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Triple Helix approach to innovation in Rwanda's agriculture resulted in a partnership between educational institutions and a private firm producing clean seed potatoes

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Abstract

Purpose – Higher productivity in the potato value chain in Rwanda requires good quality seed potatoes. The article analyzes how innovations were introduced in the framework of a development project resulting in a partnership between a firm and two educational institutions to produce better seed potatoes, using the Triple Helix approach.

Design/methodology/approach – In the Triple Helix model government, academia and the private sector work together to develop and introduce innovations. This led to producing and introducing improved seed potatoes at an affordable price through a public private partnership (PPP). Interviews with experts and a survey of local producers were carried out to identify factors influencing the success of the partnership.

Findings – A Service, Training and Innovation Center (STIC) has been created to produce the first clean potato seeds in Africa on a commercial scale, based on cultivation of in vitro potato plantlets and aeroponics to produce mini-tubers. It is called Seed Potato Advancement Centre, an education–enterprise partnership, using these plantlets to produce mini-tubers through aeroponics. Seed multipliers are responsible for the next three stages of seed multiplication. The final product is the certified potato, sold to ware potato farmers. The availability of disease-free seed potatoes in Rwanda gives a boost to the potato value chains and contributes to food security. The partnership was successful because of the support from the government and donors, with the private sector and the extension services helping to implement the innovations effectively.

Research limitations/implications – The limitation is that the number of experts interviewed is limited and the survey did not only deal with potato-related activities. The focus is on one region only, but the most important potato growing area in Rwanda.

Social implications – STICs function as a tool for cooperation between government, private sector and the knowledge sector to achieve commercial and development goals. They function as a channel for technology transfer. They allow applied research, including agronomic research; information collection; and dissemination, networking, training, organization of outreach activities. The model can be repeated in other sectors and countries.

Originality/value – The paper looks at a PPP in agriculture with educational institutions. Second, the Triple Helix and value chain literature is used to study the introduction and implementation of appropriate

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innovations, while factors determining the success of the partnership were identified. This concerns the first production of clean seed potatoes in Africa on a commercial scale.

Keywords Triple Helix, Partnerships, Seed potatoes, Ware potatoes, Value chains, In vitro plantlet, Aeroponics, Frugal innovation, Private sector, Food security

Paper type Case study

Introduction

Potatoes are increasingly becoming one of the important food security crops in East Africa [1]. Many farmers in Rwanda are involved in commercial agricultural activities, such as raising chicken, producing fruit and vegetables or growing potatoes. This paper focuses on recent innovations in the seed and ware potato value chains in Rwanda. Bananas are the major food crop in Rwanda, while potatoes have come to the second place. The objective of this paper is to analyze an effort to introduce innovations in the potato value chain in Rwanda, through a public private partnership (PPP) with two educational institutions and a commercial seed potato multiplier firm.

The potato value in Rwanda will be introduced in the following section, followed by a description of the process to achieve and introduce innovations in the seed and ware potato value chains. The Triple Helix approach to innovation led to a PPP for producing clean (disease-free) seed potatoes using the latest technology. This achievement and the partnership will be analyzed to determine which factors have influenced the results and whether a dynamic agro-cluster of potato-related activities can be expected.

The potato sector in Rwanda

There are two growing seasons for potatoes, from the end of August to early February and from the end of February to early July; 60% of the potato production comes from the north-west, in particular from the Rubavu, Nyabihu, Musanze and Burera districts. In the Northern province, potatoes generate more than half the annual household income. The production of potatoes increased from 2.2 million tons in 2013 to 6 in 2019 [2]. However, the quality of the seed potatoes and the agricultural practices need improvement to increase the productivity of these farms (Shimira *et al.*, 2020).

Most farmers plant potatoes using seed tubers kept from the last season as propagation material for the next crop. This limits the productivity of producing ware (or consumption) potatoes. Good seed potatoes need to be bought but are not always available and can be quite expensive if coming from abroad. Modern disease-free seed potatoes can only be used once. Hence, the average potato yield is low in Rwanda, while with good seed potatoes and improved crop management farmers could harvest two times more.

Rwandan farmers often have less than 1 hectare (70% has less than 0.5 hectare), which is often rented land, where the responsibility for the quality of the soil (stewardship) is less felt. They also use it for growing other crops, which makes it difficult to achieve economies of scale. Due to climate change, there is sometimes not enough water available for an optimal growth of the potatoes, particularly during the dry season.

According to a baseline study for the Sustainable Development Goals Partnership Project (SDGP, 2018), the average production of potatoes in Rwanda was 10–12 tons per hectare [3] Currently, farmers achieve 15–25 tons/hectare if all good agricultural practices are observed: proper rotation, quality seed potatoes, fertilization and the use of pesticides. Potentially, they can reach 30 tons/hectare.

Weatherspoon *et al.*, 2021 provide an overview of agricultural policies in Rwanda, focusing on efforts to achieve land reform, improve infrastructure, supply inputs and promote exports. Farmers complain that the price of ware potatoes does not take their cost of

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production into account. Because of the global crisis (COVID-19 and the Russia–Ukraine war), costs for agricultural inputs (fertilizers, pesticides, seeds, etc.) increased while the price paid to the farmers did not change much. Some farmers spent more on inputs than what they earn. The government comes in if the consumer price for ware potatoes goes beyond 450 RWF.

The quantity of quality seeds used by potato farmers in Rwanda is still a problem. Currently, the use of certified seed potatoes is only 10% of the market in Rwanda, and most ware potato farmers keep a part of their produce for next season. A solution of this problem needs to be found to assure the food security of a fast-growing population disposing of limited land for commercial agriculture. To increase the productivity of the farmers, Rwanda needed to invest and use specialized knowledge available elsewhere in the world.

The innovation: in vitro technology, aeroponics and better extension services

Growing ware potatoes becomes more profitable if certified seed potatoes are used with technical advice. This was the ambition of a newly created seed potato Service, Training and Innovation Centre (STIC), a PPP with two educational institutions and a multiplier firm supported by some donor projects. Two big projects were financed by the Netherlands government under the administration of the Nuffic [4]: the Strengthening Education for Agricultural Development (SEAD) and SEAD West project, covering the period 2015 to July 2021 and from 2019 to 2023 [5] They aimed at strengthening capacity in Rwanda through investing in agriculture and post-secondary education and training [6] The total budget for SEAD and SEAD West was € 12.5 million for strengthening the capacity of partner institutions, for demand-led curriculum development/revision and delivery, for strengthening community outreach and extension services of partner institutions. The projects should respond to the needs of the agricultural community in specific values chains. Finally, the projects strengthened research and innovation capacities of the partner institutions. The objectives of the STICs are summarized in Box 1.

The SEAD and SEAD West projects created five STICs through the Triple Helix approach by selecting the government education institutions and a private sector partner. The STIC functioned as a vehicle to forge demand-led relations between the education institutions and the private sector. Box 2 lists all STICs financed so far and mentions the public and private partners.

In this paper, we deal with the effects of one STIC that has been created to produce clean potato seeds and is called the Seed Potato Advancement Centre (SPAC). It is a joint venture between the College of Agriculture, Animal Science and Veterinary Medicine of the

Box 1.

The objectives of the STICs

(1) Improving on- and off-farm productivity
(2) Improving competitiveness of the agricultural sector
(3) Strengthening linkages across the agriculture and food value chains
(4) Contributing to knowledge development, sharing and brokering
(5) Introduction and dissemination of (contextualized) global best practices and technological innovation
(6) Investing in capacity building initiatives and skill development for actors across the value chain
(7) Reducing spoilage, increasing value added and farmer incomes
(8) Improve knowledge exchange between value chain participant

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Box 2.

STICs in Rwanda: the sector, educational institute(s) and the private company

(1) **Horticulture:** IPRC Huye/Gift Rwanda
(2) **Dairy:** UR CAVM/IPRC Musanze/Alpha Milk Company Ltd
(3) **Potato:** UR CAVM/IPRC Musanze/the Seed Potato Fund (SPF)
(4) **Poultry:** IPRC Ngoma/IPRC Gishari/ABUSOL
(5) **Agro-Tourism:** IPRC Karongi/Holland Greentech Rwanda (HGT)

Source(s): Authors' own creation

University of Rwanda (UR CAVM), the Integrated Polytechnique Regional College (IPRC) Musanze and the private partner, the Seed Potato Fund (SPF) [7] SPF itself is a joint venture of a number of potato farming cooperatives, individual potato farmers and some seed potato multipliers. The SPF has a management contract with the UR CAVM and the IPRC Musanze on how to use the facilities for the agreed purpose. The STICs are addressing needs of the education sector, the private sector and the community. The main activity of the potato STIC is the production of mini-tubers and selling them to seed multipliers.

The SEAD project introduced the STIC concept and was building on earlier knowledge development projects in the potato sector funded by the Dutch government and monitored by Nuffic, for example, the SDGP project. It funded the biggest aeroponics infrastructure in Rwanda. Bringing the private sector on board in the SPAC was done to improve the efficiency of the operations. The greenhouses in Musanze were provided by the SEAD and another project and have been transferred to the SPAC to allow them to start producing better seed potatoes. The soil used in the greenhouse has been heated to diminish the number of possible infections.

The SPAC wants to produce enough quality seed potatoes, to provide training and advisory services on seed production and to improve coordination among the key players along the potato value chain in Rwanda. The aim is to become a financially sustainable business supplying continuously quality seed potatoes. Farmers are trained in improved crop management, students can do internships and the STIC intends to establish a seed production tracking system, to guarantee the cleanness of the seed potatoes.

The SPAC, the clean seed potato-producing company, uses the in vitro plantlets supplied by the Rwanda Agricultural Board (RAB) to produce mini-tubers. Table 1 gives the details for each of the five stages necessary for producing clean seed potatoes. It takes more than two years before certified potatoes are available, which allow farmers to grow more ware potatoes, because they are less vulnerable to plant diseases (late blate, nematodes) and pests. The prices in Table 1 are determined by the Ministry of Commerce and Trade.

Aeroponic farming (also known as soil less farming) for the in vitro generated plantlet is the innovation used for producing mini-tubers. It is a new technology in East Africa. This innovation allows the production of quality seed potatoes because they are produced under controlled conditions. Using the technology on a commercial scale is currently unique for Africa. It requires skills, a laboratory or a greenhouse, while the last three stages are carried out in the open field. The multiplication in the greenhouse is a repetitive process and can quickly result in producing huge quantity of mini-tubers. The production can be done twice a year. No crop rotation is required.

It takes more than two years before you have a certified seed potato that allows the farmers to grow ware potatoes from clean seeds. The complication is that each of the five stages in the process of producing better quality seed potatoes has to have its own business

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Stage	Length of time	Price in 2022	Multiplication factor	Result, number of potatoes
Growing of in vitro plantlet	1–1.5 months	from RAB price 115 RWF/ plant	1 plantlet	1 plantlet
Plantlets used to get mini-tubers, taking 1 month	6 months of harvesting and 4 months sprouting	100 RWF per mini-tuber	1 plantlet produces 60 to 100 mini-tubers	1 gives at the average 80 mini-tubers
Generation 1 Prebasic	4 months to grow plus 4 to sprout	850 RWF per kg	10 a 12	11 × 80 = 880
Generation 2 Basic	4 months to grow plus 4 to sprout	750 RWF per kg	10 a 15	12.5 × 880 = 11,000
Generation 3 Certified	4 months to grow plus 4 to sprout	700 RWF per kg	10 a 15	12.5 × 11,000 = 137,500 certified
Total	2–3 years	450 RWF per kg	yield now and if using clean seed	12.5 to 25 t/ha (10–15; 20–30)

Source(s): Authors' own creation

Table 1.
Details of the different stages in producing certified seed potatoes in Rwanda

model. Even the laboratory or the greenhouse where the plantlets are cultivated needs to cover their cost. After producing the mini-tubers, certified farmers are involved in the next three stages and each one needs to make money, which means that the certified seed potatoes may easily become too costly for the local market.

Table 1 showed the value chain for disease-free seed potatoes, starting with tissue culture or in vitro raised plantlets, mini-tubers are produced from them using aeroponics. These are sold to certified seed potato multipliers, who grow prebasic seed potatoes. The next seed potato multiplier produces basic seed potatoes and finally, the last seed potato multiplier produces the certified seed potatoes, which are sold to the ware potato farmers.

Mini-tubers (size 25–33 mm) currently cost around 100 RWF each and are mostly sold to prebasic seed potato multipliers. These are officially registered individual farmers or firms who can assure good quality seed potato production. Experts note that it is important to get a better organization of the seed market in Rwanda. This requires advisory services for seed producers.

The Rwandese government made available 100 hectare (all virgin land) for seed multiplication to Early Generation Seed Potato (EGSP-Imbuto). The company started its operations in December 2020 to ensure the stability of early generation seed potato in Rwanda. Of all mini-tubers produced EGSP buys 80% and sells them to seed multiplier farmers [8] The reasons to create EGSP are summarized in Box 3. EGSP also provides

Box 3.

The reasons for EGSP-Imbuto existence

(1) Strengthen multiplication and availability of adequate mini-tubers and pre-basic seed
(2) Promote quality seed potato use,
(3) Promote high technology in multiplication of early generation seed
(4) Strengthen the partnership with other stakeholders in seed potato value chain

Source(s): https://egsp.co.rw

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technical support and trainings for mini-tubers producers and assists them to fulfill inspection requirements. The company produces quality potato pre-basic and basic seeds to strengthen the potato value chain in Rwanda.

Tissue cultures of seed potatoes varieties, which have been approved by Rwanda, can also be imported, but local production means Rwanda is less dependent on foreign suppliers. Sometimes, approval can be obtained to import limited quantities of mini-tubers. The facilities of the SPAC are on the UR CAVM campus in Musanze, but the IPRC Musanze is also involved as the second educational institution in the STIC. UR CAVM never used the chances offered by the equipment supplied under the previous Nuffic project. Now these facilities are rented by the SPAC.

The SPAC's mega aeroponic greenhouses are the biggest aeroponic producer of seed potatoes in the East African region with the capacity of producing 500,000 mini-tubers per season (in 6 months). The aeroponics facility was funded by Dutch government through SDGP project. The private partner SPF is a joint venture of cooperatives and seed potato traders. Initially, they were buying seed potatoes from farmers to keep them for four months (sprouting period) and put them on the market for farmers to buy. The seed potatoes sold previously were not 100% clean and quality seeds.

The challenge for the SPAC is to come to scale. The objective is to go from 300,000 (in 2022) to 400,000 mini-tubers in 2023, and they are aiming at producing eventually 700,000 mini-tubers per year. The poor quality of the seed potatoes used in the past was the reason for suggesting to start producing clean seed potatoes in the framework of the SEAD projects.

Theory and literature

The value chain literature is relevant to understand the effects of innovation. In the potato sector there are in fact two value chains. First the seed potato value chain which produces certified seed potatoes. Subsequently, the ware potato value chain depicted in Figure 2. Figure 1 summarizes the different stages in the seed potato value chain.

The quality of the seed potatoes is very important. Because of all kinds of diseases, which accumulate over time, the farmers should not use their own potatoes again and again, and certainly not after a few years. Hence, to reach a higher productivity, they have to buy the disease-free seed potatoes, which tend to be expensive because they were imported until recently. The high cost implies a risk that the farmers do not earn back their investments if there is too little or too much rain, or the harvest is negatively affected in another way.

Farmers growing ware potatoes can now buy clean potato seeds. Figure 2 shows the chain for ware potatoes from the farmer to selling them to consumers. Sometimes, the trading, transport and storage are separated, while processing activities are currently limited to a few percent of the potatoes in Rwanda.

Three bodies of literature will be used to analyze the case. In the first place, the Triple Helix theory which stipulates that innovations can only be successfully implemented if there is cooperation between academia, the public and the private sector (Van Winden and de

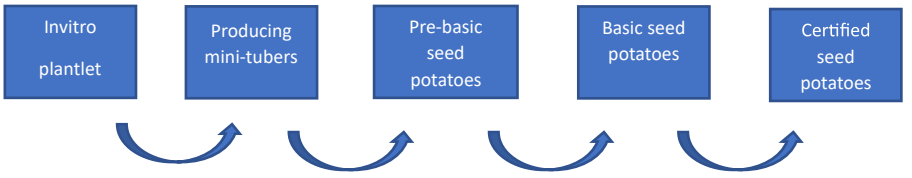

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Figure 1.
Different segments in the seed potato value chain

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Carvalho, 2015). Second, use is made of the value chain theory, allowing a holistic approach to the issues in the chain. Finally, the literature on partnership is used to identify factors that contribute to the success or failure of partnership projects.

In the Triple Helix approach Technical and Vocational Education Training (TVET) institutions (IPRC in Rwanda) or a university (UR CAVM), or the private sector may supply the innovation. However, its implementation requires collaboration with other actors. Once the technology is developed, the private sector, nongovernmental organizations (NGOs), or public sector institutions will help to deliver the improved seed potatoes with technical advice to the farmers. They make clear how to grow these potatoes and how to use inputs in an optimal way, while the national and local governments regulate the sector and encourage the use of these new technologies to serve the farmers and food production. A similar study exists for Tanzania, where the emphasis on the factors motivating farmers to invest in quality seeds of new potato varieties (Okello *et al.*, 2018).

Second, we analyze the potato value chain, using a framework suggested by Van Dijk and Trienekens (2012). They emphasize the importance of an analysis of the role of different actors, of the margins and of preparing a value chain upgrading plan. Special emphasis will be put on the research question: will a Triple Helix approach, combining government, academia and private sector efforts, generate the required innovations leading to affordable and improved seed potatoes and hence a bigger production of ware potatoes at the farmers' level?

Finally, research on the success and failure of partnerships is important because it helps to understand the factors of success (Partnership Resource Centre, 2016). Smeele (2019) listed a number of factors which may be contributing to the success of such PPPs and which will guide our research:

(1) A clear role for the different partners

(2) An agreement on who should do what

(3) Creating a win-win situation for the different partners

(4) Sharing resources and risks

(5) Working in a clear regulatory framework

These characteristics of partnerships, built through a Triple Helix approach, may contribute to the success or failure of the SPAC. If the right characteristics are in place the partnership may become the dynamic nucleus of a bigger agro-cluster of potato related activities, which may develop subsequently (Kariuku, 2023).

Methodology

Several methods were used to collect the necessary data. In the first place existing data on the potato sector in Rwanda were used, second through in depth interviews with a number of potato experts relevant information was collected and finally a survey was carried out of small and medium enterprises (SMEs) in the Western and Northern province of Rwanda,

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Figure 2.
Different segments in the ware potato value chain

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including some potato producers and traders (Van Dijk, 2023). A questionnaire for diagnostic purposes was developed, to advise the entrepreneurs, and to get to know the potential of these SMEs in these provinces. The following activities covered in the survey are part of the ware potato value chain: two farmers producing and selling potatoes, five Cooperative Potato Collection Centers (CPCC) and several restaurants buying the potatoes and several support services in the ecosystem, which help potato farmers with credit, technical advice or inputs. Also, a number of small scale enterprise experts were interviewed, giving the points of view of the different stakeholders in these value chains.

Results, following the theoretical framework

1. Triple Helix approach to generate innovation: the role of different stakeholders

Rwanda is very much aware of the importance of technology for agricultural development, but struggled to get the right technology for the development of the potato value chain, to introduce and disseminate this technology and to keep it affordable for the farmers. In the Triple Helix model chosen in the SEAD projects, a desirable product is developed through consultation with higher education or university institutes, in collaboration with the industry and the government. It emphasizes that it is not only important to innovate but also to develop and introduce the innovation. This approach has become popular when it became clear that innovations cannot be introduced without the help of the other partners. The Triple Helix forces us to specify the role of each partner and that is exactly what is done in the framework of the management contracts used for the STICs.

The Triple Helix approach is departing from traditional investment approach, by focusing also on the institutional, the environmental and financial sustainability of the project (Van Winden and de Carvalho, 2015). In the projects mentioned, the government sector was represented by the Rwanda Development Board (RDB), and academia by the UR CAVM and the Rwanda Polytechnique (RP, responsible for the IPRCs). A tender was organized to find a private party for each of the five STICs that would be created in Rwanda. After the selection the process of building the relationships between the different parties started with formulating business and strategic plans and implementing the necessary investments, in the order of 500,000 euros for each STIC.

The innovation is very much a frugal innovation in the sense of combining in an intelligent way a number of existing components (Weyrauch and Herstatt, 2017): the in vitro technology, aeroponic farming and certified multiplication. At the farm level, the use of new extension technologies and of cooperatives played a role. Providing clean potato seeds is an example of a frugal innovation introduced through the Triple Helix approach.

The final product (the certified potato) is sold directly or through traders to ware potato farmers or in neighboring countries. Important for the SPAC were suppliers of the in vitro plantlets for seed potatoes. The SPAC can produce in vitro plantlets itself but not in the quantities it requires. The approach chosen is in line with the policy of the government to produce more seed in Rwanda, which helps to make the approach successful. The equipment has been put in place, the training has been provided and production has started in 2022, although it still has to come to scale.

Kariuki (2023) studied to what extent the potato STIC has achieved its goals of being not just a clean seed potatoes production unit but also a teaching, a research and innovation platform. He concludes that the selected private partner is keen to support students to get practical skills in course of their education. The SPF already had a culture of providing internships to build a pool of skilled students from which it can recruit in the future. The SPAC is now training students to support farmers involved in seed potato multiplication as extension agents. The private partner is working on a coaching and mentoring program for

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students. They believe in the importance of innovations and are open to invest in research and starting a discussion with the academic institutions on a research agenda. However, the university also needs to invest in research and stimulate researchers to undertake research leading to more innovations.

Growing potatoes using certified potatoes is precision agriculture, an approach "that helps to guide actions needed to transform and reorient agricultural systems to effectively support development and ensure food security in a changing climate" (FAO, 2015). FAO also links precision agriculture to the Triple Helix model, a model built for developing and introducing innovations. That is why the second stage of convincing the farmers to use the seed potatoes in the right way is very important. Introducing improved seed potatoes may be considered a first step to the development of smart potato growing in Rwanda. The value chain upgrading strategy suggests to continue with informing ware potato farmers how to increase their productivity significantly. In this case, the technical part of the innovation came through projects with educational partners supported by a foreign partner, while the commercial local partner produces and tries to sell the mini-tubers and eventually the clean seed potatoes.

Why has this innovation been successful? In the first place, there has been a long preparatory period. Previous projects mainly financed by donor organizations had introduced the technology at the University of Rwanda and donated a greenhouse, a laboratory and a place to store vegetables. Second, the project received full support from the Rwandan government, which considers that potatoes play a major in achieving food security for a growing population. Finally, the private sector, with relevant experience and connections with the cooperatives and the multiplicators, came in and is now trying to make this also a financial success. The collaboration gradually developed in a Triple Helix construction and now has the potential to become a dynamic agro-cluster.

2. An analysis of the potato value chain

The value chain analysis helps to identify the real issues in the potato value chains. The RAB (the supplier of the invitro grown plantlets), the SPAC and the multiplier farmers are the most important actors in the seed potato value chain. Most of the tissue culture and in vitro plantlets production is done by the RAB. There are a few other local suppliers, but they do not produce the quantities required. The actors in the ware potato value chain are listed in Table 2. If the mini-tubers are produced in a vegetative way, there is only one harvest producing between 30 and 40 mini-tubers per plant.

Public partners	Private stakeholders
a. Rwanda Agricultural Development Board (RAB) doing research and providing extension services	h. Suppliers of inputs: quality seed potatoes (EGSP-Imbuto), fertilizers, insecticides and pesticides
b. CPCCs, collecting potatoes from members, selling to traders	i. The SPAC
c. Educational institutes like the University of Rwanda and the IPRCs	j. Imbaraga an association of thousands of potato farmers to defend their interests and with training centers
d. International donors	k. Nongovernmental organizations (NGOs) and private extension services
e. International organizations	l. The private ware potato traders, transport and storage firms
f. The Rwanda Inspectorate, Competition, and Consumer Protection (RICA) in charge of certifying and approving seed potatoes	m. Processing units, like potato chip factories
g. MINAGRI, Center for Information and Communication on Agriculture	n. Markets and supermarkets selling the final product

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Table 2. Important stakeholders in the ware potato value chains

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The Rwandan government is also an important actor in the ware potato value chain, through the extension services provided by the RAB and the support for CPCCs. International and local NGOs may contribute to the introduction of new technologies and at the farmers' level private companies provide new technologies, in this case by producing and introducing clean seed potatoes.

The government of Rwanda wants to create a knowledge-based economy and considers partnerships and the involvement of the private sector in education a priority. This approach is developed in the Rwandan Vision 2020 (GOR, 2000) and 2050 documents (GOR, 2020), two strategic plans with the aim to lift Rwanda out of poverty and become a middle and eventually a high-income country. It is also part of the Rwandan program: "Strengthening the national potato research" [9]. The Rwanda Inspectorate, Competition, and Consumer Protection (RICA) is in charge of certifying and approving the seed potato from potato multipliers. It checks whether seed potato multipliers have certificates confirming the profession and the seed potato produced.

An analysis of the margins in the value chain (who earns how much of the 100%) shows that the average farmer in Rwanda cultivates less than one hectare of land, which may make it difficult to achieve economies of scale in producing potatoes, even when improved seed potatoes are being used. The share of the consumer price for potatoes being received by the farmer is often not enough to cover all their cost. Prices paid to the farmers for the end product ranged in 2020 between 180 and 200 RF per kg in the CPCCs, while they were costing between 350 and 400 RF in the supermarkets. Prices are fluctuating heavily throughout the year and are somewhat higher in 2022 (Table 1). Kyomugisha *et al.* (2017) show what determines the efficiency of the potato market chains in Uganda and identified the potential determinants of profits, such as distance to the market and group marketing.

There is little collaboration between the different stakeholders in this value chain. The regular consumers buy their potatoes in the market or the supermarket and have no market power. They are also not involved in any governance structure. They just vote with their feet: they buy the potatoes where they are cheap and have a certain minimum quality.

The government wants to control the potato market and determines the price. In practice, the CPCCs sometimes don't have enough space or cash and fail to sell all the potatoes before they start rotting. There are plans to give up on the role of the CPCCs and give the marketing back to the private sector (USAID, 2015). This could be part of the potato value chain upgrading plan suggested at the end of this paper. The system whereby Agro Processing Trust Cooperation (APTC) arranged all transport from the dedicated CPCCs to Kigali has been abolished already a few years ago [10].

The following issues have been identified for the potatoes value chain in Rwanda. In the first place, the production of certified potatoes is still very small and hence many farmers use their own potatoes for the next harvest, which means they continue to work with infected potatoes, providing smaller yields. Second, the market for good quality potatoes may have shrunk, given fewer tourists and foreign experts have come to Rwanda since COVID 19. Potato sellers complain that in the rural and urban areas they have to deal with competition from other staple crops, like bananas and rice. However, the market for potatoes in general is not a problem, and in the future, the price of potatoes may go down if good seed potatoes result in bigger harvests.

Rwanda used to export potatoes to Burundi, Congo and Uganda (NAEB, 2022). Rwandan potatoes were even flown to Kinshasa. Because of COVID 19 and political factors some of the borders have been closed, and markets have been lost. The country has to reestablish contacts. Since tourism and processing of potatoes were limited during COVID, the demand for quality potatoes was also small. Consumers had less money to spend, accepted lower quality products and were buying less potatoes.

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Havugimana (2023) assessed the perception of farmers concerning the factors affecting potatoes production. He focused on six variables and showed the importance of diseases (83% of the sample had to deal with diseases in the field). It was found that the farmers often do not rotate and usually use "informal" seed potatoes rather than clean seed potatoes from the formal sector, which is often not available locally. The informally traded seed potatoes contain diseases and degrade every year. Based on the research, the research team prepared messages for the potatoes farmers to increase their productivity. The information emphasizes that:

(1) There is a need for better supply of clean seed potatoes

(2) The farmers need to rotate more often

(3) Information about the use of informal seed potatoes should be provided and

(4) Information on the incidence of diseases can help farmers to take better decisions.

Also the prices paid to the farmer for ware potatoes are considered low by many farmers. They are determined by the government. However, the CPCC do not always take all the potatoes and doesn't always manage to sell their stock in time and pay the farmers immediately. Finally, the quality of the final product is a continuous struggle depending also on the conditions of storage and transport (Wang'ombe and Van Dijk, 2015).

There are also other problems on the demand side. The supermarkets are demanding quality and regular supply, which is difficult for many small farmers starting to supply to modern outlets (Sunanto, 2013). Only two chip factories were buying potatoes, one in Musanze (with Dutch participation in capital and management) and one government owned in Kigali, which is currently not functioning.

Another issue is the fertility of the soil (Nibeza, 2015). Potatoes require a crop rotation scheme to avoid diseases, which is often not done regularly. In Rwanda, there are multiple agricultural seasons in a calendar year. Some farmers grow potatoes, then maize or beans and then again potatoes, which is already better. The best cropping scheme would be one-quarter of the land with potatoes and every year a different quarter, which means the soil is only used one out of two year for growing potatoes. In general, there are fewer potatoes being grown during the dry season.

There were many efforts to upgrade the potato value chain in Rwanda. The extension services are partly public, partly private or NGO. The standard governmental extension services are not only promoting potatoes but also do other crops. In the private sector, the Dutch company Delphy played a role as the lead partner in the Sustainable Development Goals Partnership project. Delphy experts organized various trainings for project partner agronomists in line with the project goals.

For the farmers growing ware potatoes, the innovation is the availability of clean seed potato. The clean seed potato production chain results in good quality and more potatoes in the ware potato chain. If farmers don't start from clean and quality seed potato, the production cannot reach the theoretical maximum under experimental conditions. Starting with clean seed potatoes is the key success factor for ware potato production, but it needs to be accompanied with all good agriculture practices.

3. The role of partnerships and cooperatives

The potato STIC wants to reach the farmers to convince them to buy the disease-free seed potatoes and to teach them which complementary inputs are necessary and what can be done to increase the productivity of their seed potatoes. Box 3 provides examples of community outreach activities undertaken in the case of potato farmers. They are a necessary part of the success of the innovation and concern potato topics like using improved seed potatoes, doing

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Box 4.

Community and outreach activities undertaken by the potato STIC

(1) Over 30 Training of Trainers (ToT) of tailor made training modules developed, covering the whole chain from production to market:
(2) Farmers/Cooperatives/agribusinesses
(3) District and Sector agronomists and Farmer Field School (FFS) facilitators
(4) As joint activity of SEAD with knowledge institutions, Districts/Sectors agronomists and veterinarians, RAB officials, MINICOM, SPF, Ikigega [11] and Imbaraga
(5) Trainings are replicated throughout SEAD's districts for wider impact
(6) Development of customized and validated outreach materials as joint activity of SEAD, MINAGRI, the Center for Information and Communication on Agriculture (CICA) and RAB
(7) Dissemination of training materials, with support of MINAGRI/RAB, to different stakeholders, and to the public, through different channels:
(8) Online/Noza ubuhinzi website, a website dedicated to farmers
(9) Printed and distributed to farmers/cooperatives and districts/RAB

Source(s): Authors' own creation

proper pest and disease management, soil preparation and using the right post harvesting technologies. Also, cross-cutting topics like calculating your cost, using irrigation if possible and doing rotations are part of the training of potato farmers.

Furthermore, the STIC is offering opportunities for training and applied research for students and staff members. For farmers, it can provide technical and advisory services through community outreach activities, workshops, seminars, field visits and exhibitions. The value chain perspective has helped to identify the issues in the potato chain and it points to solutions for the different actors in the chain, in particular the disadvantaged farmers.

The Rwandan Government provides the regulatory framework for the collaboration, determining for example which seed potatoes can be imported and what can be exported. In Rwanda, agricultural cooperatives play different roles, depending on the region and the crop. The average membership of a cooperative is about 150 farmers, and their role can be collective buying of inputs at a lower price, or providing advice on growing potatoes. The most successful potato cooperatives are aggregators. Generally, farmers bring their potatoes to the CPCCs of their cooperative, where traders come to collect and transport the potatoes to Kigali, the major food market in the country. A centralized CPCC system doesn't exist anymore and government extension services are hardly offered in the potato sector. The government does regulate the seed potato sector, but the government may withdraw from providing extension services and organizing the marketing in the potato sector, leaving more to the private sector and the cooperatives.

Training is provided in some cooperatives and is important when improved seed potatoes become available in the local market because their cultivation requires more care and the use of specific complementary inputs. The cooperatives don't always play an important role and for that reason the government has asked them to prepare a strategic plan in 2024, indicating their future role and projects. Quality storage facilities are valuable and farmers can't invest in these facilities individually. Hence, there is a role for the cooperatives there. Also, in training and extension the cooperative sector could play a more important role.

The potato cooperatives do not function in an optimal way. Farmers often prefer to sell directly to the middlemen, who pay cash and more, while the cooperative pays days later and the official prices. In line with potato aggregation and commercialization, cooperatives face challenges created by middlemen from high end market which buy the produce. The initial

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role of cooperatives was to collect ware potatoes and pay a reasonable price to farmers and put the produce on the market, but this is not always the case anymore.

Kariuki (2023) concludes that there is a potential to develop the SPAC, this collaborative effort, into a real platform for agricultural innovation: the partners have a shared vision and developed a certain level of trust. The northern region can become the center for seed potato production. Efforts to develop other products from potatoes can be supported. Potato chips and other potato-based food items can find a market in a rapidly urbanizing society.

The SPAC could become innovative platforms to transform education to drive research and development and lead to economic transformation. There could be spin-offs using local resources and talented students and staff members. SPAC can also create more student placements, jobs and allow staff and students to gain work experience and get on-the-job training. Through collaboration with local SMEs, the SPAC can develop into a dynamic agricultural cluster. The government has created the conditions for this kind of development.

Discussion

The theoretical framework used consists of the Triple Helix and value chain approach and the partnership theory. Through the Triple Helix approach cooperation started between the government, educational institutes and the private sector to help potato farmers to increase their productivity. Producing seed potatoes in Rwanda is important and it can be concluded that the potatoes value chains benefited from a Triple Helix construction, to identify the major issue and come up with a solution. A PPP or the STIC is now producing improved seed potatoes, which will give a boost to the potato sector. As the theory suggested, the cooperation between the three partners helps to develop and introduce necessary innovations.

Through innovations, clean seed potatoes have become available at a lower price than what farmers had to pay for imported seed potatoes, which may be coming from the Netherlands. Improving seed potatoes starts in a laboratory with the in vitro technique. Then, the plantlets are multiplied in a greenhouse to cater for the next three stages mentioned: producing prebasic seed potatoes, basic seed potatoes and then certified seed potatoes. The real innovation is the combination of these activities, which now all take place in Rwanda and a business model has been developed supporting them. Hence, farmers can produce more and better ware potatoes based on the improved seed potatoes.

The value chain approach helped to identify the actors, determine the margins and find out the issues in the potato chains in Rwanda as suggested by the literature. Producing good quality potatoes depends on a number of suppliers of inputs and on being able to sell the final product to traders, consumers or a commercial party for processing or retailing (the supermarkets). Marketing of the produce is through traders, or through CPCCs, where traders come to collect and transport the potatoes to Kigali food markets. Given there are also other problems in the potato value chains, upgrading of this chain is necessary. Upgrading requires a strategy which deals with the issues mentioned.

The factors mentioned by Smeele (2019) contributed to the success of the potato STIC: the management contract between the partners defined a clear role for each partners and created an agreement on who should do what. The SPAC has created a win-win situation for the partners by making available the necessary equipment to the private partner and allowing the public partner to use the facilities for training, research and outreach activities. The resources are shared and to a limited extent the risks as well. Conditions are in place to turn this SPAC into a dynamic potato cluster in the future.

Conclusions

Like in many other countries, potatoes are increasingly important for the food security in Rwanda. The innovations analyzed led to improved seed potatoes and took place in a Triple

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Helix context, given the role of the University of Rwanda, the IPRC Musanze, the Rwandan government and a private firm, which brings in a commercial approach. The current production capacity of the SPAC is about 600,000 mini-tubers per year. Given this is the first of its kind in Africa, there is a lot of interest in the production facility in Musanze, and SPAC has an export potential, once they have increased their production.

The emphasis under the SEAD projects was on developing agricultural value chains in Rwanda through creating STICs, promoting innovations and training farmers, and training the trainers of farmers (TOT). The seed and ware potato value chains are more complex than many other value chains because of the many different types of potatoes and the existence of specialized markets for different types and different quality seed and ware potatoes.

The low productivity and the rapid degradation of the modern seed potatoes means farmers should buy these clean seed potatoes all the time. Increasing production in Rwanda requires a concerted action. Multipliers also need to be trained to use the clean mini-tubers, and the government may have to involved in that training or encourage the cooperative sector to take up this duty. The challenge is to assure large-scale multiplication of quality seed potatoes in the near future. This would even allow exports to neighboring countries of seed potatoes.

The Triple Helix approach to innovation has made available good quality seed potatoes in Rwanda. The government has put in place the conditions, and the challenge is to come to scale. A value chain upgrading plan can be developed and some suggestions for such a plan have been made.

The STICs function as a tool for cooperation between government, private sector and the knowledge sector in realizing commercial and development cooperation goals. They function as a channel for technology transfer. They allow applied research, including agronomic research, information collection and dissemination, networking, training, organization of events such as outreach activities. The model can be repeated in other sectors and countries.

The SEAD projects considered the STICs as the nucleus of a dynamic agricultural cluster of related activities. An STIC provides support functions in the pre-competitive phase of new start-ups and can link them to commercial parties by showcasing their products and services, which could happen in Muzanse.

Van Dijk (2023) confirms that there is an eco-system for private enterprises in Rwanda and that the system is also important for modernizing farmers. It is developing through NGOs and private parties. Issues still to be addressed in a value chain upgrading plan concern the role of the government, the role of the private and the cooperative sector. Is the CPCC willing to give the marketing role back to the private sector, which would then have to handle larger quantities and different qualities of potatoes? Also, more diversified markets will have to be developed, where better quality potatoes command a higher price. The government can concentrate on regulating the sector and evaluating the effects of policy support, to see whether they have the desired effects or need adjustment.

The collaboration between the private and public sector for the potato sector was structured as a PPP. In the case of the potato STIC, the following parties worked together: the College of Agriculture, Animal Science and Veterinary Medicine of the University of Rwanda (UR CAVM), the Integrated Polytechnique Regional College (IPRC) Musanze and the Seed Potato Fund (SPF). Together, they have created the SPAC, as a joint venture between the UR CAVM, the IPRC Musanze and the SPF. SPAC is doing well so far because the conditions for success specified in the literature were fulfilled.

Recommendations

An upgrading plan for the potato value chains need to be developed to deal with the issues mentioned. There is for example a need for developing better postharvest storage facilities and to reduce the losses of potatoes and their quality (Minten *et al.*, 2016). Finally, more value-

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adding activities are required. However, there is not one major stakeholder dominating the value chain, which makes collaborative solutions easier.

Part of the upgrading strategy would be looking at the role of the cooperatives. Also, training of farmers and attracting investment in processing potatoes are important issues to deal with. Several donors have been active in promoting potatoes in East Africa. The East African (28-8-2021: 22)discusses a book called *Potato Signals -African edition*,', a handy encyclopedia on potatoes in Africa, published with support from the Netherlands and the United Kingdom (www.roodbont.com).

An integrated approach is necessary to upgrade the potatoes value chain (Nyasimi *et al.*, 2016). The SEAD and SEAD West projects have carried out applied research to bring out the issues and explore solutions. The STIC in the potato value chain has made a substantial contribution to increased production and improved quality of the potatoes by producing the better quality seed potatoes. This will eventually contribute to Rwanda's food security. The SPAC has to become a dynamic innovative platform and eventually a cluster creating lots of employment and entrepreneurial opportunities. This still requires additional efforts according to Kariuku (2023).

Notes

1. The East African (28-8-2021: 22) notes that production has doubled during the last 20 years in Kenya, Tanzania, Rwanda and Ethiopia.
2. https://www.agriterra.org/rwanda-increased-its-irish-potato-production/
3. The SDGP project supported the potato sector from 2019 till 2023.
4. https://rsr.akvo.org/dir/project/7735
5. The SEAD and SEAD West projects have been implemented in the framework of two Knowledge Development programs: the Netherlands Initiative for Capacity development in Higher Education (NICHE) and the Orange Knowledge Programme (OKP). Nuffic has been the program manager of NICHE and OKP for the Netherlands' Ministry of Foreign Affairs.
6. The preceding NICHE-RWA-185 project was funded by the Dutch Ministry of Foreign Affairs and implemented by Nuffic focusing on capacity building for food security through sustainable potato value chain development.
7. SPF received Dutch support through the SDGP project.
8. EGSP was created by potato seed multipliers, cooperatives, private companies and farmers organizations supported by Ministry of Agriculture and Animal resources (MINAGRI) and the Private Sector Federation (PSF).
9. The Spirit project works in the same direction (Ritter *et al.*, 2017).
10. APTC is an investment company linked to military veterans.
11. A digital way of reducing farming harvest losses through data centralization for all farmers.

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