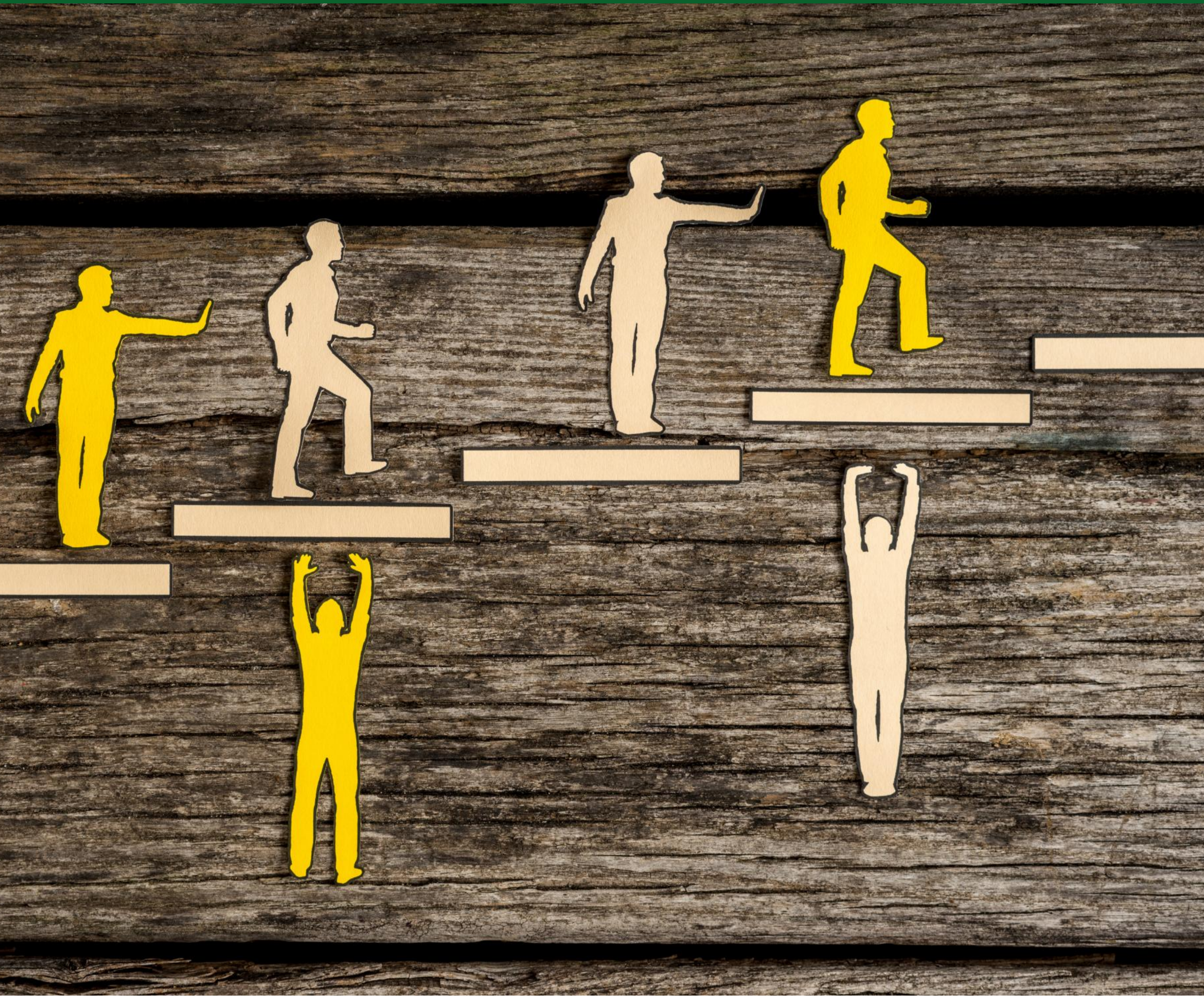
Stakeholder Consultations:

Impact Based Forecast Development



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AICCRA
Accelerating Impacts of CGIAR Climate Research for Africa

REPUBLIC OF KENYA
MINISTRY OF ENVIRONMENT AND FORESTRY
KENYA METEOROLOGICAL DEPARTMENT

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Acknowledgements

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Executive Summary

The work focuses on advancing impact-based forecasting (IBF) as a tool to better connect weather and climate information with the real needs of decision-makers and communities. Implemented in Machakos, Makueni, and Nairobi counties, the work combines research and participatory workshops with gendered facilitation to identify priority impacts, assess data gaps, and co-develop recommendations for strengthening the usability of forecasts. The consultations revealed that stakeholders are most concerned with receiving timely and actionable forecasts on the impact of planting dates on crop yield.

Other priority areas included market conditions, particularly price fluctuations and access during climate extremes; road access and transport disruptions, which directly affect market linkages and delivery of farm inputs; pest and disease outbreaks, which are strongly influenced by weather patterns; and harvest conditions, especially rainfall and humidity that influence crop losses and post-harvest handling. Recognizing that these outcomes are shaped by a range of factors, stakeholders emphasized the importance of integrating socio-economic indicators into IBF processes.

The importance of an inclusive, gender-transformative approach to implementing IBF emerged as a key finding, particularly given the distinct agricultural decision-making patterns observed across gender and age groups. These differences were connected to varying priorities shaped by caregiving responsibilities and land ownership. Men predominantly focused on farming as a source of income, whereas women and elderly men prioritized meeting nutritional requirements alongside income generation. These insights emphasize that forecasts must extend beyond simple weather data to offer actionable information about potential impacts on farming operations, market conditions, and essential infrastructure.

The discussions also highlighted a number of challenges around data availability and accessibility. At the county level, participants noted that much of the relevant data exists but remains undigitized and is available only in fragmented formats, which limits integration into forecasting systems. At the national level, stakeholders emphasized the issue of non-dynamic vulnerability datasets, which are not regularly updated to reflect changing socio-economic realities and emerging risks. Addressing these data-related challenges is essential if IBF products are to be relevant, credible, and actionable.

Based on these findings, the project recommends expanded and systematic data collection across counties, with prioritization of digitization to improve accessibility and usability. The data collection

on the vulnerability data can be done at the same time when yield datasets are being collected. At the national scale, there is a need to establish mechanisms for the regular updating of vulnerability datasets to capture dynamic changes in risk profiles. In addition, strengthening cross-sectoral collaboration will ensure that IBF integrates agricultural, market, infrastructure, and social data, thereby creating comprehensive decision-support tools that are demand-driven and user-focused.

This work carries important policy relevance. The outcomes of the project align with Kenya's National Climate Change Action Plan (NCCAP) and the County Climate Action Plans (CCAPs), both of which emphasize the importance of climate services in building resilience and informing adaptation. By embedding IBF approaches into these frameworks, national and county governments can strengthen early warning systems, improve agricultural planning, and enhance climate risk management. Ultimately, integrating IBF into policy and practice ensures that forecasts are not only scientifically robust but also socially meaningful, directly benefiting vulnerable communities and supporting Kenya's broader climate resilience agenda.

1.0 Introduction

Weather and climate services are increasingly recognized as critical components of climate adaptation strategies, particularly within the agriculture sector (Hansen, Mason, Sun, & Tall, 2011; Mburu, Mutune, & Wekesa, 2022). These services support seasonal decision-making related to crop planning, varietal selection, resource allocation, and preparedness for extreme weather events. Despite notable improvements in the accessibility of climate information, its utility in facilitating equitable and anticipatory responses, especially among vulnerable smallholder communities remains limited (Carr & Owusu-Daaku, 2016; Partey, Zougmoré, Ouédraogo, Campbell, & Nyasimi , 2020).

Impact-Based Forecasting (IBF) represents a transformative advancement in climate information services (WMO, 2021). Departing from conventional meteorological forecasts that primarily communicate atmospheric variables, IBF integrates climate, agricultural, and socio-economic data to assess the potential consequences of weather events on specific sectors and populations. This paradigm shift, from forecasting "what the weather will be" to "what the weather will do" enables risk-informed decision-making by identifying at-risk groups, estimating sectoral impacts, and guiding timely early action (Coughlan de Perez, et al., 2015; WMO, 2021).

In agriculture, IBF equips farmers, extension services, policy actors, and disaster risk managers with anticipatory insights into how climate shocks such as droughts, floods, or pest outbreaks may influence yields, livestock health, water resources, and food security. By translating forecasts into locally relevant risk scenarios, IBF supports targeted advisories, resource mobilization, and the pre-financing of adaptive responses. This approach also improves the timeliness and spatial accuracy of interventions by accounting for dynamic vulnerability patterns (Wilkinson, et al., 2018).

This study presents findings from a pilot IBF initiative conducted in Kenya's Machakos and Makueni counties. The project aims to enhance the usability of climate information by co-developing a context-specific IBF prototype for agricultural decision-making, in alignment with national adaptation goals outlined in Kenya's Climate Adaptation Strategy (GoK, 2016). Through multi-stakeholder consultations held in Machakos, Makueni, and Nairobi, the project explored stakeholder perceptions, assessed data systems, and examined how gender and social inclusion can be mainstreamed within IBF processes. This report summarizes the key insights from these consultations and offers recommendations for strengthening IBF implementation in Kenya.

2.0 Methodology

The study applied a participatory, qualitative design with stakeholder workshops in Machakos, Makueni, and Nairobi Counties. Each session engaged about forty participants, while additional one-day workshops with groups of forty smallholder farmers were held in Machakos and Makueni. The smallholder farmers were drawn from the different districts of the counties and represented diverse age groups. These workshops aimed to gather insights on seasonal agricultural planning, vulnerability to climate risks, and information needs related to impact-based forecasting (IBF).

The additional stakeholders at the county level included representatives from climate information providers, agricultural extension officers, researchers, humanitarian, county government representatives, insurance firms and banks. Each workshop followed a structured format comprising expert presentations, plenary discussions, and facilitated group exercises. The participatory approach was designed to foster dialogue across the climate services value chain, enabling the co-identification of data gaps, user needs, and institutional challenges for implementing IBF in agricultural decision-making.

A structured survey instrument was administered to all participants. To ensure internal validity, selected survey items were rephrased and repeated in different formats to triangulate responses and minimize social desirability bias. To evaluate the agricultural requirements for impact-based climate forecasting, simulation maps depicting climate–agriculture interactions were generated and presented. CHIRPS rainfall datasets (Funk et al., 2015) was utilized to come up with the drought severity and total rainfall over an area. The initial component addressed baseline climatic patterns and intra- and inter-seasonal variability across Machakos and Makueni, with emphasis on rainfall distribution (Figure 1a). Subsequent components quantified the spatial heterogeneity of climate-related hazards, particularly drought severity, and delineated zones of differential vulnerability within the two counties (Figures 1b and 1c).

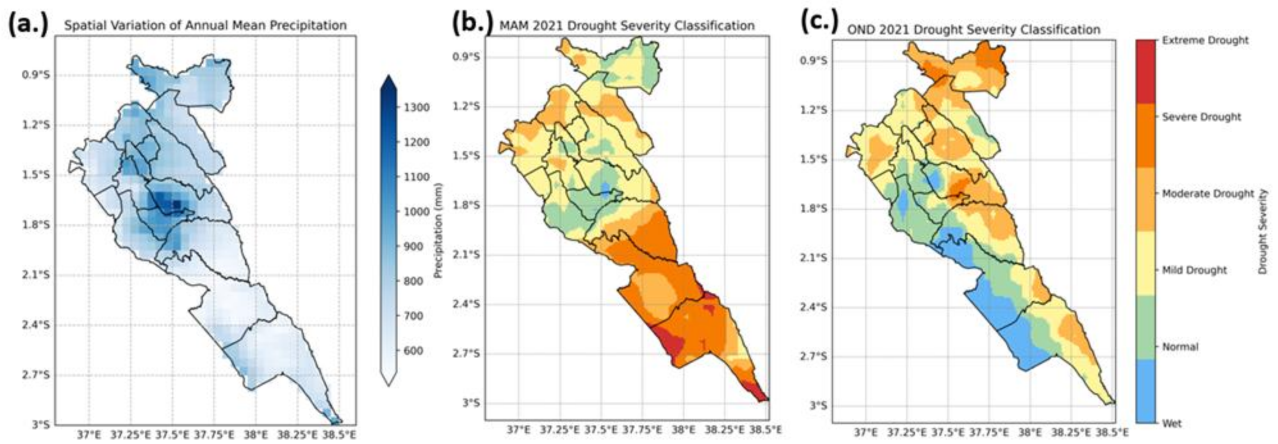

Figure 1 a.) Mean annual spatial variation of rainfall over Machakos and Makueni counties. b.) March April May Drought severity classification based on 2021 rainfall. c.) October, November, December Drought severity classification based on 2021 rainfall.

Participants were introduced to the potential agricultural impacts, with a focus on beans. Using observational datasets, water availability was analyzed across all phenological stages from planting to maturity (Figure 2). This framework illustrated the influence of climate variability on crop development, showing how deviations in rainfall, categorized as below normal, normal, or above normal, at one stage can cascade to affect subsequent growth stages and ultimately yields. Pest and disease risk profiles were also presented, identifying phenological stages most vulnerable to infestation and mapping the occurrence of key pests and diseases across seasons (Figure 3a). Additional simulations assessed the risks of waterlogging in agricultural zones, projected crop yield losses, and estimated changes in the proportion of cropland exposed to extreme weather events (Figure 3b). Finally, population-level exposure metrics were derived, quantifying the number of people potentially affected by yield reductions or cropland impacts.

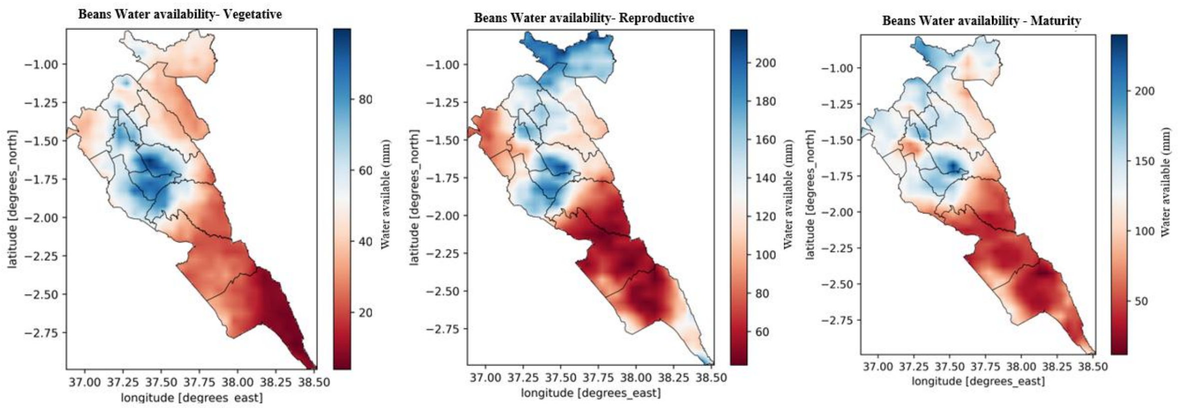

Figure 2: Beans water demand across three phenological stages (Vegetative, Reproductive and Maturity) in three months (October, November, and December) based on 2021 rainfall. The stages highlight the amount of available water in the soil to sustain bean development. Inadequate water in the preceding stage may have a significant impact on the subsequent stage, regardless of favorable conditions, and vice versa.

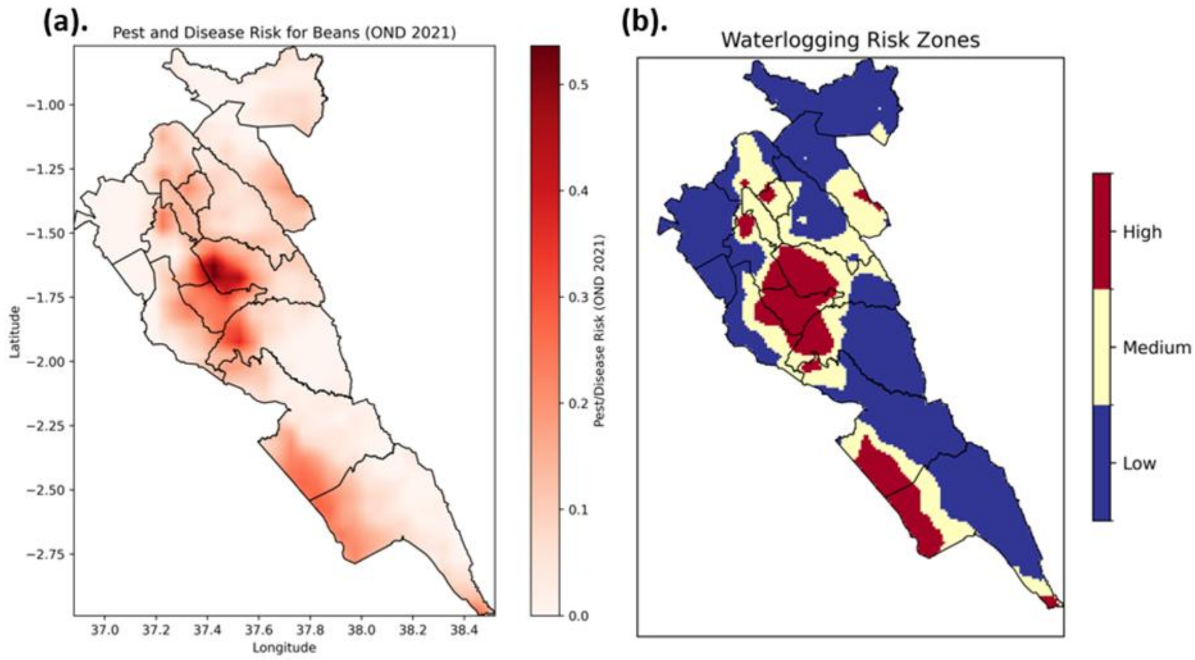

Figure 3:a) Average risk areas for seasonal pests and diseases. This is based on the variation in pests and diseases prevalence across bean phenological stages throughout the season. The average shows areas with potential simulated high-risk agricultural zones.

The presentations also focused on exposure and adaptive capacity, emphasizing their role in shaping differential risks and vulnerabilities across regions (Figure 4). An interactive session was conducted in which participants identified key factors they considered essential for assessing local adaptive capacity to climate impacts. Discussions also highlighted that the effectiveness of agricultural responses to extreme weather events is closely linked to the level of awareness and familiarity with available adaptation and mitigation measures within each region.

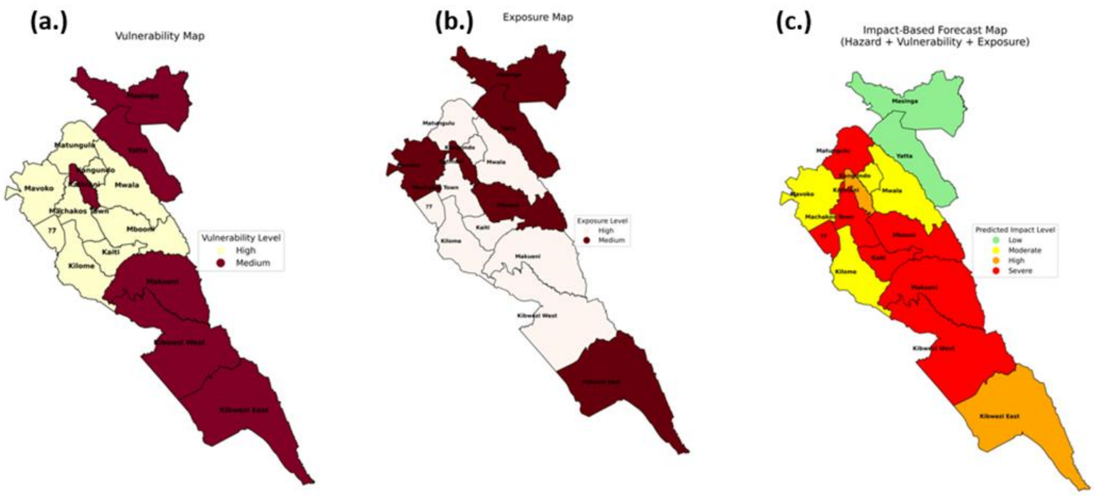

Figure 4a.) Vulnerability, b.) exposure and c.) risks/impact level analysis based on the dummy data. This is to provide information on the adaptive capacity/vulnerability level of the community, indicating whether it is well-prepared or has adequate resources and knowledge to react in the event of extreme weather events.

The presentation was followed by a plenary session that gathered comprehensive feedback, incorporating scientific expertise, traditional and indigenous knowledge, sector-specific insights, and the practical needs and experiences of smallholder agricultural stakeholders. This inclusive discussion allowed for a richer understanding of local challenges and opportunities in applying impact-based climate forecasting.

3.0 Results

3.1 Engagement with Local Farmers in Machakos and Makueni

Survey completion rates reached 70% for farmer workshop participants and 81% for intermediary workshop participants. Female farmers were primarily aged 35-54, while male farmers were evenly distributed across age groups.

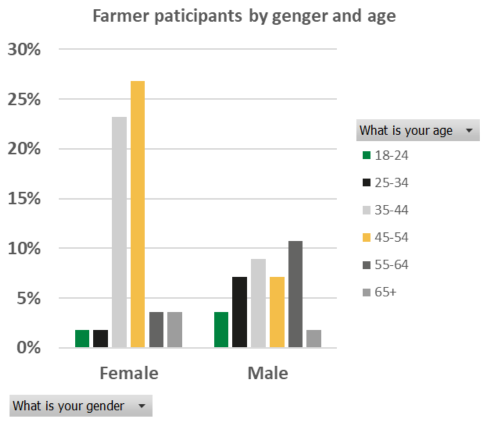

Figure 5: Demographics: Farmer Stakeholders in Machakos and Makueni disaggregated by sex and age

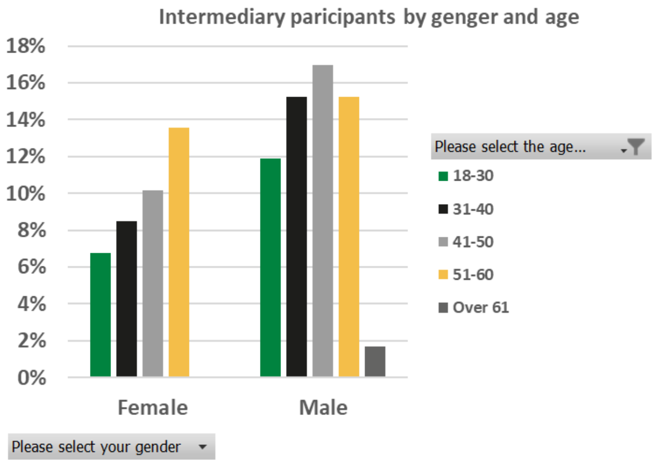

Figure 6:Demographics: Intermediaries Stakeholders in Machakos and Makueni disaggregated by sex and age

Farmers' participation in cooperatives and farmer groups is strongly associated with improved market access and agricultural productivity in Machakos and Makueni counties. For instance, in Machakos, membership in such groups significantly increased farmers' likelihood of accessing markets through better access to climate information, extension services, credit, and transportation (Ingutia & Sumelius, 2022). In a study involving 521 households in Makueni, showed that when women joined farmer groups, particularly savings-based groups, they were more likely to access credit, training, and inputs, which supported their yield stability and resilience (Machio, Sallu, Waized, Akwilina , & Kwaku , 2025).

Eighty-six percent of farmers in our engagement reported group membership, with women aged 35–54 being particularly active participants; male youth (under 35), men aged 55–64, and women over 65 also showed high levels of involvement as shown in Figure 3 below. This pattern reflects broader trends in the region, where group affiliation enhances farmers' capacity to access essential services and collectively address climate-related challenges.

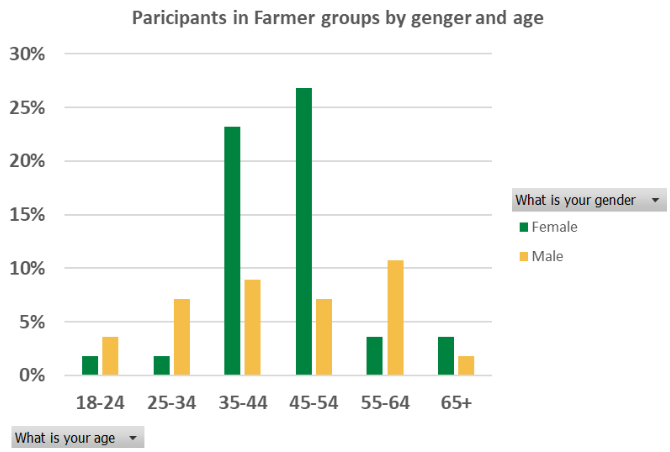

Figure 7:Participants in farmer in Machakos and Makueni disaggregated by sex and age

Among participating farmers, 46% reported selling less than half of their agricultural produce, while the majority sold more than half. However, only 7% of respondents sold over 75% of their yield. Implying that most of what is grown in the county is for household consumption. Although sex-disaggregated data did not reveal significant differences in marketing behavior, age-based disaggregation highlighted notable trends. Youth participants (under 35) reported selling between 25% and 100% of their produce, indicating greater market engagement. In contrast, elderly men over 60 years old, as noted in key informant interviews, primarily farmed for household consumption. Farmers aged 35 to 54, both male and female, commonly practiced mixed cropping, emphasizing crop diversity to support household nutrition. The highest diversity in marketing behavior was observed among individuals aged 45–54, who showed no dominant trend in the proportion of produce sold, with responses spanning all marketing categories.

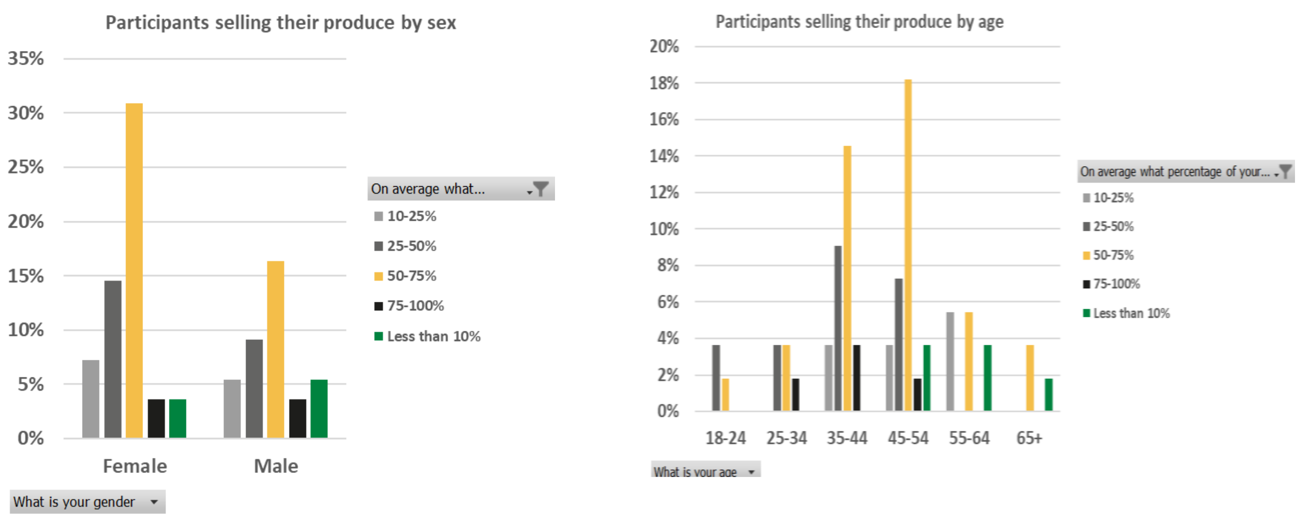

Figure 8: Percent of produce being sold by farmers disaggregated by sex and gender

Farmers in Machakos and Makueni increasingly depend on the October–December short rains (OND) as the March–May long rains (MAM) become less reliable; an observation consistent with studies showing reduced rainy days and shifting rainfall patterns across Eastern Kenya's semi-arid regions (Recha, et al., 2014; Omoyo, Jacob , & Oteng'i , 2015; Elizabeth & Mwania, 2023). 55% of intermediaries stated OND as the most important season with an additional 22% stating that both seasons were significant. Agricultural practices vary geographically; Makueni's highlands receive relatively more rain than its semi-arid lowlands, affecting cropping decisions and climate risk exposure. During focus group discussions, farmers reported a range of climate-related hazards droughts, floods, pest outbreaks, and diseases mirroring documented impacts of high climate variability on maize yields across the region (Elizabeth & Mwania, 2023).

Increasing rainfall variability, marked by poor distribution, prolonged intra-season dry spells, and off-season precipitation, was identified as a key driver of both crop failure and post-harvest losses. In addition, unexpected moisture events (e.g., fog, mist) and reduced sunshine in highlands have harmed crop drying, elevating risks of spoilage and aflatoxin contamination. Notably, farmers also reported new hazards, such as hailstorms and lightning, phenomena previously rare in the area, causing crop damage and even fatalities. These emerging risks underscore the importance of impact based climate forecasting. Yet current downscaled seasonal forecasts, while aligned to broad agroecological zones, were reported by farmers to inadequately capture micro-scale spatial variability within wards, limiting their effectiveness for local-level agricultural planning.

In Machakos and Makueni counties, smallholder farmers cultivate a diverse array of staple crops, including maize, beans, cowpeas, pigeon peas, green grams—and supplementary crops such as sorghum, sweet potatoes, and cassava. Orchard fruit trees like mangoes, oranges, pawpaws (papayas), and avocados are also commonly grown (Muhammad, Domisiano, Mwangi, & Roberto , 2009; Mbugua & Nyamongo, 2010; Peters, et al., 2012).

The cropping calendar across these counties is highly synchronized: land preparation occurs roughly one month before the onset of the short rains, followed by planting either in anticipation of rain ("dry planting"), during the early rains ("wet planting"), or as a combination of both approaches through staggered planting. As part of the stakeholder consultation sessions, farmers were tasked to collaboratively develop their own cropping calendars, drawing on local knowledge of rainfall patterns, planting strategies, and seasonal farm activities. In Makueni, the farmers were stratified into groups by gender and age (i.e., women, men, youth, and elderly), while in Machakos, groupings reflected the administrative wards they represented. During the cropping season, farmers perform weeding, spraying, and apply fertilizers, often with adhesives to reduce runoff during rains. Pest and disease monitoring are ongoing, and harvests may be timed as green harvests or after crop drying.

Crops like cowpeas are harvested during the growing season as well as the leaves are used for vegetables and the seeds harvested while green and while dry. Post-harvest, grains are further dried and either consumed or sold in local markets.

This cropping pattern involving intercropping maize with legumes like beans, cowpeas, and pigeon peas is consistent with agro-ecological practices documented in semi-arid regions of Kenya (Kyalo, et al., 2017). For example, studies in Machakos report that maize intercropped with pigeon pea can yield ~24% more than sole-maize systems while improving soil fertility over time (Rao & Mathuva, 2000). Survey data from FGDs in Machakos and Makueni confirm these stacked cropping systems, emphasizing crop diversity and food security. Fruit trees such as mangoes and avocados also contribute nutritionally and economically to smallholder livelihoods, aligning with findings from Kenya's Eastern Province.

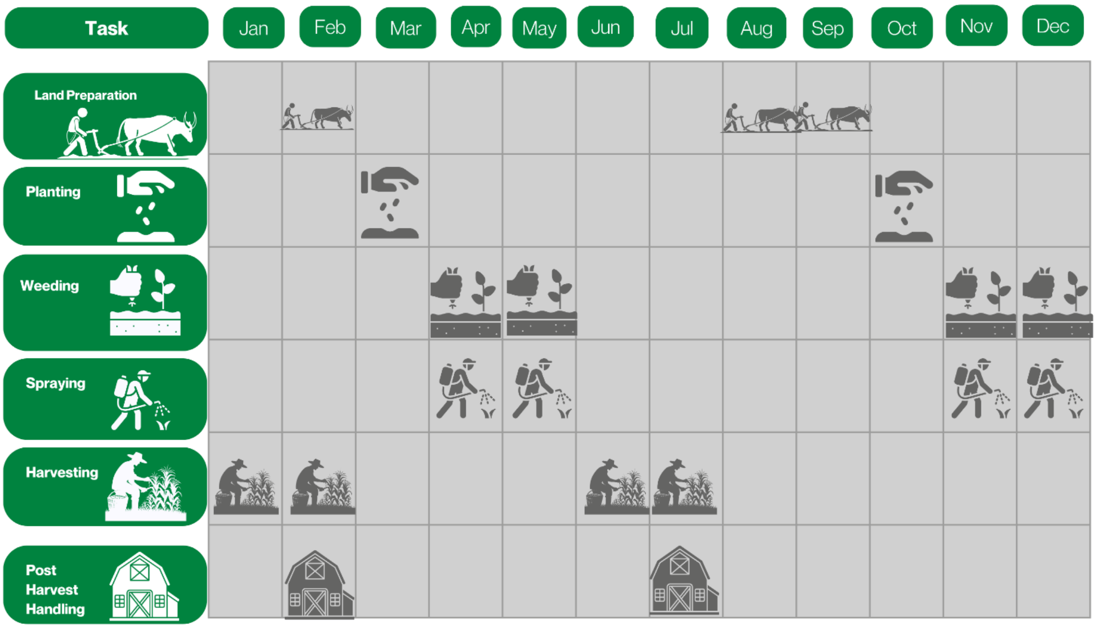

Figure 9: Compilation of farming calendars from Machakos and Makueni

Task	Preferable climatic conditions	Justification
Land Preparation		Dry weather makes for easy ploughing, rains could lead to water logging making the soil difficult to plough
Planting		Dry planting or wet planting can be done depending on preference. Challenges with dry planting include false onset which could destroy the seed
Weeding		Weeding is done during the brief dry spells during the rainfall season or through the rainfall season if no dry spells
Spraying		Spraying is mainly done in the early morning or evening. Adhesive agents (stickers) are added to pesticide if it rains to reduce wash-off and enhance effectiveness
Harvesting		Harvesting is done after the crops have been left to dry, however some of the crop is harvested while green
Post Harvest Handling		Post-harvest handling is largely done using sunshine to dry the crops, any moisture in this season could destroy the crops

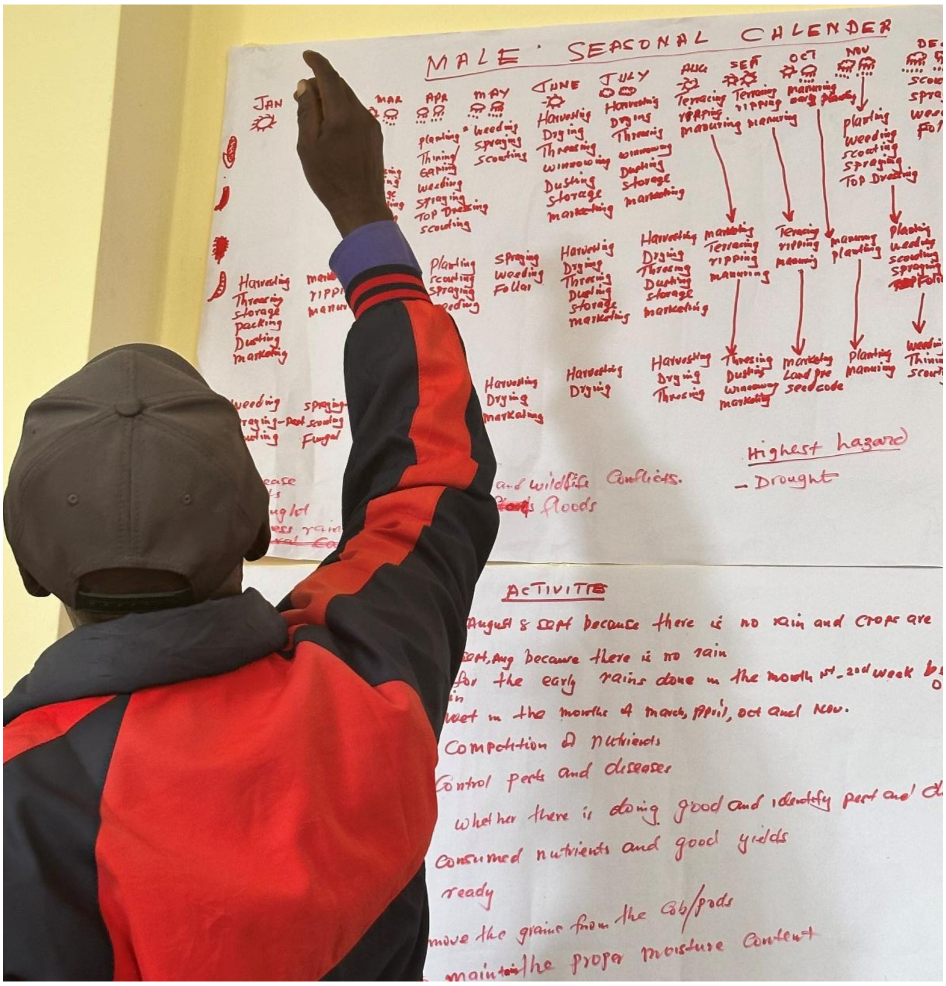

Figure 10: Impacts of weather on farming calendar in Machakos and Makueni

In the interaction with intermediary organizations who disseminate climate information to farmers, 77% of the respondents stated to know about Impact Based Forecast (IBF). All of the respondents stated an interest in receiving IBF products, reiterating that they would like information on actions to reduce negative impacts of weather. The most requested IBF product was on the impact of planting dates on the crop yield and growth, and the timing of the harvest some participants stated harvest losses due to off season rainfall, unplanned mist/dew. Other information requested includes

- Impact of pests and diseases on yield and food quality
- Impact on Water availability/planning on irrigation
- Impact of Market access/ transport disruption on income
- Impact on Livestock health and movement
- Early warnings on droughts and floods
- Post -harvest conditions

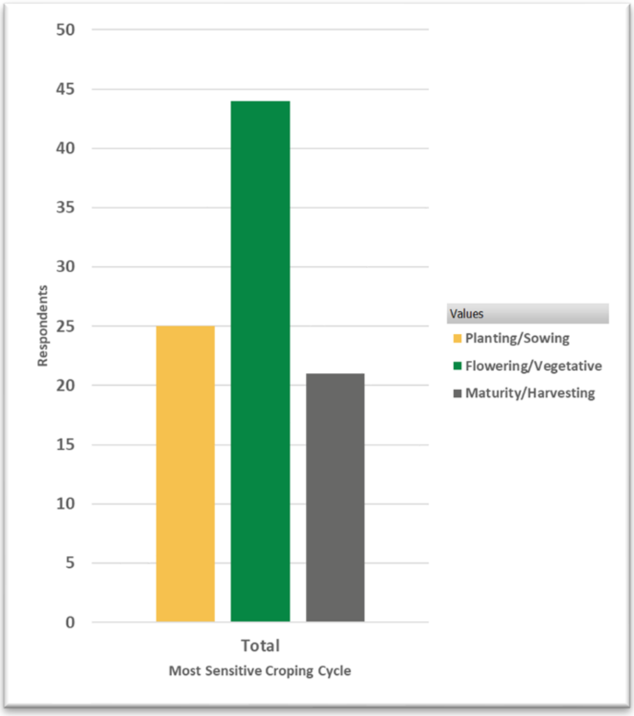

Figure 11: Cropping cycle most vulnerable to weather conditions

3.2 Engagement with stakeholders in Machakos and Makueni

In Machakos and Makueni counties, farmers intermediaries perceive the flowering and vegetative stages of crop development as the most climate-sensitive periods, consistent with broader findings from semi-arid regions of Kenya. Insufficient rainfall during these stages significantly increases the likelihood of crop failure, while excessive rain can cause issues such as waterlogging and fungal attacks. The sowing phase was identified as the next most vulnerable stage, as inadequate soil moisture impairs germination. Although crop maturity itself is considered less sensitive since physiological development is largely complete, excessive rain at harvest interrupts drying and increases post-harvest losses, echoing research from other parts of the country on how variable moisture conditions escalate aflatoxin contamination in maize during maturity and post-harvest (Temba, et al., 2021; Gachara, et al., 2022).

Emerging hazards like hailstorms and increased mist or fog in highland areas have exacerbated crop losses, highlighting gaps in current climate risk assessments, which largely focus on temperature and rainfall averages (Recha, et al., 2014). Key informant interviews stated that current downscaled forecasts, tailored to agroecological zones, inadequately capture such microclimatic variations aligns with calls in the literature for higher-resolution, locally calibrated models to guide adaptive farming practices. This mismatch between forecast resolution and observed on-farm climate variability underscores the need for improved diagnostic tools to support precision agriculture in these two counties.

When asked about their preferred channels for receiving Impact-Based Forecast (IBF) products, almost all intermediaries indicated multiple mediums of communication, however the most common preference for SMS or mobile applications, followed by email and radio. Television was the least favored option. Media personnel present at the engagement expressed a preference for conducting direct interviews with the producers of the information rather than receiving it through other communication platforms. They also emphasized the need for capacity building among journalists to improve their understanding of climate information terminology. In addition, sensitizing editors on the importance of climate information services is critical to ensure that IBF products are accurately framed, effectively prioritized in media content, and communicated in ways that support public understanding and timely decision-making. The intermediaries further stated that they would like to receive these products weekly.

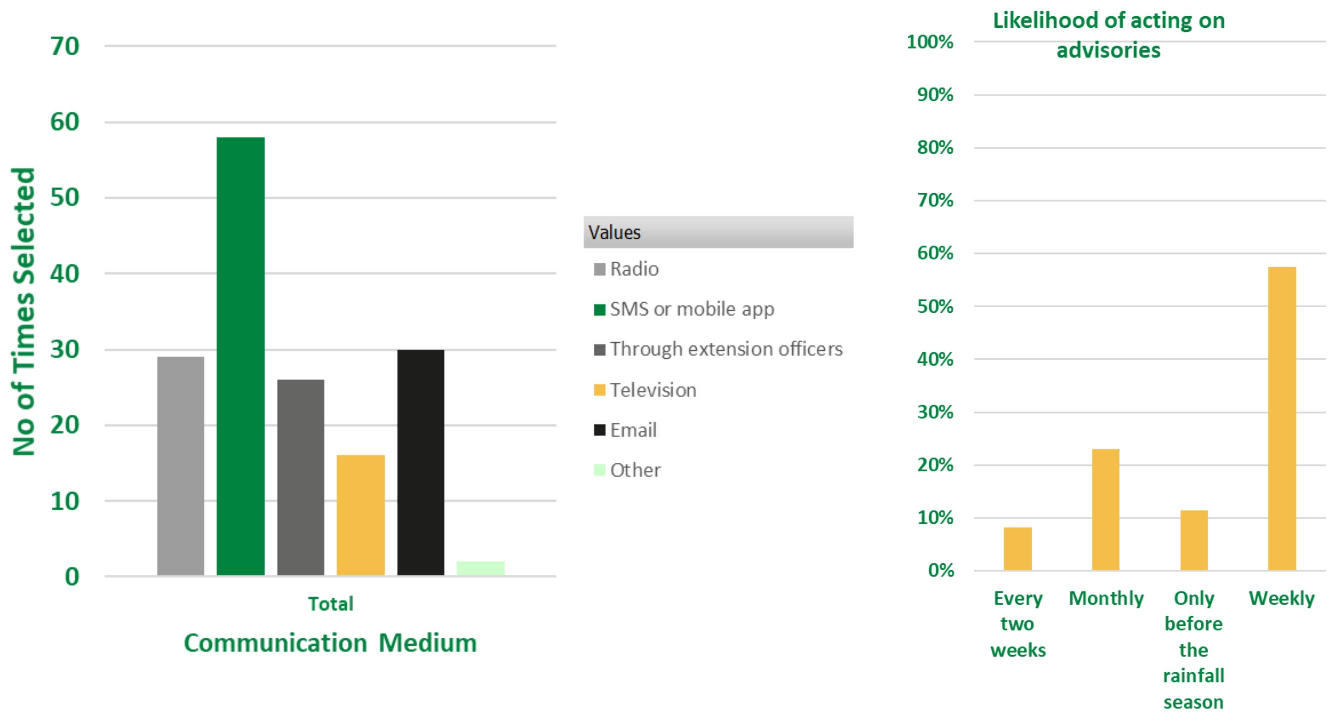

Figure 12: Most common communication channels and frequency of IBF products desired

3.3 Feedback from Intermediaries

3.3.1 Users in the Agriculture sector

When a forecast indicates potential negative impacts on crop yield, Kenya's Ministry of Agriculture initiates a structured, multi-layered response process. Initially, the Ministry assesses specific risks to farmers. If an impending disaster is identified, a coordinated meeting with other relevant departments is convened to determine appropriate intervention measures. Subsequently, county governors are engaged, and counties usually allocate 2% of their annual budgets for disaster response. Should projected damages exceed this allocation, governor's request additional funding from the national government (The World Bank, GFDRR & USAID, 2015; MoALD, 2023).

Parallel to budgetary planning, the Ministry monitors crop conditions at the ward level, targeting aid to communities with forecasted crop failures. To bolster climate resilience, the Kenyan government has collaborated with insurance providers to offer subsidized crop insurance through public–private partnerships. This scheme utilizes area-yield index insurance: when average harvests fall below historical norms, payouts compensate farmers for the shortfall. For instance, if a region's average yield is twenty bags per acre but only five bags are harvested due to adverse climate, insurance covers the difference.

Participants from the agriculture related sector indicated that farmers in Machakos and Makueni counties base their agronomic decisions on several critical factors:

- Forecast timeliness: Early receipt of seasonal forecasts enables farmers to better prepare their cropping plans, consistent with studies indicating that timely weather information enhances agricultural decision-making across Kenya (Hansen, et al., 2019; van der Horst, et al., 2022; Ahmed & Givens , 2025).
- Economic considerations: Farmers weigh the cost-effectiveness of recommended actions, such as transitioning to drought-tolerant crops instead of purchasing expensive agrochemicals; a behavior documented in Eastern Kenya's semi-arid agricultural systems.
- Spatial specificity and food security impacts: Decisions are guided by whether forecasts indicate hazards in specific areas, projected effects on food security, and coverage in terms of cultivated acreage.
- Dissemination mechanisms: The effectiveness of the forecast is judged by who delivers it, when, and by what channel (radio, SMS, social media, extension agents, or local meetings). This aligns with findings that a blended communication strategy enhances uptake of climate advisories.

- Comparative performance: Decision makers compare impacts with the previous season's and historical climate experiences to assess vulnerability.

Stakeholders expressed a strong interest in Impact-Based Forecasting (IBF) and emphasized the importance of integrating advisories that recommend crop varieties resilient to forecast climate impacts. They identified their roles within the IBF framework as contributing to the co-design of impact advisories and facilitating the dissemination of tailored information to end users.

3.3.2 Research Community

The research community comprised of climate scientist at the county level as well as researchers from the agricultural space. Their roles in IBF as described by them includes

- Monitoring of various weather parameters including soil moisture and crop phonological observations in each sub-county
- Down-scaling the National Seasonal and Sub seasonal forecasts and identifying suitable advisories
- Provision of seasonal and sub-seasonal IBF forecast for each sub-county
- Timely dissemination of IBF information.

The research team consulted on the Impact-Based Forecasting (IBF) process highlighted several challenges, including the limited density of meteorological stations across different agro-ecological zones, which has affected the spatial accuracy and usability of forecasts. Inadequate staffing for the monitoring and calibration of meteorological instruments has contributed to data gaps and issues with data quality, thereby hindering improvements in downscaled forecasts. Additionally, the limited technical capacity of county meteorological departments to generate localized IBF products was noted as a constraint. Dissemination of climate information also faces sustainability challenges due to the need for low-cost communication channels, further complicated by a general lack of media capacity to accurately interpret and convey forecast information.

Agricultural research institutions play a vital role in generating ongoing evidence on the impacts of climate variability on crop performance. They can support the development and refinement of climate adaptation tools by piloting and evaluating prototypes, both software and hardware, and providing feedback on their strengths and limitations. Furthermore, they can contribute to the creation of databases detailing crop suitability across different agro-ecological zones, including information on water requirements, agronomic practices, and climate-smart agriculture (CSA) strategies. However, these institutions often operate under constraints such as limited funding, insufficient technical capacity, and inadequate infrastructure and equipment. Additionally, the uptake of recommended crop varieties is hampered by challenges including farmers' limited access to improved seeds and resistance to adopting certain technologies, particularly genetically modified organisms (GMOs), due to prevailing negative perceptions.

The research community stated that dissemination of climate information could be enhanced by leveraging county government communication platforms, including official social media channels, to ensure timely and localized messaging. The incorporation of visual tools such as infographics and impact-based maps can significantly improve the comprehension and usability of weather and climate forecasts among target communities. Studies have shown that tailored communication strategies and visual aids improve the accessibility and uptake of forecasts, particularly in rural and semi-arid regions (Tall , Coulibaly, & Diop, 2014; Harvey, Jones , Cochrane, & Singh, 2019). Moreover, integrating climate information systems into decentralized governance frameworks supports localized decision-making and resilience planning (Vincent, Daly, Scannell, & Leathes, 2020).

The researchers further indicated their potential contribution to the co-design and testing of communication strategies, such as tailored visualizations, alerts, and messaging formats; adapted to the needs of diverse user groups. They underscored their role in generating scientific evidence and conducting impact assessments to inform climate-resilient policy development and emergency preparedness. Additionally, they highlighted their involvement in evaluating and disseminating case studies that document both the successes and challenges of implementing Impact-Based Forecasting (IBF) systems.

3.3.3 Finance and Private Sector Feedback

Private sector actors and financial institutions that support agricultural activities in Kenya, particularly in counties such as Machakos and Makueni, have expressed concern over the adverse effects of climatic extremes, notably prolonged droughts, floods, pest infestations, and erratic rainfall patterns; each of which poses significant threats to agricultural productivity and financial stability (Ng'ang'a, Karanja, & Muriithi, 2020; Wambua, Musyoki, & Omondi , 2021). During drought periods, crop failures frequently lead to increased loan defaults, prompting lenders to limit credit access to farmers due to anticipated low returns. Drought conditions also reduce customer turnout and revenue flows, while simultaneously triggering a surge in insurance claims that often exceed the liquidity of insurers, resulting in delayed or denied payouts and increased selectivity in financing (Kariuki & Omulo, 2020).

As a result, financial institutions may redirect resources toward more educated farmers and risk mitigation strategies rather than expanding lending.

Similarly, floods generate a comparable pattern of risk, with heightened default rates, disruptions in customer activity, and reduced income for crop insurance providers and microfinance entities. The volume of insurance claims during flood events overwhelms service providers, while logistical barriers and damaged infrastructure further depress agricultural outputs and income (Ochieng, Kirimi, & Mathenge, 2016). Pest outbreaks also drive up the costs of inputs such as pesticides and fungicides, elevating production expenses and compressing farm-level profits, which in turn contribute to credit repayment challenges. Moreover, supply chains are disrupted and informal brokers often dominate market access, especially under stressed conditions (Mburu, Mutune, & Wekesa, 2022).

The vulnerability to climate-related risks in Machakos county varies spatially. Communities living near water catchment areas are especially prone to flood risks, while those in the semi-arid lowlands suffer disproportionately from drought. Hilly areas face hazards such as landslides and falling trees during intense rains, whereas low-lying regions adjacent to hills experience frequent fog, which has been linked to crop blight, particularly during periods of reduced sunlight and persistent humidity.

Contrary to the prevailing narrative surrounding limited financial access among women in Machakos and Makueni counties, microfinance institutions operating in these regions reported that a majority of their clients are, in fact, women. This aligns with findings by Kabeer (2017) and Njiru et al. (2021), who note the increasing engagement of women in microfinance services as both borrowers and contributors to rural enterprise growth (Kabeer, 2017; Njiru, Muriuki, & Wambugu, 2020). Financial institutions highlighted the need for impact-based forecasts (IBF) that disaggregate affected populations by location and vulnerability to inform demand-driven decision-making processes, particularly those related to risk exposure and severity of projected impacts. Furthermore, these stakeholders emphasized the importance of receiving timely forecasts to enable proactive planning and efficient allocation of financial resources in anticipation of climate-related shocks.

Financial institutions indicated that the integration of Impact-Based Forecasting (IBF) would significantly influence their operational strategies. For instance, a forecast indicating reduced rainfall would prompt them to scale down financing and adopt more stringent criteria in selecting beneficiaries to minimize risk exposure. Conversely, projections of increased rainfall would encourage the expansion of financing, particularly for products such as water storage tanks and related infrastructure to support water harvesting and conservation.

3.4 National-Level Stakeholder Consultations

Following county-level consultations in Machakos and Makueni, a national level consultation was held in Nairobi, to further gather insights for tailoring IBF for agricultural decision-making. The engagement convened sixty-two participants from across government agencies, climate and agricultural research institutions, humanitarian and development actors, media organizations, financial and insurance service providers, and private sector stakeholders. Participants were organized into thematic breakout groups aligned with their areas of expertise, including agriculture, gender, insurance and finance, climate services, statistics, and disaster/humanitarian and development organizations. This structure facilitated targeted discussions and generated domain-specific insights into the data needs, challenges, and opportunities for operationalizing IBF.

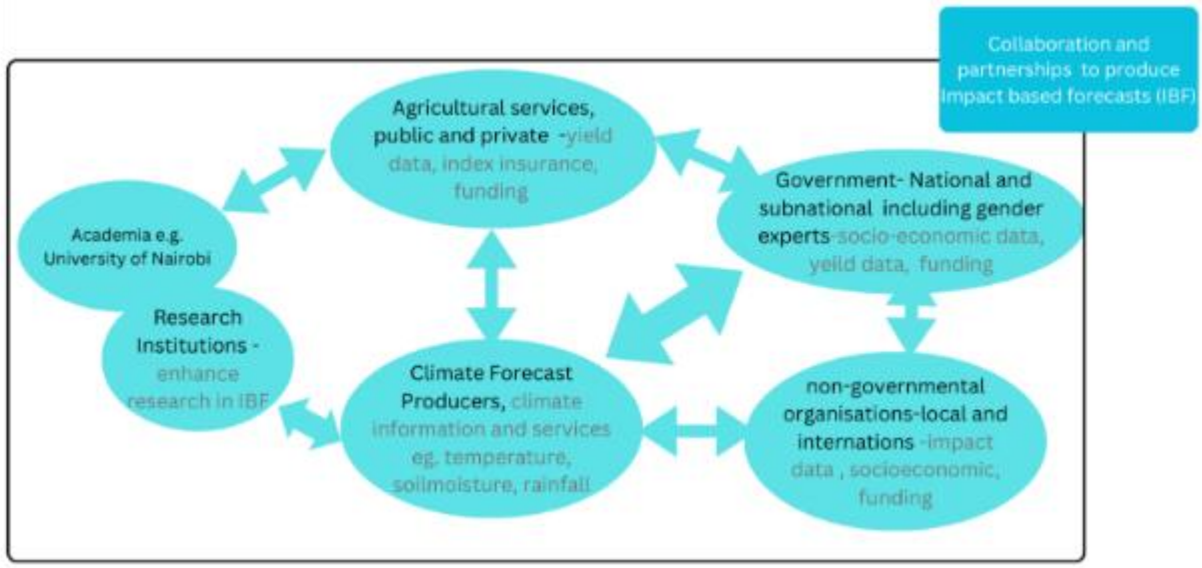

Figure 13: Stakeholder Consultations

3.4.1 Agriculture sector feedback

The agriculture breakout group at the national stakeholder consultation engaged a diverse set of actors including government ministries, research institutions, international development organizations, and private sector actors. Their discussions centred on current use of climate information, forecast-informed decision-making, data needs, preferred formats, institutional roles, and realistic operational timelines for IBF.

Participants reported that climate forecasts are currently used in a range of internal decision-making processes across institutions. For instance, the Ministry of Agriculture and Livestock Development (MOALD) uses seasonal forecasts to prepare Food and Nutrition Security Reports that inform national import-export advisories and county-level planning. Similarly, the Food and Agriculture Organization (FAO) convenes technical teams to interpret forecasts and issue preparedness advisories aligned with anticipatory action planning. The Kenya Agricultural and Livestock Research Organization (KALRO) translates forecast data into agro-ecological advisories disseminated to farmers, while the Alliance for a Green Revolution in Africa (AGRA) incorporates seasonal climate outlooks into its regional agricultural planning frameworks. Agri-tech firms such as Nuru Solutions use temperature and rainfall projections to model crop phenology and optimize planting windows.

These institutional applications of climate information underscore the relevance of IBF in the agriculture sector. However, stakeholders emphasized that to improve usability, forecasts must be accompanied by clearly articulated messages, simplified visuals, and scenario-based advisories that indicate what specific actions farmers and planners should take (Hansen, et al., 2019). There was consensus that forecast information is more impactful when it includes actionable content and clearly specifies the potential implications for different stages of crop production and food systems management.

Participants in the agriculture group also emphasized the importance of customizing IBF products to reflect the unique risks associated with different crops. For example, fall armyworm and aflatoxin contamination were identified as threats primarily affecting maize, underscoring the necessity of crop-specific impact-based forecasting and advisory content. Additionally, stakeholders emphasized that crop water requirements do not rely solely on rainfall amounts and distribution but also factor in soil type, which significantly influences infiltration, retention, and runoff patterns.

Several data gaps and analytical needs were identified as critical to strengthening IBF. Participants highlighted the importance of rainfall distribution across both time and space, as cumulative seasonal totals often mask intra-seasonal dry spells and rainfall onset delays, which are crucial for planting and weeding decisions. The inclusion of metadata and clearly referenced data sources was noted as essential for building confidence in forecasts. Stakeholders also requested forecasts that account for dynamic inter-variable relationships; for example, understanding how projected humidity and temperature levels could influence the timing of pest outbreaks or aflatoxin risks (Harrowsmith, 2020). To improve the reliability of yield forecasting, stakeholders recommended triangulating data from cooperatives, agro-dealers, sub-county agriculture offices, and remote sensing platforms, aligning with broader calls for mixed-source, decentralized data integration in climate services (Kassa, et al., 2025).

To improve the accessibility and operational relevance of IBF products, the group suggested presenting forecasts in tabular formats that pair meteorological predictions with corresponding possible impacts and advisories. For example, a forecast indicating a likely dry spell should be linked with recommendations on drought-tolerant seed varieties, early maturity crops and mulching techniques. Forecasts should include specific rainfall ranges and anticipated time windows (e.g., 40–70 mm expected between March 5–10), supported by map-based visualizations for spatial interpretation. Dissemination through county-level Agricultural Advisory Committees was also proposed as a mechanism to bridge the gap between national forecast producers and local end-users.

Participants proposed that IBF products should be available at least one month before the onset of the rainy season to support proactive planning with weekly updates. Such early dissemination would be aligned with sub-seasonal to seasonal forecast (S2S) frameworks increasingly adopted in agricultural early warning systems (Masukuwedza et al., 2025).

The group further identified key institutions that should be engaged in IBF development, including the Kenya Space Agency (KSA), Directorate of Resource Surveys and Remote Sensing (DRSRS), and the Regional Centre for Mapping of Resources for Development (RCMRD) for geospatial and earth observation data. The Kenya Red Cross Society and relevant humanitarian agencies were highlighted as critical actors in translating forecasts into community-level preparedness. Financial institutions such as the National Treasury and Central Bank of Kenya were recommended for inclusion to align fiscal preparedness with seasonal risk outlooks (IFAD, 2022; Zetterli, 2023).

Regarding their own roles, agricultural stakeholders expressed readiness to contribute through data provision (e.g., crop yield statistics, soil profiles), scenario development, and the co-production and dissemination of agro-advisories. These roles are consistent with global best practices in co-producing climate services that emphasize iterative engagement between information producers, intermediaries, and users (Muita, et al., 2021).

Finally, participants identified a one-week interval as the most operationally useful temporal resolution for IBF products, balancing accuracy with the need for timely and responsive decision-making. Weekly forecasts allow for short-term planning of field operations such as pest control, irrigation, and harvest scheduling, making them especially valuable in high-risk agro-ecological zones.

3.4.2 Climate services producers Group

The climate information producers group underscored their central role in generating, analyzing, and translating data necessary for the development of IBF systems. Their contributions span observational monitoring, remote sensing, data quality assurance, and forecasting using both automated weather stations (AWS) and manned meteorological sites. Emphasis was placed on the importance of robust data archival, metadata development, and spatially explicit baselines to support effective IBF modelling.

A major recommendation was the integration of hazard-specific vulnerability and exposure assessments. Rather than generic indicators, these would focus on context-specific risks such as floods, droughts, or pest outbreaks, enabling more precise forecast messaging and targeting (Comes, Mayag, & Negre, 2014; Harrowsmith, 2020; WMO, 2021). Stakeholders also called for the incorporation of pest and disease baseline data, soil conditions, and long-term climatology in impact modelling.

Numerous challenges to effective climate services and IBF delivery were discussed. These included: sparse observational networks; high costs and vandalism of meteorological equipment; inadequate technical capacity and computing infrastructure for running high-resolution models; and limited interagency data sharing across ministries, departments, and agencies. Such barriers contribute to institutional silos and reduce the utility of climate information across sectors (Hansen, et al., 2019).

On the communication front, the group highlighted the need for diversified decision-support tools, ranging from interactive web applications and GIS-based dashboards to mobile apps, Common Alert Protocol (CAP) alerts, bulletins, and community barazas. These tools should include multi-hazard overlays, risk maps, vulnerability layers, and explanatory summaries to aid interpretation. They emphasized that the tools must be accessible via both digital and traditional media, and presented in simplified, jargon-free language to bridge gaps with non-technical users (Coughlan de Perez, et al., 2015; Harvey, Jones , Cochrane, & Singh, 2019)..

The group emphasized the importance of coproduction with community-based organizations (CBOs), religious institutions, and traditional knowledge holders to ensure the integration of Indigenous and local knowledge (ITK), especially for areas with limited scientific coverage or trust. However, they also cautioned that documentation and verification of ITK remain challenges for integration into formal systems.

Participants identified a number of risks and concerns associated with IBF implementation, including:

- Forecast uncertainty and user misinterpretation;
- Difficulty in understanding and translating end-user needs;
- Language and cultural barriers to communication;
- Over-aggregation or under-sampling during downscaling, leading to loss of spatial accuracy;
- Fragmentation of institutional mandates and lack of coordination mechanisms;
- Unvalidated data sources and inconsistent data granularity

The group recommended stronger engagement with research and academia to strengthen the science-policy-action interface. This includes promoting interdisciplinary research, pilot studies for tool validation, institutional capacity development, and advancing new methods of analysis including AI and machine learning.

3.4.3 Gender and Social Inclusion Group Feedback

To ensure inclusivity the gender and social inclusion group emphasized that IBF systems must be gender-responsive and inclusive of intersecting identities such as age, disability, socio-economic status, and caregiving roles. These factors influence how different groups access, understand, and act on forecast information (Carr & Owusu-Daaku, 2016). Participants highlighted the importance of designing IBF systems that account for **structural barriers**, such as limited access to land, credit, and mobile technology, that has been shown to disproportionately affect women and marginalized groups (Harvey, Jones , Cochrane, & Singh, 2019). The group emphasized the need for inclusive communication strategies, such as simplified language, animated visuals, and participatory workshops, to reach users with low literacy or limited access to digital tools. The use of local languages and community-based dissemination was recommended to improve comprehension and trust.

Participants also proposed gender-sensitive indicators for monitoring IBF uptake and impact. These include the number of women, youth, and persons with disabilities receiving forecasts; their involvement in decision-making; and the extent to which they report increased agency or benefit from forecast-based decisions.

The group further advocated for participatory co-design of IBF content, incorporating local knowledge and cultural norms that shape decision-making. They highlighted the importance of recognizing that gender roles significantly influence who controls resources, who accesses information, and who makes decisions within farming households (Carr & Owusu-Daaku, 2016).

3.4.4 Research and Academia

The research and academia team outlined their primary role as providing technical expertise to ensure the robustness and scientific validity of the Impact-Based Forecasting (IBF) models. This includes supporting the identification and adoption of the most suitable methodological framework for model development, advising on the selection of high-quality and context-relevant datasets for analysis, and advancing the creation of innovative methodologies that can enhance forecast accuracy and usability. Such contributions align with best practices recommended by the World Meteorological Organization (WMO, 2021) and the Global Facility for Disaster Reduction and Recovery (GFDRR, 2022), which emphasize the integration of rigorous scientific approaches and data-driven innovations in climate service development.

Limited data availability remains a significant constraint for the research community, particularly regarding access to observed climate data, which in Kenya is currently not freely accessible (Hansen, et al., 2019). In the context of Impact-Based Forecasting (IBF), the classification and documentation of available datasets and their sources are often inconsistent, creating challenges for data selection and use (WMO, 2021). Furthermore, integrating heterogeneous datasets, such as observational, remote sensing, and model outputs, into a coherent framework for effective analysis presents methodological and technical difficulties. Finally, ensuring the clear and user-oriented communication of IBF outputs to decision-makers and at-risk communities remains a persistent barrier.

Research institutions often face significant resource constraints that limit their ability to conduct the studies required to advance Impact-Based Forecasting (IBF). In addition, securing adequate financing to effectively communicate scientific findings to the public remains a persistent challenge. Moreover, the inherently cross-disciplinary nature of IBF demands a diverse range of expertise, yet the necessary technical and institutional capacities to engage fully in IBF development and implementation are frequently lacking (WMO, 2021). Key risks in the development of Impact-Based Forecasting (IBF) include reliance on outdated datasets, such as historical soil maps, agro-ecological maps, and vulnerability assessments, which may not accurately reflect current conditions. Additional challenges arise from weaknesses in the IBF science–policy interface, which can hinder the translation of technical outputs into actionable guidance. Furthermore, linking forecast outputs to concrete decision-making remains a gap; for example, specifying what a forecast of 10 mm of rainfall implies for different sectors or communities is often not clearly defined.

3.4.5 Role of the Kenya National Bureau of Statistics (KNBS) in Impact-Based Forecasting

The Kenya National Bureau of Statistics (KNBS) plays a vital role in the Impact-Based Forecasting (IBF) process, serving as the principal data aggregator under its statutory mandate. It provides essential datasets to assess community vulnerability and adaptive capacity, such as population projections, rural–urban distribution, crop production values, and poverty indices from the Kenya Integrated Household Budget Survey (KIHBS). Additional domain-specific data include social variables (age, sex, disability, education), economic indicators (income, employment, asset ownership), and physical metrics (housing quality, transport access). KNBS also coordinates the National Statistical System (NSS), including Technical Working Groups and supports capacity-building efforts (KNBS, 2025).

KNBS has identified several obstacles hindering effective IBF implementation. These include limited historical impact datasets for correlating weather with societal outcomes, insufficiently detailed county-level data, and outdated or sparse vulnerability datasets disaggregated by gender, age, or disability. Coordination among agencies with overlapping mandates, such as the Kenya Meteorological Department and NDOC, is weak, and data-sharing protocols are often lacking or informal. Technical capacity is also constrained; staff generally lack training in geospatial analytics, climate modeling, predictive impact approaches, and early warning systems. These challenges are compounded by technological gaps, insufficient infrastructure, and constrained funding for climate services and research, which are further weakened by short-term project funding cycles.

KNBS identifies several risks associated with advancing IBF. Low-quality or outdated baseline data, including population statistics and vulnerability indicators, can undermine impact modeling. Incomplete disaggregation by socio-economic status, gender, or age; further weakens analytical robustness. Overlapping institutional mandates may lead to role confusion among agencies such as NDOC and the Ministry of Health, complicating coordination. Data sensitivity and privacy concerns also arise when handling vulnerable populations, particularly in informal settlements, requiring robust data protection frameworks. Moreover, technical capacity deficits; including limited expertise in modeling, GIS, and data science, pose additional risks to accurate implementation. To mitigate these, KNBS advocates strengthening the science-policy-action interface by promoting evidence-based policymaking and embedding IBF within national planning and budgeting processes.

To improve the integration of forecasts into action, KNBS requires high-resolution, geo-referenced impact data disaggregated by county/sub-county, gender, age, disability, and sector (e.g., agriculture, health). Updated exposure and vulnerability indicators, such as poverty levels, food security, access to water and health services, settlement patterns, and identification of at-risk groups, are critical. Institutional improvements are also needed, including formal data-sharing agreements, understanding forecast requirements, decision-making workflows, and preferred dissemination channels (e.g., SMS, dashboards, radio).

KNBS emphasizes the need to enhance capacities for integrating statistical and forecast data, linking hazard and climate projections with demographic and infrastructure datasets. This would support impact modeling. Developing and publishing impact-based indicators (e.g., persons at risk, projected food insecurity), disaggregated by region, gender, age, and disability, and embedding these into official statistics with regular updates are fundamental to improving IBF effectiveness.

3.4.6 Role of Disaster Mandated Institutions

In Kenya, the key disaster management institutions include the National Drought Management Authority (NDMA) and the National Disaster Operations Centre (NDOC). Both entities are housed under the Ministry of Interior. The NDMA is responsible for managing drought-related disasters, with a mandate to serve the arid and semi-arid lands (ASALs). When drought is projected, the NDMA develops funding requests to the NDMA Board to support targeted interventions. The Board then approves or declines the requests, with funding decisions aligned to quarterly Board meetings and seasonal forecast timelines.

NDOC, on the other hand, has a broader mandate covering all types of disasters. In the event of a projected hazard, NDOC convenes internal meetings to assess likely impacts and identify vulnerability hotspots. The Centre then undertakes resource mobilization, both internally and through partner engagement; and disseminates alerts to potentially affected locations via the National Government Administration Officers. Before deciding on a disaster response, the Ministry considers several factors:

- The scale and extent of the likely impact.
- Available resources and existing gaps.

- The presence and capacity of stakeholders or partners in affected areas.
- Existing coordination mechanisms and implementation structures.
- Specific geographic locations at risk, including multi-hazard areas, border regions, cross-border concerns, refugee populations, and identified vulnerabilities.
- Outcomes of rapid vulnerability and risk assessments.
- Joint creation of recommendations and response actions.

Both NDMA and NDOC recognized the potential value of Impact-Based Forecasting (IBF) for their operations. They noted that IBF's high granularity and sector-specific contextualization make it particularly relevant for disaster risk management. Forecasts delivered on a daily or weekly basis were considered especially useful, as they tend to be more accurate and timelier, enabling anticipatory action and improved risk management. The agencies also emphasized the importance of integrating indigenous knowledge into scientific forecasts to enhance accuracy and local relevance.

They requested that IBF products include comprehensive impact information, specifying who will be affected, the number of people, exact locations, the sectors or areas at risk, and the nature of the anticipated impacts. The presentation of IBF outputs should be simple enough for diverse audiences, incorporating infographics, illustrations, and other visual aids, while also providing a technical background for expert users. Recommendations and action plans should be tailored to different audiences, using communication channels that are relevant, effective, and accessible to those groups.

In terms of their role in the IBF process, NDMA and NDOC indicated that they can:

- Provide vulnerability data, including hazard maps.
- Offer technical support for co-production and validation of forecasts.
- Disseminate IBF products to relevant stakeholders.
- Initiate intervention measures based on forecasts.
- Coordinate IBF-related initiatives.
- Advocate for sustainable ownership of IBF systems.
- Mobilize resources for IBF implementation.

They also proposed that development partners contribute by financing IBF initiatives, supporting the implementation of related interventions, facilitating coordination among UN agencies and development actors, and providing technical assistance during IBF consultations.

3.4.7 Perspectives from the Finance and Insurance Sector on Impact-Based Forecasting (IBF)

Representatives from Kenya's finance and insurance industry highlighted droughts and floods as the primary climate-related hazards affecting their operations, largely due to the surge in insurance claims triggered by such extreme events. The Arid and Semi-Arid Lands (ASALs), specifically Mandera, Wajir, Garissa, Marsabit, Isiolo, Samburu, and Turkana, were identified as the most vulnerable regions, where rural livelihoods and pastoral economies are highly exposed to climate-related shocks. Several firms acknowledged that weather or climate forecasts are not routinely integrated into their business planning or risk assessment frameworks; instead, insurers currently rely primarily on historical data to inform product offerings and identify target markets. Nonetheless, forecasts were seen as potentially valuable tools for market discovery and for pre-emptive risk mapping via an agency-based delivery model. Notably, one firm already employs high-resolution satellite imagery and climate modeling to support underwriting and advisories for insurance providers.

The introduction of Impact-Based Forecasting (IBF) garnered strong interest, particularly for its potential to deliver highly granular, household-level forecasts. Insurance professionals noted that such forecasts could enable proactive adjustment of premiums prior to the realization of risk events and facilitate customizing insurance products based on emergent demand and risk exposure. They emphasized that risk alerts derived from IBF would support refined targeting of insurance offerings and enhance product alignment with sectoral needs. Beyond hazard insights, the private sector expressed interest in data on customer behavior and demand shifts to inform dynamic adaptation of products. Despite recognizing the value of IBF, participants noted that coverage design and deployment already operate under tight cost structures, making them more amenable to adopting IBF solutions if supported through external financing, such as public-private partnerships or donor-funded mechanisms, including cost-sharing for development, implementation, and technical support.

4.0 Conclusions and Recommendations

The consultations and workshops carried out in Machakos, Makueni, and Nairobi counties demonstrate a strong demand for transitioning from conventional forecasts to Impact-Based Forecasting (IBF). Farmers and county stakeholders emphasized that while forecast information is already being used, the most pressing impacts they seek to understand relate to the impact of onset and cessation of rains, pest and disease outbreaks, road access during the rainy season, market conditions, and conditions during harvest on the crop yield and income from the yield. This clearly shows that climate information, when linked to socioeconomic and livelihood impacts, has the potential to directly influence decision-making at the farm, community, and institutional levels.

One of the recurring findings across the three counties is that data availability is not the main barrier, but rather issues of access, digitization, and usability. A substantial portion of agro-climatic and vulnerability data exists at county level, yet remains in paper-based or fragmented formats, limiting its use for dynamic modelling and decision support. At the national level, participants raised concerns about the lack of dynamic vulnerability datasets, meaning that the same vulnerability maps are often used across multiple years despite rapidly changing conditions on the ground. Without updating and digitizing these datasets, IBF cannot achieve the granularity or timeliness required to inform anticipatory action.

The workshops also highlighted that different stakeholder groups face distinct challenges. Farmers require forecasts that are simple, localized, and cost-effective to apply; researchers are constrained by inadequate infrastructure, limited capacity, and weak coordination across institutions; financial institutions need disaggregated and location-specific forecasts to design responsive credit and insurance products; while policymakers require IBF products that can guide national and county-level preparedness, contingency planning, and resource allocation. Addressing these diverse needs will require more inclusive co-production of IBF services that draw on local knowledge as well as scientific data.

The findings further highlighted that vulnerability to climate shocks is shaped not only by climatic conditions, but also by social factors such as gender, age, disability, and access to resources. Women and youth, in particular, face barriers related to land ownership, credit, technology, and decision-making power, all of which influence how they receive and act on forecast information. To address this, participants emphasized the importance of integrating gender-related vulnerability data into the IBF process to provide a more accurate picture of what the weather will do. This would make forecasts more representative of actual exposure and adaptive capacity, enabling more targeted advisories and fostering equitable resilience across communities.

In terms of policy relevance, the findings point to clear opportunities. Embedding IBF within Kenya's agricultural and disaster risk management strategies could significantly strengthen resilience by aligning early warnings with early actions. For example, improved forecasts on pest outbreaks and road accessibility could inform pre-emptive supply chain and logistics planning, while better onset and cessation advisories would allow the Ministry of Agriculture to refine input distribution and insurance triggers. IBF can therefore act as a bridge between climate science and socioeconomic policy, ensuring that information not only informs but actively drives adaptation and resilience investments.

Based on these findings, we recommend:

1. **Expanded data collection and digitization** to ensure that vulnerability and agro-climatic datasets are regularly updated, accessible, and usable at both county and national levels.
2. **Strengthening institutional coordination** between research, government agencies, and private sector actors to harmonize methodologies and enhance the co-production of IBF services.
3. **Develop gender-responsive forecast products that address diverse livelihood priorities** to ensures that IBF implementation serves the distinct needs of men, women, youth, and elderly farmers, and persons with disabilities particularly those with limited land access or high care burdens.
4. **Localizing and customizing advisories** to ensure they are simple, actionable, and disseminated through trusted communication channels at the community level.
5. **Integrating IBF into national and county planning frameworks**, linking forecasts directly to budgetary, insurance, and preparedness mechanisms to enhance policy uptake.
6. **Investing in capacity development** across technical institutions, extension services, and farmer organizations to improve understanding, use, and communication of IBF products.

In conclusion, the project confirms that while Kenya has made significant strides in generating and using climate information, the transition to IBF offers an opportunity to make forecasts more usable, impactful, and policy-relevant. Expanding data collection, improving coordination, and tailoring information to stakeholder needs will be essential steps toward building a robust IBF system that enhances resilience, supports livelihoods, and strengthens food security. Critically, this transition must actively challenge and transform existing gender inequalities by recognizing and addressing the distinct agricultural priorities, decision-making roles, and resource constraints faced by women, men, youth, elderly farmers, and persons with disabilities. This means moving beyond simply including these groups to fundamentally reshaping forecast products and implementation approaches to redistribute power, resources, and opportunities more equitably, ensuring accessible formats and participatory processes that enable all community members to benefit from and contribute to IBF systems.

References

(n.d.).

Ahmed, M. N., & Givens , J. E. (2025). Farmers’ Climate Change Adaptation Strategies and the Role of Environmental Awareness and Education: A Review in Africa. In M. F. Mbah, P. Molthan-Hill, & E. L. Molua, *Practices, Perceptions and Prospects for Climate Change Education in Africa* (pp. 175–194). Springer, Cham. doi:https://doi.org/10.1007/978-3-031-84081-4_9

Carr, E. R., & Owusu-Daaku, K. N. (2016). The shifting epistemologies of vulnerability in climate services for development: The case of Mali's agrometeorological advisory programme. *Area, 48*(1), 7–17. doi:https://doi.org/10.1111/area.12179

Comes, T., Mayag, B., & Negre, E. (2014). Decision Support for Disaster Risk Management: Integrating Vulnerabilities into Early-Warning Systems. In C. Hanachi , F. Bénaben, & F. Charoy, *Information Systems for Crisis Response and Management in Mediterranean Countries. Lecture Notes in Business Information Processing* (Vol. 196, pp. 178-191). ISCRAM-med 2014; Springer, Cham. doi: https://doi.org/10.1007/978-3-319-11818-5_16

Coughlan de Perez, E., van den Hurk, B., van Aalst, M. K., Jongman, B., Klose, T., & Suarez, P. (2015). Forecast-based financing: an approach for catalyzing humanitarian action based on extreme weather and climate forecasts. *Natural Hazards and Earth System Sciences*, 15(4), 895–904. doi:https://doi.org/10.5194/nhess-15-895-2015

Elizabeth , I. M., & Mwania, P. (2023). Effects Of Rainfall Patterns On Crop Yield In Makueni Sub-County, Makueni County, Kenya. *Journal of African Interdisciplinary Studies (JAIS)*, 7(11), 16 – 31.

Gachara, G., Suleima, R., El Kadili, S., Barka, E. A., Kilima, B., & Lahlali , R. (2022). Drivers of Post-Harvest Aflatoxin Contamination: Evidence Gathered from Knowledge Disparities and Field Surveys of Maize Farmers in the Rift Valley Region of Kenya. *Toxins (Basel), 14*(9), 618. doi:10.3390/toxins14090618

GFDRR. (2022). *Impact-based Forecasting and Warning Services for Climate Resilience: A Practitioner's Guide. .* Washington, DC: Global Facility for Disaster Reduction and Recovery (GFDRR).

GoK. (2016). *Kenya National Adaptation Plan (NAP) 2015–2030: Enhanced climate resilience towards the attainment of Vision 2030 and beyond.* Nairobi: Ministry of Environment and Natural Resources. Government of Kenya (GoK).

Hansen, J. W., Mason, S. J., Sun, L., & Tall, A. (2011). Review of seasonal climate forecasting for agriculture in sub-Saharan Africa. *Experimental Agriculture*, 47(2), 205–240.

Hansen, J. W., Vaughan, C., Kagabo, D. M., Dinku, T., Carr, E. R., Körner, J., & Zougmoré, R. B. (2019). Climate Services Can Support African Farmers' Context-Specific Adaptation Needs at Scale. *Front. Sustain. Food Syst.*, Volume 3. doi:https://doi.org/10.3389/fsufs.2019.00021

Harrowsmith, M. N. (2020). *Impact-based forecasting for early action: the future of forecasts.* The Hague, Netherlands: Red Cross Red Crescent Climate Centre.

Harvey, B., Jones , L., Cochrane, L., & Singh, R. (2019). The evolving landscape of climate services in sub-Saharan Africa: What roles have NGOs played? *Climate and Development*, 11(1), 63–76. doi:https://doi.org/10.1080/17565529.2017.1410083

IFAD. (2022). *Climate Action Report .* Roma, ITALY: IFAD.

Ingutia, R., & Sumelius, J. (2022). Do farmer groups improve the situation of women in agriculture in rural Kenya? *International Food and Agribusiness Management Review*, Volume 25, Issue 1. doi:10.22434/IFAMR2020.0142

Kabeer, N. (2017). *Women's economic empowerment and inclusive growth: Labour markets and enterprise development.* International Development Research Centre (IDRC), School of Oriental and African Studies, UK .

Kariuki, J., & Omulo, G. (2020). The influence of climate risk on smallholder agricultural credit in Kenya. *Journal of Development and Agricultural Economics*, 12(2), 45–54.

Kassa, A. K., Zeng, H., Wu, B., Tsehai, K. K., Xingli, Q., & Gebretsadkan , T. G. (2025). Integrating Climate Data and Remote Sensing for Maize and Wheat Yield Modelling in Ethiopia's Key Agricultural Region. *Remote Sensing, 3*(17), 491. doi:10.3390/rs17030491

KNBS. (2025). *Compendium of Environment Statistics.* Nairobi: Kenya National Bureau of Statistics (KNBS0 .

Kyalo, R., Elfatih , A.-R. M., Sevgan, S., Johnson , N. O., Michael , T., Hosein, J., . . . Landmann, T. (2017). Maize Cropping Systems Mapping Using RapidEye Observations in Agro-Ecological Landscapes in Kenya. *Sensors*, 17(11), 2537. doi:https://doi.org/10.3390/s17112537

Machio, P. M., Sallu, S. M., Waized, B., Akwilina , M. W., & Kwaku , D. G. (2025). A gendered analysis of adaptive capacity and food security in Makueni County, Kenya. *Frontiers in Sustainable Food Systems*, Volume 8. doi: https://doi.org/10.3389/fsufs.2024.1494475

Masukwedza, G. I., Lazenby, M. J., Mwangi, E., & Martin C. Todd. (2025). Assessing the subseasonal forecasting skill of extreme agrometeorologically relevant dry spells over Southern Africa. *Climate Dynamics, 4*, 63. doi:10.1007/s00382-025-07674-z

Mbugua , J. M., & Nyamongo, D. O. (2010). Traditional Food Crops and Their Role in Food and Nutritional Security in Kenya. *Journal of Agricultural & Food Information*, 11:1, 36-50. doi:10.1080/10496500903466745

Mburu, J., Mutune, J., & Wekesa, A. (2022). Climate shocks, agricultural risks and farmer coping strategies in Kenya's drylands. *Climate Risk Management*, 36, 100423.

MoALD. (2023). *National Agricultural Insurance Policy (NAIP).* Nairobi, Kenya: Government of the Republic of Kenya.

Muhammad, L., Domisiano, M., Mwangi, W., & Roberto , L. (2009). *Community Assessment of Drought Tolerant Maize for Africa (DTMA) in Kenya.* Nairobi, Kenya: CIMMYT.

Muita, R., Dougill, A. J., Mutemi, J., Aura, S., Graham, R., Awolala, D., . . . Opijah, F. (2021). Understanding the Role of User Needs and Perceptions Related to Sub-Seasonal and Seasonal Forecasts on Farmers' Decisions in Kenya: A Systematic Review. *Front. Clim., 3*. doi:10.3389/fclim.2021.580556

Ng'ang'a, S. K., Karanja, F. N., & Muriithi, B. (2020). Impacts of climate variability on agricultural productivity and farmers' adaptation strategies in semi-arid Kenya. *Journal of Agricultural Extension and Rural Development*, 12(4), 72–82.

Njiru, E. N., Muriuki, H. G., & Wambugu, S. K. (2020). Women's access to microfinance and its impact on livelihood outcomes in Kenya: Evidence from rural counties. *Journal of Development and Agricultural Economics*, 13(3), 152–160.

Ochieng, J., Kirimi, L., & Mathenge, M. (2016). Climate variability and adaptation strategies among small-scale farmers in lower eastern Kenya. *African Journal of Environmental Science and Technology*, 10(7), 114–126.

Omoyo, N. N., Jacob , W., & Oteng'i , S. (2015). Effects of climate variability on maize yield in the arid and semi arid lands of lower eastern Kenya. *Agric & Food Secur*, 4, 8. doi:https://doi.org/10.1186/s40066-015-0028-2

Partey, S. T., Zougmoré, R. B., Ouédraogo, M., Campbell, B. M., & Nyasimi , M. (2020). Developing climate-smart agriculture to face climate variability in West Africa: challenges and lessons learnt. *Journal of Cleaner Production*, 258, 120566.

Peters, A. R., Domingue, G., Olorunshola, I. D., Thevasagayam, S. J., Musumba, B., & Wekundah, J. M. (2012). A survey of rural farming practice in two provinces of Kenya. 1. Demographics, agricultural production and marketing. *Livestock Research for Rural Development*, 24(5).

Rao, M. R., & Mathuva, M. N. (2000). Legumes for improving maize yields and income in semi-arid Kenya. *Agriculture, Ecosystems & Environment, 78*(2), 123-137. doi:https://doi.org/10.1016/S0167-8809(99)00125-5

Recha, J. W., Mati, B. M., Nyasimi, M., Kimeli, P. K., Kinyangi, J. M., & Radeny, M. (2014). Changing rainfall patterns and farmers' adaptation through soil water management practices in semi-arid eastern Kenya. *Arid Land Research and Management*, 229-238. doi:https://doi.org/10.1080/15324982.2015.1091398

Tall , A., Coulibaly, J. Y., & Diop, M. (2014). The role of climate services in adaptation planning in sub-Saharan Africa. *Climate Risk Management*, 4–5, 4–16. doi:https://doi.org/10.1016/j.crm.2014.01.002

Temba, B. A., Darnell , R. E., Gichangi , A., Lwezaura , D., Pardey, P., Harvey, J. J., . . . Kriticos , D. J. (2021). The Influence of Weather on the Occurrence of Aflatoxin B1 in Harvested Maize from Kenya and Tanzania. *Foods, 10*(2), 216. doi:https://doi.org/10.3390/foods10020216

The World Bank, GFDRR & USAID. (2015). *Toward a National Crop and Livestock Insurance Program.* Washington DC: The World Bank.

van der Horst, S., Goosen, H., van Selm, M., Koomen, I., Matsaba, E. O., Wesonga, J., . . . Holkenborg, M. k. (2022). Co-creation of a Scalable Climate Service for Kenyan Smallholder Farmers. *Front. Clim.*, Vol. doi: https://doi.org/10.3389/fclim.2022.859728

Vincent, K., Daly, M., Scannell, C., & Leathes, B. (2020). What can climate services learn from theory and practice of co-production? *Climate Services*, 17, 100130. doi: https://doi.org/10.1016/j.cliser.2019.100130

Wambua, M., Musyoki, A., & Omondi , P. (2021). Flood risk and its financial implications on agriculture-based livelihoods in Kenya. *International Journal of Climate Change Strategies and Management*, 13(5), 481–496.

Wilkinson, E., Weingärtner, L., Choularton, R., Bailey, M., Todd, M., Kniveton, D., & Caravani, A. (2018). *Forecasting hazards, averting disasters: Implementing forecast-based early action at scale.* ODI Working Paper. Retrieved from https://odi.org/documents/5761/12104.pdf

WMO. (2021). *WMO Guidelines on Impact-Based Forecast and Warning Services (2nd ed.).* No. 1150: World Meteorological Organization (WMO). doi:https://library.wmo.int/index.php?lvl=notice_display&id=21995

Zetterli, P. (2023). *Climate Adaptation, Resilience, and Financial Inclusion: A New Agenda.* Washington, DC: CGAP. Retrieved from https://www.cgap.org/research/publication/climate-adaptation-resilience-and-financial-inclusion-new-agenda