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Integrating indigenous knowledge into agricultural research and development: a pathway to landrace preservation and food security

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ABSTRACT

Despite growing recognition of the importance of indigenous landraces for food security amidst climate change, many landraces continue to disappear worldwide. Research notes that integrating indigenous knowledge (IK) into modern science can support landrace preservation. However, progress varies across countries. This study tries to fill this gap in Uganda by examining the state of IK integration into agricultural research and development (AR&D). A mixed-methods approach was used to collect data in all Zonal Agricultural Research and Development Institutes (ZARDIs) across Uganda. Data collection included surveys with 101 agricultural researchers, interviews with nine research directors, eight information officers, and document analysis. The findings reveal that IK integration remains limited, due to weak policies, negative perceptions of IK, and dependence on donor-driven research. Where integration occurs, findings show that it is ad hoc and focused on scientific approaches, often ignoring IK's cultural aspects. As a result, IK and related landraces are sidelined, raising their extinction risk. To preserve landraces effectively, requires policy realignment to prioritize IK in research agendas and budgets and, a holistic approach that incorporates both scientific and cultural aspects of IK to strengthen IK's contribution to food security.

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Agricultural indigenous knowledge; agricultural research and development; landrace preservation; food security; Uganda

1. Introduction

Indigenous landraces are increasingly recognised as crucial for ensuring food security amidst adverse climatic changes (Mathew & Mathew, 2023; Raggi et al., 2022). However, yield-oriented agricultural practices threaten agroecological systems, leading to the disappearance of traditional landraces (Liu et al., 2022). Landraces, in this context, refer to local or indigenous animals, crops, and plant species that develop naturally and do not require modern chemical inputs.

Globally, over 75% of indigenous landraces have been replaced by modern cultivars (Khoury et al., 2022; United Nations, 2015), with significant declines in both Europe (Raggi et al., 2022) and Africa (Mathew & Mathew, 2023). The resulting erosion of genetic diversity compromises unique adaptive traits that are critical for climate resilience. Kanyinke (2015) underscores that for communities dependent on healthy ecosystems, the loss of indigenous landraces is a significant concern, emphasising the urgent need for their preservation. Furthermore, target 2.5 of Sustainable Development Goal 2 calls for the conservation of varieties at risk of extinction and the development of strategies for the sustainable use of genetic resources (FAO, 2019, p. 24).

Responsible for agricultural developments are National and regional agricultural research and development (AR&D) institutions. These institutions are technical knowledge organisations mandated to consistently identify agricultural problems and knowledge gaps, seek knowledge sources, and integrate knowledge from diverse sources. They then integrate it with what they already know, share it with stakeholders, and use it in agricultural practices (Sanginga et al., 2026). Despite the recognised importance of integrating indigenous knowledge (IK) into development initiatives, such integration is frequently

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overlooked (Dare Kolawole, 2022; Hermans et al., 2021). Research indicates that for IK and its associated materials and practices to be acknowledged and incorporated into modern development strategies, they must undergo validation to determine their significance, reliability, functionality, transferability, and problem-solving capacity (Bodapti & Chander, 2013; Kom & Nethengwe, 2024). This process requires comprehensive engagement by Agricultural Research Organisations (AROs), which are central to shaping agricultural sustainability and development policies. Integrating IK into modern science has been identified as a key strategy for conserving landraces (Adefila et al., 2024; Hermans et al., 2021; Imoro et al., 2022). However, progress in IK integration remains inconsistent (Ciocco et al., 2023), highlighting the need for country-specific analysis to evaluate progress and identify ongoing challenges. To address the identified knowledge gap, this study examines the state of IK integration in Uganda.

1.1. Study objectives

This article examines the state and barriers of IK integration within AROs in Uganda, with the view of exploring strategies to enhance IK integration in Agricultural Research and Development (AR&D). The specific objectives are:

1. To identify and discuss current IK integration efforts, approaches and the extent of integration into AR&D
2. To identify and discuss the major barriers to IK integration into AR&D initiatives
3. To discuss actionable strategies for improvement

1.2. The study context

Uganda is a predominantly agricultural country in sub-Saharan Africa. It possesses a diverse cultural heritage with 65 indigenous communities that form a substantial base of indigenous knowledge (NEMA, 2019; Uganda Government, 2015). A large part of the population depends on agriculture for food and livelihoods. This makes the country particularly vulnerable to challenges related to climate change and food insecurity.

AROs are instrumental in generating agricultural knowledge and fostering innovation to enhance productivity, food security, and livelihoods. Over the past three decades, Uganda's AROs have promoted mechanisation to increase production and income for subsistence farmers. However, this transition has contributed to the abandonment of indigenous landraces, which previously supported healthy diets and climate resilience (Kimani et al., 2020).

In Uganda, the National Agricultural Research Organisation (NARO) oversees agricultural research within the National Agricultural Research System. In its knowledge management (KM) strategy, the NARO acknowledges the significance of IK stating that, 'Integrating scientific and indigenous knowledge is a critical step towards the modernisation of agriculture' (NARO, 2019, p. 20). The operationalization of this strategy into AR&D programmes and practices is through the NARO's sixteen Public Agricultural Research Institutes (PARIs) seven of which are National Agricultural Institutes (NARIs) and nine are Zonal Agricultural Research and Development Institutes (ZARDIs). ZARDIs are primarily located in rural areas and are distributed across all agro-ecological zones of Uganda to address grassroots problems (NARO, 2025). This enables direct interaction with rural farmers, the main holders of IK. Their positioning makes ZARDIs suitable for identifying, documenting IK throughout Uganda enabling its integration into AR&D. However, the integration of IK into AR&D programmes and practices has progressed slowly (Aluma, 2010; Munyaka et al., 2026; Muwanga, 2020).

Although targeted IK integration initiatives exist in the NARO research institutes, organisational records indicate limited integration (NARO, 2021, 2023). Existing efforts address the conservation and improvement of indigenous livestock breeds exists in a limited number of districts, rather than promoting broader, cross-institutional projects. This pattern aligns with Aluma (2010) and Muwanga (2020) earlier observations that such initiatives are both scarce and fragmented. For instance, the NARO has prioritised the prevention of indigenous cattle breed erosion (NARO, 2020) and has supported community-led goat improvement in selected districts through cross-breeding with elite Mubende and Small East African goats (NARO, 2023, p. 23). Conservation activities, such as the establishment of a shea nut gene bank in collaboration with the

World Agroforestry Centre, remain limited in both scope and in the number of partners (NARO, 2021c). Similarly, genetic enhancement initiatives for indigenous chickens are narrowly focused (NARO, 2023, p. 23). Overall, integration and collaboration across NARO institutes remain minimal, highlighting the need for more coordinated approaches. Despite these initiatives, traditional landraces in Uganda continue to decline (Adikini and Kakeeto, 2026; Graham et al., 2022; NARO, 2021c; Tabuti & Van Damme, 2012). This necessitates a nationwide approach to IK integration to preserve landraces, maintain environmental stability, and ensure food security.

2. Research about IK Integration into modern agricultural practices

Research shows that IK should be recognised as credible and valuable, challenging the notion that it is obsolete (Adefila et al., 2024). Successful integration of agricultural IK and practices with modern techniques requires respect for cultural heritage and local customs, rather than the imposition of external solutions (Gashute & Hale, 2023). Because of this, integrating IK requires approaches that build trust with local farmers, who are the main holders of IK (Shanshan & Islam, 2024). Increasingly, several studies, such as those by Adefila et al. (2024), Chimi et al. (2023), and Wiedemann et al. (2022), demonstrate that participatory approaches facilitate reciprocal knowledge exchange and the co-creation of interventions that resonate with farmers' realities. These approaches contrast the traditional top-down approaches. Even though, IK is increasingly viewed as an asset, research notes that its inclusion in formal development frameworks is often impeded by institutional barriers and insufficient policy recognition (Ngubane et al., 2026).

Ncube et al. (2025) highlight the pivotal role of policy in integrating IK asserting that government action and prioritisation are essential for linking IK to societal well-being and preservation. The absence of dedicated IK policies exposes traditional knowledge to exploitation and misappropriation (Mugambiwa et al., 2023). Integrating IK requires comprehensive policies that address documentation, access rights, funding, intellectual property rights (IPR), and sharing of IK (Ncube et al., 2025). Nevertheless, the lack of actionable IK policies provisions continues to limit effective IK integration and broader knowledge management (Ncube et al., 2025).

The Ugandan experience illustrates these issues. Uganda has developed several relevant policies, including the Uganda National Culture Policy (2006), the National Indigenous Knowledge Policy, and various intellectual property laws (Tabuti & Van Damme, 2012). The National Culture Policy mandates benefit-sharing with IK holders and promotes the integration of IK to support sustainable development (Ministry of Gender, Labour and Social Development, 2006), while the National Industrial Policy (2020) encourages technology transfer and innovation in indigenous technologies. However, despite these frameworks, implementation and explicit alignment with IK management requirements remain limited. Within organisations such as the NARO, legislation acknowledges the value of integrating scientific and indigenous methods and assigns NARO the responsibility for managing and disseminating agricultural knowledge. Yet, current laws typically require only consent for access to IK, which falls short of providing comprehensive protection for IK holders (Otim, 2024).

Notably, research shows that public organs in most African countries often run on tight budgets which affects the prioritisation of IK in their annual plans (Owolabi et al., 2022). AROs require funds to identify, collect, document and integrate IK. Without sufficient financial resources, even the most well-designed policies remain unimplemented, and integration efforts are stalled (Ncube et al., 2025).

Furthermore, the issue of perceptions of IK is vital, especially regarding its credibility. Persistent misconceptions and lack of respect frequently lead to the marginalisation or merely tokenistic inclusion of IK in policy and practice (Tabuti & Van Damme, 2012). Transforming these perceptions is vital for meaningful integration and for ensuring that IK holders are treated as genuine partners in development initiatives (Dei et al., 2025). Adefila et al. (2024) stress the need to challenge dismissive attitudes and promote the recognition of IK as valuable and relevant.

2.1. Theoretical framework

The study used Probst et al. (2000) knowledge management model as a theoretical lens in investigating IK integration into AR&D systems. The model presents eight connected parts, grouped into inner and outer cycles: the inner cycle consists of *knowledge identification, acquisition, development, distribution, application, and preservation*, while the outer cycle consists of *knowledge goals and knowledge assessment* (Probst et al., 2000). This model offers a way to theoretically understand how to integrate IK into AR&D. Development (integration) process depends on AROs actively seeking and acquiring knowledge. The model stresses the importance of recognising, valuing, and systematically acquiring knowledge, so IK is not just noticed but actually given attention in AROs' knowledge management. The outer cycle's focus on goal setting and assessment helps to ensure that IK integration is a priority and is properly evaluated (Ijatuyi et al., 2025). This framework shows how perceptions shape attitudes that influence decisions on which knowledge is valued and included. Probst et al. (2000) model points out that, without deliberate efforts to change attitudes and practices, knowledge management may be impeded. Similarly, if IK is not perceived as equally important as modern science, it may lead to negative attitudes resulting in IK being overlooked irrespective of its potential value (Ciocco et al., 2023). Furthermore, the model deals with the challenges of changing how people view different kinds of knowledge. Its broad approach helps to focus on how IK is recognised, acquired, integrated, shared, used, and preserved. The application of Probst et al. (2000) KM model in this study provides a lens to interpret the state and challenges of integrating IK into Agricultural Research and Development (AR&D) systems.

3. Methods

A mixed-methods approach was employed to collect both quantitative survey data and qualitative semi-structured interview data supplemented by document analysis. As advocated by scholars such as (Ngulube, 2022), this approach enhances breadth and depth of information by using multiple data collection instruments. According to Othman et al. (2020), mixed-methods research may employ sequential or concurrent strategies. The choice depends on the study objectives. For this study, a quantitative-qualitative (QUAN-QUAL) sequential strategy was adopted beginning with a survey followed by interviews, and document review.

3.1. Study setting

The study was conducted across all nine ZARDIs, which are part of the sixteen Public Agricultural Research Institutes (PARIs) under NARO, comprising seven National Agricultural Research Institutes (NARIs) and nine ZARDIs. Both NARIs and ZARDIs conduct applied research of national importance, while ZARDIs additionally undertake adaptive research to address grassroots challenges (NARO, 2025). This strategic focus explains their location across Uganda's agricultural ecological zones and their name as Zonal Agricultural Research and Development Institutes.

Distributed throughout all agroecological zones (Figure 1), ZARDIs directly engage with rural farmers, the main holders of IK. Their adaptive research involves testing and validating local practices, integrating those found scientifically effective, and thus incorporating indigenous knowledge. ZARDIs operate two main programmes, each with a distinct focus. The Crops and Natural Resources Programme covers agroforestry, crop science, horticulture, agronomy, plant genetics, physiology, meteorology, and soil science, with a focus on plant-based research and resource management. In contrast, the Animal Resources and Livestock Programme addresses aquaculture, apiculture, and livestock management, with a focus on animal-based research. Both programmes generate knowledge in crop and animal breeding, soil fertility, pest and disease control, climate adaptation, and food processing, areas rich in IK (NARO, 2017a).

3.2. Study population, sample selection and demographics

The total target population consisted of 188 individuals. This population was multicategory comprising of 170 agricultural researchers, nine research directors and nine information officers. These groups were targeted for their central role in knowledge generation, storage, and dissemination. Participants were selected using a combination of simple random sampling and purposive sampling methods.

Agricultural researchers represented the largest subgroup, totalling 170 individuals, comprising 97 scientists and 73 technicians across all ZARDIs. This group was included due to its role in generating

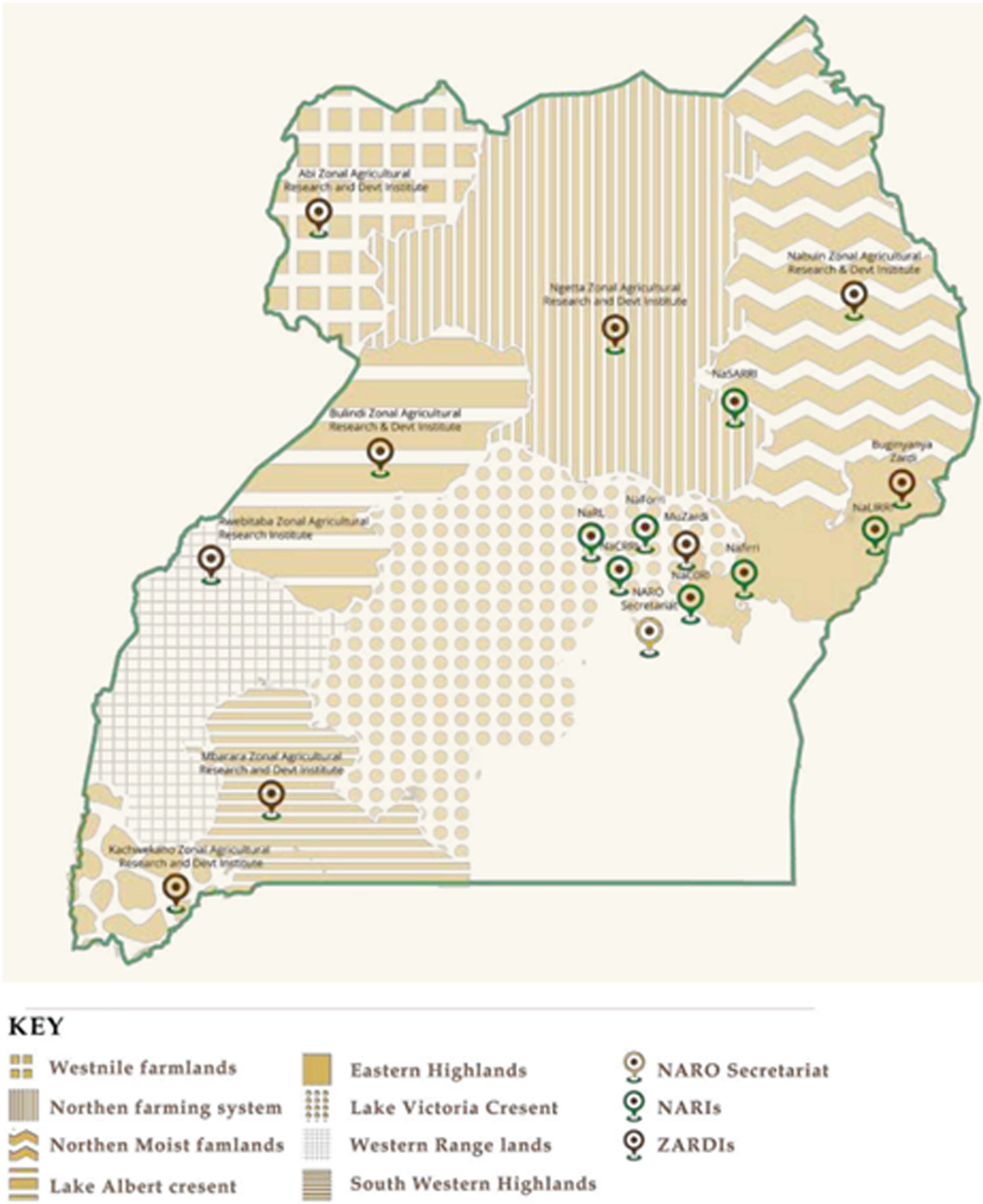

Figure 1. ZARDIs' geographical spread across Uganda.

agricultural knowledge, including IK, through direct community engagement during fieldwork. Given the geographic distribution of ZARDIs and the mobile nature of researchers' work, this subgroup was targeted for the survey. Their sample was selected using simple random techniques. First, Krejcie and Morgan (1970) simple random table was used to determine a sample size. The sample table indicated that, a population of 170 requires a sample size of 118. After determining a sample size, proportionate stratified sampling was applied to ensure equitable representation. The sample was calculated as follows:

Scientists $(97/170 \times 118) = 71$ participants.

Technicians (73/170 × 118) = 47 participants.

In total, 118 agricultural researchers were selected (see Table 1).

Interview participants i.e. Research directors and Information officers were purposively selected. All nine research directors represent each of the nine ZARDIs were chosen for their leadership roles which influence decision-making and policy. Their experience in AR&D, as well as their oversight of knowledge-generating activities, provided valuable perspectives for in-depth interviews. Similarly, Information officers were purposively selected, one from each ZARDI. This position was typically held by research scientists, often programme heads responsible for project implementation though in two ZARDIs, ICT and communications officers held this role. Regardless of their specific academic background, information officers possessed comprehensive knowledge of records related to completed and ongoing IK integration initiatives. These individuals contributed through interviews and by assisting in the identification of relevant documents for review.

Demographic variables collected about the above individuals included gender, age, education, and experience, as these may influence perceptions and attitudes toward knowledge. As summarised in Table 2, 53% of the sample were middle-aged individuals, 42% were youth, and 5% were older researchers. Most participants with more experience were middle-aged or older, factors that may shape their attitudes toward knowledge.

3.3. Data collection

Following a QUAN-QUAL strategy, data collection began with an online survey administered to agricultural researchers. The results from the survey informed the interviews with research directors and information officers, conducted in person, via Zoom, or by phone. Additional confirmatory data came from document review. These methods together made up the empirical material, all collected at ZARDIs across Uganda.

Table 1. Shows proportionate selection of scientists and technicians across ZARDIs.

ZARDIs	Population of Scientists	No of scientists selected	Population of technicians	No of technicians selected	Total samples
Abi Zonal Institute	10	7	10	7	14
Buginyanya Zonal Institute	11	8	8	5	13
Bulindi Zonal Institute	10	7	8	5	12
Kachwekano Zonal Institute	11	8	7	4	12
Mbarara Zonal Institute	10	7	8	5	12
Mukono Zonal Institute	15	13	3	1	14
Nabuin Zonal Institute	10	7	10	7	14
Ngetta Zonal Institute	10	7	10	7	14
Rwebitaba Zonal Institute	10	7	9	6	13
Total	***P* = 97**	**S = 71**	***P* = 73**	**S = 47**	***N* = 118**

Note: *P* = Population; S = Sample; *N* = Total number of agricultural researchers selected.

Table 2. Description of study participants.

Demographic variable		Agricultural researchers	Information officers	Research directors	Total
Target population	Respondents targeted	118	9	9	136
Actual participants	Actual participants	101	8	9	118
	Response rates	86%	89%	100%	87%
Gender	Male	66	5	8	79(67%)
	Female	35	3	1	39(33%)
Age	18–38 (Youth)	44	5	0	49(42%)
	39–54 (Middle-aged)	54	3	6	63(53%)
	55 and above (Older)	3	0	3	6(5%)
Education status	Diploma	8	0	0	8(6.8%)
	Bachelors	30	4	0	34(28.8%)
	Masters	44	4	0	48(40.7%)
	PhD	19	0	9	28(23.7%)
Experience	1–5 years in AR&D field	31	4	0	35(29.7%)
	6–10 years	41	4	2	47(39.8%)
	11–30 years	29	0	7	36(30.5%)

Table 3. Reliability test results showing the retained statements.

Cronbach's alpha	*N* of items	Interpretation		
.898	4	All four items are in the scale of Good		
Negative statements about IK utility and relevance	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
IK as inferior knowledge in the era of modern science	7.18	5.888	.776	.868
IK as outdated knowledge and practices	7.36	5.612	.750	.878
IK is based on based on backward beliefs and superstitions	7.37	5.654	.821	.851
I associate IK with witchcraft	7.53	5.911	.749	.877

3.4. Data analysis

Data analysis also followed a QUAN-QUAL sequential strategy, beginning with *quantitative* survey data. First, survey data were cleaned in MS Excel, then analysed using IBM SPSS 25. The questionnaire incorporated Likert scales, checkboxes, and open-ended questions to collect detailed information and opinions. Questionnaire clarity was assessed prior to administration. Three measures were employed to support validity and consistency: pretesting with three researchers, validation by a professor, and reliability testing using Cronbach's Alpha in SPSS 25. Cronbach's Alpha, which ranges from 0 to 1, was used to determine which Likert-scale items to retain. Items that increased the alpha when removed were dropped. For example, five statements about perceptions were initially included; one was dropped as its removal raised the alpha (see Table 3).

Descriptive statistical analyses were then performed to summarise IK integration efforts, methods, extent, and barriers using frequencies. Next, inferential statistical analyses, including the Chi-Square test, were conducted to examine relationships, such as whether a researcher's age influences perceptions of IK.

Qualitative data consisting of interview and documents transcripts were analysed using Atlas.ti 22. Transcripts were reviewed to find keywords and phrases. Initial coding included Invivo coding (for language-matching survey concepts) and open coding (for interpretive statements). Codes were grouped by survey framework. Since interviews aimed to supplement survey results, findings are presented in narratives, figures, and quotes.

3.5. Ethical considerations

Ethical clearance was obtained from Makerere University's Social Science Institutional Review Board (Ref. MAKSS REC 09.20.449/AR) and the Uganda National Council for Science and Technology (Ref: SS739ES). The NARO Director General subsequently granted written permission for the study at the ZARDIs, which was shared with all ZARDI Research Directors. Following approval, research directors were contacted to obtain consent for document access, interviews, and staff engagement. Upon receiving consent, staff contact lists were provided. Participant consent was subsequently requested via telephone or email. Survey respondents initially received an email, followed by telephone calls to non-respondents to provide clarification and establish rapport. Research directors and information officers were contacted as necessary, with consent forms distributed accordingly. Permission to record was requested at the start of each interview. To ensure privacy throughout the research process, all participants were assigned identification codes to ensure anonymity. In cases where content could potentially reveal identities, specific codes (such as D1, D2, D3) were used to maintain confidentiality. In addition to these procedures, several quality assurance measures were implemented to enhance the study's rigour, validity, and reliability. Validity refers to the extent to which scores represent the intended variable, while reliability indicates consistency across tests (Karnia, 2024). Both were supported through triangulation of multiple data collection methods.

4. Results

This section presents findings on the state of IK integration into agricultural research and development (AR&D). It presents findings from surveys and interviews and document review on the state od landrace erosion in Uganda, the urgent need to preserve them, and the critical role of IK integration in addressing

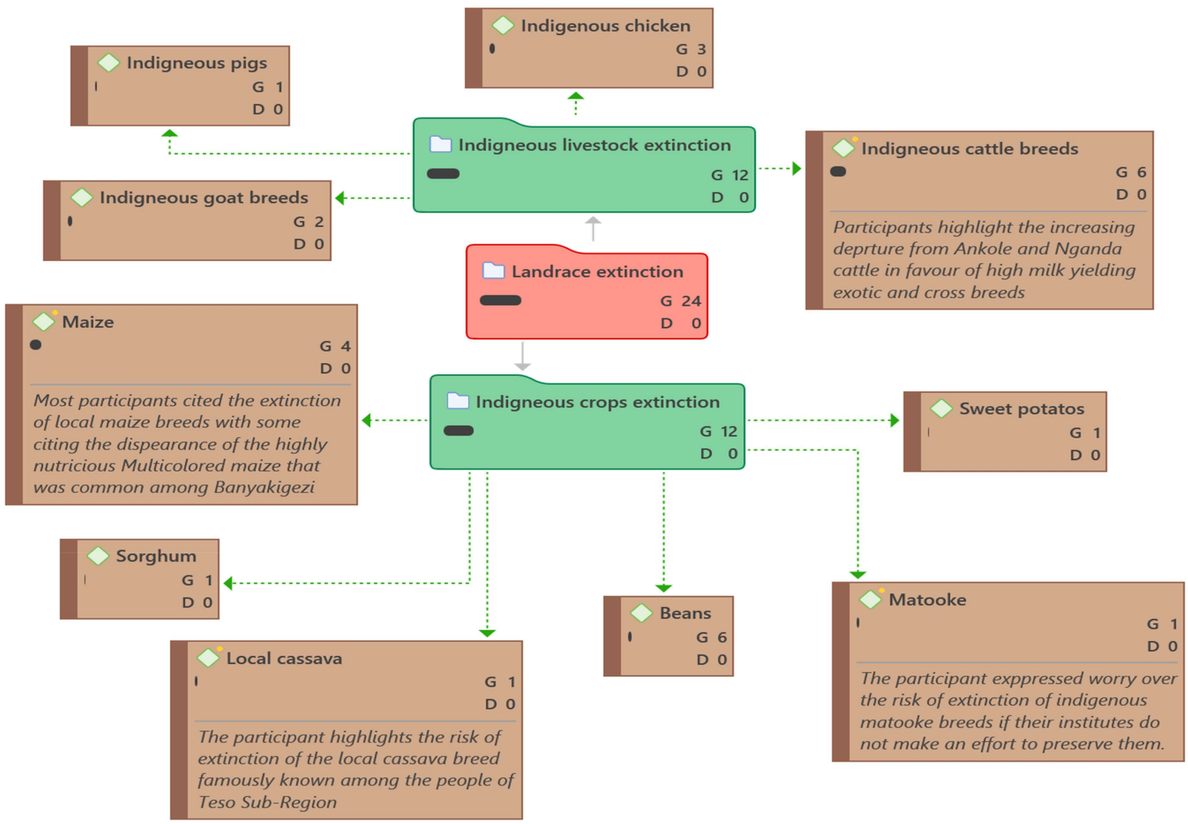

Figure 2. Interviewees' sentiments on erosion of indigenous landraces in Uganda [Output - Atlas Ti22].

these challenges. The subsequent sections delve into specific efforts to integrate IK within ZARDIs. The presentation also illustrate how IK integration can contribute to more sustainable agricultural practices and the preservation of genetic resources.

4.1. Landrace erosion and the necessity of preservation through IK integration

According to survey results, 94% of 101 respondents acknowledged the decline of traditional landraces and stressed the importance of preserving them through integration to prevent further loss. This concern and the need for IK integration are reflected in the interview data, which also underscore the mounting threats to indigenous landrace survival. In particular, interviewees, especially those aged 50 or older, voiced concern about the persistent loss of traditional landraces. To illustrate, a research director stated:

> 'Our traditional ecosystems, known as landraces, are disappearing; breeds of chicken, pigs, cows, and goats, as well as nutrient-rich crop varieties, are being replaced by GMOs [Genetically Modified Organisms]. However, these landraces have better nutritional qualities compared to GMOs. We must strike a balance by enhancing productivity while integrating both local and modern resources to optimise nutrient diversity and quantity' (D4).

Another interviewee remarked:

> 'There is a rapid increase in genetic loss. Our indigenous crops have disappeared because they have been replaced by GMOs from our research stations. The multicoloured maize, famously known among the Banyakigezi in Kabale for many generations, disappeared and is no longer available, yet it was very nutritious. We need to conserve local knowledge of genetic resources and practices to avoid their total disappearance' (D8).

Collectively, these findings underscore the importance of indigenous landraces for food security and highlight the risks associated with neglecting the Integration of related IK in research and development. Interviewees consistently identified several landraces that have either disappeared or are currently endangered (see Figure 2).

Nevertheless, an urgent need emerges to salvage IK through knowledge integration before it becomes extinct with most interviewees indicating that integrating IK into AR&D could deter their further extinction and enhance the development of innovations that resonate with farmers' realities. Despite this urgency, 86.7% of 101 respondents and all interviewees reported that IK is not a priority in their ZARDIs. While participants acknowledged that ZARDIs are strategically positioned to collect and validate IK, its actual adoption remains minimal. Nonetheless, the findings indicate that integration involves validating IK's efficacy, incorporating effective practices into conventional agricultural methods, and disseminating them for broader adoption by farmers.

4.2. Indigenous knowledge integration efforts in ZARDIs

Investigation into efforts to integrate IK in ZARDIs yielded the following findings summarised in Table 4.

The above results (Table 4) show limited overall progress in IK integration in the ZARDIs. As reflected in the *frequency counts, food security* received slightly more attention, with 60 respondents (59.5%) reporting validation efforts in pest and disease management, compared to 25 (24.8%) in livestock and 35 (34.7%) in crops. These numbers show that IK validation is more common in pest management than in other areas. Interviewees affirmed these results. One interviewee indicated that his/her ZARDI identified red pepper, tobacco, dust, and Phytolacca as natural materials effective in crop pest control, and, when these were validated, dust was most effective (D4). This focus likely reflects the persistent pest and disease challenges in farming communities. In addition, 15 respondents (14.9%) and several interviewees noted that validating and integrating local food processing and preservation methods were important for food security. For example, one interviewee described their ZARDI's work to validate traditional milk processing into ghee:

> 'Though we have not made significant progress in IK integration, we investigated a starter culture to improve ghee production after discovering that rural women use traditional starter cultures containing many bacteria,

Table 4. Efforts towards IK integration in Zonal institutes.

Agricultural aspect	Attempts towards IK integration	F	Themes identified
Crop and livestock breeding	- Use of farmers' folk varieties in conventional crop breeding, like cassava and potato vines, bananas, and beans - Traditional methods of livestock breed selection - Improving the productivity of local breeds like goats, cattle, and chickens	3	LANDRACE PRESERVATION
Mixed cropping practices	- Random mixed cropping of cereals - Intercr opping	3	FOOD SECURITY
Crop pests and disease management in the field and storage	- Conducted laboratory trials to validate the effectiveness of selected IK materials to test sporogony to control stringer in cereals - Conducted to validate selected herbal IKs, which included tobacco, neem, red pepper, animal manure, charcoal, ash, urine, and sugar cane solution in the control of weevils in maize in storage for pest management. - Assessed the effectiveness of local methods in the control of banana wilt disease	35	
Livestock pest and disease management	- We are developing acaricides to improve farmers' knowledge of tick control in animals - Validating IK used in the control of worms in livestock using local herbs	25	
Food processing and preservation	- Tested traditional methods of making wine from bananas with the intent to add science for improved yields - Testing traditional ghee making and preservation using starter culture to improve this method - Validated IK on the storage of maize above the fireplaces to determine standard measures of heat required - Trying to test milk preservation using herbs	15	
Soil fertility management	- Validated the effectiveness of using natural materials such as coffee husks, dry grass, compost manure, animal waste, and rice husks for soil fertility improvement in relation to chemical fertilisers	2	ENVIRONMENTAL CONSERVATION
Indigenous pesticides	- Conducted laboratory trials to validate the effectiveness of selected plant concoctions (bio-rations) in the management of varying crop pests		
Others	None that I am aware of	21	
Total		**101**	

some of which are hazardous to humans. We are now researching how to produce a starter culture from bacteria derived from local cattle breeds, allowing us, for the first time in the country, to enhance ghee yield using indigenous bacteria residing in Uganda' (D3).

These findings indicate two main benefits: increased ghee yield and improved hygiene. Both are essential considerations when evaluating the effectiveness of indigenous knowledge. Another interviewee disclosed his/her ZARDI's efforts to validate local food preservation methods to establish their efficacy.

'We encourage farmers to buy high-yielding varieties, but some poor farmers in remote villages cannot afford to buy modern seeds in shops, so they rely on local seeds, which, unlike our GMOs, can reproduce when planted. For example, these farmers still store maize cobs under the roof above the fireplace until the next planting season. However, we found that when exposed to excessive heat for extended periods, some seeds do not germinate, so we are trying to determine the optimal exposure time required to maintain seed viability' (D14).

These findings show that traditional crop varieties can reproduce when replanted and that natural preservation methods have potential when applied correctly. However, IK integration into research remains sporadic. Interviewees confirmed that IK is often used only as specific needs arise, rather than as a routine part of ZARDI activities. For instance, efforts to integrate IK for environmental conservation were minimal. Only 2 respondents (2%) reported using IK for soil health and natural resource conservation. They identified coffee husks, dry grass, compost, manure, and rice husks as effective natural mulches. Interviewees shared similar perspectives. For example, one explained:

'We have made limited progress in integrating IK, but we validated farmers' use of natural materials to boost soil fertility. Our findings showed that using charcoal soot, chicken droppings, and decomposed animal waste alongside urine, followed by covering the soil with coffee husks, naturally enriches the soil, unlike chemical fertilisers, which degrade its quality' (D22).

The above findings show that using indigenous resources for soil management supports biodiversity conservation. Building on this, another interviewee stated:

'We identify what farmers use, how they use it, and why they use it so that we can compare it with our new research technologies and the ones we find most used; we capture and validate them to determine their efficacy and what we find superior to our new technology; we adapt it to other communities and the crude IK, we purify it, and still make use of it, but the one that is not effective and cannot be improved is discouraged through extension messages' (D6).

The above findings suggest four main reasons for AROs' engagement with IK: (1) validating farmers' knowledge claims, (2) improving farmers' technologies and practices, (3) adapting certain indigenous farming technologies and practices, and (4) discouraging those perceived as ineffective.

4.3. Existing IK integration approaches and methods

Another enquiry on how IK is integrated into ZARDIs' conventional knowledge and practices yielded the following results.

As shown (Table 5 above), the results indicate that IK integration in ZARDIs predominantly occurs via field trials and observations (44.5%), chemical analysis or laboratory testing (20.7%), literature reviews (8.9%), and training (4.9%). This pattern suggests a reliance on research-driven, science-based integration. Additionally, 20.7% of respondents were unaware of any IK integration within their zonal research institutes,

Table 5. Shows existing Indigenous knowledge integration approaches in ZARDIs.

Ways of IK integration	No responses
Validation through literature review	9
Validation through Chemical analysis	21
Validation through Field trials and observation	45
Integration through training programmes	5
I am not aware of any IK integration at my ZARDI	21
Total	**101**

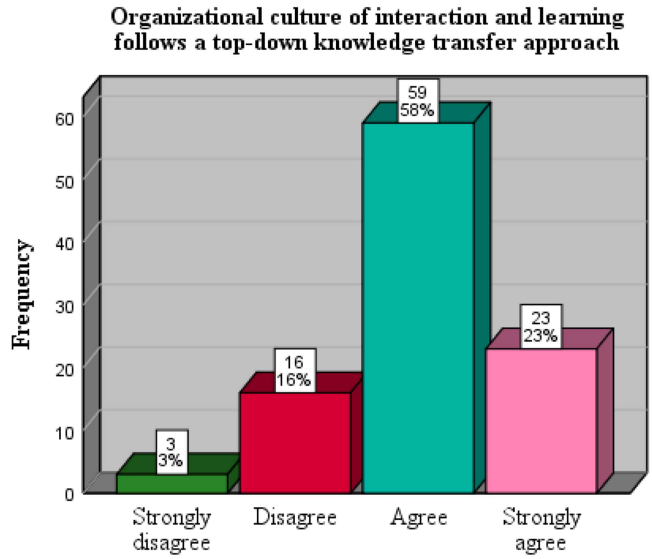

Figure 3. Top-Down Knowledge Transfer Approaches [Output - IBM SPSS 25].

suggesting that IK integration is not a usual priority item in annual plans nor a routine task within ZARDIs. Interview data support these findings and add further insight. One interviewee said:

> 'We once conducted a situation analysis to understand why some farmers do not adopt research technologies. In this process, we identified and collected relevant IK and conducted trials to assess their efficacy. If we find that they work as claimed, we recommend them to farmers for application and integrate them into our training programmes. Where we are unable to do so, we partner with other institutions, such as Makerere University, which has very good laboratories and expertise to validate some of the materials we collect' (D1).

In the extract, the use of field trials and lab analysis is highlighted. Similarly, another interviewee said that his/her ZARDI validated some IKs for managing crop pests and diseases by comparing selected natural materials with a commercial inorganic powder and dust, which was found to be more effective than the other herbal IKs.

> 'We conducted field trials on selected herbal IKs to control maize and bean weevils in the targeted districts. The trials tested dust, red pepper, tobacco, Phytolacca, and a commercial inorganic powder as controls against live adult weevils in beans. Laboratory analysis showed that dust was more effective than other herbal IKs. We have integrated successful solutions into our training programmes for farmers to adopt' (D4).

The above findings reveal that ZARDIs emphasise scientific validation of IK. Interviewees also reported ongoing validation efforts for the nutritional and healing properties of traditional plants. However, they noted that some IKs, which cannot be scientifically explained, are often disregarded during integration processes. Another interviewee explained how some IKs that do not meet the scientific criteria are often disregarded in the integration process, using an example of superstitions farmers use to ensure natural resource conservation, as the following extract illustrates:

> 'When one wants to cut down a certain forest, an elder says, do not burn that forest because your ancestor was buried there. Such individuals will listen and adhere to it because, in certain communities, such beliefs, customs, and taboos are still upheld and respected. However, for scientists, explaining the science behind such taboos is difficult; therefore, we tend to ignore such IKs' (D6)

The findings highlight that communities encourage natural resource conservation by preserving traditions and values, often through superstitions. However, such cultural components are usually excluded when assessing IK validity. One interviewee summarised this position: 'Because we are a science-based institution, we tend to abandon whatever we cannot scientifically validate' (D11). The implication is that IK without a scientific explanation is typically not integrated into ZARDIS' programmes. Furthermore, the findings reveal a significant influence of organisational culture in shaping perceptions and learning culture within ZARDIs, where learning follows a top-down approach, as reported by 81% of 101 respondents (see Figure 3).

Figure 3's findings show a framework in which AR&D researchers are typically viewed as experts, while farmers are regarded as passive recipients. This perspective is substantiated by interviewees' statements such as: 'We are the educated ones, which creates a tendency to believe we know better than illiterate farmers and what is best for them' (D1). Such organisational attitudes can impede equitable knowledge exchange.

4.4. Extent of indigenous knowledge integration

Analysis of the results, displayed in Figure 4 and detailed later, indicates minimal Integration of IK, with 50% of respondents reporting a 'small extent', 9% a moderate extent, and 41% indicating 'no integration' in their ZARDIs.

These initial results set the context for closer examination of IK integration across different ZARDIs.

A detailed look at IK integration in all ZARDIs supports the initial findings and highlights the scope of the issue (see Figure 5 below).

As shown (Figure 5), frequency counts show minimal IK integration, with only moderate efforts at Mukono (3%) and Mbarara (4%). This minimal integration stems partly from their previous involvement in an IK project. Mbarara ZARDI does not have a dedicated IK project but has validated certain indigenous herbs used by farmers to manage livestock pests and diseases. Interviews confirm this limited validation. As one interviewee explained,

> 'We do not have a systematic and comprehensive plan for validating and integrating IK. It usually occurs in an ad-hoc manner, like when there is an outbreak of a serious pest, and we want to learn what farmers are using, and how effective it is' (D7).

These findings show that only IK relevant to specific problems is selected and validated, leading to the neglect and loss of other valuable knowledge. Overall, limited IK integration is common across ZARDIs. These shortcomings introduce key barriers, which the next sub-section examines.

4.5. Impediments to indigenous knowledge integration

The study results reveal that IK is not well integrated into ZARDIs. The study highlights three key factors that limit IK integration including negative perceptions, unclear policies and guidelines, and excessive reliance on donor funding that affect what knowledge is prioritised.

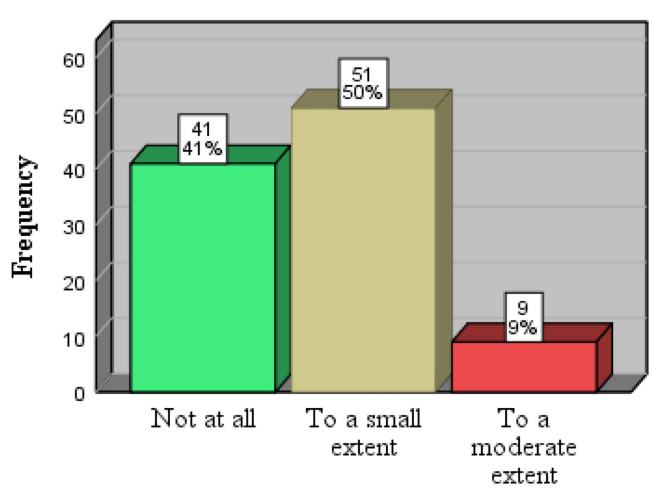

Figure 4. Extent of IK integration [Output - IBM SPSS 25].

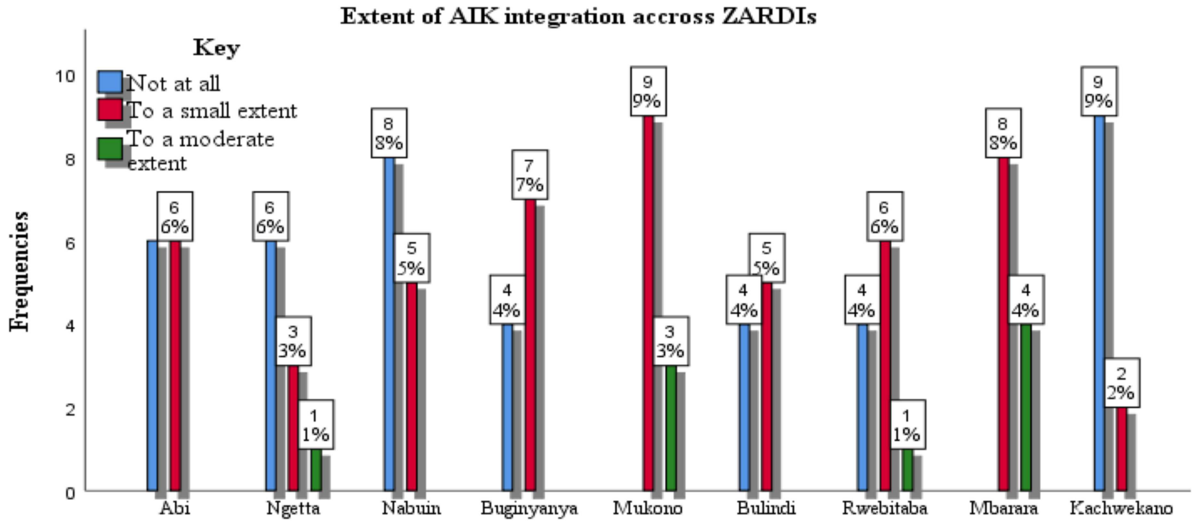

Figure 5. Extent of Indigenous Knowledge Integration across ZARDIs [Output - IBM SPSS 25].

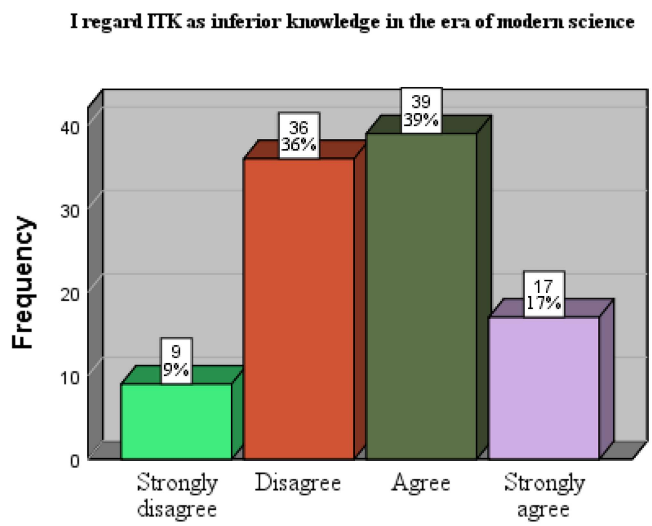

Figure 6. Perceptions of IK relevance [Output - IBM SPSS 25].

4.5.1. The perceptual problem

These perceptual issues are clear in respondents' views on IK's importance. Of 101 respondents, 56% (39 + 17) see it as inferior to modern science. Meanwhile, 44% (9 + 36) disagree, as shown in Figure 6.

Interviewees expressed similar sentiments as displayed in Figure 7.

One research director indicated a tendency among AROs to overlook IK, expressing concern that this may result in the loss of traditional landraces:

> 'There is a general trend of thinking that, as scientists modernise, we do not move with tradition, so we tend to ignore IK and local practices. Truth be told, most of it has already vanished. It is not only the knowledge itself that has vanished; wide indigenous varieties of crops have also been abandoned, and the sad truth is that these varieties were more nutritious and more tolerant of harsh climatic conditions' (D7)

Collectively, these perspectives suggest that many contemporary researchers equate modernisation with breaking from tradition and often hold a negative attitude toward IK, which limits IK integration efforts. However, the results indicate that younger AR&D researchers (ages 18–38) hold more negative views about IK than older cohorts (See Figure 8).

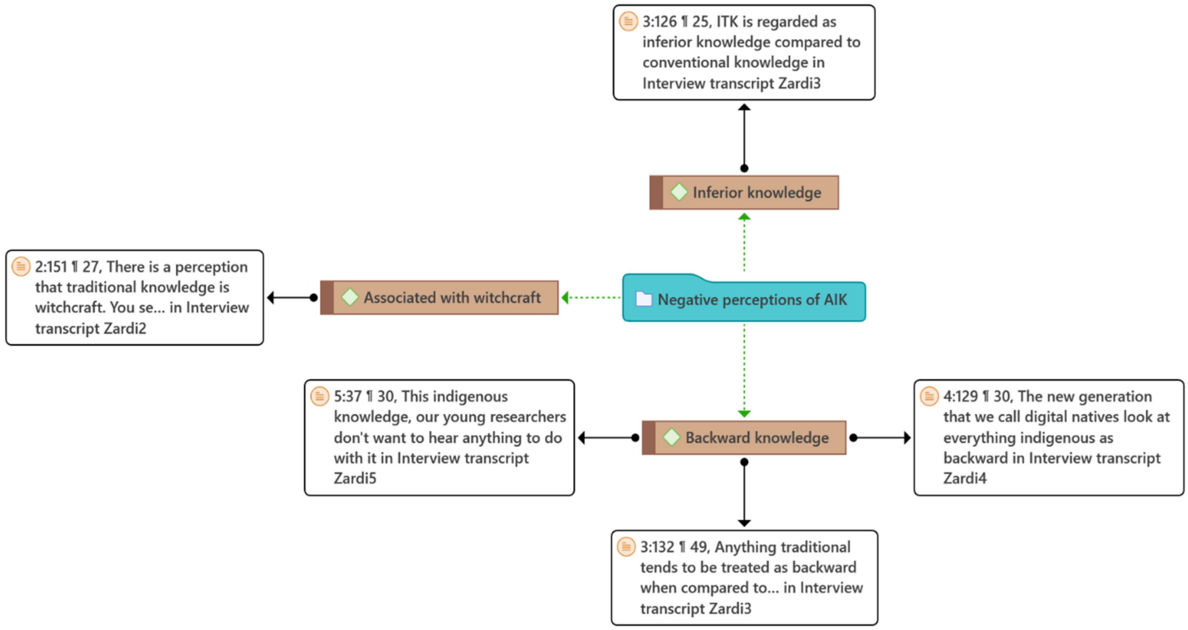

Figure 7. Negative perceptions of IK; Views from key informants: [Output - Atlas ti22].

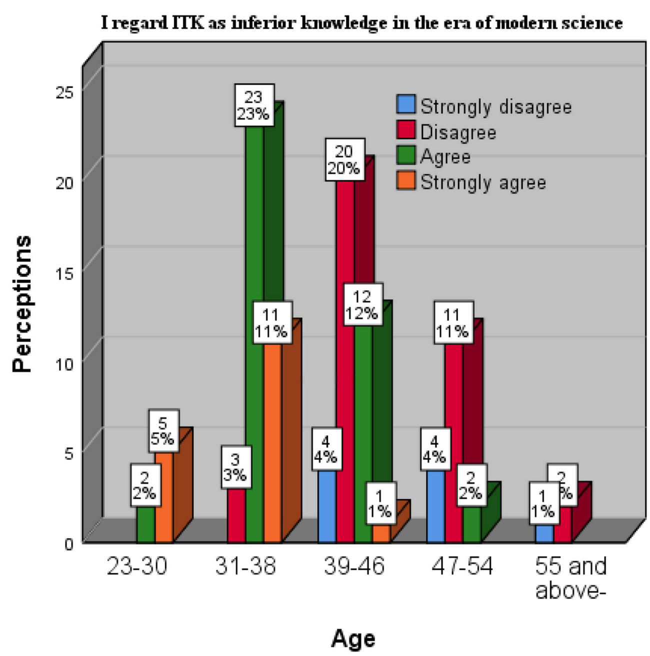

Figure 8. Perceptions in relation to age groups [Output - IBM SPSS 25].

Interviewees confirmed that age influences perceptions of IK, with older researchers emphasising the widespread disdain among younger researchers for IK. One director expressed this concern: ‘You see, the new generation, often referred to as digital natives, views anything indigenous as backward. Even our young researchers here do not want to hear anything to do with IK’ (D4). To further explain this relationship, a Chi-Square analysis tested whether age influences perceptions of IK. The null hypothesis (H0) posited that an AR&D researcher's age does not influence their perception of IK, whereas the alternative hypothesis (Ha) stated that age does.

Table 6. Relationship between respondents' age and their perception of IK.

Age groups	Mean perceptions	N	Std. deviation
18-30	2.8095	7	.27936
31-38	2.6937	37	.23738
39-46	2.4189	37	.29033
47-54	2.2549	17	.28332
55 and above-	2.2778	3	.25459
Total	2.5149	101	.32240

ANOVA Table			Sum of Squares	Df	Mean Square	F	Sig.
PERCEPTIONS * A1. Which of these represents your age group?	Between Groups	(Combined)	3.449	4	.862	11.919	.000
	Within Groups		6.945	96	.072		
	Total		10.394	100			

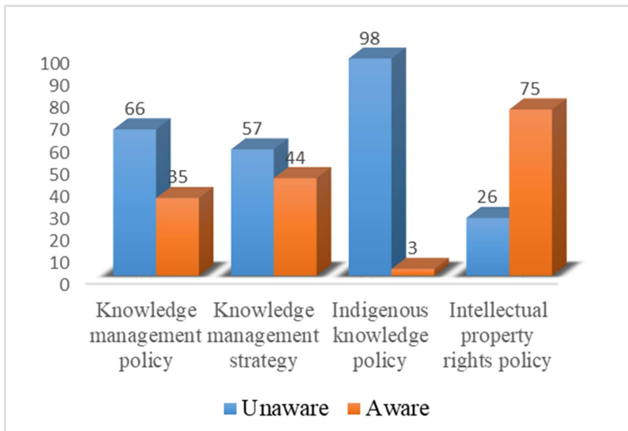

Figure 9. Awareness of existing policies about Indigenous knowledge.

Findings from the grouped data reveal differences between age groups: the 18–30 (mean = 3.0) and 31–39 cohorts have higher mean scores than the 39–46 (mean = 2.4), 47–54 (mean = 2.3), and 55 + (mean = 2.3) groups. ANOVA analysis confirmed this difference, with a significant *p*-value ($0.000 < 0.05$), indicating that age influences AR&D researchers' views on IK and thus the null hypothesis is rejected while alternative one is accepted. Young researchers hold a more negative perception of IK. As younger researchers are poised to become future leaders in AROs, their negative perceptions of IK may result in reduced engagement, raising critical questions about the future of IK (See Table 6).

4.5.2. Funding capacity

Most survey respondents (98% of 101) said their ZARDIs did not set aside budgets for IK. Furthermore, interviewees confirmed that they depended on external donors, whose support is driven by their own priorities.

> ‘We lack funding capacity and rely mainly on external donors, who often have their own agendas. Most of the time, these interests do not include promoting our indigenous knowledge; yet, we must align our proposals with their priorities’ (D3).

These findings show that foreign-funded projects often receive special treatment and are free to follow donor interests. This usually means they favor modern science over indigenous knowledge. This funding gap is closely linked to the lack of policies on indigenous knowledge, an issue discussed in the next section.

4.5.3. Inadequate policies

The results show that most respondents were unaware of the existence of an IK policy, the Knowledge Management (KM) policy, or the KM strategy. This policy gap has significant implications for IK integration, forming another barrier, as supported by the interview data in Figure 9.

In Figure 9, interview insights further highlight policy gaps among participants. While only 2 of 17 interviewees were aware of a Knowledge Management (KM) policy, neither knew its content. Three indicated that they were aware of a KM strategy, with only one able to mention that it provides for IK: 'We do not have a knowledge management policy, but we have a strategy that recognises IK' (D1). Participants were dissatisfied with policy clarity, noting IK is not explicitly addressed; as one said, '...we lack clear policies; so integration is usually conducted haphazardly' (D2). To validate these findings, a review of organisational policy documents was conducted.

As illustrated in Table 7, the review confirmed the existence of both a KM policy and a KM strategy, though these were unfamiliar to most respondents. Only the KM strategy explicitly refers to IK, noting on page 20 that, 'integration of scientific and indigenous knowledge is a critical step towards the modernisation of agriculture' (D10). However, this is a general statement without specific guidance on implementation or responsible parties. This lack of detail may contribute to inconsistent IK integration across ZARDIs. The next section discusses these findings and suggests a way forward.

5. Discussion of the findings

Participants' demographics significantly influence perceptions of knowledge. Emphasising the importance of IK can foster respect and appreciation among the AR&D researchers and AROs, encouraging their active engagement in integration efforts to enhance preservation of IK and associated landraces. The sample in this study was predominantly male, consistent with Baguma (2016, p. 119) observations of NARO's staff. Most participants were middle-aged, followed by youth, with a few older researchers. This trend shows the generation with extensive IK is nearing retirement. Therefore, it is urgent to integrate and document IK to prevent its loss and preserve continuity in communities.

5.1. Landrace extinction in Uganda

The study showed that AR&D researchers are aware of the increasing loss of indigenous landraces and associated IK in Uganda. For example, they acknowledged that wide indigenous varieties are vanishing, citing that the highly nutritious multicoloured maize breed famous among the Banyakigezi had disappeared. Maize is a vital global cereal and the main staple for many in sub-Saharan Africa (Tibaingana et al., 2022). The extinction of such indigenous landraces poses significant repercussions on sustainable food security.

Moreover, AR&D researchers in the present study recognised that indigenous breeds offer superior nutrition and withstand harsh climates, making them vital for Uganda's food security. However, the study found a growing shift from indigenous to conventional breeds from research stations, mainly to achieve higher yields, as one factor behind landrace extinction. Nimusiima and Agaba, 2024 also observed that, while indigenous breeds exhibit higher disease resistance, exotic breeds are preferred for their productivity. This shift increases the risk of indigenous landrace extinction and harms poor communities that once depended on traditional breeds, ultimately threatening food security. Research indicates that integrating IK is key to protecting indigenous landraces and supporting agricultural sustainability and development (Adefila et al., 2024; Hermans et al., 2021; Imoro et al., 2022). Still, the extent of IK integration in Uganda's agricultural research and development (AR&D) is unclear. The next sections assess the current state, approaches, extent, challenges to IK integration within Uganda's AROs.

Table 7. Shows NARO policies including their status and any direct mention of IK.

Policies	Available?	Status?	Mentions Agricultural indigenous knowledge?	Extent of mention	Citation and remarks
Knowledge management policy	*Yes*	*Final*	*No*	–	NARO (2021)
Knowledge management strategy	*Yes*	*Final*	*Yes*	*Once*	NARO (2019)
Indigenous knowledge policy	*No*	–	–	–	*None existent*
Intellectual Property Rights policy	*Yes*	*Final*	*No*	*None*	NARO (2017b)
Training policy	*Yes*	*Final*	*No*	*None*	NARO (2021b)
Guidelines on standard formats for IK capture and preservation	*No*	–	–	–	–

5.2. Integration of indigenous knowledge in AROs

It is important to note that, while integration initiatives exist in the studied AROs, emphasising the importance of participatory approaches can inspire AR&D researchers and AROs to see their role in collective efforts. The study observes that integration initiatives exist, particularly in landrace preservation, food security, and environmental conservation domains. Thus, the knowledge development phase, identified as essential in the Probst et al. (2000) model, is evident in ZARDIs' attempts to validate and integrate IK into AR&D programmes and practices. Nevertheless, overall progress remains limited due to challenges such as ad hoc efforts, lack of systematic approaches, and organisational prioritisation issues. This pattern indicates a lack of consistent application of the inner cycle described in Probst et al. (2000) model.

For example, in the domain of ***landrace preservation***, the study found that although ZARDIs have made some efforts to identify, acquire, and validate IK in indigenous landraces, their efforts to integrate and preserve IK and associated landraces were minimal and ad hoc. The limited ad hoc integration suggests that while the process of identifying, acquiring, and integrating IK occurs, it is not prioritised within the organisational routines. The lack of prioritisation of IK limits its integration and use in food security initiatives, thereby leaving valuable IK and associated landraces at risk of extinction. This finding reaffirms what Ncube et al. (2025) noted in Southern Africa that, the lack of prioritisation of IK has left it overlooked amid government efforts to address economic crises. Nonetheless, AR&D researchers in the present study recognised the importance of integrating IK to preserve indigenous landraces to avert further extinction. This perspective aligns with Chigwada and Ngulube, 2025's view, which emphasises the essential role of IK preservation in promoting sustainable development and environmental stewardship, thereby supporting the achievement of United Nations Sustainable Development Goal 15 that addresses sustainable use of ecosystems and the prevention of land degradation and desertification.

In the context of ***food security***, a key finding was ZARDIs' efforts to validate indigenous practices and food preservation methods. One such initiative concerned validating the traditional method of storing maize cobs above the fireplace to protect planting material from pests. Research notes that maize is a major cereal crop globally and a staple in sub-Saharan Africa (Tibaingana et al., 2022). Thus, storage techniques that extend maize viability without chemical inputs are vital for sustainable food security. While previous research in Uganda demonstrates that storing maize above the fireplace reduces moisture and pest infestation, thereby extending maize shelf life (Tibaingana et al., 2022), AR&D researchers in this study criticised this traditional method as lacking standardised guidelines for smoke exposure, asserting that exposing maize cobs to excessive smoke over extended periods reduces seed viability. These differing perspectives indicate that, while some researchers value traditional methods, scepticism remains regarding their reliability and standardisation. The Uganda Ministry of Agriculture, Animal Industry and Fisheries (MAAIF) acknowledges the effectiveness of traditional methods but classifies them as 'non-standard.' (MAAIF, 2016). This scepticism reflects a tendency among AR&D researchers and AROs to equate methodological validity with scientific verification, thereby diminishing the perceived legitimacy of IK and contributing to its marginalisation in research agendas. Despite ongoing debate, research indicates these traditional practices remain prevalent in many developing countries (Tibaingana et al., 2022), underscoring the need for evaluation of optimal environmental conditions and smoke levels for maize preservation.

Nevertheless, integrating such practices can reduce reliance on synthetic chemicals, which holds promise for seed preservation and food quality. National AROs are pivotal in advancing these efforts. Past studies show that progress in integrating IK and modern agriculture in East Africa, particularly in Kenya, Tanzania, and Uganda, has been most notable in Kenya, with much of the advancement across all three countries driven by non-governmental organisations, raising concerns about sustainability (ReliefWeb, 2025). Therefore, national AROs must assume a leading role and oversee IK integration efforts nationwide for maximum impact. In Uganda, the NARO's strategic ZARDI network offers a strong foundation for leading such initiatives. ZARDIs can deliberately undertake the identification, documentation, validation, and integration of IK across the board to facilitate its use in development.

Environmental conservation is another important aspect where IK integration is crucial. Climate change significantly impacts soil fertility, negatively affecting agricultural production and food security in Uganda (Kabasiita et al., 2022). The importance of indigenous materials in maintaining soil health without harming the environment was acknowledge by respondents. However, they indicated that, the drive for increased production and income fosters greater reliance on modern scientific knowledge and methodologies, such as the increased use of artificial chemicals. These findings affirm what other researchers such as Oltramare et al. (2023) have noted the continued use of these chemicals severely degrades soil health, negatively affecting agricultural productivity and food security in Uganda. The study further revealed that the use of traditional natural materials is cost effective which is important for disadvantaged smallholder farmers, the majority in Uganda. Despite these benefits, efforts to integrate IK remain limited, irregular, and ad hoc, putting traditional knowledge and practices at risk of loss. The study further noted that existing IK integration approaches are predominantly science-based and top-down.

5.3. Shortcomings in current IK integration approaches in Uganda

5.3.1. Reassessing the one-size-fits-all science-based approach

This study established that AROs employ a 'scientific validation approach' as a principle standard for evaluating the efficacy of IK during the integration process. However, many forms of IK constitute cultural knowledge that often operates through traditional customs and practices. For instance, findings highlighted the use of inorganic powders by ZARDIs as controls in validating the efficacy of indigenous pest control materials (dust, red pepper, tobacco, targets, phytolacca, tobacco on bean weevil) in which laboratory analyses rated dust as superior to various herbal IKs. This practice of utilising scientific parameters to assess indigenous materials underlines a discrepancy between modern scientific validation and the cultural foundations of IK. While previous studies affirm that resource-poor farmers predominantly rely on IK, the imperative for scientific validation emerges to facilitate IK integration into contemporary knowledge systems (Ijatuyi et al., 2025). Yet, it is crucial to recognise that IK encompasses not only scientifically verifiable components but also significant cultural dimensions that do not conform to scientific scrutiny. This tension between traditional and contemporary approaches to knowledge management necessitates a clear understanding that while scientific validation holds merit, its application is insufficient for culturally driven manifestations of IK.

Moreover, while scientific approaches offer numerous advantages, such as increased yields, they also pose long-term affordability and soil health challenges. For instance, the use of artificial fertilisers can enhance agricultural productivity. However, their continuous use is required, resulting in high costs and unsustainable impacts on low-income populations. Other researchers also found that long-term use of artificial inputs is detrimental to soil health and the environment (Jisna et al., 2021). These challenges highlight the value of IK. Achieving agricultural sustainability in Uganda therefore, requires integrating IK with modern science and methodologies to develop climate-resilient, cost-effective solutions. However, formally recognising farmers' IK as integral to development is urgently needed. This study revealed that including IK in AROs' annual plans and budgets can stimulate agricultural researchers' enthusiasm and willingness to engage with it. However, this one-size-fits-all approach reveals a narrow application of the development and application components of Probst et al. (2000) KM model, in which only selected forms of IK that meet scientific criteria are valued and integrated. Other scholars have argued that contemporary challenges cannot always be addressed through singular, mechanistic, science-centred solutions (Sachet et al., 2021). Therefore, a transition from a one-fits-all validation paradigm to a more holistic perspective is required, in which effective IK practices are supported rather than dismissed as outdated or unscientific. However, AROs' prevailing organisational culture, which fosters top-down approaches to knowledge sharing and learning, further limits these efforts.

5.3.2. The top-down approach

This study revealed the predominance of a top-down learning-and-knowledge-sharing approach, which institutionalises AR&D researchers as knowledge experts while treating farmers as passive recipients. The study showed that this approach stems from AROs' organisational culture, which prioritises modernisation and formal scientific knowledge and regards IK as inferior. In such situations, IK holders may feel undervalued or dismissed, which, in turn, may lead them to withhold their expertise, limiting opportunities for co-learning and collaborative innovation. Ultimately, the prevailing culture shapes perceptions of what is considered valid knowledge and determines the processes by which knowledge is shared, integrated, or isolated within the organisation and its broader stakeholder networks (Nemogá et al., 2022). Probst et al. (2000) KM model's emphasis on distributing and preserving knowledge aligns with the need to recognise and share IK with stakeholders and sustain it for future generations. However, the study reveals that current approaches to IK integration are largely top-down which often inhibits reciprocal knowledge exchange and the co-production of innovations, limiting the effective distribution, use, and preservation of IK. This approach contradicts participatory approaches that encourage reciprocal knowledge exchange. Studies by Adefila et al. (2024) and Wiedemann et al. (2022) demonstrate that participatory approaches facilitate knowledge exchange and co-creation of interventions that resonate with farmers' realities. Elsewhere, Chimi et al. (2023) also emphasise that participatory approaches enhance reciprocal knowledge exchange and the co-production of innovations.

Notably, both the theoretical framework and the study's discussion emphasise the need for a holistic, participatory approach to IK integration that combines scientific and cultural perspectives, values reciprocal exchange, and recognises farmers as knowledge holders. Reforming the epistemic culture within AROs to more inclusively recognise local knowledge systems is therefore essential to fostering open dialogue between AR&D researchers and farmers and to enhancing the overall integration of local knowledge into AR&D frameworks. Doing this mirrors the model's call for continuous reassessment and adaptation of knowledge management strategies. In the Ugandan context, however, three major impediments prevail.

5.4. Main Impediments to indigenous knowledge integration into AR&D in Uganda

The study revealed three major impediments to IK integration: (1) perceptual problems, (2) Inadequate funding capacity, and (3) inadequate policies.

5.4.1. Perceptual problem

Jiang and Lu Wang (2006) defined perception as the level of one's judgement, interpretation, and evaluation of services and products provided to a specific group of interest. The demographic data of this study show that age and experience influence how people interpret and judge the value of knowledge or certain practices. Most participants labeled IK as inferior knowledge, with some calling it 'full of gambling'. This view of IK demonstrates AR&D researchers' lack of confidence in the utility and relevance of local knowledge systems. These findings support previous studies showing that AROs' positivistic agricultural practices grounded in Western education often relegate local knowledge systems, leading some AR&D researchers to disregard IK (Masango & Mbarika, 2022; Muwanga, 2020). Negative perceptions of IK are particularly common among younger researchers, reflecting a generational gap and evolving lifestyles. Younger individuals tend to adapt more swiftly to new ways of life, and their continual exposure to Western education with its strong orientation towards modern science may have had a strong influence on how they perceive IK resulting in negative attitudes towards IK. Past research shows that this mindset is particularly pronounced among youth, who are often less inclined than older generations, traditionally custodians of IK, to appreciate local knowledge systems (Kwabena Donkor et al., 2020; Lwoga et al., 2020). Probst et al. (2000) model also highlights the role of perceptions in valuing different forms of knowledge. The study's findings echo this, showing that negative perceptions of IK, especially among younger researchers act as significant impediments to IK integration. This finding supports the framework's assertion that the absence of deliberate efforts to address perceptions and organisational culture may lead to valuable knowledge being overlooked or dismissed. Therefore, fostering a more positive attitude toward local knowledge systems is needed. Motivating researchers to adopt a positive attitude is crucial for fostering the integration of IK into AR&D. Although financial incentives are commonly regarded as effective motivators, they may not always be feasible due to budget constraints within AROs. Therefore, prioritising the integration of IK in research agendas and implementing awareness programmes is essential to enhance agricultural researchers' recognition of IK. In Uganda, the NARO's knowledge management strategy recognises the importance of integrating scientific and indigenous knowledge for agricultural modernisation (NARO, 2019). This acknowledgement necessitates concrete actions. The study indicates that incorporating IK into annual plans and budgets could increase researchers' willingness to engage with it. Formal inclusion may foster greater enthusiasm for IK integration, even when attitudes toward local knowledge are mixed.

5.4.2. Funding capacity

Capturing, validating, and integrating IK requires financial resources for coordination, supervision, skill development, and management support. This study reveals that funding significantly influences the knowledge AROs generate and the projects they prioritise. The findings indicate that donors finance a substantial proportion of projects at the ZARDIs. Respondents voiced concern about over-dependence on donor funding, noting that donors often align funding with their interests, which predominantly promote modern scientific knowledge. The findings show that foreign-funded projects often enjoy privileged status and greater autonomy to pursue research aligned with donor agendas, as donors make them the primary recipients of funding. This dependence leads researchers to fear that IK-focused proposals may not receive the necessary financial support. In response, researchers can seek collaborations with entities interested in indigenous food systems. Research acknowledges that these collaborations are crucial for integrating IK into climate adaptation policies (Chimi et al., 2025). However, AROs must avoid pursuing initiatives with uncertain sustainability, a factor that has led to the premature closure of some IK projects in ZARDIS. While external funding remains unpredictable, acknowledging IK in research agendas, budget considerations, and actionable plans can improve integration. Achieving this requires policymakers to create a supportive policy environment that prioritises IK.

5.4.3. Inadequate policies

The policy environment determines what knowledge can be prioritised and the knowledge management goals. The outer cycle of Probst et al. (2000) model, which involves setting knowledge goals and evaluating knowledge stocks, is particularly salient in explaining the inadequacy in prioritising IK integration. The findings indicate that, without explicit organisational goals and policies prioritising IK, integration efforts remain underfunded and fragmented. AROs operate within structured frameworks, guided by policies that govern their activities. Although Uganda has numerous policy documents related to IK (Tabuti & Van Damme, 2012), this study found that IK is insufficiently addressed in the NARO's overarching policy framework. The lack of a clear IK policy limits IK integration efforts, and dedicated budget lines within the NARO and ZARDIs further underscore this shortcoming. There was consensus among respondents on the need for a well-defined policy on IK to standardise integration processes and to prioritise IK in the research agenda. These findings underscore the critical role of policy clarity in facilitating IK integration. Furthermore, without a defined IK policy, integration will continue to be excluded in budget allocations and will limit interest and prioritisation of IK integration within AROs. Therefore, there is a need for a defined policy on IK to foster interest and comprehensive integration.

Notably, the model's stress on systematic acquisition and preservation of knowledge presupposes supportive policy and resource environments. The empirical findings highlight that inadequate policies and insufficient funding capacity are key barriers to comprehensive IK integration. Without institutional commitment reflected in policy and budgets, the model's processes cannot be effectively operationalized.

6. Conclusion and recommendations

Probst et al. (2000) KM model provides a comprehensive framework for diagnosing both the progress and barriers to IK integration in Uganda's AROs. The empirical findings reveal partial alignment with the models' processes but also highlight significant gaps. For instance, the study's findings and the subsequent discussion have shown that IK is not included in priority items in annual plans and budgets. Gaps are also evident in cultural valuation, and participatory knowledge exchange, knowledge perceptions and policy inadequacies reflecting inadequacies in application of the model's goal-setting and assessment components. The following actionable recommendations are proposed to address these gaps.

6.1. Addressing perceptual impediments

The research found that negative perceptions of IK contribute to its marginalisation within the NARO's research agenda, thereby hindering its acquisition, and integration. This negative view arises from various factors, including cultural biases. When AR&D researchers fail to recognise IK holders as valuable knowledge sources, their attitudes towards IK inevitably diminish. If IK is not acknowledged as vital to modern development efforts, its formal documentation and accessibility are consequently hindered. Some respondents suggested that organisational policies can mitigate negative attitudes, yet the study revealed a significant inadequacy in these policies. However, addressing negative perceptions and the resulting marginalisation of IK practices and technologies should be pursued through both strategic and institutional interventions.

Strategic-level interventions: The government should position ZARDIs as dedicated IK collection centres within the NARO framework. This role should be explicitly articulated in the Ministry's strategic plans and aligned with the NARO's operational directives, fostering increased researcher engagement in IK collection and integration.

Institutional level responsibilities: The NARO should address several critical dimensions:

- Awareness committees: Establish committees composed of representatives from ZARDIs, NARIs, extension services, and farmer groups to conduct promotional campaigns encouraging the application and conservation of indigenous plant species, seeds, and breeds, thus combating the ongoing genetic erosion.
- Budget allocation: MAAIF should incorporate IK into its strategic planning and budgetary allocations, and extend this approach to NARO's annual budgetary plans. Including IK in annual plans is essential for motivating researchers in IK integration efforts.

6.2. Establishment of relevant policies governing IK documentation and integration

Education reform policy: A fundamental education system reform focusing on African IK is necessary to address climate change, food insecurity, poverty, and underdevelopment through dual worldviews. The Ministry of Education should lead this strategic initiative to increase the recognition and application of IK. The reform should integrate practical Indigenous courses into educational curricula, particularly at higher education institutions where they remain underrepresented. Incorporating Indigenous subjects, including traditional agricultural technologies, livestock management, crop production, post-harvest handling and storage, medicinal knowledge, food processing, and climate change adaptation strategies, will build trust and interest in local knowledge among the educated populace.

National IK policy and guidelines: The Ministry of Agriculture, Animal Husbandry, and Fisheries (MAAIF) should implement a national IK policy and guidelines to support the comprehensive IK documentation and integration. While several Ugandan policy documents implicitly advocate for IK preservation, a comprehensive master policy covering IK management and integration is lacking. This alignment is essential for integrating local knowledge into research agendas and institutional budgets. Following national policy implementation, the NARO and its PARIs should adopt and operationalise these provisions. At the institutional level, the NARO must align its knowledge management policy and strategy to address IK explicitly.

6.3. Adopting holistic approaches for enhancing IK integration

Blended validation approach: The study noted that the current IK validation practices often neglect the cultural context, limiting IK integration and accelerating the loss of valuable knowledge. Since IK is rooted in cultural beliefs, values, and norms that scientific approaches may not adequately explain, a balanced approach that considers scientific and cultural relevance would enhance IK acceptance within contemporary AR&D frameworks.

Role of village experts: Evaluating IK efficacy through cultural parameters requires involving village experts, particularly elders with extensive traditional farming experience. These experts can explain how beliefs, values, and norms inform IK application, enhancing its practical relevance. This participatory approach enhances farmers' trust and their willingness to share their IK. However, careful selection of village experts is essential given the diverse cultural landscape in countries like Uganda, where IK application varies considerably.

6.4. Future research directions

While the study addressed IK integration and aspects of indigenous landrace extinction, further research should examine ZARDIs' current preservation efforts to reduce genetic loss in Uganda, identify materials requiring protection, and use these findings to enhance genetic preservation and prevent further losses.

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Author contributions

CRediT: **Christine Kiconco:** Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Writing – original draft, Writing – review & editing; **Constant Okello-Obura:** Methodology, Supervision, Validation, Writing – review & editing; **Maria Lindh:** Conceptualization, Methodology, Supervision, Writing – review & editing.

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Data availability statement

Datasets generated during and/or analysed during this article are part of a PhD study and are not publicly available because no permission was sought from participants and institutions to share the data collected from them. However, the data will be shared upon reasonable request.

Informed consent statement

Both written and verbal informed consent was obtained from all the participants. All procedures involving human participants were performed in accordance with the Makerere University's Research Ethics Committee (REC) ethical standards and Uganda's National Council for Science and Technology as detailed under Methods sub-section.

Use of AI

We used AI Grammarly for language editing.

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