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Final report

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1 Acknowledgments

The MKUKI-Kwale project was a complex and ambitious project designed to take a novel approach to research-for-development. Although the project was not seen through to completion, the research team would like to express our gratitude to the many organisations and individuals involved in developing the concept and providing guidance and support throughout the project period.

The project would not have existed without the work carried out beforehand through the Kwale Livelihoods Program, and significant support and contribution of the Kwale Livelihoods team throughout the project period. Base Titanium (Kwale Livelihoods Program funder) also provided invaluable support and endorsement for MKUKI-Kwale, for which the research team is grateful.

We are also grateful to the numerous farmers, cooperative representatives and value chain actors who shared their insights and helped the research team understand the project context and priority areas for intervention.

MKUKI-Kwale was fortunate to receive support from the Government of Kenya at the National and County levels – specifically, the Ministry of Cooperatives, Ministry of Mining, and County Government of Kwale. We would also like to thank the current and previous Australian High Commissioners to the Republic of Kenya, Her Excellency Ms Jenny Da Rin and His Excellency Mr Luke Williams respectively, for their interest in the project and visits to the project site.

Given the project's complexity, the research team was keen to draw on the knowledge and expertise of a diverse range of people. Although their contribution was ultimately not required due to early project termination, the research team would like to thank the following people who had committed to contributing towards the project as Project Reference or Expert Advisory Group members: Mr Jean-Claude Rubyogo of PABRA (Pan-Africa Bean Research Alliance); Mr Michael Ngutu and Mr Tito Arunga of FAO (Food and Agriculture Organization of the United Nations); Ms Danielle Martin and Ms Amber Rowntree of ICMM (International Council on Mining and Metals); Mr Roman Shera of County Government of Kwale; Ms Jane Kamau of NITA (National Industrial Training Authority); and Mr Alex Mwanthi of the Cooperative Bank of Kenya. We would also like to extend our gratitude to Dr Laurie Bonney, who played a key role in development of the concept and proposal.

The research team would like to acknowledge the invaluable support provided to PAVI, which has enabled the cooperative to embark on its transformation. Support has been provided by the County Government of Kwale, Ministry of Cooperatives, IFAD (International Fund for Agricultural Development) and the Kyeema Foundation.

Finally, our thanks to the ACIAR team for their support and willingness to consider the project for funding.

2 Executive summary

The 'Mradi wa Kuimarisha Kilimo-Biashara Kwale' (MKUKI-Kwale) project aimed to develop a sustainable and inclusive value chain change model in a mine-dependent smallholder farming community. The project name and acronym reflect the essence of the project's Research Objectives – the full name translates to 'Kwale Agribusiness Strengthening Project' in Swahili and its acronym, MKUKI, translates to 'spear', representing the sharp, focused, targeted transformation of Kwale. As a research-for-development project, MKUKI-Kwale was to generate evidence to increase sustainable growth in agribusiness for the benefit of smallholder farming communities following mine closure.

Project background

The MKUKI-Kwale project was delivered as a partnership between the Palladium Group, Kenya Agricultural and Livestock Research Organization (KALRO), Pwani University and Kwale Pamba and Viazi Farmers' Cooperative Society ("PAVI") (see Appendix 1 for further details). Furthermore, the project took advantage of the opportunity to build off an established livelihoods program – the Kwale Livelihoods Program (KLP).

MKUKI-Kwale was originally planned as a five-year project; however, it was terminated 12 months into the project period (equivalent to 8% of the original budget). As such, the MKUKI-Kwale Final Report has been written as follows:

- The Methodology section includes the methodology for both completed and planned activities, explaining how completed activities were to fit into the broader research plan.
- The Impacts section has been used to describe anticipated Impact Pathways rather than impacts achieved.

Key results

Despite the project's early termination, several key findings and results were achieved.

1. **Baseline research**

   Baseline research activities generated a diverse body of knowledge, valuable for understanding and prioritising the many opportunities for intervention. There were some successful farmers in the project region; however, challenges throughout the value chain made it difficult for others to achieve similar outcomes, with the greatest constraints at the production end being low use of inorganic fertilisers, inadequate extension service personnel, unreliable rainfall, cultural beliefs against the use of certified seed, poor/low adoption of mechanisation, poor soil health leading to declining yields and lack of soil testing. Kwale's highly dispersed population, poor roads and low education levels further exacerbated these challenges.

   Furthermore, PAVI's association with the mining company and their livelihoods program meant that the cooperative's business model had predominantly focused on loss-making activities such as farm extension and limited profit-making activities such as value addition.

2. **PAVI Farmer Schools**

   Baseline research revealed that farmers were receiving limited extension services and those who were, primarily received services from PAVI. However, PAVI's extension approach involved a one-to-one relationship between field agents and farmers, a high-cost approach with inconsistent improvements to farmer yields.

The Farmer Field School approach[1] was introduced by MKUKI-Kwale, adapted for the specific context and named PAVI Farmer Schools (PFS) to give ownership to the groups as they were mainly comprised of PAVI members. This approach provides farmers with the opportunity to select the methods of production through a discovery-based approach, bringing them together to carry out collective and collaborative action in solving their problems. Eight PFSs were established by MKUKI-Kwale, with an additional 16 established by PAVI given early signs of success and the level of interest by farmers.

3. Transformation of PAVI's business and operating models

With the introduction of PFSs and farmers becoming more self-sufficient, PAVI had the opportunity to move further down the value chain and focus on more profitable activities while also providing its members with improved market access.

As a result of MKUKI-Kwale's recommendations, the PAVI/KLP team developed a revised business model focusing on cotton, maize and the associated value-added products of stockfeed and maize flour. There were also several micro, small and medium enterprise (MSME) opportunities that had been identified as a result of these changes.

Recommendations

The following recommendations are made to continue the work undertaken by MKUKI-Kwale:

- Encourage the adoption of the PFS model more broadly and use PFSs to continue building the capacity of farmers, through the introduction of higher-value crops, adoption of good agronomic practices, enhancing accessibility and affordability of inputs like quality seed, fertilisers and pesticides, and leveraging successful farmers as role models and easier points of skills transfer. Training farmers on improved crop varietal selection and appropriate application of inputs will further contribute to increasing incomes and reducing costs.
- Continued skills development through experiential learning within the PFSs where farmers have a research interest in solving challenges identified within their farms – developing local solutions to local problems. With the participatory soil sampling and profiling successfully concluded, further research is required on the best value chains suited for the various agro-ecological conditions with suitable crop varieties and the right fertiliser application regimen for optimum crop production.
- Continued transformation of PAVI's business and operating models to become a profitable cooperative that is trusted and valued by its members, playing an influential role in Kwale representing the smallholder farming community. Continuation of advocacy activities with local and national government, and the Post-Mine Land Use (PMLU) initiative.

[1] FAO. (n.d).Themes | Global Farmer Field School Platform | Food and Agriculture Organization of the United Nations.

3 Background

Sub-Saharan Africa is one of the fastest growing regions in the world based on population growth, making food insecurity and undernourishment a top challenge. The region's extreme vulnerability to climate change and its impact on agriculture means building the resilience of smallholder farmers – approximately 70% of the region's population[2] and contributing up to 90% towards national food production in some countries[3] – is a priority.

Kwale county, situated along the coastal region of Kenya, has one of the highest poverty indices in the country with a population of 70.7% living below the poverty line, compared to the national estimate of 45.2%[4]. Furthermore, Kwale is a mine-affected community influenced by a history of aid and corporate social responsibility investments, with low literacy levels. 84.8% of Kwale households are involved in crop farming although mainly subsistence, yet the county has experienced far lower agricultural productivity compared to the rest of Kenya without material differences in factors such as rainfall.

Base Titanium's Kwale Operation, which commenced production in late 2013, is Kenya's largest mining operation and accounts for 65% of Kenya's mining industry by mineral output value[5]. Much like other mining communities around the world, Kwale Operation has influenced the socioeconomic landscape of the Kwale community through employment, community investment and the physical footprint of mining and associated activities, plus flow-on effects on livelihoods, economic activity, and social structures. Given the prevalence of subsistence farming in the county, Base Titanium has been investing in KLP since 2014, aiming to contribute towards development of a non-mine dependent economy post mine closure.

KLP's aim was to elevate smallholder farming communities from subsistence farming by establishing market-driven collaborative value chains. The focus had been on community acceptance of alternative farming approaches, proving the feasibility and effectiveness of agronomics and economics, and developing cross-sector partnerships, working across households, community groups, and institutions. PAVI, a member-owned cooperative, was established in 2016 under KLP. The cooperative has acted as a critical link connecting smallholder farmers with markets and other services, such as farm extension, access to quality inputs and input loans. PAVI is intended to help taper off the community's reliance on Base Titanium, leaving a legacy of sustainable economic activity.

Kwale Operation is scheduled to close at the end of 2024, with remediated land being returned to the community as part of this process. The Government of Kenya has appointed a 19-member committee to collect views from a wide range of stakeholders, including the community, to make recommendations on what the land should be used for. One recommendation is for at least 1,000 acres of remediated land and associated mine infrastructure to be returned to the community in Kwale for agriculture in 2025. The return of remediated land unlocks an opportunity for PAVI to access a large, contiguous block of land, enabling agriculture at scale and exponential benefits for the community through the introduction of intensive agriculture to complement smallholder farming.

Previous work under KLP had taken a test-and-learn approach. Furthermore, findings and learning outcomes had been generated but not consolidated into a body of knowledge to provide clear guidance on the implementation of future project activities. The absence of a knowledge dissemination plan to the community and similar environments across Kenya

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[2] Alliance for a Green Revolution in Africa (AGRA). (2017). Africa Agriculture Status Report 2017. Africa Agriculture Status Report.

[3] Suttie, D. R., Benfica, R. M. S., & Strategy and Knowledge Department (SKD), International Fund for Agricultural Development, IFAD. (n.d.). Fostering Inclusive Outcomes in African Agriculture: Improving Agricultural Productivity and Expanding Agribusiness Opportunities through Better Policies and Investments.

[4] County Government of Kwale. (2022). Kwale Spatial Land Use Plan (2022-2032).

[5] Base Resources Limited. (2020). Kwale Mining Operation.

and beyond had also been an impediment to reaching other audiences that could benefit from the Kwale experience.

The research opportunity for MKUKI-Kwale has been leveraging existing investments, knowledge and established relationships developed through KLP, while introducing scientific rigour, distillation of learnings and capacity building. MKUKI-Kwale also aimed to enhance KLP’s contribution towards Kwale’s economic and social transition post mine closure. Given PAVI’s significant role in delivering benefits to the community, building the capacity of the cooperative to meet the evolving needs of the community has been of critical importance, simultaneously developing broader learnings regarding what is required for a cooperative to be successful.

MKUKI-Kwale has built on the farm systems approach taken by KLP and integrated biophysical, social science and value chain research to design and implement research activities spanning the following:

- Development of a sustainable and inclusive value chain system change model, describing critical success factors and developing a change framework, targeted at a private sector audience to encourage the adoption of this approach.
- Development of an intensive farming model on remediated land, integrating improved agricultural productivity and sustainable farming practices with the adoption of climate smart crop varieties, effective water use management as well as healthy soils management, and communication and dissemination of applied scientific outcomes.
- Demonstrating the advantages of integrating Environmental, Social and Governance (ESG) principles into cooperative development, with benefits for cooperatives, private sector partners, government, funders and development agencies.
- A range of capacity building approaches specifically designed to target different types of learning groups, underpinned by social science research.

4 Objectives

MKUKI-Kwale’s aim was to develop a sustainable and inclusive agri-food value chain system change model that incorporates linkages to multi-national corporations, contributing towards their ESG strategies while benefiting smallholder farming communities.

The project’s Research Objectives were as follows:

1. Identify the critical success factors for developing a sustainable and inclusive agribusiness value chain system change and distil these factors into a change model that can be adapted to other locations and contexts.
2. Identify and enable smallholder farming communities to transition from mine dependency to an agriculturally productive community through improved skills, policies, resources and structures.
3. Demonstrate how companies and smallholder farming communities can mutually benefit from linking companies’ ESG metrics with the development of smallholder farming communities.
4. Identify opportunities for traditional and innovative capacity building techniques to work together to drive continuous capacity building and innovation within a smallholder farming community.

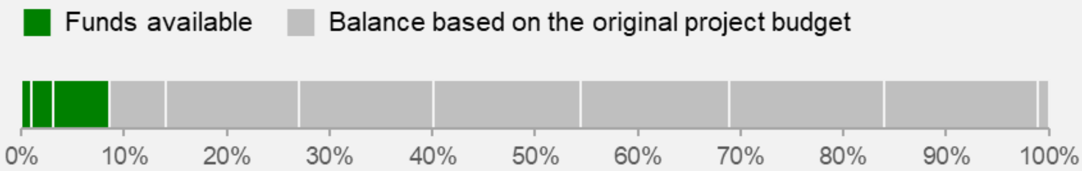
5 Methodology

5.1 Approach

The first year of the project's activities were focused on establishing a baseline understanding of the system in which the project was operating, through the lens of social science, biophysical and value chain research. Findings from the baseline research were used to validate hypotheses used when developing MKUKI-Kwale's initial Theory of Change (refer Appendix 2) and refine planned research activities for the subsequent four years – an approach that also worked within the constraints of the project budget's phasing, which was skewed towards the later years (see Figure 1).

Figure 1: Project budget by pay period

Note: The first and last pay periods were 3 months; all others were 6 months.



Social science research was prioritised in year 1 as findings would be used to understand barriers/challenges to behaviour change and develop a socio-ecological framework, helping to shape the design of research activities across all aspects of the project. Biophysical research was time-critical given the timing of long and short rains (starting in April/May and September respectively). Value chain research, which had the most flexibility, was to intensify in subsequent years.

The first year of MKUKI-Kwale also focused on developing the project's partnership and stakeholder network to enhance research activities in subsequent years and establish multiple channels for disseminating learnings throughout the project period (refer Section 7.4, 'Stakeholder engagement, collaboration and dissemination of learnings').

Although the project had four discrete Research Objectives, project activities under any one Research Objective were designed to complement and reinforce outcomes across the others. For example, the introduction of PAVI Farmer Schools encouraged farmers to work collectively in diverse groups (e.g., age, gender, ethnic group) – a critical shift in mindset that would be necessary for working together under an intensive farming model if a collective approach was to be taken. Furthermore, a transdisciplinary approach was taken to strengthen project outcomes and in recognition of the complex context in which the project was operating.

5.2 Baseline research

5.2.1 Desk research

There was a significant number of documents available for review given that MKUKI-Kwale was building on seven years of work under KLP[6]. Documents were sourced from various stakeholders that had been involved in KLP and spanned project planning documentation, progress updates, agronomic reports, livelihoods survey data, process

[6] Implementation phase.

maps, and presentations. Stakeholders included the Palladium Group (KLP implementing organisation), PAVI, Base Titanium, Kwale County Government, research institutions such as KALRO, and institutions of higher learning such as Pwani University.

Desk research had a slightly different focus across research disciplines:

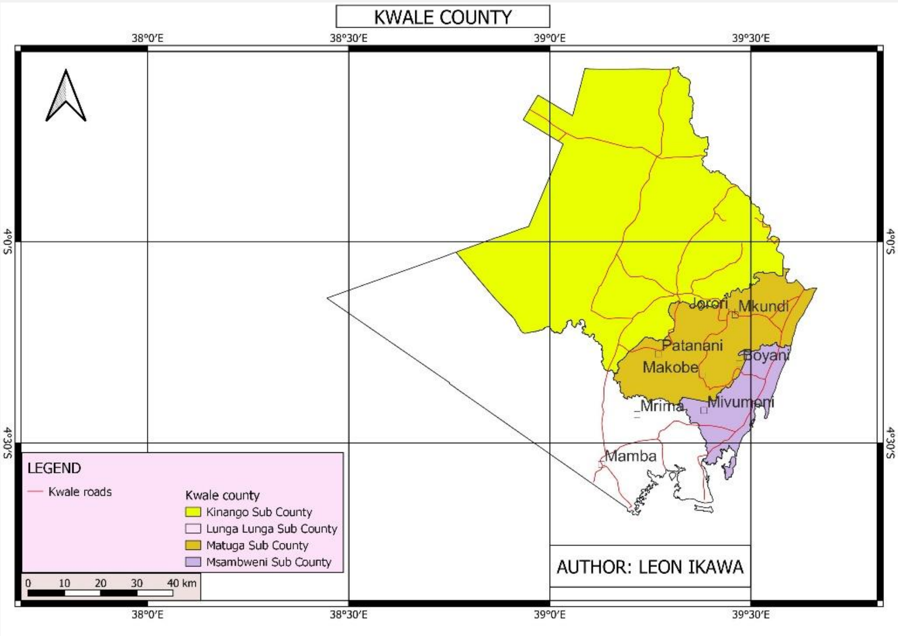
- Social science: Extracting the socio-ecological learning experiences in programming and implementation of the project(s) previously undertaken by implementing agencies. In doing so, the social research team was able to improve the primary study protocol and enhanced the study design to cover knowledge gaps in the project cycle.
- Biophysical: Review records of previous successes and identify gaps in local agricultural practices, identifying bottlenecks to optimal agricultural productivity and learnings which were integrated into the biophysical research project design.
- Value chain: Understanding the value chains that had been explored historically, what had worked well, not worked and why. Learnings would be used to help prioritise and design value chain interventions and other associated project activities.

5.2.2 Fieldwork

The biophysical and social science teams worked with farmers to understand possible underlying biophysical, religious, social, and cultural practices and bottlenecks limiting agricultural production within the county. This was carried out through groundworking, village immersion and focus group discussions. The activities were carried out in 56 villages across four sub-counties.

The criterion for selection of the sub-counties was based on PAVI's active areas of operation. The cooperative has members in Msambweni, Lunga-Lunga, Matuga, Shimba-Hills[7] and Kinango sub-counties; however, Kinango sub-county was excluded due to its distance from PAVI.

Figure 2: Project area – Eight PAVI Farmer School sites



Source: Leon Ikawa (2024)

[7] Shimba Hills is a new sub-county and therefore not reflected in Figure 2.

Initial meetings were held with all relevant local administration officers and agricultural extension officers, followed by transect walks and focus group discussions at farm level.

1. **Meeting with local administration, agricultural officers and gatekeepers**

   Meetings were carried out through courtesy calls and included County Executive Committee members for agriculture, the County Director of Agriculture, Deputy County Commissioners in the respective sub-counties, Sub-County Agricultural Officers, Ward Administrators, Chiefs, Assistant Chiefs, village administrators and village elders.

2. **Site-specific transect walks**

   Transect walks consisted of site-specific systematic walks along defined paths (transect) across the target site/village/community with the local people to explore available resources and conditions by observing, asking, and listening. Data was collected for each site.

3. **Focus group discussions**

   Focus group discussions were conducted in each target village. The discussions were carried out in farmers' fields and comprised a minimum of four farmers. Participants were randomly selected ensuring good representation of both men, women, and youth where possible. The main aim of the focus group discussions was to provide more information concerning the resources and challenges identified during the transect walks. Refer Appendix 3 for details regarding village representation for focus group discussions.

5.2.3 Key informant interviews

147 key informant interviews were conducted to complement desk research and fieldwork, primarily for the social science and value chain streams, and to understand critical cooperative success factors. Respondents included farmers (both PAVI members and non-members across the four sub-counties), representatives from other comparable cooperatives, PAVI Board members (current and previous) and employees, County Directors, value chain actors and KLP team members.

5.2.4 Surveys

Quantitative surveys were carried out with 112 farmer representatives – 28 from each of the four sub-counties including PAVI members and non-members. Questions explored demographics, access to land, extension services and information, agricultural activities, behavioural drivers, and level of involvement in PAVI.

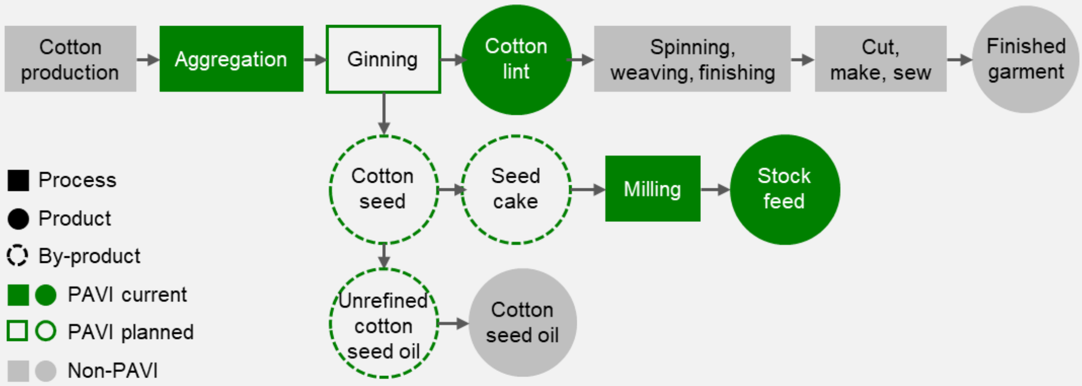
5.3 Planned activities

Due to the project's early termination, a significant proportion of research activities could not be completed with the limited time and budget available; however, the planned methodology is described below for completeness. Associated Impact Pathways are described in Section 8, 'Impacts'.

Objective 1: Identify the critical success factors for developing a sustainable and inclusive agribusiness value chain system change and distil these factors into a change model that can be adapted to other locations and contexts.

A sustainable value chain analysis was planned for year 2 focused on the cotton value chain. The cotton value chain had been selected as it had been included in the scope of KLP since inception and is a focus for PAVI's future value addition activities; the cotton-to-garment industry is also a strategic priority for the Government of Kenya and therefore research learnings would have direct applicability in Kenya. Research Objective 1's focus on cotton would also support PAVI leveraging the Government of Kenya's investment in construction of a cotton gin at PAVI's business park, which commenced in 2024 (the first in southern Kenya), and the multiple value addition opportunities available from vertical integration (i.e., cotton lint, seed oil and seed cake – see Figure 3).

Figure 3: Vertical integration of the cotton value chain



A traditional value chain analysis considers the following:

1. Understanding the product attributes that consumers value in a product.
2. Identifying where in the chain value is created, to help prioritise investment and eliminate waste.
3. How information is generated, shared, and used throughout the value chain, and its accuracy.
4. The strength of relationships throughout the value chain, strategic alignment, and distribution of value.

MKUKI-Kwale was to go a step further and consider the main environmental impacts of the chain and whether these activities could be reduced to create value while also enhancing the long-term sustainability and resilience of PAVI. Taking a sustainable value chain approach would also complement Research Objective 3, helping to develop a case study to demonstrate the value of cooperatives incorporating ESG principles into their business model.

The planned approach was particularly pertinent to cotton given its reputation for poor environmental credentials, and the Kenyan context given the country's low agricultural productivity and a significant focus on mitigating climate change and environmental impacts.

Figure 4: Kenya's climate change vulnerability and readiness (index)

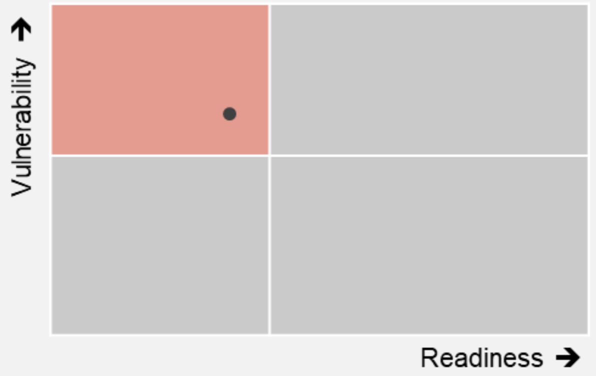
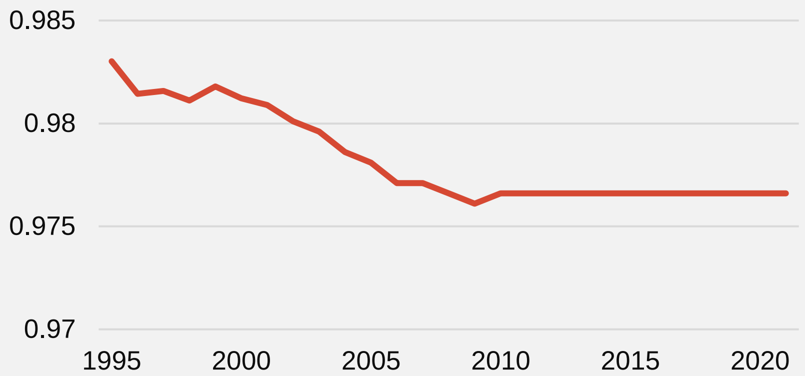


Figure 5: Kenya's agricultural productivity (index)



Source: Analysis from the ND-Gain Index[8]

Objective 2: Identify and enable smallholder farming communities to transition from mine dependency to an agriculturally productive community through improved skills, policies, resources and structures.

Crop trials were planned both on farmers' fields and the remediated land, which would be scaled up progressively to test agronomics, climate adaptive farming practices, soil and water management, and to develop the intensive farming system. This included identifying the complementary infrastructure and services required to effectively manage the land on behalf of the community, and the most suitable governance and collaborative community approach, drawing from findings across social science, value chain and biophysical research. The planned approach would support the improved skills, policies, resources and structures necessary for an agriculturally productive community.

The design of MKUKI-Kwale research activities included collaboration with stakeholders involved in other areas identified by Base Titanium for the remediated land, specifically training (National Industrial Training Authority) and conservation (WWF and Kenya Forestry Services), helping to create sustainable project outcomes.

The remediated land also presented a unique opportunity to extend on KALRO's probiotic research, which had previously been used to increase livestock production and reduce methane gas emissions. MKUKI-Kwale planned to adapt KALRO's research to

[8] University of Notre Dame. (2023). Country Index // Notre Dame Global Adaptation Initiative // University of Notre Dame. Notre Dame Global Adaptation Initiative.

demonstrate that a similar process could be used to improve soil health, optimising agricultural productivity. This research would have broader application across any land that needed remediation, not just post mining.

Objective 3: Demonstrate how companies and smallholder farming communities can mutually benefit from linking companies' ESG metrics with the development of smallholder farming communities.

The original approach to Research Objective 3 was to work with Cotton On Group (COG) and introduce metrics that would move away from KLP's historical focus on direct sourcing of cotton to a broader focus on investing in smallholder farming cotton communities, demonstrating mutual benefit for both a multinational corporation and the community. However, due to significant changes at COG it was no longer possible to take this approach. An alternative approach was being developed that would still address Research Objective 3, focused on how cooperatives could position themselves as sustainable commercial entities in line with the following ESG pillars:

1. Sustainable smallholder farming integration into local and modern global value chains resulting in improved livelihoods.
2. Environmental sustainability through circular and climate adaptive agricultural practices and compliant with relevant international practices.
3. Community inclusiveness resulting in improved social cohesion and community development through capacity building.

The planned methodology was as follows:

1. Identifying ESG approaches relevant to agricultural marketing cooperatives and smallholder farmers. This included exploring opportunities and risks for smallholder farmers working with large corporations.
2. Assessing the alignment of PAVI's business and operational model with relevant ESG approaches and proposing an ESG strategy for PAVI, drawing on outputs from the sustainable value chain analysis carried out as part of Research Objective 1.

Outputs for Research Objective 3 would be:

- A clear business case for engagement of various government and private sector actors in sustainability-oriented cooperatives, for example, funders prioritising social and environmental impact.
- ESG strategy and performance metrics for PAVI and a framework for sustainability-oriented cooperatives to develop their own strategy and metrics.

Objective 4: Identify opportunities for traditional and innovative capacity building techniques to work together to drive continuous capacity building and innovation within a smallholder farming community.

The scope of Research Objective 4 was capacity building opportunities across smallholder farmers and PAVI, with a focus on designing approaches for continuous capacity building.

Smallholder farmers

Key constraints to extension services in Kwale are the large numbers of farmers, vast distances and poor roads. Capacity building approaches for smallholder farmers aimed to work around these constraints.

PAVI Farmer Schools

As described further under Section 7.2, 'PAVI Farmer Schools', PAVI's historical approach to extension relied on one-to-one relationships between field agents and farmers. The time and cost of visiting each farmer individually impacted the frequency of field agent visits and fostered farmers' dependency on them.

The PFS group learning approach was introduced by MKUKI-Kwale and was to be developed further throughout the project to build the capacity of smallholder farmers.

mLearning

To complement the PFS model, an innovative approach to farmer training was to be developed. Short interactive stories capturing farmer training in sync with the season would be delivered audibly over analogue mobile phone, reinforcing learnings delivered through face-to-face means. Traditional storytelling techniques would be combined with technology in an inclusive way.

This approach would enable farmers who are illiterate to benefit from remote training, which typically requires the user to be literate. It would also involve a low marginal cost of training for each additional farmer, allowing benefits to easily scale beyond the PAVI membership base.

Vocational training

There will be an increasing need for vocational skills as farmers are progressively introduced to modern farming techniques. MKUKI-Kwale was to explore partnering with vocational institute and state corporation, the National Industrial Training Authority (NITA), to develop appropriate curricula. NITA has a training centre in nearby Mombasa and is also expected to develop part of the remediated land for training, alongside agriculture.

Vocational training was to be built into learning pathways facilitated by PAVI, starting with the existing PFS training and for those farmers who are interested and capable, progress to formal vocational learning. This would also demonstrate the role cooperatives can play collaborating with training institutions.

PAVI Cooperative

A three-part approach was used to assess PAVI's current organisational effectiveness:

1. Informal feedback from community members.
2. Assessment against critical cooperative success factors, identified through a literature review.
3. Formal organisational effectiveness assessment tool (SVA Fundamentals for Impact[9]).

The assessment identified priority areas for capacity building given PAVI's critical role working with smallholder farmers and potentially as operator of the remediated land set aside for agriculture. MKUKI-Kwale was to identify PAVI capacity building areas that were dependencies for project activities under the other Research Objectives, then co-develop and implement an appropriate capacity building strategy.

[9] SVA Fundamentals for Impact - Social Ventures Australia. (2019, January 16). Social Ventures Australia.

6 Achievements against activities and outputs/milestones

References to ‘Planned completion’ dates reflect the dates listed in the project proposal.

Objective 1: Identify the critical success factors for developing a sustainable and inclusive agribusiness value chain system change and distil these factors into a change model that can be adapted to other locations and contexts.

no.	activity	outputs/ milestones	completion date	comments
1.1	Baseline studies and development of the monitoring, evaluation and learning framework, covering all three project disciplines and disaggregated by gender and age group as appropriate.	Baseline reports and datasets; monitoring, evaluation and learning framework, which will be used for the evidence-based mid- and end-of-project evaluations.	Baseline studies Mar 2024 MEL framework in progress	Baseline studies were completed as planned, covering 56 villages and spanning social science, biophysical and value chain research. A draft MEL framework was in development for consideration by the Project Reference Group review (scheduled May 2024).
1.2	Review and evaluate learnings from current and past ACIAR projects.	Guidelines for current project and inter-project linkages.	In progress	Given the potential breadth of projects for review, the plan was to revisit this activity post the Project Reference Group review once feedback had been incorporated into the project plan.
1.3	Review and evaluate learnings from Kwale Agribusiness Program work to date.	Learnings for integration into the design of MKUKI-Kwale.	Mar 2024	Learnings captured in the baseline reports.
1.4	Analysis of the system to identify key partners and influencers, vulnerable groups, cultural and religious dynamics and constraints.	Partnership agreements with key partners identified, including the private sector, government, research institutions and NGOs; identification of vulnerable groups, including consideration of factors such as gender, age, culture and religion, and a strategy for ensuring vulnerable groups are represented.	Feb 2024	Learnings captured in the baseline reports. Youth were identified as a potential group to work with regarding services that were necessary for a well-functioning value chain but would be best for PAVI to outsource rather than bring in-house. Refer Section 7.4, ‘Stakeholder engagement, collaboration and dissemination of learnings’ regarding partners. Women were observed to be more directly involved in farming and were also more willing to work in groups.

no.	activity	outputs/ milestones	completion date	comments
1.5	Based on Activities 1.1 to 1.4, design the research program for the rest of the project period to establish the desired inclusive agribusiness value chain system.	Research program for the rest of the project period across all three project disciplines.	In progress	The draft research program was on track for presentation to the Project Reference Group for feedback, which would then be revised and finalised once feedback was incorporated.
1.6	Implement the research program, adjusting as required to reflect the evolving needs of the agribusiness value chain system.	Science-based approach to the development of the agribusiness value chain system; documented change model outlining the framework for developing a sustainable and inclusive agribusiness value chain system in comparable contexts to KLP.	Planned completion Mar 2028	N/A

Objective 2: Identify and enable smallholder farming communities to transition from mine dependency to an agriculturally productive community through improved skills, policies, resources and structures.

no.	activity	outputs/ milestones	completion date	comments
2.1	Conduct crop trials on the 1,000 acres of remediated land, scaling up from 5, 20, 50 to 1,000 acres over the project period.	Evaluation of the most appropriate crop mix for the remediated land under an intensive farming system.	Planned completion Mar 2028	Memorandum of Understanding in progress between Base Titanium and PAVI (on behalf of MKUKI-Kwale) with respect to crop trials on the remediated land. Crop trials were expected to commence by June 2024.
2.2	Research and analysis of options for the intensive farming model, drawing from the outputs of activities associated with Research Objective 1.	Assessment of different intensive farming models.	Planned completion Dec 2024	N/A

no.	activity	outputs/ milestones	completion date	comments
2.3	Co-design the intensive farming model with the community through PAVI.	Co-designed intensive farming model for the 1,000-acre block of remediated land; identification of and engagement with community members and other stakeholders who will take an active role in the intensive farming model.	Planned completion Sep 2025	N/A
2.4	Implementation of the intensive farming model proof-of-concept.	Evidence-based learnings from the proof-of-concept, which will be incorporated into a continuous feedback loop for further development of the intensive farming model; identification of entrepreneurial opportunities introduced by the intensive farming model, particularly those that will empower women, youth and other vulnerable groups.	Planned completion Dec 2026	N/A
2.5	Research to support the next stage of implementation after the proof-of-concept has been established.	Evidence-based learnings to inform the next stage of implementation.	Planned completion Mar 2028	N/A

Objective 3: Demonstrate how companies and smallholder farming communities can mutually benefit from linking companies' ESG metrics with the development of smallholder farming communities.

no.	activity	outputs/ milestones	completion date	comments
3.1	Assess the alignment of KLP with COG's ESG metrics.	Documented linkage between BTL and COG ESG metrics and KLP activities, outputs and outcomes.	Refer comments	The original plan was to use Cotton On Group as a case study to achieve Objective 3. However, due to significant organisational changes at COG, this was no longer a viable approach. An alternative approach was in development, focused on integrating ESG principles into PAVI's revised business model supported by a sustainable value chain analysis as part of Objective 1.

no.	activity	outputs/ milestones	completion date	comments
3.2	Monitoring and evaluation of ESG metrics throughout the project period.	Baseline dataset of relevant ESG metrics; ESG metric datasets collected throughout the project period.	Planned completion Sep 2027	N/A
3.3	Document COG case study to highlight how Kwale community and COG have mutually benefited from linking ESG metrics to the development of Kwale.	Case study linking ESG metrics to smallholder farming community development.	Planned completion Sep 2027	N/A

Objective 4: Identify opportunities for traditional and innovative capacity building techniques to work together to drive continuous capacity building and innovation within a smallholder farming community.

no.	activity	outputs/ milestones	completion date	comments
4.1	Stakeholder mapping to identify opportunities for capacity building, building on Activity 1.4.	Identification of key stakeholders to target and engage for capacity building through this project.	Dec 2023	Done – refer 'Objective 4: Identify opportunities for traditional and innovative capacity building techniques to work together to drive continuous capacity building and innovation within a smallholder farming community'.
4.2	Establish capacity building strategy and activities covering the target stakeholders.	Co-designed capacity building strategy and activities.	In progress – planned completion Jun 2024	As above.
4.3	Identify opportunities for the engagement of community youth.	Identification of opportunities to engage community youth in the project; sub-research program designed specifically to engage community youth; identification and engagement of university students/ community youth to carry out research activities as part of MKUKI-Kwale.	In progress – planned completion Jun 2024	Students from Pwani Uni were to be involved in the crop trials on remediated land. MSME opportunities had been identified for services that would be best for PAVI to outsource (e.g., aggregation of produce), aligning with the type of work that was more appealing to youth based on feedback received through the project's baseline research.
4.4	Development of learning pathways for farmers within PAVI and working with an external institution such as the National Industrial Training Authority (NITA).	Defined learning pathways for farmer training within PAVI; formal accreditation for smallholder farmers who are interested and capable, benefiting PAVI members and non-members alike.	Planned completion Sep 2026	N/A

no.	activity	outputs/ milestones	completion date	comments
4.5	Development of an inclusive, audio-based farmer training solution to enhance the learning approach.	Inclusive, audio-based farmer training solution with a financially sustainable business model.	Planned completion Sep 2027	N/A
4.6	Needs assessment of PAVI Cooperative to assess baseline capacity and co-design a capacity building strategy and activities.	Internal audit report of PAVI Cooperative's baseline capacity.	Needs assessment Oct 2023 Capacity building – Planned completion Sep 2027	An initial needs assessment was completed by way of assessing PAVI's organisational effectiveness. Results indicated that PAVI's strength was external engagement but there was significant improvement required with respect to internal operations, particularly with the cooperative taking on increasingly more complex activities in the near future. Table 3 for a summary of assessment results.

7 Key results and discussion

7.1 Baseline research

Baseline research was carried out across all three research disciplines and supplemented by an assessment of PAVI's baseline organisational effectiveness. This research was used to develop a system map that would help identify priority Impact Pathways and refine research activities for the rest of the project.

Social science

Qualitative and quantitative research revealed 16 key barriers to crop production and farmer participation in agricultural activities spanning finance and risk; cultural and social; food insecurity; knowledge and skills; and other. These are listed in Table 1; further details can be found in Appendix 4. Barriers were consistent with findings from the biophysical and value chain research.

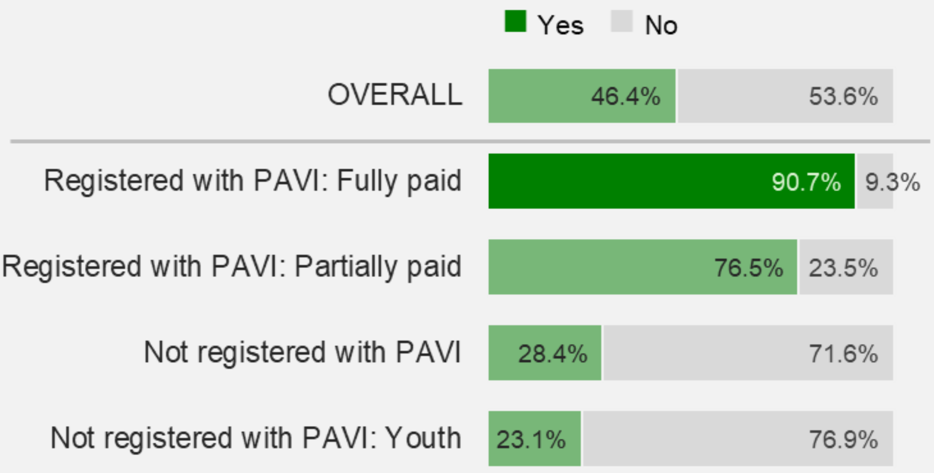
Table 1: Barriers to crop production and farmer participation

Finance and risk	1. Agriculture is not perceived as a business. 2. Cashflow challenges, high cost of living and underperforming economy. 3. Negative experiences with farming. 4. Mistrust in the cooperative concept. 5. Middlemen.
Cultural and social	6. Multi-generational land tenure system. 7. Low participation of youth in agriculture and agricultural value chain activities. 8. Aging farming communities. 9. Gender and farming. 10. Individual and group mechanics in farming.
Food insecurity	11. Overreliance on food relief and aid. 12. Preference for fast-maturity, less intensive food crops.
Knowledge and skills	13. Overreliance on traditional farming practices. 14. Discouragement due to declining yields.
All other	15. Too much labour with some crops. 16. Uncoordinated and unreliable extension service support.

The social science baseline study confirmed that most households in Kwale are food insecure and this was attributed to low household food production. Most farmers were at production nodes where farming cannot meet the threshold of being an occupation or a business. Few farmers produce a surplus, which would provide the possibility of agribusiness. Even across PAVI's members there was low productivity despite the cooperative's input subsidy program.

Most farmers, even though not producing enough to meet their food needs in a year, were still selling to generate income to meet other needs and consequently exacerbating the food insecurity problem at household level.

Figure 6: Sale of farm produce is highest among farmers registered with PAVI
Survey question: "Do you sell any of your harvests?"
% of responses

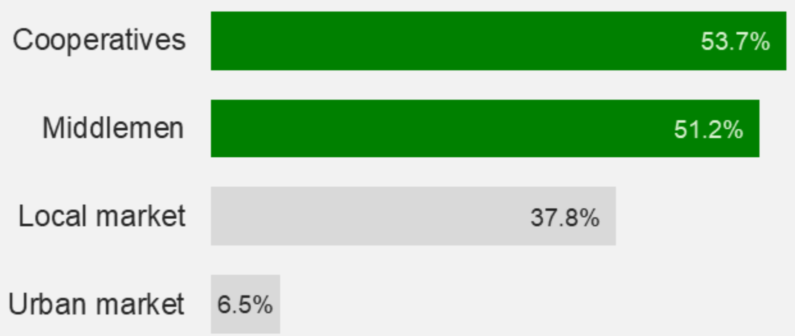


Source: Analysis from quantitative survey (Feb 2024)

Farmer education levels were low. Most had received primary education while very few had secondary and tertiary education. This has an influence on the adoption of technologies and innovations to improve agriculture, also hindering their knowledge of agricultural science and their ability to seek inputs and other services that would increase farm output.

Entrepreneurial skills and secure market access were very low among cooperative members, impeding the transition from subsistence to agribusiness. Also, high levels of poverty pushed farmers to be price-takers and not price-givers at the market, with many of them reliant on intermediaries and selling their produce to exploitative middlemen.

Figure 7: Market access is primarily through an intermediary
Survey question: "How would you describe your main market for agricultural goods?"
% of responses



Source: Analysis from quantitative survey (Feb 2024)

PAVI was observed to lack the capacity to effectively drive the agribusiness agenda. Most of the capacity gaps were in skill and capital. However, PAVI was reported to enjoy goodwill with project-implementing stakeholders and needed to leverage on the expertise from these agencies. Furthermore, there is urgency for concerted efforts in reversing these issues so that PAVI can competently drive the transition from subsistence to agribusiness through a research-for-development project such as MKUKI-Kwale.

In summary, the survey results indicated inadequate capacity of the population to fully harness the potential of their farms and the agribusiness opportunity. This was exacerbated by poor access and utilisation of farm inputs, lack of agribusiness model case(s) and a vibrant producer organisation with power to negotiate market access and therefore transition from subsistence to agribusiness. In view of the aforementioned findings, the study recommended for continual delivery of hands-on skill and technology training targeting farmers coupled with the introduction of higher value crops, adoption of good agronomic practices, enhancing accessibility and affordability of inputs like quality seed, fertilisers and pesticides; and leveraging successful farmers as role models and easier points of skills transfer. PAVI required microeconomic restructuring to become a competitive business entity that was at least breaking even.

The findings of this research were not only useful to the study context but can be generalised to a wider audience. The findings helped guide implementation of KLP and could also contribute towards a body of knowledge locally and internationally regarding agricultural value chain development interventions for post-mining agricultural communities.

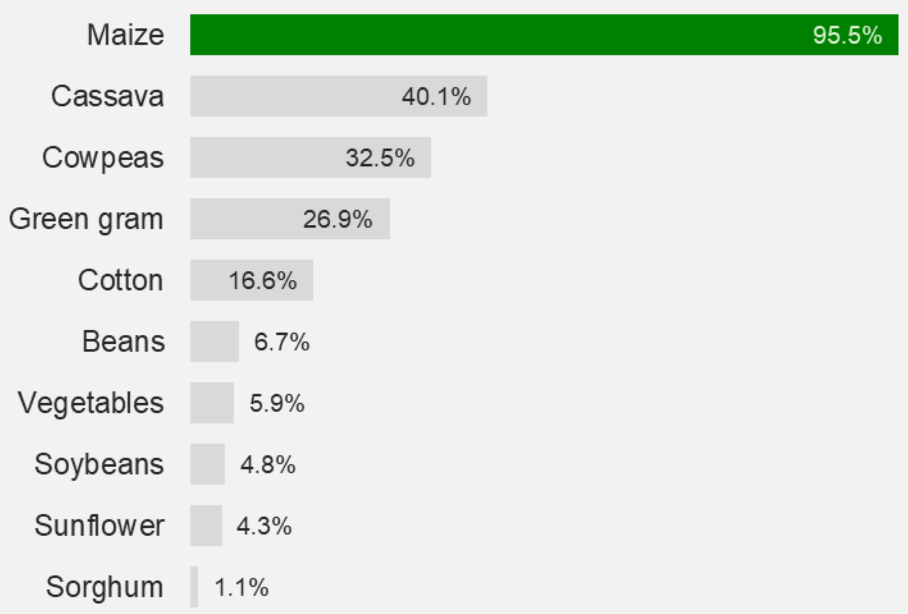
Biophysical

Findings from village immersion and focus group discussions across the four sub-counties revealed that maize was the predominant crop grown by most farmers.

Figure 8: Maize was farmed by almost all survey respondents

Survey question: "Which crops did you farm last year?"

% of responses



Source: Analysis from quantitative survey (Feb 2024)

Other crops such as cashew nuts and coconut have traditionally grown within the county although most trees were reported to be old with diminishing production. Commercial crops grown were sugarcane, cotton and Bixa, as well as plantation forests with Eucalyptus trees.

The crops were predominantly grown by small-scale farmers under either monocrop or intercropping systems on average farm sizes of one acre or less. Although all farmers grow most of these crops, Bixa, cotton and chillies were only grown by select farmers affiliated with organisations such as PAVI.

Livestock were mainly for household consumption and oxen used for ploughing. Some of the more preferred livestock included ducks, local and improved chicken, indigenous Zebu cattle and local goats. Beekeeping was also noted with apiaries observed in farmers' fields.

Challenges contributing to low agricultural productivity included low use of inorganic fertilisers, inadequate extension service personnel, unreliable rainfall, cultural beliefs against use of certified seed, poor/low adoption of mechanisation, poor soil health leading to declining yields and lack of soil testing. Lack of access to quality inputs, pests and diseases were also reported as challenges leading to poor yield. Furthermore, lack of extension services coupled with poor literacy levels and lack of skills was identified as a major bottleneck to production.

Figure 9: Factors contributing to low agricultural productivity

Survey question: "What would you say are the main problems with your farming that most negatively affects your yields?"

% of responses

Category	Factors	Registered with PAVI		Not registered with PAVI	
		Fully paid	Partially paid	Non-youth	Youth
Rain/ moisture	Too much rain	44.8%	58.3%	37.3%	46.2%
	Unreliable rainfall	32.6%	56.3%	27.9%	23.1%
Money	Lack of money	44.8%	16.7%	44.8%	51.9%
Crop protection	Too many pests and crop disease	32.6%	37.5%	41.2%	46.2%
	High cost of pesticides	7.0%	6.3%	19.1%	13.5%
	Lack of pesticides	11.6%	12.5%	5.9%	21.2%
Weed control	Weed control	27.9%	31.3%	11.8%	13.5%
	High cost of herbicides	7.0%	0.0%	4.4%	7.7%
Labour	High cost of labour	20.9%	31.3%	7.4%	9.6%
	Unavailability of labour	20.9%	0.0%	4.9%	7.7%
	Poor quality of labour	3.4%	8.3%	1.5%	5.8%
Fertiliser	High cost of fertilisers	18.6%	12.5%	32.4%	28.8%
	Unavailability of fertilisers	16.3%	18.8%	22.1%	19.2%
	Late inputs	16.3%	12.5%	5.9%	5.8%
	Inadequate fertiliser knowledge	0.0%	8.3%	1.5%	1.9%

Category	Factors	Registered with PAVI		Not registered with PAVI	
		Fully paid	Partially paid	Non-youth	Youth
Soil	Poor soil fertility	14.0%	12.5%	19.1%	25.0%
	Soil erosion	3.4%	0.0%	3.0%	1.9%
Skill	Lack of farming skills	11.6%	6.3%	2.9%	9.6%
	Poor extension services	3.4%	0.0%	6.0%	7.7%
Seed	High cost of seed	2.3%	12.5%	19.1%	15.4%
	Poor quality seed	0.0%	0.0%	1.5%	5.8%
Mechanisation	High cost of tractors	2.3%	6.3%	14.7%	13.5%
	Unavailability of tractors	0.0%	6.3%	5.9%	1.9%

Source: Analysis from quantitative survey (Feb 2024)

Modern mechanisation was low, leading to limitations in how much land could be cultivated per season. The highest use of basal fertiliser was observed with PAVI members because of the input loan program. There was generally low usage of top-dressing fertiliser.

Figure 10: Use of farm inputs

Survey question: “Please tell me which of the following inputs you used in your crop farming in the last season?”

% of responses

Category	Inputs used	Registered with PAVI		Not registered with PAVI	
		Fully paid	Partially paid	Non-youth	Youth
Land preparation	Ploughing by hand	0.0%	0.0%	37.0%	48.0%
	Ploughing with a tractor	20.9%	25.0%	11.8%	3.8%
	Ploughing using an animal	81.4%	81.3%	51.5%	48.1%
	Harrowing	23.3%	18.8%	14.7%	13.5%
Soil fertility	Basal fertiliser (DAP or NPK)	83.7%	75.0%	20.6%	17.3%
	Top dressing fertiliser (CAN)	58.1%	12.5%	16.2%	9.6%
	Foliar fertiliser	32.6%	31.3%	13.2%	3.8%
	Animal manure	44.2%	50.0%	33.8%	36.5%
Crop protection	Pesticide	76.70%	56.30%	52.90%	51.90%
Weed control	Herbicide	23.30%	18.30%	2.90%	5.80%

Category	Inputs used	Registered with PAVI		Not registered with PAVI	
		Fully paid	Partially paid	Non-youth	Youth
Seed	Certified seed	79.10%	81.30%	47.10%	30.80%
	Local/recycled seed	7.00%	6.30%	36.80%	63.50%

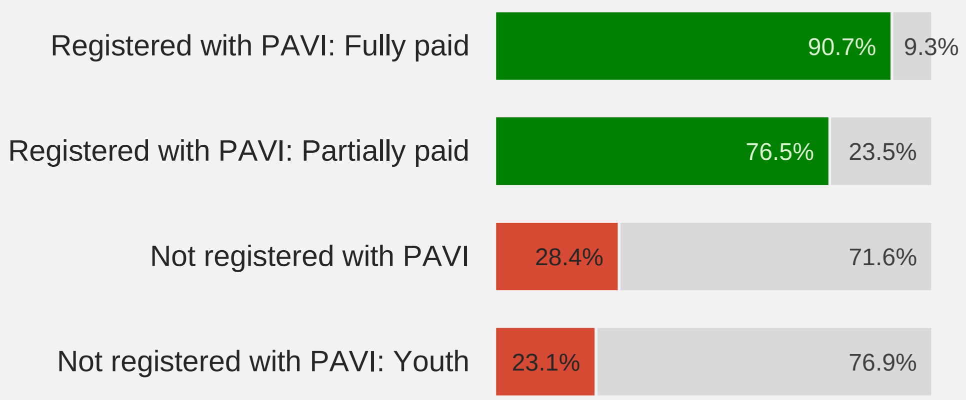
Source: Analysis from quantitative survey (Feb 2024)

Extension services seemed to reach PAVI members only. Other extension service providers (i.e., government and other cooperatives) appeared to have limited reach.

Figure 11: Access to extension services

Survey question: "Do you receive any agricultural extension services?"

% of responses



Source: Analysis from quantitative survey (Feb 2024)

Value chain

Since 2016, PAVI has evolved from being an extension of Base Titanium's livelihoods programs to a standalone entity with a defined business model. This progression has influenced KLP/PAVI's approach to value chains, historically exploring many different value chains from year to year driven by farmer preference. Refer Appendix 5 for a summary.

To draw out key learnings from work under KLP, three value chains were selected for further analysis – cotton, maize and vegetables. These value chains were selected as they represent a mix of food and cash crops, strategic importance at the national government level, and the involvement of women and youth. Furthermore, all three value chains were included in the 2023 season providing a recent baseline at the time of the analysis.

Key findings from the baseline value chain analysis were as follows:

- As a livelihoods program the previous focus was on maximising the number of farmers; however, this came at the expense of cotton yields. In 2020 the focus shifted to working only with committed farmers, which led to significant increases in the volume harvested[10].

Figure 12: Number of cotton farmers by season

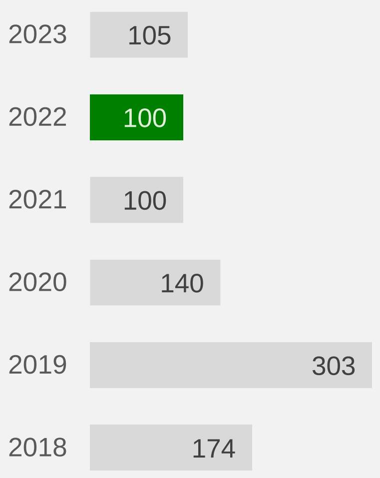
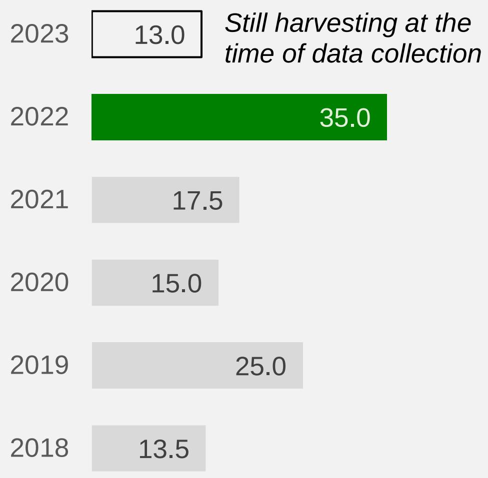


Figure 13: Average volume harvested per farmer (kg)



Source: Analysis from Kwale Livelihoods Program records

- Very few farmers had dedicated farm storage; therefore, harvested crops were typically stored in the household dwelling. Lack of dedicated farm storage reduced a household's livable space, putting pressure on PAVI to collect harvested crops frequently and increasing transport costs.
- Transport was outsourced to a third party to collect produce from farmers and was a significant cost to PAVI. Poor road infrastructure often led to truck breakdowns, impacting PAVI's relationship with farmers in situations where they had agreed to meet at a central collection point.
- PAVI's historical unreliability with input distribution, transport, payments, etc. had resulted in farmers registering with PAVI to access input loans, selling their produce to middlemen and repaying PAVI in cash. This meant that PAVI struggled to procure sufficient produce to meet minimum volumes required for processing.

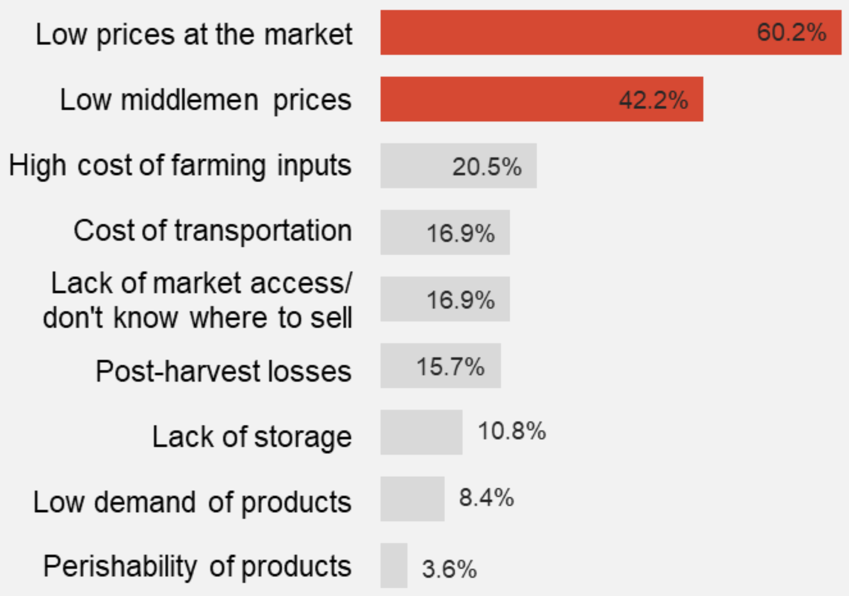
Responses from the quantitative survey highlighted that the key challenges to high crop output for respondents were low prices, followed by the high cost of farming inputs. This corresponded with responses to the highest-valued services provided by PAVI.

[10] Details regarding the total land area under cultivation were not available, therefore yield improvements could not be confirmed. However, the KLP team had advised that average field sizes had not changed significantly from year to year.

Figure 14: Prices were the biggest challenges for survey respondents

Survey question: "What would you say are the main challenges that negatively affect high crop output?"

% of respondents



Source: Analysis from quantitative survey (Feb 2024)

Figure 15: Value of PAVI activities to farmers

Survey question: "Which one of the following activities do you associate with PAVI Cooperative?"

% of responses

Source: Analysis from quantitative survey (Feb 2024)

PAVI's organisational effectiveness

A literature review and key informant interviews with other comparable cooperatives revealed common themes of successful cooperatives, which can be grouped into three categories – operating model, members and governance (see Table 2).

Table 2: Common themes of successful cooperatives

Operating model	• Focused on developing one or two value chains and involved in value addition. • Competitive advantage against other cooperatives by supplying better produce/value-added products. • Most of the cooperatives have embraced technology to collect farmer data and improve operational processes. • Limited employees and high workforce retention. Use of casual labour and outsourced service providers to supplement the cooperative's workforce. • Employees are suitably qualified for their role. • Ability to protect themselves against external factors affecting the success of cooperatives, such as political interference.
Members	• Different incentive mechanisms to attract members (e.g., dividends and distribution of bonuses to members) and invest in marketing the cooperative to raise awareness of it. • An informed and trained membership (e.g., improved agricultural practices, leadership, co-operative strategy and activities, etc.). • Able to weather market fluctuations by raising share capital from members. • Willingness of members to compromise where needed to support the cooperative.
Governance	• Stable governance structures, and strict policies created by the Board that are adhered to and enforced. • Democracy, trust and transparency of the cooperative's Board and administration to its member farmers.

When PAVI was established under KLP, the original intent was for PAVI to be an agricultural marketing cooperative; however, there had been an unintentional blurring of boundaries between PAVI commercial and the livelihoods program activities. This has inhibited PAVI's ability to evolve as required to become commercially sustainable. A key learning from this experience was that although such initiatives benefit from being seed funded by the private sector, stakeholders should encourage independence and a clear separation of 'brands' between the private sector and for-purpose entities.

The organisational effectiveness assessment also found that PAVI's operational effectiveness needed significant improvement to take on the challenges of the next few years, with the impending mine closure, moving into cotton and maize processing, and potentially becoming operator of the 1,000-acre block of remediated land. Refer Table 3 for a summary of assessment results.

Table 3: Organisational effectiveness assessment results[11]

Increasingly developed ➔

			1	2	3	4
Client centred	Focus on impact and end beneficiaries				●	
	Evidence informed and appropriate services				●	
Effectively run	PLAN	Mission/Vision/Ambition		●		
		Organisational strategy			●	
	DELIVER	Financial health		●		
		Skills and capabilities		●		
		Operational efficiency		●		
	LEARN	Learning culture		●		
		Measurement and evaluation practices		●		
	GOVERN	Leadership		●		
		Governance			●	
		Values		●		
Engaged with ecosystem	Understanding and contributing to ecosystem				●	
	Networking and collaboration					●
	Accessibility and responsiveness to stakeholders				●	

System map development

A system map was developed and refined throughout the project's 12-month period to identify and prioritise key points of leverage to guide research activities, within the constraints of the Research Objectives. The system map was refined based on learnings from the social science, biophysical and value chain baseline research activities. Refer Appendix 6 for the latest version of the system map; an interactive version can also be found here.

Development of the system map helped to identify the following key points of leverage, which were used to prioritise Impact Pathways. It can also be used by other stakeholders in Kwale, such as government and NGOs, to help inform interventions.

[11] The SVA Fundamentals for Impact assessment is comprised of two tiers of questions for each assessment area. Due to time and budget constraints, only the first tier of questioning could be completed with the PAVI Board and KLP team members; however, this was sufficient to generate an understanding of PAVI's current state of organisational effectiveness and stimulate robust discussions amongst the participants.

Table 4: Key points of leverage and relative alignment to research disciplines

Increasingly greater alignment →

Leverage point	Social science	Biophysical	Value chain
Collective movement			
Culture			
Agribusiness mindset			
Role models			
Crop/livestock type			
Good agricultural practices			
Logistics/transport			
Finance			
Knowledge			
Recordkeeping			
Capacity building			

Two key opportunities were identified that would either directly address or lay the foundations for future project activities:

1. Introduction of PAVI Farmer Schools, modelled on FAO's 'Farmer Field School' approach.
2. Transformation of PAVI's business and operating models.

7.2 PAVI Farmer Schools

PAVI's historical extension approach involved a one-to-one relationship between field agents and farmers, a high-cost approach with inconsistent improvements to farmer yields and a clear weakness in PAVI's value chains.

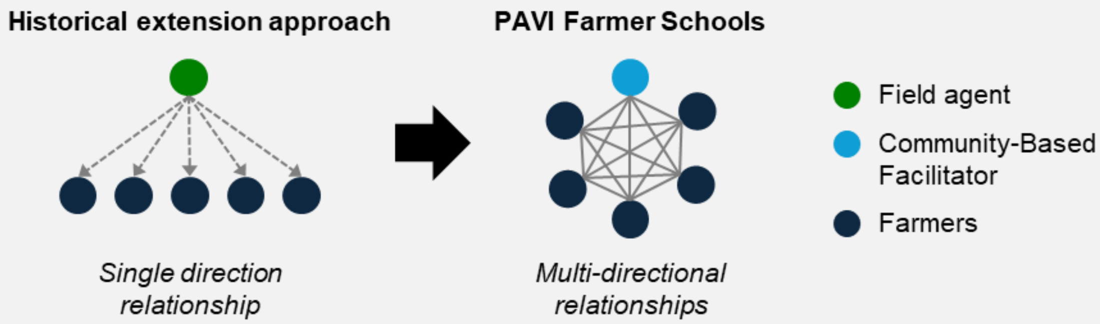
A farmer participatory research model was adapted to suit the local context, resources available and MKUKI-Kwale's research approach, borrowing from the Farmer Field School (FFS) approach[12], which is described as a 'School without Walls'. The FFS approach to extension involves farmers learning by doing through comparative experimental trials. Farmers are given the opportunity to select the methods of production through a discovery-based approach, bringing farmers together to carry out collective and collaborative action in solving their problems. It empowers farmers with the knowledge and skills to make them experts in their own fields, sensitising farmers on new ways of thinking and problem solving. The field schools were named PAVI Farmer Schools to give ownership to the groups as they were mainly comprised of PAVI members. The PFS approach would address all leverage points identified in the system map.

Furthermore, the revised extension model would help farmers become more comfortable with working together in groups to solve related problems such as access to finance (e.g.,

[12] FAO. (n.d).Themes | Global Farmer Field School Platform | Food and Agriculture Organization of the United Nations.

through table banking). PFSs also enabled farmers to learn from each other regarding crops that PAVI was not involved in.

Figure 16: Revised extension service approach



Eight PFSs were established, with two in each of the four sub-counties as illustrated in Figure 2. To manage the PFSs, potential community-based facilitators (CBF) were identified within the sub-counties. They were retooled in an intensive training curriculum on the FFS methodology before being posted to various PFSs within their home sub-counties.

Group criteria for selection of PFSs was as follows:

- Group had more than 25 members.
- Majority number of PAVI-registered members in the group.
- Availability of at least one acre of suitable agricultural land for participatory research.
- Representation of women and youth within the group.
- Readiness of the group to meet for three to four hours at least once per week.
- Readiness of group members to practice what they learnt in the trial plots on their farms.

The interest by farmers in the PFSs has since led PAVI to establish and lead an additional 16 PFS (independent from MKUKI-Kwale), bringing the total number of PFS to 24.

Figure 17: A PFS in session with the day's schedule

Crop varietal selection

Trials were initiated in each of the eight PFS trial plots of various varieties of maize, cow peas and green gram against farmer preferred local varieties, and two cotton varieties at different planting densities. Preliminary results showed farmers have already begun appreciating the varietal variation in different selected crops.

Crop growth data was collected through the AESA charts prepared for data entry.

Figure 18: Germination of seven maize varieties seven days after sowing

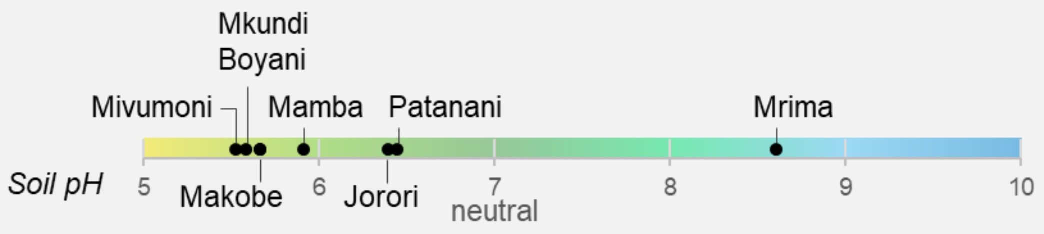
Figure 19: Data collection for various cow pea varieties

Soil health management

Soil samples were collected from the eight PFS trial plots for soil nutrition and microbial analysis, with the participation of farmer group members. Soil samples were also collected from virgin forest land to compare the soil microbiome to that from farmers' fields. Participatory soil sampling and profiling carried out with farmers within the eight PFSs revealed that farmers' knowledge of their agricultural soils, soil testing and their management was very low, highlighting a priority capacity building area.

General soil fertility was low in all sampled sites with a pH range of 5.5 to 6.5, with one exception (Mrima), and organic carbon content that ranged from 3% to 19%. Organic carbon, total nitrogen, exchangeable phosphorus, potassium, calcium, sulphur, base saturation, cation exchange capacity and assorted micronutrients was deficient in most sampled soils. Total organic carbon in all soil samples analysed was low and therefore had inadequate soil organic matter content. Inadequate soil organic matter content results in low water holding capacity and low water infiltration rate which may result in soil erosion by surface runoff during the rains.

Figure 20: Top horizon soil fertility (pH) across the sampled sites



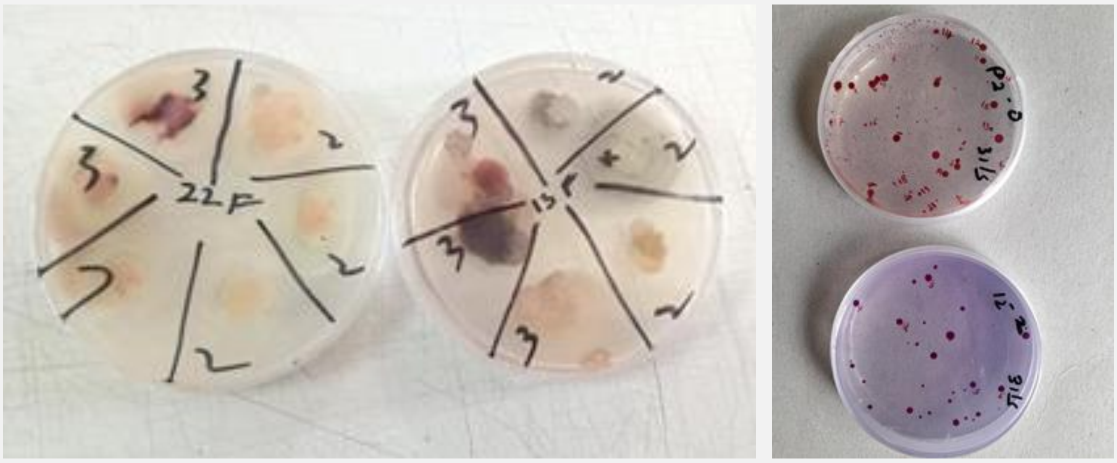
Soil organic matter also impacts positively on soil microbial activity. The application of well rotten manure or compost was recommended to improve the organic matter content in all the farms. This would also supplement soil nutrients and improve soil structure, water retention capacity and soil microbial activities, which was also low.

The general microbial populations (colony forming units) for the bacteria and rhizobium were below the expected range of 100,000 to 1,000,000 colony forming units in more than half of the soil samples. The colony forming units were obtained by computing the average among the set of dilution factor (100, 10^{-1} and 10^{-2}) from different layers of soil. Topsoil showed the highest count with an average of (37.8×10^5) as compared to the sub-soil (27.2×10^5). However, the results were also high in the virgin forest lands both for the sub soil and topsoil, likely because the soils were undisturbed. The isolates were characterised using cultural and biochemical techniques. The Gram stain reaction showed that 53% of the isolates were Gram positive while 47% were Gram negative, and they grew well at pH ranging from 5- 6.5 and temperature range of 25ºC to 35ºC.

Refer microbial and nutritional soil analysis report in Appendix 7.

Figure 21: Sample preparation and culturing at KALRO's National Agricultural Research Laboratories (NARL) - Kabete

Figure 22: Isolation of pure cultures



This study demonstrated that Kwale soils harbour diverse bacteria with specific biochemical properties. However, the microbial load was low hence reducing their ability to be involved in the nutrient recycling within the region leading to reduced soil fertility.

Table 5: Characteristics of microbes isolated from Kwale soils

Microbe	Genus	Species	Starch hydrolysing	Nitrogen fixing	Phosphate solubilisation
Bacteria	Bacillus	*Bacillus Subtilis*	Positive		
		Bacillus Megaterium	Positive		
	Clostridium	*C.Perfringes*			
	Psedomonas	*P-Putida*			Positive
Fungi	Aspargillus				
	Trichodarma		Positive		
	Penicillium				
	Fusarium			Positive	
Rhizobium	Rhizobium	*R. Fredii*		Positive	
	Prokyryotes			Positive	
Actinomycetes	*streptomyces*	*s.auriginosa*	Positive		Positive

Soil profiling findings

Soil profiling was carried out for all eight PFS sites following FAO soil description guidelines. The profiling exercise was executed using a participatory approach, aimed at helping farmers understand their soils in reference to aggregation and depth/horizonation which in turn informs texture, porosity, water-holding capacity, nutrient-holding capacity, soil biota diversity and activity, short- and long-term overall soil health and water resource management.

Figure 23: Participatory profile description exercise

The profiles of the eight PFS sites were observed to be stable, dominated by blocky and angular structures and a clay rich B-horizon – an indicator of good agricultural soils. The soils were also deep with A-Horizon extending beyond 0.6 metres deep and B-horizon extending beyond 1.5 metres deep except the Jorori site where the transition to C-Horizon was evident within 0.3 metres depth (Figure 24). The topsoil colour in all sites ranged from 10R4/1 to 2.5YR4/2 indicating the presence of oxidised iron and/or organic matter.

Figure 24: Soil profiles

Deep soil profile

Shallow soil profile

The top 20 cm of Patanani, Mivumoni, Jorori, Mrima and Mkundi soil was dominated by clay textured soils while Makombe and Boyani had sandy clay texture. However, all the subsoils were clay textured indicating the presence of good bulk density and water-holding capacity. This subsoil and topsoil texture indicates the presence of quality soils that can be highly productive with moderate climate smart water resource management. Although the soil reaction of seven sites was observed to range from moderately to slightly acidic (pH 5.0 to 6.5) and Mrima soils were slightly alkaline (pH 7.9 to 8.4), all sites had very high levels of exchangeable iron and aluminium. Exchangeable acidity was moderately low in all sites indicating minimal soil acidity challenges within the area.

Total soil nitrogen (TN), soil organic carbon (SOC) and cation exchange capacity (CEC) was observed to be low in all sites except Patanani, Mrima and Mamba, indicating the need for nitrogen, carbon and base cations management. Exchangeable potassium (K) on the other hand was adequate in Patanani, Mrima and Mamba and low in all the other sites, indicating the need for potassium management through careful selection of potassium-rich organic and inorganic amendments.

Likewise, phosphorus (P), being the second most important nutrient in plant growth and productivity and an essential element, was observed to be low in all sites except Mkundi and Jorori. This was evident through the very high phosphorus sorption indices (PSI) of the soils indicating the need for phosphorus management through soil health management in all sites.

Laboratory analysis of composite soil samples extracted from the top 30 cm depth from 15 locations in each of the eight PFS sites showed that soils pH ranged from neutral to moderately acidic (Table 6). Mkundi soils were the only soils with near neutral pH with all the other sites being either slightly or moderate acidic. Organic carbon was deficient in all sites while nitrogen was deficient in all sites except Mrima and Patanani. Phosphorus was deficient in all sites except Patanani, while potassium was deficient in Mrima, Makombe, Mamba and Jorori. Calcium, magnesium, copper and sodium were adequate in all sites while zinc was deficient in all sites except Mkundi and Mrima.

Table 6: General soil fertility status of soils within the eight PFSs

■ High ■ Adequate ■ Deficient

Parameter	Mkundi	Mrima	Makobe	Mivumoni	Mamba	Jorori	Patanani	Boyani
Soil pH	6.88 neutral	6.35 slightly acidic	6.13 slightly acidic	5.8 mod. acidic	5.39 mod. acidic	6.67 slightly acidic	6.47 slightly acidic	5.9 mod. acidic
Total Nitrogen (%)	0.19	0.23	0.16	0.12	0.1	0.12	0.21	0.12
Total Organic Carbon (%)	1.86	2.27	1.61	1.2	1.03	1.15	2.06	1.18
Phosphorus (Ppm)	16.7	27	1.3	8.35	0.05	27.15	35.7	3.9
Potassium (meq%)	0.74	0.2	0.14	0.24	0.16	0.04	0.56	0.24
Calcium (meq%)	7.6	2.8	3.4	3.8	2.2	0	29.8	2.6
Magnesium (meq%)	2.43	2.58	1.75	2.45	2.12	2.64	2.63	2.72
Manganese (meq%)	0.53	0.59	0.75	0.62	0.39	0.71	0.45	0.49
Copper (ppm)	2.56	3.22	1.68	1.68	1.47	1.68	3.65	1.34
Iron (ppm)	35.93	8.15	Trace	34.07	3.83	18.64	31.78	8.79
Zinc(ppm)	8.78	35.4	1.74	2.5	1.46	87.3	2.17	0.57
Sodium (meq%)	0.28	0.14	0.12	0.32	0.28	0	0.52	0.18

The concentration of soil titanium in the topsoil of the profiles was found to lie within the global average and media except in Mrima and Mamba soils (Table 7). Similarly, niobium levels were high in Mrima and Mamba profiles. Chromium levels on the other hand were high for all sites except Jorori, Boyani, Makobe and Mkundi while arsenic, lead, gallium, uranium and rubidium were low in all sites. Patanani and Mamba sites were also found to have high vanadium and thallium levels with Mamba having the highest level. This finding calls for further diagnosis of the scope of the elements in reference to food safety.

Table 7: Textural class and selected chemical properties of top horizon of soils within the eight PFSs

Parameter	Mkundi	Mrima	Makobe	Mivumoni	Mamba	Jorori	Patanani	Boyani
Ti (mg/kg)	2,355.5	**25,810.5**	1,100.5	6,073	**28,422**	2,238	5,430	536
V (mg/kg)	54.25	<LOD	<LOD	<LOD	1655.5	12.5	171	<LOD
Cr (mg/kg)	31.5	62	<LOD	167	166	18.5	96.5	<LOD
Ga (mg/kg)	10.5	17	4	8.5	27	10.5	18	4
As (mg/kg)	<LOD	<LOD	<LOD	<LOD	64.5	<LOD	63	<LOD
Rb (mg/kg)	98	36.5	5.5	20	96	88	99.5	<LOD
Nb (mg/kg)	10.75	**571**	<LOD	34	**170.5**	12.5	33	<LOD
Pb (mg/kg)	124	<LOD	<LOD	<LOD	<LOD	202.5	<LOD	<LOD
Th (mg/kg)	8	13.5	7	7.5	24.5	9	24	7
U (mg/kg)	2	<LOD	1	<LOD	<LOD	2	3.5	1

Ti-Titanium; V- Valadium; Cr-Chromium; Ga-Gallium; As-Arsenic; Rb-Rubidium; Pb-Lead; Nb-Niobium; Th-Thallium; U-Uranium

From the baseline studies, 83% of PAVI-registered farmers across Kwale county use basal fertilizer (DAP or NPK) and 58% use CAN for top-dressing. Optimal crop production requires crop-specific and site-specific plant nutrition (refer soil test results in Appendix 8). For example, in Patanani PFS, the soils are slightly acidic with low levels of OC and Zn. They are deep vertisols (black cotton soils) with the ability to support all climate adapted shallow and deep-rooted crops. The following recommendations were made to farmers:

- Maize establishment requires three handfuls of farmyard manure per planting hole, 50kg/acre of NPK blended with zinc at planting, and top-dressed with split application 50kg/acre CAN.
- For cotton, farmers should apply 50kg/acre of NPK blended with zinc at planting, and top-dress with split application 50kg/acre CAN.
- For legumes, chillies and vegetables, place three handfuls of well decomposed farmyard manure per hole. During planting, apply 10 grams of NPK fertiliser blended with zinc (Mavuno/Yara/MEA). At 30 and 45 days after planting, apply 10g/plant and 20g/plant of CAN fertiliser for chillies and vegetables respectively.

Soil fertility analysis results provided a suitable baseline to support exploration of soil health management techniques over the course of the project for both smallholder plots and remediated land, which would provide significant scope for dissemination of learnings more broadly, particularly in relation to smallholder farming and post-mine land use.

7.3 Transformation of PAVI’s business and operating models

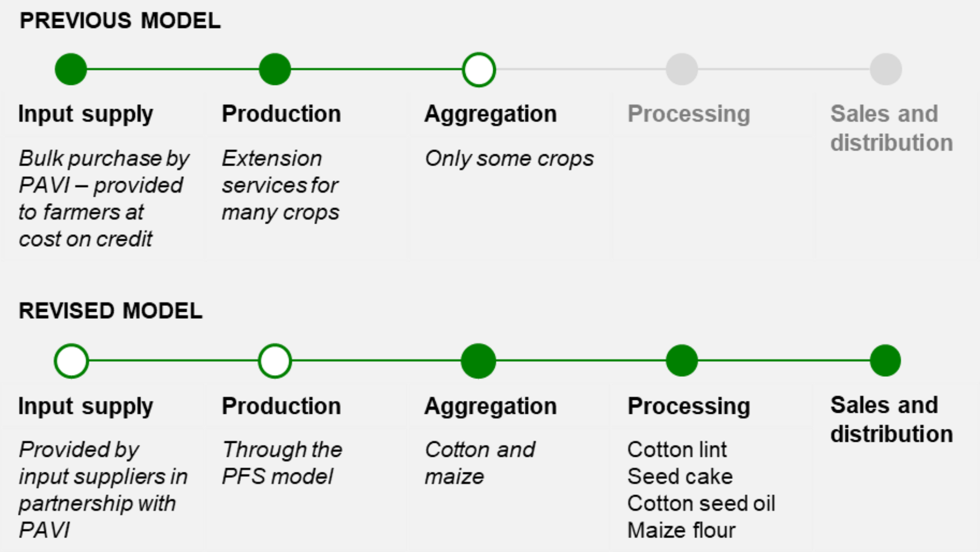
PAVI is known for providing farm inputs on credit and at cost to members, extension services, and a guaranteed market for members’ produce. Despite support from PAVI however, even cooperative members achieved below average yields per acre thus bringing to question PAVI’s return on investment of extension services. For PAVI to be the secure market for farmers’ produce, significant microeconomic restructuring needed to take place.

A recommendation was made by MKUKI-Kwale for PAVI to review its business and operating models, with the following in mind and drawing from the common themes of successful cooperatives described in Table 2:

- PAVI needed to review its cost structure to ensure that the cooperative invested in activities that would improve profitability. Consideration should be given to outsourcing certain services to strategic partners, such as extension services and farm inputs.
- Focusing on a few core value chains coupled with a group learning approach would enable PAVI to improve profitability and livelihood impact, as skills could be transferred to other crops that farmers are growing.
- Low yields and the geographical spread of PAVI’s members means high transaction costs. Value addition and scale were critical for PAVI to achieve profitability.
- PAVI’s membership base needed to grow to help improve economies of scale. This included reaching other sub-counties where the cooperative was barely known.
- Once the revised business and operating models were determined, PAVI would need to focus on operational effectiveness and efficiency to become an independent entity, not reliant on external support.

As a result of MKUKI-Kwale’s recommendations, the PAVI/KLP team developed a revised business model focusing on cotton, maize and the associated value-added products of stockfeed and maize flour. Work has also commenced on PAVI’s business and operating model transformation. This will address multiple leverage points from MKUKI-Kwale’s system map and would have supported planned project activities (e.g., value chain research). There are also several MSME opportunities that have been identified as a result of PAVI’s changes, such as aggregation at the village level as PAVI plans to accept produce at the cooperative going forward for a higher price, rather than travelling to villages.

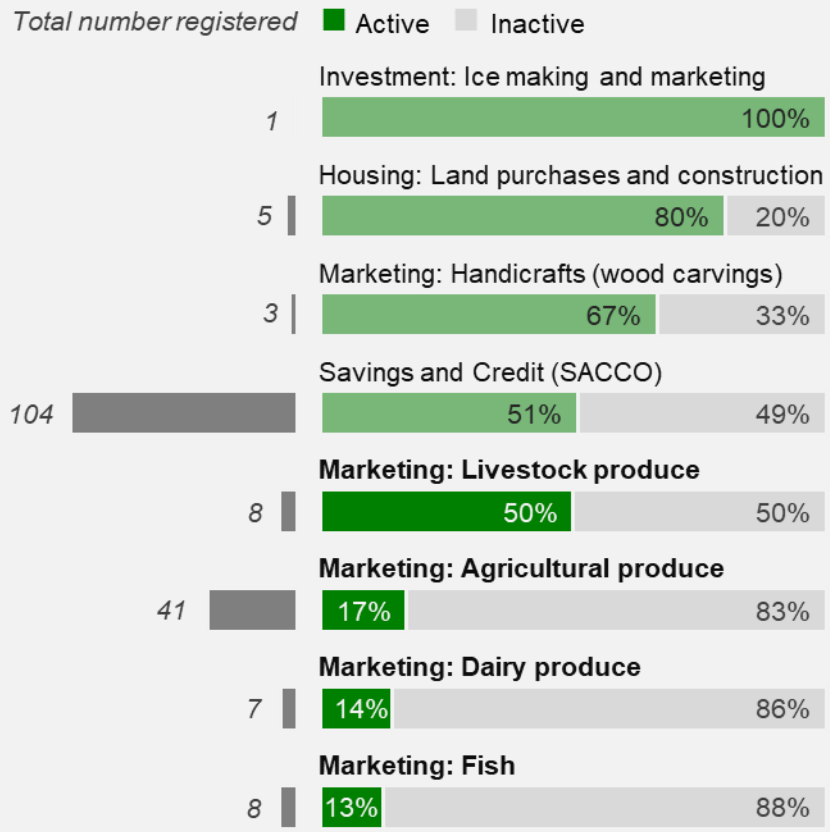
Figure 25: PAVI’s business and operating model transformation



PAVI's experience will provide a useful case study for Kwale County Government and other interested stakeholders, such as the Ministry of Cooperatives, regarding a multi-dimensional approach taken to cooperative transformation. This is particularly relevant for Kwale County, which has had low success with agricultural marketing cooperatives.

Figure 26: Marketing cooperatives have the lowest % of active cooperatives

Registered cooperatives in Kwale County, 2018



Source: Analysis from Kwale Spatial Land Use Plan (2022-32)[13]

7.4 Stakeholder engagement, collaboration and dissemination of learnings

The scope of MKUKI-Kwale offers a wide range of opportunities for broader learnings. Furthermore, for learnings to be adopted and continued beyond the life of the project, stakeholder engagement and collaboration is key. Developing a stakeholder network alongside research activities was a priority at the start of the project as it was recognised that the initial investment would pay-off throughout the life of the project.

Research partnerships

- **World Wide Fund for Nature (WWF)** – Wildlife interference was a key risk on the large block of remediated land and methods such as electric fencing would be too costly. Discussions were underway between MKUKI-Kwale and WWF with respect to

[13] County Government of Kwale. (2022). Kwale Spatial Land Use Plan (2022-2032). *Excludes categories with no active cooperatives.*

joint research on wildlife management techniques that would be cost-effective for smallholder farmers and could also be used for the remediated land.

- **The Center for International Forestry Research and World Agroforestry (CIFOR-ICRAF) –** Early discussions were underway with respect to potential areas for collaboration, for example, land reclamation and water use efficiency.

County Government

PAVI had an existing relationship with the Kwale County Government, which was strengthened through the introduction of MKUKI-Kwale. This was demonstrated by:

- The Minister for Agriculture, Livestock and Fisheries agreeing to join as a member of the MKUKI-Kwale Project Reference Group (see separate section 'Project Reference Group').
- Formation of a joint working committee between PAVI and KCG.
- Joint approach to recruiting farmers as PAVI members.
- Ongoing discussions regarding access to seeds, fertiliser and other farm inputs (e.g., PAVI received a seed delivery from Kwale County Government in April 2024).

Post-Mine Land Use

Determining how the remediated land will be used post mine closure has involved a rigorous process led by Base Titanium in consultation with the Government of Kenya and parties interested in managing the land on behalf of the community.

PAVI has been advocating to operate the land set aside for agriculture, which was also a critical component of Research Objective 2. MKUKI-Kwale has enhanced PAVI's credibility as a prime candidate for this role, with key stakeholders recognising the alignment and overlap of PMLU and scope of MKUKI-Kwale and acknowledging the more scientifically robust approach that was taken.

Project Reference Group

Establishing a Project Reference Group (PRG) was a project requirement as MKUKI-Kwale was deemed to fit the description of a project that was 'forging new partnerships, operating in contentious spaces or working in spaces that are novel and/or difficult to define'.

The role of PRG members was to:

1. Provide input based on their depth of experience and understanding and to endorse the proposed approaches that were presented by the team as the project progressed.
2. Capture lessons from this project and future projects like this, by identifying:
   - What has worked well that we must not lose?
   - What was important but could have been done better or more effectively?
   - What would we not do next time?
   - What wasn't been done that we would do in the future?
3. Monitoring key project drivers/risk factors.

The PRG requirement was embraced as an opportunity to strengthen the project's approach, gain different perspectives and enhance dissemination of learnings. With this in mind, the following membership composition was established:

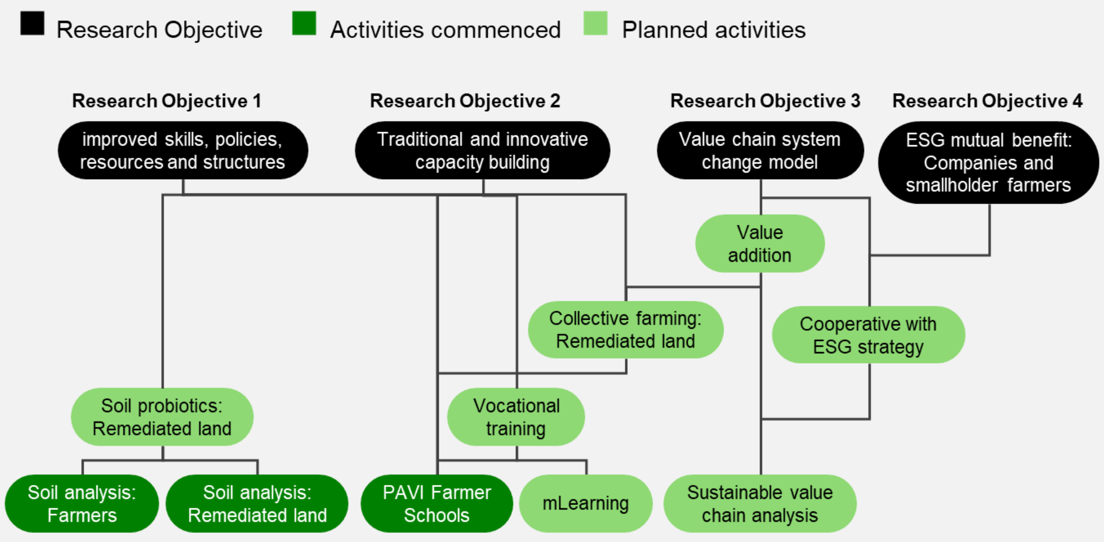
- Kwale County Government – Minister for Agriculture, Livestock and Fisheries
- Pan-Africa Bean Research Alliance (PABRA) – Programme Leader and Director

- Food and Agriculture Organization of the United Nations (FAO) – National Crops Officer and Inclusive Value Chains Sub-Programme Leader
- International Council on Mining and Metals (ICMM) – Director for Social Performance and Senior Manager for Social and Economic Development

8 Impacts

Given the project's early termination, this section has been used to describe anticipated Impact Pathways. As a starting point, Figure 27 summarises the linkages between MKUKI-Kwale activities and Research Objectives.

Figure 27: Linkage between activities and Research Objectives



The following impacts were identified in the project's Theory of Change (Appendix 2), with early progress made during the 12-month project period. Impact Pathways can also be viewed in the interactive version of the system map.

1. **Improved food and income security for smallholder farming families and the broader Kwale community.**

   Good agricultural practices, crop/livestock selection, land management systems and increasing women's involvement in farming were identified as key leverage points for improving food and income security. These were all being addressed through PFSs as follows and as covered in Section 7.2:

   - Improving good agricultural practices is the core objective of the PFS approach.
   - Crop varietal selection and improving soil health, as a component of land management systems, were the first two topics being covered through the PFSs.
   - Increasing women's involvement was being addressed through the group selection criteria for PFS.

   Furthermore, as part of the process of PAVI transforming its business and operating model, decisions were being made regarding services to outsource (for example, aggregation), which would creating MSME opportunities for the community.

2. **Better resilience for smallholder farming families through improved cashflow and diversified crop systems.**

   Addressed through the PFS approach and MSME opportunities as described in point 1 above.

   Furthermore, PAVI's shift towards a more financially sustainable model and potential to become farm operator of the remediated land better positions the cooperative to earn sufficient profit for dividend distribution to its members, creating an additional source of income for their families.

3. **Sustainable growth of Kwale community (non-mine dependent).**

   Agriculture is viewed as a priority sector by Kwale County Government, particularly with respect to the post-mine economy transition. However, agricultural marketing cooperatives have had limited success in Kwale.

   PAVI has been set on the path to becoming a leading co-operative in Kwale, particularly with planned cotton ginning activities given that PAVI will be the only cotton ginning operation in southern Kenya. This in turn would benefit PAVI members and the broader community through profit share and the creation of additional job opportunities.

   If PAVI successfully becomes farm operator of the remediated land, there is the additional potential for intensive farming, cotton seed multiplication, and establishing a hub for training and conservation – all contributing towards the sustainable growth of Kwale community.

4. **Improved social cohesion within the Kwale community.**

   At a grassroots level, the PFS model encourages working together in diverse groups. Early signs were observed during the project period as each PFS created their own group song, with members singing it together in their own language/dialect.

   Longer term, improvements to income and food security were anticipated to improve social cohesion.

8.1 Communication and dissemination activities

A communications plan was developed following comprehensive ACIAR communication training (refer Appendix 9). The communications plan was designed for the upcoming six-month period of the project and as research activities had just commenced, there were no scientific communications to be shared. However, the plan was to be updated regularly as the project progressed.

Please refer to Section 7.4, 'Stakeholder engagement, collaboration and dissemination of learnings' regarding dissemination activities.

9 Conclusions and recommendations

9.1 Conclusions

Findings from the MKUKI-Kwale research-for-development project revealed a wide range of challenges to improving agricultural productivity as well as sustainable and inclusive value chain change, exacerbated by the Kwale context of a mine-impacted community with a dispersed population, poor roads and low levels of education.

By taking a system-level approach it was apparent that a ‘hub-and-spoke’ model – empowering farmers at the village level (spokes) connected to a cooperative (hub) could yield significant improvements, noting the importance of also addressing the mindsets and behaviours that were inhibiting the county’s agricultural development. A two-pronged approach was taken during the limited project period to lay the groundwork for this model:

- **PAVI Farmer Schools** – Improving the cost effectiveness and learning outcomes of field extension, while empowering farmers to learn from each other and problem solve.
- **PAVI business and operating model transformation** – Streamlining and strengthening the cooperative to improve its sustainability so it may continue benefiting the community beyond mine closure.

9.2 Recommendations

The following recommendations are made to continue the work undertaken by MKUKI-Kwale:

- Encourage the adoption of the PFS model more broadly, acknowledging that PAVI has already started to group the rest of their members into PFSs. Given the importance of agriculture to Kwale county and similar constraints to extension services faced by KCG, the Farmer School approach should be considered beyond PAVI members.
- Continual delivery of hands-on skill and technology training through PFSs coupled with the introduction of higher-value crops, adoption of good agronomic practices, enhancing accessibility and affordability of inputs like quality seed, fertilisers and pesticides, and leveraging successful farmers as role models and easier points of skills transfer. Training farmers on improved crop varietal selection and appropriate application of inputs will further contribute to increasing incomes and reducing costs.
- Skills development should be encouraged through experiential learning within the PFSs where farmers develop solutions to address challenges within their farms – local solutions to local problems. With the participatory soil fertility and profile analysis, further research is necessary to identify value chains and varieties suited for the various agro-ecological zones in Kwale county as well as fertiliser application regimens for optimum crop production. Research on the use of biofertilisers and biopesticides should also be explored for reduced harm and better environmental management.
- Continued transformation of PAVI’s business and operating models to become a profitable cooperative that is trusted and valued by its members and playing an influential role in Kwale representing the smallholder farming community. This includes commercialising value-add activities, creating a cotton processing hub in southern Kenya and providing an affordable source of maize flour and stockfeed to the local community, which will improve food security. To do so, PAVI will need to increase its working capital and continue advocacy and stakeholder engagement to improve awareness of the cooperative.

Longer term, there are also future opportunities for PAVI and Kwale county with the return of remediated land post mining and the development of Mombasa Special Economic Zone, proximate to Kwale, which has the potential to significantly benefit the county's economic growth.

10 References

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10.2 List of publications produced by project

N/A

11 Appendices

11.1 Project partners: MKUKI-Kwale and Kwale Livelihoods Program

11.2 Theory of Change

11.3 Village representation: Focus group discussions

11.4 Social science findings

11.5 Value chain overview

11.6 System map

11.7 Microbial and nutritional soil analysis of soils within Kwale county

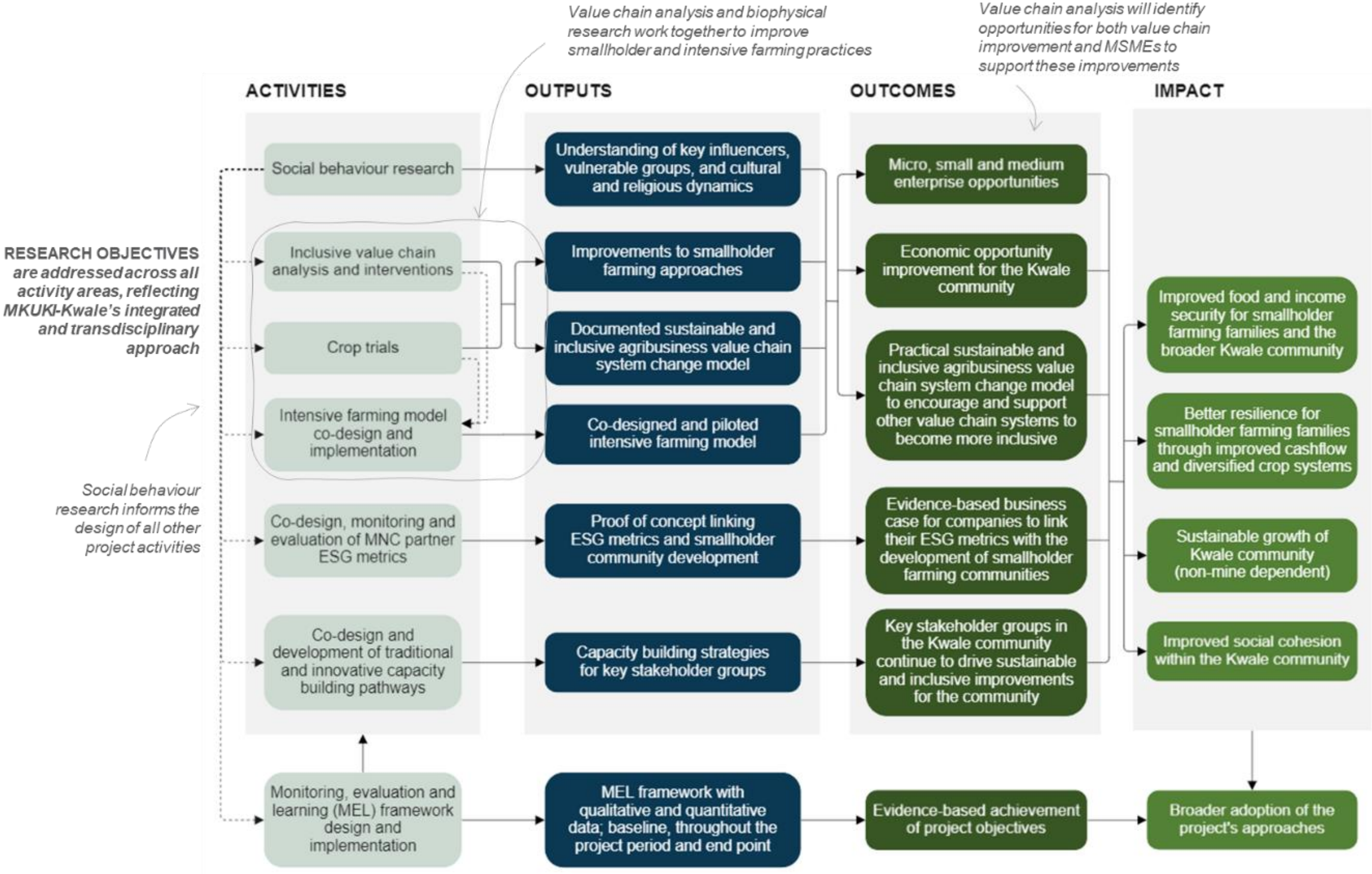
11.8 Soil test results with recommendations

11.9 Communication plan

11.1 Project partners: MKUKI-Kwale and Kwale Livelihoods Program

MKUKI-KWALE Funded by ACIAR (In-kind support from Base Titanium and Cotton On Group)			
Palladium Group Overall project management, research discipline leads and value chain expertise *Commissioned Organisation*	**KALRO** Microbiology and social science expertise *Collaborating Organisation and Government of Kenya Designated Cooperating Authority*	**Pwani University** Crop and soil science expertise *Collaborating Organisation*	**PAVI Cooperative** Local partner and community representation *Collaborating Organisation*
KWALE LIVELIHOODS PROGRAM Funded by Base Titanium and Cotton On Group			
Palladium Group Overall project management and delivery			PAVI Cooperative established through KLP

11.2 Theory of Change



11.3 Village representation: Focus group discussions

Sub-county	Village	Total	Men (149)	Women (96)	Youth (41)
		286			
Matuga	Msula	18	8	6	4
Matuga	Voroni	14	5	5	4
Matuga	Jorori	14	4	8	2
Matuga	Patanani	13	9		4
Matuga	Tsunguni	11	6	3	2
Matuga	Kilole	11	5	3	3
Matuga	Mzimalume	9	3	2	4
Matuga	Kinyajui	9	3	3	3
Matuga	Mwanjamba	8	3	3	2
Matuga	Mlungu Nipa	7	6		1
Matuga	Ganze Galana	7	3	2	2
Matuga	Kivyoko	6	2	4	
Matuga	Fihoni	6	2	3	1
Matuga	Mwamivi	4	3	1	
Shimba Hills	Mkongani Mkomba	11	5	6	
Shimba Hills	Mkundi	8		4	4
Shimba Hills	Mkongani Deri	7	7		
Shimba Hills	Mangawani	6		6	
Shimba Hills	Sagalato	5	3	2	
Shimba Hills	Mwaluvanga	5	5		
Shimba Hills	Manyatta	5	5		
Shimba Hills	Lukore	5	5		
Shimba Hills	Mwapala	4	4		
Shimba Hills	Mwagodzo	4			4
Shimba Hills	Kidiani	4		4	
Lunga Lunga	Ziwani	10	8	2	
Lunga Lunga	Mwachanongo	9	4	5	
Lunga Lunga	Perani	8	6	2	
Lunga Lunga	Nguzo	8	7	1	
Lunga Lunga	Kiwegu	6	3	3	
Lunga Lunga	Mrima	5	2	3	
Msambweni	Michungwani	14	8	6	
Msambweni	Likoni	9	5	4	
Msambweni	Kidiani	6	4	1	1
Msambweni	Mafisini	5	4	1	
Msambweni	Kilulu	5	2	3	

11.4 Social science findings

Results from the qualitative and quantitative social science research revealed the following barriers to crop production and farmer participation in agricultural activities:

FINANCE AND RISK

1. **Agriculture is not perceived as a business.**

   Agriculture is a loss-making enterprise for many farmers and thus does not qualify to be a business since it does not return a profit. It is therefore perceived as a subsistence activity, not warranting serious investment. This creates a vicious cycle of low input, low output, low income, back to low input. Lack of profitability is exacerbated by low prices at the time of harvest and cash pressures force farmers to sell their produce at a loss.

2. **Cash flow challenges, high cost of living and an underperforming economy**.

   These three interrelated economic factors have an impact on decisions farmers make regarding farming, which ultimately affects crop yield. In times of economic constraints (e.g., low employment, high cost of living, and low producer prices), basic needs and survival take precedence, and investment in agricultural activities is compromised or not prioritised. Thus, farmers may compromise crucial farm activities and decisions, such as the quality of farm inputs and land preparation. Ultimately, this affects crop yields as fewer farmers invest in farming or productive farming activities are compromised.

3. **Negative experiences with farming**.

   Past social, economic, physical and political experiences significantly shape individuals' expectations, emotions, and judgments. Ultimately these experiences influence how an individual perceives, interprets and makes decisions on future endeavours. Negative experiences tend to instil fear and discourage future involvement in similar experiences. For example, the lack of a reliable market for sorghum and cotton after a farmer has been encouraged to grow these crops for the first time may discourage a farmer to try alternative crops in the future.

4. **Mistrust in the cooperative concept.**

   PAVI Cooperative is currently not effective in creating social bonds amongst members. There is mistrust regarding PAVI’s ability to return a dividend to members. Poorly managed and collapsed cooperatives in the past have reinforced the perception that cooperatives are avenues for retirees to misappropriate funds for personal gain. For PAVI specifically, a good number of farmers see an opportunity to get farm inputs on credit and then repay PAVI after selling their produce to middlemen, rather than selling to PAVI. Few farmers see the benefit of selling their produce through the cooperative. PAVI is well known in some areas and poorly known in others. Therefore, there is an absence of ‘active awareness’, i.e., knowledge of the benefits of being a PAVI member.

5. **Middlemen**

   Farmers are aware of the unfair trade practices of middlemen but still prefer to trade with them because they offer the convenience of coming to collect produce at the farmer’s door and pay cash. This is particularly compelling for households experiencing financial insecurity.

CULTURAL AND SOCIAL

6. **Multi-generational land tenure system.**

   Ownership of land has an impact on its use. In the coastal part of Kenya, land ownership is still with first generation in the family lineage. In fact, land ownership has not been transferred to the 2nd and 3rd generations. This affected individual decisions about farm and crop production or use land to access credit. Additionally, if an individual decides to develop a section of the land, it creates legitimacy problems and insinuates that the larger family is disintegrating. Also, there is no guarantee for ownership of any trees grown on communal land. Overall, this contributes to poor participation in farming and crop production.

2. **Low participation of youth in agriculture and agricultural value chain activities.**

   Like other parts of Kenya, most youth do not want to participate in agricultural production activities. Kwale youth advised that agriculture is not attractive as it does not offer quick cash and requires a lot of effort. The few who were engaged in farming tended to prefer short period maturing crops like vegetables.

   Youth also dislike working close to their parents and tend to farm in groups on borrowed land far from their own family land. They feared that transparency with their parents would lead to them being given financial responsibilities.

   The preference for youth to work in groups presents an opportunity to reach them in their group settings. Cooperative participation by youth is limited as cooperatives are perceived to be for parents/older people.

3. **Aging farming communities.**

   The age of the farmers and/or farming community members engaged in agricultural production and value chain development activities was a major concern. There was an overrepresentation of older age groups and an underrepresentation of youth. Aged farmers tend to lack the motivation to search for more lucrative markets. A case in point was comments from some PAVI members that they are unable to deliver farm produce at PAVI in Kinondo because they are aged.

4. **Gender and farming.**

   More women than men were directly involved in running the farming enterprise. It is not that men are disinterested in farming; men have a duty to provide daily for the family's needs and therefore are engaged in activities that provide a daily cash wage. Women generally spend more time on farming activities and are likely to have higher skills and experience than the men.

5. **Individual and group mechanics in farming.**

   Women are comfortable with working in groups and can therefore be more easily reached in larger numbers through these groups. In contrast, most men do not have economic or social groups. Women groups drive the farming enterprise through peer-to-peer skill transfer and collective bargaining in marketing.

FOOD INSECURITY

6. **Overreliance on food relief and aid**

   Food relief/aid has been used to respond to acute needs of families facing chronic food insecurity. However, reliance on relief has rendered farming communities in high risk and/or prone areas developing a dependency on relief. The project area is not exempt – some farmers noted relief food as one of their coping mechanisms for food insecurity. In fact, further discussions revealed that some farmers wished for crises to benefit from relief food, e.g., some farming communities along river Umba in Vanga seemed to be content with food relief whenever there were floods.

7. **Preference for fast-maturity, less intensive food crops**

   As the community faces food insecurity, most farmers tend to choose dual purpose crops such as maize which is both a staple food and cash crop. Even though farmers are open to high-value crops, recognising the opportunity to increase cash income, cash crops still remain risky ventures for less established farmers because of the need for upfront cash investment, their poor agronomic skills and the risk of insecure markets.

KNOWLEDGE AND SKILLS

8. Overreliance on traditional farming practices

Farmers have historically been producing low yields due to the use of traditional farming practices. They are used to a low yield average per acre. It is hard to convince them that a transformation to high yield is possible and that they can be part of that transformation.

9. Discouragement due to declining yields

There is a general declining trend of yield per acre, which casts a bleak future of farming, discouraging farmers from investing in farming. Even though most farmers are not able to adequately explain the reason for reducing yields, looking at both their farming practices and the prevailing environment, an absence of crop rotation, lack of/inadequate use of fertilisers, lack of/inadequate use/poor timing of pesticides and poor seed quality was observed.

ALL OTHER

10. Too much labour with some crops

Cotton, particularly, is perceived as requiring too much labour because of the continuous flowering and bursting of pods with lint, making the harvesting process more laborious than other crops.

11. Uncoordinated and unreliable extension service support

Farmers seemed overwhelmed with regular/endless meetings and engagement with different stakeholders offering extension services. A case to note is the KCEP–Cral project vis-à-vis PAVI in which most PAVI members enrolled under KCEP-Cral could not join PAVI’s input loan program due to duplication.

11.5 Value chain overview

● Use and end market
○ Planned end market

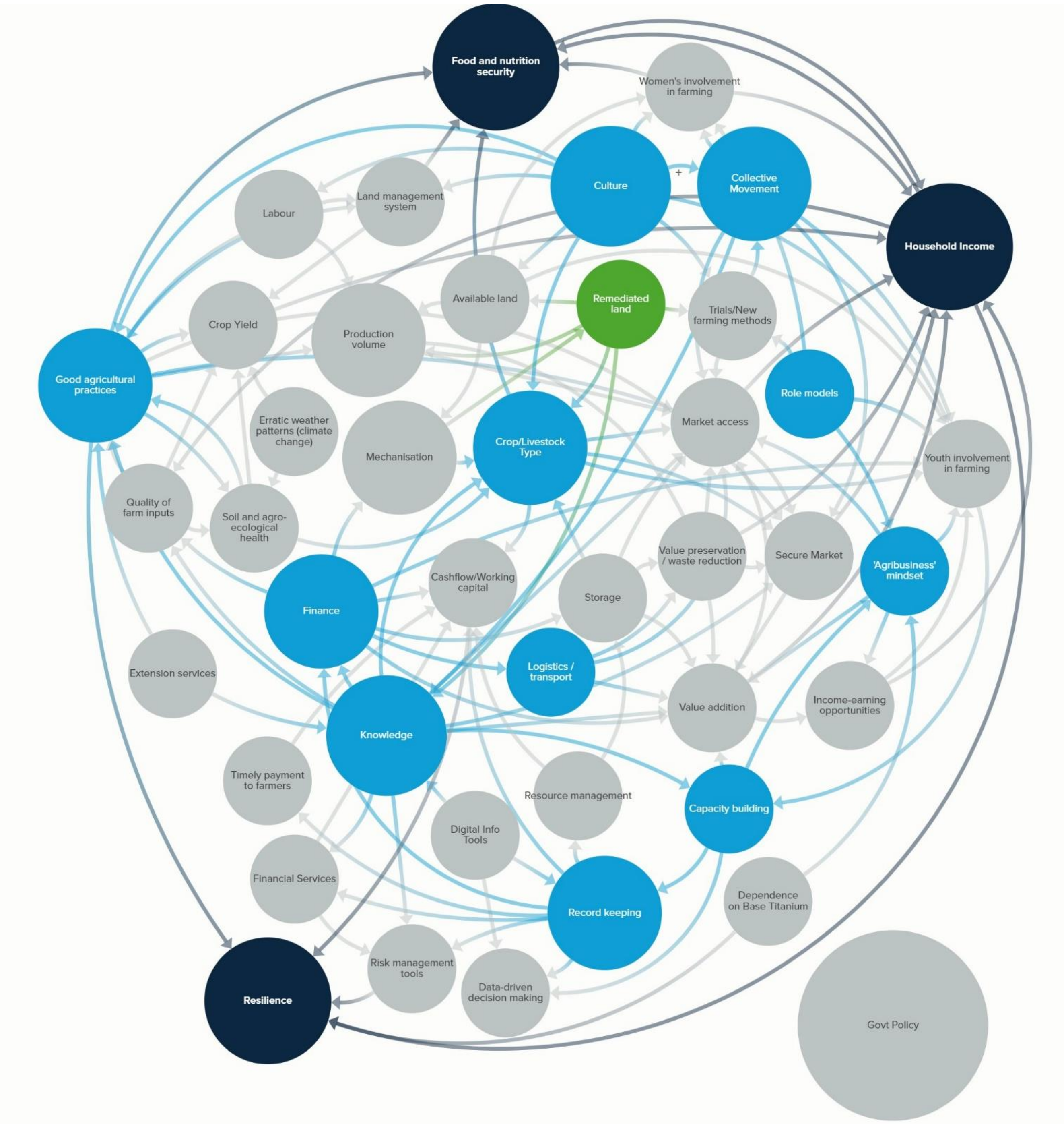
● Smallholder farms • Demo plots
● Extension of Base Titanium program
● Secondary value chain

Food crop	Farm system[13]	Local market	Global market		2023	2022	2021	2020	2019	2018	2017	2016	2015	2014[14]
	●	●	○	Cotton	●	●	●	●	●	●	●	●	●	●
●		●		Maize	●	●		●	●	●	●	•		
●		●		Vegetables	●	●	●	●	●					
●		●	○	Sorghum		●		●	●	●	●	●		
●	●	●	○	Green gram		●	●	●		●	●	●		
●	●	●	○	Cowpea						●	●	●		
●		●		Soybean		•			●	●	●	●		
●		●		Potato	•					●	●	●	●	●
●		●		Upland rice					●	•		●		
●		●		Cassava					●	●				
●		●		Sunflower		●			●					
●		●	○	Sesame		●	●	●						
●	●	●		Groundnut		●	●							
●		●		Sweet potato	•									
	●			Agroforestry	●									
●		●		Pearl millet		•								
		●	○	Cocoa						•		●		
			○	Winter wheat								●		
●	●	●		Poultry	●	●	●	●	●	●	●	●	●	
	●	●		Stockfeed	●	●	●	●	●	●	●	●		

[14] *Crops that improve the farm system, for example, nitrogen-fixing crops*
[15] *Pilot project*

11.6 System map

An interactive version can be accessed here.



11.7 Microbial and nutritional soil analysis

Technical Report -By Willis A Adero

Microbial and Nutritional soil analysis of soils within Kwale county

INTRODUCTION

1.0 Topography, soils and climate of Kwale County

The total surface area of Kwale is 825,700 ha of which 731,300 ha can be regarded as suitable for agricultural production. The remaining land includes the Shimba Hills National Reserve (21,740 ha), human settlements (estimated population of 866,820) (KNBS, 2019), roads, lakes, swamps and unsuitable steep slopes (Jaetzold & Schmidt, 1983). In the county, three main topographical units can be distinguished: the coastal plain which is generally below the 30 m contour line; the coastal uplands which rise steeply behind the coastal plain to an altitude of some 462 m (Dzombo Hill); and the Nyika plateau, an erosional 20 plain which extends from the western margin of the coastal uplands to the boundary with Taita-Taveta. The soils of Kwale county vary with topography and geology. They are strongly weathered, due to the present and Pleistocene era climatic conditions. The most strongly weathered soils (pure Ferrasols) are found in the eastern part of the county, where annual rainfall is highest. Further inland, diminishing rainfall causes gradual transition from Acrisols, Luvisols and Planosols to less weathered Cambisols and Lithosols. Top soils of most areas are dominated by low organic matter contents which compromise general fertility within the area (Kenya Soil Survey, 1978).Main crops grown in Kwale county are maize, cassava, beans, peas, grams and semi-commercial crops like coconuts and mangoes. The cash crops grown are cashew nuts, sugarcane, cotton, simsim, bixa and tobacco.

1.2 General Causes of soil fertility decline

Declining soil fertility occurs when the amount of nutrients removed from the ground exceeds the amount added. Plants will then extract nutrients from ground reserves. Reserves are depleted until no more resources are available for plant development.

There is a general decline in land productivity due to declining soil fertility arising from the following factors. (Hamdy and Aly 2014)

- Continuous mining of soil nutrients by crops without adequate replenishment;
- Inappropriate farming practices such as lack of crop rotation, cultivation down the slope, etc;

- Soil compaction due to mechanisation;
- Land degradation due to erosion of fertile top soils;
- Continuous use of acidifying fertilisers by farmers;
- Inadequate knowledge on crop requirements and soil characteristics;
- Inadequate use of farm inputs;
- Blanket fertilizer recommendations; among others.

Loss of soil fertility has a significant negative impact not only on agricultural production but also on the surrounding ecosystems. Land depletion causes desertification, biodiversity loss.

1.3 Objectives

1.3.1 General objective To determine the diversity of soil bacteria and their possible contribution to soil fertility from within Kwale county.

1.3.2 Specific objectives

- To carry out morphological and biochemical characterization of dominant soil bacteria in selected regions of Kwale County
- To characterize and identify the bacterial isolates using Phenotypic and Molecular techniques
- To Develop a soil conditioner based on the results obtained in 1&2 Above

2.0 MATERIALS AND METHODS

2.1 Study site

The soil samples were collected from Kwale county within sub counties which included Matuga, Msambweni, Lungalunga and Shimba hills. Kwale county is located s located at around 4°10′28″S 39°27′37″E; 30 km southwest of Mombasa and 15 km inland. The town has an urban population of 10,063 (2019 census). Temperature range from 13^{o} C and 26^{o}C. Laboratory work was carried out at KALRO NARL -KABETE

2.2. Soil samples The soil in this region regions is Sandy textured soils with poor water holding capacity, hence sampling for microorganisms was done at depths of no more than 50 cm. In this study, the maximum sampling depth was also limited to 50 cm due to the thin soil layer. A total of 32 samples were collected from eight sample sites located at different elevations. Each site had two sample quadrats (5 m x 5 m) which were approximately 25 m apart, and each quadrat had five sampling points, one at each corner and one at the center. Soil samples were collected from two layer (0–20 cm and 20-40cm). Samples from the same soil layers were then combined to form one sample, and labeled according to soil depth for each quadrat. All samples were placed in zip-lock plastic bags, numbered, and stored in a sampling box containing ice packs. The samples were transported to the laboratory and stored in a refrigerator at − 20 ◦C for later use.

3.0 Soil fertility. Microbial results and recommendations

3.1 Matuga Sub County

Soil samples in this sub county were represented by : (Lukore,Makobe and Jorori)

In this regins the soil pH ranges from strongly acid (5.69) to moderately alkaline (6.67) (Refer to Table 1). 95% of all the farms sampled have their soil pH within the maize growing range (5.0-8.0) and therefore suitable for the growth of maize. It is important for the farmers in this region to apply manure or compost regularly to maintain and sustain the organic matter content and maintain the pH of the soil within this range. This will also alleviate aluminium toxicity thereby increasing availability of phosphorus. This is through organic colloids preventing dissolved phosphate from coming into contact (being fixed) with free aluminium and iron (Muller-Samann and Kotschi, 1994). To maintain the pH within the maize growing range and prevent further rising of pH acidifying fertilizers such as Diammonium phosphate (DAP), Monoammonium phosphate, Ammonium sulphate, urea, etc should be applied in farms with pH greater than 6.5. Farms with pH ≤ 6.5 neutral fertilizers such as triple super phosphate (TSP), single super phosphate (SSP), compound fertilizers N:P:K 17:17:17, 15:15:15, 23:23:0, 20:20:0, calcium ammonium nitrate (CAN) and mavuno should be preferred for application. In the Sub county, the soil organic matter content ranges from (1.03 Total Organic Carbon (TOC)) to (1.87 TOC) as shown in Table . All sampled farmers within this region had low levels and therefore inadequate soil organic matter content. The inadequate soil organic matter content results in low water holding capacity and low water infiltration rate which may result in soil erosion by runoff surface water during the rains. Soil organic matter impacts positively on the microbial activities in the soil. Application of well rotten manure or compost will improve the organic matter content in all the farms in this Sub County. This will also supplement the soil nutrients and improve soil structure, water retention capacity and soil microbial activities which was also found to be low **Table 1**. Nitrogen levels were also found to be below adequate levels. Where nitrogen, phosphorus, potassium and calcium are low, fertilizers containing these nutrients should be applied to supplement what is available in the soil.

Soil Parameters	Min result	Max result	Turget critical levels	Class	
PH	5.69	6.67	Moderate acidic		
Nitrogen %	0.19	0.12	Deficient		
Carbon %	1.15	1.87	Deficient		
Phosphorous(Mehlich) ppm	27.15	163.35	High		
Potassium meq%	0.04	0.54	Adequate		
Calcium (me%)	2.2	6.4	Adequate		
Magnesium (me%)	2.05	2.64	Adequate		
Manganese(me%)	0.39	0.71	Adequate		
Copper ppm	1.35	1.44	Adequate		
Iron ppm	5.06	34.07	Deficient		
Zinc ppm	1.46	34.8	Deficient		
Sodium meq%	0.20	0.28	Adequate		

Table. 1 *As regards Magnesium, copper they are adequately supplied in the soil in some of the farms. This could be attributed to regular applications of organic and inorganic inputs to replenish the removed nutrients through crop harvest and nutrients lost through avenues such as leaching, vaporization. The micro nutrient Iron and Zinc are low in 95% of the farms respectively. According to the International Zinc Association, maize yields are reduced by zinc deficiency and may result in reductions in yields of up to 40% without the appearance of distinct leaf symptoms (www:zinc. org/crops/resourceserve/zinc facts_sheet_maize, Landon, 1991)*

3.2 Msambweni Sub County

The sub county was represented by: BTL Lands, and Mvumoni.

In Msambweni Sub County, the soil pH ranges from strongly acid (4.70) to moderately alkaline (6.82-6.1) (Refer result table attached). 95% of all the farms sampled have their soil pH within the maize growing range (5.0-8.0) and therefore suitable for the growth of maize. It is important for the farmers in this region to apply manure or compost regularly to maintain and sustain the organic matter content and maintain the pH of the soil within this range. This will also alleviate aluminium toxicity thereby increasing availability of phosphorus. This is through organic colloids preventing dissolved phosphate from coming into contact (being fixed) with free aluminium and iron (Muller-Samann and Kotschi, 1994). To maintain the pH within the maize,cotton growing range and prevent further rising of pH acidifying fertilizers such as Diammonium phosphate (DAP), Mono ammonium phosphate, Ammonium sulphate, urea, etc should be applied in farms with pH greater than 6.5. Farms with pH ≤ 6.5 neutral fertilizers such as triple super phosphate (TSP), single super phosphate (SSP), compound fertilizers N:P:K 17:17:17, 15:15:15, 23:23:0, 20:20:0, calcium ammonium nitrate (CAN) and Mavuno should be preferred for application. In the Sub county, the soil organic matter content ranges from (0.91 Tota1 Organic Carbon (TOC)) to (0.98 TOC) as shown in **Table 2** TOC are at low levels and therefore inadequate soil organic matter content. The inadequate soil organic matter content results in low water holding capacity and low water infiltration rate which may result in soil erosion by runoff surface water during the rains as well as the mining activity that has changed the soil profile (Franzluebbers, A. J. (2002). These has impacted results impacts negatively on the microbial activities in the soil. Application of well rotten manure or compost will improve the organic matter content in all the farms in this Sub County, This will improve and supplement the soil nutrients and improve soil structure, water retention capacity and soil microbial activities. The the most limiting nutrients are nitrogen with 77%, phosphorus with 82%, potassium with 33% and calcium with 30% of the farms with below adequate levels. Where nitrogen, phosphorus, potassium and calcium are low, fertilizers containing these nutrients should be applied to supplement what is available in the soil

As regards, copper, iron and zinc they are inadequately supplied in the soil in most of the farms. However to maintain adequate levels of nutrients, regular applications of organic and inorganic inputs to replenish the removed nutrients through crop harvest and nutrients lost through avenues such as leaching, vaporization etc. is encouraged. The micro nutrient copper, iron and zinc are low in 93 %, 67 and 92 % of the farms respectively. According to the International Zinc Association, maize yields are reduced by zinc deficiency and may result in reductions in yields of up to 40% without the appearance of distinct leaf symptoms (www:zinc. org/crops/resourceserve/zinc facts_sheet_maize, Landon, 1991). It is recommended that during application of fertilizers in zinc depleted soils, application of zinc fertilizers or using zinc-fortified NPK fertilizers is an important practice for maize growth to maintain high yields and profitability. Sulphate salts containing copper, iron and zinc micro elements at 5-10 kg/h may be mixed with other fertilizers during application. Foliar fertilizers containing these elements may also be applied especially for agri-business (high value) crops. Modification of pH closer to the optimum pH may render the micro elements which were otherwise unavailable available. However, most nutrient deficiencies can be avoided in soils of pH ranges of 5.5 to 7.0, provided that the soil minerals and organic matter contain the essential nutrients. In Msambweni Sub county, non-acidifying and acidifying fertilizers are recommended for application because most of the farms have their pH above 6.0. Non acidifying fertilizers such as Triple Super Phosphate (TSP), Single Super Phosphate (SSP), compound fertilizers N:P:K such as 23:23:0, 20:20:0, 17:17:17, Calcium ammonium nitrate (CAN) and Mavuno are recommended for areas with pH below 6.5 and fertilizers such as DAP, urea, ammonium sulphate (AS) in areas with pH above 6.5. This Sub County has nitrogen, phosphorus, potassium and calcium inadequately supplied by the soil. Hence, farmers need to carry out regular soil testing to monitor the pH and plant nutrients trends for future soil fertility management. This will also give a direction into specific types of fertilizers suitable for individual farms in future.

Sub County general fertilizer recommendations Manure: Planting: 6 t/ha 250 kg/ha N: P: K 23:23:0 Top dressing: 125kg/ha CAN

Soil Parameters	Min result	Max result	Turget critical levels	Class	
PH	6.82	5.8	Moderate acidic		
Nitrogen %	0.1	0.12	Deficient		
Carbon %	0.12	0.97	Deficient		
Phosphorous(Mehlich) ppm	8.35	16.8	Deficient		
Potassium meq%	0.24	0.32	Adequate		
Calcium (me%)	3.8	2.0	Adequate		
Magnesium (me%)	2.45	2.23	Adequate		
Manganese(me%)	0.62	0.45	Adequate		
Copper ppm	1.68	1.25	Adequate		

Iron ppm	34.08	95.19	Deficient		
Zinc ppm	2.0	2.5	Deficient		
Sodium meq%	0.32	0.14	Adequate		

Table. 2 *Copper, iron and zinc are inadequately supplied in the soil in most of the farms. However to maintain adequate levels of nutrients, regular applications of organic and inorganic inputs to replenish the removed nutrients through crop harvest and nutrients lost through avenues such as leaching, vaporization etc. is encouraged. The micro nutrient, iron and zinc are deficient on the farms respectively.*

3.3 Lunga Lunga Sub County

The sub county was represented by: represented by Nzombo and Mrima

In Lunga Lunga Sub county, the soil pH ranges from moderately acid (5.35) to moderately alkaline (7.80). All the 60 farms sampled have their soil pH within the maize growing range (5.0-8.0) and therefore suitable for the growth of maize. It is important for the farmers in this region to apply manure or compost regularly to maintain and sustain the organic matter content and maintain the pH of the soil within this range. This will also alleviate aluminium toxicity thereby increasing availability of phosphorus. T his is through organic colloids preventing dissolved phosphate from coming into contact (being fixed) with free aluminium and iron (Muller-Samann and Kotschi, 1994). To maintain the pH within the maize growing range and prevent further rising of pH acidifying fertilizers such as Diammonium phosphate (DAP), Monoammonium phosphate, Ammonium sulphate, urea, etc should be applied in farms with pH greater than 6.5. Farms with pH $\leq$ 6.5 neutral fertilizers such as triple super phosphate (TSP), single super phosphate (SSP), compound fertilizers N:P:K 17:17:17, 15:15:15, 23:23:0, 20:20:0, calcium ammonium nitrate (CAN) and mavuno should be preferred for application. In the sub county, the soil organic matter content ranges from (0.16% Total Organic Carbon (TOC)) to (2.77% TOC) as shown in Table 3 98% of all farms have TOC at low levels and therefore inadequate soil organic matter content. The inadequate soil organic matter content results in low water holding capacity and low water infiltration rate which may result in soil erosion by runoff surface water during the rains. Soil organic matter impacts positively on the microbial activities in the soil. Application of well rotten manure or compost will improve the organic matter content in all the farms in this Sub County. This will also supplement the soil nutrients and improve soil structure, water retention capacity and soil microbial activities.

Soil Parameters	Min result	Max result	Turget critical levels	Class	
PH	6.5	5.7	Moderate acidic		
Nitrogen %	0.34	0.25	Deficient		
Carbon %	3.37	2.57	Deficient		
Phosphorous(Mehlich) ppm	135.75	88.87	Deficient		
Potassium meq%	1.42	0.98	Adequate		
Calcium (me%)	8.0	4.0	Adequate		
Magnesium (me%)	2.57	0.49	Adequate		
Manganese(me%)	0.77	0.49	Adequate		
Copper ppm	11.57	8.67	Adequate		
Iron ppm	50.12	36.54	Deficient		
Zinc ppm	17.08	10.31	Deficient		
Sodium meq%	0.50	0.22	Adequate		

Table 3*. The soil reaction is moderately and slightly acid. Organic Carbon is low. Cotton. Maize: Place 3 handfuls of well decomposed Farm Yard manure per hole. At planting, apply 50kg/acre Maize, cotton) of N:P:K (23:23:0) fertilizer. Top dress Maize with 50kg/acre using CAN fertilizer. At 50 and 70 days after planting, apply 50 kg/acre of CAN fertilizer respectively (Cotton)*

4.1 Soil microbial biomass

Soil microorganisms are important components of ecosystem functioning as they determine the mineralization of soil organic matter and energy flow (Robertson and Groffman, 2007). Microbial recycling of crop residues provides an important component to improve the soil organic matter pool and soil productivity in agricultural management systems, particularly in the tropics, where microbial soil organic matter turnover time is usually shorter as opposed to temperate agro-ecosystems (Oelbermann et al., 2004). The turnover and mineralization of crop residues is largely dependent on soil microbial processes warranting the recycling of nutrients (e.g. nitrogen) supplied to both plants and microbes (Crecchio et al., 2004). Differences in residue decomposition have mainly been explained by differences in biochemical quality of residues (e.g. C-to-N ratio) (Kaewpradit et al., 2008). Residue quality is known to alter microbial decomposition processes by containing compounds of varying recalcitrance (Palm et al., 2001), requiring specific microbial communities for their degradation.

Nitrogen availability controls the decomposition rate of crop residues (Hadas et al., 2004), particularly those with a high C-to-N ratio (e.g. in maize, soil bacteria play pivotal roles in various biogeochemical cycles (BGC) (Wall and Virginia, 1999) and are responsible for the cycling of organic compounds. There is decreased knowledge of soil microbial diversity mainly due to inability to culture soil microorganisms (Torsvik et al., 1990). This research focused on the diversity of soil bacteria, their importance as well as their possible contribution to soil fertility and eventual developmemt of a soil conditioner in small scale

4.2 Bacteria isolated

Bacteria are a very diverse group of organisms in soil, with major taxonomic groups being represented in most soils. The extent of the diversity of microorganisms in soil is seen to be critical to the maintenance of soil health, since a wide range of bacteria are involved in the important soil functions. The objectives of this study were to isolate, characterize and identify groups of bacteria that are associated with soil fertility in Kwale county of Mombasa within the Kenya coast line and eventual development of a soil conditioner that will be used to improve soil conditions. Thirty eight isolates were obtained using two categories of media, namely dilute nutrient broth agar and Tryptone soy agar, Potatoe dextrose agar (PDA), MRS . Kwale soils had a pH range of 6.5 to 5.5 and organic carbon content that ranged from 3% to 19%. The isolates were characterized using cultural and biochemical techniques. The Gram stain reaction showed that 53% of the isolates were Gram positive while 47% were Gram negative, and they grew well at pH ranging from 5- 6.5 and temperature range of 25^{o}C to 35^{o}C. This study demonstrated that Kwale soils harbours diverse bacteria with specific biochemical properties like the ability to reduce nitrate to nitrite, nitrogen fixation, ability to produce urease enzyme that splits urea into carbon dioxide and ammonia, ability to hydrolyse starch and to solubilise phosphate which suggests their involvement in the nutrient recycling within the region hence improving soil fertility. Thus these can be used as indicators of soil health or as bio fertilizers.

4.3 Isolation and characterization of Bacteria: The inoculated plates were incubated at 25^{o} C and observations were made as from day two of growth. Using enrichment culture methods, a total of thirty two pure isolates were obtained from sampled sites.

4.4 Morphological characterization of bacterial isolates

4.4.1 Colony and Cell morphology

Morphological characterization was based on classical macroscopic attributes of colour, form, shape, and elevation of pure colonies. Most colonies were able to grow within 2-3 days of incubation at 25 ºC. The colony morphology of the isolates obtained from the sampled area ranged from circular, entire, flat and filamentous or branching. They were smooth or rough and the colour ranged from white to cream and brown 53 % of the isolates were Gram positive while 47 % were Gram negative. The cells ranged from long rods, short rods to coccus Most (96%) isolates were rods and only 4% were cocci in shape.

4.2 Bacterial viable cell count The viable cell counts were performed on the bacteria that were able to form visible colonies within 2- 3 days of inoculation. Soil samples were diluted in normal saline, and aliquots from dilutions were plated onto the media in replicates. The amount of variation in colony numbers between replicate plates in counting set decreased with increased dilution factor. The colony forming units were obtained by computing the average among the set of dilution factor (100 , 10^{-1} and 10-^{2}) from different layers of soil. Top soil showed highest count with an average of (37.8 x 105) as compared to the sub-soil (27.2 x 105) results attached. However the results were also high in the virgin lands both for the sub soil and top soil this was probably because the soils are undisturbed.

4.3 Future work to be done

- Molecular characterization of isolated isolates
- Metagenomic analysis of the isolates
- Development of a soil conditioner
- On-station and on-farm evaluation of the developed soil conditioner.

Table: Characteristics of microbes isolated from farmer soils from Kwale farmer fields.

No.	Microbe	Genus	Species	Starch hydrolysing	Nitrogen fixing	Phosphate solubilisation	Nitrate to Nitrite	Photo
1	**Bacteria**	Bacillus	*Bacillus Subtilis*	Positive				1a
			Bacillus Megaterium	Positive				1b
		Clostridium	*C.Perfringes*					1c
		Psedomonas	*P-Putida*			Positive		2a
2	**Fungi**	Aspargillus						2b
		Trichodarma		positive				2c
		Penicillium						2d
		Fusarium			Positive			2e
3	**Rhizobium**	Rhizobium	*R. Fredii*		Positive			3a
		Prokyryotes			Positive			3b
4	**Actinomycetes**	*streptomyces*	*s.auriginosa*	Positive		Positive		4a

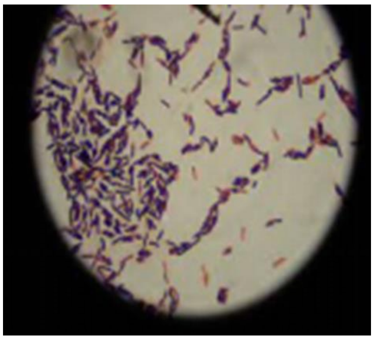


Fig 1a: Bacillus subtil

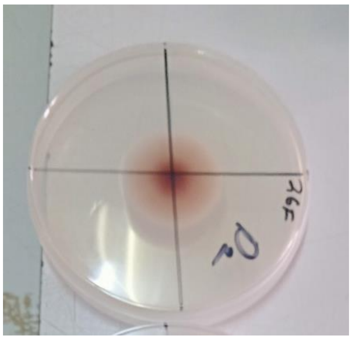


Fig 2b: Fusarium

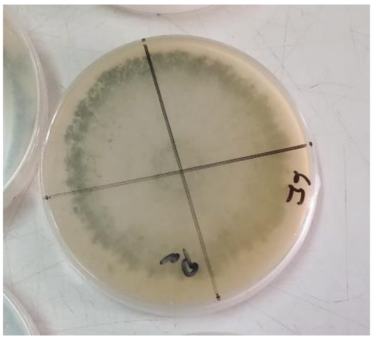


Fig 2c: Trichoderma

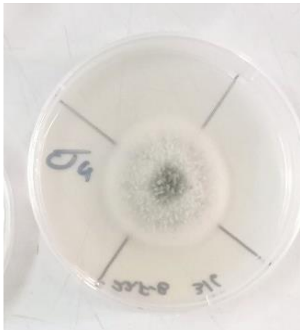


Fig 2d: Penicillium

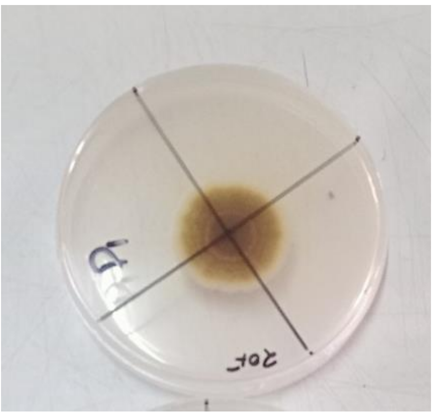


Fig 2e: Aspergillus

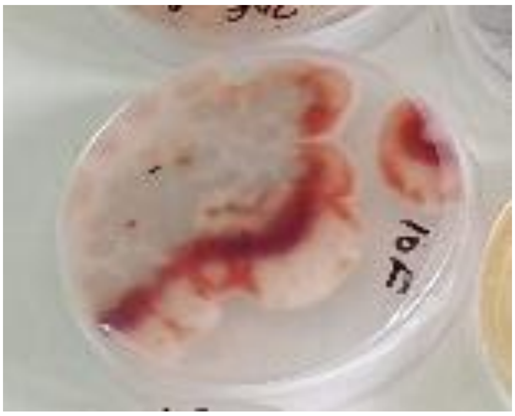


Fig 3a: Rhizobium

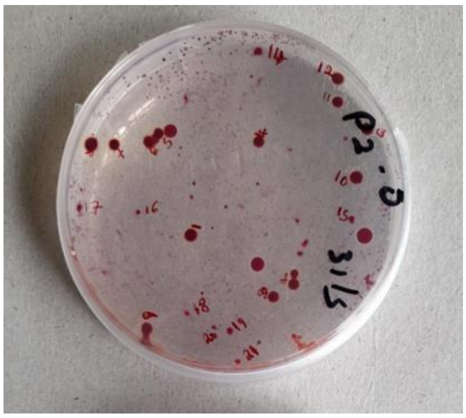


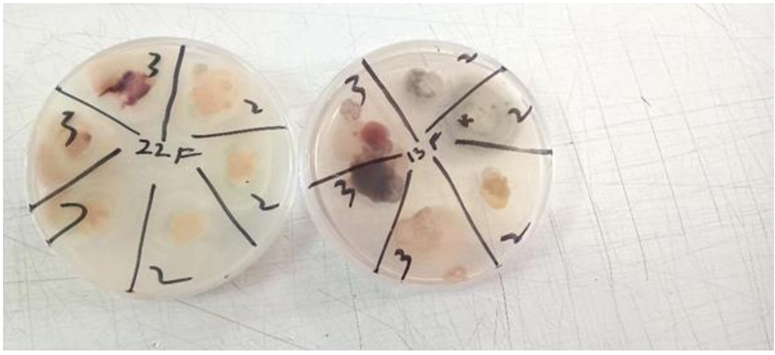
Fig 4a: S.auriginosa

Figure: Morphological characterization of microbes isolated from soil samples.

PICTORIALS

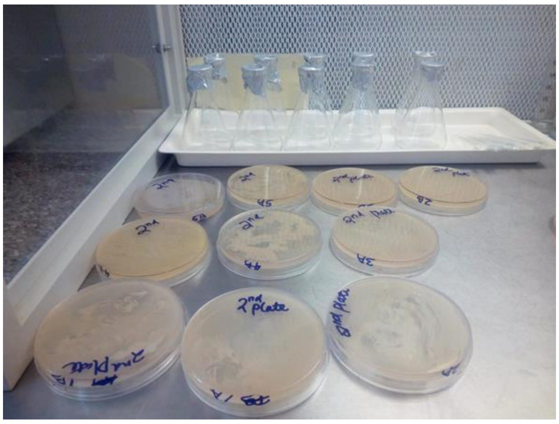
Fig 1: sample preparation

Fig 2: sample culturing and incubation at 37^{o}Cin the lab



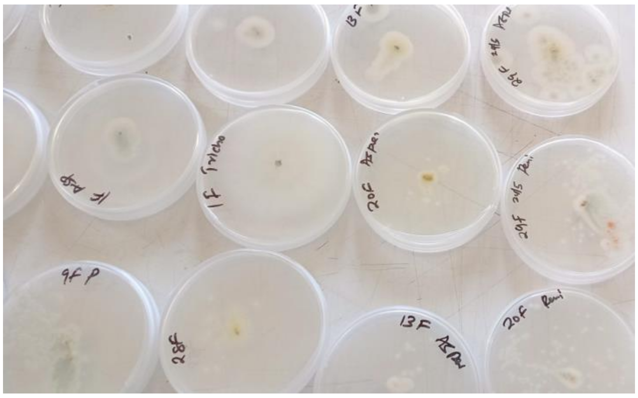
3(a)

Fig 3(a) Sample isolated in the lab

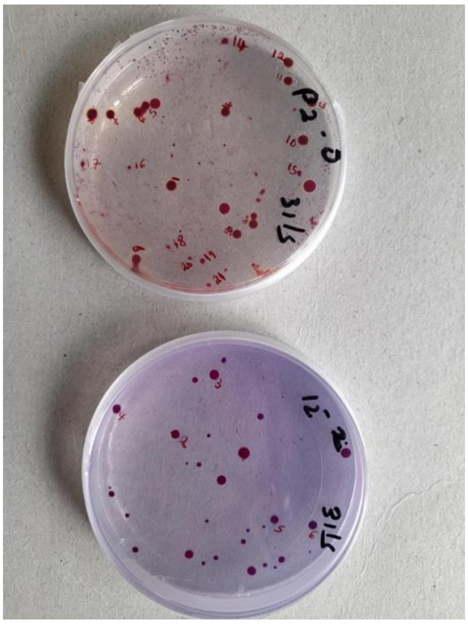


4(a)

Figure 4 (a): Isolation of pure cultures



5(a)



5(b)

Figure 5 (a&b): Pure cultures isolated for identification

Fig (6a)

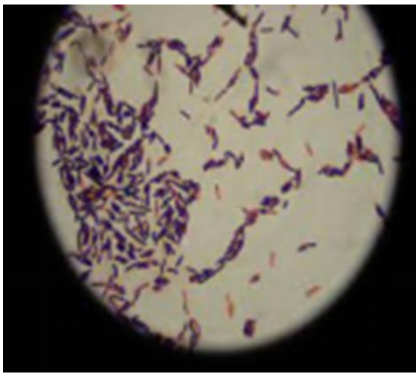


fig (6b)

Fig 6 (a). On going Molecular identification of microbial isolates and Fig (6b)

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11.8 Soil test results

Kenya Agricultural & Livestock Research Organization
National Agricultural Research Laboratories
P. O. Box 14733, 00800 NAIROBI
Email: soil.labs@kalro.org

SOIL TEST REPORT

Name	Esther Muindi, C/O Pwani University
Address	0734617020
Location of farm	Various, Kwale
Crop(s) to be grown	Legumes, Chilli, Vegetables
Date sample received	12/04/2024
Date sample reported	10-06-24

	Soil Analytical Data							
Field	**Sample 1**		**Sample 2**		**Sample 3**		**Sample 4**	
Sample designation								
Lab. No/2024	1557		1558		1559		1560	
Soil depth cm	Top		Top		Top		Top	
Fertility results	value	class	value	class	value	class	value	class
Soil pH	5.93	Mod. acid	5.90	Mod. acid	6.37	Slight acid	6.43	Slight acid
Exch. Acidity meq%								
Total Nitrogen %	0.16	Deficient	0.12	Deficient	0.17	Deficient	0.16	Deficient
Total Org. Carbon %	1.63	Deficient	1.18	Deficient	1.73	Deficient	1.60	Deficient
Phosphorus (Mehlich) ppm	10.7	Deficient	3.9	Deficient	26.8	Deficient	5.5	Deficient
Phosphorus (Olsen) ppm								
Potassium meq%	0.34	Adequate	0.24	Adequate	0.42	Adequate	0.48	Adequate
Calcium meq%	4.2	Adequate	2.6	Adequate	20.0	Adequate	3.0	Adequate
Magnesium meq%	2.83	Adequate	2.72	Adequate	2.35	Adequate	2.57	Adequate
Manganese meq%	0.43	Adequate	0.49	Adequate	0.31	Adequate	0.39	Adequate
Copper ppm	1.78	Adequate	1.34	Adequate	5.53	Adequate	5.09	Adequate
Iron ppm	31.72	Adequate	8.79	Deficient	25.99	Adequate	29.17	Adequate
Zinc ppm	1.60	Deficient	0.57	Deficient	1.54	Deficient	0.69	Deficient
Sodium meq%	0.24	Adequate	0.18	Adequate	0.70	Adequate	0.32	Adequate
Electr. Conductivity mS/cm								

Interpretation and Fertilizer Recommendation

The soil reaction is **moderately and slightly acid. Nitrogen, Organic Carbon, Phosphorus, Iron and Zinc** are deficient. **Legumes, Chillies, Vegetables:** Place **3 handfuls of well decomposed Farm Yard manure** per hole. During planting, apply **10g** per hole of **N:P:K Blended** fertilizer containing **Zinc (Mavuno/Yara/MEA). At 30 and 45 days** after planting, apply **10g/plant and 20g/plant of CAN** fertilizer respectively **(Chillies,Vegetables).**

NOTE: Test results are based on customer sampled sample(s).
Methods used: Information is given out on client’s request.

Reporting officer (through Director NARL) F. WANDERA

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SOIL TEST REPORT

Name	Esther Muindi, C/O Pwani University
Address	0734617020
Location of farm	Various, Kwale
Crop(s) to be grown	Legumes, Chillies,Vegetables
Date sample received	12/04/2024
Date sample reported	10-06-24

	Soil Analytical Data							
Field	**Sample 5**		**Sample 6**		**Sample 7**		**Sample 8**	
Sample designation								
Lab. No/2024	1561		1562		1563		1564	
Soil depth cm	Top		Top		Top		Top	
Fertility results	value	class	value	class	value	class	value	class
Soil pH	6.18	Slight acid	5.51	Mod. acid	6.85	Neutral	6.36	Slight acid
Exch. Acidity meq%								
Total Nitrogen %	0.11	Deficient	0.10	Deficient	0.11	Deficient	0.16	Deficient
Total Org. Carbon %	1.11	Deficient	1.04	Deficient	1.14	Deficient	1.64	Deficient
Phosphorus (Mehlich) ppm	4.7	Deficient	3.9	Deficient	348.4	High	174.6	High
Phosphorus (Olsen) ppm								
Potassium meq%	0.38	Adequate	0.40	Adequate	0.80	Adequate	1.28	Adequate
Calcium meq%	1.0	Deficient	1.0	Deficient	22.6	High	5.2	Adequate
Magnesium meq%	2.79	Adequate	2.63	Adequate	1.56	Adequate	2.64	Adequate
Manganese meq%	0.40	Adequate	0.33	Adequate	0.44	Adequate	0.46	Adequate
Copper ppm	1.34	Adequate	1.34	Adequate	2.67	Adequate	11.26	Adequate
Iron ppm	28.54	Adequate	15.80	Adequate	12.61	Adequate	30.45	Adequate
Zinc ppm	2.70	Deficient	Trace	Deficient	52.00	Adequate	9.59	Adequate
Sodium meq%	0.46	Adequate	0.48	Adequate	0.28	Adequate	0.28	Adequate
Electr. Conductivity mS/cm								

Interpretation and Fertilizer Recommendation

The soil reaction is **moderately, neutral and slightly acid. Nitrogen, Organic Carbon, Phosphorus, Calcium and Zin**c are deficient. **Legumes, Chillies, Vegetables:** Place **3 handfuls of well decomposed Farm Yard manure** per hole. During planting, **apply 10g (Sample 5, 6) and 5g (Sample 7,8)** per hole of **N:P:K Blended** fertilizer containing **Calcium and Zinc (Mavuno/Yara/MEA).** At **30 and 45 days** after planting, apply **10g/plant and 20g/plant of CAN** fertilizer respectively **(Chillies,Vegetables).**

NOTE: Test results are based on customer sampled sample(s).
Methods used: Information is given out on client’s request.

Reporting officer (through Director NARL) F. WANDERA

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SOIL TEST REPORT

Name	Esther Muindi, C/O Pwani University
Address	0734617020
Location of farm	Various, Kwale
Crop(s) to be grown	
Date sample received	12/04/2024
Date sample reported	29/04/2024

	Soil Analytical Data							
Field	**Sample 9**		**Sample 10**		**Sample 11**		**Sample 12**	
Sample designation								
Lab. No/2024	1565		1566		1567		1568	
Soil depth cm	Top		Top		Top		Top	
Fertility results	value	class	value	class	value	class	value	class
Soil pH	6.02	Slight acid	5.87	Mod. acid	6.02	Slight acid	5.30	Mod. acid
Exch. Acidity meq%							0.4	Adequate
Total Nitrogen %	0.18	Deficient	0.09	Deficient	0.07	Deficient	0.07	Deficient
Total Org. Carbon %	1.80	Deficient	0.94	Deficient	0.67	Deficient	0.72	Deficient
Phosphorus (Mehlich) ppm	28.5	Deficient	3.8	Deficient	0.1	Deficient	3.6	Deficient
Phosphorus (Olsen) ppm								
Potassium meq%	0.20	Deficient	0.14	Deficient	0.16	Deficient	0.24	Adequate
Calcium meq%	2.6	Adequate	2.2	Adequate	1.8	Deficient	1.4	Deficient
Magnesium meq%	1.52	Adequate	1.19	Adequate	1.17	Adequate	2.09	Adequate
Manganese meq%	0.25	Adequate	0.19	Adequate	0.15	Adequate	0.52	Adequate
Copper ppm	1.12	Adequate	1.12	Adequate	0.68	Deficient	1.12	Adequate
Iron ppm	3.06	Deficient	3.06	Deficient	10.06	Adequate	15.80	Adequate
Zinc ppm	1.36	Deficient	2.88	Deficient	0.20	Deficient	0.87	Deficient
Sodium meq%	0.14	Adequate	0.16	Adequate	0.14	Adequate	0.18	Adequate
Electr. Conductivity mS/cm								

Interpretation and Fertilizer Recommendation

The soil reaction is **moderately and slightly acid. Nitrogen, Organic Carbon, Phosphorus, Potassium, Calcium, Magnesium, Iron and Zinc** are deficient. **Legumes, Chillies, Vegetables:** Place **3 handfuls of well decomposed Farm Yard manure** per hole. During planting, apply **10g per hole of N:P:K Blended** fertilizer containing **Calcium, Magnesium and Zinc (Mavuno/Yara/MEA)**. At **30 and 45 days** after planting, apply **10g/plant and 20g/plant of CAN** fertilizer respectively **(Chillies,Vegetables).**

NOTE: Test results are based on customer sampled sample(s).
Methods used: Information is given out on client's request.

Reporting officer (through Director NARL) F. WANDERA

11.9 Communication plan

Introduction

Our communication strategy is a vital instrument for facilitating knowledge sharing, engaging the farming community, and fostering increased interest among the youth in agriculture. To effectively reach our target audience, we have devised a multifaceted approach leveraging various channels. This includes utilising local radio stations for targeted broadcasts, distribution of flyers, hosting exclusive field events to showcase innovations, and forming alliances with national media houses to reach a broader audience. Additionally, our active presence on social media platforms ensures regular communication, fostering engagement, relevance, and memorability. This comprehensive communication strategy aligns with our commitment to transparency, community engagement, and impactful outreach, contributing to the success of MKUKI-Kwale.

Communications-specific goal

Facilitate comprehensive and effective communication strategies to amplify awareness, engagement, and support for the MKUKI-Kwale project, fostering a positive perception and understanding among key stakeholders.

Objectives

- **Raise project awareness:** Develop and implement a targeted communication plan to increase awareness of MKUKI-Kwale within the local community and among stakeholders.
- **Engage stakeholders**: Establish regular communication channels to engage with project stakeholders, including farmers, government entities, project partners, and the wider community.
- **Highlight achievements and milestones:** Create a dynamic content calendar to showcase and communicate the significant strides made by the farmers' co-operative, emphasizing the installation of the maize mill and progress in acquiring the cotton ginnery.
- **Position agribusiness as a catalyst for growth**: Craft and disseminate compelling narratives that highlight the transformative impact of the project, particularly its role as a catalyst for growth across adjacent sectors such as education, transportation, warehousing, processing, and packaging.
- **Emphasise financial empowerment and social impact**: Develop targeted messages to underscore the financial empowerment aspect of the project, specifically addressing the issue of children dropping out of school due to a lack of fees (a key challenge in Kwale county). Showcase how the project contributes to meeting essential community needs.
- **Share lessons learned and global impact:** Establish a platform to share key insights and lessons learned from the MKUKI-Kwale project, with a focus on extrapolating these lessons for the benefit of other mine closure sites across Africa and globally.
- **Utilise varied communication channels:** Implement a multi-channel communication strategy, incorporating local radio stations, flyers, field days, national media houses, and social media platforms to ensure a comprehensive and targeted approach for different audiences.
- **Measure and analyse communication impact:** Implement robust monitoring and evaluation mechanisms to measure the impact of communication strategies, assessing engagement levels, sentiment, and the overall effectiveness of the communication plan.

By aligning communication efforts with these specific objectives, we aim to create a strong and positive narrative around the MKUKI-Kwale oroject, fostering understanding, support, and sustainable growth within the community and beyond.

Aim

Knowledge sharing, engage audience and increase youth interest in agriculture. The stakeholders listed below include Research Scientists, National Research Institutions, Input suppliers, offtakers.

Communications schedule (April to September 2024)

Activity and purpose	Output	Frequency	Target audience	Channels (% reach)[17]
Project overview Share a brief write up introducing the project, its mission, and objective	A write up on the project its objectives, the problem its solving and potential impact	Recurrent for 8 weeks Bi-Annually	Farmers Stakeholders Policy makers	Radio Brochures (80%)
Farmer field day Farmer interviews, Share photos of the projects progress	Photos of project area, beneficiary, farms, and products	Quarterly	Farmers Stakeholders Policy makers	TV Radio Social media (80%)
Farmer spotlight Feature a beneficiary of the project	Story of a beneficiary and why they joined the project	Monthly	Farmers Stakeholders Policy makers	Social media (50%)
Fun fact Friday Share an interesting agricultural fact or trivia to engage followers	Agricultural fact or trivia that will be engaging audience and motivating their creativity and interest in the project	Last Friday of every month	Farmers Stakeholders Policy makers	Social media (50%)
Sound bite Create sound bite of the month	Sound bite relating to the project	Last Friday of every month	Farmers General public	Social media (50%)
Sustainable practices Share tips on sustainable farming practices or highlight eco-friendly initiatives	Photos, videos, and results of sustainable farming practices that are eco-friendly	Monthly	Farmers General public	Social media (50%)

[17] Social media refers to Facebook, Instagram and LinkedIn.

Activity and purpose	Output	Frequency	Target audience	Channels (% reach)[17]
Technology in agriculture Discuss the use of technology in farming, such as precision agriculture or farm management apps.	Photos of training process using technology, either digital platform on farm exercise with a beneficiary	Quarterly	Farmers General public	Social media (50%)
Behind the scenes Give a behind-the-scenes look at daily production processes	Short, interesting videos of feed processing and maize milling process from production to packaging	Quarterly	Farmers General public	Social media (50%)
Community engagement Highlight any community events, partnerships, or collaborations	Farming training event coverage with collaborators and invited partners	Monthly	Farmers General public	Social media (50%)
Product highlight Showcase a specific product, its uses, and customer testimonials	Maize flour show case, photos of product, customer testimonials	Monthly	Farmers General public	Social media (50%)
PAVI member testimonials Share testimonials or reviews from satisfied members	Poultry farmer testimonial with photos of the farmers birds or eggs from using project poultry feed	Quarterly	Farmers General public	Radio Social media (50%)
Seasonal planting tips Share tips and best practices for planting crops during the current season	List of crops and when they should be planted according to the season	Monthly	Farmers General public	Social media (50%)
Farm-to-table recipes Share recipes using farm products	A short meal easy to make recipe and video of a meal from product.	Quarterly	Farmers General public	Social media (50%)

Activity and purpose	Output	Frequency	Target audience	Channels (% reach)[17]
Team spotlight Feature testimonials from team and the role they play in the project	Interview coverage of team.	Last Friday of the month	Farmers General public	Social media (50%)
Seasonal harvest celebrations Celebrate the harvest season with special posts and offers	Photos of harvested product, beneficiary harvesting, and produce presented for value addition.	Bi-annually	Farmers General public	TV Social media Village baraza Flyers (50%)
Farmer's market feature Promote participation in a local farmer's market or share insights from one	Show evidence with photos and videos from farm to market to show completion of the chain	End of every cropping season	Farmers General public	Social media (50%)