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A structural–functional diagnostic of Mpumalanga's agricultural education and training system

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Increasing capabilities are required to develop solutions to wicked problems whilst the economic, environmental, and social contexts of farming have become more turbulent. There is a growing focus on developing systemic capabilities that enable the identification, development, and scaling of shared solutions. This requires a cohesive agricultural education and training (AET) system that identifies needs of entire food systems and delivers responsive pedagogies that combine learning sources. However, South Africa's AET system remains in dire need of governance reform directed towards greater integration. This study investigates the performance of the AET system in the Mpumalanga Province, South Africa, utilising an agricultural innovation system (AIS) lens to identify where there are absent or poor-quality infrastructures and interactions, and cognitive, regulatory, and normative institutions that hinder AET-system performance. Evaluations of AET-supportive innovation structures were coupled with articulations of innovation functions that support transdisciplinary demand articulation, knowledge co-development, and networking. Results highlight an absence of communication and coordination mechanisms, hindering vertical and horizontal interactions between multi-actor groups. This absence contributes to a disenabling environment for AET-supportive networking, facilitation, and brokerage, leading to missed opportunities to facilitate between food system actors and AET providers to develop transdisciplinary research and pedagogies that harness diverse knowledge, resources, and networks to maximise impact. Whilst there are industry-led needs assessment structures, these operate in silos and lack public sector engagement that could enable organisations with complementary mandates, knowledge, and infrastructures to respond to common priorities.

Significance:

This paper advances scholarly interests in South African agriculture by applying an AIS-diagnostic lens to evaluate Mpumalanga's AET system to identify systemic blockages that hinder multi-actor collaboration within Mpumalanga's citrus and maize subsystems. This research goes beyond previous studies that focus on local-level agriculture, the influence of extension officers, or commodity-specific insights. Further, most agricultural studies in Mpumalanga focus on linear-modelled developmental pathways, whilst this study extends research by evaluating how multi-actor access and capabilities influence outcomes and the development of disenabling or enabling environments for AET in Mpumalanga.

Introduction

Increasing individual, organisational, and systemic capabilities to develop solutions to wicked problems are required as the economic, environmental, and social contexts of farming have become more turbulent.[1,2] In response, there is a growing focus on developing systemic capabilities that enable the identification, development, and scaling of shared solutions.[3] A primary way in which such dynamic capabilities are developed are through agricultural education and training (AET) and research systems. Whilst there are shifts towards participatory and systemic approaches to addressing food system challenges, the South African state-led AET system has changed little since its establishment, part of the ongoing legacy of colonialism. Poorly integrated AET, paradigms of linear technology transfer, diminishing budgets, and outdated curricula have contributed to South African AET being unable to replicate the performance of similar state-led systems.[4,5] Whilst paradigms of linear transfer of technologies remain prevalent in South Africa[6], there is growing momentum to integrate agricultural innovation system (AIS) theories and practices into AET, driven by an understanding that solving wicked problems requires integrated approaches[7] that include diverse knowledge bases and forms of learning[8-10]. AET systems need to operate in an integrated manner to address systemic problems that contain multiple root causes, each with context-specific and multilevel drivers, including sectoral and spatial path dependencies and vulnerabilities.[11,12] The complex and contested nature of agricultural systems requires integrated AET services that diagnose and respond to multidimensional challenges that have developed through and reinforce food system vulnerabilities.[13]

Responsive, complexity-aware AET should utilise an AIS len to identify opportunities to co-develop solutions to unpredictable yet recognisable challenges.[14] The systemic perspectives within AIS allow for an understanding of interdependent networks that affect nonlinear innovation processes.[15,16] This is vital to ensuring AET curricula and pedagogies capitalise on the multitude of learning environments within Mpumalanga and continuously adapt AET to multistakeholder needs and priorities.[17-19] The design of multidimensional AET recognises that sustainable and transformative developmental outcomes cannot be predicted by understanding the attitudes or behaviours of individuals[20], posing challenges to historic modes of food system governance built around top-down policymaking and solely technological solutions[21].

This paper supports the functioning of Mpumalanga's AET system by identifying systemic blockages that hinder multistakeholder collaboration, critically identifying shared and interdependent aims, capabilities, and challenges.

This research goes beyond previous research on agricultural systems in Mpumalanga, which has predominantly focused on farming at local levels[22-25], the role of extension officers as change agents[26,27], or commodity-specific insights. Further, the majority of agricultural studies undertaken within Mpumalanga[24,27,28] have used a linear-developmental lens. As such, this study extends current research by providing an AIS lens through which to evaluate the disenabling or enabling environments for AET in Mpumalanga and contributing to theoretical development in AIS studies.

Structural–functional framework

This study's systemic focus requires a framework that incorporates diverse knowledge centres whilst identifying stakeholder-specific constraints and opportunities.[29,30] Building on methodological frameworks developed in diagnostic AIS work[9,17,31], this structural–functional framework enables the mapping of AIS structures to provide a basis from which to identify elements that cause weakness or deficiencies in AIS functions[30].

Structural framework

The framework considers four key AIS structural components:

1. **Actors:** individuals and organisations learning and putting into use new ways and methods of working.[32,33]
2. **Institutions:** shared habits and routines used by actors organised by repetitive rules, norms, and strategies.[34,35]
3. **Interactions:** networking and engagement mechanisms and facilitated activities that aid interactive learning and negotiation between actors.[10,36]
4. **Assets:** physical, knowledge, and financial assets and resources.

To support the identification of actors who influence AET, this study drew from the United Nations Food and Agriculture Organization's (FAO's)[37] categorisation of key AIS actors (see Table 1). Given the sector's historical and structural bias towards codified knowledge[8], we made efforts to include stakeholder groups operating within tacit and informal spheres.

Functional framework

This framework develops a nuanced analytical lens to examine which functions support or inhibit the presence, absence, and quality of innovation-supportive structures. Functions are seen as targeted interactions, often with specific AET or systemic facilitation aims. Drawing from the typologies of Bergek et al.[38] and Hekkert et al.[39], and the identification of innovation support services by Ndah et al.[40], the below functions focus on AET activities that develop individual, organisational, and systemic innovative capabilities.

1. **Awareness, development, and exchange of knowledge:** development of codified and tacit knowledge in formal and informal settings; inclusion of new and existing knowledge inputs to innovation processes.[41,42]
2. **Advisory, consultancy, and backstopping:** identification and articulation of knowledge, priorities, roles, and resource-specific needs[43]; market demand; and provision of technical, legal, economic, environmental, and social advice.
3. **Networks, facilitation, and brokerage:** multilevel and monolevel stimulation between stakeholders with the objective of improving the quality of interactions and facilitation of networks.[44]
4. **Capacity building:** theory-based and interactive learning processes for individuals and organisations.[20]

Combined framework

The combination of structural and functional frameworks enables the analysis of the presence, absence, and quality of system structures, and what and how AIS structures affect who can access innovation-supportive functions. This framework was used to develop initial interview and focus group protocols and to set up a multistakeholder workshop that facilitated reflection on study findings (Table 2).

Table 1: Actor categories and potential agricultural innovation system roles

Actors/ subcategories	Potential roles
Farmer organisations	Providing advisory services
	Representing farmers in value chains and policy arenas
	Facilitating access to agricultural inputs, credit, and markets
Advisory services	Brokerage of knowledge between farmers and other actors
	Making new technology and practices available
	Forging networks and supporting farmers' organisations
Educational institutes	Improving the education level of all actors
	Education and training of professionals in the agricultural sector
	Development of better knowledge and skills for agricultural actors
Researchers	Developing and improving technologies, practices, and processes
	Testing and validation of locally developed technologies and processes
	Documenting the ways new practices and technologies are adapted
Policymakers	Formulating, implementing, and reflecting on strategies, policies, and regulations
	Allocating resources for research and human resources development
	Facilitating networks and partnerships

Source: Adapted from the FAO[37] under a CC BY-NC-SA 3.0 licence.

Methodology

Systems boundaries

This study's focus on analysing Mpumalanga's AET system through an AIS lens requires the setting of system boundaries to identify which actors, infrastructures, institutions, and interactions are included in the analysis, and implicitly which are excluded. The multifaceted challenges facing Mpumalanga's AIS have developed from an interplay of biophysical, technological, social–cultural, economic, institutional, and political dimensions[45], and this poses a boundary-setting challenge. This is because of the difficulty in establishing who has key influence and interest in Mpumalanga's AET system, and thus who should be included as a study participant. For example, the study boundary could finish at value chains located only within Mpumalanga, national businesses that purchase agricultural goods and services from within Mpumalanga, or international markets that have an influence on what and how specific crops are grown in Mpumalanga. We deployed spatial and commodity-specific foci to in response to this methodological challenge.

Spatial boundary

AET's multilevel, cross-commodity and inter-commodity foci and the integration of codified and tacit learning sources require a boundary that is able to cover multistakeholder interactions across multiple levels and dimensions.[20] As such, whilst the spatial boundary has been set primarily within Mpumalanga, this spatial boundary is fluid to incorporate national stakeholders with a significant influence on Mpumalanga's AET, for example national policymakers and centralised industry groups.

Selection of commodity chains

As this study sought to determine systemic blockages within Mpumalanga's AET, we were not directly concerned with specific crops or value chains.

However, to support the identification of system structures, we focused on two specific commodity chains. The initial selection of commodities was informed using the analysis of Mpumalanga's agricultural sector, with commodities selected based on their importance in Mpumalanga's food system.[46] A value chain complexity matrix (Figure 1) was used to select two commodity systems, citrus and maize, because of their contrasting system structures and levels of socio-material and socio-organisational complexity.

Data collection

Data were primarily collected using semi-structured interviews, focus groups, and a reflexive multi-actor workshop. Reviews of grey literature on Mpumalanga's AET, citrus, and maize subsystems helped tailor data collection tools to study participants' interests. Semi-structured interviews allowed for flexibility to explore stakeholder-specific comments and for interviewees to discuss topics of interest, creating more reflexive interviews.[47] Half of the study interviews and one focus group were held in-person, either at the University of Mpumalanga or at the offices and farms of participants' organisations, with other interviews and focus groups taking place online. Of the 38 participants, 20 were men and 18 were women (Table 3).

Twenty-four semi-structured interviews were held between 13 July and 29 August 2023, with two focus groups held on 6 August 2023. A rapid analysis of the findings was undertaken to allow for the findings to be discussed by participants in a workshop held at the University of Mpumalanga on 15 August 2023 (Table 4).

Data analysis

Interviews, focus groups, and the workshop were recorded and transcribed with the consent of participants. Preset codes from the structural–functional framework and emerging codes were assigned to text containing similar content. Codes were then organised into code families to obtain thematic categories. Analysis was then conducted on codes, with further analysis completed to identify where access to AET structures and functions was influenced by stakeholder characteristics.

Findings

Findings are presented in two sections that highlight the different structural and functional capacities of Mpumalanga's education and training, and research systems. The delineation of education and training, and research into separate but interlinked subsystems is because of differing structural dynamics that influence the quality of innovation structures and functions that operate within the wider AET system.

Education and training system

Poor multi-actor AET coordination

Articulated by van Saden's analysis of AET innovation within the North-West's AIS[48], responsive curricula and learning systems require the organisation of social learning between food system actors, government bodies, and AET providers. Complementing her findings, the results show that significant collaborative efforts are required

Table 2: Combined structural–functional framework

Structures	Actors	Institutions	Interactions	Infrastructures
What structural components contribute to realising each function, the presence and/or absence, or capability and/or quality of each structural component?				
Functions	Awareness, development, and exchange of knowledge	Advisory, consultancy, and backstopping	Networks, facilitation, and brokerage	Capacity building
What functions are performed by agricultural education and training stakeholders, and how well do these support innovative capabilities at individual, organisational, and system levels?				
Combined analysis				
Which structures enable which functions, for whom, and how?				
Which functions support the development of innovative capabilities, for whom, and how?				

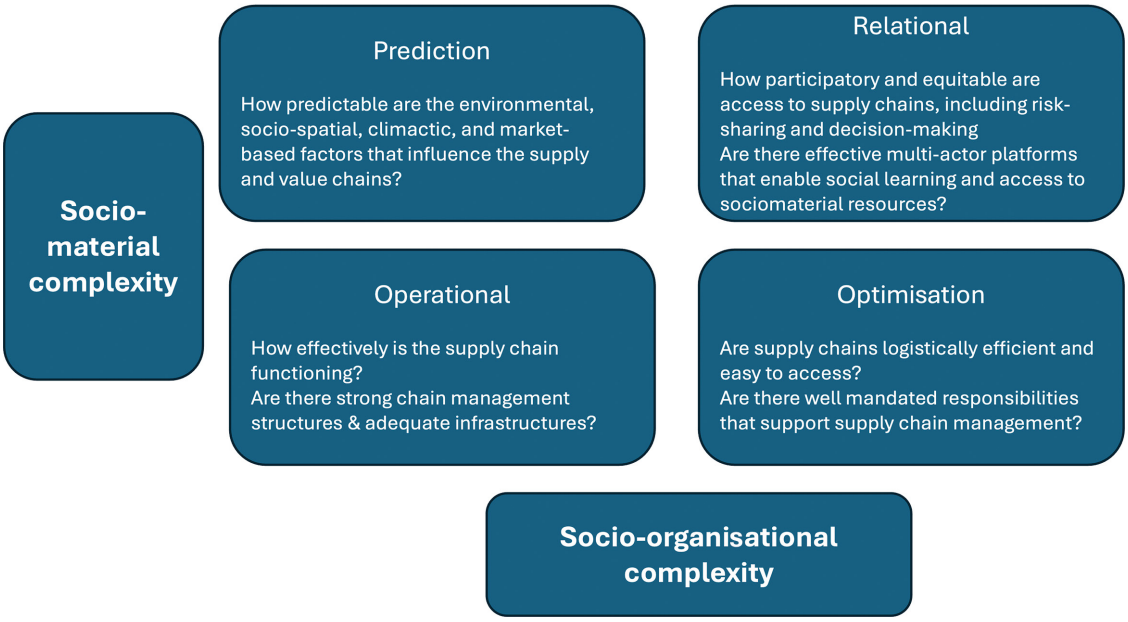

Figure 1: Socio-relational supply chain complexity matrix.

Table 3: Stakeholder association of study participants

Stakeholder groups		Diversity within stakeholder groups	Number of participants
1.	Farmer organisations	Industry bodies, smallholder associations, and non-governmental organisations	14
2.	Training providers	University lecturers, non-governmental organisations, governmental bodies, and industry bodies	13
3.	Government and funding bodies	Policymakers, extension officers, commodity, and development funders	5
4.	Researchers	Government, university, private, and commodity body researchers	6

Table 4: Stakeholder groups of in-person and online study participants

Stakeholder group		In-person workshop participants	Online workshop participants
1.	Farmer organisations	3	5
2.	Training providers	4	2
3.	Government and funding bodies	4	3
4.	Researchers	4	3

between institutions that enable multi-actor reflexive engagement in the development and delivery of agricultural curricula and pedagogies.

Findings from this study indicate that there are weak educational coordination mechanisms, leading to a lack of facilitated interactions between public and private AET providers. The absence of an intra-educational system coordination poses challenges not only to AET-focused actors but also to the capacity of Mpumalanga's entire food system to respond to ongoing challenges. Absent relationship-building structures between education providers and the wider AIS contribute to mismatches in required and produced skill sets between education providers and employers. Subsequently, graduates regularly do not possess sufficient role-specific knowledge, networks, and soft skills to easily transition into employment. Organisations in Mpumalanga's food system frequently have to invest significant resources to upskill new employees to provide them with the requisite technical knowledge, soft skills, and multi-actor relationships that are specific to sectors, value chains, and local food systems.

> [We need] *collaboration between the university and the department* [of Agriculture]. *We can't be producing students and then when they go to the market they can't be absorbed.* [University educator]

> *We are working in silos. I'm doing my own things, the investors* [are] *doing their own things, the department* [of Agriculture], [are doing] *their own things. But all of us are focusing on the same people.* [NGO staff]

Poor-quality intrasystem coordination is driven by weak communicative structures unable to identify multisectoral training needs and opportunities to incorporate experiential learning within existing pedagogies. Universities do not have access to real-world learning environments to provide soft skill development that meets the multifaceted needs of complex food systems in Mpumalanga. This absence emanates from weak institutional links between government, industry, and education providers, hindering potential education sharing between actors to combine theory-based and practical pedagogies. Whilst there is a wide recognition of the benefits of collaboration between education providers and employers, such benefits, for example of co-identifying industry needs, are not enabled by institutional norms or regulations. This disenabling environment is compounded by the complex nature of the multilevel AET system in Mpumalanga, and this challenge is increased as government and employers are not mandated to seek out educational partnerships.

> *Industry* [should] *support students from the university or college level, however there is not a platform to develop those relationships.* [Smallholder association manager]

> *All these discussions we have been having with these other institutions, they have been on an ad hoc basis. We need something, like a programme or a hub, that allows us to structure our engagements.* [Government extension manager]

Experiential learning is highly valued but faces a disenabling environment

Experiential learning is recognised as crucial to students' abilities to understand the multidimensional factors that influence food systems and should be considered a core component of Mpumalanga's AET system. Limited examples exist of mechanisms that integrate theoretical and practical learning environments, with examples including internships and studentships between private sector actors and the Agricultural Research Council (ARC). However, there is no system-wide framework that identifies experiential learning opportunities within the whole food system.

> *We now realise, after having appointed this guy* [an extension officer without a degree] *with his incredible, incredible wealth of practical knowledge, that that's where the focus should be… the universities would be doing everybody a favour by getting a more practical focus in their curricula.* [Commodity training provider]

> *We want people from the universities that will fit our profile… we usually can't find them because they aren't given that type of training… in most cases, universities don't do that kind of training.* [Private researcher]

Limited attempts to develop integrated learning environments have been stymied because of poor connectivity between local, municipal, and provincial systems in Mpumalanga; government working in silos; and a lack of a central structure that brokers educational partnerships.

Public and private extensions face resourcing constraints, compounded by a lack of collaboration

Commodity-group-employed extension officers access crop-specific continuous professional development (CPD) that helps them adapt to changing needs. Strong vertical integration supports commodity groups to inform their extension training programmes by gathering top-down and bottom-up information through surveys and frequent industry forums.[49] These multilevel needs-gathering structures allow training to respond to industry needs and are a considerable strength. However, industry-led training providers are often unable to access sufficient training infrastructures to capitalise on demand-driven training opportunities.

> *We use conferencing facilities, which… drives up the costs considerably, but there isn't really training facilities that are accessible and useful and well equipped.* [Commodity group training provider]

> *Training facilities are not freely available.* [Commodity group training provider]

Contrastingly, there is insufficient CPD for public extension officers, with the ARC only providing limited support, whilst the provincial Department of Agriculture does not fully capitalise on the recent growth of the University of Mpumalanga. The lack of multi-institutional coordination limits the identification of needs and opportunities between government extension, AET role players, and industry. This absence has led to missed opportunities to strengthen extension education and provision by combining the CDP of extension officers with the development of experiential learning placements for university students.

Poor networking compounds systemic challenges

Another example of poor intrasystem communication can be found in the recently (2023) closed Assistant Agricultural Extensionist programme through which the South African Department of Agriculture, Land Reform and Rural Development appointed 5000 new extension officers throughout South Africa on 3-month contracts. However, provincial departments of agriculture were not allocated sufficient resources, including vehicles, laptops, and phones, to support new assistant extension officers to fulfil their roles. Improved collaboration with food system actors could have helped identify mutually beneficial opportunities for collaborative working that enabled the sharing of resources, for example, by organisations travelling to the same locations together to combine extension provision with students' experiential learning.

> *The assistant extension practitioners were unable to do anything as they didn't have … access to resources.* [DARDLEA research manager]

> *These* [assistant] *extension officers cannot do full work without a full extension officer supervising them… they will need to be driven to the farms by the existing extension officers.* [DARDLEA extension official]

Research and innovation system

Commodity structures enable industry collaboration

Well-established national commodity organisations have developed co-ordination systems that combine bottom-up and top-down approaches to inform research agendas. These coordination systems enable research to respond to ongoing and novel challenges by facilitating multilevel commodity-specific interactions. Interactions are supported by regulations and normative expectations that have been established by commodity levy-funding structures. For example, the Citrus Growers' Association draws upon funding from the citrus value chain through a levy charged on growers' exports. This levy-funding sets research expectations of citrus value chain stakeholders[50], with service delivery communicated through well-structured agreements. The commodity-focused research system enables the collection of multilevel needs and supports the functioning of the national agricultural research system by enabling multi-institutional interactions.[51] Funding bodies mandate multi-institutional research consortia in funding calls, acting as a systemic enabler that brings actors together around identified system needs (Figure 2).

The stated purpose of the Citrus Growers' Association is the "interests of the producers of export citrus"[52(p.96)], and, as such, research coordination models primarily respond to the priorities of commercial and export-focused agriculture. Whilst the Citrus Growers' Association has ringfenced 20% of levy fees to support emerging farmers, the overarching aim of the Association is to increase exports of citrus, and thus this remains the central developmental pathway promoted for emerging farmers. Whilst elements of such commercial developmental pathways can support the resilience and sustainability of emerging farmers, there are significant risks associated with the promotion of cash crops and commercial markets for such actors.[49] As dominant system structures, including input, infrastructure, and information systems, are built around the capabilities and networks of commercial farmers, these systems are often unsuitable for farmers whose focus is on local food security. An ongoing challenge that is beyond the scope of this paper is how to ensure that commodity groups help develop food systems that reduce smallholder exposure to market and climatic shocks by supporting domestic markets for traditional food baskets. An over-reliance on such export-orientated structures could expose smallholder and emerging farmers to unnecessary short-term risks as agricultural environments become more unstable.

Public research structures need leadership and investment

Public research coordination structures, including the Mpumalanga Agricultural Research Committee, are visible in Mpumalanga. However, a lack of ownership from public actors has resulted in poor-quality networking, facilitation, and exchange of knowledge. Such provincial research coordination structures are, however, still in their infancy, and strong leadership is required to enable such structures to identify and support systemic needs, priorities, and resources. A key focus of public agricultural bodies should be to support interactions that enable the shared utilisation of infrastructures between public research stakeholders to create efficiencies in service delivery that reduce the ongoing funding challenges faced by public bodies.

Discussion and conclusion

This study confirms that there is a disenabling environment for AET in Mpumalanga, with research and educational subsystems facing structural weaknesses through a lack of translevel interactions.[53] There is an absence of a coordination framework across the AET system that enables communication between different levels, commodity

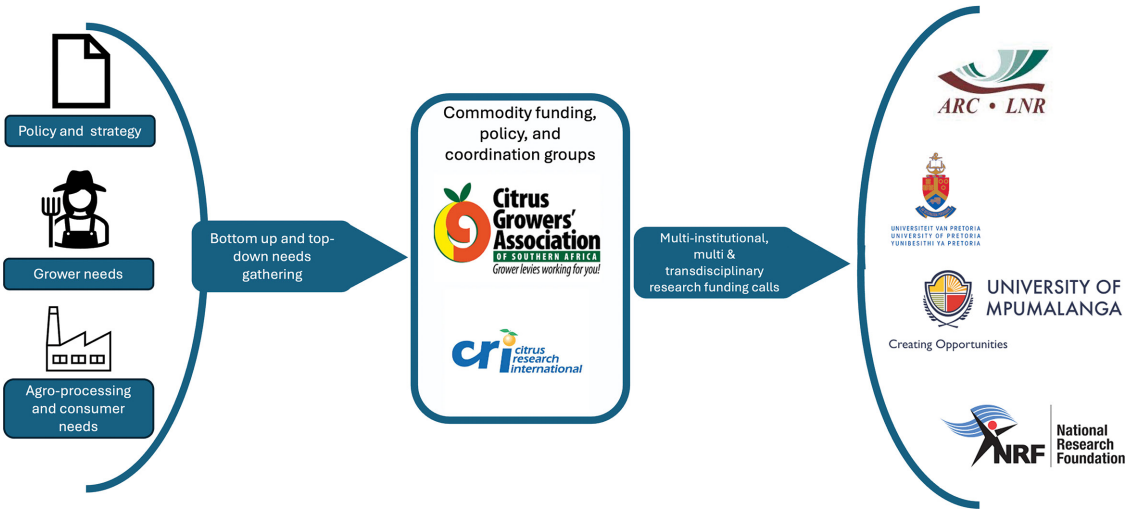

Figure 2: Commodity-research system.

chains, and formal and informal networks. The ensuing lack of networking, facilitation, and brokerage is a fundamental systemic blockage, causing many actors to operate in silos. This weak networking environment significantly contributes to poor awareness and exchange of knowledge between actors and inhibits advisory and backstopping services through limited intrasystem awareness of needs and resources. Whilst commodity-research structures have embedded norms, regulations, and well-developed communicative mechanisms, system-wide platforms that support cross-commodity, public and private innovative capabilities are lacking. The University of Mpumalanga (UMP), the Agricultural Research Council of South Africa (ARC), and the Mpumalanga Department of Agriculture, Rural Development, Land and Environmental Affairs (DARDLEA) should provide leadership to strengthen provincial AET structures. These should build on the Water Research Commissions' research on how to frame a comprehensive multilevel agricultural learning system[54] that brings together complementary strengths and resources to respond to systemic needs. UMP, ARC, and DARDLEA have the legitimacy, resources, and access to networks and infrastructures to consolidate multilevel and multi-actor networks around common goals and should co-develop a coordination mechanism that pools knowledge and resources for mutual benefit. Further, their mandates and access to a diverse range of human and organisational resources provide them with the capabilities to effectively coordinate with an equitable and impactful provincial AET system that complements existing commodity-coordination structures.

Of significance is the absence of interactions between actors operating in formal and informal spheres. This contributes to a systemic inability to take advantage of complementary skills, networks, and resources. A system-wide coordination platform should facilitate between public and private AET providers and users by capitalising on the mandates of extension officers to act as innovation intermediaries that link formal and informal networks. Further, collaboration between public and private extensions should be strengthened to identify complementary needs and resources and respond to limited extension resourcing. Participatory and multi-actor identification of problems would enable industry, government, ARC, provincial departments, and UMP to work together on extension CPD and identify where sharing of resources between extension stakeholders is desirable and feasible.

Such a platform should integrate with commodity-coordination and communication structures that enable commodity-research subsystems to meet bottom-up and top-down needs. Government, UMP, and the ARC should learn from such commodity systems to understand how to facilitate multidisciplinary and transdisciplinary research consortia that identify and build on complementary skills and resources. In-kind investments between such bodies in a public research coordination system would enable the identification of synergies in research activities, infrastructures, and networks to maximise impact. Agenda-setting exercises between such actors should be used to facilitate backstopping and networking functions and build on pre-existing initiatives, for example the Mpumalanga Agricultural Research Committee. Undertaking research and needs mapping between such bodies would provide the basis for awareness, development, and exchange of knowledge and resources. This would identify where there are opportunities to collaborate on mutually beneficial research and education and training activities.

As recommended by the ASSAf Consensus Study[53], AET actors in Mpumalanga should adopt a land grant model as an AET-system-wide coordination mechanism. Articulated by Kopp[55], a land grant model could act as a systemic enabler by facilitating demand-driven relationships between ministries and education and research bodies to promote usable science. This builds on the Department of Science, Technology and Innovation's Decadal Plan[56] that envisages a transformed research institutional landscape with greater integration between all actors and would act as a starting point to create enabling environments for multi-actor AET that provides responsive, demand-driven research and education that capitalises on the diversity of knowledge, networks, and resources in Mpumalanga.

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Data availability

The data pertaining to this article are not available.

Declarations

We have no competing interests to declare. We have no AI or LLM use to declare. Ethical clearance was received from the School of Agriculture, Policy, and Development, University of Reading (Number: 2200C). This study contributed to the fulfilment of T.F.'s MSc, awarded by the University of Reading.

Authors' contributions

T.F.: Conceptualisation, methodology, investigation, formal analysis, validation, data curation, writing – original draft, writing – review and editing. A.S.: Supervision, project leadership, project administration, funding acquisition, writing – review and editing. S.C.: Supervision, project leadership, writing – review and editing. All authors read and approved the final manuscript.

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