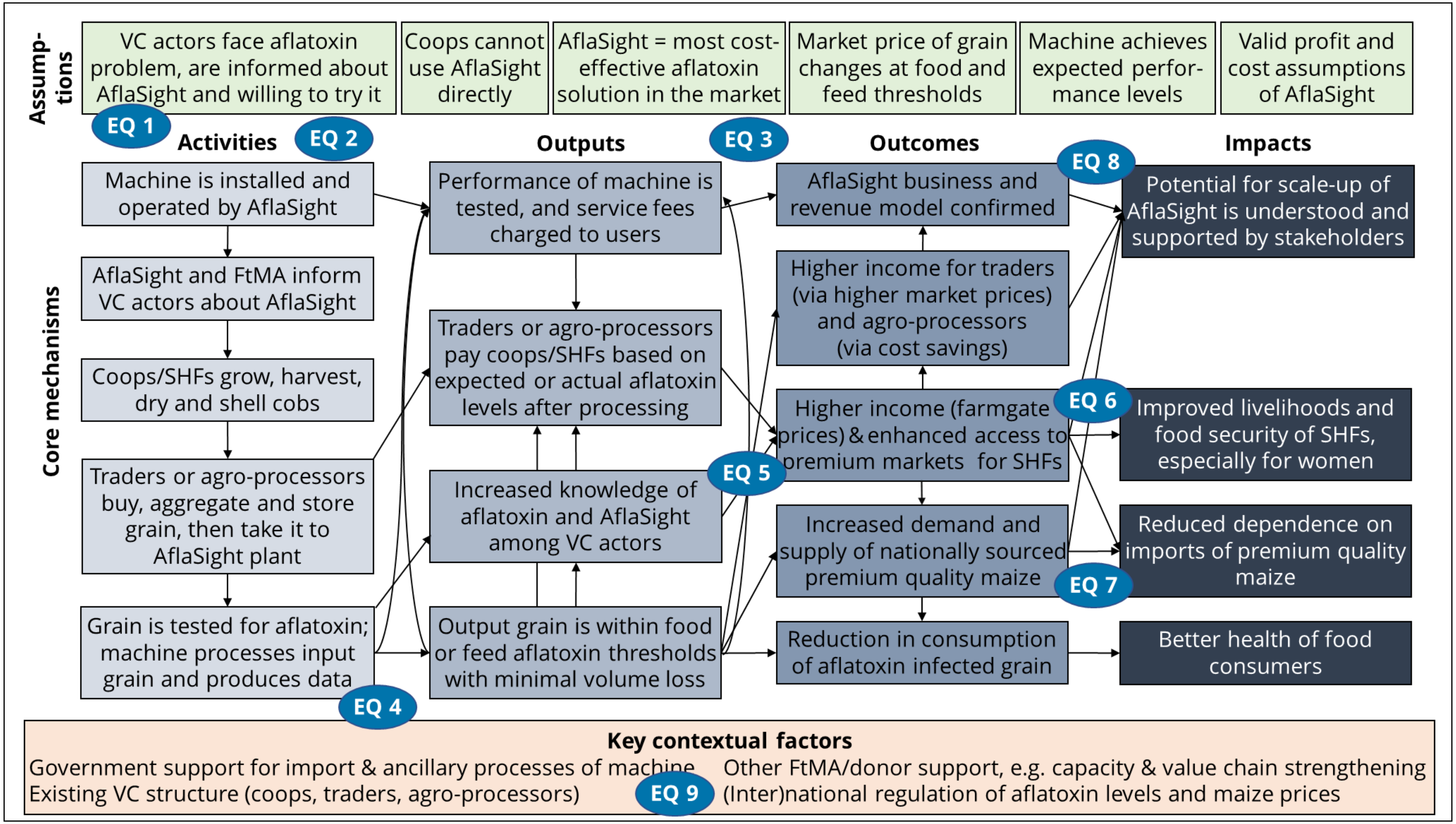


Note: The maps show the locations of the AflaSight plant in the Special Economic Zone of Kigali, as well as the sectors within the Gisagara and Nyanza districts that host the activities of the four pilot cooperatives and were visited by the evaluation team for qualitative data collection and by the survey team for quantitative data collection.

Source: District maps of the National Institute of Statistics Rwanda (2015) with activity locations added by the evaluation team.

ANNEX 4 THEORY OF CHANGE

Figure 7: Reconstructed Theory of Change for the AflaSight pilot



VC = Value chain.

Source: Evaluation team.

ANNEX 5 FINAL VS. ORIGINAL EQ'S

Table 7: Final versus original EQs

Evaluation criteria	Final EQs	Original EQs (ToR)
Relevance	**EQ 1:** To what extent is the pilot activity appropriate for the realities and needs of the targeted beneficiaries, including smallholder farmers, specifically women, as well as other value chain actors?	To what extent is the pilot activity appropriate for the realities and needs of the targeted beneficiaries, including smallholder farmers, specifically women, as well as other value chain actors?
	EQ 2: To what extent is the introduction and use of the technology accepted, understood by, and accessible for smallholder farmers (especially women) and other stakeholders?	To what extent is the introduction and use of the technology accepted by key beneficiaries and stakeholders?
Efficiency	*Omitted.*	Is this pilot activity cost-efficient in terms of operating costs for the machine and the overall business model?
	EQ 3: Is this pilot activity cost-effective in terms of higher-level outcomes (reduction in aflatoxin levels, smallholder integration of maize value chains)?	Is this pilot activity cost-effective in terms of higher-level outcomes (# beneficiaries served, reduction in aflatoxin levels, increases in farmer incomes, etc.)?
Effective-ness	*Partially integrated into EQ 8 below.*	To what extent have the objectives and assumptions behind the pilot design been realized in practice?
	EQ 4: How well does the LumoVision technology and its related processes perform in the local context, and what factors influence its effectiveness in achieving the technical objectives?	How well did the LumoVision technology perform in the local context? What factors influenced its effectiveness in achieving stated objectives?
	EQ 5: To what extent will the technology help smallholder farmers (especially women) to connect with premium buyers, why and how, and what enabling or disabling factors are present?	To what extent were women farmers (especially those with very small holdings) informed about the LumoVision technology and able to access and benefit from it?
Impact	*Omitted (partially covered in EQ 4).*	To what extent did the introduction of the LumoVision machine and operational model lower the prevalence of aflatoxins in target maize products/value chain?
	EQ 6: What effects, or emerging effects, are being realized for smallholder farmer livelihoods, especially for women?	What effects, or emerging effects, have been realized for smallholder farmer livelihoods, especially for women, such as integration into and volume of sales into formal markets, incomes? Were there any differences, including any differential results across groups, especially for women? Why and how? What enabling or disabling factors are present?
	EQ 7: What are the likely outcomes within the wider market systems and maize value chain?	What are the emerging outcomes within the wider market systems and maize value chain? What are the unintended positive/negative results?
Sustaina-bility	**EQ 8**: Is the pilot activity based on realistic assumptions, is it technically and financially viable, and should it be scaled up – and if so, what could be scaled, how, and why?	Is the pilot activity viable, and should it be scaled up? What could be scaled, how, and why?
	EQ 9: Are there adequate local capacity and institutional arrangements to sustainably continue the operations?	Are there adequate local capacity and institutional arrangements to sustainably continue the operations?
	Omitted.	Is the current business model financially viable? Why or why not?

Source: Evaluation team (final EQs) and Terms of Reference (original EQs).

ANNEX 6 EVALUATION MATRIX

Table 8: Detailed evaluation matrix

Sub-questions	Indicators (examples)	Data collection methods and sources	Data analysis methods/ triangulation
EQ 1 – Relevance: To what extent is the pilot activity appropriate for the realities and needs of the targeted beneficiaries, including smallholder farmers, specifically women, as well as other value chain actors?			
1.1 Does the design of the pilot provide an appropriate and affordable solution to the market access problem of smallholder farmers (especially women)?	• Baseline levels of (and barriers to) SHF access to premium buyers • Baseline technologies/processes for aflatoxin reduction • Additional constraints for women • SHF perceptions about aflatoxin and market access • Level of user costs in AflaSight business plan	• Review of aflatoxin research and studies on maize value chains in Rwanda/East Africa, and AflaSight project documents • Compilation of FtMA and third-party M&E and survey data • KIIs: FtMA, WFP RBN+ Rwanda, AflaSight • IDIs with traders, extension service providers, management of cooperatives • FGDs and survey with SHFs • Direct observation of existing aflatoxin control procedures	• Context analysis • Literature review • Thematic analysis of interview and FGDs transcripts/notes • Survey data: descriptive stats, test for gender differences • Triangulation of qualitative vs. quantitative data and of different interviewees and studies
1.2 Does the design of the pilot appropriately address the aflatoxin problem of other value chain actors?	• Baseline aflatoxin presence in maize value chain and expected reduction • Expected changes in required imports of Grade 1 maize • Stakeholder perceptions about feasibility of the process + effectiveness of the machine	• Review of LumoVision technology and AflaSight project documents • KIIs with agro-processors, WFP RBN and Rwanda, FtMA, AflaSight, MINAGRI, RAB • IDIs with traders	• Context analysis • Thematic analysis of interview notes • Comparison of project/ technology documents vs. stakeholder expectations
1.3 Is the pilot aligned with relevant government and WFP policies and strategies?	• Degree to which the pilot objectives support the targets for smallholders + food security/safety stated in national policies for agriculture, food and nutrition, gender • Degree of alignment of the pilot with the WFP CSP for Rwanda, WFP Strategy for Smallholder Support, WFP Gender Policy, FtMA Strategic Planning, etc.	• KIIs with WFP RBN and Rwanda • KIIs with ministries (MINAGRI,...) • Document review of Government and WFP policy and strategies (see indicators)	• Analysis of interview notes • Policy and strategy analysis of documents

Sub-questions	Indicators (examples)	Data collection methods and sources	Data analysis methods/ triangulation
EQ 2 – Relevance: To what extent is the introduction and use of the technology accepted, understood by, and accessible for smallholder farmers (especially women) and other stakeholders?			
2.1 Are smallholder farmers – especially women – and other stakeholders aware of the technology, do they under-stand it, and are they willing to try and able to access it?	• Level of understanding shown by SHFs (e.g. measured through a short knowledge test in the survey) • Motivation to participate reported by SHFs • Level of access via AflaSight, FtMA and traders – both actual and perceived	• KIIs with FtMA and AflaSight • FGDs with SHFs • SHF survey	• Thematic analysis of interview and FGDs transcripts/notes • Survey data: descriptive stats, test for gender differences • Triangulation of qualitative vs. quantitative data
2.2 What type of barriers to technology adoption do the different value chain actors face or perceive, and how does the pilot plan to mitigate these barriers?	• Type and severeness of barriers (knowledge, logistics, commercial, etc.) identified at each stage of the value chain • Adequacy of mitigation strategies considered in AflaSight and FtMA plans	• Review of FtMA, AflaSight and other market and aflatoxin research • KIIs with FtMA, AflaSight, agro-processors • IDIs with traders and cooperative management • FGDs with SHFs • SHF survey	• Context and document analysis • Thematic analysis of interview and FGDs transcripts/notes • Survey data: descriptive stats, test for gender differences • Triangulation of qualitative vs. quantitative data and of different interviewees and studies
EQ 3 – Efficiency: Is the pilot activity cost-effective in terms of higher-level outcomes (reduction in aflatoxin levels, smallholder integration in maize value chains)?			
3.1 How do the operating and user costs of AflaSight compare to alternative aflatoxin reduction solutions used in the region?	• LumoVision costs with + without subsidies • Costs of alternative solutions (e.g. Aflasafe, Kumwe Cob Model, drying sheets/tarps) reported in studies • Cost comparison between these solutions (e.g. relative to parts per billion of aflatoxin reduction and accounting for volume loss)	• Research studies on other approaches for aflatoxin reduction • AflaSight and Kumwe market and business data and plans, LumoVision documents • KIIs with AflaSight and Bühler, WFP RBN	• Document review • Analysis of secondary data on performance, users, and costs of alternative approaches • Cost-effectiveness analysis if sufficient data available • Triangulation of different studies.
3.2 How cost-effective is the pilot relative to other approaches for smallholder market access and value chain integration (especially those promoted by FtMA)?	• Cost of FtMA activities and result indicators (increased sales etc.) outside the pilot • Qualitative perceptions of stakeholders about relative cost-effectiveness of different market access approaches	• Review of FtMA business plan and reports • Compilation of FtMA M&E data/surveys • KIIs with WFP Rwanda, FtMA, MINAGRI, RAB	• Cost analysis • Quantitative analysis of M&E data/surveys • Thematic analysis of interview notes

Sub-questions	Indicators (examples)	Data collection methods and sources	Data analysis methods/ triangulation
EQ 4 – Effectiveness: How well does the LumoVision technology and its related processes perform in the local context, and what factors influence its effectiveness in achieving the technical objectives?			
4.1 What is the performance of the machine in terms of daily throughput, removal of infected kernels (aflatoxin reduction), and volume loss; and what factors affect the performance?	• Performance data on throughput (tons), aflatoxin reduction (ppb), volume loss (percent) registered by the machine • Difference between actual and target values in Rwanda, and factors explaining it • Differences in performance - Rwanda vs. other settings, and factors explaining it	• Time series of registered performance data of the machine (see indicators) • Review of LumoVision technology docs and pilot studies in other settings • KIIs with Bühler, AflaSight • IDIs with traders	• Statistical analysis of LumoVision performance data • Quantitative comparison of performance data from different batches/sources of grain • Structured document review • Thematic analysis of interview notes
4.2 What ancillary processing (particularly drying) and requisites (e.g. limits for moisture and infection levels for input samples) are needed for the process to work and reach the desired quality?	• Presence of other factors that reduce process performance • Tolerance levels for input grain • Ability of value chain actors to improve input grain to meet these tolerances	• Review of LumoVision technology docs and pilot studies in other settings • Time series / registered data of the machine • KIIs with Bühler, AflaSight • IDIs with traders, other service providers • Direct observation of the drying process	• Statistical comparisons of LumoVision performance data for different batches of input grains • Document review • Thematic analysis of interview notes
EQ 5 – Effectiveness: To what extent will the technology help smallholder farmers (especially women) to connect with premium buyers, why and how, and what enabling or disabling factors are present?			
5.1 How may the technology lead to a change in the agricultural practices and post-harvest procedures of cooperatives, and what may enable or disable this shift?	• Observed and reported changes in agricultural practices (grain cleaning, etc.) and post-harvest procedures (storage, drying, etc.) due to AflaSight/LumoVision • Agricultural, technical and market factors in value chain that foster/inhibit changes	• Compilation of FtMA M&E/survey data • IDIs with cooperative management • FGDs with SHFs • SHF survey • Direct observation of practices and procedures in cooperatives	• Statistical analysis of survey and M&E data • Thematic analysis of interview notes • Triangulation of qualitative vs. quantitative data and across different interviewees
5.2 Is the technology likely to enhance the links of smallholder cooperatives with traders and agro-processors, and are there any barriers?	• Number of cooperatives participating in the pilot, and volumes of maize delivered to the machine (by cooperative) • Changes in volume of maize purchased by premium buyers • Evidence of changes in cooperatives' relationships with traders	• AflaSight and FtMA business/M&E data • KIIs with agro-processors, FtMA, AflaSight • IDIs with traders and cooperative management	• Statistical analysis of survey and M&E data • Thematic analysis of interview notes • Triangulation across interviewees

Sub-questions	Indicators (examples)	Data collection methods and sources	Data analysis methods/ triangulation
5.3 To what extent does other FtMA support help smallholder farmers (especially women) to benefit from the technology for enhanced market access?	• Evidence of other FtMA support enhancing the chances of participation in the pilot (e.g. logistic support or preparation of input grains using skills acquired in FtMA training) • Evidence of FtMA support enhancing the benefits of pilot results for farmers (e.g. helping them to manage newly established links in value chains) • Differential benefits perceived by female and male SHFs	• KII with FtMA • IDIs with cooperative management • FGDs with SHFs • SHF survey • AflaSight M&E data • Direct observation in the field	• Survey data: descriptive stats, test for gender differences • Triangulation of qualitative vs. quantitative data and across different interviewees
5.4 Are smallholder farmers (especially women) likely to face any risks from using the technology and shifting to premium markets?	• Risks or adverse effects reported by technology users (especially women) • Reasons for hesitation of SHFs (especially women) to deepen their participation	• KIIs with FtMA, WFP and AflaSight • IDIs with cooperative management • FGDs with SHFs • SHF survey	• Survey data: descriptive stats, test for gender differences • Triangulation of qualitative vs. quantitative data and across different interviewees
EQ 6 – Impact: What effects, or emerging effects, are being realized for smallholder farmer livelihoods, especially for women?			
6.1 To what extent (and how) is the process likely to increase the income of smallholder farmers from maize production, and are these effects likely to differ between women and men?	• Volume and price of maize delivered to and sold via AflaSight • Volume and price of maize sold in informal markets (baseline and post-pilot, where possible AflaSight users vs. non-users) • Cost of drying and other services charged to SHFs (baseline and post-pilot) • Gender differences in the above indicators	• IDIs with management of cooperatives • FGDs with SHFs • SHF survey • FtMA/AflaSight M&E data • AflaSight service delivery/financial data	• Thematic analysis of interview and FGDs transcripts/notes • Survey data: descriptive stats, tests for gender differences, comparison with FtMA baseline • Cost analysis • Triangulation of qualitative vs. quantitative data and of different quantitative data sources
6.2 Are any income increases for smallholder farmers (if any) likely to continue in the future, and what income risks remain?	• Percent of SHFs who plan to continue using AflaSight services after the pilot • Changes in SHFs' maize production triggered by the pilot • Income scenarios under alternative service models for users (SHFs, traders)	• IDIs with management of cooperatives • FGDs with SHFs • SHF survey	• Thematic analysis of interview and FGDs transcripts/notes • Survey data: descriptive stats • Triangulation of qualitative vs. quantitative data

Sub-questions	Indicators (examples)	Data collection methods and sources	Data analysis methods/ triangulation
6.3 How will female and male smallholder farmers likely use the additional income from the process?	• Reported changes in SHFs" household expenditure on food, housing, education, health due to income from maize • Reported investment of additional income in maize/other agricultural production • Differences between expenditure plans of male/female SHF beneficiaries	• FGDs with SHFs • SHF survey	• Thematic analysis of interview and FGDs transcripts/notes • Survey data: descriptive stats, tests for gender differences • Household expenditure analysis • Triangulation of qualitative vs. quantitative data
EQ 7 – Impact: What are the likely outcomes within the wider market systems and maize value chain?			
7.1 Has there been, or is there likely to be, a reduction in grain rejected by agro-processors, and is treated grain now (or likely to be in future) accepted into the food chain for milling and food processing?	• Quantities of locally produced maize (i) rejected by agro-processors and (ii) purchased for milling/processing – changes due to the pilot • Evidence of agro-processors increasingly using locally sourced maize in final products (flour, etc.)	• KIIs with agro-processors, FtMA, AflaSight, MINAGRI, RAB • IDIs with traders • AflaSight M&E data on traders	• Thematic analysis of interview notes • Trend analysis in traders' sales
7.2 How would an increase in the local production of Grade 1 maize affect the quality, sales and profitability of flour and other maize products in domestic and export markets?	• Perception of changes in domestic markets with LumoVision (e.g. potential cost savings and increased uptake of products with locally sourced maize) • Projected changes in export opportunities in the region	• Market studies on maize (value chains) in Rwanda/East Africa • KIIs with agro-processors, MINAGRI, RAB	• Document review using structured framework • Thematic analysis of interview notes • Triangulation across studies and interviewees
EQ 8 – Sustainability: Is the pilot activity based on realistic assumptions, is it technically and financially viable, and should it be scaled up – and if so, what could be scaled, how, and why?			
8.1 From the currently available data, does the pilot indicate whether the technology is likely to be effective for aflatoxin reduction in the specific local setting, and is the pilot likely to be technically viable?	• Evidence that the LumoVision technology has been adequately tested in representative conditions for Rwanda • Evidence that the technology meets its goals in terms of aflatoxin reduction with a large variety of input grains tested	• KIIs with AflaSight, Bühler, RAB, FtMA, WFP RBN and Rwanda	• Thematic analysis of interview notes • Triangulation across interviewees

Sub-questions	Indicators (examples)	Data collection methods and sources	Data analysis methods/ triangulation
8.2 Is the pilot likely to deliver sufficient results (and is the local setting adequate) to test the business model, and is the business model financially viable?	• Degree to which the market conditions of the pilot are representative/can inform scale-up and long-term business strategy • Availability of sufficient, reliable technical and financial data to verify business model • Probability of positive profit margin for AflaSight and income increases for other value chain actors in the long run	• Review of AflaSight business plan • Review of aflatoxin studies/research • Compilation of data registered by machine • KIIs with AflaSight, FtMA, WFP RBN + Rwanda, agro-processors • IDIs with traders, coop management • FGDs and survey with SHFs	• Document review • Business plan reality check • Thematic analysis of interview and FGDs transcripts/notes • Survey: descriptive stats
8.3 How should the pilot be scaled up to maximise its benefit, and what parts of the activity should be modified – and why?	• Demand for the technology in value chain. • Robustness of the business model to local variation in agricultural/market conditions • Realism and limitations of alternative business models (service/trading models) • Identified needs for change in ancillary processes (logistics, drying, etc.) • Stakeholder support for scaling	• Document review of AflaSight business plans, aflatoxin research, studies on the market and its enabling environment • KIIs with AflaSight, FtMA, WFP RBN + Rwanda, agro-processors • IDIs with traders, business service providers, cooperative management • FGDs and survey with SHFs	• Document review • Thematic analysis of interview and FGDs transcripts/notes • Survey: descriptive stats
EQ 9 – Sustainability: Are there adequate local capacity and institutional arrangements to sustainably continue the operations?			
9.1 Are there sufficient local capacity and acceptable systems for aggregation and delivery of grain to the machine, in the scenarios with one vs. multiple processing units in the country?	• Presence of wider aggregation systems able to supply grain for the machine operating at full capacity. • Extent to which current aggregation systems could supply processing units in other parts of the country.	• KIIs with AflaSight, FtMA, RAB • IDIs with traders, extension service providers, cooperative management	• Thematic analysis of interview notes
9.2 Is the capacity /manage-ment of the processing site likely to be adequate to con-tinue/expand the operation?	• Estimated capacity for the current processing site, and potential limitations to operating the machine at full capacity.	• Compilation of data registered by machine • Review of LumoVision technology docs • KIIs: AflaSight, FtMA WFP Rwanda, RAB	• Analysis of performance data • Document review • Thematic analysis of interview notes
9.3 What type of government support is in place or can be expected to support the operations in the long run?	• Current resources and types of institutional support provided by MINAGRI, RAB, etc. • Evidence of interest and commitment (and benefits perceived by) government stakeholders for future operations.	• KIIs with MINAGRI, RAB	• Thematic analysis of interview notes

Source: Evaluation team.

ANNEX 7 LIST OF INTERVIEWS AND FOCUS GROUP DISCUSSIONS

Table 9: List of interviews and focus group discussions conducted

Location	Organization	Position, name, gender (M/F)
Key informant interviews (regional/national level)		
WFP		
Kigali	WFP Rwanda CO	Ahmareen Karim, Deputy Country Director (F)
		Ammar Kawash, FtMA Coordinator and Head of SAMS (M)
		Adeline Uwonkunda, M&E Officer FtMA (F)
		Alain Caboré, Head of Supply Chain Unit – Food Safety (M)
		Anicet Muriro – Logistics Officer (Food Technologist) (M)
Remote	WFP RBN	Jeremie Pige, Head of WFP Innovation Hub for Eastern Africa (M)
	WFP Innovation Accelerator	Nicolas Umuhizi, New Ventures Consultants (M)
Private sector		
Kigali	AflaSight	Kathryn Rendon, Managing Director (F)
	Kumwe	Alexandra Sanderson, former Managing Director (currently IFC – see below) (F)
Remote		Cyril Khamsi, Chief Executive Officer (M)
	Bühler	Aron Demeter, Global Head of Segment (M)
Kigali	AIF	Julie Ludvigsen, Value Chains Operations and Special Projects Manager (F)
	EAX	Clement Kayitakire Chief Operations Officer (M)
		Innocent Katabazi, Deputy Chief Operations Officer (M)
	Minimex	Moses Ndayisenga, Operations Manager (M)
	Traders	Brief discussions with 4 traders at IFC event
Public sector		
Kigali	RAB	Illuminée Kamaraba, Post-Harvest Division Manager (F)
	RSB	Jean Pierre Bajeneza, Acting National Certification Division Manager (M)
		Alphonse Mbabazi, Acting National Quality Testing Laborat. Division Manager (M)
		Egidia Nkezabera, Mycotoxin Laboratory Officer (F)
	FAO	Otto Muhinda, Assistant FAO Representative (M)
	IFC	Vasco Cruz Branco Dos Santos Nunes, Senior Operations Officer (M)
		Alexandra Sanderson, Food Safety Advisor for IFC (formerly Kumwe – see above)
	IITA Rwanda	Madjaliwa Nzamwita, Research Associate and Aflasafe Coordinator (M)
		Matieyedou (Abdou) Konlambigue, Senior Agribusiness Specialist (M)
In-depth interviews (district/cooperative level) and focus group discussions (beneficiaries)		
Huye	WFP Field Office	Pascal Habumugisha, Programme Associate FtMA and SAMS
Gisagara district	RWARRI	Gaetan Niyirora, Senior Extensionist
	Cooperative Cojyamugi	Interviews with President, Accountant, Agronomist
		4 focus groups with cooperative members (2x women, 2x men)
	Cooperative CCM Muganza	Interview with Accountant and focus groups with Executive Committee
		4 focus groups with cooperative members (2x women, 2x men)
	Cooperative Coamanya Gishubi	Interviews with President, Accountant, Trainer
		4 focus groups with cooperative members (2x women, 2x men)
Nyanza district	Cooperative Coamanya Nyanza	Interviews with President, Accountant, Trainer
		4 focus groups with cooperative members (2x women, 2x men)

ANNEX 8 DATA COLLECTION TOOLS

Table 10: Interview guides with links to evaluation matrix

		KIIs				IDIs
EQ	**Interview questions**	**WFP**	**AflaSight and Bühler**	**Agro-processors, traders**	**Public sector interviewees**	**Coop leadership**
EQ 1						
1.1	Do SHFs have access to premium buyers now - what are the barriers?	oo	oo	o	oo	oo
	How might AflaSight improve access?	oo	oo	o	oo	oo
	Is the design realistic to improve access?	oo	oo	o	o	oo
	What constraints are there currently for women SHFs?	oo	o		oo	oo
	Does the design address these constraints?	oo	o		o	oo
	How could the design be improved to meet the needs of SHFs?	o	oo	o	o	oo
	What perceptions do SHFs have about aflatoxin and market access?		o		o	oo
	Is the design sufficiently attractive for commercial partners? What market opportunities and costs are involved?	o	oo	oo	o	oo
1.2	How serious is aflatoxin to maize production, the grain market and health?	o	oo	oo	oo	oo
	How will AflaSight change the market for grain in Rwanda?	oo	oo	oo	oo	o
	Is it realistic to think that it will reduce imports?	o	o	o	oo	
	So far, does it look like the technology is working?	o	oo	o		o
	What problems have you seen, or do you foresee at a later stage?	o	oo	o		o
1.3	How is AflaSight aligned with WFP policies and strategies in Rwanda and globally?	oo				
	How is AflaSight aligned with government policies and strategies?	o	o		oo	
	What key government policies relate to maize production and aflatoxin contamination?	o	o		oo	
	In what ways does the AflaSight project diverge from/conflict with government policy?	o	o		oo	
EQ 2						
2.1	Are SHFs aware and understand the objectives and processes involved in AflaSight?	o	o	o		oo
	Do SHFs want to be involved?	o	o			oo
	What opportunities/risks does AflaSight present to SHFs?	oo	oo	o	o	oo
	What involvement have SHF/coops/Traders had with AflaSight so far?	oo	oo	o		oo

		KIIs				IDIs
EQ	Interview questions	WFP	AflaSight and Bühler	Agro-processors, traders	Public sector interviewees	Coop leadership
2.2	What barriers do you see to adoption of AflaSight? Are these barriers being mitigated by AflaSight/FtMA? How else should the design be changed to make it work better?	oo oo o	oo oo oo	oo oo oo	o o o	oo oo o
EQ 3						
3.1	How do the operating costs compare with alternatives (e.g. no treatment/Aflasafe/ improved drying and storage/cob model)? Is the machine and its processing line achieving the promised results? Get data on cost, losses and aflatoxin reduction. What real technical/cost advantages does AflaSight have over alternatives? What technical/cost disadvantages does AflaSight have over alternatives?	o o o o	oo oo oo oo	o o o o	oo o o	o
3.2	How does AflaSight compare with other approaches being promoted by FtMA and others? Does the process work better than other initiatives in improving SHF market access and integrating the value chain?	oo oo			o o	o o
EQ 4						
4.1	What are the results so far? Throughput, volume losses, aflatoxin reduction To what extent does the machine meet the different quality thresholds? Are the results the same as in other countries? How to explain any differences? Are the results as expected (targets)? What accounts for differences?	o o	oo oo oo oo			
4.2	What differences are there between different sources of grain and how does the machine cope with variations? What tolerances are there for input grain and how likely are these tolerances to be met by the available grain? Can farmers/coops/traders improve the quality of grain to meet the standards?	 o	oo oo oo	 o		 o
EQ 5						
5.1	If the pilot is successful, what changes do you expect to see in agricultural practices and post-harvest procedures?	oo	o	o	oo	oo

		KIIs				IDIs
EQ	**Interview questions**	**WFP**	**AflaSight and Bühler**	**Agro-processors, traders**	**Public sector interviewees**	**Coop leadership**
5.2	Would there be any changes in the roles or influence of SHFs in the coop or community?	oo	o		o	oo
	Are higher prices received by intermediaries likely to trickle down to coops and SHFs?	o	o	oo	o	oo
	If so, how would this happen? If not, why not?	o	o	oo	o	oo
	How will the relationships between value-chain members (farmers, coops, traders and agro-processors) alter with the introduction of the technology?	o	o	oo	o	oo
	Have any changes happened already?	o	o	o	o	o
5.3	Do FtMA support measures increase the likelihood that farmers will benefit also from the introduction of AflaSight? Skills/training/ability to improve grain quality?	oo	o			oo
	... Or will these skills become unnecessary?	oo	oo			oo
	Is there likely to be a synergy between FtMA and AflaSight activities - increasing the value of both -, either through additional income or improved access to markets?	oo				oo
	What particular effects will there be on women farmers and gender balance in the community?	oo				oo
5.4	What potential negative effects are there for women farmers through the introduction of AflaSight?	o			o	oo
	Are women SHF more or less risk averse in the introduction of new technology?	o			o	oo
	Why might women hesitate to participate?	o			o	oo
	How can these risks/ adverse effects be mitigated?	o			o	oo
EQ 6						
6.1	What effects have there been (or are likely to be) on the volume of sales, price received and overall income of SHFs through the introduction of AflaSight?	o	oo	o		oo
	What other benefits might AflaSight bring?	o	o	o		oo
	Are there any additional costs involved? If so, for what (e. g. drying) and how much?		oo	o		oo
	Are there any differences in these factors between man and women SHFs?	o	o	o		o
6.2	If increased income has been achieved (or is expected) is it likely to be repeated in future seasons and years?	o	o	o	o	oo
	Will SHFs increase their production or invest in better seed fertilisers/storage etc?	o			o	oo
	What might stop this income improvement?				o	o
	How do coops think that incomes may be affected for member farmers?					o
	Which of the service models are most practical/ likely to succeed and why?	o	o	o		oo
6.3	Are there any changes in householder expenditure due to additional income?	o				o

		KIIs				IDIs
EQ	**Interview questions**	**WFP**	**AflaSight and Bühler**	**Agro-processors, traders**	**Public sector interviewees**	**Coop leadership**
EQ 7						
7.1	*These questions may refer to the present or expectations for the future:*					
	Are agroprocessors accepting maize processed by AflaSight?		oo	oo		oo
	Has this increased their total purchase of Rwandan maize?		o	oo		o
	Is more Rwandan maize being used for food?			oo		
	Do they pay more for the grain?	o	o	oo		oo
	How far back along the value chain does the increased reach - all the way to SHFs?		o	oo		oo
	How is the purchased grain being used?			oo		
	What use is made of grain meeting each different quality thresholds?			oo		
	Has grain from all thresholds been sold and accepted for their expected use?			oo		
	Is there a reduction in grain rejection?		oo	oo		oo
	Are there adequate regulations and checks in place to ensure that grain reaching human food meets health standards?		oo	oo	oo	
	What needs to be done to improve the supervision of food quality (by AflaSight/processors/government)?		oo	oo	oo	
7.2	What changes might the more widespread introduction of AflaSight bring to:					
	- the value chain	o	o	oo	oo	o
	- the income and health of farmers and the rural population and women in particular	o		o	oo	oo
	- maize grain imports		o	oo	oo	
	- maize grain exports		o	oo	oo	
EQ 8						
8.1	Has the technology been adequately tested yet?		oo	oo		
	If not, then what critical aspects have not yet been tested?		oo	oo		
	From evidence so far - does AflaSight meet its technical targets ?		oo	oo		
	What main barriers are there to success - technical, commercial or political?	o	oo	oo	o	o
	What should be the next steps in the development of the technology?	o	oo	oo	o	o

		KIIs				IDIs
EQ	**Interview questions**	**WFP**	**AflaSight and Bühler**	**Agro-processors, traders**	**Public sector interviewees**	**Coop leadership**
8.2	Has (or will) AflaSight be implemented on a sufficient scale and in different seasons and trading conditions to allow an assessment of its commercial potential?	oo	oo	oo		o
	If not, what still needs to be done?	oo	oo	oo		
	Is there sufficient added value from AflaSight to drive a substantial commercial business?	o	oo	oo		o
	If not, what needs to be done?	o	oo	oo		o
8.3	Assuming technical success and sufficient added value, how should the technology be scaled up?	oo	oo	oo		o
	How quickly should it be scaled up?	o	oo			o
	What financial partners and other stakeholders could be involved in the scale-up process?		oo	o	o	
	Are there competitor systems that may make the system unprofitable?		oo	o	o	
EQ 9						
9.1	How can sufficient grain be aggregated to service the capacity of the machine and the capital investment involved?		oo			
	What are the prospects for investments in further processing facilities in other parts of the country?	o	oo	o		
	Would there be sufficient grain of the required initial quality available?	o	oo	o	o	
	Would there be a market for the produce?	o	oo	oo	o	
9.2	What is the daily/annual capacity for the current site?		oo			
	Is it likely to remain available?		oo			
	What limitations are there under the current arrangement?	o	oo	o		
	What would restrict the process from running at full capacity?		oo			
9.3	What support does government give to AflaSight?	o	o		oo	
	What is the view of government regarding its future development?				oo	
	Is government likely to continue support of the pilot beyond the AflaSight pilot - providing that there are no significant barriers to scaling up?				oo	
	What forms could that support take?				oo	

oo: Much information expected **o:** Less information expected Try to ask all "oo" questions and choose some "o" questions according to time available and likely relevance.

Source: Evaluation team.

Table 11: Topic guide for FGDs with SHFs

Access to markets – current situation • Who buys produce from you (coop/ neighbours/traders)? • Discuss ways that coops and traders buy crop? Immediate payment? Minimum quantity? Any quality standard? • What happens to crop after – sent to Kigali or consumed locally? • Longstanding trading arrangement or variable? • Do they sell all crop or save some for home consumption or private sale? • Enough to make a living? • Gender differences?
Aflatoxin • Awareness – where does knowledge come from? • Know that it comes from a mould? • Know what conditions in field/storage make it worse? • Know that it is bad for health? What does it do? • Aware that it affects grain price? • Know control measures on farm (drying/ storing in dry conditions) • What happens to mouldy grain – if used for human or animal, what sickness does it cause? • Any gender differences in knowledge about aflatoxin?
FtMA • What do they do? • What did they learn about aflatoxin from FtMA? • Does FtMA help them control aflatoxin? How? • Have FtMA helped SHFs to increase their income? If yes, then how? • Gender differences in learning or benefit from FtMA?
AflaSight • Awareness of the project? What it does? Why started? • If aware: how did they hear about it? • Any of their grain (or other members of their coop's grain) sorted by LumoVision? If necessary, explain that AflaSight is a trial of a sorting machine that removes the aflatoxin grains from the harvested maize and allows the remaining crop to be sold at a higher price for food use. • If this works, do they think they would earn more from their crop? If not, why not? • If they got more money from crop – how would they use the additional earnings? • Would they increase their crop area? • Would they invest in better cleaning or storage? • Any long-term change for them? • Health benefit in the community?

Table 12: Survey questionnaire for smallholders

<table>
<tr><th colspan="2">PARTICIPANT IDENTIFICATION AND INFORMED CONSENT</th></tr>
<tr><td>Enumerator, please select your name</td><td>[list enumerators]</td></tr>
<tr><td>[enum], please select the Cooperative according to the respondent list.</td><td>[list cooperatives]</td></tr>
<tr><td>[enum], please select the farmer ID of the cooperative member.</td><td>[list id]</td></tr>
<tr><td colspan="2">Thank you for giving us the time to explain the research that we wish to carry out with you today. My name is …. I am part of a research team conducting research on behalf of IPAR, a research institute based in Kigali. We invite you to participate in a survey. Data collected from farmers like you will be used to understand how post-harvest handling practices of maize can increase your income and the income from other farmers. You will be asked questions about your post-harvesting practices of maize, your income from selling maize, and other related questions. You are part of a group of 400 farmers who were randomly selected from a list of farmers. All participants are asked the same questions and are treated equally by the research team. All collected data will be kept completely confidential. Only averages will be reported, not your personal responses. Your private details, such as your address and contact details will remain anonymous. Identifying information (e.g., respondent name or phone number) will be deleted from the data before analysis and will NOT appear in any report.
Participation in this interview is voluntary and you may refuse to participate, discontinue the interview at any time, or skip any question you do not want to answer with no penalty or loss of benefits to which you are otherwise entitled. You are allowed to ask questions concerning the research, both before agreeing to participate in the interview, during, and after the interview. This questionnaire is expected to take around 1.5 – 2 hours. You may find some of the questions sensitive and you can refuse to answer any question without any consequence whatsoever. If you have any problems or questions about this study, about your rights as a research participant, or about any research-related injury, you may contact ………, the local research coordinator. Moreover, you may contact ……. Before I start, do you have any questions or is there anything I have said on which you would like further clarification? By consenting you confirm that I may proceed with interviewing you:</td></tr>
<tr><td>Do you give consent?</td><td>1. Yes 0. No</td></tr>
<tr><td>Why not?</td><td></td></tr>
<tr><th colspan="2">MODULE A
KEY SOCIO-DEMOGRAPHIC CHARACTERISTICS</th></tr>
<tr><td>A3. Is [name] your correct full name?</td><td>1. Yes 0. No</td></tr>
<tr><td colspan="2">Note: enter -99 for do not know and -98 for refuse to answer</td></tr>
<tr><td>A4. What is your first name?</td><td>____</td></tr>
<tr><td>A5. What is your last name?</td><td>____</td></tr>
<tr><td>A7. What is your age?</td><td>____ years</td></tr>
<tr><td>A7a. What is your age?</td><td>1. 18-35 years old 2. 36-64 years old
3. 65+ years old</td></tr>
<tr><td>A8. What is your gender?</td><td>0. Male 1. Female</td></tr>
<tr><td>A14. What is your phone number?</td><td>_|_|_|_|_|_|_|_|_|_|</td></tr>
<tr><td>A15. What is another number you can be reached on?</td><td>_|_|_|_|_|_|_|_|_|_|</td></tr>
<tr><td>A9. In which province do you live?</td><td>[list provinces]</td></tr>
<tr><td>A10. In which district do you live?</td><td>[list districts]</td></tr>
<tr><td>A11. In which sector?</td><td>[list sectors]</td></tr>
<tr><td>A12. In which cell?</td><td>____</td></tr>
<tr><td>A13. How long does it take you to reach the cooperative maize collection centre after Season C ends, with your usual means of transportation?</td><td>1. Up to 10 minutes
2. 10 to 60 minutes
3. More than one hour</td></tr>
<tr><td>A18. What was the highest level of education that you completed so far?</td><td>1. None (yet)
2. Pre-primary
3. Primary School
4. Post-primary/Vocational/Secondary school</td></tr>
</table>

	5. Tertiary 6. Don´t know
A19. Can you read and write in Kinyarwanda?	1. Yes 0. No
A30b. Do you work part time, full time or not at all on the farm?	1. Full-time 2. Part-time 0. Never
A27. Are you the head of the household?	1. Yes 0. No
A28. Which gender is the head of your household?	0. Male 1. Female
A29. What age is the head of your household?	____ years
A29a. What is the age of the head of your household?	1. 15-17 years old 2. 18-35 years old 3. 36-64 years old 4. 65+ years old
A30. What is your relationship to the head of the household?	10. Spouse of Household head 1. Son/Daughter of Household head 2. Stepchild /adopted 3. foster child of Household head 4. Father/Mother of Household head 5. Brother/Sister of Household head 6. Grandchild of Household head 7. Parent-in-law to Household head 8. Brother/sister-in-law to Household head
Enumerator READ: We will now ask you questions about your household. A household refers to a group of people who live together (in a single house), who eat together and recognize the authority of the head of this household. If any individual has been absent from the household for more than 6 of the past 12 months, he should not be considered a household member unless she/he falls under any of these conditions: ● She/He is the household head (de jure or de facto); ● She/He was not living in another household; ● She/he is a child that was away at school or people who have left to work and live in hotels; ● She/he recently joined the household as a permanent member: o Newly married; o Newly adopted children; o New-borns less than 6 months old; o People who recently joined the household and will reside there permanently.	
A20. How many people live in your household (including yourself)?	____
A21. How many members are between 0-4 years of age?	____
A22. How many members are between 5-9 years of age?	____
A23. How many members are between 10-14 years of age?	____
A24. How many members are between 15-17 years of age?	____
A25. How many elderly people (65 years old and above) live in your household?	____
A26. How many people in your household earn an income (including yourself)?	____
A41. Does your household have access to electricity?	1. Yes 0. No
A42. What is the main construction material used for the exterior (OUTER) wall?	1. Mud bricks or tree trunks with mud without cement 2. Mud bricks or tree trunks with mud and cement / Other
A43. What is the main construction material used for the floor?	1. Beaten earth or hardened dung 2. Other
A44. Does your household own a radio (with or without a CD player)?	1. Yes 0. No
A45. In the past 12 months, have you purchased any beef meat?	1. Yes 0. No
A46. In the past 12 months, have you purchased any pineapple?	1. Yes 0. No

MODULE B POST-HARVEST HANDLING PRACTICES, HARVEST, AND SALES OF MAIZE	
B3a. How much land did you cultivate in this current SEASON C?	_____
B3b. Unit	1. Hectares 2. Ares 3. Square meters
B4a. How much of the land you cultivated was planted under maize in this current SEASON C? (Include intercropped areas)	____
B4b. Unit	1. Hectares 2. Ares 3. Square meters
READ: I would like to ask some questions about MAIZE after you harvested it. I would like you to respond the following questions based on your household's practice. During this current SEASON C:	
B10. Did you or are you going to process (drying maize cobs, shelling, drying grain, sorting, cleaning, or storing grain maize) some or all of your green cobs from this current SEASON C after harvesting?	1. YES: I did/am going to dry SOME of my Season C cobs, shell, dry grain, clean, sort OR store grain 2. YES: I did/am going to dry ALL of my Season C cobs, shell, dry grain, clean, sort OR store grain 3. NO: I did NOT, and I am NOT going to dry my Season C cobs, shell, dry grain, clean, sort OR store grain
B11a. Did you already finish drying this current SEASON C maize cobs after picking?	1. Yes 0. No
B11b. Are you currently drying or are you going to dry this current SEASON C maize cobs after picking?	1. Yes 0. No
B12a. On what did you dry this current SEASON C maize cobs? *Do not read options; Select all that apply*	1. On the ground 2. On plastic sheets 3. On canvas/tarpaulin 4. On sisal bags 5. On mats 6. On sarisa (woven nylon bags) 7. On cement floor 8. In hangals/ at the aggregation centre/collection centre 88. Other (Specify)
B12b. On what are you currently drying or are you going to dry this current SEASON C maize cobs? *Do not read options; Select all that apply.*	1. On the ground 2. On plastic sheets 3. On canvas/tarpaulin 4. On sisal bags 5. On mats 6. On sarisa (woven nylon bags) 7. On cement floor 8. In hangals/ at the aggregation centre/collection centre 88. Other (Specify)
B13a. Did you already finish shelling this current SEASON C maize cobs after drying?	1. Yes, but not at the cooperative / Yes, at the cooperative 0. No
B13b. Are you currently shelling or are you going to shell this current SEASON C maize cobs after drying?	1. Yes, but not at the cooperative / Yes, at the cooperative 0. No
B14a. How much did you spend on paid labour for shelling this current SEASON C maize?	___ RWF
B14b. How much did you already or are you going to spend on paid labour for shelling this current SEASON C maize?	___ RWF
B14c. How much money are you saving, or will you save by having unpaid labour for shelling this current SEASON C maize?	___ RWF
B15a. Did you use a machine for shelling this current SEASON C maize?	1. Yes, all grain was shelled or is going to be shelled with a machine provided by a premium buyer 2. Yes, some grain was shelled or is going to be shelled with a machine provided by a premium buyer and some grain was shelled or is going to be shelled either by hand or using another machine 3. Yes, but without any machine provided by a buyer. Only using another machine (e.g., Cooperative provided, or operated by hand) 4. No
B15b. Are you currently using or are you going to use a machine	1. Yes, all grain was shelled or is going to be shelled with a machine provided by a premium buyer

for shelling this current SEASON C maize?	2. Yes, some grain was shelled or is going to be shelled with a machine provided by a premium buyer and some grain was shelled or is going to be shelled either by hand or using another machine 3. Yes, but without any machine provided by a buyer. Only using another machine (e.g., Cooperative provided, or operated by hand) 4. No
B16a. How much did you spend to use the machine for shelling this current SEASON C maize?	___RWF
B16b. How much did you already or are you going to spend to use the machine for shelling this current SEASON C maize?	___RWF
B15c. How much of the shelled WET grain that was obtained from the machine provided by the premium buyer this current SEASON C did you or are you going to sell to premium buyers?	___RWF
B15d. How much did you already or are you going to receive for the [b15c] kg of the shelled WET grain that was obtained from the machine provided by a premium buyer?	___RWF
READ: I would like to ask some questions about MAIZE after shelling. I would like you to respond the following questions based on your household's practice. During this current SEASON C:	___RWF
B17a. Did you already finish drying this current SEASON C shelled maize grain?	1. Yes, without a machine 2. Yes with a machine 0. No
B17b. Are you currently drying or are you going to dry this current SEASON C shelled maize grain?	1. Yes, without a machine 2. Yes with a machine 0. No
B19a. On what did you dry this current SEASON C maize grain? *Do not read options; Select all that apply*	1. On the ground 2. On plastic sheets 3. On canvas/tarpaulin 4. On sisal bags 5. On mats 6. On sarisa (woven nylon bags) 7. On cement floor 8. In hangals/ at the aggregation centre/collection centre 88. Other (Specify)
B19b. On what are you currently drying or are you going to dry this current SEASON C maize grain? *Do not read options; Select all that apply*	1. On the ground 2. On plastic sheets 3. On canvas/tarpaulin 4. On sisal bags 5. On mats 6. On sarisa (woven nylon bags) 7. On cement floor 8. In hangals/ at the aggregation centre/collection centre 88. Other (Specify)
B20a. How did you decide when to stop drying this current SEASON C maize grain? *Do not read options; Select all that apply*	1. Knowing the length of time, it normally takes to dry it 2. Moisture meter 3. Shake the grain 4. Grain makes cracking sound when drop it 5. Put hand in bag 6. Grain is hard when you bite it 7. Grain has changed colour 8. Put grain in bottle with salt, if salt doesn't stick, it's dry 9. You just see it is dry 10.Took a sample to be checked by an extension officer / buyer 11.The cooperative and not the farmer himself monitors when to stop drying 12.They float an empty bottle in the bag of maize and listen to the sound 88. Other, (Specify)
B20b. How are you deciding or are you going to decide when to stop drying this current SEASON C maize grain? *Do not read options; Select all that apply*	1. Knowing the length of time, it normally takes to dry it 2. Moisture meter 3. Shake the grain 4. Grain makes cracking sound when drop it 5. Put hand in bag 6. Grain is hard when you bite it 7. Grain has changed colour 8. Put grain in bottle with salt, if salt doesn't stick, it's dry

	9. You just see it is dry 10.Took a sample to be checked by an extension officer / buyer 11.The cooperative and not the farmer himself monitors when to stop drying 12.They float an empty bottle in the bag of maize and listen to the sound 88. Other, (Specify)
B21a. How much did you spend to dry your current SEASON C grain with a machine?	____RWF
B21b. How much have you already or are you going to spend to dry your current SEASON C grain with a machine?	____RWF
B29a. How much did you spend on paid labour for drying this current SEASON C grain?	____RWF
B29b. How much have you already or are you going to spend on paid labour for drying this current SEASON C grain?	____RWF
B29c. How much money are you saving, or will you save by having unpaid labour for drying this current SEASON C maize grain?	____RWF
READ: I would like to ask some questions about MAIZE after completing drying shelled maize. I would like you to respond the following questions based on your household's practice. During this current SEASON C:	____RWF
B31a. Did you already finish sorting this current SEASON C maize grain before storing?	1. Yes 0. No
B31b. Are you currently sorting or are you going to sort this current SEASON C maize grain before storing?	1. Yes 0. No
B32a. Did you already finish treating this current SEASON C maize grain before storing?	1. Yes 0. No
B32b. Are you currently treating or are you going to treat this current SEASON C maize grain before storing?	1. Yes 0. No
B33a. With what did you treat this current SEASON C maize grain before storing?	1. Ash 2. Chemical dust 3. chemicals like Malaxyim, Malta etc. 88. Other (Specify)
B33b. With what are you currently treating or are you going to treat this current SEASON C maize grain before storing?	1. Ash 2. Chemical dust 3. chemicals like Malaxyim, Malta etc. 88. Other (Specify)
B34a. Have you already bought material for treating this current SEASON C maize grain?	1. Yes 0. No
B34b. How much did you spend on material for treating this current SEASON C maize grain?	____RWF
B34d. How much did you spend on material for treating this current SEASON C maize grain?	____RWF
B34c. How much are you going to spend on material for treating this current SEASON C maize grain?	____RWF
B30a. Did you already finish storing this current SEASON C maize grain after completing drying?	1. Yes, but not at the cooperative / Yes, at the cooperative 0. No
B30b. Are you currently storing or are you going to store this current SEASON C maize grain after completing drying?	1. Yes, but not at the cooperative / Yes, at the cooperative 0. No
B35a. Which equipment did you use for storing this current SEASON C maize grain?	1. Regular bag 2. Hermetic bag 3. Plastic silo 4. Metal silo 5. Traditional granary
B35b. Which equipment are you currently using or are you going to use for storing this current SEASON C maize grain?	1. Regular bag 2. Hermetic bag 3. Plastic silo 4. Metal silo 5. Traditional granary
B37a. Did you buy new bags for storing this current SEASON C maize grain?	1. Yes 0. No

B37b. Are you going to buy new bags to store this current SEASON C maize grain?	1. Yes 0. No
B38a. How much did you spend on bags?	____RWF
B38b. How much are you going to spend on bags?	____RWF
B40c. In this current SEASON C, did you or will you incur into any other post-harvesting costs that you didn't already report above (e.g., Additional transportation costs, etc.)?	____RWF
B40d. From the answers you gave above it looks like you spent or are going to spend in total approximately [XX] RWF in Post Harvesting this current Season C. How much did you spend last year in Season C in post harvesting?	____RWF
B73a. How much land did you plant under maize in SEASON C last year?	____
B73b. Unit	1. Hectares 2. Ares 3. Square meters
B69. How much maize did you have after harvest in SEASON C last year?	____Kg
B41. How much maize did you have after harvest in this current SEASON C? *In kg.*	____Kg
B43a. How much of your own green cobs did you dry in this current SEASON C?	____Kg
B43b. How much of your own green cobs are you currently and/or are you going to dry in this current SEASON C?	____Kg
B44a. How much dry cobs did you have after completing the drying in this current SEASON C?	____Kg
B44b. How much dry cobs are you are you going to have after completing the drying in this current SEASON C?	____Kg
B42a. How much of your own dry cobs did you use for grain processing (shelling, drying grain, sorting, treating, or storing) in this current SEASON C?	____Kg
B42b. How much of your own dry cobs are you currently and/or are you going to use for grain processing (shelling, drying grain, sorting, treating or storing) in this current SEASON C?	____Kg
B45a. How much maize grain did you have in this current SEASON C? (Does not include the ___ kg of maize grain sold to premium buyers right after shelling (Q. b15c))	____Kg
B45b. How much maize grain are you going to have in this current SEASON C? (Does not include the kg of maize grain sold to premium buyers right after shelling (Q. B15c))	____Kg
B48a. This means the respondent lost or is going to lose all grain after drying, sorting, shelling, or cleaning, correct?	1. Yes 0. No
B48b. What happened then? Why is there no grain after drying, sorting, shelling, or cleaning? Something is strange. Go back and correct or explain here.	____
B48c. How much of your Season C maize did/will you lose after drying, sorting, shelling, or cleaning?	____Kg
B43d. How much of your SEASON C self-processed (not bought) maize grain have you OR plan to consume at home?	____Kg
B46. How much of your SEASON C self-processed (not bought) maize grain have you OR plan to give away as gift or payment, or to make beer?	____Kg
B47. How much of your SEASON C self-processed (not bought) maize grain have you OR plan to use for animal feed?	____Kg
B48. Out of 100kg of grains, how much of your Season C maize did/will you lose after drying, sorting, shelling, or cleaning?	____Kg
B49c. how much of your current SEASON C green cob have you sold to your cooperative?	____Kg
B50c. how much have you received for the [b49c] kg of green cobs that you sold to the cooperative?	____RWF
B49d. how much of your current SEASON C green cob are you going to sell to your cooperative?	____Kg
B50d. how much are you going to receive for the [b49d] kg of green cobs that you are going to sell to the cooperative?	____RWF
B55b. Last year, how much of your SEASON C green cob did you sell to your cooperative?	____Kg
B56b. Last year, how much did you receive for the [b55b] kg of green cobs that you sold to the cooperative?	____RWF

B51c. how much of your current SEASON C green cob have you sold to your local market and middlemen?	____Kg
B52c. how much have you received for the [b51c] kg of green cobs that you sold to the local market?	____RWF
B51d. how much of your current SEASON C green cob are you going to sell to your local market and middlemen?	____Kg
B52d. how much are you going to receive for the [b51d] kg of green cobs that you are going to sell to the local market and middlemen?	____RWF
B57b. Last year, how much of your SEASON C green cob did you sell to your local market and middlemen?	____Kg
B58b. Last year, how much did you receive for the [b57b] kg of green cobs that you sold to the local market and middlemen?	____RWF
B70a. How much of your SEASON C harvested (not bought) green cobs have you OR plan to consume at home?	____Kg
B49a. how much of your current SEASON C dry cob have you sold to your cooperative?	____RWF
B50a. how much have you received for the [b49a] kg of dry cobs that you sold to the cooperative?	____RWF
B49b. how much of your current SEASON C dry cob are you going to sell to your cooperative?	____Kg
B50b. how much are you going to receive for the [b49b] kg of dry cobs that you are going to sell to the cooperative?	____RWF
B55a. Last year, how much of your current SEASON C dry cob did you sell to your cooperative?	____Kg
B56a. Last year, how much did you receive for the [b55a] kg of dry cobs that you sold to the cooperative?	____RWF
B51a. how much of your current SEASON C dry cob have you sold to your local market and middlemen?	____Kg
B52a. how much have you received for the [b51a] kg of dry cobs that you sold to the local market and middlemen?	____RWF
B51b. how much of your current SEASON C dry cob are you going to sell to your local market and middlemen?	____Kg
B52b. how much are you going to receive for the [b51b] kg of dry cobs that you are going to sell to the local market and middlemen?	____RWF
B57a. Last year, how much of your SEASON C dry cob did you sell to your local market and middlemen?	____Kg
B58a. Last year, how much did you receive for the [b57a] kg of dry cobs that you sold to the local market and middlemen?	____RWF
B70b. How much of your SEASON C self-processed dry cobs have you OR plan to consume at home?	____Kg
B49e. how much of your current SEASON C grain maize have you sold to your cooperative?	____Kg
B50e. how much have you received for the [b49e] kg of grain maize that you sold to the cooperative?	____RWF
B49f. how much of your current SEASON C grain maize are you going to sell to your cooperative?	____Kg
B50f. how much are you going to receive for the [b49f] kg of grain maize that you are going to sell to the cooperative?	____RWF
B49g. Did you sell or are you going to sell AS SEEDS any of the [XX] kg (B49e + B49f) of maize grain you just mentioned?	1. Yes 0. No
B49h. How much of the [XX] kg (B49e + B49f) of maize grain you just mentioned did you sell as seeds?	____Kg
B49i. How much did you receive or are you going to receive for the [b49h] kg of seeds grain maize that you sold or are going to sell to the cooperative?	____RWF
B55c. Last year, how much of your SEASON C grain maize did you sell to your cooperative?	____Kg
B56c. Last year, how much did you receive for the [b55c] kg of grain maize that you sold to the cooperative?	____RWF

B51e. how much of your current SEASON C grain maize have you sold to your local market and middlemen?	____Kg
B52e. how much have you received for the [b51e] kg of grain maize that you sold to the local market and middlemen?	____RWF
B51f. how much of your current SEASON C grain maize are you going to sell to your local market and middlemen?	____Kg
B52f. how much are you going to receive for the [b51f] kg of grain maize that you are going to sell to the local market and middlemen?	____RWF
B57c. Last year, how much of your SEASON C grain maize did you sell to your local market and middlemen?	____Kg
B58c. Last year, how much did you receive for the [b57c] kg of grain maize that you sold to the local market and middlemen?	____RWF
B66. Do you know what Africa Improved Food Rwanda Ltd (AIF) is?	1. Yes 0. No

B69a. Do you know if last year in Season C your cooperative sold green cobs to premium buyers?	1. Yes, they sold to premium buyers 0. No, they didn't sell to premium buyers -99. I don't know 2. No sales of green cobs/dry cobs/grain
B69b. Do you know if last year in Season C your cooperative sold dry cobs to premium buyers?	1. Yes, they sold to premium buyers 0. No, they didn't sell to premium buyers -99. I don't know 2. No sales of green cobs/dry cobs/grain
B69c. Do you know if last year in Season C your cooperative sold grain maize to premium buyers?	1. Yes, they sold to premium buyers 0. No, they didn't sell to premium buyers -99. I don't know 2. No sales of green cobs/dry cobs/grain
B69d. Do you know whom your cooperative is selling green cobs to this current year in Season C? *Select all that apply*	1. FtMA/WFP (PAM) 2. Minimex 3. AIF 4. EAX 5. RGCC 6. ProDEV 7. Sarura 8. Rumbuka 9. RDO 88. Other (Specify) -99. I don't know 0. No sales of green cobs/dry cobs/grain
B69e. Do you know whom your cooperative is selling dry cobs to this current year in Season C? *Select all that apply*	1. FtMA/WFP (PAM) 2. Minimex 3. AIF 4. EAX 5. RGCC 6. ProDEV 7. Sarura 8. Rumbuka 9. RDO 88. Other (Specify) -99. I don't know 0. No sales of green cobs/dry cobs/grain
B69f. Do you know whom your cooperative is selling grain to this current year in Season C? *Select all that apply*	1. FtMA/WFP (PAM) 2. Minimex 3. AIF 4. EAX 5. RGCC 6. ProDEV 7. Sarura 8. Rumbuka 9. RDO 88. Other (Specify) -99. I don't know 0. No sales of green cobs/dry cobs/grain

B61a. Have you ever received any support from FtMA/WFP?	1. Yes 0. No

	GAP Training	PHHS training	Nutrition Training	Saving groups	Contracting support
B61. What kind of FtMA/WFP support did you receive?					
B62a. To what extent did FtMA/WFP support XX help you to get a higher income for your maize?					
B62b. To what extent did FtMA/WFP support XX help you to get non-financial benefits for your maize?					

MODULE C CONSUMPTION BEHAVIOUR		
C1. Do you believe that your income from Season C maize this year is or will be higher, same, or lower compared to Season C last year?		1. Higher 2. Same 3. Lower
C2. Compared to season C last year, did your household change its expenditure in …		
a) housing?	5. Large increase 4. Slight increase 3. No changes at all 2. Slight decrease 1. Large decrease	
b) food?	5. Large increase 4. Slight increase 3. No changes at all 2. Slight decrease 1. Large decrease	
e) education?	5. Large increase 4. Slight increase 3. No changes at all 2. Slight decrease 1. Large decrease	
d) health?	5. Large increase 4. Slight increase 3. No changes at all 2. Slight decrease 1. Large decrease	
C6. Was increased expenditure in ,,, due to the additional income from maize?		1. Yes 0. No
C7. Did you do any investments with the additional income from maize? *Select all that apply*	1. Hand tools 2. Traditional seeds and seedlings 3. Improved seeds and seedlings 4. Sacks and packing 5. Hired labour (wages, excluding terracing) 6. Fencing material 7. Transportation means (e.g., Motorcycle) 8. Storage of harvest 9.Equipment rental 10. Organic fertilizer 11. Chemical fertilizer 12. Insecticides 13. Irrigation, drainage fees 14. Terracing (wages) 15. Pole for beans 16. Additional livestock 0. None 88. Other (Specify)	
C8. What plans for the future do you have with the additional income from maize? *Select all that apply*	1. repaying debts 2. buying new things for the house 3. repairing something in the house 4. medical care services 5. education 6. cleaning material / household services 7. Contributions to religious and other organizations 8. ceremonies 9. taxes 10. insurance 11. Agricultural production 12. Starting/expanding business 13. entertainment 14. buy more (nutritious) food 15. Saving 16. Additional livestock 17. Transportation means (e.g. Motorcycle) 0. None 88. Other (Specify)	
C9. What plans for the future would you have if you had additional income from maize? *Select all that apply*	1. repaying debts 2. buying new things for the house 3. repairing something in the house 4. medical care services 5. education 6. cleaning material / household services 7. Contributions to religious and other organizations 8. ceremonies 9. taxes 10. insurance 11. Agricultural production 12. Starting/expanding business 13. entertainment 14. buy more (nutritious) food 15. Saving 16. Additional livestock 17. Transportation means (e.g. Motorcycle) 0. None 88. Other (Specify)	

MODULE D AFLATOXIN, PERCEPTION OF AFLASIGHT SERVICES, AND THE COB MODEL	
D2. Have you ever heard of aflatoxin?	1. Yes 0. No
D5. Can you tell me what aflatoxin is? [*Do not read responses*]	1. Mentions mould only 2. Mentions toxin only 3. Mentions both 88. Other (Specify) -99. Does not know
D6. Do you know what causes aflatoxin? *Select all that apply*	1. Damp/ poorly dried maize 2. Poorly stored maize 3. Insect 4. Premature Harvest 5. Rain 6. maize touches soil 88. Other (Specify) -99. Does not know
D7. By looking at maize, can you tell if it has aflatoxin?	1. Yes 0. No
D13. Do you know any health problems that come from eating aflatoxin? *Select all that apply*	1. Stomach pain 2. Diarrhoea 3. Lung problems 4. Jaundice 5. Liver failure 6. Liver cancer 7. Death 8. Stunting 88. Other (Specify) -99. Does not know any 0. There are no health issues
D15. In season C this year, did you or are you going to take any measures to prevent Aflatoxin from affecting your maize?	1. Yes 0. No
D16. Which ones? *Select all that apply*	1. Dry well 2. Treat maize with chemical 3. Proper storage 4. appropriate drying facility/space/location 5. Sorting grain 88. Other (Specify)
D15a. Last year in Season C, did you take any measures to prevent Aflatoxin from affecting your maize?	1. Yes 0. No
D16a. Which ones? *Select all that apply*	1. Dry well 2. Treat maize with chemical 3. Proper storage 4. appropriate drying facility/space/location 5. Sorting grain 88. Other (Specify)
D17. In your opinion, what may prevent you from adopting practices related to aflatoxin reduction? *Select all that apply*	1. I don't know what the cause of aflatoxin is 2. I don't want to adopt any pre-harvest technologies because I don't know how well they work 3. I don't want to adopt any post-harvest technologies because I don't know how well they work 4. Pre-harvest aflatoxin solutions are too expensive 5. Post-harvest aflatoxin solutions are too expensive 6. There is nowhere to buy/access any pre-harvest technologies 7. There is nowhere to buy/access any post-harvest technologies 8. Aflatoxin solutions require too much labour 12. Lack of appropriate drying facility/space/location 9.I don't think that reducing aflatoxin is important. I would still receive the same price 10. I don't think that reducing aflatoxin is important for our health 11. I don't adopt practices related to aflatoxin simply because I don’t know (anything) about it (or its effects) 13. I am already doing everything I need to do to prevent aflatoxin 14. Lack of adequate skills 88. Other (specify)

D17a. Taking all the issues just mentioned, how difficult is it for you to reduce further aflatoxin in your maize?	1. Very difficult 2. Difficult 3. Neither difficult nor easy 4. Easy 5. Very easy -99. Does not know about aflatoxin
D18. In your opinion, why is it not possible for the cooperative to help you further reduce aflatoxin in your maize? *Select all that apply*	1. Cooperative does not provide me with information about aflatoxin 2. Cooperative does not provide me with information about technologies to reduce aflatoxin 3. Cooperative does not provide me with any pre-harvest technologies 4. Cooperative does not provide me with any post-harvest technologies 5. I want to use technologies to reduce aflatoxin, but other members do not want to 6. I don't think that reducing aflatoxin is important. I would still receive the same price 7. I don't think that reducing aflatoxin is important for our health 8. the cooperative is already doing everything they need to do to prevent aflatoxin 9. The cooperative lacks adequate storage facility 88Other (Specify)
D19. Do you think that a higher price is offered for an aflatoxin free maize?	1. Yes 0. No -99. Don't know
D23. Have you ever heard of AflaSight and their services?	1. Yes 0. No
D24. Can you tell me what they are? *Select all that apply*	1. Respondent mentions "reduces aflatoxin" 2. Respondent mentions "aflatoxin sorting" 3. Respondent mentions "aflatoxin drying" 4. Respondent mentions "seed cleaning" 5. Respondent mentions "removes infected kernels" 7. Respondent mentions "a service that takes care of sorting, and seed cleaning" 0. Cannot explain/Does not know
D24a. Have you heard about AflaSight and their services?	1. Yes 0. No
D25. Has some of your Season C grain been run through or will some of your Season C grain be run through the AflaSight machine line?	1. Yes, it has 2. Yes, it will 0. No -99. I don't know
D25a. Will some of your grain from future harvests be passed through the AflaSight machine line?	1. Yes 0. No -99. Don't know
D26. Think about your agricultural and post harvesting handling practices. Did you change your practices because your grain is or was run through the AflaSight machine line?	1. Yes, agricultural practices 2. Yes, post-harvest handling practices 3. Yes, agricultural practices and post-harvest handling practices 0. No
D26b. Think about your agricultural practices and post harvesting handling practices. Would you change your practices if your grain was run through the AflaSight machine line?	1. Yes, agricultural practices 2. Yes, post-harvest handling practices 3. Yes, agricultural practices and post-harvest handling practices 0. No -99. I don't know
D27. How beneficial has it been for you that the cooperative used AflaSight services?	1. Not beneficial at all 2. Slightly beneficial 3. Moderately beneficial 4. Beneficial 5. Very beneficial -99. I don't know

D29. How beneficial would it be for you if your cooperative used these AflaSight services?	1. Not beneficial at all 2. Slightly beneficial 3. Moderately beneficial 4. Beneficial 5. Very beneficial -99. I don't know
D30. Do you think that running your Season C maize through the AflaSight machine line has increased or will increase your income?	1. Yes, it will increase it 2. No, it will decrease it 3. No, it will stay the same 4. Yes, it has increased it 5. No, it has decreased it 6. No, it has stayed the same -99. I don't know
D32. Which of the following statements do you agree the most with?	1. I don't want to use AflaSight services 2. I will/would use the AflaSight services sometimes 3. I have no preference between using or not using AflaSight services 4. From now on I will/would mostly use the AflaSight services 5. From now on I will/would always use AflaSight services
D33. Have you ever heard of the Cob model?	1. Yes 0. No
D34. Can you tell me what it is? *Select all that apply*	1. Respondent mentions "someone else takes care of the drying, shelling, storage" 2. Respondent mentions "reduces aflatoxin" 3. Respondent mentions "lower contamination" 4. Respondent mentions "cobs are taken to a central location" 0. Cannot explain/Does not know
D34a. Have you ever heard of the Cob model?	1. Yes 0. No
D35. Were some of your cobs ever sold via the Cob model?	1. Yes, they were for past harvests 2. Yes, this Season C cobs were 3. Yes, both past harvests and this season C cobs 0. No -99. I don't know
D38. How beneficial has it been for you that the cooperative sold your cobs through the Cob model?	1. Not beneficial at all 2. Slightly beneficial 3. Moderately beneficial 4. Beneficial 5. Very beneficial -99. I don't know
D40. How beneficial would it be for you if your cooperative sold your cobs through the Cob model?	1. Not beneficial at all 2. Slightly beneficial 3. Moderately beneficial 4. Beneficial 5. Very beneficial -99. I don't know
D41. Do you think that selling your maize through the Cob model has increased your income?	1. Yes, it has increased it 2. No, it has decreased it 3. No, it has stayed the same
D41d. How much did you have to pay for charcoal or woods for cooking energy to make up for the cobs you sold through the Cob model?	____RWF
D42. Which of the following statements do you agree the most with?	1. I don't want to use the cob model 2. I will/would use the cob model sometimes 3. I have no preference between using or not using the cob model 4. From now on I will/would mostly use the cob model 5. From now on I will/would always use the cob model

D43. Which technology would you prefer to use in the future? The AflaSight services, the Cob model or other aflatoxin solutions?	1. Cob model 2. AflaSight services 3. Other solutions to reduce aflatoxin 4. None of the above 5. All of the above 6. Cob model or AflaSight services is fine 7. Cob model or other solutions (not AflaSight) to reduce aflatoxin is fine 8. AflaSight services or other solutions (not Cob Model) to reduce aflatoxin are fine
D44. What is the biggest advantage of the Cob model?	1. I don't have to shell, dry, and store the maize. Someone else does it for me 2. I get paid more 3. It reduces labour costs and post-harvest costs 4. I have more free time 5. I can grow more maize 6. I can grow other crops 0. I don't see any advantage -99. I don't know 88. Other (specify)
D45. What is the biggest advantage of the AflaSight services?	1. I get paid more / I have a higher income 2. It reduces labour costs and post-harvest costs 3. I have more free time 4. I can grow more maize 5. I can grow other crops 0. I don't see any advantage -99. I don't know 88. Other (specify)
D49. What is the biggest disadvantage of the Cob model?	1. I don't trust someone else shelling, drying, and storing my maize. 2. I get paid less 3. Higher labour costs and post-harvest costs 4. I have less free time 5. I can grow less maize 6. I can grow fewer crops 7. I would need to change my buyers 8. I don't trust the machines they use 9. Lack of firewood because the model takes the cobs 0. I don't see any disadvantage -99. I don't know 88. Other (specify)
D50. What is the biggest disadvantage of the AflaSight services?	1. I would still need to shell, dry, and store my maize. 2. I get paid less 3. Higher labour costs and post-harvest costs 4. I have less free time 5. I can grow less maize 6. I can grow fewer crops 7. I would need to change my buyers 8. I don't trust the machines they use 0. I don't see any disadvantage -99. I don't know 88. Other (specify)
Enter any comments relevant to the survey	

ANNEX 9 SURVEY METHODOLOGY

Sampling strategy

219. The target population of the survey includes female and male members (farmers) of the four FtMA-supported farmer cooperatives that cultivated maize in season C 2021 and operate in the districts of Nyanza and Gisagara. The sample therefore includes potential and actual users of AflaSight services.

220. The sampling method considered five sectors (the administrative sub-division of districts) as primary sampling units. Each of the three cooperatives in Gisagara operates in one sector, and the cooperative in Nyanza operates in two sectors (see Table 13 below). Within sectors, farmers were stratified by gender, and a subset of randomly sampled female and male farmers[141] within each of the four cooperatives (and sectors in Coamanya Nyanza) was surveyed.

221. The sampling frame of smallholder farmers belonging to the cooperative Coamanya Nyanza was received from WFP in electronic form and the sampling was conducted by the survey team with a replicable STATA do file. The member lists for the remaining cooperatives were obtained by the field team directly from the presidents or accountants of the cooperatives, and sampling was conducted on site with an established randomization protocol.

222. The table below summarizes the total number, as per inception report, of female and male farmers surveyed within each cooperative and sector. Originally, it was planned to interview 50 female and 50 male farmers in each cooperative (200 women and 200 men in total); however, the list obtained for CCM during fieldwork revealed that there were only 32 female cooperative members cultivating maize in season C 2021. In addition, the list received from Coamanya Gishubi was incomplete and only allowed the survey team to interview 48 female farmers. To maintain the total number of 200 female farmers, the sample of female farmers in Cojyamugi was increased accordingly. This revision of the sampling strategy, however, does not affect the results since 'design weights' were used in the analysis as described below.

Table 13: Number of smallholder farmers in the sample and sampling frame

Cooperative	District	Sector	Number of cooperative members interviewed			Total no. of cooperative members cultivating maize in season C 2021		
			Male	Female	Total	Male	Female	Total
CCM Muganza	Gisagara	Muganza	49	25	74	146	32	178
Coamanya Gishubi		Gishubi	50	48	98	558	332	890
Cojyamugi		Mamba	50	77	127	1,300	1,200	2,500
Coamanya Nyanza	Nyanza	Ntyazo	25	25	50	210	101	311
		Kibirizi	25	25	50	90	69	159
Total			199	200	399	2,304	1,734	4,038

223. In order to have a sufficient number of observations from each cooperative/sector, the evaluation team oversampled cooperative members from CCM Muganza, Coamanya Gishubi, and Coamanya Nyanza (Ntyazo and Kibirizi) relative to the Cooperative Cojyamugi. This means that respondents were selected so that some cooperatives made up a larger share of the survey sample than they do in the population of interest (all members of the four cooperatives cultivating maize in season C 2021). For example, if a proportional number of respondents to the size of cooperatives had been selected, it would have meant interviewing only 18 farmers in CCM, one of the smaller cooperatives, and 247 respondents in Cojyamugi, the largest cooperative.

224. Moreover, the survey team oversampled female farmers (50 percent in the sample, but only 42.9 percent of the total population of interest) to guarantee a large enough number of observations on women to produce meaningful descriptive statistics by gender. However, this also means that the selection

[141] Enumerators were instructed to interview one cooperative member per household. In the event that more than one cooperative member in the sampling list belonged to the same household, a farmer from the randomly generated replacement list would be interviewed instead.

probabilities of the sub-groups of interest were altered. Any inference based on simple (unweighted) sample means of the survey responses would thus not reflect the true composition of the population of interest, but be biased towards the sub-groups who were oversampled (i.e. women and smaller cooperatives). To adjust for oversampling, the sub-groups were weighted with their shares in the total farmer population to calculate the total sample means[142].

Questionnaire design and training of the survey team

225. The design of the questionnaire involved several steps.

- The full questionnaire (see Table 12 in Annex 8) was designed in-house based on the evaluation matrix. It was then shared with WFP and the local partner for comments.
- The comments were incorporated in a first round of revisions, and the questionnaire (as well as all updates) were translated into Kinyarwanda.
- The questionnaire was then pre-tested (on 12 November 2021) by the survey supervisors (each conducted one full interview with farmers from the cooperative Coamanya Nyanza). The feedback from the pre-test was incorporated in a second round of revisions.
- Thereafter, the face-to-face supervisor training was completed (15 November 2021) and the enumerator training was conducted (16-20 November 2021). During these trainings, each survey question was discussed in detail. Several sessions and mock interviews were conducted with all enumerators in Kinyarwanda to assess the quality of the translation. Further adjustments to the questionnaire were constantly made during the enumerator training.
- After the training, a pilot test was conducted (on 22 November 2021) in both sectors of the Cooperative Coamanya Nyanza, during which each enumerator conducted at least two full interviews in a real-life interview setting with the same aims as for the pre-test.
- In a comprehensive debriefing after the pilot (24 November 2021), final feedback on the questionnaire and the translation was obtained and incorporated prior to the launch of the survey.

Data collection

226. The data collection from SHFs took place from 29 November to 13 December 2021. It was implemented by local field teams hired for the duration of the survey, both covering the two districts of Nyanza and Gisagara. Each team consisted of one supervisor and five enumerators. The supervisors were responsible for on-site quality assurance, including spot checks and calls to a randomly selected number of respondents to verify the data entered for key questions and assess their satisfaction with the interview. One field coordinator was responsible for the overall coordination of the two teams, logistics, and identification of the sampled cooperative members.

227. One challenge the field team faced during data collection was tracking the sampled farmers. This was especially true for the Cooperative Cojyamugi due to the high number of cooperative members. While a randomly sampled replacement list had been created by the survey team to replace unknown or non-eligible farmers, the field teams still dedicated extensive time tracing the sampled respondents.

228. Another issue was that data collection was conducted while season C was still ongoing[143]. Indeed, only 11.8 percent of the farmers interviewed had already finished their post-harvest work at the time of the interview, while the rest were still in the process of completing it. As a second-best solution, farmers were hence asked to provide estimates regarding their post-harvest handling practices, costs to be incurred, quantities to be sold, and earnings to be obtained.

[142] 'Design weights' are equal to the inverse probability to have been interviewed, i.e. 1/ (number of interviewees in each stratum in each sampling unit/ size of each stratum in each sampling unit).

[143] This was especially true for cooperative Coamanya Gishubi, where harvesting had not been completed yet when the respondents were interviewed. At the time of the interview, most farmers were unsure if their maize was going to be sold by the cooperative on-cob or off-cob since they hadn't been informed yet by the cooperative leaders. Therefore, the survey team approached the cooperative leaders directly to learn how the cooperative was planning to sell the maize of the cooperative members. With this information at hand, the farmers were able to estimate their season C maize sales.

229. Irrespective of where farmers stood in the agricultural cycle, they found it difficult to relay information on the volume of harvest obtained (green cobs), given than they are generally only aware of the exact weight when selling it as dry cob or grain.

Data monitoring, cleaning and analysis

230. The survey was administered using the computer-assisted personal interviewing software SurveyCTO. The designed questionnaire was carefully programmed into the software and the programming contained many quality checks on logical inconsistencies and out of range responses.

231. During the data collection, the field team enumerators uploaded the data to a secure server on a daily basis. The survey researchers performed a series of quality checks using STATA software for continuous, real-time quality monitoring. Detected inconsistencies or errors were flagged and reported back to the supervisors and enumerators in the field for further clarification. After the data collection was completed, another set of quality checks was conducted to identify inconsistencies that had not previously been detected. These were again fed back to the field team for clarification with the enumerators or respondents.

232. After the consistency checks, the dataset was cleaned using STATA. All additional information shared by the field teams was incorporated, the data structure was adjusted, and indicators necessary for the analysis (linked to the evaluation matrix) were created.

233. The quantitative data analysis for this report mainly consists of descriptive statistics (means and standard deviations of the survey responses) and simple hypothesis testing (t-test) for gender differences in the survey responses.

234. The latter aims to detect any systematic differences in the means of survey variables between female and male farmers. If gender differences in the sample are statistically significant, one can be relatively certain that these reflect systematic differences in the total population of cooperative members. If the gender differences are not statistically significant, female and male farmers are considered to be on average similar in these characteristics (or at least the differences are too small to be detected with the given sample size).

235. As mentioned before, farmers had to provide estimations regarding their season C 2021 harvest, earnings, etc., which may lead to inaccurate figures. However, assuming random and equal measurement errors on average by gender, the total sample means are not affected.

236. Finally, this survey report presents quantitative data on both season C 2021 and – based on farmer's recall – season C 2020. However, any "before/after" comparison reported here should be interpreted with caution since no statistical causality can be inferred. Indeed, given that only (potential and actual) users and no comparison households were interviewed, it is not possible to disentangle program effects from other changes over time such as changes in climatic conditions.

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ANNEX 10 SURVEY RESULTS

TABLE OF CONTENT – SURVEY RESULTS

LIST OF TABLES – SURVEY RESULTS

LIST OF FIGURES – SURVEY RESULTS

237. This annex presents the findings from the quantitative data analysis in text, tables and figures. The tables report the means of the survey variables for the total sample, the sub-samples of female and male farmers, as well as the results of the t-tests for gender differences. The narrative (text) summarises the results for the total sample but highlights gender differences in means only if they are statistically significant.

- Section A1 starts by providing an overview of the socio-economic background of the cooperative members.
- Section A2 describes the maize farming practices adopted, as well as harvests and earnings obtained in season C 2020.
- Section A3 explores farmers' knowledge of aflatoxin, their understanding and perception of AflaSight services and the Cob model alongside their access to the technologies. It also reports on any barriers they face in adopting aflatoxin prevention measures.
- Section A4 studies the current adoption of aflatoxin prevention measures, as well as (actual or expected) self-reported changes in agricultural or post-harvesting practices resulting from of technology adoption. It also describes the main advantages of the AflaSight and cob models from the farmers' perspective and the contribution of FtMA support to gains from maize cultivation.
- Section A5 reviews farmers' concerns regarding the technologies.
- Section A6 presents the results from season C 2021, in terms of harvest, earnings and profit from maize.
- Section A7 focuses on self-reported changes in income from maize as well as expenditures and investments (expected to be) made with the additional income from maize.
- Section A8 discusses the survey results on the sustainability of the technologies in the future.

A1. FARMER PROFILE

238. This section provides an overview of the population of interest. It presents a picture of the farmers' profile based on descriptive statistics on their socio-economic characteristics, educational level, livelihood, and composition of their households. The statistics described in this first section are illustrated in Table A - 1 and Figure A - 1.

239. Table A - 1 reveals that the average age, in completed years, of cooperative members is 47.8 years old. On average, 84.1% are household heads, with 93.5% working full-time on the farm. This engagement is measured in terms of the time that is invested, not in terms of the income generated from the occupation. The majority of farmers, 68.4% on average, have completed their education at the primary school level, with 18.7% having completed no schooling and 5.9% and 7%, having obtained a pre-primary and post-primary education, respectively. In line with the level of schooling achieved, 79.7% of cooperative members are able to read or write in Kinyarwanda.

240. On average, farmers' households comprise 5 household members. In assessing their compositions, there are, on average, around 2 children per household aged below 15 and roughly 3 household members between the ages of 15 and 64. In general, most households do not have older members above the age of 64. Table A - 1 also reports the age dependency ratio, which represents the dependency between household members typically not active in the labour market (children below the age of 15 and elderly above the age of 64) and adults aged 15-64 normally active in the labour market (as per The World Bank definition). The average age dependency ratio is 0.88, which is slightly higher than the 2020 country estimate of 0.74 (World Bank 2020[144]). In addition to the age dependency ratio, the number of breadwinners per household and the income dependency ratio[145] are reported in the table. On average, there are 1.9 breadwinners per household, with an income dependency ratio of 0.39.

241. The table also reports the travel times cooperative members face when travelling to their respective cooperative maize collection centre with the usual means of transportation. The majority of cooperative members (71.8%) face a travel time of between 10 and 60 minutes. Similarly, 21.4% of cooperative members

[144] World Bank. 2022. Open Data.

[145] The income dependency ratio is the ratio of the number of breadwinners to the household size.

face a travel time of less than 10 minutes, while 6.8% report taking much longer than 60 minutes to travel to their respective cooperative maize collection centre with the usual means of transportation.

242. Several statistically significant gender differences in farmer profiles are worth highlighting. The average age of female cooperative members, in completed years, is higher than their male counterparts (51 years old and 46 years old, respectively). More than half of the females (63.1%) and almost all males are household heads (99.9%). The figure for females is above the Rwandan average, which stood at 31.9% in 2020 (World Bank, 2020[146]). This large difference with the national average is expected, though, as the survey targeted female cooperative members who tend to be heads of their households. A higher share of women than men have not completed any form of schooling (32.1% vs 8.6%). Similarly, more men than women have completed primary school (78.1% vs 55.4%). This is also reflected in the literacy level of the cooperative members. A lower share of females than males indicate that they can read or write in Kinyarwanda (69.3% vs 87.5%). On average, the size of female-headed households is smaller than male-headed ones (around 4 and 6 members respectively). Moreover, there are gender differences in the household composition as well. Indeed, female-headed households consist of, on average, fewer children below the age of 15 (1.4 vs 2.5) as well as fewer members between the age of 15 and 64 (2.6 vs 3.5) than male-headed households. In contrast, the former has more older members (above the age of 64) than the latter (0.2 vs 0.1) on average. These results on household composition appear consistent with the gender difference detected in the cooperative members' age. There are, on average, fewer breadwinners in women's households (1.5) than in men's households (2.1) and higher average income dependency ratio in women's households (0.42) as opposed to men's households (0.38). These results are also in line with the gender differences found in household size.

243. In order to gain insights into the livelihoods of the cooperative members, an analysis of the Poverty Probability Index® (PPI®) has been conducted[147]. The PPI has the advantage of not relying on self-reported measures. Indeed, the PPI is a poverty measurement tool that uses a survey and scoring system to estimate the probability that a household lives below national and international poverty lines. In its basic form, it consists of a 10-question scorecard[148] and a poverty likelihood table which, based on the score recorded, provides the likelihood that the survey respondent's household is living below various poverty lines. The questionnaire used for data collection integrated the exact PPI questions in section A of the survey. It is also important to note that the PPI scorecard is based on data from a nationally representative group of households.

244. The average poverty rate of farmers is computed as the weighted average of the poverty likelihoods of all the respondents and is also shown in Table A - 1. According to the national poverty line, which is used in the analysis, the estimated poverty rate is 37.8. Similarly, the estimated poverty rate is 41.3 for male and 33.1 for female farmers. This means that roughly 37.8% of all farmers, 41.3% of male farmers and 33.1% of female farmers fall below the national poverty line. The difference between females and males may be explained by the significantly smaller household size and fewer children in females' households; two variables which are included in the PPI scorecard.

Table A - 1. Characteristics of cooperative members and their households

	N	(1) Total Mean/SE	N	(2) Male Mean/SE	N	(3) Female Mean/SE	t-test Difference (2)-(3)
Characteristics of cooperative member							
Age	399	47.81	199	45.56	200	50.81	-5.25***
		[0.72]		[0.97]		[1.03]	
Head of the household	399	0.84	199	1.00	200	0.63	0.37***
		[0.02]		[0.00]		[0.04]	
Farming							
Full-time farming	399	0.94	199	0.93	200	0.94	-0.00
		[0.02]		[0.02]		[0.02]	

146 World Bank. 2022. Open Data.

147 The PPI is a public good powered by Innovations for Poverty Action (IPA): www.progressoutofpoverty.org

148 The scorecard was created in 2019 and is based on data from Rwanda's 2016/17 Integrated Household Living Conditions Survey (EICV5) produced by the National Institute of Statistics Rwanda and the Ministry of Finance and Economic Planning.

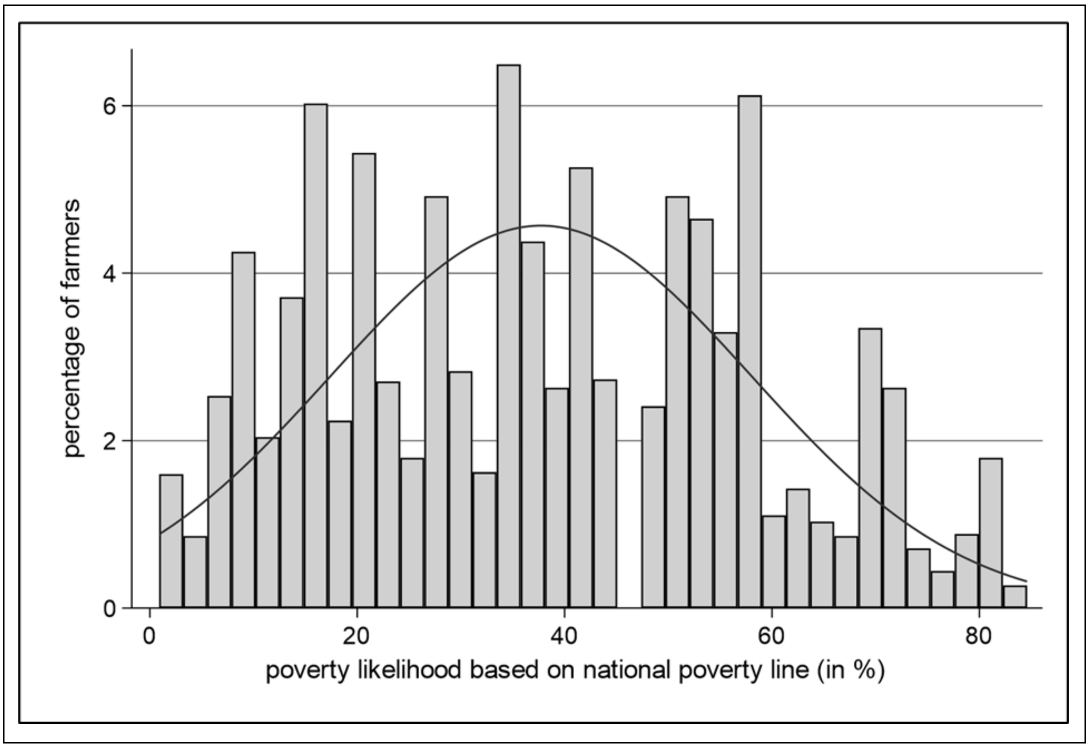
	N	(1) Total Mean/SE	N	(2) Male Mean/SE	N	(3) Female Mean/SE	t-test Difference (2)-(3)
Part-time farming	399	0.06 [0.02]	199	0.07 [0.02]	200	0.06 [0.02]	0.01
Education level							
None completed (yet)	399	0.19 [0.02]	199	0.09 [0.02]	200	0.32 [0.04]	-0.23***
Pre-primary education	399	0.06 [0.01]	199	0.05 [0.02]	200	0.07 [0.02]	-0.02
Primary education	399	0.68 [0.03]	199	0.78 [0.03]	200	0.55 [0.04]	0.23***
Post-primary/ vocational/ secondary education	399	0.07 [0.02]	199	0.08 [0.02]	200	0.05 [0.02]	0.03
Literate in Kinyarwanda	399	0.80 [0.02]	199	0.87 [0.03]	200	0.69 [0.04]	0.18***
Household characteristics							
Number of household members	399	5.32 [0.13]	199	6.09 [0.18]	200	4.29 [0.16]	1.80***
Number of household members below 15 years old	399	2.03 [0.09]	199	2.48 [0.13]	200	1.43 [0.10]	1.05***
Number of household members 15-64 years old	399	3.15 [0.11]	199	3.55 [0.15]	200	2.62 [0.14]	0.93***
Number of household members above 64 years old	399	0.14 [0.02]	199	0.06 [0.02]	200	0.24 [0.04]	-0.18***
Number of breadwinners in a household	399	1.87 [0.05]	199	2.13 [0.06]	200	1.52 [0.06]	0.60***
Age dependency ratio	385	0.88 [0.05]	198	0.92 [0.06]	187	0.82 [0.07]	0.10
Income dependency ratio	399	0.39 [0.01]	199	0.38 [0.01]	200	0.42 [0.02]	-0.04*
Distance to cooperative maize collection centre							
Less than 10 min	399	0.21 [0.03]	199	0.24 [0.04]	200	0.18 [0.03]	0.06
Between 10 and 60 min	399	0.72 [0.03]	199	0.71 [0.04]	200	0.73 [0.04]	-0.02
More than 60 min	399	0.07 [0.02]	199	0.05 [0.02]	200	0.09 [0.03]	-0.04
Livelihood							
Estimated poverty rate	399	37.79 [1.22]	199	41.33 [1.58]	200	33.08 [1.84]	8.25***

Notes: The value displayed for t-tests are the differences in the means between male and female respondents. Standard errors are robust. Observations are weighted using design weights. ***, **, and * indicate significance at 1, 5, and 10 percent.

245. Figure A - 1 below shows the weighted distribution of the poverty likelihood variable, which permits an assessment of the distribution of this variable. The figure reveals that the bottom 25% (first quartile) of

farmers have up to 18.1% likelihood of falling below the national poverty line. Similarly, half of the farmers face a poverty likelihood of up to 35.3% (median), while the top 25% (75th percentile) of farmers face a poverty likelihood of at least 54.9%.

Figure A - 1. Distribution of farmers' poverty likelihood



Notes: Observations are weighted using design weights.

A2. FARMERS' PRACTICES, HARVEST AND EARNINGS FROM MAIZE IN SEASON C 2020

246. This section describes the aflatoxin prevention measures adopted by farmers in season C 2020 as well as their harvest and earnings obtained from maize in the past season C.

Aflatoxin prevention measures

247. As reported in Table A - 2, almost all farmers (99.7%) have cultivated their land with maize in season C 2020 and obtained some maize harvest from their land (98.4%). All farmers who obtained some maize harvest in season C 2020 were asked to indicate whether they adopted any measures to prevent aflatoxin, and if so, which measures. The vast majority of farmers (93.9%) report having taken steps to prevent aflatoxin in season C 2020.

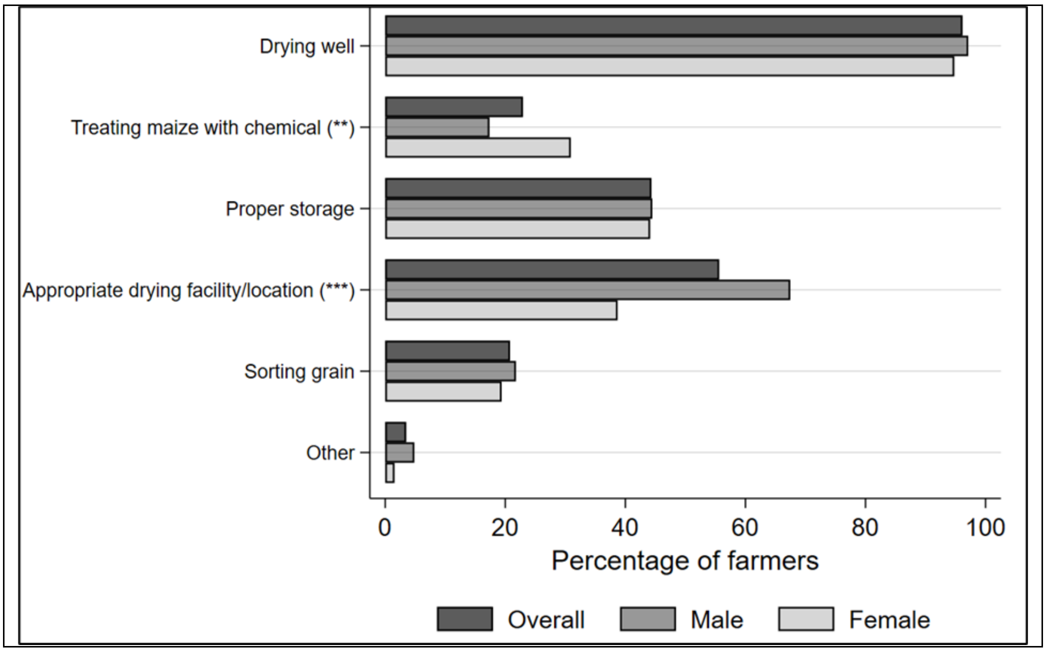
248. Statistically significant gender differences are found in terms of the share of women and men who obtained some maize harvest (100% vs 97.3%), and adopted post-harvest measures against aflatoxin (89% vs 97.7%) in season C 2020.

Table A - 2. Maize cultivation and aflatoxin prevention measures (season C 2020)

	N	(1) Total Mean/SE	N	(2) Male Mean/SE	N	(3) Female Mean/SE	t-test Difference (2)-(3)
Cultivated maize in season C 2020 (dummy)	399	1.00	199	1.00	200	0.99	0.01
		[0.00]		[0.00]		[0.00]	
Harvested maize in season C 2020 (dummy)	397	0.98	199	0.97	198	1.00	-0.03*
		[0.01]		[0.02]		[0.00]	
Used post-harvest prevention measures (dummy)	394	0.94	196	0.98	198	0.89	0.09***
		[0.01]		[0.01]		[0.03]	

Notes: The value displayed for t-tests are the differences in the means between male and female respondents. Standard errors are robust. Observations are weighted using design weights. ***, **, and * indicate significance at 1, 5, and 10 percent.

Figure A - 2. Aflatoxin prevention measures used in season C 2020



Notes: T-tests for gender differences are performed with robust standard errors. Observations are weighted using design weights. **, **, and * indicate significance at the 1, 5, and 10 percent. Number observations 366; number observations male: 187; number observations female: 179

249. Figure A - 2 shows the type of aflatoxin-prevention measures adopted by cooperative members. Almost all farmers who adopted any measures at all report having dried maize well (96.2%) and approximately half of the farmers used appropriate drying facilities and stored maize properly (55.6% and 44.3% respectively). Finally, a small share of farmers treated maize with chemicals (22.9%) or sorted their grain to prevent aflatoxin (20.8%).

250. Differences between female and male farmers concern the use of chemicals for treating maize and appropriate drying facility or location. While more female farmers than male farmers report having treated maize with chemicals (30.9% vs 17.4%), the opposite is true when it comes to drying maize in an appropriate facility or location (38.7% vs 67.5%).

Harvest, post-harvest handling costs and earnings from maize

251. Table A - 3 reports the season C 2020 maize harvest, post-harvest costs, earnings and price per kilo of maize sold. The results show that those farmers who cultivated maize devoted on average 0.27 hectares of their land to the crop. Farmers who did not lose all of their harvest, obtained on average 756 kg of maize. The average land productivity is 4,684.1 kg of maize per hectare and the median is lower at 3,466.7 kg/ha (Table A - 22). Both mean and median are reported since the mean is sensitive to extreme values and the median is robust against them. While extreme values may be outliers, it cannot be a certainty. In fact, farmers confirmed their answers even after being probed by enumerators.

252. Farmers were also asked about the costs incurred during the post-harvest process. Table A - 3 shows that they have spent on average 22,346.6 RWF in post-harvest costs.

253. Moreover, the table presents the share of farmers who sold green cobs, dry cobs and grain to the cooperative or local market/middle man in season C 2020. As it was to be expected, only 1.2% sold green cobs to the cooperative. Indeed, selling green cobs to the cooperatives is forbidden. A greater share of farmers sold grain (60.6%) as opposed to dry cobs (25.5%) to the cooperative. Very few farmers sold either green cobs (2.6%), dry cobs (2.1%), or grain (15.6%) to the local market or middle man.

254. Accordingly, farmers sold on average 76.7 kg of dry cobs and 221.1 kg of grain to the cooperatives and earned on average 18,350.1 RWF from dry cob and 84,534.8 RWF from grain sales to the cooperative. This results in farmers receiving an average price of 235.4 RWF per kilo for dry cobs and 364.6 RWF/kg for grain sold to the cooperative.

255. Several statistically significant gender differences are detected in the season C 2020 figures presented in Table A - 3. Men report obtaining on average a larger harvest than women, the difference being 368.7 kg. At the same time, men also believe to have incurred higher post-harvest costs than women, with a difference of 11,197.2 RWF. Though very few female and male farmers sold green cobs to cooperatives, more women (2.5%) than men (less than 1%) have done so and sold on average, a larger amount (10 kg vs 0.02 kg). Further, a greater share of women (71.9%) than men (51.9%) sold grain to the cooperative, though with no significant difference in the average amount sold. Male farmers sold, on average, more dry cobs than women to the cooperative (99 kg vs 48 kg), received larger earnings from these sales (24,973.2 RWF vs 9836.7 RWF) and obtained a higher per kilo price of dry cobs sold (255.4 RWF/kg vs 202.3 RWF/kg).

Table A - 3. Season C 2020 harvest and earnings from maize

	N	(1) Total Mean/SE	N	(2) Male Mean/SE	N	(3) Female Mean/SE	t-test Difference (2)-(3)
Season C 2020 land size and harvest							
Land size cultivated with maize (ha)	397	0.27	199	0.28	198	0.24	0.04
		[0.02]		[0.02]		[0.02]	
Harvest (kg)	391	756.00	193	917.61	198	548.88	368.73***
		[46.42]		[77.77]		[26.36]	
Yield (kg/ha)	388	4684.11	191	4546.85	197	4857.57	-310.72
		[235.97]		[309.07]		[363.17]	
Season C 2020 post-harvest costs (RWF)							
Post-harvest costs	392	22346.63	196	27191.72	196	15994.52	11197.21***

	N	(1) Total Mean/SE	N	(2) Male Mean/SE	N	(3) Female Mean/SE	t-test Difference (2)-(3)
		[1249.12]		[1919.28]		[1198.01]	
Season C sales of maize (dummy)							
Sold green cobs to cooperative	394	0.01 [0.01]	196	0.00 [0.00]	198	0.03 [0.01]	-0.02**
Sold dry cobs to cooperative	394	0.26 [0.02]	196	0.29 [0.04]	198	0.22 [0.03]	0.07
Sold grain to cooperative	394	0.61 [0.03]	196	0.52 [0.05]	198	0.72 [0.03]	-0.20***
Sold green cobs to local market	394	0.03 [0.01]	196	0.04 [0.02]	198	0.01 [0.01]	0.03
Sold dry cobs to local market	394	0.02 [0.01]	196	0.02 [0.01]	198	0.02 [0.01]	0.00
Sold grain to local market	394	0.16 [0.02]	196	0.13 [0.03]	198	0.19 [0.03]	-0.05
Season C 2020 quantity of maize sold (kg)							
Green cobs sold to cooperative	394	4.38 [2.15]	196	0.03 [0.03]	198	10.04 [4.92]	-10.01**
Dry cobs sold to cooperative	393	76.69 [9.70]	195	98.99 [16.02]	198	48.03 [8.45]	50.96***
Grain sold to cooperative	394	221.12 [18.21]	196	232.85 [27.71]	198	205.88 [21.39]	26.97
Green cobs sold to local market	394	0.95 [0.43]	196	1.46 [0.73]	198	0.29 [0.27]	1.17
Dry cobs sold to local market	394	1.94 [0.86]	196	1.41 [0.95]	198	2.63 [1.55]	-1.22
Grain sold to local market	394	13.10 [3.46]	196	15.28 [5.64]	198	10.26 [3.10]	5.02
Season C 2020 earnings from maize (RWF)							
Green cobs sold to cooperative	394	1323.36 [882.10]	196	5.32 [5.35]	198	3037.49 [2020.58]	-3032.18
Dry cobs sold to cooperative	393	18350.13 [2419.03]	195	24973.21 [4075.47]	198	9836.67 [1799.01]	15136.54***
Grain sold to cooperative	394	84534.85	196	90323.36	198	77006.82	13316.55

	N	(1) Total Mean/SE	N	(2) Male Mean/SE	N	(3) Female Mean/SE	t-test Difference (2)-(3)
		[8609.95]		[13334.56]		[9543.29]	
Green cobs sold to local market	394	150.84	196	221.10	198	59.47	161.63
		[76.15]		[127.74]		[54.35]	
Dry cobs sold to local market	394	473.17	196	354.80	198	627.12	-272.32
		[205.99]		[237.16]		[360.49]	
Grain sold to local market	394	3310.19	196	3894.78	198	2549.93	1344.85
		[851.93]		[1415.08]		[671.19]	
Season C 2020 price per kg of maize sold (RWF)							
Price per kg of dry cobs sold to cooperative	148	235.37	85	255.44	63	202.32	53.12***
		[5.76]		[5.44]		[8.88]	
Price per kg of grain sold to cooperative	192	364.56	81	369.54	111	359.88	9.66
		[13.08]		[18.67]		[18.38]	
Price per kg of dry cobs sold to local market	8	256.69	4	256.53	4	256.93	-0.41
		[12.99]		[7.23]		[33.70]	
Price per kg of grain sold to local market	51	263.92	22	261.76	29	265.94	-4.18
		[7.44]		[8.77]		[11.95]	

Notes: The value displayed for t-tests are the differences in the means between male and female respondents. Standard errors are robust. Observations are weighted using design weights. ***, **, and * indicate significance at 1, 5, and 10 percent.

Access to premium buyers

256. Farmers' awareness of cooperatives' access to premium buyers was also investigated. Table A - 4 shows that more than 70% of the farmers (77.7%) are aware that their cooperatives had access to premium buyers in season C 2020. Moreover, a statistically significant gender difference is detected in the share of male and female farmers reporting that their cooperative had access to premium buyers (81.6% male and 72.7% female).

Table A - 4. Cooperatives' access to premium buyers (according to farmers)

	N	(1) Total Mean/SE	N	(2) Male Mean/SE	N	(3) Female Mean/SE	t-test Difference (2)-(3)
Access to premium buyers (yes vs no and don't know)	399	0.78	199	0.82	200	0.73	0.09*
		[0.03]		[0.03]		[0.04]	

Notes: The value displayed for t-tests are the differences in the means between male and female. Standard errors are robust. Observations are weighted using design weights. ***, **, and * indicate significance at 1, 5, and 10 percent.

A3. AWARENESS AND ACCESS TO AFLASIGHT SERVICES AND COB MODEL

257. This section investigates farmers' knowledge of aflatoxin, before reporting the findings on their awareness, understanding and access to the AflaSight Services and Cob model. Moreover, the farmers' perception on the benefits of these technologies are discussed. Finally, an overview is presented of the obstacles that farmers are facing in preventing aflatoxin from infecting their maize.

General knowledge of aflatoxin

258. The evaluation team created a score taking value 0 to 6 to verify farmers' knowledge of aflatoxin at the time of the survey. A score of 6 indicates very good knowledge of aflatoxin while 0 indicates no knowledge of aflatoxin. The score was built based on the following criteria: 1. awareness of aflatoxin; 2. ability to explain what aflatoxin is; 3. knowledge of what causes aflatoxin; 4. recognition of aflatoxin symptoms on maize; 5. knowledge about aflatoxin-related health issues. The highest score is obtained when a farmer has heard of aflatoxin, mentions both mould and toxin when explaining aflatoxin, recognises damp/poorly dried maize, poorly stored maize, or maize touching soil as causes of aflatoxin, reports being able to recognize aflatoxin-infected maize, and knows at least one health issue connected to aflatoxin.

259. Table A - 5 shows that **nearly all farmers have at least some basic awareness of aflatoxin**: only 1.8% of farmers have no knowledge at all. The average score obtained is quite high, at 4.5. The distribution of the scores shows that 33.9% of the farmers achieve lower scores from 1 to 4, but a larger share reach the higher scores of 5 (36.7%) and 6 (27.6%).

260. **Men appear to be significantly more knowledgeable about aflatoxin than women**. Indeed, men attain a higher average score than women (4.7 vs 4.1). The distribution of scores shows that more women than men have no knowledge at all (3.6% vs 0.4%) and obtain the lower score of 3 (16.6% vs 7.7%). Despite more women achieving the score of 5 (42.4%, vs 32.5%), a much larger share of men reach the highest score of 6 (37% vs 15.1%).

Table A - 5. Aflatoxin knowledge score

	N	(1) Total Mean/SE	N	(2) Male Mean/SE	N	(3) Female Mean/SE	t-test Difference (2)-(3)
Knowledge score	399	4.45 [0.10]	199	4.72 [0.13]	200	4.10 [0.14]	0.62***
Score 0	399	0.02 [0.01]	199	0.00 [0.00]	200	0.04 [0.01]	-0.03**
Score 1	399	0.05 [0.01]	199	0.04 [0.02]	200	0.07 [0.02]	-0.03
Score 2	399	0.06 [0.02]	199	0.07 [0.02]	200	0.06 [0.02]	0.01
Score 3	399	0.11 [0.02]	199	0.08 [0.02]	200	0.17 [0.03]	-0.09**
Score 4	399	0.11 [0.02]	199	0.12 [0.03]	200	0.10 [0.02]	0.02
Score 5	399	0.37 [0.03]	199	0.32 [0.04]	200	0.42 [0.04]	-0.10*
Score 6	399	0.28 [0.03]	199	0.37 [0.04]	200	0.15 [0.03]	0.22***

Notes: The value displayed for t-tests are the differences in the means between male and female respondents. Standard errors are robust. Observations are weighted using design weights. ***, **, and * indicate significance at 1, 5, and 10 percent.

261. Table A - 6, Figure A - 3, Figure A - 4 and Figure A - 5 present the results for each of the criteria used to build the score.

262. In terms of criteria 1 and 2**, a large share of farmers** (83.4%) **report having heard of aflatoxin** and **almost all those aware of it can describe aflatoxin** as a mould (33.6%), toxin (8%) or both (57.6%). Those farmers who, during the interview, did not recall hearing the term 'aflatoxin' were provided with a brief description of it. Afterwards, all farmers were asked to indicate the cause of aflatoxin, whether they were able to spot infected maize as well as whether and which health problems aflatoxin led to.

263. With respect to criterion 3, **most farmers correctly identify what causes aflatoxin**, with 82% of the farmers mentioning poorly dried maize and 43.3% of the farmers indicating poor maize storage. A smaller share of farmers (22.7%) also correctly report maize coming into direct contact with soil as one of the causes of aflatoxin. However, some farmers incorrectly believe that aflatoxin is caused by rain (27.6%) or insects (4.4%). In terms of criterion 4, the table shows **that almost all farmers** (96.4%) **believe to be able to spot aflatoxin on maize**. As far as criterion 5 is concerned, **almost all farmers are aware that aflatoxin causes health issues**. Indeed, less than 1% of the farmers does not believe that aflatoxin causes health problems but 27.6% of the farmers is not able to name any specific health issue related to aflatoxin. Farmers seem to associate mostly diarrhoea (40.5%), liver cancer (36.1%) and lung problems (16%) with aflatoxin.

264. In line with the gender difference found in the aflatoxin knowledge score, significant differences are also detected in the criteria just described. More men than women confirm having heard about aflatoxin (87.6% vs 77.9%). More women than men seem to associate aflatoxin with a toxin (15.6% vs 2.9%). A larger share of women also cannot name any causes of aflatoxin (12.9% vs 3.6%), or incorrectly identify rain (42.4% vs 16.4%) and insects (7.3% vs 2.2%) as factors. Among the correct causes of aflatoxin, a larger share of women reports maize touching soil (14.8% vs 28.7%), and a larger share of men mentions poor storage of maize (52.4% vs 31.1%). While most men and women believe they can recognize aflatoxin on maize, more men report being able to do so (98.6% vs 93.4%). More women than men mention stomach pain (32.2% vs 5.6%), diarrhoea (51.9% vs 31.9%) and death (5.3% vs 1.3%) among the aflatoxin related issues, while the reverse is true for liver cancer (26.1% vs 43.6%) and jaundice (0.2% vs 7.1%).

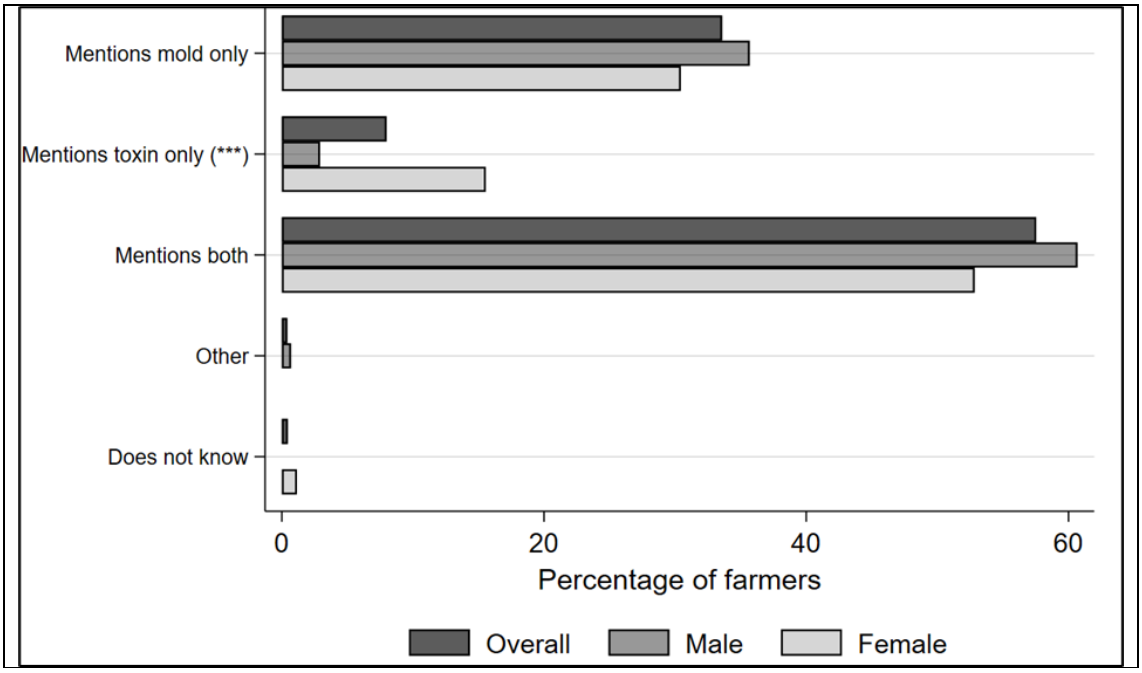
265. Table A - 6 also shows that **almost all farmers** (97.6%) **believe that aflatoxin-free maize is sold at a higher price**. This means that farmers associate aflatoxin-free maize with a higher value and the possibility of obtaining a better selling price for their crop. However, in line with the findings on aflatoxin knowledge, more men than women believe that a higher price is offered for aflatoxin-free maize (99% vs 95.7%).

Table A - 6. Aflatoxin knowledge

	N	(1) Total Mean/SE	N	(2) Male Mean/SE	N	(3) Female Mean/SE	t-test Difference (2)-(3)
Heard of aflatoxin							
Heard about aflatoxin	399	0.83 [0.02]	199	0.88 [0.03]	200	0.78 [0.04]	0.10**
Can recognize aflatoxin-infected maize							
Can tell if maize has aflatoxin by looking at it	399	0.96 [0.01]	199	0.99 [0.01]	200	0.93 [0.02]	0.05**
Price associated with aflatoxin-free maize							
Higher price not offered for aflatoxin-free maize	399	0.02 [0.01]	199	0.01 [0.00]	200	0.04 [0.02]	-0.03*
Higher price offered for aflatoxin-free maize	399	0.98 [0.01]	199	0.99 [0.00]	200	0.96 [0.02]	0.03*
Does not know	399	0.00 [0.00]	199	0.00 [0.00]	200	0.01 [0.00]	-0.00

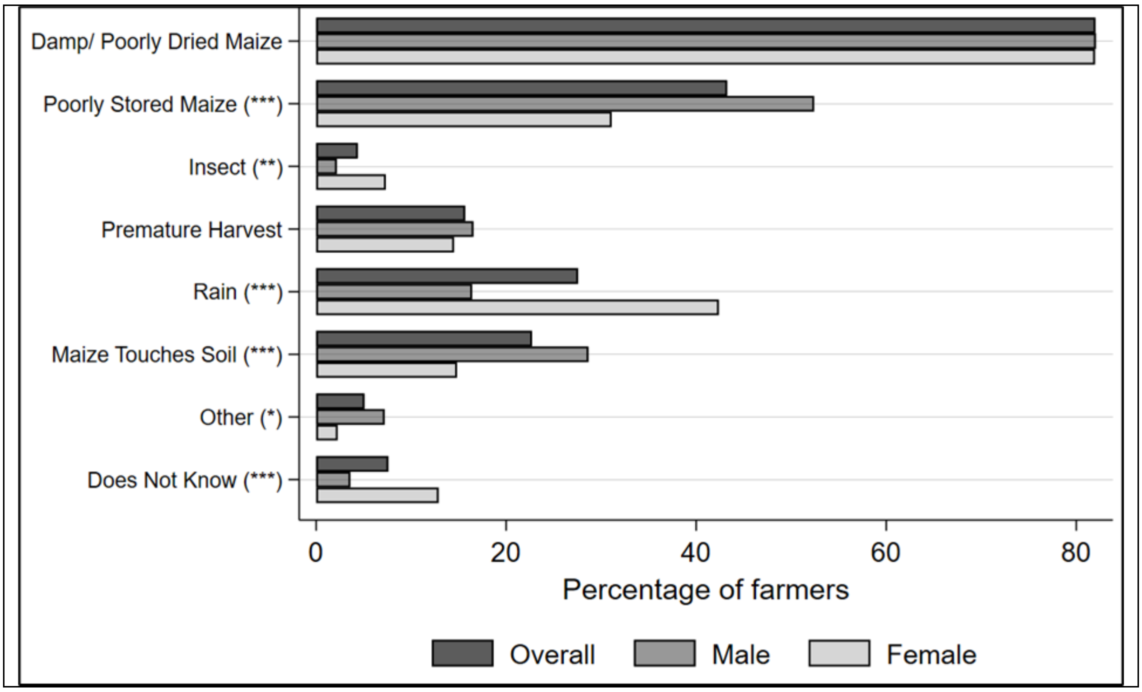
Notes: The value displayed for t-tests are the differences in the means between male and female respondents. Standard errors are robust. Observations are weighted using design weights. ***, **, and * indicate significance at 1, 5, and 10 percent.

Figure A - 3. Explanation of aflatoxin provided by farmers



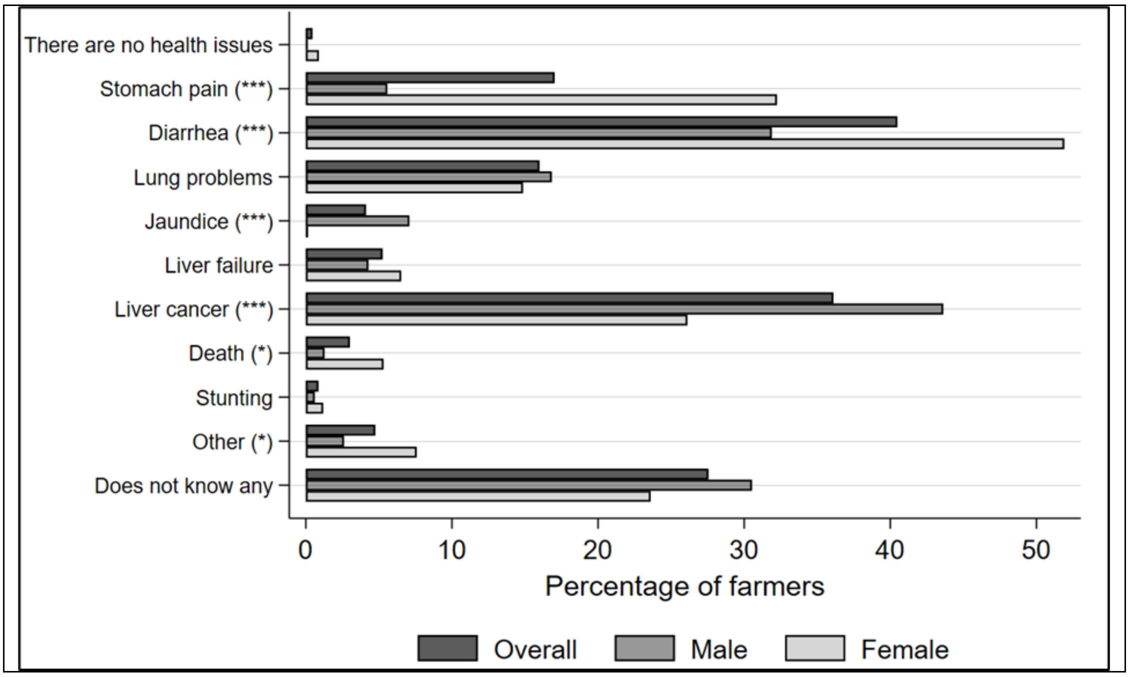
Notes: T-tests for gender differences are performed with robust standard errors. Observations are weighted using design weights. ***, **, and * indicate significance at 1, 5, and 10 percent. Number observations 322; number observations male: 173; number observations female: 159

Figure A - 4. Causes of aflatoxin according to farmers



Notes: T-tests for gender differences are performed with robust standard errors. Observations are weighted using design weights. ***, **, and * indicate significance at 1, 5, and 10 percent. Number observations 399; number observations male: 199; number observations female: 200

Figure A - 5. Aflatoxin-related health issues according to farmers



Notes: T-tests for gender differences are performed with robust standard errors. Observations are weighted using design weights. ***, **, and * indicate significance at 1, 5, and 10 percent. Number observations 399; number observations male: 199; number observations female: 200

Aflatoxin post-harvest risk behaviour

266. The farmers' aflatoxin post-harvest risk behaviour was assessed with a score that takes value 0 to 5. A score of 5 indicates a highly risky behaviour and 0 a non-risky behaviour. The score is based on the following criteria and refers to the practices adopted in season C in 2021: 1. grain drying method; 2. grain moisture measurement; 3. grain sorting; 4. grain treating; 5. grain storing method. The highest score is obtained when grain is dried on the ground, moisture is measured with non-improved methods, grain is not sorted, grain is not treated when not stored in a plastic or metal silo, and grain is stored in regular bags. By construction, this score classifies as non-risky the aflatoxin post-harvest behaviour of farmers who sell all their maize on cob to premium buyers right after shelling using the machine provided by the buyers.

267. As seen in Table A - 7, **farmers show on average a low risky behaviour (score of 1.7) in season C 2021.** With the distribution of scores it is possible to see that 15.8% of the sample have a non-risky behaviour, 65.4% display a low-risky behaviour (scores 1 and 2) and only 18.8% adopt more risky practices (scores of 3 and above).

268. **The gender comparison reveals that men present, on average, a significantly less risky behaviour than women.** Indeed, men achieve on average a lower score of 1.4 compared to women who reach a score of 2.1. When looking at the distribution of scores, the largest share of men achieve up to the low-risk score of 1 and most women obtain the more risky score of 2. While men do not score more than 3, women also reach up to the highest possible (and high-risk) score of 5. Specifically, more men than women adopt a non-risky behaviour (score 0: 20.5% vs 9.7%) or a low-risky behaviour (score 1: 38.1% vs 10.9%). On the other hand, more women than men (56.2% vs 26%) show a slightly risky behaviour (score 2). While no male farmer has a score higher than 3, 10.6% of female farmers adopt a highly risky behaviour (score of 4) and 3.6% show a very highly risky behaviour (score of 5).

Table A - 7. Aflatoxin post-harvest risk behaviour score

	N	(1) Total Mean/SE	N	(2) Male Mean/SE	N	(3) Female Mean/SE	t-test Difference (2)-(3)
Risky behaviour score	399	1.68	199	1.36	200	2.11	-0.74***
		[0.07]		[0.09]		[0.10]	
Score 0	399	0.16	199	0.20	200	0.10	0.11**

	N	(1) Total Mean/SE	N	(2) Male Mean/SE	N	(3) Female Mean/SE	t-test Difference (2)-(3)
		[0.02]		[0.04]		[0.03]	
Score 1	399	0.26	199	0.38	200	0.11	0.27***
		[0.03]		[0.04]		[0.03]	
Score 2	399	0.39	199	0.26	200	0.56	-0.30***
		[0.03]		[0.04]		[0.04]	
Score 3	399	0.13	199	0.15	200	0.09	0.06
		[0.02]		[0.03]		[0.03]	
Score 4	399	0.05	199	0.00	200	0.11	-0.11***
		[0.01]		[0.00]		[0.03]	
Score 5	399	0.02	199	0.00	200	0.04	-0.04**
		[0.01]		[0.00]		[0.01]	

Notes: The value displayed for t-tests are the differences in the means between male and female respondents. Standard errors are robust. Observations are weighted using design weights. ***, **, and * indicate significance at 1, 5, and 10 percent.

269. Results for each of the criteria used to build the score are presented in Table A - 8, Figure A - 6, Figure A - 7 and Figure A - 8. The findings show that **most farmers who dry their grain use adequate methods for drying, and follow the correct practice of sorting the grain before storing.** However, **only about half of farmers** who dry their grain **use reliable systems to decide when to stop drying and treat grain before** storing (when not storing in plastic or metal silo). Moreover, **most farmers who store grain use the non-so-optimal regular bags.**

270. A very large share of farmers who dry their grain in season C 2021 use canvas/tarpaulinas (81%) and some farmers dry their grain in hangals, at the aggregation centre or collection centre (13.5%). Only 8.5% adopt the non-optimal method of drying grain on the ground (criterion 1). Figure A - 8 reveals, in terms of criterion 2, a widespread use of moisture meters, a very reliable method to decide when to stop drying (43.5%). However, the adoption of other reliable methods is low; 3.4% have a sample of their grain checked by an extension officer or buyer, 5.6% report that their cooperative monitors the drying, 1.4% use the salt and bottle method. At the same time, less adequate methods continue to be adopted, such as grain texture when bitten (41.1%), grain appearance (26.9%), or listening to the cracking sound when grain is dropped (21.1%). With regard to criterion 3, almost all farmers who do not sell their grain to a premium buyer right after shelling using the machine provided by the buyer, correctly sort their grain (96.6%). Yet only half of them adopt the correct practice of treating their grain before storage (45.9%), when not storing grain in plastic or metal silos (criterion 4). Concerning criterion 5, almost all farmers who store their grain in season C 2021, use the least optimal method, that is regular bags.

271. Several statistically significant gender differences are found in terms of the criteria illustrated above. **Consistently with the higher risk behaviour score obtained by women, it also appears that more women than men use inadequate methods to dry and store their grain as well as determining when to stop drying the grain.**

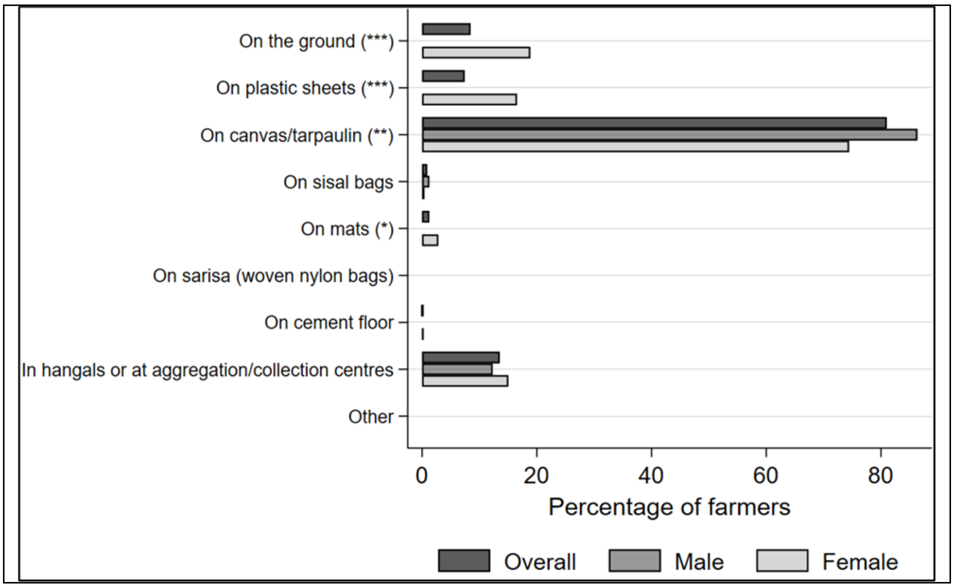
272. While none of the male farmers dry their grain on the ground, or using plastic sheets or mats, both reliable methods, 18.9% of female farmers use the first unreliable method, 16.6% use the second one, and 28.5% the third one. On the other hand, more men (86.4%) than women (74.5%) correctly use canvas or tarpaulinas. Regarding the reliable methods available to determine when to stop drying grain, a much larger share of men than women use moisture meters (59.4% vs 23.9%) and a slightly larger share of women take a sample to the extension officer or buyer to check (6.8% vs 0.5%), or use the salt and bottle method (2.8% vs 0.3%). More female cooperative members follow the unreliable practices of waiting for the usual length of time it takes (17.8% vs 1.3%), shaking the grain (17.6% vs 0.4%), listening to the cracking sounds after dropping the grain (32.7% vs 11.6%), putting a hand in the bag (16.7% vs 1.9%), biting the grain (55.5% vs 30%), and looking at colour (17.8% vs 1.1%) or appearance of the grain (52.5% vs 6.1%). Also, more men than women who do not sell their grain to premium buyer right after shelling display a correct behaviour of sorting their grain (98.4% vs 94.4%). More women than men incorrectly use regular bags to store grain (98.6% vs 93.6%). On the other hand, more men than women use the appropriate storage methods of plastic silo (5.3% vs 0%) and metal silo (3.7% vs 0%).

Table A - 8. Variables determining aflatoxin post-harvest risky behaviour score

	N	(1) Total Mean/SE	N	(2) Male Mean/SE	N	(3) Female Mean/SE	t-test Difference (2)-(3)
Sorts grain in season C 2021	368	0.97	178	0.98	190	0.94	0.04**
		[0.01]		[0.01]		[0.02]	
Treats maize grain in season C 2021 (no storing in silo)	361	0.46	171	0.50	190	0.41	0.10
		[0.03]		[0.05]		[0.04]	

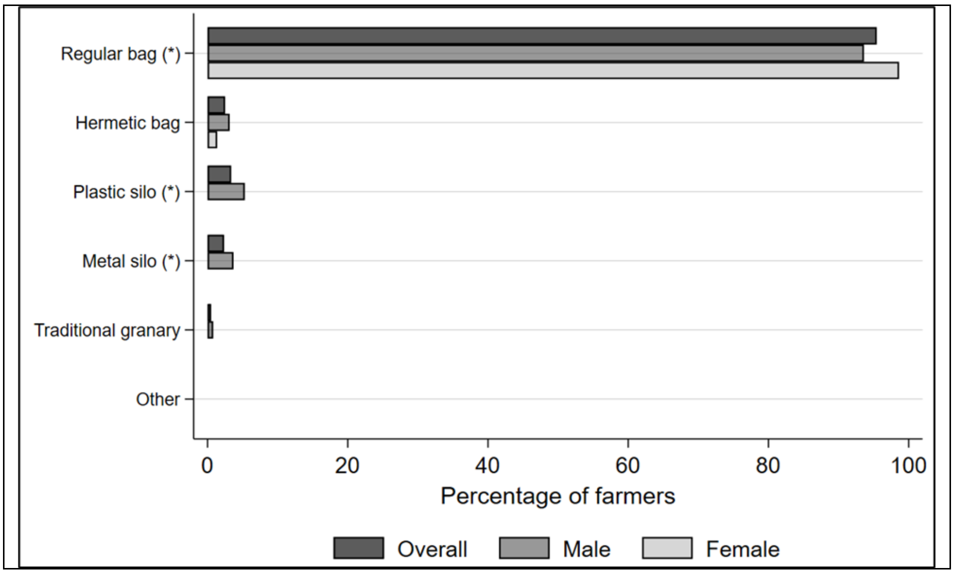
Notes: The value displayed for t-tests are the differences in the means between male and female respondents. Standard errors are robust. Observations are weighted using design weights. ***, **, and * = significance at 1, 5, and 10 percent.

Figure A - 6. Methods for drying grain in season C 2021



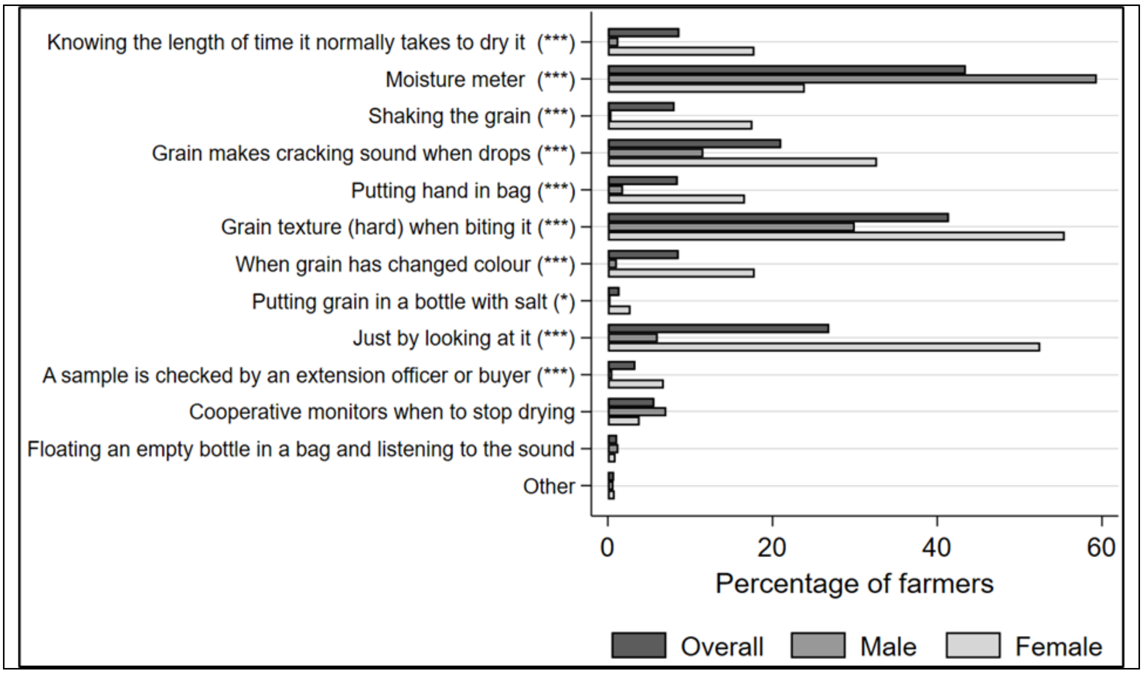
Notes: T-tests for gender differences are performed with robust standard errors. Observations are weighted using design weights. ***, **, and * indicate significance at 1, 5, and 10 percent. Number observations 362; number observations male: 174; number observations female: 188

Figure A - 7. Equipment used for storing in season C 2021



Notes: T-tests for gender differences are performed with robust standard errors. Observations are weighted using design weights. ***, **, and * indicate significance at 1, 5, and 10 percent. Number observations 196; number observations male: 109; number observations female: 87

Figure A - 8. Methods used to decide when to stop drying in season C 2021



Notes: T-tests for gender differences are performed with robust standard errors. Observations are weighted using design weights. ***, **, and * indicate significance at 1, 5, and 10 percent. Number observations 362; number observations male: 174; number observations female: 188

Awareness and understanding of AflaSight Services and Cob model

273. This sub-section presents farmers' awareness as well as understanding of the AflaSight services and Cob model, as showed in Table A - 9 below. Awareness was assessed by whether farmers had heard about each of these models. Understanding was assessed by whether farmers mentioned certain key words when describing the two models.

274. **It appears that farmers are much more aware of the Cob model as opposed to the AflaSight services, as it was to be expected.** The table reveals that on average, 18.9% of farmers were aware of AflaSight services. Almost all of those farmers who were aware of AflaSight services (93.3%), also demonstrated an understanding of the services. In the case of the Cob model, Table A - 9 reveals that while most farmers (92.9%) were aware of the model, 99.2% of these farmers showed an understanding of the model.

275. **This is consistent with the timing of the information campaigns about AflaSight at cooperative and smallholder farmer levels.** FtMA informed the leadership of the four cooperatives about AflaSight only in the first week of the survey (29 November – 3 December 2021), and smallholder farmers were only informed thereafter in general assemblies of their cooperatives. Purchases of premium buyers from coops started in the second week of December 2021. The chances that smallholder farmers had already heard of AflaSight (18.9% percent, see previous paragraph) or reported that some of their maize had already passed through the machine (3.1%, see further below) by the time they were interviewed were thus low.

276. Several gender differences in Table A - 9 are also worth highlighting. In the case of awareness of AflaSight services, 26.8% of male farmers and 8.3% of female farmers were aware of them. More women than men, however, also demonstrated an understanding (100% vs 91.7%). In the case of the Cob model, more men than women were aware of the model (95.9% vs 88.8%).

Table A - 9. Awareness and understanding of AflaSight services and Cob model

	N	(1) Total Mean/SE	N	(2) Male Mean/SE	N	(2) Female Mean/SE	t-test Difference (1)-(2)
Awareness of AflaSight services (Dummy)	399	0.19 [0.03]	199	0.27 [0.04]	200	0.08 [0.02]	0.18***

	N	(1) Total Mean/SE	N	(2) Male Mean/SE	N	(2) Female Mean/SE	t-test Difference (1)-(2)
Understanding of AflaSight services (Dummy)	68	0.93 [0.04]	49	0.92 [0.05]	19	1.00 [0.00]	-0.08*
Awareness of Cob model (Dummy)	399	0.93 [0.01]	199	0.96 [0.02]	200	0.89 [0.03]	0.07**
Understanding of Cob model (Dummy)	362	0.99 [0.00]	189	1.00 [0.00]	173	0.99 [0.01]	0.01

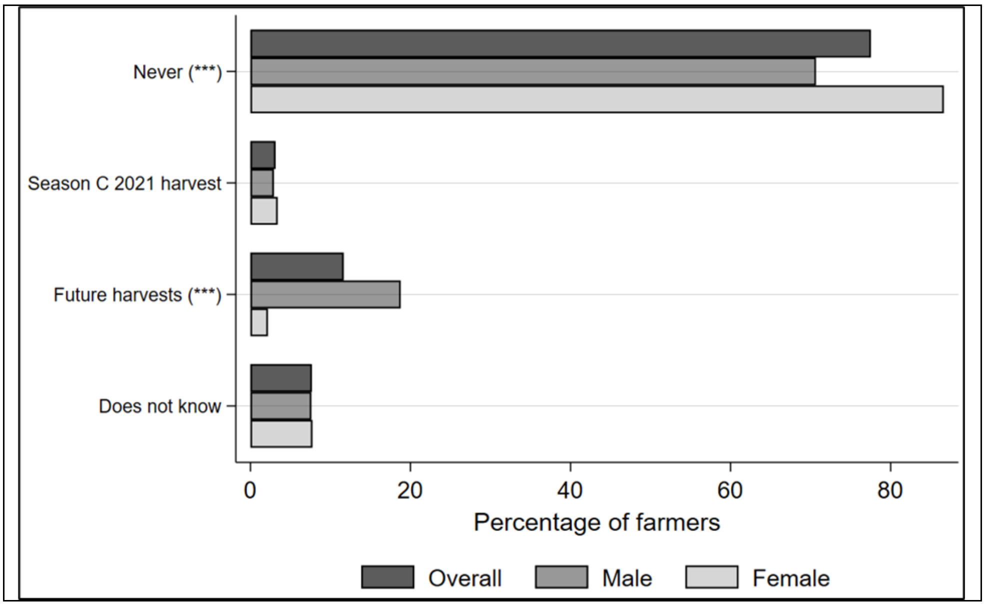
Notes: The value displayed for t-tests are the differences in the means between male and female respondents. Standard errors are robust. Observations are weighted using design weights. ***, **, and * = significance at 1, 5, and 10 percent.

Access to AflaSight services and Cob model

277. Figure A - 9 below reports access to both AflaSight services and the Cob model. Access was assessed by asking farmers whether or not they have used either model during the current season C harvest. For the case of the Cob model, access was assessed for both the current season C harvest as well as for past harvests. In the event that farmers were not aware of either technology, the enumerators provided first a brief description. The figure reveals that, **at the time of the survey, the vast majority of farmers report not having used AflaSight services yet**. Specifically, 77.5% of farmers report that they have never used the services. For the current season C harvest, only 3.1% farmers report that their season C grain is passed through the AflaSight services. Similarly, only a small share of farmers (11.7%), state that their grain will be passed through the AflaSight services in the future. Interestingly, a larger share of female farmers (86.7% vs 70.7% for male farmers) indicate that they have not used AflaSight services in Season C and do not expect to do so in the future. Accordingly, a larger share of male farmers (18.8%) believe that their grain will be passed through the AflaSight services in the future relative to female farmers (2.2%).

278. However, as outlined in paragraph 275, the **FtMA information campaigns about AflaSight, and premium buyer purchases of Season C maize, only started when the data collection for the survey was ongoing.** This explains the very low number (18 observations) of AflaSight users/adopters in the survey sample. The subsequent **results on AflaSight hence omit this small 'adopter' sub-sample** and only present results for the large majority of survey respondents who claim to not have used AflaSight yet.

Figure A - 9. Access to AflaSight services

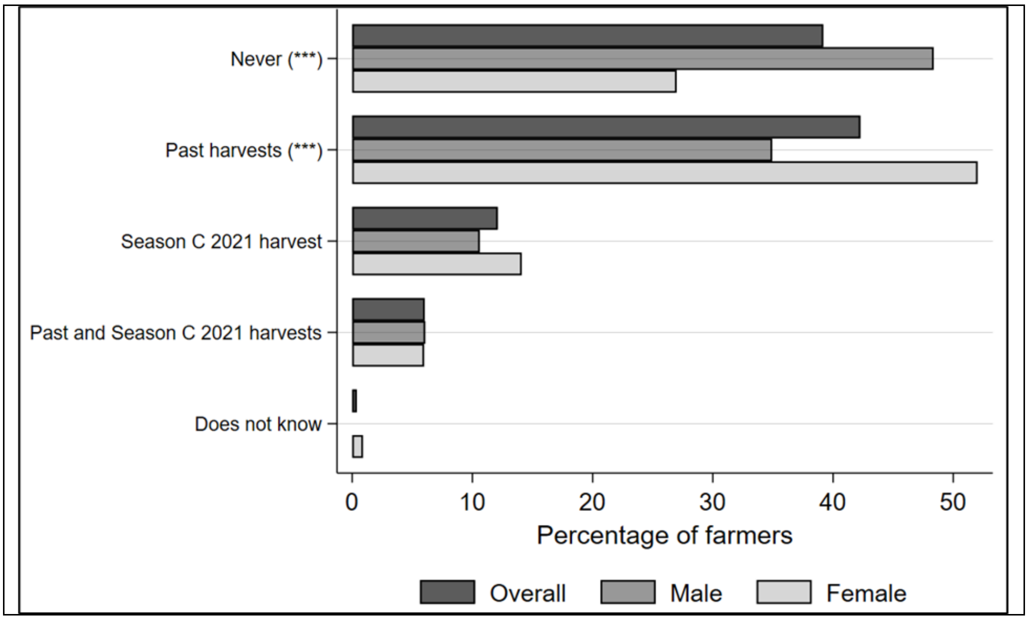


Notes: T-tests for gender differences are performed with robust standard errors. Observations are weighted using design weights. ***, **, and * indicate significance at 1, 5, and 10 percent. Number observations 399; number observations male: 199; number observations female: 200

279. **The situation is different for the Cob model,** which was already used in previous seasons, allowing to **distinguish Cob model adopters and non-adopters**, both with sufficiently large sub-samples.

280. Figure A - 10 reveals that 39.2% of farmers report never having used the Cob model, but that **just over 40% of farmers report having used it for past harvests and 12.1% for** current season C harvest. 6% report to have used the Cob model both in past harvests and current season C. Again, the low share of Cob model users in the current Season C may have been affected by the fact that premium buyer purchases only started during the survey data collection and not all cooperatives and smallholder farmers had already decided whether they would sell on cob or grain when they were interviewed.A larger share of male farmers (48.4%), report never having used the Cob model relative to female farmers (27%), while a larger share of female farmers report having used it for past harvests only (52% vs 34.9% of male farmers).

Figure A - 10. Access to Cob model



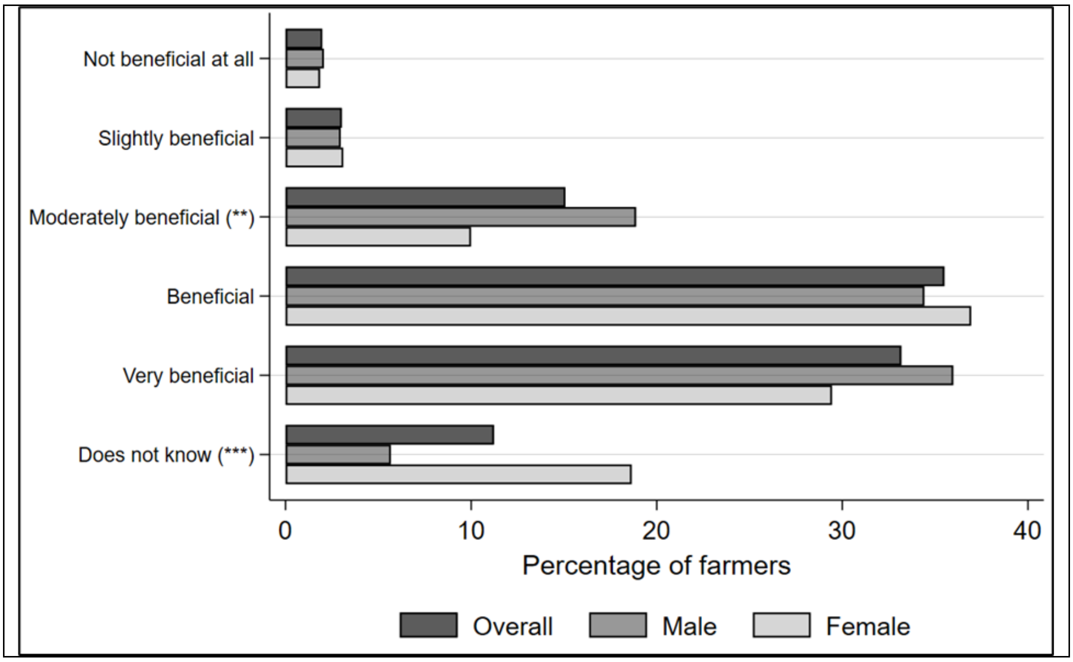
Notes: T-tests for gender differences are performed with robust standard errors. Observations are weighted using design weights. ***, **, and * indicate significance at 1, 5, and 10 percent. Number observations 399; number observations male: 199; number observations female: 200

Perception of AflaSight services and Cob model

281. Figure A - 11 presents perception towards AflaSight services, for those farmers who report not having access to AflaSight services in season C 2021 (non-adopters). The figure reveals that **the majority of the farmers who have not used AflaSight yet believe that it would be beneficial or very beneficial**. Indeed, very few farmers (2.1%) report that they would find AflaSight services not beneficial at all, while roughly 3% consider the services slightly beneficial. A larger share of farmers (15.1%) report that they would find AflaSight services moderately beneficial, with gender differences in the perception that AflaSight services are moderately beneficial (18.9% for male and 10% for female farmers). Similarly, an even larger share of farmers report that they would find the services beneficial and very beneficial (35.5% and 33.2%, respectively).

282. A description of the perceptions of farmers towards the Cob model is presented next. To this end, Figure A - 12 below presents a description of farmers' perceptions towards of the model, for those farmers that report having used it either in the current season, past seasons or both (adopters). **The majority of farmers with access to the technology do not seem to have a positive perception of the Cob model, considering it not beneficial at all or only slightly beneficial.** Specifically, the figure reveals that close to half of farmers with access to the Cob model (44.6%), do not find the model beneficial at all. Similarly, 25.8% of farmers with access to the Cob model report finding the model only slightly beneficial, while only 8.2% find the model moderately beneficial. Very few farmers with access perceive the Cob model (12.3% and 6.7%, respectively) to be beneficial and very beneficial, respectively.

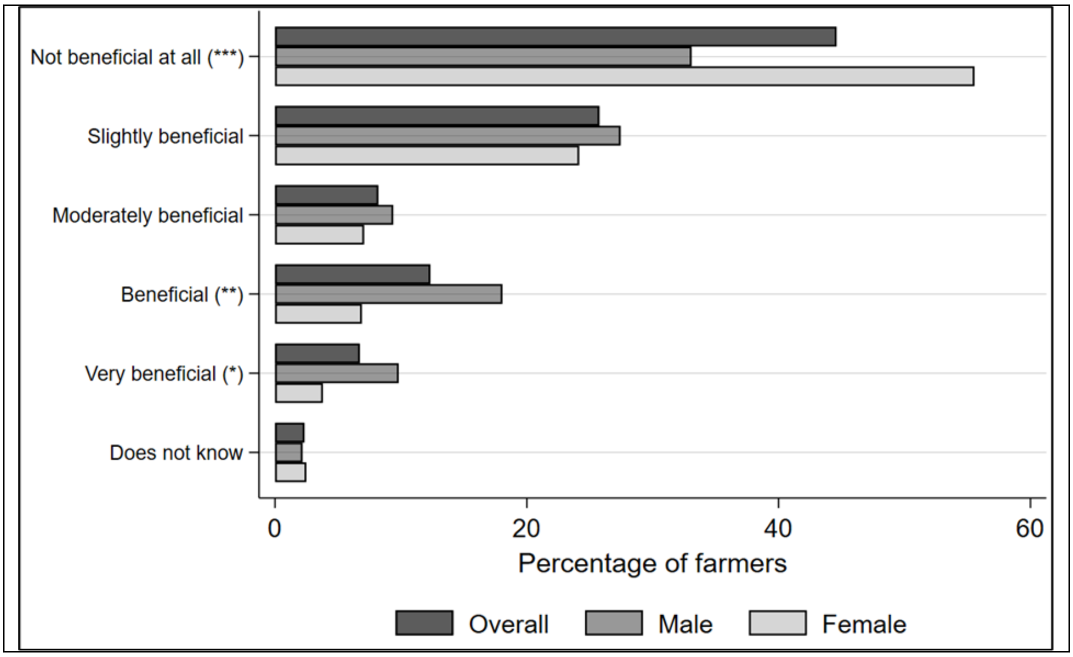
Figure A - 11. Perception of AflaSight services (non-adopters)



Notes: T-tests for gender differences are performed with robust standard errors. Observations are weighted using design weights. ***, **, and * indicate significance at 1, 5, and 10 percent. Number observations 381; number observations male: 192; number observations female: 189

283. Several gender differences in the perceptions of farmers with access to the Cob model are statistically significant and thus worth highlighting. **Male farmers seem to have a slightly more positive perception of the Cob model compared to female farmers.** A larger share of female relative to male farmers perceive the model to be not beneficial at all (55.6% vs 33.1%). In contrast, a larger share of male relative to female farmers with access, perceive the model Cob model to be beneficial (18.1% vs 6.9%). Similarly, a larger share of male farmers with access perceive the Cob model to be very beneficial relative to female farmers (9.8% vs 3.8%).

Figure A - 12. Perception of Cob model (adopters)

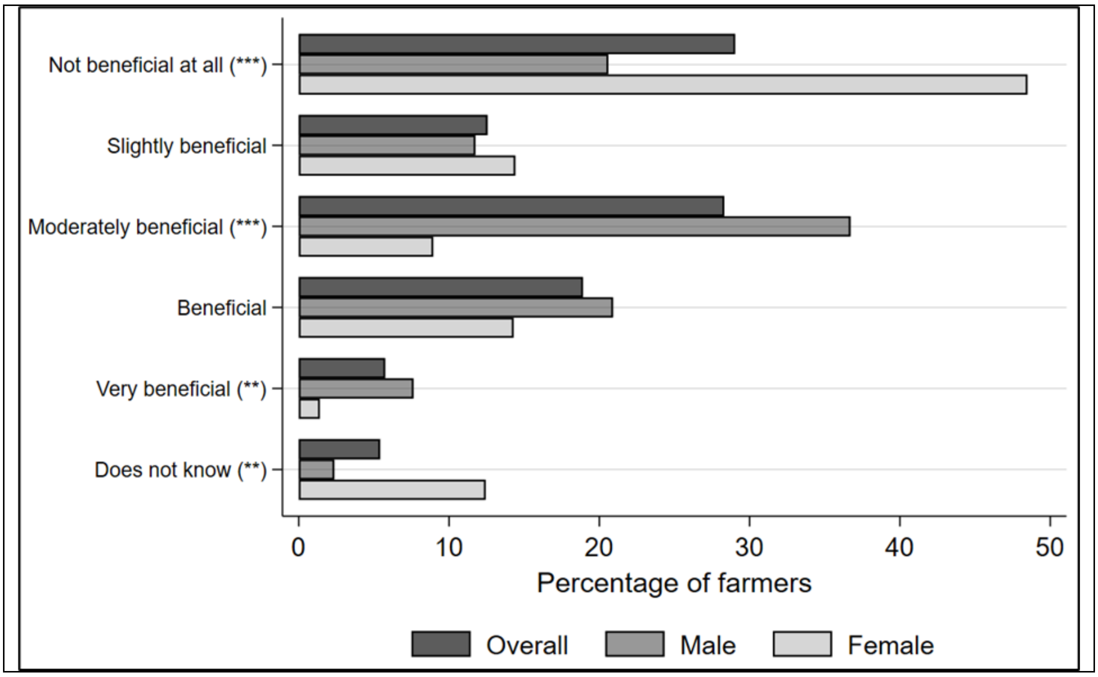


Notes: T-tests for gender differences are performed with robust standard errors. Observations are weighted using design weights. ***, **, and * indicate significance at 1, 5, and 10 percent. Number observations 245; number observations male: 110; number observations female: 135

284. Several gender differences in the perceptions of farmers with access to the Cob model are statistically significant and are thus highlighted. Also here **male farmers show a more positive attitude towards the Cob model**. The share of female farmers with no access reporting that they perceive the Cob model as not being beneficial at all is over twice as larger as the share of male farmers (48.5% vs 20.6%). Consistently, more male farmers with no access to the model report perceiving the Cob model as moderately beneficial (36.7% vs 9%) and very beneficial (7.6% vs 1.4%).

285. The perceptions of farmers with no access to the Cob model (non-adopters) are presented in Figure A - 13 below. **In this case as well, a majority of farmers with no access to the model do not seem to have a positive perception of the model, considering it not beneficial at all or only moderately beneficial.** Specifically, close to 30% of the farmers perceive the Cob model as not being beneficial at all. Only 12.6% of the farmers perceive the model as being slightly beneficial, while about double this figure (28.3%) perceive the model to be only moderately beneficial. A relatively smaller share of the farmers (18.9% and 5.8%, respectively) perceive the model to be either beneficial or very beneficial.

Figure A - 13. Perception of Cob model (non-adopters)



Notes: T-tests for gender differences are performed with robust standard errors. Observations are weighted using design weights. ***, **, and * indicate significance at 1, 5, and 10 percent. Number observations 154; number observations male: 89; number observations female: 65

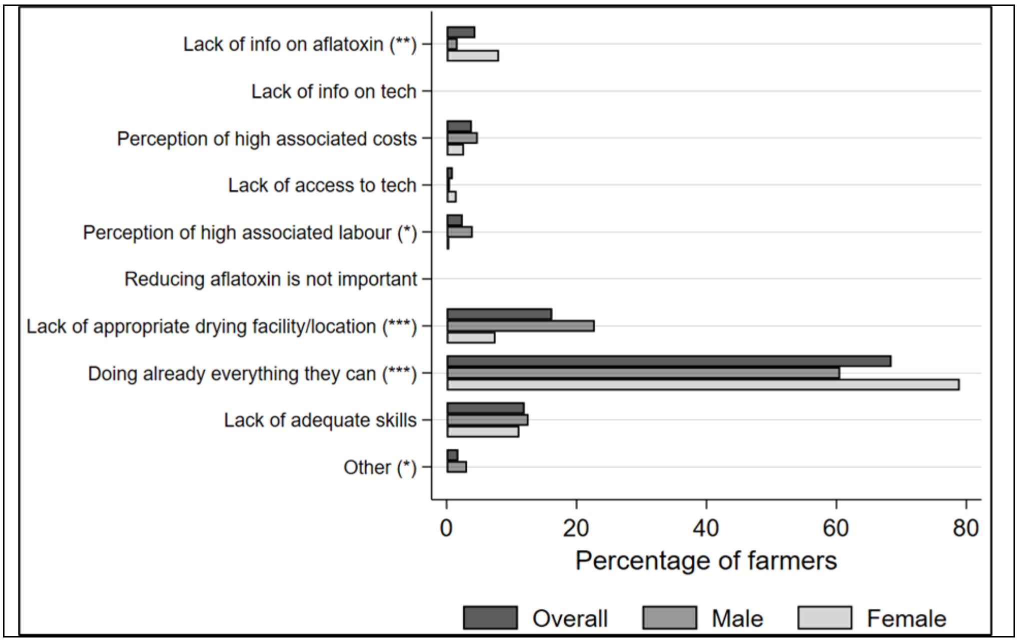
Obstacles to aflatoxin prevention

286. Figure A - 14 and Figure A - 15 below illustrate the obstacles that seem to be preventing farmers as well as their cooperatives from adopting aflatoxin prevention practices. Generally, **the majority of the farmers believe that both they as well as their cooperatives are already doing everything they can to prevent aflatoxin from infecting their maize.** Examination of Figure A - 14 reveals that close to 70% of farmers (68.5%) believe that they are already doing everything they can to prevent aflatoxin. A small share of farmers only report that they are facing some obstacles. Namely, lack of appropriate drying facility or location is reported as one of the main barriers by 16.2% of farmers; lack of adequate skills is pointed out by 12% of farmers; lack of information on aflatoxin is identified as one of the factors by 4.4% of farmers; high associated costs and labour are recognized by 3.9% and 2.5% of farmers, respectively. Farmers also report a lack of access to technology (0.9%) as another obstacle to adopting aflatoxin prevention practices.

287. Figure A - 14 also reports some gender differences in obstacles adopting aflatoxin prevention practices. A larger share of female farmers report that they are doing everything they can to prevent aflatoxin relative to male farmers (79% vs 60.6%). Similarly, a larger share of female farmers also report a lack of information on aflatoxin as an obstacle (8.1% vs 1.7% for male farmers). These results are consistent with female farmers' lower knowledge of aflatoxin as opposed to male farmers. However, in the case of a lack of

appropriate drying facility or location, this appears to be more of an obstacle for male farmers (22.8% vs 7.5% for female farmers).

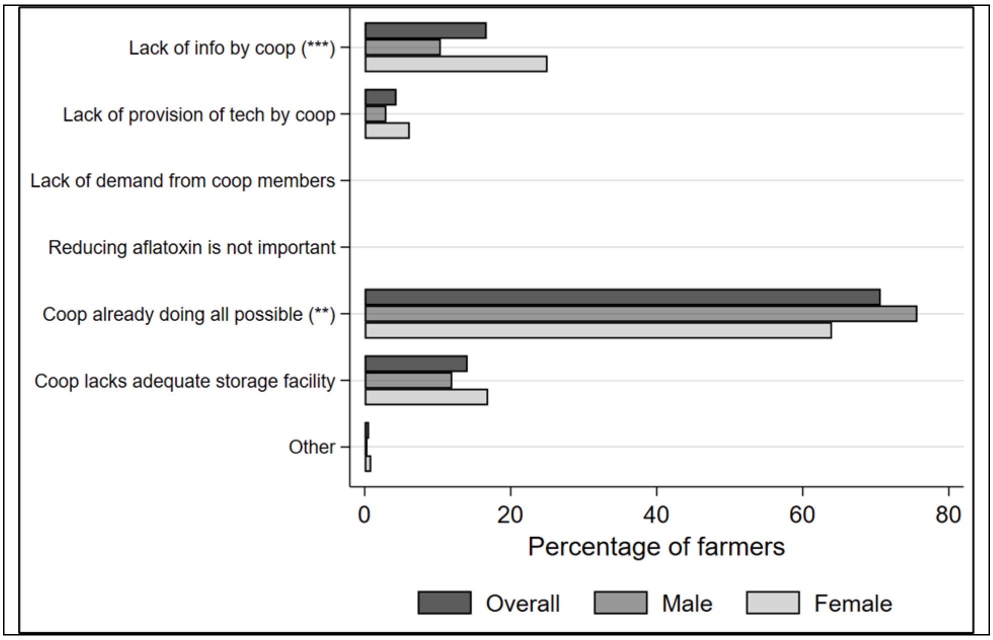
Figure A - 14. Obstacles for farmers to aflatoxin prevention



Notes: T-tests for gender differences are performed with robust standard errors. Observations are weighted using design weights. ***, **, and * indicate significance at 1, 5, and 10 percent. Number observations: 399; number observations male: 199; number observations female: 200

288. Figure A - 15 shows that the largest share of farmers believe that cooperatives are already doing everything they can to prevent aflatoxin (70.7%). However, poor dissemination of information on aflatoxin by the cooperatives features among the most problematic obstacles to aflatoxin prevention practices, reported by 16.7% of farmers. This is followed by lack of adequate storage space at the cooperative facilities which is reported by 14.1% of farmers. A considerably smaller share of farmers (4.4%), cite a lack of technology provision by their cooperative as an obstacle impeding the adoption of the prevention practices.

Figure A - 15. Obstacles for cooperatives to aflatoxin prevention



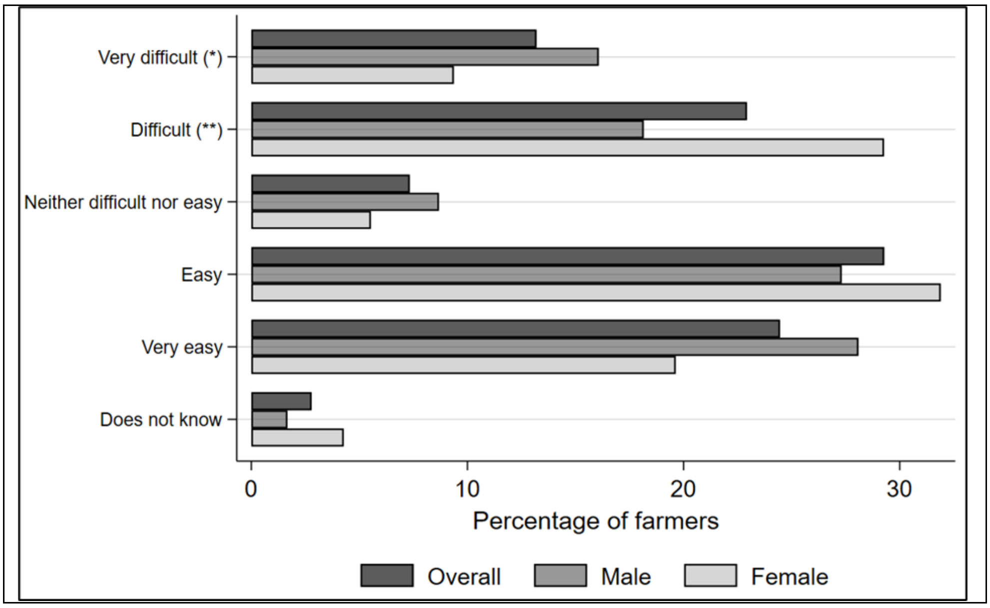
Notes: T-tests for gender differences are performed with robust standard errors. Observations are weighted using design weights. ***, **, and * indicate significance at 1, 5, and 10 percent. Number observations: 399; number observations male: 199; number observations female: 200

289. Figure A - 15 also reveals several gender differences in the obstacles reported to be constraining cooperatives adopting aflatoxin prevention practices. Considerably more male farmers believe that cooperatives are already doing everything they can to prevent aflatoxin (75.7% vs 64% of female farmers). In line with the results of the aflatoxin knowledge score, a larger share of female relative to male farmers report poor dissemination of information on aflatoxin by the cooperatives as an obstacle (25.1% vs 10.4%).

290. Farmers were also asked to indicate how difficult they find prevention of aflatoxin. Figure A - 16 reveals that **the majority of farmers find aflatoxin reduction easy or very easy**. Specifically, 13.2% of farmers report finding aflatoxin prevention very difficult, while 22.9% reporting finding it difficult. Less than 10% of farmers report finding aflatoxin prevention neither easy nor difficult. The largest share of farmers report finding aflatoxin prevention easy or very easy (29.3% and 24.5%, respectively).

291. More male farmers report finding aflatoxin prevention very difficult, relative to the female farmers reporting a similar experience (16.1% vs 9.4%). At the same time, more female farmers report finding aflatoxin prevention difficult (29.3% vs 18.2% for male farmers).

Figure A - 16. Level of difficulty in aflatoxin reduction



Notes: T-tests for gender differences are performed with robust standard errors. Observations are weighted using design weights. ***, **, and * indicate significance at 1, 5, and 10 percent. Number observations: 399; number observations male: 199; number observations female: 200

A4. CHANGES IN AGRICULTURAL AND POST-HARVEST PRACTICES

292. This section describes first farmers' aflatoxin prevention measures in season C 2021. Thereafter, the section explores any changes that farmers have implemented or might implement in their agricultural and post-harvest practices following the actual or potential adoption of the technologies illustrated above. An overview of the advantages of the technologies identified by farmers is then provided. Finally, the section outlines the support that farmers have received from FtMA and how it has affected their ability to grasp financial and non-financial gains from maize.

Changes in agricultural and post-harvest practices due to AflaSight services

293. An assessment of the adoption of aflatoxin prevention measures as well as the specific measures adopted is presented below in Table A - 10 and Figure A - 17. **Similar to season C 2020, the vast majority of farmers (94.8%) report adopting aflatoxin prevention measures, with proper drying being the most common aflatoxin prevention measure**. Also similar to season C 2020, a higher share of male farmers adopt aflatoxin prevention practices (97.6% vs 91.1% female).

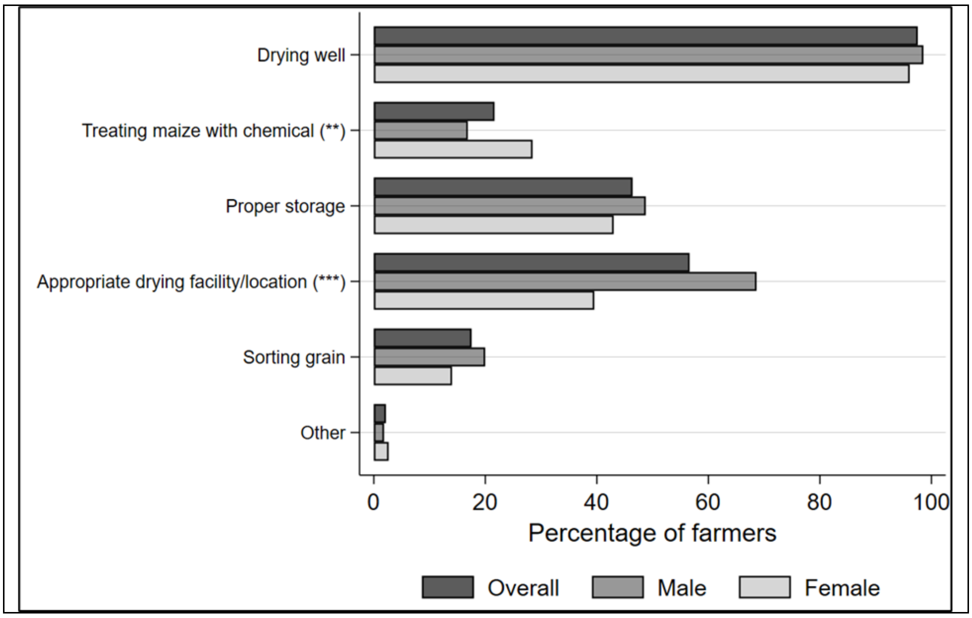
Table A - 10. Adoption of aflatoxin prevention measures (season C 2021)

	N	(1) Total Mean/SE	N	(2) Male Mean/SE	N	(3) Female Mean/SE	t-test Difference (2)-(3)
Used post-harvest prevention measures in season C 2021 (dummy)	399	0.95 [0.01]	199	0.98 [0.01]	200	0.91 [0.02]	0.06**

Notes: The value displayed for t-tests are the differences in the means between male and female respondents. Standard errors are robust. Observations are weighted using design weights. ***, **, and * = significance at 1, 5, and 10 percent.

294. Figure A - 17 shows the specific types of aflatoxin prevention measures most adopted by farmers in the current season C. The figure reveals that virtually all farmers (97.6%), indicate proper drying as the top aflatoxin prevention measure. The next most adopted methods are the use of an appropriate drying facility or location (56.6%) and proper storage (46.4%). Farmers mention relatively less often treating maize with a chemical (21.7%) and sorting of the maize grain (17.5%). Just like for season C 2020, a larger share of female farmers treat maize with a chemical (28.5% vs 16.9% of male farmers) and a larger share of male farmers use an appropriate drying facility or location (68.6% vs 39.5% of female farmers) to avoid aflatoxin.

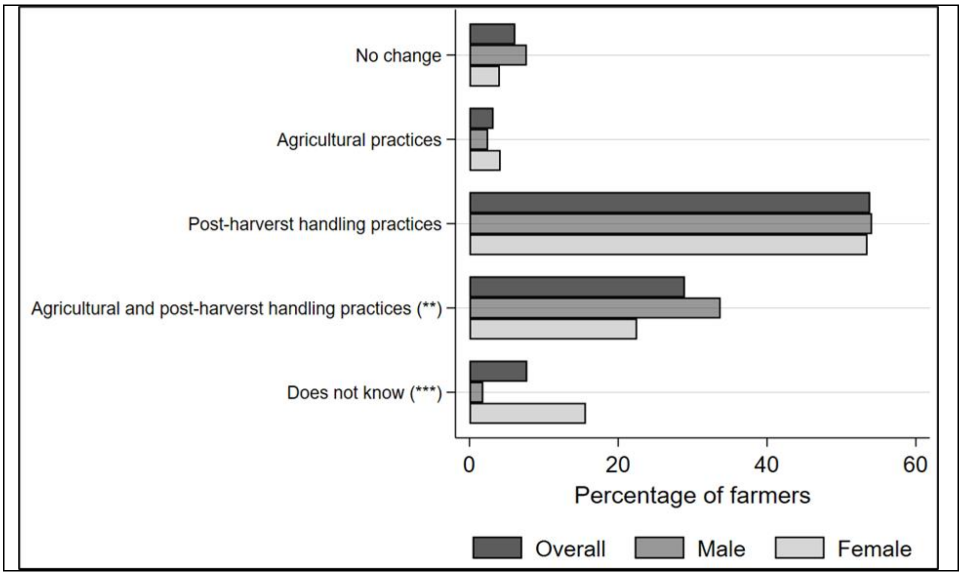
Figure A - 17. Aflatoxin prevention measures used in season C 2021



Notes: T-tests for gender differences are performed with robust standard errors. Observations are weighted using design weights. ***, **, and * indicate significance at 1, 5, and 10 percent. Number observations: 374; number observations male: 190; number observations female: 184.

295. Figure A - 18 reveals that the majority of those farmers who report not having adopted AflaSight services would change their post-harvest handling practices if they used the technology. Specifically, only small shares of the farmers report no change in either their agricultural or post-harvest handling practices or that they would change their agricultural practices (6.2% and 3.2%, respectively). On the other hand, much larger shares of farmers indicate that they would change their post-harvest handling practices (53.9%) or both their agricultural and post-harvest handling practices (29%) if they had access to the technology. Given the nature of the AflaSight services, this finding is not surprising and would seem to be driven by the relatively larger share of male farmers relative to female farmers (33.8% vs 22.5%).

Figure A - 18. Farmers' perception on changes in agricultural and post-harvest procedures if AflaSight services were adopted (non-adopters)



Notes: T-tests for gender differences are performed with robust standard errors. Observations are weighted using design weights. ***, **, and * indicate significance at 1, 5, and 10 percent. Number observations: 381; number observations male: 192; number observations female: 189

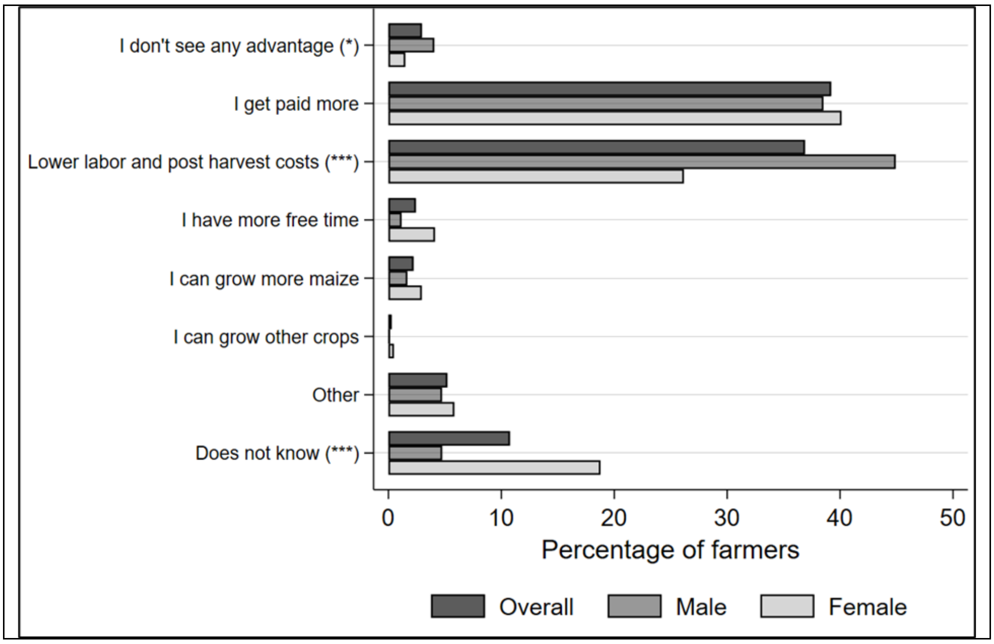
Advantages of AflaSight services and Cob model

296. Adopting and non-adopting farmers of AflaSight services or the Cob model were also asked what they perceived to be the main advantage of using either model, respectively. A discussion of the reported benefits begins in Figure A - 19 below. **Farmers perceive being paid more and accruing lower labour and other post-harvest costs as the potential main advantages of adopting AflaSight services**. Approximately equal shares of farmers report either of the above as potential benefits (39.2% and 36.9%, respectively). Less than 5% of farmers report other potential reasons which include, having more free time; being able to grow more maize and being able to grow other crops, respectively.

297. The perception of lower labour and other post-harvest costs owing to would seem to be driven more by male farmers (44.9% vs 26.2% of female farmers). Similarly, a larger share of male farmers report that they would not see any advantage from the adoption of AflaSight services (4.1% vs 1.5% of female farmers).

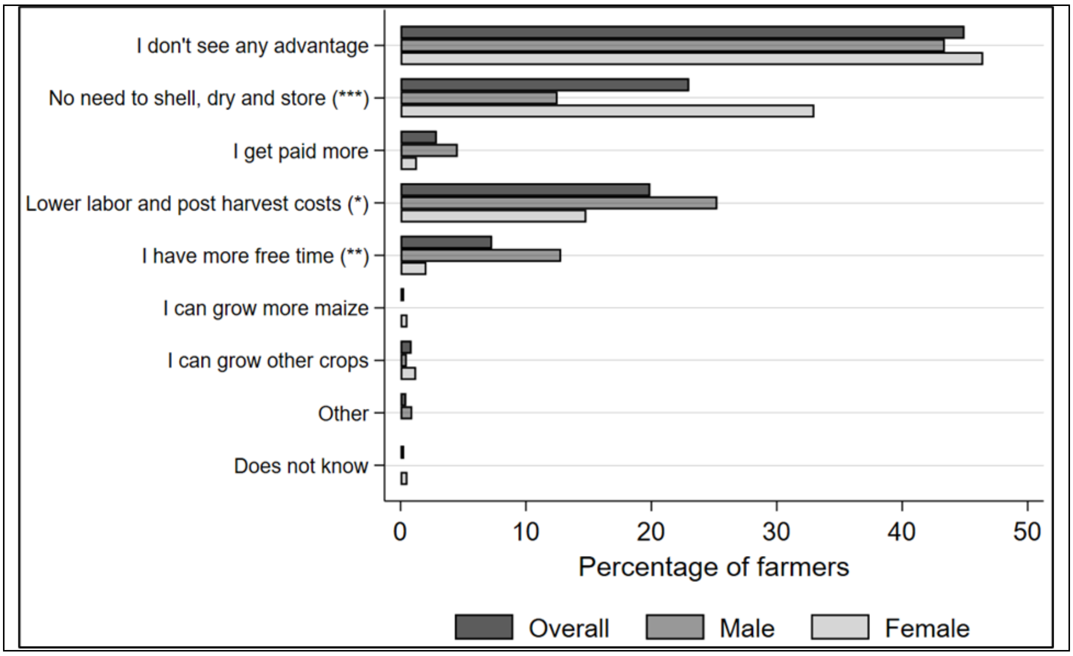
298. For the case of farmers adopting the Cob model, the main advantages of the model, in the farmers' perspective, are contained in Figure A - 20 below. **Close to half of farmers adopting the Cob model report that they do not perceive any particular advantage arising from using the model.** Indeed, this is the case for approximately 45% of these farmers, while 23% report no need to shell, dry and store maize as a perceived benefit of the model. A similar share of farmers (19.9%) report lower labour and other post-harvest costs as an advantage of the model. Approximately 10% of farmers mention other benefits such as being paid more; having more free time; being able to grow more maize and being able to grow other crops, respectively. The perception of lack of need to shell, dry and store maize as a benefit would seem to be driven more by female farmers (33% vs 12.5% for male farmers). However, perception of lower labour and other post-harvest costs as well as more free time owing to adopting the Cob model would seem to be driven more by male than by female farmers (25.3% vs 14.8% and 12.8% vs 2.1% respectively).

Figure A - 19. Farmers' perception of main advantage of AflaSight services (non-adopters)



Notes: T-tests for gender differences are performed with robust standard errors. Observations are weighted using design weights. ***, **, and * indicate significance at 1, 5, and 10 percent. Number observations: 381; number observations male: 192; number observations female: 189

Figure A - 20. Farmers' perception of main advantage of Cob model (adopters)



Notes: T-tests for gender differences are performed with robust standard errors. Observations are weighted using design weights. ***, **, and * indicate significance at 1, 5, and 10 percent. Number observations: 245; number observations male: 110; number observations female: 135

299. Figure A - 21 below shows the perceptions of the main advantages according to the non-adopters of the Cob model. The **majority of non-adopting farmers report that they don't see any benefit of the Cob model (33.8%) or perceive lower labour and post-harvest costs (48%) as the major advantage that would accrue from the model**. Also, lack of a need to shell, dry and store maize is seen as an advantage by 11.5% of the farmers. Less than 5% of the farmers perceive other advantages from the Cob model including: being paid more, having more free time and being able to grow more maize respectively, as advantages of the Cob model.

300. A larger share of the female relative to male farmers report not seeing any advantage of adopting the Cob model (45.5% vs 28.7%). However, a higher proportion of male relative to female farmers report that they perceive lower labour and other post-harvest cost as an advantage that would accrue from the Cob model (60.7% vs 18.7%).

Figure A - 21. Farmers' perception of main advantage of Cob model (non-adopters)

Notes: T-tests for gender differences are performed with robust standard errors. Observations are weighted using design weights. ***, **, and * indicate significance at 1, 5, and 10 percent. Number observations: 154; number observations male: 89; number observations female: 65

FtMA support

301. Farmers were asked whether they had ever received support from FtMA/WFP. Table A - 11 shows that only 34.1% of the farmers confirm receiving support, with **a larger share of male** (40.9%) farmers as opposed to female farmers (25.1%) reporting so.

Table A - 11. FtMA support

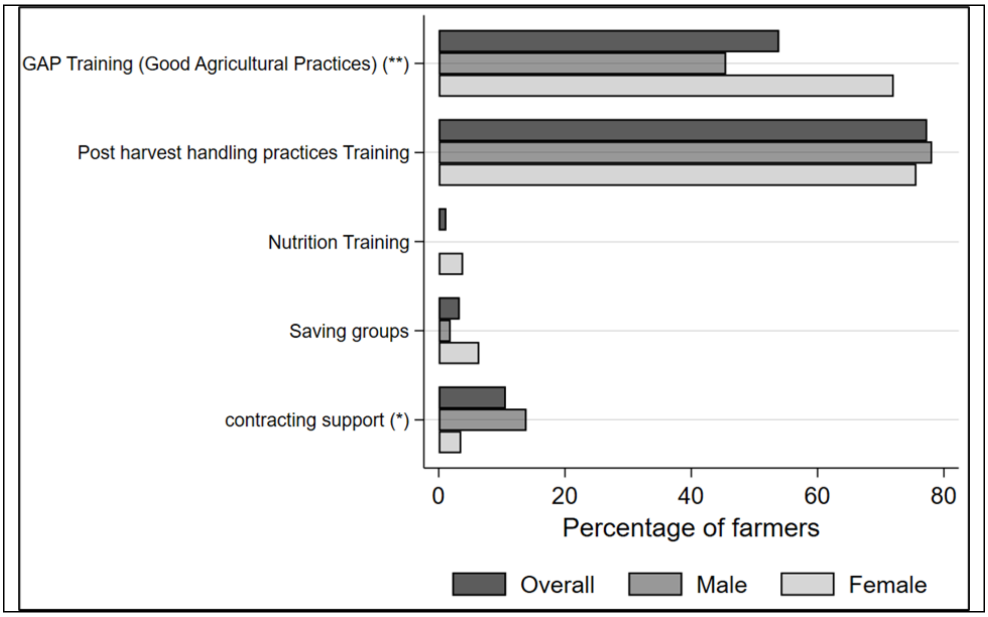
	N	(3) Total Mean/SE	N	(1) Male Mean/SE	N	(2) Female Mean/SE	t-test Difference (1)-(2)
Received FtMA/WFP support (dummy)	399	0.34 [0.03]	199	0.41 [0.04]	200	0.25 [0.04]	0.16***

Notes: The value displayed for t-tests are the differences in the means between male and female respondents. Standard errors are robust. Observations are weighted using design weights. ***, **, and * indicate significance at 1, 5, and 10 percent.

302. As illustrated in Figure A - 22, the vast majority of farmers who received support attended trainings on post-harvest handling practices (77.4%) and on good agricultural practices (GAP) (53.9%). A smaller share of farmers (10.6%) received contracting support. While more women than men received training on GAP (72.1% vs 45.5%,), the reverse is true for contracting support (13.9% vs 3.6%). Very few farmers report to have attended nutrition trainings or saving groups assistance organized by FtMA/WFP.

303. Figure A - 23 and Figure A - 24 show the extent to which FtMA/WFP supports have enhanced financial and non-financial gains from maize, from the farmers' perspective. It appears that **the most attended trainings, that is GAP and PHHP, are regarded by farmers either as beneficial or very beneficial in terms of financial and non-financial gains.**

Figure A - 22. FtMA/WFP support received by farmers

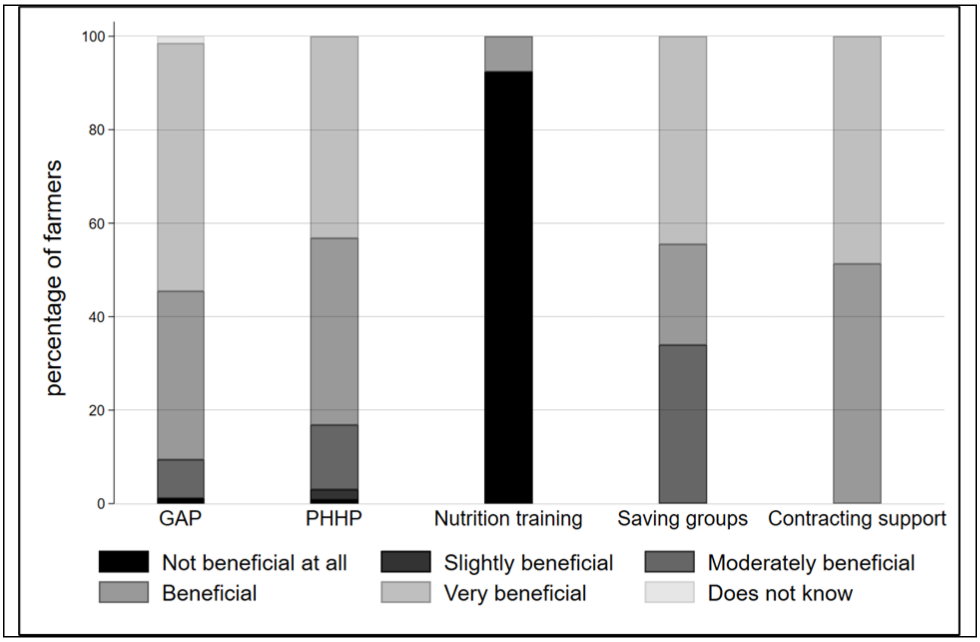


Notes: T-tests for gender differences are performed with robust standard errors. Observations are weighted using design weights. ***, **, and * indicate significance at 1, 5, and 10 percent. Number observations: 146; number observations male: 88; number observations female: 58

304. Roughly 10% of the male and female farmers consider GAP training as moderately beneficial in terms of financial and non-financial gains; a larger share of farmers deem the training beneficial in terms of financial and non-financial gains (roughly 35%). Approximately half of the attendees found it very beneficial both with regard to financial and non-financial gains.

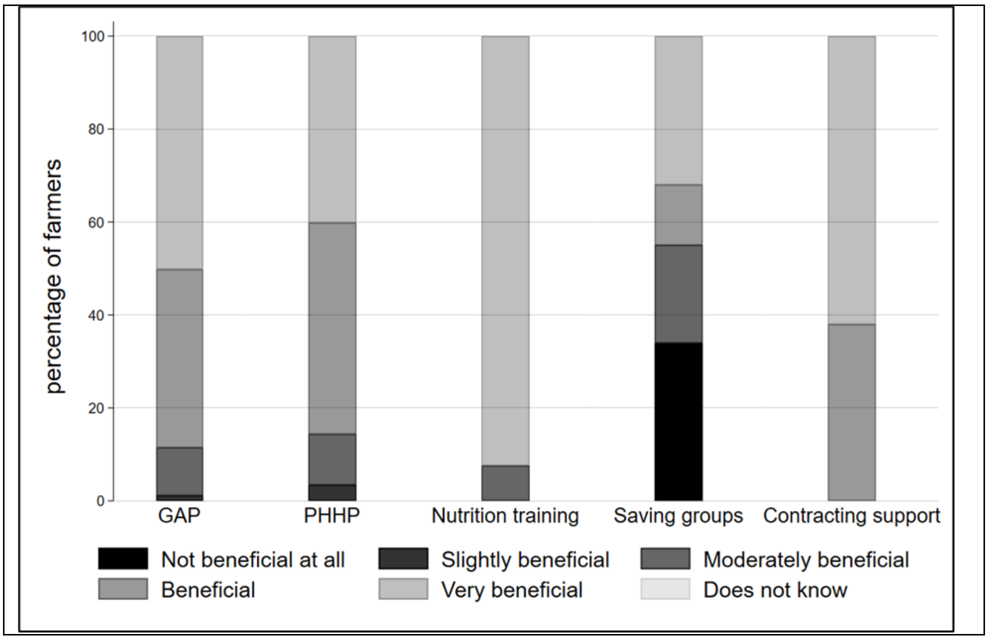
305. The figures below also reveal that approximately about 10% of the farmers consider PHHP training conducted by FtMA/WFP as moderately beneficial in terms of financial and non-financial gains. A larger share of cooperative members deem it beneficial in terms of financial and non-financial gains (roughly 39% and 45% respectively). Finally, about 40% of the members see it (approximately 70% and 25%) as advantageous both financially and non-financially.

Figure A - 23. Farmers' perception of how beneficial FtMA supports have been in receiving financial gains from maize



Notes: Observations are weighted using design weights. Number observations GAP: 79; Number observations PHHP: 113; Number observations Nutrition training: 2; Number obs. Saving groups: 10; Number obs. Contracting support: 14

Figure A - 24. Farmers' perception of how beneficial FtMA supports have been in receiving non-financial gains from maize



Notes: Observations are weighted using design weights. Number observations GAP: 79; Number observations PHHP: 113; Number observations Nutrition training: 2; Number observations Saving groups: 10; Number observations Contracting support: 14

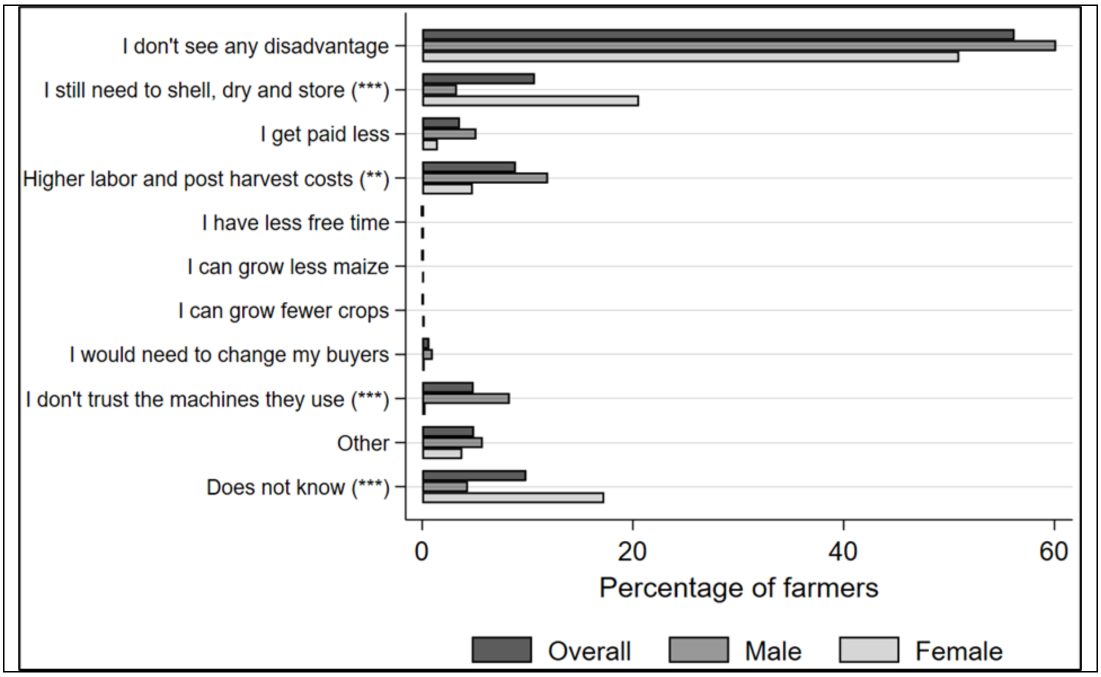
A5. RISKS AND UNINTENDED EFFECTS

306. There may also be unintended effects of farmers' choices to use AflaSight services and/or the Cob model or not. In order to assess this, both sets of farmers were also asked to report what they might have perceived as the main disadvantage of the two technologies. These results are presented below.

307. Figure A - 25 below shows **that over half of the farmers who have not used AflaSight yet do not perceive any disadvantage from the adoption of AflaSight services**. Specifically, 56.2% of these farmers report not perceiving any disadvantage from AflaSight services, while 10.7% report the need to still shell, dry and store maize as a disadvantage. Less than 5% of the farmers report other disadvantages such as: getting paid less; having less time; growing less maize as well as other crops and the need to change buyers.

308. The figure also reveals that a larger share of female relative to male farmers report the need to still shell, dry and store maize as a disadvantage of AflaSight services (20.6% vs 3.3%, respectively). However, a larger share of male relative to female farmers report higher labour and other post-harvest costs as a disadvantage (12% vs 4.8%, respectively). Similarly, more male relative to female farmers (8.3% vs 0.3%), report not trusting the machines used for AflaSight services as a disadvantage.

Figure A - 25. Farmers' perception of main disadvantage of AflaSight services (non-adopters)

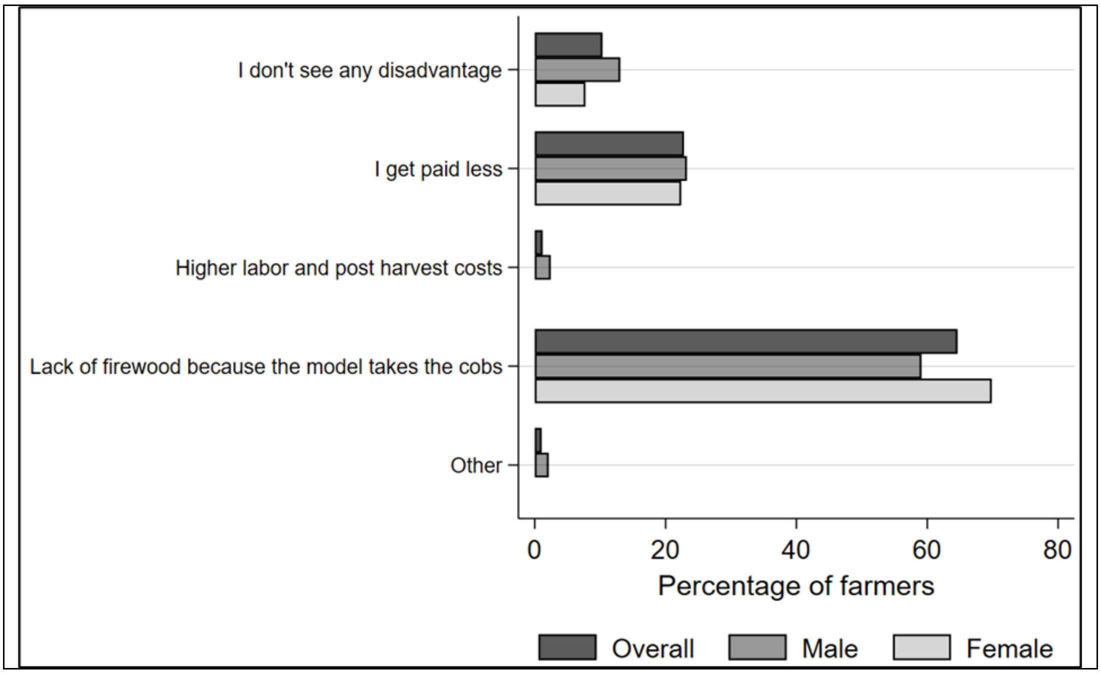


Notes: T-tests for gender differences are performed with robust standard errors. Observations are weighted using design weights. ***, **, and * indicate significance at 1, 5, and 10 percent. Number observations: 381; number observations male: 192; number observations female: 189

309. For the case of the Cob model, the perceptions of its disadvantages for adopting and non-adopting farmers are presented below. Figure A - 26 contains the perceptions of adopters of the Cob model. The figure reveals that **well over 60% of the farmers perceive a lack of firewood, due to the cobs being taken away, as the main disadvantage of the Cob model**. A relatively lower share of these farmers (10.3%) report that they do not perceive any disadvantages from adopting the Cob model. Over double of this share (22.8%), report getting paid less as a disadvantage of the Cob model.

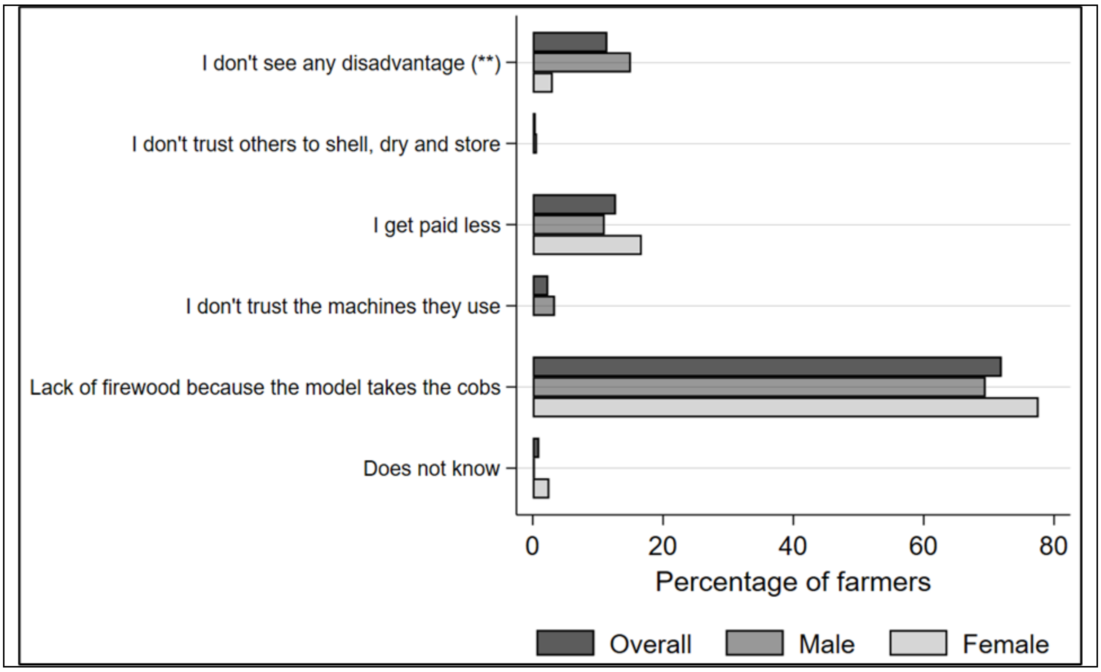
310. The pattern of perceptions of disadvantages for non-adopters of the Cob model is similar and is presented in Figure A - 27 below. **Over 70% of non-adopting farmers also perceive a lack of firewood as the main disadvantage of the Cob model**. Only a small share of non-adopters (11.4%) report that they don't see any disadvantage associated with the model. A similar share of these farmers (12.8%) believe getting paid less is the main disadvantage of the Cob model. Less than 5% of the farmers report other perceived disadvantages including: not trusting others to store, dry and shell the maize and not trusting the machines used, respectively. A larger share of male relative to female farmers report that they don't see any disadvantage associated with the model (15.1% vs 3.1%).

Figure A - 26. Farmers' perception of main disadvantage of Cob model (adopters)



Notes: T-tests for gender differences are performed with robust standard errors. Observations are weighted using design weights. ***, **, and * indicate significance at 1, 5, and 10 percent. Number observations: 245; number observations male: 110; number observations female: 135

Figure A - 27. Farmers' perception of main disadvantage of Cob model (non-adopters)



Notes: T-tests for gender differences are performed with robust standard errors. Observations are weighted using design weights. ***, **, and * indicate significance at 1, 5, and 10 percent. Number observations: 154; number observations male: 89; number observations female: 65

311. Owing to the observation that the major disadvantage of the Cob model as perceived by both adopter and non-adopter farmers, is the resulting lack of firewood when maize cobs are taken, an examination of charcoal expenditure by farmers would also be instructive. Table A - 12 below therefore presents farmer expenditure on charcoal disaggregated by gender for those farmers who are adopters of the Cob model. Indeed, the table reveals that the average farmer reports spending 7,053.3 RWF on charcoal.

Interestingly, while male farmers report spending 8,964.5 RWF on charcoal, female farmers report spending only 5,235.2 RWF on average.

Table A - 12. Farmers' expenditures in charcoal

	N	(1) Total Mean/SE	N	(2) Male Mean/SE	N	(3) Female Mean/SE	t-test Difference (2)-(3)
Amount spent on buying charcoal to compensate for sold cobs (in RWF)	245	7053.29 [671.38]	110	8964.54 [1217.02]	135	5235.17 [519.84]	3729.38**

Notes: The value displayed for t-tests are the differences in the means between male and female respondents. Standard errors are robust. Observations are weighted using design weights. ***, **, and * indicate significance at 1, 5, and 10 percent.

A6. SEASON C 2021 HARVEST, CONSUMPTION AND INCOME FROM MAIZE

312. This section describes the land cultivated with maize during season C 2021, the harvest that is obtained, how it is utilized, and the earnings derived from maize by the end of season C 2021.

Land and harvest

313. Table A - 13 reveals that in season C 2021, farmers cultivated, on average, 0.26 hectares of land with maize and harvested on average 711.9 kg of maize. In terms of productivity of the land, the average yield is 4,785.6 kg/ha and the median is lower at 3,166.67 kg/ha (see Table A - 22). It appears that, on average, farmers cultivated slightly more land with maize and obtained more harvest in the past season C, but the productivity of their land was slightly lower than in the current year. Men also planted, on average, larger areas of land with maize (0.28 ha vs 0.22 ha) and collected higher amounts of harvest than women (820.6 ha vs 567.5 kg).

Table A - 13. Season C 2021 land and harvest

	N	(1) Total Mean/SE	N	(2) Male Mean/SE	N	(3) Female Mean/SE	t-test Difference (2)-(3)
Land size cultivated with maize (ha)	399	0.26	199	0.28	200	0.22	0.05**
		[0.01]		[0.02]		[0.02]	
Harvest (kg)	399	711.90	199	820.56	200	567.52	253.04***
		[35.55]		[49.87]		[47.30]	
Yield (kg/ha)	396	4785.59	198	4594.03	198	5041.59	-447.56
		[282.35]		[409.13]		[368.68]	

Notes: The value displayed for t-tests are the differences in the means between male and female respondents. Standard errors are robust. Observations are weighted using design weights. ***, **, and * = significance at 1, 5, and 10 percent.

Consumption

314. Table A - 14 reports season C 2021 consumption of harvested and self-produced maize by the cooperative members' households. Households consume on average more grain (51.4 kg) than green cobs (30 kg) or dry cobs (6.3 kg). Results also differ significantly by gender when it comes to consumption of green cobs and self-produced grain. Indeed, the average household consumption of green cobs and self-produced grain among female farmers is lower than the average household consumption among male farmers, by 21.3 kg and 13.8 kg respectively.

Table A - 14. Season C 2021 consumption of maize

	N	(1) Total Mean/SE	N	(2) Male Mean/SE	N	(3) Female Mean/SE	t-test Difference (2)-(3)
Consumption (kg) of harvested green cobs	399	30.04	199	39.18	200	17.90	21.29***
		[2.79]		[4.54]		[1.95]	
Consumption (kg) of self-processed dry cobs	399	6.32	199	5.95	200	6.82	-0.87
		[1.62]		[2.25]		[2.30]	
Consumption (kg) of self-produced grain	398	51.36	198	57.31	200	43.48	13.83**
		[3.17]		[5.09]		[2.87]	

Notes: The value displayed for t-tests are the differences in the means between male and female respondents. Standard errors are robust. Observations are weighted using design weights. ***, **, and * = significance at 1, 5, and 10 percent.

Post-harvest costs

315. Table A - 15 below presents a breakdown of the post-harvest costs incurred by farmers during season C 2021. During the shelling stage, farmers report spending on average 7,156 RWF for labour and estimate that they are able to save 3,884.1 RWF by having unpaid labour. Moreover, farmers pay 2,349.1 RWF to get access to a shelling machine. At the drying stage, farmers incur, on average, lower costs for labour (3,457.1 RWF) than during the shelling process. However, they believe to save, on average, a similar amount

of money by having unpaid labour for drying maize grain (3,052.7 RWF). In order to buy material for treating grain and bags for storing grain, farmers spend on average 1,024.8 RWF and 1,682.2 RWF respectively. Additional costs amount to an average of 6,625.7 RWF.

316. Men incur higher costs than women at every post-harvesting stage. Indeed, female farmers report paying on average 4,504.1 RWF while men report spending on average 9,251.7 RWF for labour required for shelling. Labour costs incurred by men during the grain drying process also appear higher than for women (5,098.5 RWF vs 1,438.3 RWF). At the same time, men believe to be saving more than women with unpaid labour used for shelling (5,058.2 RWF vs 2,398.2 RWF) and drying (3,376.3 RWF vs 2,654.6 RWF). Among those farmers who use a machine for shelling in season C 2021, men report spending more than women to access the machine (2,674.1 RWF vs 1,571.4 RWF). Again, men spend more for treating grain (1,371.2 RWF vs 478.4 RWF for women) and on bags for storing grain (1,950.7 RWF vs 1,227 RWF for women).

Table A - 15. Season C 2021 post-harvest costs

	N	(1) Total Mean/SE	N	(2) Male Mean/SE	N	(3) Female Mean/SE	t-test Difference (2)-(3)
Shelling costs (RWF)							
Labour for shelling	372	7156.02	181	9251.65	191	4504.08	4747.57***
		[793.96]		[1360.45]		[413.64]	
Labour costs saved by having unpaid labour for shelling	372	3884.07	181	5058.20	191	2398.24	2659.96**
		[714.88]		[1266.99]		[152.22]	
Machine for shelling	138	2349.07	81	2674.10	57	1571.38	1102.72*
		[393.87]		[541.38]		[305.52]	
Drying grain costs (RWF)							
Labour for drying grain	362	3457.14	174	5098.52	188	1438.26	3660.27***
		[359.97]		[594.42]		[231.29]	
Labour costs saved by having unpaid labour for drying grain	362	3052.68	174	3376.32	188	2654.61	721.71**
		[182.78]		[291.13]		[195.97]	
Treating grain costs (RWF)							
Material for treating grain	144	1024.76	73	1371.17	71	478.42	892.75***
		[118.23]		[170.79]		[88.15]	
Storing grain costs (RWF)							
Bags for storing grain	185	1682.15	101	1950.71	84	1226.98	723.73***
		[150.61]		[225.56]		[119.88]	
Other costs (RWF)							
Other post-harvest processing costs	399	6625.71	199	7132.25	200	5952.66	1179.59
		[503.33]		[704.20]		[704.11]	

Notes: The value displayed for t-tests are the differences in the means between male and female respondents. Standard errors are robust. Observations are weighted using design weights. ***, **, and * indicate significance at 1, 5, and 10 percent. Costs incurred by male and female farmers for drying grain with a machine are not reported because there are not enough observations.

Sales and earnings from maize

317. Table A - 16 describes the amount of maize sold in season C 2021, the earnings derived from these sales to the cooperatives and local market/middle men as well as the resulting price per kilo of maize sold.

318. While only a few farmers sell green cobs to the cooperatives in season C 2021 (0.4%), a higher share of farmers sell dry cobs (42.4%) and grain (no seeds) (43.3%) to the cooperatives. Moreover, some farmers (11%) produce and sell seeds and 25.6% of the farmers sell grain to premium buyers right after being passed through the shelling machine provided by the buyers.

319. Only a small portion of the maize harvested and processed is sold to the local market or middle man. Indeed, grain is sold by 18.7% of the farmers, green cobs by 1.4% and dry cobs by 0.4%.

320. Regarding sales to the cooperatives, on average, farmers sell 116.8 kg of dry cobs and obtain 26,779.7 RWF from these sales, obtaining an average per kilo price of 250.4 RWF. The latter appears to be on average slightly higher than the price received in the past season C. However, as mentioned above, any comparison between the two seasons should be interpreted with caution as it is not possible to conclude that any differences can be causally attributed to a specific factor.

321. Farmers sell on average 95.1 kg of grain (no seeds), earning on average 27,913.3 RWF, with an average price of 286.5 RWF per kilo. The average amount of seeds sold is only 32.6 kg generating on average 19,883.4 RWF in revenues, with an average price of 581.4 RWF per kilo. The sales of grain to premium buyers right after it is shelled with a buyers' machine amount to, on average, 96.5 kg and return on average 29,878.4 RWF, meaning an average price of 310.6 RWF per kilo.

322. A significantly greater share of women than men (16.5% vs 6.7%) sell seeds to their cooperatives in season C 2021 and more men than women sell grain to premium buyer after passing it through the shelling machine of a buyer (30.2% vs 19.4%). Men also are found to sell, on average, more grain than women to premium buyers right after shelling (136.9 kg vs 43 kg) and earn more from these sales (by 30,909 RWF). The earnings and price per kilo obtained from the sales of grain (no seeds) to the cooperative are, on average, higher for men than for women (by 15277.8 RWF for the earnings and 42.4 RWF/kg for the per kilo price). The per kilo price obtained from the sales of dry cobs to the cooperative is also higher for men than for women (266.1 RWF/kg vs 236.7 RWF/kg).

Table A - 16. Season C 2021 earnings from maize

	N	(1) Total Mean/SE	N	(2) Male Mean/SE	N	(3) Female Mean/SE	t-test Difference (2)-(3)
Season C sales of maize (dummy)							
Sold or will sell green cobs to cooperative (dummy)	399	0.00 [0.00]	199	0.00 [0.00]	200	0.01 [0.01]	-0.01
Sold or will sell dry cobs to cooperative (dummy)	399	0.42 [0.03]	199	0.39 [0.04]	200	0.47 [0.04]	-0.08
Sold or will sell grain (not including seeds) to cooperative (dummy)	399	0.43 [0.03]	199	0.40 [0.04]	200	0.48 [0.04]	-0.08
Sold or will sell grain seeds to cooperative (dummy)	399	0.11 [0.02]	199	0.07 [0.02]	200	0.17 [0.03]	-0.10**
Sold or will sell grain to premium buyer after shelling (dummy)	399	0.26 [0.03]	199	0.30 [0.04]	200	0.19 [0.03]	0.11**
Sold or will sell green cobs to local market/ middle man (dummy)	399	0.01 [0.01]	199	0.02 [0.01]	200	0.01 [0.01]	0.01
Sold or will sell dry cobs to local market/ middle man (dummy)	399	0.00 [0.00]	199	0.01 [0.01]	200	0.00 [0.00]	0.01
Sold or will sell grain to local market/ middle man (dummy)	399	0.19 [0.03]	199	0.16 [0.03]	200	0.22 [0.04]	-0.06
Season C 2021 quantity of maize sold (kg)							
Amount of green cobs sold to cooperative	399	0.39 [0.39]	199	0.00 [0.00]	200	0.90 [0.90]	-0.90
Amount of dry cobs sold to cooperative	399	116.78 [13.90]	199	113.32 [21.36]	200	121.38 [15.66]	-8.07

	N	(1) Total Mean/SE	N	(2) Male Mean/SE	N	(3) Female Mean/SE	t-test Difference (2)-(3)
Amount of grain (not including seeds) sold to cooperative	399	95.08 [12.37]	199	111.32 [18.60]	200	73.52 [15.02]	37.80
Amount of seeds sold to cooperative	399	32.56 [9.14]	199	28.22 [13.55]	200	38.32 [11.37]	-10.09
Amount of grain sold to premium buyer after shelling	398	96.51 [13.80]	198	136.94 [22.77]	200	42.98 [8.31]	93.96***
Amount of green cobs sold to local market/ middle man	399	0.48 [0.32]	199	0.29 [0.17]	200	0.73 [0.72]	-0.44
Amount of dry cobs sold to local market/ middle man	399	0.19 [0.15]	199	0.34 [0.26]	200	0.00 [0.00]	0.34
Amount of grain sold to local market/ middle man	399	13.92 [2.68]	199	15.91 [4.24]	200	11.29 [2.66]	4.62
Season C 2021 earnings from maize (RWF)							
Earnings from green cobs sold to cooperative	399	104.20 [104.14]	199	0.00 [0.00]	200	242.66 [241.96]	-242.66
Earnings from dry cobs sold to cooperative	390	26779.73 [3456.96]	190	25681.65 [5412.73]	200	28118.79 [3932.09]	-2437.14
Earnings from grain (not including seeds) sold to cooperative	395	27913.30 [3851.23]	195	34530.14 [6161.81]	200	19252.34 [3844.16]	15277.81**
Earnings from seeds sold to cooperative	399	19883.38 [5763.23]	199	17728.08 [8655.57]	200	22747.18 [6942.66]	-5019.10
Earnings from grain sold to premium buyer after shelling	398	29878.40 [4477.28]	198	43179.12 [7459.49]	200	12269.90 [2253.69]	30909.21***
Earnings from green cobs sold to local market/ middle man	399	71.36 [40.74]	199	61.85 [37.60]	200	83.99 [80.71]	-22.14
Earnings from dry cobs sold to local market/ middle man	399	43.13 [31.72]	199	75.60 [55.72]	200	0.00 [0.00]	75.60
Earnings from grain sold to local market/ middle man	399	4155.46 [838.99]	199	4870.63 [1363.19]	200	3205.19 [724.01]	1665.43
Season C 2021 price per kg of maize sold (RWF)							
Price per kg of dry cobs sold to cooperative	158	250.35 [6.67]	76	266.14 [9.07]	82	236.73 [9.57]	29.41**
Price per kg of grain (not including seeds) sold to cooperative	154	286.46 [6.15]	69	305.14 [9.48]	85	262.79 [6.81]	42.36***

	N	(1) Total Mean/SE	N	(2) Male Mean/SE	N	(3) Female Mean/SE	t-test Difference (2)-(3)
Price per kg of seeds sold to cooperative	45	581.38 [25.09]	12	630.99 [29.76]	33	554.76 [34.80]	76.23
Price per kg of grain sold to premium buyer after shelling	94	310.59 [16.00]	48	316.44 [20.87]	46	298.64 [23.79]	17.80
Price per kg of green cob sold to local market/ middle man	5	154.73 [42.12]	3	166.95 [66.18]	2	125.21 [23.50]	41.73
Price per kg of grain sold to local market/ middle man	61	292.82 [7.01]	27	297.58 [10.90]	34	288.21 [9.02]	9.38

Notes: The value displayed for t-tests are the differences in the means between male and female respondents. Standard errors are robust. Observations are weighted using design weights. ***, **, and * = significance at 1, 5, and 10 percent.

Access to premium buyers

323. Farmers were also asked to name the premium buyers that their cooperatives have access to in season C 2021. As can be seen in Table A - 17, only 57.2% of the farmers were able to identify their cooperatives' premium buyers for season C 2021 and significantly more men than women were able to do so (66.7% vs 44.6%). This year, however, the bargaining process was still on going at the time of data collection. This might be the reason why a high percentage of uncertainty among farmers is observed.

Table A - 17. Awareness of premium buyers in season C 2021

	N	(1) Total Mean/SE	N	(2) Male Mean/SE	N	(3) Female Mean/SE	t-test Difference (2)-(3)
Able to identify premium buyers in season C 2021	399	0.57 [0.03]	199	0.67 [0.04]	200	0.45 [0.04]	0.22***

Notes: The value displayed for t-tests are the differences in the means between male and female respondents. Standard errors are robust. Observations are weighted using design weights. ***, **, and * = significance at 1, 5, and 10 percent.

324. Among those who are aware of the premium buyers connected to their cooperatives, AIF appears to be the most named followed by Rumbuka (detailed data omitted).

A7. EXPENDITURES AND INVESTMENT

325. This section describes the self-reported changes in income from maize between the current and past season C. It also illustrates the expenditures and investments made with the additional income from maize.

326. Table A - 18 reveals that slightly **more than half of farmers (54.2%) consider their income to be worse off this year as compared to last year.** However, a lower share of farmers (36.6%), actually consider their income from maize to be higher this year relative to the last. Less than 10% of farmers report that they do not see any changes in income from maize between the two years.

327. It is interesting to look at the farmers' perception of their income fluctuation in light of the self-reported earnings obtained from maize in each year. Indeed, on average, farmers receive similar earnings from maize in both years.

Table A - 18. Self-reported change in income from maize in season C 2021 compared to season C 2020

	N	(1) Total Mean/SE	N	(2) Male Mean/SE	N	(3) Female Mean/SE	t-test Difference (2)-(3)
Increase in income from maize in season C 2021 compared to season C 2020	399	0.37	199	0.39	200	0.33	0.07
		[0.03]		[0.04]		[0.04]	
No change in income from maize in season C 2021 compared to season C 2020	399	0.09	199	0.08	200	0.11	-0.02
		[0.02]		[0.02]		[0.03]	
Decrease in income from maize in season C 2021 compared to season C 2020	399	0.54	199	0.52	200	0.57	-0.04
		[0.03]		[0.04]		[0.04]	

Notes: The value displayed for t-tests are the differences in the means between male and female respondents. Standard errors are robust. Observations are weighted using design weights. ***, **, and * indicate significance at 1, 5, and 10 percent.

328. Table A - 19 reports perception of income fluctuation, broken down by adopters of and non-adopters of the Cob model. No causality between income change and technologies adoption should be inferred from these findings. Most of the season C 2021 adopters of the Cob model (58.4%) feel that their income from maize decreases in the current year and 31.7% feel there is an increase compared to last year. The results are not as clear among the non-adopters where 48% of farmers see a decrease in their income but a similar share of 44.2% believe it increases compared to last year.

Table A - 19. Self-reported change in income from maize in season C 2021 compared to season C 2020 (by adoption of Cob model)

	Cob model adopters		Cob model non-adopters	
	Frequency	Percent	Frequency	Percent
Increase in income from maize in season C 2021 compared to season C 2020	79	31.70	66	44.15
No change in income from maize in season C 2021 compared to season C 2020	28	9.94	14	7.93
Decrease in income from maize in season C 2021 compared to season C 2020	138	58.35	74	47.93
Total	245	100.00	154	100.00

Notes: Observations are weighted using design weights.

329. Figure A - 28 below shows the changes in several categories of expenditures (relative to the previous year) reported by farmers who expect an increase in income from maize in season C 2021. The specific expenditure categories shown are housing, food, education as well as healthcare.

330. In the case of housing, 39.9% of farmers report no change in expenditure at all. Slightly over 30% of the farmers report a slight increase in expenditure, while 19.6% report a large increase in expenditure

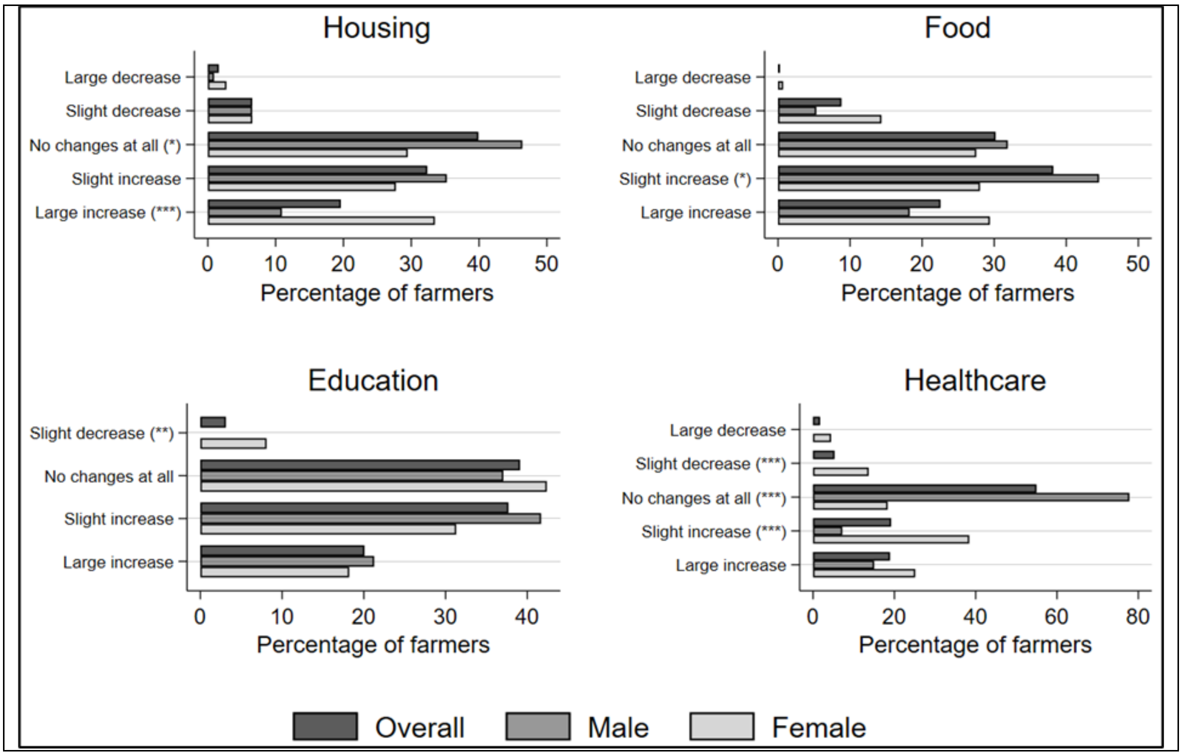
towards housing. Only 1.6% of the farmers report a large decrease in expenditure towards housing. Furthermore, a larger share of male relative to female farmers report no change at all in their housing expenditure (46.4% vs 29.5%). Interestingly, more female farmers report large increases in expenditure towards housing relative to male farmers (33.5% vs 10.9%).

331. For food, 38.2% of farmers report a slight increase in expenditure, while 30.2% report no change at all in their expenditure. However, 22.6% of the farmers report experiencing a large increase in their expenditure towards food. Only a small share (less than 1%) of farmers report experiencing a large decrease in expenditure. The reported slight increase in expenditure towards food would seem to be driven more by male farmers (44.6% vs 28%).

332. In the case of expenditure towards education, 39.1% of farmers report experiencing no change at all, while 37.7% report experiencing only a slight increase. However, 20.1% of farmers report a large increase in expenditure. A small share of farmers (3.1%), report experiencing a slight decrease in expenditure towards education, a decrease reported exclusively by female farmers (8.1%).

333. In the case of healthcare, slightly over half of farmers (54.9%) report experiencing no change in expenditure at all. Smaller shares of farmers report experiencing slight increases and large increases in expenditure towards healthcare (19.2% and 18.9%, respectively). Only a few farmers report experiencing slight and large decrease in expenditure towards healthcare (5.3% and 1.7%, respectively).

Figure A - 28. Changes in expenditures among farmers who experience an increase in income from maize in season C 2021



Notes: T-tests for gender differences are performed with robust standard errors. Observations are weighted using design weights. ***, **, and * indicate significance at 1, 5, and 10 percent. Number observations: 145; number observations male: 78; number observations female: 67

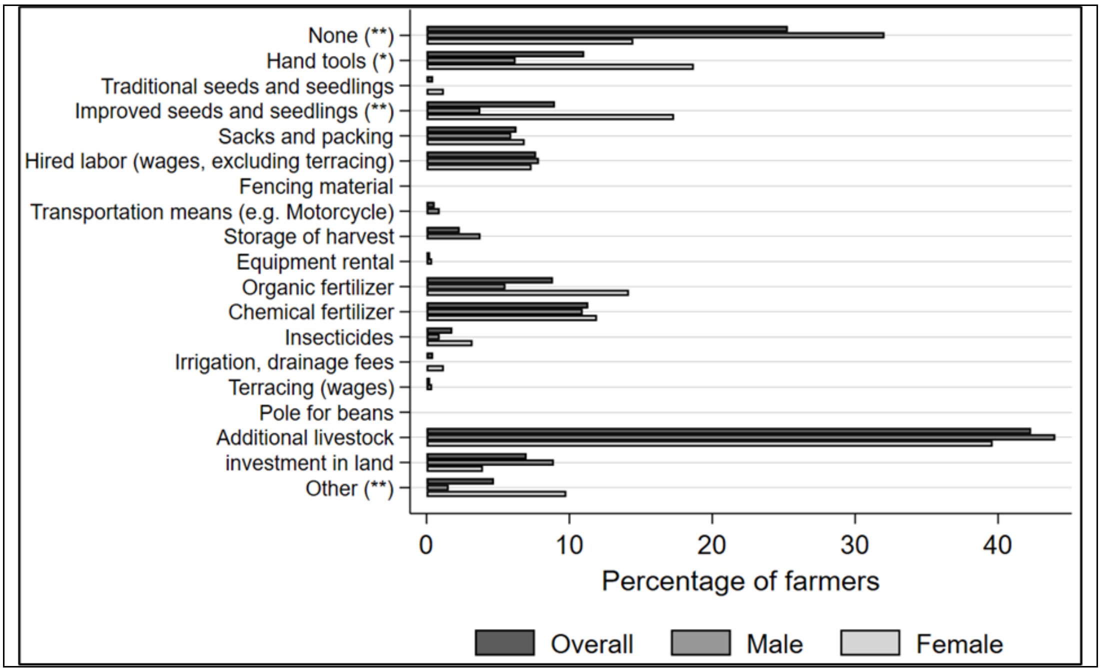
334. The actual investments made with additional income, future plans for investments with additional income from maize as well as future plans for hypothetical investments with the additional income from season C 2021 maize are displayed in Figure A - 29, Figure A - 30 and Figure A - 31 below. Overall, the figures reveal that the **most common type of investment among farmers, appears to be additional livestock.** It is also **common for farmers to report having made no investment at all** with their additional income from season C 2021 maize.

335. Figure A - 29 below shows the (short-term) agricultural investments that farmers report to make, or have already made, with their additional income earned from season C 2021 maize. The figure reveals that the vast majority (42.3%) of farmers who expect and income increase in season C 2021 invest this additional

income in additional livestock. Similarly, 11.3% and 11% of farmers report investing in chemical fertilizer and hand tools, respectively. However, 25.3% of the farmers report making no investments at all with their additional income earned from maize.

336. Several gender differences in reported investments are worth highlighting. A larger share of female farmers report investing in hand tools (18.7% vs 6.2% of male farmers). Similarly, more female farmers also report investing their additional income in improved seeds and seedlings (17.3% vs 3.8% of male farmers). However, more male farmers report making no investments at all (32.1% vs 14.5%).

Figure A - 29. Short-term agricultural investments made with additional income from maize



Notes: T-tests for gender differences are performed with robust standard errors. Observations are weighted using design weights. ***, **, and * indicate significance at 1, 5, and 10 percent. Number observations: 145; number observations male: 78; number observations female: 67

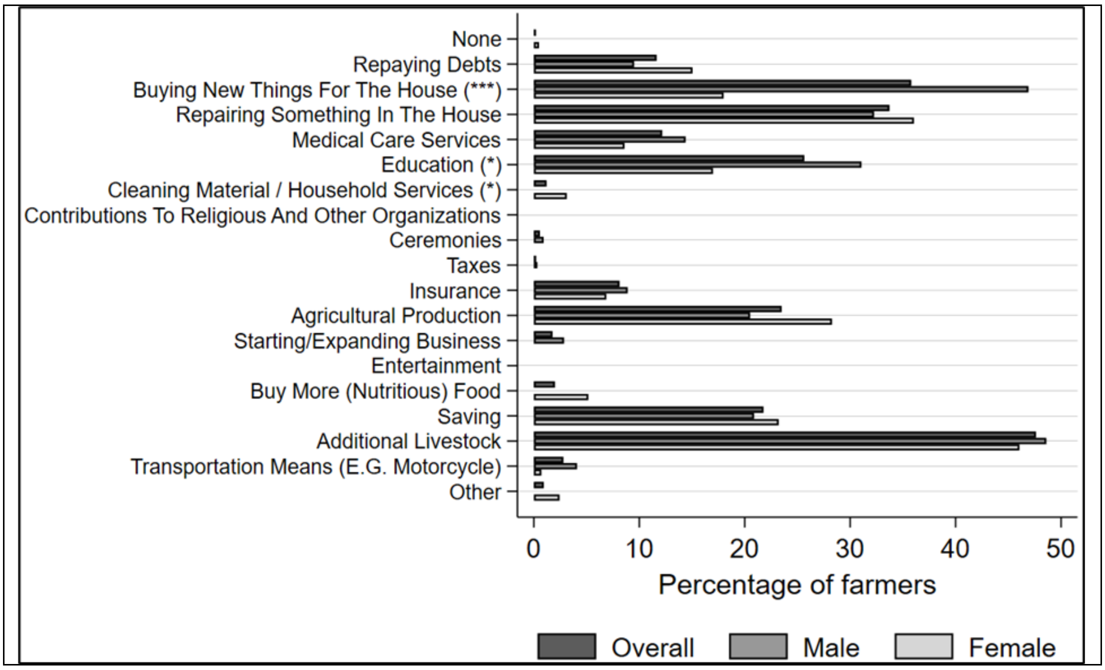
337. Figure A - 30 shows farmers' future (longer-term) investment plans (not limited to agriculture) for their additional income earned from season C maize. The figure reveals that **close to half of the farmers (47.6%), report that they would also invest in additional livestock in the future**. Similarly, farmers report that they would invest in buying new things for the house and repairing something in the house in the future (35.8% and 33.7%, respectively). Compared to the previous categories, relatively smaller shares of farmers report that they would invest in agricultural production and saving in the future (23.5% and 21.8%, respectively). Similarly, only 11.6% of the farmers report that they would invest in repaying debts in the future.

338. As regards gender differences in future investment plans, a larger share of men relative to women report that they would buy new things for the house (46.9% vs 18%). Similarly, a larger share of men relative to women also report that they would invest in education (31.1% vs 17%). However, only women report that they would invest in cleaning material or household services (3.1%).

339. Figure A - 31 below shows the investment plans that farmers reporting no income increase in season C 2021 would have made had they received any additional income from maize. The figure reveals that the largest share of farmers report that they would invest hypothetical additional income from maize in more livestock (45.3%) and repairing something in the house (42.6%). Similarly, the farmers also report that they would invest hypothetical additional income to buy something for the house, into agricultural production and education (31.8%, 29.2% and 22.6%, respectively). Relative to the previous categories of investments, a much smaller share of farmers report that they would save any hypothetical additional income (16.1%).

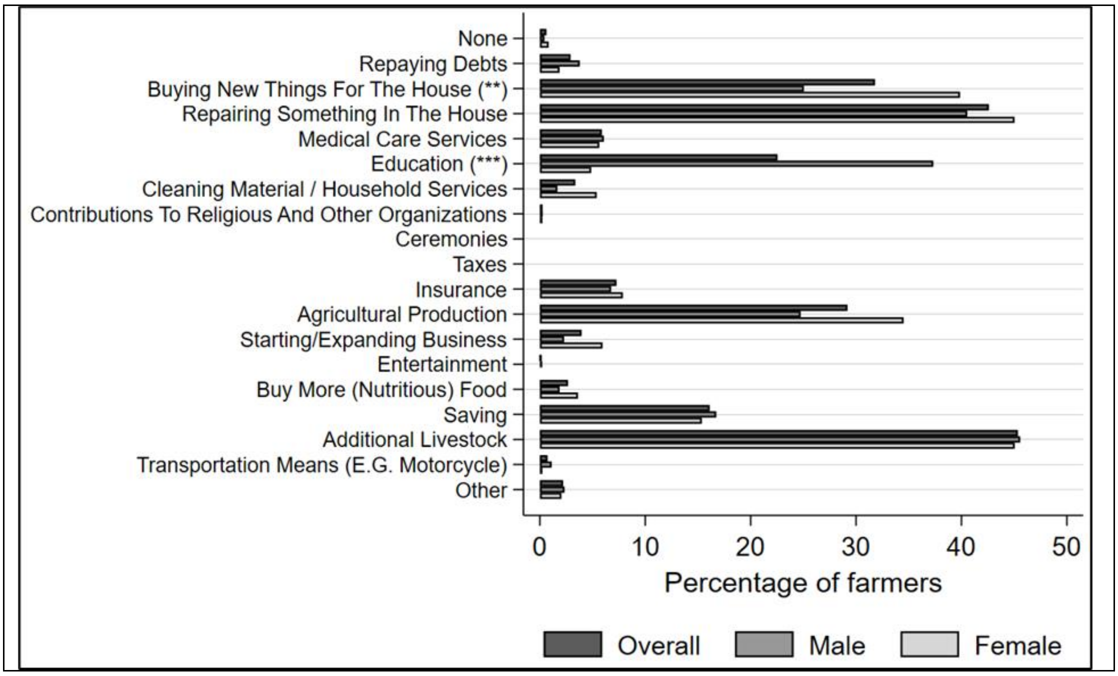
340. As regards gender differences in investment plans with hypothetical additional income from maize, more women than men also would have bought new things for the house (39.9% vs 25.1%). However, more men than women report that they would invest in education (37.3% vs 5%).

Figure A - 30. Future plans with additional income in maize



Notes: T-tests for gender differences are performed with robust standard errors. Observations are weighted using design weights. ***, **, and * indicate significance at 1, 5, and 10 percent. Number observations: 145; number observations male: 78; number observations female: 67

Figure A - 31. Investment plans with hypothetical additional income from maize



Notes: T-tests for gender differences are performed with robust standard errors. Observations are weighted using design weights. ***, **, and * indicate significance at 1, 5, and 10 percent. Number observations: 254; number observations male: 121; number observations female: 133

A8. POTENTIAL FOR LONG-TERM ADOPTION OF THE TECHNOLOGY

341. The adopters of the Cob model were asked whether they obtained a higher income from maize due to model. From Table A - 20, and consistent with the farmers' unfavourable perception of the Cob model, the majority of Cob model adopters indicate that the technology did not lead to higher income. Indeed, only 25.9% of the farmers are under the impression that the Cob model ensured them higher income. However, this positive impression is more prevalent among men than women (37.8% vs 14.6%).

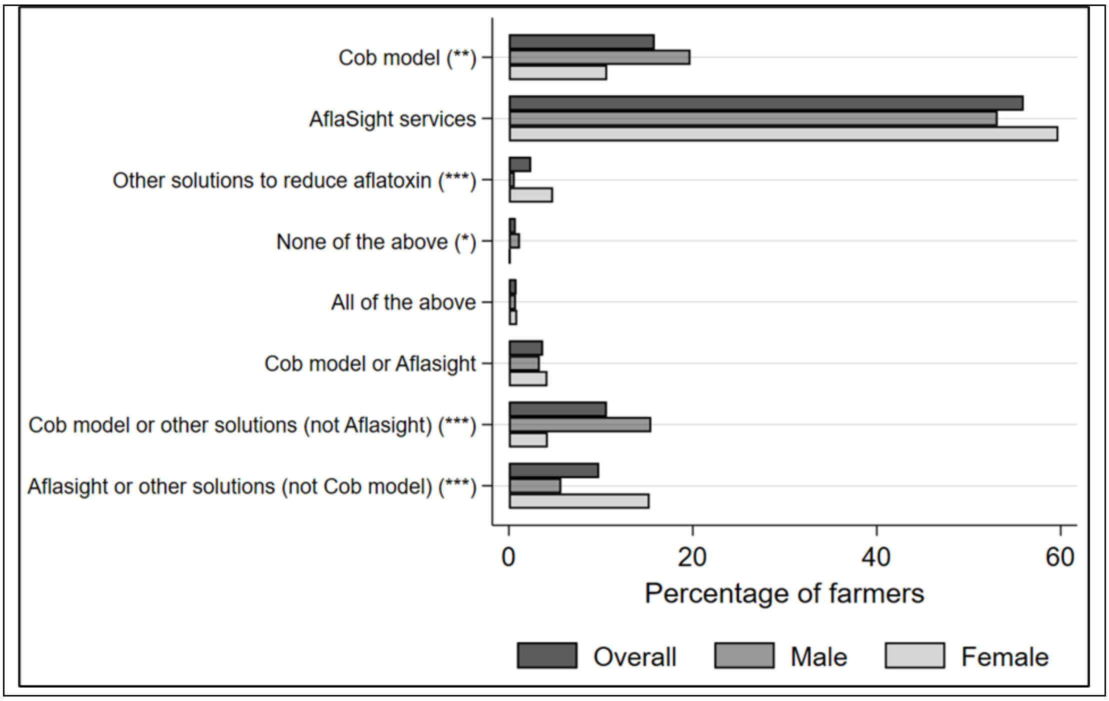
Table A - 20. Reported income change among adopters (Cob model)

	N	(1) Total Mean/SE	N	(2) Male Mean/SE	N	(3) Female Mean/SE	t-test Difference (2)-(3)
Reported higher income due to Cob model	245	0.26 [0.03]	110	0.38 [0.06]	135	0.15 [0.04]	0.23***

Notes: The value displayed for t-tests are the differences in the means between male and female respondents. Standard errors are robust. Observations are weighted using design weights. ***, **, and * indicate significance at 1, 5, and 10 percent.

342. Considering the results discussed in the previous sections, it is not surprising that most farmers (56%) regard AflaSight services as the preferred technology to reduce aflatoxin and only 15.9% would choose the Cob model to prevent aflatoxin (Figure A - 32). A lower share of farmers would be indifferent between AflaSight or other solutions as long as it does not include the Cob model (9.8%). A similar share of farmers (10.7%), on the other hand, would rather use the Cob model or other solutions that do not include AflaSight services.

Figure A - 32. Farmers' preference regarding aflatoxin reduction methods



Notes: T-tests for gender differences are performed with robust standard errors. Observations are weighted using design weights. ***, **, and * indicate significance at 1, 5, and 10 percent. Number observations: 399; number observations male: 199; number observations female: 200

343. Table A - 21 reports farmers preferences, by adopters and non-adopters of the Cob model. The preferences appear similar in both sub-categories. The majority of both sub-groups would choose AflaSight services, with the largest share found among adopters (non-adopters: 43.6%, adopters: 64.1%). The second most preferred choice among adopters is the Cob model (17.4%) and Cob model or other solutions (excluding AflaSight) by the non-adopters (23.1%).

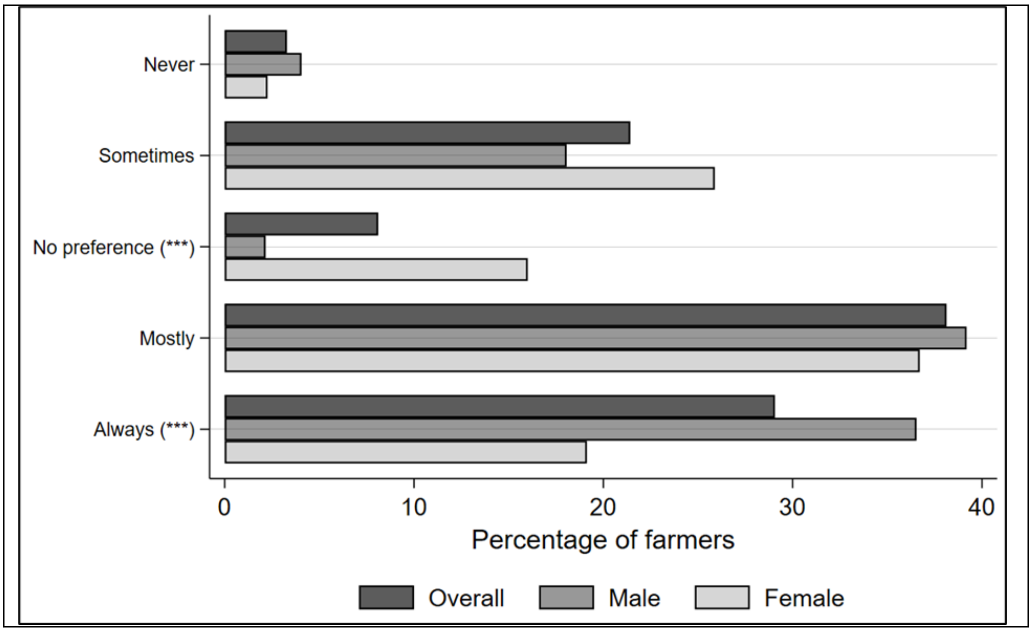
Table A - 21. Farmers' preference regarding aflatoxin reduction methods (by adoption of Cob model)

	Cob model adopters		Cob model non-adopters	
	Frequency	Percent	Frequency	Percent
Cob model	56	17.40	20	13.49
AflaSight services	132	64.09	69	43.60
Other solutions to reduce aflatoxin	10	2.42	9	2.41
None of the above	1	0.34	5	1.37
All of the above	3	1.22	1	0.23
Either Cob model or AflaSight services	14	3.95	6	3.35
Either Cob model or other solutions (not AflaSight)	6	2.49	26	23.11
Either AflaSight services or other solutions (not Cob model)	23	8.09	18	12.45
Total	245	100.00	154	100.00

Notes: Observations are weighted using design weights.

344. Finally, farmers were asked to what extent they would be willing to use the AflaSight services in the future (as showed in Figure A - 33). A large share of respondents feel that they would be willing to use AflaSight services mostly (38.1%) and even always (29.1%). Some cooperative members would be open to use the technology sometimes (21.4%). While more men than women would use the technology always (36.5% vs 19.1%), more women than men have no preference about AflaSight use (16% vs 2.2%).

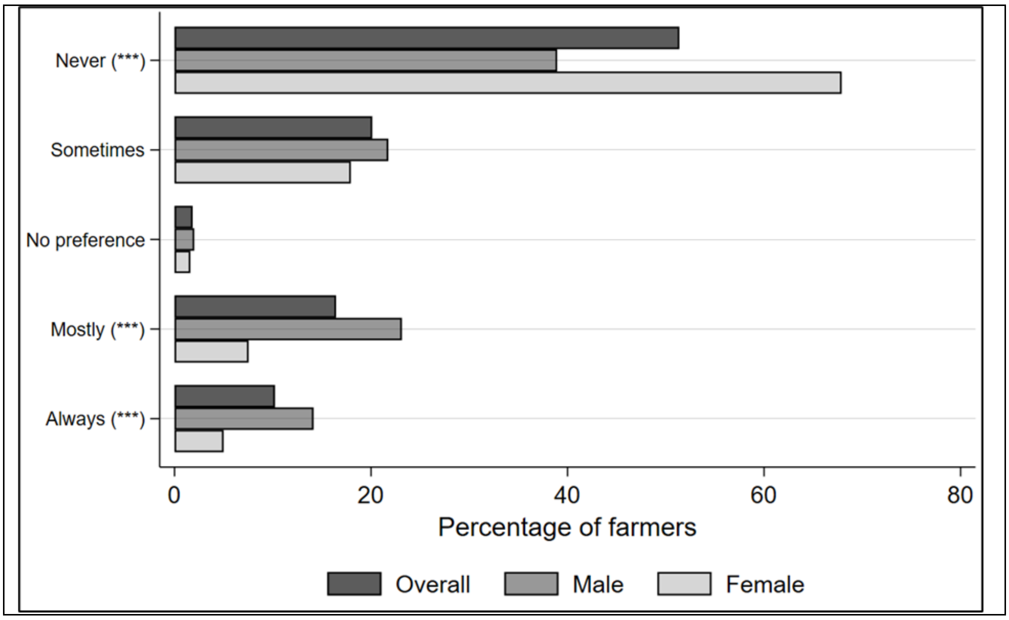
Figure A - 33. Future use of AflaSight services



Notes: T-tests for gender differences are performed with robust standard errors. Observations are weighted using design weights. ***, **, and * indicate significance at 1, 5, and 10 percent. Number observations: 399; number observations male: 199; number observations female: 200

345. By the same token, respondents were asked to indicate to what extent they would be willing to use the Cob model in the future (as showed in Figure A - 34). Again, it seems that **farmers, mostly women, do not believe that the Cob model would be a good fit for them.** Half of the farmers report never (or never gain) wanting to use the Cob model (51.4%), a smaller share would only use the model sometimes (20.1%), and 16.4% report that they would mostly adopt the Cob model. Albeit small, a share of farmers (10.2%) believe that they could be permanent adopters. Consistent with the more negative perception of the model found among female farmers, more women than men would never (or never again) use the model in the future (67.9% vs 39%). In contrast, male cooperative members as opposed to female cooperative members report that they would adopt the technology mostly (23.1% vs 7.5%) or always (14.2% vs 5%).

Figure A - 34. Future use of Cob model



Notes: T-tests for gender differences are performed with robust standard errors. Observations are weighted using design weights. ***, **, and * indicate significance at 1, 5, and 10 percent. Number observations: 399; number observations male: 199; number observations female: 200

A9. SUMMARY STATISTICS

Table A - 22. Summary statistics

	N	Mean	Median	SD	Min	Max
Farmer profile						
Age of cooperative member	399	47.81	48.00	11.91	22.00	89.00
N. household members	399	5.32	5.00	2.12	1.00	13.00
N. of household members below 15 years old	399	2.03	2.00	1.49	0.00	7.00
N. of household members 15-64 years old	399	3.15	3.00	1.70	0.00	9.00
N. of household members above 64 years old	399	0.14	0.00	0.37	0.00	2.00
N. of breadwinners in a household	399	1.87	2.00	0.74	1.00	5.00
Age dependency ratio	385	0.88	0.67	0.76	0.00	4.00
Income dependency ratio	399	0.39	0.33	0.18	0.13	1.00
Season C 2020 harvest, post-harvest handling costs and earnings						
Land size cultivated with maize (ha)	397	0.27	0.20	0.26	0.01	2.00
Harvest (kg)	391	756.00	550.00	712.50	50.00	6000.00
Yield (kg/ha)	388	4684.11	3466.67	4157.83	250.00	26666.67
Post-harvest costs	392	22346.63	16000.00	21037.69	1000.00	200000.00
Amount of green cobs sold to cooperative	394	4.38	0.00	43.01	0.00	600.00
Amount of dry cobs sold to cooperative	393	76.69	0.00	180.43	0.00	1500.00
Amount of grain sold to cooperative	394	221.12	130.00	345.55	0.00	4500.00
Amount of green cobs sold to local market/middle man	394	0.95	0.00	7.95	0.00	200.00
Amount of dry cobs sold to local market/middle man	394	1.94	0.00	16.62	0.00	300.00
Amount of grain sold to local market/middle man	394	13.10	0.00	53.44	0.00	1000.00
Earnings from green cobs sold to cooperative	394	1323.36	0.00	14698.37	0.00	216000.00
Earnings from dry cobs sold to cooperative	393	18350.13	0.00	44566.61	0.00	375000.00
Earnings from grain sold to cooperative	394	84534.85	35400.00	134234.42	0.00	988000.00
Earnings from green cobs sold to local market/middle man	394	150.84	0.00	1075.37	0.00	15000.00
Earnings from dry cobs sold to local market/middle man	394	473.17	0.00	3750.59	0.00	54000.00
Earnings from grain sold to local market/middle man	394	3310.19	0.00	13069.27	0.00	240000.00
Price per kg of dry cobs sold to cooperative	148	235.37	250.00	50.91	150.00	350.00
Price per kg of grain sold to cooperative	192	364.56	300.00	153.95	140.00	650.00
Price per kg of dry cobs sold to local market/middle man	8	256.69	250.00	39.46	180.00	320.00
Price per kg of grain sold to local market/middle man	51	263.92	250.00	48.95	150.00	400.00
Risks and unintended effects						
Amount spent on buying charcoal to compensate for sold cobs (in RWF)	245	7053.29	4000.00	8432.45	245	7053.29

	N	Mean	Median	SD	Min	Max
Season C 2021 land and harvest						
Land size cultivated with maize (ha)	399	0.26	0.20	0.23	0.01	1.50
Harvest (kg)	399	711.90	500.00	601.34	20.00	5000.00
Yield (kg/ha)	396	4785.59	3166.67	5015.07	108.33	39166.67
Season C 2021 maize consumption						
Consumption of harvested green cobs	399	30.04	20.00	48.01	0.00	500.00
Consumption of self-processed dry cobs	399	6.32	0.00	24.27	0.00	150.00
Consumption of self-produced grain	398	51.36	50.00	47.48	0.00	300.00
Post-harvest costs						
Labour for shelling	372	7156.02	4200.00	11199.05	0.00	100000.00
Labour costs saved by having unpaid Labour for shelling	372	3884.07	2000.00	9112.66	0.00	100000.00
Machine for shelling	138	2349.07	1000.00	3914.08	0.00	30000.00
Labour for drying grain	362	3457.14	1000.00	5645.46	0.00	40000.00
Machine for drying grain	1	0.00	0.00	0.00	0.00	0.00
Labour cost saved by having unpaid Labour for drying grain	362	3052.68	2000.00	3075.97	0.00	30000.00
Material for treating	144	1024.76	800.00	1165.31	0.00	6000.00
Bags for storing	185	1682.15	1200.00	1578.81	140.00	10000.00
Other post-harvest processing costs	399	6625.71	3000.00	9021.04	0.00	140000.00
Sales and earnings from maize						
Amount of green cobs sold to cooperative	399	0.39	0.00	6.21	0.00	100.00
Amount of dry cobs sold to cooperative	399	116.78	0.00	204.10	0.00	1200.00
Amount of grain (not including seeds) sold to cooperative	399	95.08	0.00	232.60	0.00	2100.00
Amount of seeds sold to cooperative	399	32.56	0.00	135.27	0.00	1086.00
Amount of wet grain sold to premium buyer after shelling	398	96.51	0.00	223.56	0.00	1600.00
Amount of green cobs sold to local market/middle man	399	0.48	0.00	5.35	0.00	80.00
Amount of dry cobs sold to local market/middle man	399	0.19	0.00	3.32	0.00	75.00
Amount of grain sold to local market/middle man	399	13.92	0.00	38.80	0.00	300.00
Earnings from green cobs sold to cooperative	399	104.20	0.00	1676.22	0.00	27000.00
Earnings from dry cobs sold to cooperative	390	26779.73	0.00	50150.61	0.00	300000.00
Earnings from grain (not including seeds) sold to cooperative	395	27913.30	0.00	74483.52	0.00	650000.00
Earnings from seeds sold to cooperative	399	19883.38	0.00	84741.17	0.00	705900.00
Earnings from wet grain sold to premium buyer after shelling	398	29878.40	0.00	70382.03	0.00	480000.00
Earnings from green sold to local market/middle man	399	71.36	0.00	779.96	0.00	15000.00
Earnings from dry cobs sold to local market/middle man	399	43.13	0.00	775.52	0.00	21000.00
Earnings from grain sold to local market/middle man	399	4155.46	0.00	11968.88	0.00	80000.00

	N	Mean	Median	SD	Min	Max
Price per kg of green cob sold to cooperative	1	270.00	270.00	0.00	270.00	270.00
Price per kg of dry cob sold to cooperative	158	250.35	250.00	63.68	100.00	600.00
Price per kg of grain (not including seeds) sold to cooperative	154	286.46	300.00	79.62	140.00	650.00
Price per kg of seeds sold to cooperative	45	581.38	600.00	142.12	150.00	1000.00
Price per kg of wet grain sold to premium buyer after shelling	94	310.59	300.00	111.06	150.00	700.00
Price per kg of green cob sold to local market/middle man	5	154.73	112.50	89.07	100.00	300.00
Price per kg of dry cob sold to local market/middle man	2	216.86	200.00	61.19	200.00	280.00
Price per kg of grain sold to local market/middle man	61	292.82	300.00	50.11	150.00	400.00

Notes: Observations are weighted using design weights.

ANNEX 11 FIELD MISSION SCHEDULE

Table 14: Primary data collection schedule

Date	ET/ST members	Location	Activities
Qualitative primary data collection (interviews, focus groups, direct observation)			
Kigali and remote			
Before 15 Nov 2021	ET 1, 2	Remote	KIIs prior to field mission (AflaSight – Managing Directors and CEO; WFP CO – FtMA Coordinator; WFP Head of Innovation Hub for Eastern Africa)
15 Nov 2021	ET 1, 2, 3, 4	Kigali	KIIs with WFP staff at CO: • Deputy Country Director • FtMA Coordinator/Head of SAMS • M&E Officer FtMA • Head of Supply Chain Unit – Food Safety • Logistics Officer (Food Technologist) KII with IITA, Research Associate and Senior Agribusiness Specialist
16 Nov 2021		Kigali SEZ	Visit to AflaSight plant Direct observation of AflaSight processing line (unloading, drying, cleaning, and optical sorting equipment and processes) KII with AflaSight, Managing Director KII with AIF, Value Chain Operations and Special Projects Manager
17 Nov 2021	ET 1, 4	Kigali	KII with FAO, Assistant FAO Representative KII with Minimex, Operations Manager
		Remote	KII with Bühler, Global Head of Segment
18 Nov 2021		Kigali	KII with RAB, Deputy Director General KII with RSB, Director General
19 Nov 2021	ET 1	Kigali	IFC Symposium on Maize Quality: Brief meetings with traders
23 Nov 2021		Kigali	Follow-up meeting with FtMA Coordinator KII with EAX, Chief and Deputy Chief Operating Officers
		Remote	KII with WFP Innovation Accelerator, New Ventures Consultants KII with IFC, Senior Operations Officer
30 Nov 2021	1, 2, 3, 4	Remote	Remote debriefing with CO and RBN
Southern Province – part 1			
17 Nov 2021	ET 2, 3	Kigali – Huye	Road trip to Huye
		Huye	IDI with WFP Programme Associate
18 Nov 2021		Gisagara district	Cooperative Coyjamugi: • 2 FGDs with women and 2 FGDs with men • IDI with President
19 Nov 2021		Gisagara district	IDI with RWARRI, Senior Extensionist Cooperative Coyjamugi: • IDIs with Accountant and Agronomist • Direct observation of maize plantation and drying facilities
	ET 1	Kigali – Huye	Road trip to Huye
	ET 1, 2	Huye	Team meeting
20 Nov 2021	ET 1, 3	Gisagara district	Cooperative CCM Muganza: • 2 FGDs with women and 2 FGDs with men

Date	ET/ST members	Location	Activities
	ET 2	Huye – Kigali	Road trip to Kigali
22 Nov 2021	ET 1, 3	Gisagara district	Cooperative CCM Muganza: • 1 FGD with Executive Committee • IDI with Accountant
		Huye – Kigali	Road trip to Kigali
Southern Province – part 2			
12 Dec 2021	ET 3, 4	Kigali – Huye	Road trip to Huye
13 Dec 2021		Nyanza district	Cooperative Coamanya-Nyanza: • 2 FGDs with women and 2 FGDs with men • Direct observation of drying facilities and post-harvest work
14 Dec 2021		Nyanza district	Cooperative Coamanya-Nyanza: • IDIs with President, Accountant, and Trainer • Direct observation of drying facilities and post-harvest work
	ET 3	Huye – Kigali	Road trip to Huye
15 Dec 2021	ET 4	Gisagara district	Cooperative Coamanya-Gishubi: • 1 FGD with women and 1 FGD with men • IDI with Trainer
16 Dec 2021		Gisagara district	Cooperative Coamanya-Gishubi: • 1 FGD with women and 1 FGD with men • IDI with President
17 Dec 2021		Remote	Cooperative Coamanya-Gishubi: • IDI with Accountant
		Huye – Kigali	Road trip to Kigali
Quantitative primary data collection (smallholder survey)			
Kigali and Southern Province			
12 Nov 2021	ST researchers, supervisors	Nyanza district	Pre-test of the survey with SHFs of Cooperative Coamanya-Nyanza
15 Nov 2021		Kigali	In-class supervisor training
16-20 Nov 2021	ST all members	Kigali	In-class enumerator training
22 Nov 2021		Nyanza district	Piloting of the survey with SHFs of Cooperative Coamanya-Nyanza
24 Nov 2021		Kigali	Training and pilot debrief
29 Nov – 13 Dec 2021		Gisagara and Nyanza districts	Data collection from SHFs of all cooperatives (Coyjamugi, CCM Muganza, Coamanya-Gishubi, Coamanya-Nyanza)

ET = evaluation team (member), ST = survey team

ANNEX 12 GROSS MARGIN ESTIMATES FOR FARMERS

Table 15: Gross margin (per kg) calculations for SHFs in the four pilot coops, season C 2021 maize

Model	Cob model * (configuration B)	Grain model without AflaSight (configuration C)
Assumed aflatoxin levels	Cob bought <7 ppb	Grain bought <7 ppb
Sub-sample size in SHF survey	167	233
Gross margin (profit) calculations per kg		
Farmgate price per kg of grain (equivalent) paid by premium buyer [a]	270 RWF	300 RWF
Total PHHS costs per kg excl. unpaid labour (see breakdown below)	38 RWF	119 RWF
Value of charcoal/wood purchase to make up for 1 kg of cobs sold [b]	37 RWF	
Total gross margin per kg	**195 RWF**	**181 RWF**
Breakdown of total PHHS costs per kg by cost category [c]		
Cost per kg: Shelling cobs - paid labour [d]		28.11 RWF
Cost per kg: Shelling cobs - use of machine [d]		5.24 RWF
Cost per kg: Drying grain - paid labour [e]		37.78 RWF
Cost per kg: Treatment of dried grain [e]		5.92 RWF
Cost per kg: Storage of grain - bags [e,f]	2.00 RWF	8.21 RWF
Cost per kg: Other PHHS activities [g]	36.38 RWF	18.27 RWF
Weight loss per 100 kg of grain during drying (in kg) [h]		*5.55*
Cost per kg associated with weight loss from drying		15.38 RWF

Sources: Evaluation team analysis of SHF survey data from pilot coops (all costs); FtMA (farmgate prices).

Samples: Farmers who sold or expected to sell some cob (167 farmers) or grain (233 farmers) to coop or premium buyers in season C 2021.

Note: The costs do not include unpaid (own) of farmers. Cost for coop fees and cob drying are assumed to be small and equal in both models and therefore not included either.

* In the cob model, the per-kg prices and costs refer to kg of grain equivalent after drying, cleaning, and shelling. Weight losses from these procedures are thus already factored into the price and costs.

[a] Actual farmgate prices paid to the four coops in season C 2021 (for simplification, ignoring that one coop received 280 RWF/ kg for cob). To avoid mixing prices and costs between different models, the calculations assign all farmers the prices of the model (cob or grain) they predicted and provided cost estimates for. For almost all farmers, this also reflects the actual prices they received (only a few members of coops that ultimately sold on cob had erroneously predicted the wrong model).

[b] Absolute costs divided total kg of grain equivalent (77%) of dry cobs (expected to be) sold to coops.

[c] Unconditional means, i.e. zero values for the few farmers in the given sub-samples who did not engage in the specific activity.

[d] Absolute costs divided by total kg of grain (expected to be) shelled.

[e] Absolute costs divided by total kg of grain (expected to be) processed after shelling (i.e. kg amount in previous footnote minus kg of wet grain (expected to be) sold to premium buyers directly after shelling).

[f] Cost of storage bags for cob were included in other PHHS costs in the survey, but here imputed from *KIT. 2019. Understanding the costs and benefits of the cob model for maize farmers in Rwanda.* 1.93 RWF/kg + assumed 0.07 RWF/kg increase since then.

[g] In the cob model, the proportional share of other PHHS was calculated was calculated for the many farmers who also processed grain for own consumption.

[h] Excluding wet grain directly sold to premium buyers after shelling.

ANNEX 13 FINDINGS CONCLUSIONS RECOMMENDATIONS MAPPING

Table 16: Mapping of findings, conclusions, and recommendations

Recommendation	Conclusions	Findings
Based on conclusions 3, 4, and 6 **Recommendation 1**: WFP/FtMA should support (throughout the life of the FtMA programme) coops whose grain passes through the AflaSight process, as a means of increasing the income of SHFs (and women in particular) and continuing the shift from subsistence to commercial farming. ***Based on conclusions 3 and 6*** **Recommendation 2:** WFP/FtMA should continue to monitor and support the engagement of SHFs with the AflaSight pilot to maximise its value for them and to maximise the access of coops to the technology.	**Conclusion 4:** Women and men have equal access to the technology, but they may benefit from it somewhat differently although it is too early to tell with certainty.	EQs 1.1, 5.1, 6.1, 6.3
	Conclusion 6: FtMA will play an important role in the introduction of AflaSight to guide farmers and coops as to how they maximise their chances to sell to processors and share the value added from the technology.	EQ 2.1, 5.3, 6.1
	Conclusion 3: AflaSight should enable farmers to sell a larger quantity of grain to premium markets and increase their income, provided that they are able to connect – and negotiate higher farmgate prices for aflatoxin-affected grain – with the direct users of AflaSight.	EQs 2.2, 3.2, 5.2, 5.4, 6.1
Based on conclusion 7 **Recommendation 3:** The Innovation Hub for Eastern Africa, with support of the Rwanda CO, should mobilise innovation funding for AflaSight until the results are better understood and can inform the decision on scale-up (while already exploring funding options for scale-up).	**Conclusion 7:** The pilot clearly needs to continue for several more months to gain more experience with the process itself, learn how value chain members make use of it, and make decisions on scaling up.	EQs 3.1, 4.1, 5.1, 6.1, 8.1, 8.2, 8.3, 9.2
Based on conclusions 1 and 5 **Recommendation 4:** WFP should explore opportunities to work with RICA to support their efforts to widen the enforcement of aflatoxin standards and to carry out market surveys. ***Based on conclusion 5*** **Recommendation 5:** WFP should work with the authorities and key stakeholders such as EAX to explore the opportunity to further develop a warehouse receipt system in Rwanda in the context of the quality "insurance" provided by AflaSight ***Based on conclusions 1, 2, and 5*** **Recommendation 6:** WFP (RBN) should commission a study to identify which countries in East Africa would most benefit from access to the Bühler LumoVision technology.	**Conclusion 2:** The machine's performance in the pilot so far is likely to be sufficient to reduce aflatoxin levels in grain and provide a cost-effective solution for increasing the volume of domestic grain available to processors.	EQs 3.1, 4.1
	Conclusion 1: Aflatoxin is a major problem in Rwanda and optical sorting has the potential to make a big contribution and generate direct or indirect benefits for all members of the maize value chain.	EQs 1.1, 1.2
	Conclusion 5: There are many potential advantages for consumers and the economy.	EQs 7.1, 7.2

Source: Evaluation team.

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ANNEX 15 ACRONYMS

AIF	Africa Improved Foods
C4ED	Center for Evaluation and Development
CGIAR	(formerly) Consultative Group on International Agricultural Research
CO	Country Office
CSP	Country Strategic Plan
DE QS	Quality Service for Decentralized Evaluations
EAC	East African Community
EAX	East Africa Exchange
EQ	Evaluation Question
ER	Evaluation Report
ERG	Evaluation Reference Group
ET	Evaluation Team
FAO	Food and Agriculture Organization of the United Nations
FGD	Focus Group Discussion
FtMA	Farm to Market Alliance
GAFSP	Global Agriculture and Food Security Programme
GAP	Good Agricultural Practices
GEEW	Gender Equality and Empowerment of Women
IDI	In-Depth Interview
IFC	International Finance Corporation
IFPRI	International Food Policy Research Institute
IITA	International Institute of Tropical Agriculture
IPAR	Institute of Policy Analysis and Research
IR	Inception Report
kg	kilogram
KII	Key Informant Interview
KIT	Royal Tropical Institute
M&E	Monitoring and Evaluation
MINAGRI	Ministry of Agriculture and Animal Resources of Rwanda
MINICOM	Ministry of Trade and Commerce
mVAM	mobile Vulnerability Analysis and Mapping
N	Number of Observations
OECD-DAC	Organisation for Economic Co-operation and Development – Development Assistance Committee
PHHS	Post-Harvest Handling and Storage
ppb	Parts per Billion
PPI	Poverty Probability Index
QLI	Qualitative
QTI	Quantitative
RAB	Rwanda Agriculture Board
RBN	Regional Bureau of Nairobi
RICA	Rwanda Inspectorate, Competition and Consumer Protection Authority
RGCC	Rwanda Grains and Cereals Corporation
RSB	Rwanda Standards Board
RWARRI	Rwanda Rural Rehabilitation Initiative
RWF	Rwandan Franc
SD	Standard Deviation

SDG	Sustainable Development Goal
SE	Standard Error
SEZ	Special Economic Zone
SHF	Smallholder Farmer
ST	Survey Team
t	ton
ToC	Theory of Change
ToR	Terms of Reference
UN	United Nations
USD	United States Dollar
UV	Ultraviolet
VC	Value Chain
WFP	World Food Programme

WFP Rwanda Country Office

https://www.wfp.org/countries/rwanda

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