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Evolution of Zimbabwe's Maize Innovation Ecosystems: Building an Institutional Innovation Infrastructure that Supported Food Security

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Abstract

This article focuses on some of the historical innovation institutional infrastructures in Zimbabwe that supported the genesis of a vibrant maize sector, and analyses institutions for technology, policy, skills, knowledge development and attendant financing mechanisms. We discuss the country's maize innovation ecosystems, focusing on the technological capabilities in breeding and extension services, the architecture of financial institutions to support agriculture, and bridging institutions that supported technology adoption and innovation diffusion. In the process, we highlight elements of co-evolution, co-specialisation, collaboration and linkages amongst innovation communities for maize over a period spanning the pre- and post-independence eras. Our discussion covers the uneven colonial institutional, technological and financial support availed to white commercial farmers and how the shift in focus of government policy and support post-independence, resulted in the centre of gravity shifting to communal farmers, who now contribute the bulk of maize production. We discuss the critical roles played by Agritex (a technology broker and accelerator) and a state procurement agent (the Grain Marketing Board) as a market creator and signalling tool, as well as how specialised agriculture financing by state and commercial banks supported the rise of maize as a food security crop. Our key argument is that there were focused knowledge and technology flows between government research institutions, the private sector and others, such as the Seed Maize Association, which was involved in seed multiplication and marketing to the white commercial farmers pre-independence. This relationship shifted after independence in order to support small-scale commercial farmers, who were mainly black farmers.

Keywords: Innovation ecosystems, collaboration, co-complementation, technological capabilities, bridging institutions, innovation

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Résumé

Cet article porte sur certaines infrastructures institutionnelles et historiques, d'innovation au Zimbabwe qui ont soutenu la création d'un secteur du maïs dynamique. Il analyse la technologie, la politique, les compétences, le développement de connaissances et les mécanismes de financement à l'aune des institutions qui leur sont associés. Nous discutons des écosystèmes d'innovation dans la culture du maïs dans le pays, en nous focalisant sur les capacités technologiques dans les services de production et de vulgarisation, l'architecture des institutions financières qui soutiennent l'agriculture, et les institutions-relais favorables à l'adoption de la technologie et la diffusion de l'innovation. Cet article met en lumière les éléments de co-évolution, de co-spécialisation, de collaboration et de liens entre les communautés d'innovation pour la culture du maïs, sur les périodes pré- et post-indépendance. Notre argumentation couvre le soutien institutionnel, technologique et financier colonial inégal dont bénéficiaient les exploitations agricoles commerciales appartenant aux blancs et la manière dont, après l'indépendance, le changement d'orientation de la politique gouvernementale et du soutien a entraîné le déplacement du focus vers les agriculteurs communautaires, qui contribuent désormais à l'essentiel de la production de maïs. Nous discutons des rôles importants joués par Agritex (courtier et accélérateur de technologies) et un agent d'approvisionnement de l'État (Grain Marketing Board) en tant qu'indicateurs et créateurs de marchés, ainsi que de la manière dont le financement agricole spécialisé par l'État et les banques commerciales a soutenu la montée en puissance du maïs en tant que culture de sécurité alimentaire. Notre argument principal est qu'il existait des flux ciblés de connaissances et de technologies entre les institutions gouvernementales de recherche, le secteur privé et d'autres, comme la Seed Maize Association, qui, avant l'indépendance, était impliquée dans la multiplication et la commercialisation de semences auprès des agriculteurs commerciaux blancs. Cette relation a évolué après l'indépendance pour soutenir les petits exploitants, qui sont principalement des agriculteurs noirs.

Mots-clés : écosystèmes d'innovation, collaboration, co-complémentation, capacités technologiques, institutions-passerelles, innovation

Introduction

This article discusses the peculiar case of the Zimbabwean maize innovation ecosystem, whose evolution is intricately interwoven with strands of the political economy of colonialism, enclave colonial economies' centre–periphery industrial dynamics, and sustained local industrial capabilities building accelerated by WWII trade and commerce disruptions (Pangeti et al. 2000; Phimister 2000; Riddell 1990). The peculiarity of this case emerges from six perspectives: the strategic linkages of the state-industry-industry associations nexus, a form of unofficial public-private partnership (PPP); directed resource allocations to institutions building that supported organisational co- evolution and collaborations within and external to the agricultural sector; evolution of a technology and innovation institutional infrastructures that drove local technological capabilities building; agriculture-specific public and private financing mechanisms; bridging or broker institutions, such as agricultural extension services, and the role they played in technology and innovation adoption and diffusion; and the Grain Marketing Board (GMB), an aggregator that drove market formation and signalling, thereby promoting maize production. We argue that what drove the rise and dominance of maize as a cereal crop, and its impact on food security was the state, private sector and other institutions' co-evolution, collaboration, co- specialisation and co-complementation within the context of a technological innovation system. Value creation was embedded in building maize research, innovation and translation capabilities in breeding, seed maize trials, seed maize production and marketing to farmers. We acknowledge that, pre- 1980, the non-inclusive system was built on racial grounds with specific agricultural mechanisation and production policies that allocated resources and technologies to only white commercial farmers. Pre-1980, there was no concerted programmed policy and resource allocation to support indigenous smallholder farmers (see Table 1).

Although not native to Zimbabwe or Africa, maize has become an important staple grain for the country and the southern African region, and a key crop for commercial, small-scale and communal farmers in Zimbabwe. It is believed that maize, with its origins as the teosinte plant in Mexico, was introduced by Portuguese traders to the African continent around the sixteenth century. It later moved inland from the coastal areas, taking off in the early twentieth century with the advent of white settlers (Byerlee and Heisey 1997). Compared to local traditional grains, maize was more attractive because of its ease of storage and processing (see Table 1). Variety improvement to suit semi-arid agri-ecological regions sparked intensive breeding as early as 1909 (Zerbe 2001). Maize became a significant contributor to food security, rising over the years to contribute 36 per cent of all cereal calorific intake in the SADC region by 2011 (Grant et al. 2012). During the same period, cereals constituted 62 per cent of total diet; maize contributed 76 per cent of the cereals diet and 47 per cent of total diet (ibid). Maize is the staple crop for up to 98 per cent of the population, and excess harvest contributes financial resources for about 60 per cent of communal farmers. Consequently, it is not surprising that annually more than 30 per cent of Zimbabwe's Ministry of Agriculture's input budget is allocated to seed maize procurement for under-resourced communal farmers, and the remainder allocated to fertiliser procurement (Kassie et al. 2017).

The evolution of Zimbabwe's maize innovation ecosystem is linked to the promise of the 'second Rand' (the discovery of gold in Zimbabwe), based on initial gold findings in South Africa. The mining ventures failed, triggering a shift to agriculture, which led to the genesis of land dispossession (Wild 1992; Helmsing 1990) and, in turn, the liberation war and land redistribution after independence. The shift to agriculture was propelled and supported by the pervasive use of laws such as the Land Apportionment Act of 1894, which forcibly pushed indigenous communities off fertile soils to infertile sandy soils in the 'tribal trusts', or communal areas. For a more detailed discussion on land policy and land redistribution, and how the law was used to dispossess and disenfranchise indigenous populations, see Rukuni (1994). During the early days of mining, the foreign miners interacted harmoniously with local farming communities, who traded agricultural produce for food with them (Wild 1992). However, the shift to agriculture required labour and there were shortages of farm and mine labour. Again, the law was perversely used to coerce people to become farm labourers, through the introduction of the hut tax (Wild 1992).

We focus on Zimbabwe for three reasons: Zimbabwe was the first country in the world to locally produce a single-cross hybrid – the famous SR52 (Southern Rhodesia 52); the country developed a local vibrant and sustainable seed maize development and production sector, which successfully launched numerous maize varieties tailor-made to local conditions, which improved food security in the country and region; and after the 2000s, local seed companies such as SeedCo expanded into eastern and southern African markets, demonstrating their market leadership.

What is of interest are the key state, private and other sectors' institutional infrastructures that supported innovation and technological development in the seed maize sector, human capital and skills development in (initially, racially segregated) agricultural tertiary educational institutions, the role played by the financial services sector, and agriculture supporting industries. We also focus on the Agricultural Technical and Extension Services (Agritex) role as a key technology and innovation broker as well as legitimation tool for new maize varieties (new technologies) promotion, adoption and diffusion. From a technological innovation systems perspective we examine the intervention of the GMB (Grain Marketing Board), as another legitimation tool which was critical for market formation and signalling.

Our interests lie in exploring knowledge, technology and financial flows, how they supported rapid local technological capabilities development, and how particular institutional infrastructures emergence supported the historically nascent maize innovation ecosystem. The central argument rests on how Zimbabwe (then Rhodesia) developed linkages and collaborations between different knowledge production systems (elsewhere called the research economy and the commercial economy) to forge strategic technological capabilities development. These efforts were supported by innovation/technology brokers who bridged nascent value-chain gaps to create markets for maize and processed maize products. The argument also focuses on the importance of institutional and infrastructural architectures' co-evolution, collaboration, co-specialisation and co-complementation to support the evolution of the Zimbabwean maize innovation ecosystem.

The rest of the article is set up as follows: we discuss the conceptual framework, followed by the methods; an analysis of the four key elements of the article: (i) technology and innovation institutional infrastructures, (ii) technological capabilities building, (iii) financing and bridging institutions critical for innovation/technology adoption, and (iv) diffusion as well as market formation and signalling. The text then proceeds to the discussion and conclusion sections.

Conceptual Framework

Our conceptual framework draws from innovation ecosystems – the Rogers Innovation Diffusion Model, technological innovation systems and Agricultural Innovation Systems (AIS) – to contextualise the sociotechnical systems, institutions, actors, collaborations, linkages and policy strategies that drove the rise and dominance of maize as a food security crop in Zimbabwe.

Innovation ecosystems

Innovation is an iterative and non-linear process that spans technological artefacts, processes and procedures, and novel social arrangements such as marketing and organisation. Ayele et al. (2012: 334) define innovation as 'Successful introduction and exploitation of knowledge and technologies for social and economic benefit.' Klerkx et al. (2012:458) highlight the importance of social relations and the sociotechnical imaginaries of innovation as follows:

> Innovation is not just technology, but is rather a comprehensive vision of what the future should look like and which requires changes in many ambits. Innovation is driven by people's needs, ambitions and dreams, and requires that people at different positions in society change the way they work and live.

Achieving these sociotechnical imaginaries depends on resource allocation and government policies and strategies that shape innovation trajectories designed to achieve particular social, economic and technological goals. Klerkx et al.'s (2012) view above also addresses criticisms of the static nature of contemporary innovation systems frameworks, their ex post analysis and inability to project forwards.

Turning to innovation ecosystems, they are defined as collaborative networks (Rabelo and Bernus 2015) that involve communities for innovation that are linked by demand and supply. They are also composed of networks of knowledge generators, innovators, regulators and funders, amongst others (Wang 2009). Innovation ecosystems pay greater attention to intricate connections amongst diverse innovation actors, open innovation and emphasise 'niches' for different agents (Oh et al. 2016). We adopt the synthesised definition of Granstrand and Holgersson (2020:3), which states that innovation ecosystems are '… the evolving set of actors, activities and artefacts, and the institutions and relations, including complementary and substitute relations, that are important for the innovative performance of an actor or a population of actors'. Other definitions include mechanisms for goal-oriented strategies to create new goods and services, focusing on elements such as actors, capital, infrastructure, regulations, knowledge and ideas, and non-tangible elements such as interface, culture and architectural principles. Gobble (2014:55) describes innovation ecosystems as 'dynamic, purposive communities with complex, interlocking relationships built on collaboration, trust and co-creation of value and specialisation in the exploitation of a shared set of complementary technologies or competencies'. The major difference between predecessor innovation systems and innovation ecosystems is the former's non-recognition of the dissimilarity between 'innovation events and innovation structure' (Mercan and Goktas 2011) as well as the impetus to innovate. As a concept, innovation ecosystems borrow from biological systems to conceptualise the relational linkages, collaborations and feedback mechanisms amongst economic agents, economic relations and non-economic constituents (which are comprised of institutions, technology, sociological interactions and culture) (Rabelo and Bernus 2015; Mercan and Goktas 2011). Amongst these diverse definitions of innovation ecosystems, the common elements and emphasis are on institutions and the facets of co-evolution, co-specialisation, competition, artefacts embodied in products and technologies, collaboration and complementation, and actors/agents.

Ritala and Almpanopoulou (2017) argue that innovation ecosystems, similar to innovation systems, are plagued with varied definitions and a lack of theoretical depth. Another criticism of innovation ecosystems is the danger of using metaphors. Papaioannou, Wield and Chataway (2009) caution that innovation ecosystems are not evolved but are a product of design and subject to governance systems. Cognisant of the aforementioned, we still adopt the innovation ecosystems concept because of its useful emphasis on value creation, institutional co-evolution, collaboration, complementation and interaction of a population of innovation actors. We particularly highlight its further utility in identifying strategic linkages and collaboration of state, private and other organisations, whose goals are knowledge and innovation generation, adoption and diffusion. A major challenge of application of innovation ecosystems or innovation systems frameworks to agriculture in an African country are their origins in developed countries and application to primarily the manufacturing sectors. Application to agriculture is difficult because of the complex hybrid interactions between the state, firm and non-firm actors. We use agricultural innovation systems to bridge these shortcomings and link the state, firm and non-firm actors through policies that support knowledge and innovation, and connecting innovation and knowledge generators and users through broker institutions with(in) broader agriculture value-chain actors.

Agricultural innovation systems, technology diffusion and adoption

Spielman and Birner (2008) proposed an agricultural innovation system framework composed of three central pillars: (i) agricultural research (public, private and civil society) and education systems (primary, secondary, tertiary education and vocational training); (ii) bridging/broker institutions embodied in stakeholder platforms, agricultural extension systems and contractual agreements; and (iii) agricultural value-chain actors and organisations.

The role of the first pillar is knowledge and innovation generation, and human skills and technological capabilities development. Bridging institutions are broker institutions that serve as conduits for innovation translation. They aid the process of technologies' conversion into economically useful outputs in the third pillar through agricultural value-chain actors and organisations. The three pillars are built on the foundations of innovation policy and investment as well as agricultural policies. These in turn promote linkages to other economic sectors, and science, technology and innovation strategies. Informal institutions, practices and attitudes drive issues such as trust, learning and routines (Spielman and Birner 2008). The bridging institutions (in this paper the extension services) are instrumental in technology adoption and diffusion. We use the Rogers Innovation Diffusion Model to cover this aspect of technology adoption and diffusion.

Rogers (1962) argued that innovation diffuses through social systems. Focusing on the adoption of hybrid corn (maize) in the USA from the 1930s to 1950s, Rogers (1983: 34–35) defined innovation diffusion as 'the process by which an innovation is communicated through certain channels over time among the members of a social system. Diffusion is a special type of communication concerned with the spread of messages that are new ideas.' Rogers highlighted seven key factors that influence innovation diffusion: compatibility of the new technology or innovation with current ways of doing things and social norms; complexity of the innovation and ease of trialling; ease of evaluating impact of the innovation after the trial; whether the decision is made collectively, individually or by a central authority; communication channels used to acquire information; social systems in which adopters are embedded, norms and degrees of interconnectedness; and the extent of change agents (e.g. extension agents) promotion effects.

In the case of Zimbabwe, Agritex was a critical broker institution in new technology introduction, adoption and innovation diffusion. Rogers' Innovation Diffusion Model has five key elements: *knowledge* – exposure to a technology and understanding its use; *persuasion* – positive or negative perception creation; *decision* – adoption decision; *implementation* – actual use of the technology; and *confirmation* – corroboration or rejection based on outcome, which leads back to *knowledge*, iteratively. We argue that these five stages were the remit of Agritex and, as we elaborate later, they were enabled by accrued social and cultural capital. The extension officers (technocrats) lived in the same communities as the farmers and this proximity promoted trust between the community and the technocrats who had attended agricultural colleges and acquired knowledge of local soils, plant varieties, agronomy and other technical know-how through linkages with other tertiary institutions, seed and fertiliser companies, and the Ministry of Agriculture.

Methods

The article uses a case-study method, which is appropriate when investigating a phenomenon in its real-life context (Yin 2003). It is based on a desk study supported by key informant interviews with respondents who had in-depth knowledge of agriculture, agricultural institutions and agricultural financing in Zimbabwe. Data collection for this article involved extensive review of peer-reviewed and grey literature on Zimbabwe's agricultural production, financing, technology and supporting institutions. This secondary literature was supported as described earlier with key informant interviews with respondents who worked at Agritex, the Ministry of Agriculture and financial institutions, as well as farmers – especially the communal and small-scale farming sectors. The interviews with key informants were telephonic as the study was finalised during the Covid19 pandemic. Some of the data was from the author's critical reflection of over a seven-year period of working in the financial services sector as a banker, managing a portfolio composed of seed maize companies, agro-processing industries, an Agro-research institution, the fertiliser manufacturing industry, food manufacturing companies and the broader manufacturing sector in Zimbabwe. Notes were taken during telephonic interviews, and key themes were identified manually. These key themes are presented later.

Zimbabwe's Maize Revolution

Zimbabwe's Green Revolution was launched in 1960, five years before India's, and was predicated on high-yielding maize varieties such as SR52 (Southern Rhodesia #52), a world-first, single-cross hybrid which came from twenty-eight years of indigenous research (Byerlee and Eicher 1997). It was based on rain-fed maize cultivation, compared to India's irrigated wheat and rice crops. As described earlier, historically, maize evolution was spearheaded by white commercial farmers and not indigenous smallholder farmers, who were ignored in pre-independent nations in the 1960s generally (ibid). At independence (1980), the nationalist Zimbabwean government launched programmes targeting smallholder farmers to increase food and cash crop production. These programmes were supported by the distribution of hybrid maize varieties, and policies that opened up access to credit, guaranteed good maize prices from GMB, and marketing subsidies. This policy thrust resulted in communal and resettled farmers increasing local maize production to surpass that of the historically advantaged white commercial farmers.

Zimbabwe displays four innovation infrastructure preconditions: technology and innovation institutional infrastructures that supported new technology and innovation generation in public and private research organisations based on collaboration and co-complementation; development of technological capabilities in breeding and extension services; evolution of financial systems architecture to specifically support agriculture; and availability of bridging/broker institutions critical for technology and innovation adoption and diffusion.

We discuss each of these facets in turn and show how their form, structure and function, albeit shaped on colonial legacies and reimagined for equity post-independence, drove the rise and dominance of maize as a key food security crop. We also show the shift in dominant maize grower farmer communities shaped by research and production expansion priorities changes after independence, which were directed to solving smallholder challenges (Poulton et al. 2002). However, there was huge disinvestment from public agricultural research institutions activities in the 1990s precipitated by ESAP (Economic Structural Adjustment Programmes). This led to significant and still persisting deceleration of state-led agricultural research and innovation activities.

Co-evolution of supporting technology and innovation infrastructures

In the pre-1980 epoch, there was a perverse use of the law and allocation of scarce resources to support the development of inequitable technology and innovation institutional infrastructures that responded to challenges faced by white farmers. Table 1 shows how, from 1890, land settlement laws and the hut tax were used to confiscate land and assure a pool of cheap labour to farmers. New government departments were formed to address specific issues. They constitute part of the innovation ecosystem and which is broadly classified into three categories: knowledge, technology and innovation generators; policy and practice organisations; and brokers or bridging institutions. We detail these developments below.

There was co-evolution of knowledge, technology and innovation generators to address specific challenges through establishment of organisations. Some of these organisations include the Department of Agriculture (established 1903), Salisbury Experimental Station (1909), Rhodesia Seed Maize Association (1940), Department of Research and Specialist Services (DRSS) (1948), Agricultural Research Council of Central Africa (ARCCA) (1961) and Agritex (Agricultural Technical and Extension Services) (1980). The roots of Agritex go back to 1972 through the establishment of the Department of Conservation and Extension (Conex) and the Department of Agricultural Development (DEVAG). Agritex was an important institution whose remit spanned knowledge, technology and innovation adoption and diffusion through its brokers or bridging institution roles. The Department of Agriculture, established in 1903, was instrumental in embedding scientific research in agriculture . Its establishment marked the genesis of a culture of research and innovation focusing predominantly on tobacco, cotton and maize – key cash crops for export. The Salisbury Experimental Station, a complementary research institution, was set up in 1909. Over the next four decades trial sites and demonstration stations expanded (Roseboom et al. 1995). Technology and innovation efforts were underpinned by these early breeding programmes. Zerbe (2001) reports that formal breeding programmes started in 1909, with a primary focus on adapting varieties to local conditions. Thus, over a period of nineteen years – from the early settlers' arrival (1890) to formal breeding – two institutions that supported research and innovation in agriculture the Department of Agriculture and the Salisbury Experimental Station were established within six years of each other. Testament to agricultural research investment and technological efforts, UNESCO (2014) reports that 18.11 per cent of scientific articles produced in the period 1960 to 1979 were on agriculture, second to general internal medicine, at 22.19 per cent. Due to this investment in technology, research and innovation, there was an 18 per cent increase in maize exports between 1909 and 1930, driven by the demand for white starch imports by England's starch industry.

Table 1: A brief scan of policy and practice events that drove the evolution of maize production in Zimbabwe

Year / Period	Key Policy or Practice Event	Driving Factor	Source
16th century	Maize arrives on the African continent through Portuguese traders. Maize moved inland from the coast.	Easy to store and process compared to traditional grains such as millet.	Byerlee and Heisey (1997)
1890+	In Southern Africa, maize took off when white settlers moved in around 1890.		
1890–1980	Settlers gained control over prime agricultural land (regions 1 and 2 where large-scale commercial farms constituted 52.7% and 63.7% of the areas respectively).	Land settlement acts passed, which guaranteed white dominance and locals' poverty. Maize was important as food source for mine labourers.	Herbst (1990); Alumira and Rusike (2005)
	Land confiscation and depressed wages for farm and migrant workers, hampering profitability of small-scale farmers.	Assured large pool of labourers for large commercial farms and generating a 'good' macroeconomic environment for commercial farmers	Eicher and Kupfuma (1997)
1903	Department of Agriculture was established.	Building institutional infrastructural and organisational capabilities to support agricultural development, improve varieties and adaptation to local climatic conditions	Roseboom et al. (1995).
1909	Salisbury Experimental Station set up. Formal breeding programmes start.		Zerbe (2001); Roseboom et al. (1995).
1909–1930	Maize exports increased annually at 18 per cent	Demand for white maize in England's booming starch industry. Institutionalisation of research and breeding efforts to meet demand.	Masters (1994); Rusike (1995); Zerbe (2001).

1930+	Maize becomes an important crop for the smallholder farmers. Hybrid breeding programmes commence in earnest.	Maize serves as both a subsistence and cash crop. Expanding railway infrastructure encourages maize production.	
1931	Maize Control Board established.		
1940	Zimbabwe (Rhodesia) Seed Maize Association (SMA) – comprising a small group of farmers who produced seed under supervision of Ministry of Agriculture. Government researchers focused on breeding and production of foundation seed.	Government lacked resources to commercially produce hybrid varieties that performed better than open pollinated varieties in low rainfall regions. They encouraged the private sector to do the work. SMA had exclusive rights to multiply and market government-produced hybrid maize, a version of a Public Private Partnership, and assured a market for their output.	Tattersfield and Havazvidi (1994) Zerbe (2001)
1945	Land and Agricultural Bank established.	Provision of medium- to long-term loans. Institutional infrastructure enhancement to solve the capital needs of the sector.	Pandey and Ramnarayan (1994)
1948	Department of Research and Specialist Services (DRSS)	Bridging institution between the public and private research organisations and extension services	UNESCO (2014)
1949	Commercial release of hybrid varieties. Distributed first hybrid maize to commercial farmers.	SR1 double hybrid produced in 1949 from local inbred lines by SMA.	Zerbe (2001) Rusike (1995)
1950s	Government released 12 new higher yield hybrids with improved grain properties and agronomy traits. However, government policy was still skewed towards white large-scale commercial farmers Grain Marketing Board established.	Demand for hybrids grew. Government started paying attention to neglected small-scale farmers who were now accounting for 46% of maize production.	Zerbe (2001)
1952	Department of Native Agriculture procured 5kg packs of hybrid maize from SMA to distribute to small-scale farmers.		
1954	Government researchers breeding programmes focus on unpredictable rainfall areas.	More than 60% of arable land under maize commercial crops.	Rusike (1995)

1954–1965	Diminishing role of small-scale farmers because of skewed policies that supported white farmers at the expense of black farmers.	Government focused on white farmers and small-scale farmers' contribution fell to 14% by 1965	Zerbe (2001)
1960	Government released the famed SR52, the world's first single-cross hybrid.	Originally developed for high precipitation and good soil areas it was also productive under poorer soils and rain conditions.	Rusike (1995)
1961	Agricultural Research Council of Central Africa (ARCCA).	Researching soil fertility, controlling the tsetse fly problem and cotton pest control	UNESCO (2014)
1967	Agricultural Marketing Authority established.		
1970s	Varieties R200, R201 and 215 released.	These varieties were targeted at large-scale commercial farmers working on marginal land to diversify production.	Friis-Hansen (1995)
1971	Agricultural Finance Corporation established by amalgamating the Land and Agricultural Bank with the Agricultural Assistance Board.	Rationalises financial facilities offered by government to the agricultural sector.	Pandey and Ramnarayan (1994)
1972	Department of Conservation and Extension (Conex) and Department of Agricultural Development established.	Genesis of agricultural extension services by Emory D. Alvord.	Hanyani-Mlambo (2002).

Source: Constructed by author from references identified in the table

Turning to broker and bridging institutions, the Department of Research and Specialist Services (DRSS), established in 1948 (UNESCO, 2014), was a critical bridging institution between public and private research organisations. It was linked with the agricultural extension services, which in turn served as a bridge between the innovators and the farmers (Figure 2). The third category of policy and practice organisations include the Agricultural Research Council of Central Africa (ARCCA), which was established in 1961. Part of its remit included research into soil fertility and the control of tsetse fly and cotton pest (UNESCO 2014). Commercial farmer associations were the key beneficiaries of interventions from organisations. They collaborated with ARCCA in various ways, and the relationship changed over time, and they worked with government research institutions on seed maize production and marketing (Table 2). In 2001 DRSS was merged with Agritex (Agricultural and Technical Extension Services) to form AREX (Agricultural Research and Extension), which was changed to the Department for Agricultural Research for Development (DAR4D) in 2007 and back to DRSS two years later (UNESCO 2014). In addition to the DRSS, other key public research centres/stations included Henderson Research Station and Rattary Arnold Research Centre, including others spread across various provinces. Rattary Arnold Research Station (private) developed the maize varieties R200 and RR215, which were suitable for low-rainfall areas. Other private sector players in research and generation of hybrid varieties included Pannar Seed (Pvt) Ltd, Pioneer Hi-Bred Seed (Pvt) Ltd., Monsanto Zimbabwe and, of significant importance in research and new seed variety production, SeedCo (Pvt) Ltd. We argue that these public-public, public-private collaborative and co-complementary institutional arrangements set the foundation for technology and innovation infrastructures. They in turn supported knowledge, technology and innovation generation which were important components of the Zimbabwean maize innovation ecosystem. Key informant interviews suggest that the technology and innovation institutional infrastructure setup was important on two fronts: the revolving door phenomenon characterised by skilled researchers and breeders moving between the public and private sectors; and the generation of trust and social capital, which was important for effective cross-sectoral collaborations between the public and private sectors and innovator-user bridging institutions, such as agricultural extension services.

Development of technological capabilities in breeding and in the fertiliser industry

The second attribute is the development of technological capabilities in breeding, and agricultural skills critical for the extension services that drove technology and innovation adoption and diffusion. A key agriculture informant reported that Zimbabwe had an elaborate network of tertiary educational institutions that trained plant breeders, agronomists and specialists in other agricultural disciplines. He reported that some of the researchers and innovators were trained outside the country and in addition, the private sector imported technology and expertise into the country. An agriculturalist and former Agritex technocrat pointed out that the University of Zimbabwe was instrumental in training skilled personnel who later became maize breeders in the public and private sectors. He also explained that some plant breeders were trained on the job – a reflection of learning by doing. However, most breeders attained Master's and PhD degrees outside the country. The respondent further reported that agricultural colleges trained agriculturalists at diploma and certificate levels, many of whom joined agricultural extension services. Gwebi and Blackfordby agricultural colleges were reserved for the white population during colonial times and trained up to diploma level. For the indigenous farmers, Chibelo Agricultural College trained agriculturalists at diploma level, and Kushinga Phikelela, Mlezu, Makoholi and Essexvale (now Esigodini) trained at certificate level, whereas Domboshawa trained farmers using the short courses approach. An agriculture key informant explained that development of crop-specific skills was shaped by particular institutions. For example, DRSS focused on wheat and soyabean crops. It also majored in developing capabilities in plant pathology and management, and dairy and livestock breeding. DRSS achieved this through collaborations with the private sector and the Faculty of Agriculture at the University of Zimbabwe. The respondent reported that Henderson Research Centre focused on cattle, Makoholi and Matopos research stations focused on small grains, whilst capabilities in maize were the remit of CIMMYT (the International Maize and Wheat Improvement Centre) and ICRISAT (International Crops Research Institute for the Semi-Arid Tropics). In conjunction with the local university and other collaborators, these research stations were instrumental in developing scientific and technological capabilities in plant breeding, soil and crop science, agricultural economics, hydrology and plant pathology, amongst others. A former Agritex technocrat reported that cross-crop transferable skills were developed at other state research stations, such as the Tobacco Research Board and Cotton Research Board. These plant breeding and supporting technological capabilities were instrumental in establishing and sustaining the broader communities of agricultural research and innovation. Key to this was the role of government policy, funding and support for agriculture.

Upstream input industries also played a role in technological capabilities building. In interviews with fertiliser companies dating to the early 2000s, technocrats revealed how their in-house research teams worked with agronomists and chemists in the public and private sectors to formulate new crop variety fertilisers. Up to the early 2000s, Zimbabwe had four key fertiliser companies: Windmill, ZFC (Zimbabwe Fertiliser Company), Zimphos (which is part of Chemplex) and Sable Chemicals. The genesis of fertiliser companies was linked to the need for the country to remain sustainable especially when it unilaterally declared independence from Britain, hence the historical role of fertilisers in supporting agriculture in the country. The government had a shareholding in all the fertiliser companies through their investment wing, IDC (Industrial Development Corporation) (interviews with fertiliser firms in the 2000s). The interlink between fertiliser firms, the customisation of fertilisers for new plant varieties, and the different ecological zones, meant the country had complementary technological capabilities from the private sector supporting the maize innovation ecosystem starting from seed maize to grain production. Minde et al. (2010) provide a comprehensive analysis of the evolution of the fertiliser industry dating back to 1903 and how it responded to policy depending on the state's agriculture development priorities. Rusike et al. (1997) reiterate the fact that the agricultural system was initially set up for large-scale white farmers, and in the 1970s, fertiliser research supported extension and marketing targeted at these farmers and a few smallholder farmers, especially in high-precipitation areas. Takavarasha (1995) showed that the new Zimbabwe government made huge efforts from 1980 to support smallholder agriculture, through the procurement of seeds and fertilisers. Fertiliser sales rose from 24,000 tonnes in 1974/75 to 90,000 tonnes in 1980/81, peaking at 130,000 tonnes by 1986/87, and these levels were sustained up to 1990/91. This extended the research activities of the private sector to the emerging smallholder sector. It is important to note that technological capabilities were not limited to crop input schemes only, but also covered other support sectors, such as local agrochemical production by firms such as Agricura and specialised aerial crop-spraying using helicopters and planes by a specialist crop-dusting firm, Agric-Air, which operated from Charles Prince Airport in Mount Hampden, Harare. Specialist irrigation systems were installed and maintained by firms such as Dorre and Pitt, which had their headquarters in Harare. The development of these local capabilities in breeding, fertiliser research and other supporting crop health industries contributed to the emergence of a sustainable and resilient maize innovation ecosystem.

Evolution of financial institutions architecture to support agriculture

Public and private finance to the sector was important for supporting the research and commercial economies. The state funded the research economy, providing basic and applied research as well as translational activities. It also complemented the private sector in funding agriculture through the Agricultural Finance Corporation (AFC), which later became Agribank. Before independence, the AFC funded about 3,000 white commercial farmers but not black farmers (Pandey and Ramnarayan 1994). Established through an act of Parliament in 1971 the AFC came from the amalgamation of the Land and Agricultural Bank with the Agricultural Assistance Board. Whilst it had 6,000 clients in 1978, by 1986 and reflecting the new government's inclusivity it was handling 100,000 farmers. The unintended consequence of this rapid expansion was the managerial and technical skills challenges that arose and high transaction costs from handling too many small loans (ibid). These challenges aside, we argue that purposive and progressive setting up of financial institutions addressed or at least tried to address agricultural financing needs, albeit initially for the minority (see Table 2).

Table 2: Key financial institutions that were instrumental in supporting agriculture in general and, by implication, maize production

Agriculture Specific Financial Institutions/ Organisations	Commercial Banks with Agri-Banking Divisions	Other Financial Institutions
1924 – Land Bank: assists large-scale farmers to acquire more land.	Barclays Bank – The Agribank division focused specifically on Agri-lending	Insurance companies
1930s – Financing of irrigation in small-scale areas, extended in 1956 to include dryland commercial farmers (see Chimedza 2006)	ANZ Grindlays, which later became Stanbic, a subsidiary of Standard Bank of South Africa	Leasing companies for acquisition of machinery and equipment
Land and Agricultural Bank – provided medium- and long-term loans	Rhobank, which at independence became Zimbank and later ZB Bank.	Building societies (see Chimedza 2006)
African Loan Development Trust	Standard Chartered Bank	
Agricultural Finance Corporation	BCCI, later CBZ Bank	
Programme-specific funding mechanisms (see text and *Rhodesian Farmer* 1970)		

Source: Pandey and Ramnarayan (1994), *Rhodesian Farmer* (1970), interviews and author's recollection of the financial services sector

Prior to the setting up of the AFC in 1971 (Pandey and Ramnarayan 1994) there had been multiple funding schemes, which included: the Land Bank, Agricultural Diversification Scheme, Farm Irrigation Fund, Matabeleland Development Council, Agricultural Assistance Board (including Farmers' Assistance Committee), Cold Storage Commission, Sabi-Limpopo Authority, Drought Relief, Insiza Scheme, Mkwasine Scheme, Coffee Scheme, Tenant Farming, Tenant Farm Development, Tenant Farm Contributory Purchase Scheme, Contributory Purchase Scheme, Deferred Purchase Scheme, and Ex-Servicemen's Settlement Scheme (*Rhodesian Farmer*

1970). The AFC was set up to consolidate these disparate funding schemes for the sector and was complemented by the agribusiness divisions of commercial banks, which also advanced loans to the agricultural sector. As discussed earlier, historically the AFC financed only white commercial farmers; however, after independence it extended its services to small- and medium-scale farmers who had title deeds (interview with the son of a small- to medium-scale farmer in Zvimba District). To avoid fund diversion, the AFC did not advance funds to small- and medium-scale farmers but opted to pay directly for all farm inputs (fertilisers, seeds and agrochemicals) to the providers, and goods were delivered directly to the farmer's premises. These financing schemes for both commercial and small- to medium-scale farmers helped to fund working capital requirements, which at most could be carried for between four to six months, a tall feat for under-resourced farmers. Takavarasha (1995) provides a detailed analysis of the AFC's role in financing large-scale, and later small-scale, resettlement and communal farmers.

Commercial banks financed farmers through their agribanking divisions. A former banker recounted how commercial banks such as Zimbank, Standard Chartered Bank, Barclays Bank, Stanbic and the Commercial Bank of Zimbabwe (CBZ) (Table 2) all had agrifinancing divisions, which also focused initially on large-scale commercial farmers. In addition to banks, there was a well-developed insurance sector that insured farming operations against drought and crop failure. Insurance as a risk management tool made lending to farmers attractive to banks because, in the event of a crop failure, loans could be repaid by claiming against an insurance policy. Commercial banks factored in and depended on title deeds as security for credit appraisals and subsequent security for advanced loans. The lack of title deeds for new farmers after the land repossession exercise was a major friction point that caused banks to refuse advancing loans to new farmers. This challenge saw a drastic reduction in credit lines to the agricultural sector especially after 2003. Banks argued that they felt insecure and overexposed if they provided loans to the new farmers without tangible assets as security. Consequently, the agribanking divisions mentioned above throttled back their support to the sector and some banks closed these units. A former banker described how banks strategically resourced their agribanking divisions with agricultural graduates from agricultural colleges as well as the University of Zimbabwe. Staffing these divisions with bankers endowed with agricultural knowledge and skills allowed the financial institutions to astutely analyse and manage agricultural enterprises risk – what we describe elsewhere as financial capabilities critical for lending into technocratic operations (Banda 2013). These technically specialised agricultural and finance skilled bankers monitored and controlled their lending operations through farm visits and detailed analysis of cropping dynamics, amongst other assessments. This finding resonates with the argument on knowledge generation and how these skilled personnel were involved in understanding and shaping both upstream and downstream value-chain activities through funding. These risk management and financing capabilities were a critical component of the financial institutions that formed the maize innovation ecosystem.

From the demand side, the GMB played a critical financing role through its grain procurement activities. It also played a critical value-chain and market role through its broader market formation, price support and signalling. GMB played three key roles: first as the government procurement agency; second, as a broker, integrator and aggregator organisation, procuring maize from all maize producers and thereby creating scale; and third, in creating market confidence for local maize production through setting pre-planting, pre- and post-harvest, pan-territorial and pan-seasonal pricing (Poulton et al. 2002) (see Figure 1). That GMB used state grain procurement as an industry policy tool to support the growth of the maize sector cannot be disputed. We have previously described this in the health sector as innovative procurement for industry development (Chataway et al. 2017). We argue that GMB, through the Ministry of Agriculture and in conjunction with the Ministry of Finance, traditionally acted as a signalling mechanism to promote maize cropping amongst the farmers and to input suppliers to the maize sector through pricing announcements (Figure 1).

Poulton et al. (2002) argue that the announcement of producer prices before the planting season served as an incentive to signal the viability or otherwise of maize cropping and the need to timeously acquire inputs, thereby fulfilling the policy goal of enabling early farmer cropping decision-making. Agribanking professionals reported that this early decision-making and planning facilitated early negotiations between farmers and their bankers on possible financing mechanisms. Pre- and post-harvest price announcements in April-May gave the government an opportunity to estimate potential crop size and risk management of stockholding levels (Poulton et al. 2002) and ensure that GMB's strategic grain reserves were not depleted. Pan-territorial and pan-seasonal pricing were tools used to signal cross-country price uniformity as well as annual producer and consumer price targets respectively (ibid). These and other policy instruments helped to level prices across the whole nation and encouraged centralised grain storage at the GMB rather than on the farm, where at times quality could be difficult to assure.

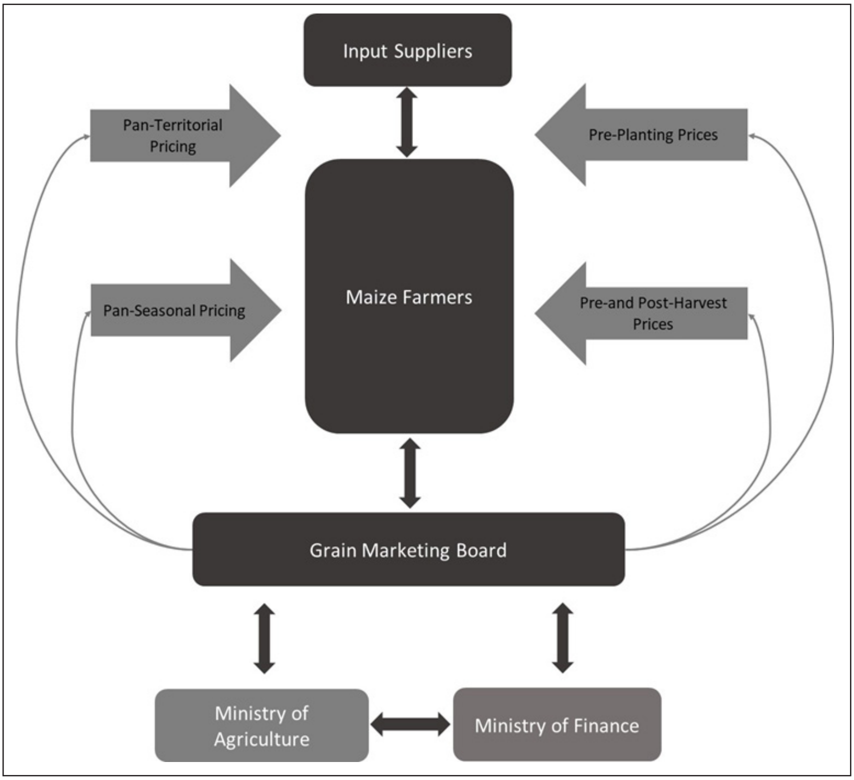

Figure 1: Market formation and signalling function of the GMB
Source: Constructed from Poulton et al. (2002) and author's input

Bridging institutions – technology/innovation adoption and diffusion

The fourth aspect that we discuss is the role that agricultural and technical extension services as well as institutional support played in creating the maize innovation ecosystem. Agricultural and technical extension services were introduced in Zimbabwe in 1972 by Emory D. Alvord; later, the Department of Conservation and Extension (Conex) and Department of Agricultural Development were established. These departments were merged in 1980 to form Agritex (Hanyani-Mlambo 2002). Agricultural extension services form the middle bridging pillar of agricultural innovation systems and in Zimbabwe, they played a pivotal role. Earlier on in this article, under technological capabilities, we discussed how agricultural training institutes trained agricultural extension officers. In this section, we discuss at a micro level how the extension officers interacted with the farmers, innovators and government policy. In an interview with a former Agritex technocrat it emerged that agriculture extension workers were mostly trained at Chibelo, Gwebi and other colleges, graduating with certificates or diplomas; thus, the majority were generalists. The extension workers lived amongst the communities, and agricultural extension officers who had diplomas or degrees and were deemed generalists were located at district level. At provincial level there were specialists who focused on, for example, livestock (small-scale dairy or poultry) or crops – for example, cotton, for those trained at the cotton research centre in Kadoma, who knew the complete cycle of growing cotton. Located at the Agritex head office were all the specialists in irrigation, crops, farm management (who helped farmers with marketing) and plant protection. Agritex gave free advice to commercial and communal farmers, as their role was to support commercial and communal farmers in their district. Poulton et al. (2002) also report that post-1980 there was a purposive approach to redirect Agritex's extension services to the communal areas and smallholder sector, and Agritex is credited with the rapid uptake of hybrid varieties of maize in the country. This was echoed by an ex-Agritex senior manager, who, however noted that these extension services were drastically reduced during the ESAP era.

What made the extension work successful in technology and innovation adoption and diffusion was the social capital they accrued by both their lived and experiential expertise. This endowed them with the right technical, variety, input and agri-ecological zone know-how. This made it easier to navigate the Rogers Innovation Diffusion Model described earlier (knowledge, persuasion, decision, implementation and confirmation) because of the social and cultural capital the extension officers had. A key informant described how Agritex was the largest organisation in the country with grass-roots representation, which recommended the right crops, crop rotation and fertilisers based on research from DRSS, in addition to knowledge from private sector seed companies such as SeedCo and Pioneer, amongst others. In addition, Agritex collaborated with the Central Statistics Office and Meteorological Station to form an early warning unit, and using modelling and sampling they could predict farming risks. This collaborative effort was a critical link to food security and is one of the functions that are claimed to have been lost when the department was downsized.

This article has shown that this innovation brokerage role played by Agritex was instrumental in smoothing the key challenges that Rogers (1983) highlighted. As a result of the extension officers establishing trust with local farmers, and the support structure they received from district and provincial experts, it was easier to mediate technology transfer and new variety adoption and diffusion as reported by the ex-Agritex technocrat.

Discussion

Our analysis of the key elements shows that the system of innovators, the state and private sector, deployment of public-private partnerships, bridging institutions as well as upstream and downstream value actors, such as input suppliers, farmers and agroprocessors, was built on a maize innovation ecosystem that was connected by funds, knowledge and technology/product flows, as illustrated in Figure 2.

Funding flows

We have argued that the maize innovation ecosystem came about because of strategic investment and the progressive construction of a technology and innovation infrastructure that supported innovators and technology generators. Upstream technology and innovation generation was funded by the state (arrows emanating from the state on the left side of Figure 2). The state funded the government research institutions, tertiary educational institutions, Agritex and the GMB. Where resources were limited, the state entered into public-private partnerships with industry associations such as the Zimbabwe Maize Seed Association, to take technologies developed at, for example, DRSS, and progress their translation and be the sole marketer to the farmers (see Table 1) (Tattersfield and Havazvidi 1994; Zerbe 2001).

The upstream funding by the state was augmented up and downstream by commercial banks in addition to the GMB (which was state-funded). We discussed the co-evolution of the financial institutions architecture with agriculture and Figure 2 illustrates how the commercial financing of upstream actors such as fertiliser and seed companies supported the maize production value chain. The GMB – a state grain procurement agent – functioned in multiple roles: as financier (in the procurement of grain), in market signalling and market formation, and as a value-chain integrator. It connected farmers and downstream agroprocessors in the food (human and animal) and other industries as well as exports. Our analysis points to an integrated funding mechanism as a key ingredient of a sustainable maize innovation ecosystem. Zimbabwe historically managed well in this respect until 1993, with the onset of ESAP, and more recently until 2002/3, at the commencement of the land reform programme. If the country wanted to fund agriculture sustainably, we argue that learning from this historical financial institutional architecture could be useful in sustainably rebuilding agriculture instead of seeking, de novo, new approaches.

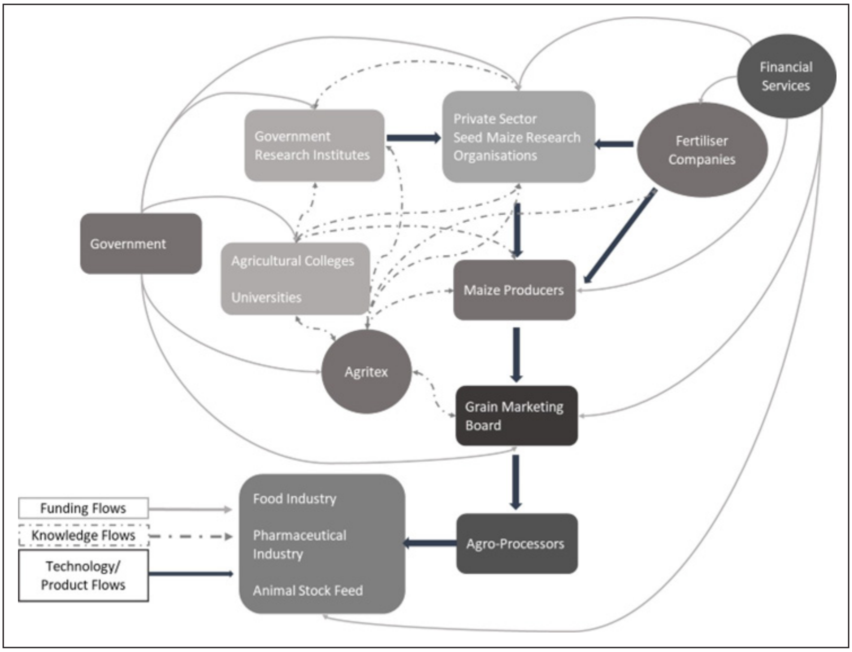

Figure 2: Illustration of funds, knowledge and technology/innovation flows and innovators and knowledge generators, bridging institutions and key value-chain actors' linkages

Source: Constructed by the author using literature in Table 2, interviews and local knowledge

Knowledge flows

Five key players were strategic to knowledge flows: government, tertiary educational institutions, Agritex, farmers and the private sector (input industry and seed maize producers). Government and private sector research institutes collaborated and co-complemented each other in technology and knowledge generation. An informal public-private partnership between the state and industry association played a critical role in innovation translation. This association was triggered by resource limitation. Figure 2 shows an abridged depiction of knowledge flows. What emerges is the complexity of the knowledge flows in multidirectional ways between the various knowledge generators, bridging institutions and other upstream and downstream maize value-chain actors. Given Zimbabwe's current challenges, a revival of the sector would call for the emergence of a coordinator and integrator institution to facilitate networking and collaborations amongst current disparate actors and organisations. However, this requires adequate resourcing of the financial, technological, innovation and knowledge actors in the innovation communities. Given that the maize innovation ecosystem took over 100 years to emerge into the structure depicted in Figure 2, it may call for patience to resuscitate the wider maize innovation ecosystem and the structure that emerges may take a different form and function. Thus, any efforts to revive the maize sector, and indeed any other crop or industry, would require a strategic re-evaluation of how knowledge and funding flows are intertwined and ultimately how they are woven into the third product of the innovation ecosystem – technology and product flows.

Technology and product flows

As discussed earlier and illustrated in Figure 2, our analysis shows three generators of technologies embodied in products and innovations: government research institutions, private sector institutions, and input industries exemplified by fertiliser companies. Technologies and products flowed between these innovation actors and maize producers, who played a dual role of seed maize multiplication and maize grain production. What is interesting in this case study is the way government research institutions passed on certain varieties to the private sector for translational activities – a public investment in research and innovation as a public good because of the food security accruals from enhanced maize varieties on the market. Interaction with seed companies in the period 2000 to 2006 revealed that private-sector seed companies contracted out seed multiplication to farmers. These farmers worked with in-house private-sector extension officers in planning, planting and seed production. The seed companies explained that the price per tonne for seed maize was appreciably higher than for grain maize because of the requirements for seed maize multiplication, such as sparser planting distances and the need for buffer zones. Technology and product flows show the intricate linkages between the public-private sectors, commencing with seed technologies development, trialling and seed multiplication and grain production. We argue that the integration of the innovators, integrators and commercial value chain actors made possible the technology and product flows through push and pull mechanisms. We argue that integration of the innovation community actors is important for designing an innovation ecosystem and that contemporary Zimbabwe can leverage this local knowledge and experience to resuscitate the agricultural sector.

Conclusion

The maize innovation ecosystem of Zimbabwe and its attendant local innovation and technological capabilities building – and the technology institutional infrastructure building at least until 2000 – is steeped in the legacies and political economy of the colonial state. Government policy, incentives and financial support were instrumental in setting up the technology- and innovation-supporting institutions and infrastructure that enabled the rise of maize as a key food security crop. State and private sector research institutions working with extension services, financial institutions and supporting industries constituted the innovation communities that supported renowned technological and innovation capabilities in seed maize and grain production in Zimbabwe. It can be argued that Zimbabwean maize innovation systems benefited from legacy institutional, technological and infrastructural capabilities that were established more than a century ago, and that the country benefited from the post WWII import substitution policies of the 1950s and 1960s. However, the integration of the public and private sector with, for the most part, functional market linkages through sustainable value chains played a key role in establishing the maize innovation system, directly contributing to food security for the country at least until just before the land redistribution era.

We argue that there are broader institutional, infrastructural, policy and practice lessons that can be drawn from this analysis. Purposive crafting of policies and allocation of resources for technology and innovation institutional setups can support, broadly, the re-emergence and sustenance of critical agricultural innovation communities that constitute the research and commercial economies that positively reinforce each other. Critical to the agricultural innovation ecosystem is careful consideration of an innovation community that collaborates, is complementary, and takes into account the fact that co-evolution of institutions and organisations is part of building a sustainable ecosystem. One of the greatest challenges that the country may face is the loss of institutional memory pertaining to the maize innovation ecosystems. Because of the turbulent economic times post-2003, the country has lost many technocrats in innovation communities, many of whom possessed this institutional memory. Reimagining the systems in the financial sector, in agriculture and agriculture policy, technology and innovation generators, and integrator institutions such as GMB, may be a difficult endeavour. However, the country can tap into the diaspora and use the learning-by-doing approach by recalling some of the skilled technocrats from retirement. Suffice to say, all this will be predicated on crafting an agricultural innovation ecosystem that learns from how, historically, the country forged technological capabilities in breeding and extension services, in financial institutions' architecture to support agriculture, and in bridging institutions that support technology adoption and innovation diffusion.

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