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Beyond the talk? Understandings of, expectations for, and barriers to climate services for climate adaptation in Tanzania

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Declaration

I, Emma Lea Wheeler, declare that this thesis is a result of my research investigations and findings. Sources of information other than my own have been acknowledged and a reference list has been appended. This work has not been previously submitted to any other university for award of any type of academic degree.

Signature......................................

Date..

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Summary

We are talking a lot…but can farmers rely on this?
- NGO representative, Morogoro, Tanzania

This thesis examines the complexities and potential misalignments between the aim of co-produced climate services (CS) and the perspectives, livelihood realities, and practical challenges such services must address if they are to achieve the goals and objectives associated with strengthening climate adaptation amongst smallholder farmers. Countries, such as Norway, support and promote the provision of co-produced climate services for climate adaptation under the assumption that enhanced climate information will support local adaptation efforts. *Co-production* is advocated as a way to bring together the relevant actors involved in producing, communicating, and using CS to overcome the limitations of top-down approaches and increase user relevance and uptake of these services. However, as illustrated by the opening quote, despite efforts toward achieving co-production, a gap exists between the "talk" of scientific research and the actual impact it has on informing smallholder farmers' climate adaptation in practice.

Through exploration of diverse understandings of, expectations from, and barriers to co-produced climate services for climate adaptation in Morogoro Region, Tanzania, findings in this study push back on the assumption that increased climate information, even when tailored to the assumed needs of recipients, inherently leads to enhanced climate adaptation. Perspectives of smallholder farmers and other stakeholders involved in producing, communicating, and using climate information show that how, when, and if climate information is useful and usable varies depending on individual and subjective backgrounds, experiences, ways of knowing, and decision-making contexts. Institutional and social barriers to access of information, as well as existing vulnerability among smallholder farmers in the studied locations, further limit the extent to which climate information and services, even when potentially useful, are operationally used.

Despite widespread donor and governmental support for co-produced climate services in Tanzania and elsewhere, there remains a lack of convincing evidence for the uptake of such services by smallholders in ways that can support enhanced decision-making and climate adaptation in practice. Drawing on empirical data collected during participatory observation of a climate services co-production workshop, I investigate the different ways in which stakeholders understand and approach the process of climate service co-production and the different assumptions and expectations they bring to such processes. I further draw on qualitative

interviews conducted with men and women smallholders and potential climate service intermediaries at local, national, and international levels to investigate the extent to which the seasonal forecast information that is currently produced at the national level is viewed as being accessible, relevant, trustworthy, and actionable and responsive to farmers needs in practice. To analyze the data, I employ a hybrid conceptual and analytical framework based on principles of "salience", "credibility", "legitimacy" (Cash et al., 2003) and "usefulness" and "usability" (Lemos & Morehouse, 2005) that have emerged from literature assessing the key criteria for enabling scientific information to inform and support adaptive action across the science-policy-society interface.

Abbreviations	
COGENT	Co-producing Gender-responsive Climate Services for Enhanced Food and Nutrition Security and Health in Ethiopia and Tanzania
CS	Climate Services
CSA	Climate Smart Agriculture
FAO	Food and Agricultural Organization
GFCS	Global Framework for Climate Services
GFCS APA	Global Framework for Climate Services Adaptation Programme for Africa
ITK	Indigenous and Traditional Knowledge
MVIWATA	Mtandao wa Vikundi vya Wakulima Tanzania (*National Network of Farmers' Groups in Tanzania*)
NORCAP	Norwegian Capacity
NFCS	National Framework for Climate Services
NGO	Non-Government Organization
NMHS	National Meteorological and Hydrological Service
SAT	Sustainable Agriculture Tanzania
SUA	Sokoine University of Agriculture
TARI	Tanzania Agricultural Research Institute
TMA	Tanzania Meteorological Authority
USAID	United States Agency for International Development
WFP	World Food Program
WMO	World Meteorological Organization

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1. Introduction

Despite ample evidence for climate change, its environmental and societal impacts, as well as an increased interest in and availability of robust climate information over the past decades, there has not been a corresponding translation into widespread and effective adaptation planning and practices (Vincent et al., 2020). Heterogenous and often conflicting perceptions of what makes climate information useful and usable in society has created a "usability gap" (Lemos et al., 2012:789) – a gap between scientific research and its operational use in societal decision-making. Aiming to make scientific research that better matches the needs of intended recipients, climate services (CS) – defined by the World Meteorological Organization (WMO) as, "a decision aide derived from climate information that assists individuals and organizations in society to make improved ex-ante decision-making" – have emerged over the past decade as a way to better help society address increased climate risk through tailoring and packaging climate and weather information to specific application needs (WMO, 2015; Vaughan & Dessai, 2014).

Climate services, such as seasonal forecasts and early warnings of extreme events, are especially applicable in areas where climate variability contributes to food insecurity and decreased livelihood opportunities, as is the case in Sub-Saharan Africa where smallholder farmers relying on rain-fed agriculture provide almost 80% of the food supply (FAO, 2012; Hansen et al., 2019).[1] Nonetheless, CS have been criticized for meeting the *assumed* demand of users more accurately than they meet users' *actual* demand (Findlater et al., 2021; Porter & Dessai, 2017), further entrenching the usability gap rather than overcoming it. One way to create usable knowledge, and by extension support high quality, actionable CS, is to promote interaction between the producers and the users of knowledge through a process known as *co-production* (Dilling & Lemos, 2011). Co-production takes place across a variety of actors all involved in the development, implementation, communication, and use of CS, referred to as *stakeholders*.[2] While co-produced CS aim to meet specific needs and demands articulated by intended users of this information, previous research shows that the socially differentiated

[1] Unless otherwise noted, the terms *smallholder farmers*, *smallholders*, and *farmers* are used interchangeably.
[2] I use *stakeholder* in this thesis to describe individuals who are invested in or impacted by climate change and who are potentially engaged in the process of co-producing CS. Similarly to the description proposed by Lemos et al. (2018), this can include anyone whose livelihood is informed by environmental knowledge, such as farmers, extension officers, community members, policymakers, researchers, NGO, or government representatives.

perspectives, capacities, needs, realities, and knowledge held by men and women smallholders may go unaccounted for in the planning and implementation of CS projects (West et al., 2018). Although much research exists into how to best produce needs-driven CS, the factors that differentiate *assumed* from *actual* needs, as well as the underlying differences that might lead to these misalignments, remain largely unexplored.

1.1 Problem statement and research questions

This thesis takes its starting point in the view that efforts to co-produce demand-driven CS that can support climate adaptation amongst smallholder farmers should be grounded in a nuanced understanding of smallholder farmers' own perspectives, needs, and lived realities vis-à-vis such services. From this starting point, I examine and describe the diverse understandings of, expectations from, and barriers to co-produced CS for climate adaptation that I encountered while conducting field research as a Master's degree student attached to an ongoing research project in Tanzania that aimed to co-produce gender-responsive climate services for food and nutritional security and health in Morogoro Region. Guided by an overarching question – *How do stakeholder understandings of and expectations for climate services co-production align and/or differ?* – the study explores nuances underlying the assumed link between CS and climate adaptation among smallholders.

The following sub-research questions further guided the study:

1) How do different stakeholders understand and assess existing seasonal forecast information and associated terminology in terms of its availability, relevance (salience), trustworthiness (credibility), inclusiveness (legitimacy), usefulness, and usability?

2) What are stakeholder perspectives on the co-production process and its applicability for linking climate services to climate adaptation?

3) What are some of the barriers and enablers of climate adaptation among smallholder farmers that need to be addressed in order to close the gap between climate information and services that are potentially useful and those that are operationally used?

1.2 Study location and context

Although the consequences of climate variability and change are increasingly felt across the globe, the impacts are felt more severely in countries with limited adaptive capacity and where reliance on rainfed agriculture for income and livelihoods makes populations particularly vulnerable (Muema et al., 2018). In Tanzania, rising temperatures and increasingly intense and frequent extreme weather events, such as droughts and heavy precipitation, cause costly socio-economic impacts (i.e., Chang'a et al., 2017; Kijazi et al., 2021). Agriculture is the dominant sector in Tanzania's economy and employs 65% of Tanzanians (United Republic of Tanzania, 2013; World Bank and FAO, 2022). Ninety percent of rural households are classified as poor and rely on subsistence agriculture for their livelihoods (Chivaghula, 2020), leaving many Tanzanians highly vulnerable to increasing climate variability and more frequent and intense extreme events, such as droughts and flooding.

Crop yields are widely dependent on the timing and amount of rainfall, and thereby on farmers' ability to make informed and effective decisions about when, what, and where to plant. Increasingly erratic and unpredictable weather and climatic conditions create challenges for smallholders who depend on rainfed farming for their livelihood (i.e., Chang'a & Yanda, 2010; Kijazi et al., 2021; Yanda et al., 2015). Climate and weather information are therefore acknowledged as key tools to enable decision-making related to climate and weather impacts (i.e., Kijazi et al., 2021; Yanda et al., 2015).[3] Although much research in co-produced CS exists, most studies and literature are based on CS in developed countries (Bremer & Meisch, 2017). There is growing interest in CS for climate adaptation in developing contexts (Vincent et al., 2018). This study thus adds to growing literature on how and when CS may serve as a tool for climate adaptation among smallholders in developing contexts.

1.3 Approach and outline

Through participatory observation and analysis of a co-production workshop involving meteorologists, agricultural practitioners, smallholder farmers, and researchers in Morogoro Town, Tanzania, and follow-up interviews with men and women smallholder farmers and potential climate service intermediaries, including extension officers, researchers, government, and NGO representatives, this thesis explores selected stakeholders' perceptions and understandings of climate services and attendant terminology, views on appropriate ways to pursue co-produced CS, and impressions of the quality of existing seasonal forecast information

[3] Climate and weather information includes information about both short-term (weather) impacts, such as daily to seasonal forecasts, storm, and drought warnings, and long-term (climate) predictions and trends.

in terms of whether it is perceived to be accessible, relevant, trustworthy, and actionable. I further employ a hybrid conceptual and analytical framework based on five principles that have emerged in the science-policy literature as key criteria for judging the efficacy of scientific information to inform and support decision-making. The first three, "salience" (relevance to decision-making context), "credibility" (trustworthiness of data and institutions), and "legitimacy" (inclusiveness and transparency of process) were originally proposed by Cash et al. (2003). Building on these criteria, "usefulness", whether knowledge or information is provided to users on a temporal and spatial scale that fits their practice and needs, and "usability", the extent to which users' actually access and use the information for decision-making, are employed to explore factors that lead CS to go from being *potentially usable*, to *operationally used* by smallholders (Lemos & Morehouse, 2005).

In this first chapter, I have introduced the topic, study location, and context along with the research aim and questions explored in this thesis. Chapter Two provides background into what CS are and how the field has evolved, and how co-production aims to link CS to climate adaptation efforts. Chapter Three presents the conceptual and analytical framework, emphasizing past studies that have linked the knowledge quality criteria to co-producing CS. Chapter Four presents the research design, methods used in the study, and ethical considerations and limitations. My empirical findings are then presented in Chapter Five. In Chapter Six, I discuss the findings in light of the knowledge quality criteria presented in the conceptual framework and existing scholarship across climate services, critical climate adaptation literature, and literature on co-production. Building on this, I make suggestions for further research. Finally, Chapter Seven presents my conclusions.

2. Background

Over the past decades, advances in science and technology have enhanced our understanding of the climate system. Calls made by practitioners to better link scientific research to policy and practice have led to questions about how improved climate information can best be used (Lemos et al., 2012; Lemos & Morehouse, 2005; Vincent et al., 2020). Since the late 19th century, the World Meteorological Organization (WMO) has worked to create a framework to coordinate international climate research that has focused increasingly on enhancing the relevance and use of this scientific research for society (Vaughan & Dessai, 2014). Climate Services (CS) have since emerged as a potential way to bridge the identified gap between research and action through focusing on the provision of climate information that is relevant to and usable by decision-makers (Hewitt, 2012). Different uses for, definitions, and applications of CS exist – resulting in varying understandings of both definition and aim across disciplines, organizations, and countries (Brasseur & Gallardo, 2016). For example, scholars within the field of climate services have found that there is currently greater focus on justifying the need for CS and describing organizational failings than defining and describing what climate services *are,* through critique, elaboration, and discussion of implementation challenges. This has resulted in diverse, debated, and often ad-hoc descriptions and applications of CS across practice and research as well as across different scales of producers and users (Harjanne, 2017; Howarth et al., 2022).

To establish background into the field of climate services, this section gives a brief background to the development of CS as an emerging field of research and practice (2.1), the emergence of co-production of CS (2.2), and ongoing communication of climate and weather information in Tanzania (2.3).

2.1 Climate Services: an emerging field of research and practice

Climate services as a field is born out of the acknowledged need for scientists to produce information that is not only scientifically accurate but also understandable and useful to decision-makers in various societal contexts. The term *climate services* is used across various disciplines to refer to different types of climate and weather information and associated advice, delivered at different levels of society (from policymaking, sectoral decision-making, to individual end-users), and on different timescales (from short-term forecasts and alerts, such as improved early-warning systems, to longer-term seasonal or annual forecasting). The Global Framework for Climate Services (GFCS) was established in 2012 to facilitate cooperation and collaboration between experts, practitioners, and policymakers with these goals in mind (Hewitt, 2012; Vaughan & Dessai, 2014). The goal of the GFCS is to "to strengthen and coordinate existing initiatives and develop new infrastructure where needed to meet society's climate-related challenges" (Hewitt, 2012:831) to support better and more informed climate risk decision-making. Since the establishment of GFCS, interest in CS specifically in developing countries has increased, which, combined with increasingly felt negative impacts of climate change has resulting in more attention from potential funders within research and from development organizations (Vincent et al., 2018).

In 2014, the pilot initiative GFCS Adaptation Programme for Africa (GFCS APA) was launched in Malawi and Tanzania with financing from the Norwegian Government. GFCS APA was a cross-sectoral initiative that aimed to develop user-driven climate services for food security, health, and disaster risk reduction in collaboration with the National Meteorological and Hydrological Services (NMHS) in Malawi and Tanzania (Yanda et al., 2015). In Tanzania, the program was led by WMO together with seven international partners and collaborators in the two countries.[4] National partners in Tanzania included Tanzania Meteorological Authority (TMA), Tanzania Red Cross Society, Tanzania Ministry of Health and Social Welfare, WFP Tanzania, and the University of Dar es Salaam Centre for Climate Change Studies (West et al., 2018). A second phase of the pilot was funded from 2017–2019.[5] In 2018, under GFCS APA and spearheaded by TMA, Tanzania launched the National Framework for Climate Services (NFCS) with the aim of improving the "availability and use of tailored weather and climate services necessary to strengthen resilience to climate change and extreme weather" through increased coordination and facilitation across sectors of government and society. NFCS are promoted under the GFCS and are being adopted by an increasing number of countries globally (WMO, 2018).

Although WMO and GFCS are widely known and established frameworks for global CS coordination, other coordinating initiatives, such as the European Roadmap for Climate Services

[4] NMHS operate and own the infrastructure to provide weather, climate, water, and other environmental services at a national level and are therefore the main providers and disseminator of climate services.
[5] For more information about GFCS APA, see https://www.gfcs-climate.org/CSA_Africa/.

(European Commission et al., 2015), also exist along with as an increasing number of projects designed to enhance climate services production and uptake in both developed and developing country contexts.[6]

Climate services are based on a logic of intervention that entails a linear process of information generated by experts (service production) that is distributed and communicated by NMHS and intermediary bodies with the aim of enhancing decision-making and actions taken by intended users (Vogel et al., 2019). A host of projects and programs funded variously by governments, development aid, research funding bodies, the UN, and private and humanitarian organizations focus on all or varying parts of the so-called climate service "value chain". Figure 1, below, illustrates a conventional CS value chain whereby step-by-step, linear communication of weather and climate information leads to added value for end-users (WMO 2015).[7]

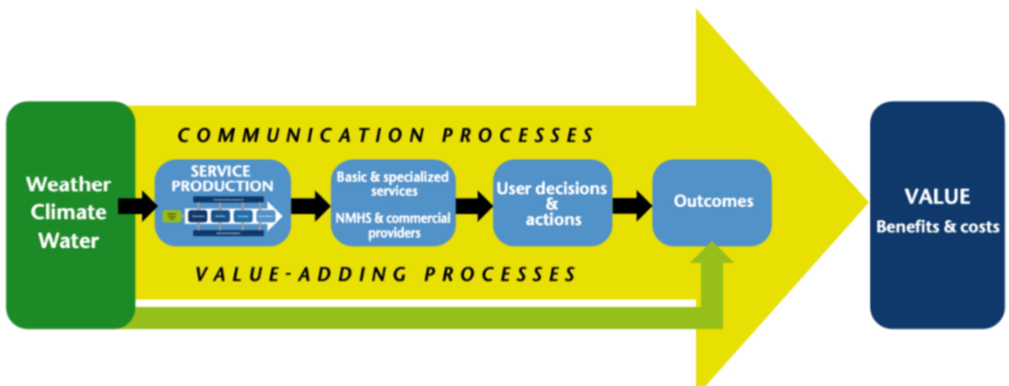

Figure 1. A conventional, linear, value-chain of Climate Services (WMO, 2015)

Early climate services for agricultural were developed to link seasonal predictions with agricultural modeling and agrometeorology and thereby aid agricultural management, research, and decision-making (Hansen et al., 2019), following a logic similar to that depicted in Figure 1. Although smallholders' information needs, options, and capacity to act on climate information are often very context specific, aspects of climate information, such as format, spatial scale, and experiences of implementing services, seem to be generalizable across contexts (Hansen et al., 2019). In response to increasingly erratic and unpredictable weather and climatic conditions, CS have the potential to inform smallholders decisions regarding when, what, and where to plant

[6] Some examples of such projects relevant to Tanzania include the COGENT project that this thesis is part of, Weather and Climate Information Services (WISER) program, initiated and funded by the UK government, and the Co-production of Climate Services for East Africa (CONFER) project, an EU-funded research project.
[7] WMO (2015) defines a value-chain as the process of communication that links the production and delivery of climate services to decisions made by users, including the outcomes and values resulting from those decisions.

(Kijazi et al., 2021). However, a mismatch between the needs of farmers and the types of climate services commonly available across sub-Saharan Africa suggests a gap between producers and users, causing scholars to increasingly critique information flow diagrams, such as Figure 1, as being overly simplistic, missing the complex reality in which climate services producers, intermediaries, and users interact (Vincent et al., 2018).

2.2 The drive to co-produce climate services

Rather than focus primarily on achieving technical advances aimed at meeting the research agendas of scientists, it is increasingly acknowledged that CS should be driven by the needs of those who will use them (Bremer et al., 2022). The conventional value chain (Figure 1) arguably does not leave adequate space for attending to how users, both within and across conventional groupings, such as farmers, extension officers, or scientists, may understand and experience climate variability and change (Vogel et al., 2019). As pointed out by many actors, the process of generating useful CS is rarely linear; it is, rather, a complex and iterative process that requires communication and coordination across many potential stakeholders (e.g., Mwangi et al., 2020; Vaughan & Dessai, 2014; Warner et al., 2022; Yanda et al., 2015). Alternative conceptualizations of the CS value chain move away from a supply-driven, linear approach (as depicted in Figure 1) and towards services that are driven by the articulated demand of stakeholders via a process known as *co-production.*[8] This approach is seen as a way to involve relevant stakeholders in the process of identifying, developing, and communicating information about climate and weather to enhance climate adaptation.[9] The idea is that a more iterative,

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[8] Although the term *co-production* is widely used across research and practice to mean different things (see, for example, Bremer & Meisch, 2017), in this thesis, co-production is defined as the interaction of science providers and intended users in order to produce more usable climate information.

[9] The term *adaptation* is used broadly across different disciplines and contexts with nuanced and differing meanings. André et al. (2021) use climate adaptation to describe the process of ongoing learning that builds understanding of changing climate and allows individuals or communities to adapt accordingly: climate adaptation efforts for smallholder adaptation should thus be guided by information that is perceived as high-quality by its intended users. When built on contemporary understandings of the decision-making context of users and engagement with the perceptions of individuals and the surrounding social structures, climate services can serve to catalyze transformational adaptation. Although outside the scope of this thesis to explore, Carr (2023) points to the distinction between the opportunity for CS to catalyze transformational changes in society through facilitating interaction across the science-society boundary, versus their current use, in many cases, as a technology to aid adaptation in an incremental way. Carr (2023) and Eriksen et al. (2021), describe the difference between incremental and transformational adaptation efforts in terms of the extent of systematic change they promote. Transformational adaptation strategies seek to reconfigure both the trajectory and meaning of development, while incremental adaptation maintains the status quo, taking a programmatic approach that protects and preserves the existing system and behaviors (Eriksen et al., 2021).

circular approach focuses less on the predominance of climate data delivery and more on user interaction and capacity building (Vogel et al., 2019).

Although diverse definitions exist, in practice co-production can be seen as a CS methodology that overcomes barriers to knowledge application and use with the meaningful involvement of all relevant stakeholders throughout the production and communication process. Co-production efforts aim to ensure that the produced CS match the demand-need of those intending to make use of it (Lemos et al., 2018). This has been referred to as "iterative interaction" and is one of multiple identified approaches taken to co-production across research and practice (Bremer & Meisch, 2017). While the diversity of stakeholders involved in co-producing CS ideally increases the quality, relevance, and uptake of such services, it also creates challenges, especially when communicating and translating across diverging backgrounds, experiences, perceptions, and lived realities (Vaughan & Dessai, 2014). The extent to which co-production is feasible furthermore depends on financial and human resources that are often not available within developing contexts, posing significant practical barriers to potential co-production efforts. Efforts to co-produce CS with smallholders have improved its delivery and the dialogue between stakeholders yet have had little impact on the actual use of climate information in decision-making (Hansen et al., 2019).

2.3 Communication of climate and weather information

In addition to the decision-making context of farmers themselves and challenges related to delivering climate and weather services that meet their context-specific reality, challenges related to producing, communicating, and translating a climate service are widespread (Hewitt et al., 2012). Although CS are promoted as a way to ensure that climate information contributes to enhanced decision-making on the ground, multiple challenges to producing and distributing climate information and services in Tanzania have been documented over the past decades. These challenges include both technical and financial limitations, institutional limitations, and differing experiences and expectations, which in turn influence perceived quality and usability of forms of climate services across different stakeholders (Daly & Dilling, 2019; West et al., 2018; Yanda et al., 2015). Information about climate and weather has long been provided to citizens by NMHS, the typical producers of climate and weather information. In Tanzania, the NMHS is the Tanzanian Meteorological Authority (TMA). TMA has the sole public authority that is authorized to produce and distribute climate and weather information in Tanzania (Daly & Dilling, 2019). The channels and processes used to develop and deliver climate information and services to smallholders are important determinants of whether users will trust the information and thus must be considered when discussing the quality and usability of existing and potential climate services (West et al., 2018).

Studying the provision of seasonal climate forecasts offers a way to understand long-term challenges and benefits of CS for smallholders and, as such, the most used climate service for examining the usability gap between producers and users (Hansen et al., 2019).[10] Although both short- and long-term CS, such as early warning systems, disaster risk reduction efforts (short-term) and annual to decadal climate models and predictions (long-term), can be important to farmers' decision-making, building on other studies in the Tanzanian context, this thesis focused specifically on the use of seasonal forecasts as the main provision of climate information for smallholders. Therefore, unless otherwise specified, *climate information and services* are used to refer to a *seasonal forecast*, indicating climate information and associated advisories regarding seasonal weather patterns.[11] An example of a seasonal forecast is the TMA seasonal forecast for the *vuli* season, which is normally delivered online, over text message, and via other mass media and social media platforms prior to the onset of the rainy season. The seasonal forecast from the 2022 *vuli* season delivered online from TMA is included as Appendix 1. The forecast includes advice that is specifically related to the needs of sectors considered to be end-users, such as agriculture and transportation.[12] At the national level, end-users of climate services include ministries of transportation, agriculture and food security, disaster risk reduction, livestock and fisheries, shipping, aviation, health and social welfare, national defense, labor, infrastructure, natural resource management, and academic and research institutions. At the sub-national level, the main users include district departments of agriculture, beekeeping, livestock, planning and finance, water, natural resources and environment, land, and public health (Yanda et al., 2015).

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[10] Seasonal forecasts can be defined as probabilistic estimates of precipitation and temperature for the forthcoming season, offered on two-to three-month time scales (Ziervogel & Calder, 2003).

[11] Unless otherwise noted, the terms, *climate information, climate and weather information*, and *seasonal forecast* are used interchangeably for simplicity's sake. It should be noted that in other CS literature and practice, climate and weather information may also be used to refer to shorter or longer timescales and types of information than are discussed in this thesis.

[12] *End-user* refers to the intended recipients of climate information and services. WMO defines end users as a "heterogeneous mix of stakeholders from the national, sub-national and community levels. Each user can derive a benefit – potential or actual – in using climate services" (Tall, 2013).

In this study, the end-users included farmers and extension officers, but also NGOs, farmers' groups, researchers, and other community members.

TMA sends out climate and weather information in two main "streams" (Yanda et al., 2015: 12), one to the public and one to government bodies. The first is communication to the public through mass media, such as radio, television, and newspapers, on their website, and via mobile phones. In the second stream, TMA delivers information to government bodies through letters, email, fax, telephone, and face-to-face. As highlighted by Yanda et al. (2015), TMA alone does not have the capacity to design, develop, and deliver climate services to the wide range of potential end-users. To do so, they rely on collaboration between many stakeholders at both national and sub-national levels. Those who receive the climate information are therefore often tasked with interpreting and communicating the information in a way that suits the needs of a particular sector. This is the case for agricultural weather forecasts, which are first distributed from TMA to Regional Secretariats, where the agricultural department re-analyzes the forecast and tailors it to farmers in the specific region. This forecast is then delivered via post to the Departments of Agriculture at the District Council level. The district agriculture department again re-analyzes the forecast to suit the needs of the given district. From here, the information is communicated to local farmers and pastoralists by agricultural extension officers in the form of advisory services (Yanda et al., 2015).

As pointed out by Tall et al. (2013), not all users of CS are the ultimate end-user but rather act as an intermediary between the producers and end-users (in this case, smallholders). Such intermediaries are often described as "boundary agents" or "boundary organizations" and are important actors in facilitating interaction across the science-society divide (Cash et al., 2003). In this study, intermediary bodies included agricultural extension officers at both village and ward levels, as well as farmers' organizations, researchers, and NGOs, as they all act as communicators of climate information from the producers (TMA) to smallholders.

2.4 Use of seasonal forecasts for climate adaptation among smallholders

Societies adapt to climate change using a plurality of traditional, local, practical, scientific, and technical systems of knowledge (Bremer et al., 2022). To understand the use of climate information and services, it is key to understand the context in which smallholder farmers operate and make decisions (Vogel & O'Brien, 2006). Studies among smallholders in Tanzania have documented that the most important types of climate information desired include forecast of the start of the rainy season, expected rainfall amount over the season, the end of the season, number of days of rainfall, and the probability of extreme events (Coulibaly et al., 2015). Farmers predict rainfall using a variety of indicators, not only the scientific information and weather forecasts from NMHS. These include indigenous weather forecasting methods, local indicators such as bird sounds, insect movement, local weather patterns (and more), as well as relying on past-experience and the advice or experience of fellow farmers. Local indicators have been documented to be less consistent and reliable due to longer-term changes in climate (Kihila, 2018).

Adaptation options for farmers based on diversified agricultural practices are determined not only by climate- and weather-related factors, but by compounding environmental, economic, institutional, cultural, and demographic factors (Muema et al., 2018). To ensure food-security, farmers' decision-making context is often shaped by differential ability to use climate and weather information based on factors such as gender, size of household, income level, geographical location, and access to irrigation (i.e., West et al., 2018; Yanda et al., 2015). Agricultural practitioners thus make decisions based on complex and compounding factors, so climate and weather information and associated advice are therefore only one of many considerations for users (André et al., 2021).

3. Conceptual and Analytical Framework

To explore the perceptions and expectations of users for climate services in relation to smallholder decision-making, this study builds on science-policy-oriented climate services scholarship that seeks to understand the quality of climate and weather information for informing adaptive actions in the face of climate variability and change. Studies of climate information and services for smallholder adaptation in Tanzania have documented a disconnect between the expressed interest in, and need for, scientific information to enhance adaptation possibilities. For example, West et al. (2018:54), in a review of the GFCS APA phase I project, found that "respondents at the local level generally consider scientific information about the weather and climate to be potentially 'useful' information that can complement traditional forecasts and local and indigenous sources of knowledge". However, issues, such as translating forecast information into understandable terminology and the timing and scale of the forecast delivery, have been documented as challenges to going from services that are considered potentially useful to ones that are operationally used (Coulibaly et al., 2015). The conceptual approach taken in this thesis aims to link such challenges, and others highlighted by study participants, to established ways of assessing scientific information for societal decision-making through the criteria of salience, credibility, legitimacy, usefulness, and usability, explored further in this section.

3.1 Linking knowledge to action in climate services

It is widely acknowledged in both research and practice that, to be useful, climate information needs to meet the context-specific needs of the people who will use it (i.e., Cash et al., 2006; Brasseur & Gaillardo, 2016; Lemos & Morehouse, 2005). As indicated in Figure 1 (Chapter 2), CS have conventionally been developed following what Cash et al. (2006:484) refer to as the "loading-dock model", where recipients are seen as passive receivers of scientific information, which is produced and delivered by scientists. Other scholars describe this similarly as a supply-oriented approach, where the focus is on producing and supplying information *to* users, rather than driving information production based on the demands *of* users, and co-developing said information (Findlater et al., 2021; Vincent et al., 2018).

Although scholars take varying approaches to describing the perceived gap between production and use of scientific information, there is increasing agreement that bridging the gap between science and policy, or similarly between knowledge and action, requires a shift in how scientific quality is assessed. Linking knowledge to action relies on translating across boundaries that demarcate science from policy (Cash et al., 2006). Conventionally, however, scientific research on the impacts of climate change has focused on quantifying current and future climate change impacts using a limited range of parameters (Apraku et al., 2021). Whitfield (2016:34) refers to this as a “model-centric approach” and highlights that climate impact models now have a “privileged position within the activities and agenda-setting of international climate and agricultural research centers”. Increasingly, however, scholars within climate services are questioning the technocratic, model-centric approach and instead pushing for climate information, and climate science in general, to be assessed based on value to society as opposed to scientific accuracy only (i.e., André et al., 2021; Bremer et al., 2021; Wall et al., 2017; and others). Thus, in a demand-driven approach, the primary focus is on the decision-making context and user-identified needs. Bremer et al. (2021:2) describes this distinction as a division between a focus on “getting the science right” (assessing the rigor of scientific information) as opposed to “getting the science used”, a division which can reinforce a disconnect between science and practice as well as lead to overlooking relevant, but less tangible cultural, social, and ethical qualities promoted by CS.

3.2 Assessing the quality and usability of climate services

Standard tools for evaluating scientific research are thus increasingly acknowledged as failing to consistently capture the impact of research on decision-making and policy. While evaluating scientific credibility, they do not necessarily address factors such as relevance (salience) to decision-makers, nor how different stakeholders perceive and trust both the process of developing the knowledge and the produced knowledge itself (Cash et al., 2003; Wall et al., 2017). Scholars of CS are addressing the usability gap more and more in practice through developing or reviewing ways of actively assessing the perceived quality of knowledge and its relevance to intended users. Included in this category are reviews and studies undertaken by André et al. (2021), Bremer et al. (2021), Daly and Dilling (2019), Norström et al., 2020, Vincent et al. (2020), West et al. (2018) and Yanda et al. (2015) that are concerned with understanding how to improve the quality and relevance of climate information for decision-making. Within such studies, the so-called knowledge quality criteria of “credibility”, “legitimacy”, and “salience”, initially proposed by Cash et al. (2003), as well as the two further criteria of "usefulness" and "usability" (Lemos & Morehouse, 2005) have been used and built upon in the context of CS. The criteria are called upon to assess the extent to which weather and climate information have the potential to be acted on by stakeholders in ways that enhance their resilience to climate risks.

3.2.1 Credibility, Legitimacy, and Salience

In this study, I use and contextualize the criteria as defined in the original scholarship by Cash et al. (2003) and Lemos and Morehouse (2005). *Credibility* refers to the trustworthiness of knowledge and its "scientific plausibility and technical adequacy" (Cash et al., 2003:4). A lack of trust and perceived unreliability of climate information has been reported as a main hindrance to utilization of CS among smallholders in Tanzania (Daly & Dilling, 2019; West et al., 2018; Yanda et al., 2015) as well as in Kenya (Muema et al., 2018), indicating that credibility is likely also an important factor in measuring perceived quality of climate information and services in the studied contexts. *Legitimacy* indicates the fairness of the process in terms of who determines the steps taken in developing knowledge and how; the politics involved in these decisions, and whether and how relevant stakeholders were consulted. Questions, such as whether the knowledge is perceived as unbiased are important to determine legitimacy (André et al., 2021). In their study of co-produced CS with pastoralists and smallholders in Tanzania, Daly and Dilling (2019) found that, in and of itself, ensuring an iterative co-production process does not inherently lead to agreement among stakeholders about what constitutes usable knowledge, largely due to unequal power relations: some stakeholders have more influence than others in determining the process and outcome. Therefore, it is essential to consider *whose* priorities and perceptions influence the outcome and how different power relations play into this and, in turn, how different stakeholders perceive the legitimacy of the process differently. *Salience* refers to the relevance of the produced knowledge to user contexts and needs and has been shown to be a key indicator of information use and uptake, in some cases underlying the other criteria (André et al., 2021). Assessments of CS development and delivery in Tanzania, such as those done by Yanda et al. (2015) and West et al. (2018), found that a lack of perceived credibility, legitimacy, and salience were all established as hindrances to the use of climate and meteorological information among smallholders.

According to Cash et al. (2003), overlap and tensions often exist between the criteria, and meeting one often comes with tradeoffs to the others. For example, increasing public participation through co-production may increase the salience of research for users, yet decrease the credibility of the information for peers in science communities (Cash et al., 2006). Although acknowledged as critical to developing high-quality knowledge, the criteria of salience, credibility, and legitimacy do not, in and of themselves, adequately determine whether knowledge is used in practice (André et al., 2021; Vincent et al., 2020). Therefore, I further build on scholarship that draws on the further criteria of usefulness and usability, originally suggested by Lemos and Morehouse (2005).

3.2.2 Usefulness and Usability

Usefulness refers to whether the knowledge and information is provided on temporal and spatial scales that match the practices and needs of users (Lemos & Morehouse, 2005). According to Vincent et al. (2020:2), useful information is the first component of generating effective climate services for adaptation, and "requires an understanding of decision-making contexts, users' climate information needs, climate metrics that address users' needs, and the ability to deliver identified metrics". Secondly, *usability* refers to whether intended users can access and use the information in the form in which it is provided (Lemos & Morehouse, 2005). Delivery of information varies greatly depending on the context, type of information, resources available to producers, etc., (André et al., 2021). For example, a seasonal forecast may be delivered online or on paper, in Swahili or a local language, or using complex scientific jargon vs. terminology that is commonly used and understood among farmers. As pointed out by Vincent et al. (2020), presenting probabilistic seasonal forecasts using overly technical language or models may impede potentially useful information from being usable.

Now more than a decade ago, Lemos et al. (2012) pointed out that despite the increasing scholarship examining different aspects of the usability gap, there had been little focus on how information went from being *useful* to being *usable.* More recently, Vincent et al. (2020) showed that this is still the case in sub-Saharan Africa. Using case examples from the tea and water sectors, Vincent et al. (2020:3) describes an often overlooked "link in the chain": whether knowledge that is both useful and usable is then actually *used* to inform decision-making and "climate resilient planning" that enables adaptation and the factors required to make this happen.

Their study identified three components that are necessary to overcoming the usability gap between CS that are *usable* and CS that are *used* (Figure 2). The first two components, usefulness and usability, are described as "characteristics of the information itself" – suggesting a focus on developing information that meets the knowledge quality criteria of salience, credibility, and legitimacy. The third component, "characteristics of the enabling environment", necessitates the existence of supportive institutions, policy frameworks, and individuals who have adaptive capacity and the agency to make decisions.

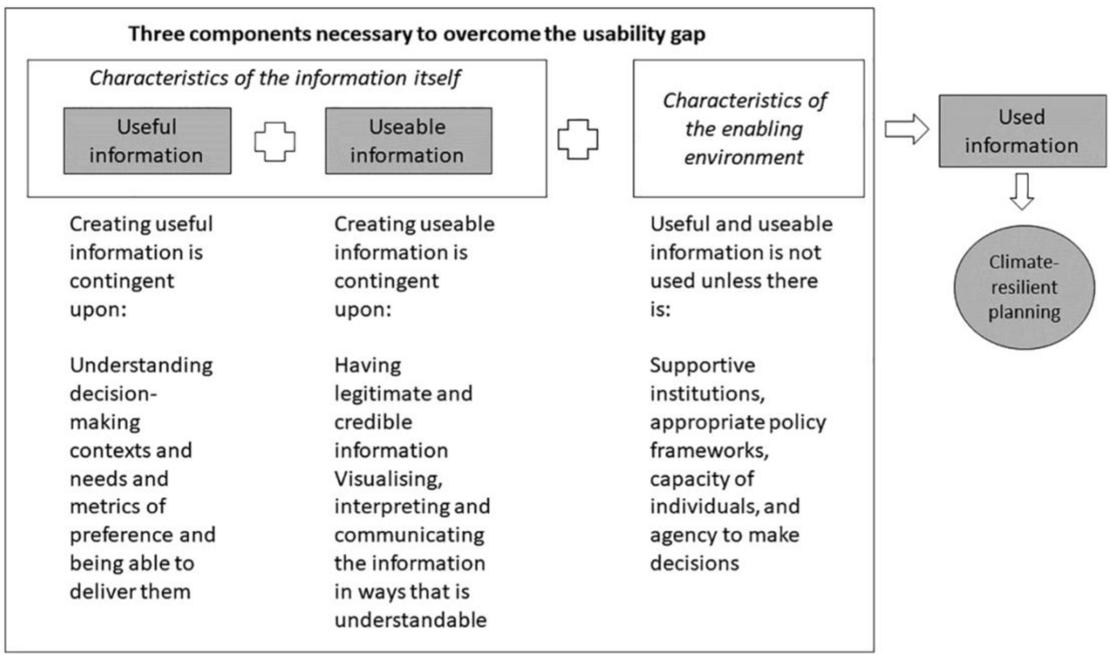

Figure 2. "Three components necessary to overcome the usability gap": A conceptual framework proposed by Vincent et al. (2020:3) outlining factors needed to ensure that knowledge is useful and usable for climate-resilient planning,

The distinction between factors that determine the potential usability of CS from whether it is actually used is similarly explored in studies, such as André et al. (2021) and Bremer et al. (2021), which highlight that access to information, despite its potential usefulness, does not always mean that it is *actionable* in each context. In the Tanzanian context, Daly and Dilling (2019), West et al. (2018), and Yanda et al. (2015) are among studies that have used the five-knowledge quality criteria to assess CS use among smallholders and pastoralists. These studies found that despite the increasing attention being paid to co-production of climate services as well as diverse decision-making contexts, a gap remains between the recognized and potential usefulness and usability of climate information and services and their practical use. Daly and Dilling (2019:72) found, for example, that perceptions of the same quality criteria can vary significantly among stakeholders; thus, overly focusing on salience, when determined by the level of "forecast downscaling" came at the cost of legitimacy and credibility, ultimately challenging the overall perceived usability of the service among potential users. By using the same criteria, the data collected in this study builds on previous findings related to the perceived quality of climate and weather information and associated services among smallholders in Tanzania to explore the usability gap.

In addition to using the knowledge quality criteria to explore perceptions of the climate and weather information itself (i.e., the potential products of co-production), scholars have also used the criteria as a starting point for exploring potential outcomes of the *processes* involved in co-producing climate services, including both the tangible and intangible outcomes (Bremer et al., 2022). Multiple scholars thus also point to a need for assessing perceived quality, not only in terms of the co-produced service itself (product) but also the co-production process (i.e., André et al., 2021; Bremer et al., 2021; Vincent et al., 2020). For example, the process of co-production can help create long-term networks and relationships and build trust (André et al., 2021; Wall et al., 2017). Arguably, a shift in focus from end-product to the overall process of knowledge creation may also catalyze a shift away from the conventional supply-driven approach that drives climate services production in a top-down, technology-centered manner (i.e., Carr, 2023; Whitfield, 2016) towards a user-oriented, demand-driven process (Findlater et al., 2021). However, as highlighted by Vincent et al. (2020), a focus solely on the knowledge quality criteria may overlook such intangible outcomes (André et al., 2021; Bremer et al., 2021;). Therefore, in addition to exploring perspectives and experiences of farmers and extension officers in terms of the knowledge quality criteria outlined above, I explore other potential benefits and challenges of co-production and highlight some of the factors that may give nuance to our understanding of how, when, and why potentially useful and usable climate services may or may not be used operationally among smallholders.

4. Methods

4.1 Philosophical and methodological foundation of the thesis

The thesis is grounded in an empirical investigation and a conceptual and analytical framework linking climate services to climate adaptation via co-production of high-quality knowledge. In doing so, I employ established criteria of salience, credibility, legitimacy, usefulness, and usability (so-called knowledge-quality criteria) and adopt a critical realist (CR) epistemology, whereby the "real world" is seen as "theory-laden but not theory determined" and theoretical explanations of reality are therefore considered to be "fallible" (Bhaskar, 1979 in [Fletcher, 2017:188]). Although situated explanations of reality (for example, those of research participants, theorists, and scientists) are seen as equally fallible, they introduce "competing explanations of a phenomenon and some must be taken as more accurate than others" (Fletcher, 2017:188). The fact that scientific ways of knowing are more "accurate" than experiential explanations is not assumed in CR, nor is it assumed that there is one, "true" explanation of reality for all (Fletcher, 2017). The epistemological standpoint of many climate scientists is that scientific knowledge, such as seasonal forecasts, is the most valid form of knowledge for navigating climate risks (Carr & Owusu, 2016), and the most appropriate "solution" for climate adaptation is enhanced access to scientific information, placing less value on the experiential explanations and knowledge held by research participants. This reflects on the often-assumed link between increased climate information and climate adaptation. In this study, I take the standpoint that experiential explanations and knowledge of participants should be considered as equally valid explanations of reality and thus determinants of when and why CS are adopted and used.

4.2 Research strategy and design

The data collection for this study took place within the Research Council of Norway-funded project "Co-producing Gender-responsive Climate Services for Enhanced Food and Nutrition Security and Health in Ethiopia and Tanzania" (COGENT – 2020–2023). The project is an interdisciplinary collaboration between social and natural science researchers in Norway, Tanzania, and Ethiopia working in global development studies, sociology, medicine and public health, meteorology, agriculture, and food and nutritional security. The project's primary objective has been to “identify and address opportunities and barriers for co-producing gender-responsive climate services that enhance household food and nutrition security, and health outcomes in the face of climate change in selected areas of Ethiopia and Tanzania.” (CMI et al., n.d.).[13]

COGENT work packages (WP) 1 and 3 are particularly relevant for the questions explored in this thesis. WP 1 explores social contexts in which climate information is used, driven by the hypothesis that “the usability of climate services will increase with a better understanding of intra-household climate-agriculture-health vulnerabilities and decision-making dynamics at the grassroots”. WP 3 explores the institutional contexts in which climate- and weather-related decision-making take place, driven by the hypothesis that “[t]he quality of climate services and their communication to grassroots actors will improve with closer liaison between meteorological agencies, the ministries of agriculture and health, and agricultural and health extension officers” (CMI et al., n.d.).

Given this thesis’ placement within the COGENT project, the study location and chosen interviews took place within the context of the larger project. Field work was made possible by support from the Norwegian partner, CICERO,[14] as well as grants from the Norwegian University of Life Sciences (NMBU) and the TOWARDS project.[15] The costs covered included transportation, lodging, food, translation, compensating interviewees, other necessary running costs while in Tanzania, and a license for the MAXQDA coding software. The field work was facilitated by researchers at Sokoine University of Agriculture (SUA) and conducted simultaneously with follow-up data collection for the COGENT project WP1 fieldwork, which allowed for triangulation of my own primary data collection through discussion with COGENT researchers and observation of focus group discussions (FGDs) conducted during the field work. The wider project data collection was a follow-up of fieldwork conducted in 2021 in the region and included both individual interviews with farmers and extension officers and four FGDs. The FGDs were conducted in two villages: Njage in Mlimba district and Mkindo in Mvomero

[13] The project partners in COGENT are Christian Michelsens Institutt (CMI), CICERO, NORCE research, TMA, and Ethiopia Meteorological Institute (EMI). The COGENT project application (unpublished) was authored by all partners, but led by CMI, and is therefore cited as CMI et al.
[14] CICERO is the Norwegian Center for International Climate Research (https://cicero.oslo.no/en/about)
[15] TOWARDS is an NMBU Sustainability Arena project running from 2021–2024 and for “[e]xploring the transformation of cities and communities towards socially just and sustainable futures”. For more information see: https://www.nmbu.no/en/research/projects/nmbu-sustainability-arena-towards-sustainable-cities-and-communities

district. Follow-up interviews with village extension officers were conducted in Mkindo and Lungo Villages (Mvomero district) and in Njage. Both villages are in Morogoro region and have formal irrigation schemes. The FGDs were conducted in Swahili and translated to English by the same interpreter who translated the interviews for this study. Each group had around eight participants, all of whom were farmers from the village. In Mkindo village, the two focus group discussions were divided by gender. In Njage village, the two focus group discussions were divided by farmers having access to irrigation and farmers without access to irrigation. The division was made to fill gaps in the field work conducted previously. I recorded observations by taking notes of discussions and interactions between the researchers and farmers. These notes were then summarized following the FGD, supplementing the primary data collected through interviews and observation of the COGENT workshop, which I describe below.

4.3 Description of study sites

Morogoro is one of 20 regions in Tanzania and is characterized by mountainous areas, plains, and plateaus. The region is divided into seven districts: Mvomero, Kilosa, Kilombero, Mlimba, Ulanga, Morogoro Urban, and Morogoro Rural. It experiences average annual temperatures between 18 degrees Celsius and 30 degrees Celsius. Due to complex topographical patterns, Tanzania's climate varies considerably by region (Kijazi & Reason, 2009). Northern and eastern Tanzania experience two distinct rainy seasons. The short *vuli* rains last from October through December ('OND'), while the long *masika* rains occur in March, April, and May ('MAM'). The southern, western, and central parts of Tanzania typically experience only one rainy season (*msimu*), which is continuous from October through April/May. Morogoro Region straddles the patterns of seasonal rainfall distribution of northern and southern Tanzania whereby Southern Morogoro experiences one rainy season annually and Northern Morogoro has a bimodal pattern, experiencing both OND and MAM rainfall. Annual rainfall across the region varies between 600mm and 1800mm (Mkonda, 2015; Ojoyi et al., 2015).

This study took place in Morogoro region, in Morogoro Urban, Mvomero, and Mlimba districts, indicated on Figure 3, below.

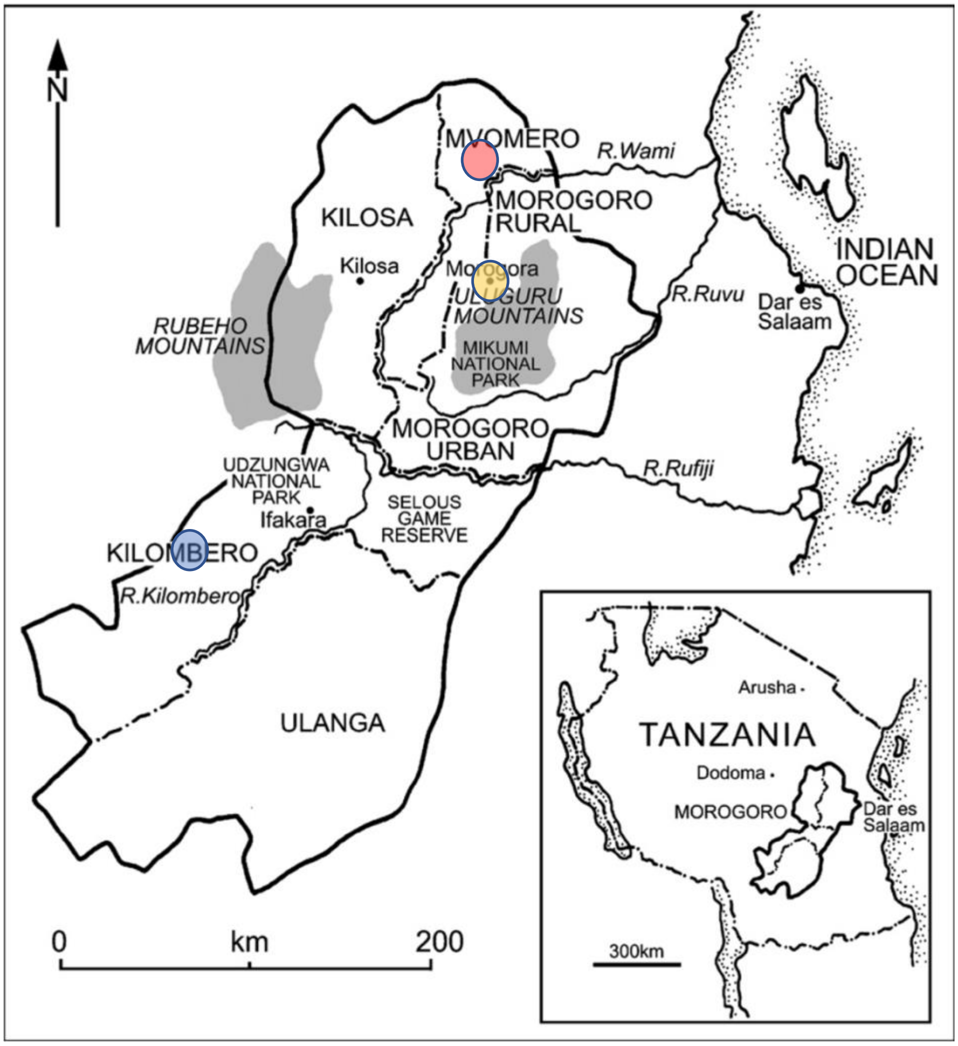

Figure 3. Map of Morogoro region, with study areas highlighted. Kilombero district is now divided into two districts: Kilombero to the north and Mlimba to the south. The study took place in Mvomero, Mlimba, and Morogoro districts. (Adapted from Paavola [2008]) Study locations within the districts are highlighted in three different colors. Blue: Njage and Mlimba villages (Mlimba district), yellow for Morogoro town (Morogoro Urban), and red for Lungo and Mkindo villages (Mvomero district).

The major food and cash crops grown in these districts include maize and rice as well as root crops, such as cassava and legumes, oilseeds, and vegetables. Food security in Morogoro, one of the major agricultural regions of Tanzania, is high compared to other regions (Mkonda & He, 2016). Staple crops in Morogoro include rice, maize, sorghum, cassava, and millet. Commercial (high value) crops produced and sold in the region include mainly sunflower, coconut, sugarcane, and sisal. Morogoro is one of the main rice-producing regions of Tanzania, producing more than 100,000 tons per year (Chivaghula, 2020). Many farmers grow and sell a mix of these staple and commercial crops through a variety of market channels (Kangile et al., 2020). The extensive paved road system in Mvomero, access to a developed city (Morogoro Town), and relatively high levels of agricultural production make Morogoro one of the most accessible regions in Tanzania relative to other parts of the country. However, transportation throughout Mlimba district, located in the Kilombero Valley and bordering a wetland, is often difficult in the rainy season when secondary roads become flooded and seasonally unpassable. The reliance of many inhabitants' livelihoods on agriculture and livestock-keeping makes the region particularly vulnerable to changing weather and rainfall patterns as well as periodic droughts and flooding. Livelihood diversification is a common strategy employed by farmers to adapt to climate stressors. Thus, many farming households engage in income-generating activities, such as shopkeeping, livestock raising, or other small business endeavors alongside agriculture (Paavola, 2008).

As stated, Morogoro region is on average more food secure given its relatively high agricultural output as well as its relatively well-developed infrastructure. However, there is wide internal variation within the district. A main distinction in this study can be made between Mlimba district, which lies in the Kilombero Valley in Southern Morogoro – an area that experiences higher annual rainfall and is generally more prone to flooding (see Figure 3) – and Mvomero District, which is in the drier northwestern Morogoro with relatively less rainfall. A hypothesis explored in the COGENT project is that variations in food and nutritional security can be expected also within the two districts based on factors such as whether farmers have access to irrigation. The findings in this study should be understood within this context, although it was outside the scope of the study to explore detailed experiences of how access to irrigation impacts smallholder food security and livelihoods.

4.4 Primary data collection

This study employed qualitative data collection methods, including participatory observation of a co-production workshop organized by the COGENT project and held at Sokoine University of Agriculture (SUA) in October 2022, along with key informant and semi-structured interviews conducted with smallholder farmers (the intended beneficiaries of CS) and other stakeholders in the production, communication, and use of CS, in January–February 2023. A qualitative approach using purposive sampling was deemed to be the most fitting for the study given its embeddedness within an existing project, time, and resource constraints, and the focus on understanding subjective stakeholder experiences of climate change impacts and adaptation, and the potential role of CS in addressing these. This data was complemented by non-participatory observation of focus-group discussions organized by the COGENT researchers in the study villages in Mvomero and Mlimba districts, which took place at the same time as interviews.

Interviewing and participant observation allow concepts and theories to emerge out of the data as it is collected (Bryman, 2016). In this study, it was important to both enter the field with some prior understanding of CS and related theories and concepts, for example those related to co-production and the knowledge quality criteria, as well as to allow participants' own concepts and theories to emerge. Keeping space for both perspectives enabled me to question common assumptions made in ongoing CS and co-production theory and practice as well as reflect on and compare how different concepts and terms were operationalized by different stakeholders.

4.4.1 Recruitment and Procedure

Participants in this study were recruited with the aim of including actors across various roles in the conventional CS value chain (Figure 1). At the village-level, smallholder farmers and agricultural extension officers who both had, and had not, participated in the COGENT stakeholder workshop were interviewed. Workshop participants were interviewed to understand in what ways, if any, the workshop had influenced their understanding, use of, and/or communication of climate and weather information over the past season, and their perspectives on climate and weather information and services more generally. Farmers and extension officers who had not participated in the COGENT workshop were interviewed in the same villages to explore perspectives and expectations for climate and weather information that were not directly shaped by the workshop.

Study participants were chosen based on recommendations from SUA researchers or SUA contacts within the villages. The time and place of interviews were coordinated by SUA researchers based on contacts developed previously under the COGENT project and in some cases facilitated in by village extension officers. All extension officers and farmers interviewed were compensated for their time and, where applicable, travel. Interviews took place either at farmers' homes, work, or (in the case of extension officers) at their office or our hotel. Some interviews included a visit to the farmer's plot/farm. Discussions during the walk to the plot were not recorded or transcribed but notes were taken during and summarized as soon as possible following the visit.

4.4.2 Study Participants

In total, this study included 19 participants. Semi-structured interviews were conducted with stakeholders having various roles or potential roles in relation to CS production, communication, and uptake or use. Further details about study participants are included in Appendix 2.

1. *Smallholder farmers (intended users of climate and weather information):* Six interviews were conducted with smallholder farmers who were selected from three rural villages: Vigaeni village in Mlimba district and Lungo and Mkindo villages in Mvomero district based on existing connections within the COGENT project. In this study, most farmers interviewed owned or rented between 2–10 Ha.[16] Two of the six farmers who were interviewed had participated in the COGENT workshop in 2022. Interviewees in this group were also chosen to represent both those having access to irrigation (either formal or informal) and those with no access to irrigation, since this was one of the criteria for the selection of study villages in the COGENT project. Each interview lasted from 1.5–2 hours.
2. *Potential intermediaries of climate and weather information:* This group involved interviews with potential intermediaries of climate and weather information within the Morogoro region. Interviews were conducted individually with three representatives from local and national organizations who all used climate and weather information from TMA in directly working with smallholder farmers. Interviewees had all participated in the COGENT workshop and were from the following organizations: Sustainable Agriculture Tanzania (SAT), an NGO based in Morogoro, MVIWATA, a nation-wide farmers' union, and Tanzania Agricultural Research Institute (TARI), a government-funded research institute. Four individual interviews were conducted with extension officers in three different villages: two village extension officers and two ward-level extension officers. The four extension officers who were interviewed were also farmers – either

[16] The Food and Agricultural Organization (FAO) classifies "smallholder farmers" as managing between 1-10 Ha of land (FAO, 2012).

renting or owning their own land (in one case farming 100 ha). Of the four extension officers interviewed, one had participated in the COGENT workshop. These interviews lasted from 1–1.5 hours. Extension officers selected were from the same villages as the farmers who were interviewed (Vigaeni, Mkindo, and Lungo villages).

3. *Producers of climate and weather information:* One interview was conducted with a meteorologist from Tanzania Meteorological Authority (TMA) in order to explore perspectives and challenges faced by producers of climate and weather information in Tanzania. This interview lasted 45 minutes. The interviewee was also involved in the COGENT field work and was therefore familiar with the project and had participated in the COGENT workshop. Although ideally multiple TMA representatives would have been interviewed, the interviews were limited to one representative due to availability at TMA and my own time and resources.
4. *Key informant interviews* were conducted with two CS experts (working for NORCAP)[17] and four SUA researchers. These interviews supplemented the data collected in the field. Respondents were selected purposively based on having particular knowledge either in the field of CS, development studies, agricultural extension services, or health and nutrition. The two NORCAP CS experts who were interviewed currently work for the UN World Food Program (WFP) headquarters in Rome, Italy. These interviewees were contacted based on my concurrent work at the NORCAP head office and chosen based on their specific experience with CS in Tanzania, having both worked with TMA on the GFCS project. These experts are labeled "NORCAP expert 1" and "NORCAP expert 2" in the results. Each interview lasted 60 minutes. The four interviews conducted with researchers at SUA were chosen based on their contextual knowledge of climate adaptation and agricultural extension in Morogoro. Two researchers (labeled "researcher 3" and "researcher 4") participated in the COGENT workshop. Researchers labeled "researcher 1" and "researcher 2" did not participate in the workshop.

[17] NORCAP stands for "Norwegian Capacity" and is a section of the Norwegian Refugee Council (NRC) that focuses on development aid. NORCAP deploys staff with specific expertise within a field as secondees to partner organizations, such as NMHS and UN: https://www.nrc.no/norcap/

Interview guides (see Appendix 3) were developed for different types of interviewees and tailored to their context and prior experience with CS. The first interview guide was prepared with the aim of interviewing the targeted and potential CS end-users – smallholder farmers. The second interview guide was developed for potential CS communicators and intermediaries at national and sub-national levels. The third interview guide was used for TMA. Here, questions were largely focused on production and dissemination of climate information and CS, as well as staff experiences based on attendance and engagement at the COGENT workshop. A fourth interview guide was used for NORCAP experts, while for interviews with SUA researchers the interview guide used for CS intermediaries was used.

4.4.3 Participatory observation at the COGENT Workshop

To gain an introduction and background for the study and prepare for and complement data collected through interviews, I was given an opportunity to take part in and observe a co-production workshop, organized and facilitated by the COGENT project, which took place on the 4th and 5th of October 2022 at SUA in Morogoro. Although the most common use of the word *case* is to describe a single location or organization (Bryman, 2016), a case can entail exploring a specific *process* (Creswell & Creswell, 2018). In this study, I approached the COGENT workshop as an example, or case, of co-production of climate services that are intended for smallholder agricultural use in Morogoro. The workshop program is included as Appendix 4.

Participants at the workshop included smallholder farmers from across Morogoro region, agricultural and health extension officers in the COGENT study districts (Mvomero and Mlimba), NGO representatives, researchers from SUA departments in Health and Nutrition, Agricultural Extension and Development studies, and representatives from TMA. Together with one of the COGENT project researchers from Norway, I helped facilitate small group discussions focused on participants' understanding and definitions of terminology related to CS and climate adaptation (Sessions 3 and 4, Appendix 4). I was thereby both participant and observer at the workshop. Bryman (2016) refers to participant observation specifically as observation whereby the observer (researcher) engages in activities alongside research participants, thus observing the behavior of members within a certain setting. It should be acknowledged that a participatory research approach normally entails the observer immersing themselves in the study context over a prolonged period. Limitations due to the short observation period in this study as well as from language barriers (the workshop was conducted in Swahili) are addressed in section 4.6.2. I took notes based on my observations during plenary and small group discussions and discussions with participants during breaks. These observations and my interpretations of them were then discussed in subsequent months with researchers involved in the COGENT workshop, who helped me process and contextualize my observations and experiences and prepare for up-coming interviews.

4.5 Data analysis and trustworthiness considerations

The 19 interviews were audio recorded and transcribed in two rounds, first using Microsoft Word transcription software to generate a rough automated transcript, and second by re-listening to the audio to ensure that the automated transcript was accurate. Time limitations precluded generating more than a rough transcript for the four key-informant interviews with SUA researchers. For the interviews conducted in Swahili, only the English translation was transcribed due to time and funding constraints. Limitations with this approach are discussed in section 4.6.2.

After transcription, the interviews were coded using Thematic Analysis. Coding helps to synthesize the data obtained during interviews and to categorize and label it by theme (Bryman, 2016). According to Braun and Clarke (2006: 61), codes are the "building blocks of analysis" which help the researcher organize and make sense of the data in relation to the research questions. In this study, I followed Braun and Clarke's (2006) "Six Step Thematic Analysis Process". An outline of these steps is included in Appendix 5. The initial round of coding was done by hand, allowing categories to emerge from the text as I read through the transcripts. Using categories (codes) generated during the initial round, I then used MAXQDA coding software to do a second and third round of coding, starting with the codes generated during the first round. In this study, coding helped to explore and elaborate on differences and similarities both within and across study participants, which in turn helped establish the themes presented in the findings. The knowledge quality criteria of salience, legitimacy, credibility, usefulness, and usability were not specifically coded for during initial analysis, rather, I linked these criteria to the bottom-up generated themes while describing and contextualizing the findings. This approach allowed for both the generation of organic, or bottom-up, analytical categories from the empirical data as well as establishing linkages to relevant theories.

4.5.1 Trustworthiness of the data

Qualitative research is often evaluated based on its *trustworthiness*, which can in turn be measured using four criteria: *credibility, dependability, transferability*, and *confirmability* (Bryman, 2016). *Credibility* in qualitative research refers to the degree to which the findings, interpretations, and conclusions are accurate and acceptable to others, and includes methods such as triangulating data materials, detailed (thick) description to convey the context in which the study took place and discussing the findings with other researchers (debriefing) (Bryman, 2016). In this study, data collection in the form of key-informant interviews and discussion with COGENT researchers served as a way of triangulating the data collected through in-depth interviews and observation. The term *triangulation* refers to a process whereby the researcher uses "more than one method or source of data in the study of a social phenomenon so that findings may be cross-checked" (Bryman, 2016: 697). Furthermore, *debriefing* with the interpreter and the other COGENT researchers during field work was used as a way of increasing credibility. Following the data analysis, findings in the study were discussed with a NORCAP climate services expert and COGENT researchers.

Dependability refers to the extent to which the researcher keeps records of all phases of the research process (Bryman, 2016). Dependability is important because qualitative research often involves subjective interpretations and is influenced by the researcher's decisions and actions. A research journal was kept throughout all stages of data collection and processing, with ideas and initial formulations of the project being shared and checked by my two supervisors. Prior to and during fieldwork, notes and interpretations were discussed with the interpreter and the SUA team to gain mutual understanding of terminology, study aims, and so on.

Transferability refers to how possible it is to transfer the studies' findings to another context. In qualitative research, however, findings tend to reflect unique contexts and significant aspects of social worlds being studied (Bryman, 2016). Transferability in this sense then requires the researcher to describe the context such that other researchers can make their own judgements about its transferability (Lincoln & Guba, 1985 [in Bryman 2016]). In this study, I have attempted to document and share each step of the study process, as detailed in the studies' methodology (Chapter 4). Furthermore, the context of the study is described such that, although one cannot apply the findings from the empirical data collected to other contexts, wider themes are identified and the ways in which this study pushes back on some key assumptions can be applied in other studies and similar research in CS.

Confirmability is a way of evaluating the extent to which my own values may have intruded in the study (Bryman, 2016). In evaluating confirmability, it is important to note first of all my own affiliation with NORCAP Climate Services project. Having worked with the NORCAP Climate Services project for over a year gave me background in multiple perspectives in how CS is used in development projects, both from the funding point of view and from interactions with CS experts working in regional centers and with NMHS. Through using purposive sampling, I was able to reach interviewees with different perspectives and experiences in the use of CS. However, this sampling technique also means that the interviewees in this study are largely people who have been in contact with similar projects before, which may have influenced their answers. If time and resources allowed, it would strengthen the study to rely more on sampling techniques that reached a broader range of interviewees who had not been previously involved in research or workshops related to climate services.

4.6 Positionality, reflexivity, and ethical considerations

The methodology we choose as researchers is shaped by subjective interests, assumptions, and purposes (Taylor et al., 2016); it is therefore important to reflect on the choices I have made as a researcher in this study and the study's limitations in this regard. In this section, I discuss the ethical considerations that were taken into account and the study's framing and methodology in light of language, time, and resource barriers. I also discuss factors influencing the trustworthiness of the findings. Finally, I reflect on my own positionality as a researcher in the context of this study.

4.6.1 Ethical considerations

The steps enumerated below were taken to ensure that proper ethical considerations were in place. The Norwegian Agency for Shared Services in Education and Research (SIKT) approved the research project before any data were collected.[18] The approval from SIKT involved how to handle personal data, gain consent, process data, and ensure information security. During field

[18] SIKT was formerly known as the Norwegian Centre for Research Data (NSD). The name change took place in 2023, hence any supporting thesis documents use the former name (NSD).

work, data was stored on a password-protected personal laptop. As soon as possible following fieldwork, all interview data were transferred to either an NMBU university server or CICERO Microsoft Teams platform, which were only accessible with a password. Transcripts uploaded to MAXQDA coding software were labeled using codes that did not identify the interviewee.

During interviews, the following steps were taken to ensure informed consent from participants: interviewees were made aware of their rights during the interview and asked for consent (see Appendix 6). Personal data from the interviews, including the names and organizations, were stored on a separate document as soon as recordings were transcribed. This document was then stored separately from the interview transcripts and will be destroyed once the project is completed.

In so far as possible, ethical considerations in terms of unintended consequences or harm for the study participants for having participated in the study were also accounted for. Establishing contact and consent with participants through SUA researchers who were familiar with the study context and area and bound by ethical and research clearances obtained for the wider project helped ensure that participants were not placed at risk. I made it clear during the interview that I was a student and, although affiliated with SUA and the COGENT project, could not promise any immediate outcomes or benefits from my research. I explained that I would pass along any statements respondents wished me to communicate to the SUA team. It is important to acknowledge the risk that answers given during interviews were not fully accurate or detailed because the participant was skeptical of being involved in unfamiliar research or potentially only participated for the monetary compensation. However, as described, this was mitigated as much as possible through triangulation with the ongoing COGENT research, the COGENT workshop observations, and follow-up conversations with the SUA team.

4.6.2 Limitations

Language

Limitations including time and resources, language barriers, and understanding of context were particularly important for this study. Despite its limitations, cross-cultural research can help scholars appreciate and understand the culturally specific nature of findings in social science research (Bryman, 2016). The interviews conducted with farmers and extension officers all took place in Swahili with the help of an interpreter, a native Tanzanian from Dar es Salaam who works as a teaching assistant at SUA. The interpreter was familiar with the study material and context having translated documents previously for the COGENT project. In transcribing interviews, only the English translation was used, meaning that information from farmers and extension officers was not understood or communicated directly to me. A possible limitation is thus that the interpreter gave a different translation than what was originally said, or that nuances in the languages caused confusion. Furthermore, as highlighted by Bryman (2016:65), even when translation of data is carried out competently, "insensitivity to specific national and cultural contexts" is still a potential problem. Therefore, one important limitation in this study is my lack of both linguistic and contextual background.

In order to take specific context into account during interviews as, prior to data collection, a researcher from SUA and COGENT project reviewed the interview guides for farmers and extension officers. I also discussed the interview questions and themes with the rest of the COGENT field work team, including two SUA researchers and one TMA meteorologist, who all have extensive experience in the area and with the topics. The feedback received when going over the interview guides ensured that the way the questions posed were 1) suitable to the farmers and extension officers' contextual understanding of CS and climate adaptation, and 2) using language that would be easily translated to Swahili during the interview.

Time and Resources

As this research was conducted as part of a master's thesis, time in the field and the available resources were limited during both data collection, translation, and analysis. For example, while I aimed to conduct interviews with stakeholders at various levels of the CS value-chain, there are many perspectives I was not able to capture in this study. These include that of UN representatives outside of NORCAP, district and national level government officials working within agriculture in Tanzania, and representatives from regional organizations working with weather and climate communication or forecasting. Farmers and extension officers were selected for interviews based on being a resident with access to irrigation in a village that was among the focus villages in the COGENT project, but not with consideration to age, gender,[19] or income

[19] Gender differences in use of CS was a central focus in the COGENT project. In this study, observing FGDs separated by gender revealed important differences in men and women smallholders' perspectives and experiences of CS. Due to limited time and resources, gender was not a main consideration in choosing interviewees. However, Table 2, Appendix 2, shows the number of male and female smallholders interviewed.

level directly. This way of narrowing eligible interviewees meant that I did not interview a representative sample of farmers in any of the study locations. Had time allowed, a broader range of interviewees would have added breadth to the study. The findings in the study thus highlight nuances and local complexity within CS for agricultural climate adaptation within and across the selected villages but cannot be taken to be a representative picture of the full range of smallholder farmers' diverse experiences with climate adaptation and CS use within the study locations.

Participant Skepticism

Another limiting factor lies in the fatigue and skepticism of interviewees towards outsider researchers. In interviews, multiple farmers mentioned skepticism towards researchers and "outside experts" based on past interactions. Thus, it was not only a lack of contextual and experiential knowledge, which – in addition to the short study timeline addressed above – hindered me from developing a trusting relationship with interviewees. My status as a white researcher coming from Norway, which is also the country funding the COGENT workshop, influences power dynamics and potentially what and how participants share their experience. In part, this was mitigated by the role of the interpreter, who in many cases engaged in conversation with the interviewees before and after the interviews; farmers were more inclined to share more information when engaged in informal conversation without simultaneous translation.

This limitation was further addressed by spending a few hours with most of the farmers and extension officers whom I interviewed, during which time I walked with them to visit their farm or around the village. This allowed for a more casual conversation, and I often found that they elaborated much more on their initial answers or stories from interviews during these conversations and tours.

A further limitation is the risk that participants told me how they think the system should work, but not necessarily how it is working in practice. For example, the Ward extension officer in one village gave me information about a functioning "shift schedule" within the village irrigation scheme. However, interviews with farmers, observation of the FGD, and my own experience while visiting the scheme showed that the shift system described by the extension officer was not working as well in practice as I had understood based on the description that was first provided by the extension officer. Interviewing farmers and extension officers in the same village, as well as cross-checking with COGENT findings and the FGDs, helped to mitigate such potential misunderstandings.

Reflections on my own learning throughout data collection

Transcribing and coding the interviews also led me to pick up on inconsistencies in my own interviewing method as well as the ways in which I learned better practice as the fieldwork proceeded. For example, in the initial interviews my questions were longer, which sometimes led to confusion both for the translator and the interviewee. I adjusted the phrasing of my questions for the later interviews, leading to a better discussion. There was also a difference in my understanding of context and farming practices between the initial interviews and the later interviews, which allowed me to ask more targeted questions in the interviews conducted towards the end of the field work period. In listening back through the interview recordings while transcribing, I noted instances where the way in which I phrased questions may have influenced the information I received during the interview. For this reason, it was especially important that I went back and transcribed the initial interviews rather than only relying on field notes taken during and following the interview. This was a way of addressing the *conformability* of the study, as I was able to pick up on ways in which my own positionality and lack of contextual knowledge influenced initial interviews differently than subsequent ones.

Positionality

According to Creswell and Creswell (2018:43), when planning a study researchers should consider how their personal philosophical worldview and assumptions they bring to the study influence how the research is designed and conducted, including "the specific methods or procedures of research that translate the approach into practice". Furthermore, researcher bias is an important consideration in evaluating the study. There are many factors that shaped my personal conceptualization and design of this project. Primarily driven by an interest in how we communicate across scales, culture, practices, worldviews, and so on, and how this shapes discussions around climate adaptation, I went into the study with my own assumptions about differences in local vs. national and global perspectives on adaptation needs and pathways. These were shaped not only by my current study program in International Environmental Studies, but also by the experiences I have learned from through working in the Climate Services team at

NORCAP, as well as by the experiences and more local understanding of my two supervisors, who have conducted extensive research in the field of CS in developing countries. Acknowledging that our philosophical worldview and assumptions are not only shaped in academia, my upbringing in a middle-income family in Norway and the United States also shape my understanding of climate change and its impacts and thus influence my perspective coming into this study. This was mitigated through ongoing dialogue about my interpretations with COGENT researchers and NORCAP CS experts familiar with both Tanzanian and Norwegian contexts. Triangulation of data sources and discussions with the other COGENT researchers during the data collection process also helped make sure my interpretations made sense given the specific context and that I had understood given meanings and terms correctly.

5. Findings

In this section, I present the studies' findings in three parts. In the first section, findings related to study participants' understandings, framings, and expectations of climate services are explored (5.1). Following this, expectations and experiences of potential co-production processes are presented (5.2). In these two first sections, data are explored with respect to the bottom-up categories that were identified during analysis of the data. Linkages to the knowledge quality criteria of salience, credibility, and legitimacy are noted when relevant, but did not serve as a starting point for analysis and are therefore discussed in the next section (Chapter 6). Finally, section 5.3 presents findings related to the usefulness and usability of seasonal forecast information and services, emphasizing practical barriers that might hinder CS from being useful and showing that in the studied context there are nuances that complexify how participants' view and define the usability of climate information and services.

Smallholder and extension officer participants have been given pseudonyms. To improve readability, answers from farmers and extension officers, which were translated from Swahili to English, have been re-written to first person and are italicized without quotation marks. Double quotation marks indicate direct quotes from interviews conducted in English.[20]

5.1 Respondent understandings and expectations of climate information and services

This section summarizes findings related to stakeholder understandings of key technical terms that are used in CS projects: these terms include *climate services*, *climate adaptation*, and *co-production*. The section draws primarily on observations of the COGENT workshop as well as on responses given during interviews conducted with national and sub-national agricultural extension, research, and NGO respondents. Different and nuanced understandings of climate services and climate adaptation were clear across stakeholders, both between and within groups such as farmers, extension officers, or researchers. With the exception of CS experts and the meteorologist from TMA, *climate services* and *co-production* were not known or used terms among study participants, who were more familiar with the terms, *climate information* and *climate adaptation*, and associated terms climate *risk* and *advisory services*.

[20] To maintain a distinction between direct quotes and translated answers, long responses from farmers and extension officers have not been extracted from the text.

5.1.1 Terminology

The COGENT workshop highlighted the variety of ways in which different actors use and understand terminology associated with climate change. During the workshop, a session was held on understanding of weather and climate concepts and terms for decision-making (Sessions 3 and 4, Appendix 4). In a group of about 10 participants, four terms related to climate and weather concepts were discussed: *climate services, risk, adaptation*, and *advisory services*. These terms were chosen by the facilitators. Each participant was asked to define the term, after which the terms were discussed in break-out groups. The aim of the session was to facilitate discussion among different actors, so each group was a pre-decided mix of participants, with one TMA representative in each group. The four terms were predetermined by workshop organizers (COGENT researchers) and were confusing particularly to some farmers and extension officers.

Distinctions between climate and weather

Findings and discussion during the session showed that the distinction between *weather* and *climate* is not commonly made in Swahili. There were also difficulties translating the English words *risk* and *co-production* and in making a distinction between climate services and climate information between and within the languages. There were thus multiple instances and opportunities identified which may lead to miscommunication during the co-production process, across both English and Swahili as well as within each language. In addition to miscommunication during co-production, potential miscommunication during the delivery of CS was also noted, for example due to the technical language used in the forecasts. A NORCAP expert described: "[we need to] come up with common terminologies or replace [the existing] terminologies with icons or colors or something else [so] that [the forecast] can be easy for [the] majority to understand without distorting the information" (NORCAP expert 1). These findings indicate the multiple instances where miscommunication may occur in the (co-)production and delivery of CS, both between and within languages.

Climate Services

Definitions of climate services varied across study participants. The responses given highlight that actors distinguish between climate services and climate information to varying extents. When familiar with CS, participants' understandings of the aim also differed. When a clear definition of CS was given at the workshop and in subsequent interviews, a common definition was: “the services that are provided to increased advice or advisories tailored to the needs of end-users based on existing weather and climate information” (Meteorologist at TMA). Similarly, most answers stressed the importance of tailoring climate information to user needs in order to make it a climate service. However, among respondents, differences in both what the potential user needs are and how to tailor the information to meet these needs varied. For example, an NGO representative described climate services as the “services regarding climate that need to be acquired by the users who might be farmers, road users and event planners so that this information can help them make decisions on the number of activities such as Agriculture, transportation etc.” (MVIWATA).

Interaction with users as a step in developing a climate service was only emphasized by a TARI researcher and by NORCAP experts, who described participation from the intended user in the development or follow-up of the service as essential. For example, a government research representative explained that “you can provide information, but when you say ‘service’ it means you … have to [provide] follow [up to] the information” (TARI), and a NORCAP expert similarly describing that if you “don't co-produce that [climate] advisory with the farmer, it's not a service anymore” (NORCAP expert 2). Further emphasizing not only the importance of tailoring to assumed or identified user needs, but incorporating mechanisms that aim to continuously evaluate the relevance (salience) of climate services, NORCAP experts highlighted that, in general, a successfully co-produced climate service was one where all stakeholders had agreed on the process and with an incorporated feedback mechanism, so that the “last mile user, the policymaker, and the producer of climate information” (NORCAP expert 2) could be in touch throughout the season. As an informal feedback mechanism, NGO representatives and extension officers (although not all) described that they may have a close relationship with the farmers they work with and get continuous feedback from them.

An educational component of climate services was described by one SUA researcher, who said that climate services should incorporate “education or training on how to make sure that you maintain your environment as you produce enough…like education on how you can produce enough without disturbing other organisms that are using the same environment” (SUA researcher 3). In this quote, education was seen in a unidirectional way (from expert to farmer), whereas a different SUA researcher highlighted the (potentially missed) opportunity for multi-directional learning:

> You know, I think what I would say which probably many people don't know is that these farmers are very intelligent. These farmers are very enthusiastic. These farmers are very eager to learn. The problem is [us]. The management, the researchers, the extension officers, is the problem, but not the farmers. Not the farmers… they know a lot of things. A lot of things which if you allow them…they are going to demonstrate. But if you don't, then they will keep quiet. (SUA researcher 2)

For many interviewees, there was not a clear distinction between climate information and climate services. For example, an NGO representative described that "I can't talk much about the services, though about the information is much more clear [sic]" (SAT). This was especially the case among extension officers and farmers, who were only familiar with the term *climate services* if they had participated in the COGENT workshop.

Co-production

At the workshop it was noted that co-production, or related terms such as joint-production or co-development, were new terms to many participants, especially to farmers and extension officers. Therefore, interviews conducted with farmers and extension officers in this study did not ask specifically about a definition for co-production, but rather about who should be involved in developing and communicating climate information and services (explored in section 5.2). Definitions of co-production given in interviews with government, researchers, and NGO representatives are highlighted in this section.

Although there was no real distinction between study participants' different definitions of the aim and benefit of co-production, participants had different understandings of how and when co-production should take place. Responses from NORCAP, SUA, and SAT emphasized active participation from end-users in development of climate services, whereas TMA actively practices *co-production* as a consultation process only once the climate information has already been developed. Both NORCAP experts described co-production as an "opportunity for users and producers to sit together, discuss, know what their needs [are], know how they can tailor their services to meet the needs of the users and things like that" (NORCAP expert 1), emphasizing that co-production meant "the participation of users and not just to validate that what you're doing is right, but participation of users to meet their needs with the climate information that you are producing" (NORCAP expert 2). A TMA meteorologist, on the other hand, described co-production as listening to stakeholder representatives' "opinion[s], what do they say about this weather and forecast. They will tell us that information, we make them together with our information[sic]. That is co-production" (Meteorologist at TMA). TMA indicated that they do not consult individual farmers but rather sectoral representatives when co-producing the seasonal weather forecast.

Other respondents emphasized the importance of considering who should be involved in co-production: an SAT representative described co-production as a term used when discussing participatory methods, so the *needs of everyone should be addressed. To do so, one needs the representation of women, men, youth, disabled people* (SAT [paraphrased]). A researcher at SUA described it this way:

> We are producing understanding, knowledge…the bottom line is including or giving space for the affected people to take part in generation and in implementing the actions. We should not implement the actions for them, no. But we should not create actions without involving them. (SUA researcher 1)

Climate adaptation

Climate adaptation was understood by all interviewees as largely revolving around the changes that communities need to make to cope with the impact of climate change. A distinction was made as to the level of adaptation efforts: some saw adaptation as *ongoing* within the community, while others emphasized adaptation as a *strategy* to be introduced in a top-down manner. Some interviewees highlighted both definitions. The distinction showed different perceptions of *who* initiates and drives adaptation efforts: one view of adaptation is as a plan or strategy that needs to fit the community needs and capacity but that is developed by external experts, whereas another was an understanding of adaptation efforts as the actions continuously ongoing and led by the community. A description by a NORCAP interviewee illustrates the distinction:

> When we talk about climate adaptation, I think it has to be in different categories, like adaptation at the global level, at the country level, district, and then we go down to the local level because so many things are not applicable to [smallholders]. First of all, they don't have

the capacity to adapt based on those suggestions from the technical people. The money they don't have [sic]… It's important to know exactly what is applicable to them to support their adaptation means or capacity related to climate change and not use the suggested global adaptation measures, they don't work. (NORCAP 1)

Similarly, a representative from SAT described the importance of bottom-up adaptation strategies: "climate adaptation is either just identifying and planning for the actions which will combat the risk associated with climate change. And this has to be participatory. It doesn't have to be a top down[sic]" (SAT).

A quote by MVIWATA representative illustrated how adaptation may be understood as already ongoing in communities: "those activities that a farmer normally does depending on the particular weather information that has been provided." Similarly, adaptation was defined as the ways in which: "[farmers] have to make adaptations in many aspects. For example, they have to make adaptations in terms of what they grow, but also… in their economical practices… You see so adaptations have to be in in many ways, but also in the mindset" (SUA researcher 1).

Smallholders and extension officers gave definitions of adaptation that were both related to their background or role in the community or based on using expert advice. For example, an extension officer said adaptation was *employing techniques to lower water use*, whereas some definitions of adaptation by farmers were related to use of information and advice provided by experts, such as *abiding by what TMA brings* and *listening to/following advice from extension officers*. Highlighting the potential disconnect between expert knowledge and locally relevant knowledge when discussing agricultural advice and trainings on new techniques promoted through climate adaptation interventions, one farmer described that *the issue is that the people coming to administer the trainings don't understand the local context … They are given general procedures that aren't based on the condition of the farmland, which leads to confusion. It's not easy for farmers to accept or understand* (Samwel, farmer).

5.2 Expectations and experience of the co-production process

The way in which stakeholders understand and define climate services, climate adaptation, and co-production can serve as tools to understand the experiences that shape how different actors might diversely perceive the process of co-production, form expectations for the outcomes, and thus evaluate its potential impact. Building on the varying understandings of key terminology and experiences in the past section, findings in this section relate specifically to the expectations and experiences of the co-production *process,* using perspectives raised during the COGENT workshop as a case study. This section includes perspectives from all interviewees, both workshop participants and non-participants.

5.2.1 Perceived relevance and potential outcomes of co-production

In general, co-production was understood by COGENT workshop participants as an important method for gaining insight into the factors that influence users' decision-making processes with potential to improve the relevance of climate services. Participants agreed that the workshop was a good experience overall and that learnings from the workshop were relevant to their work or livelihood. Among smallholders and extension officers, the experience was described as a learning opportunity. Of the six smallholders who were interviewed, two participated in the COGENT workshop. Both stated that after the workshop they were better able to understand the seasonal forecast from TMA. Joyce, a farmer from Mvomero district, stated that, *in the past, I didn't understand the information, so I was ignoring them. But now I pay more attention to information*. Now that Joyce has a better understanding of the forecast, she uses it more in decision-making: *If they say that the rain will come early, [then] whenever it starts to rain, like the early showers, then I will start to prepare the farm. Not like in the past*. It is important to note that Joyce has access to irrigation and thus expressed that she has more flexibility in decision-making, as the risk of making a wrong choice is lower than for farmers without access to irrigation. Findings related to decision-making are explored further in section 5.3.

SUA researchers and NGO participants raised questions as to the *actual* impact the workshop would have for climate adaptation among farmers. Participants from SAT, TARI, and SUA described that although important questions, such as how climate information can be improved were central to discussions at the workshop, they were still unsure how this would translate to reality. The description from SAT was common: "We are having different strategies used to get written form [of climate information], but how can we be actualizing it at community level, and can it be feasible? Can farmers depend on this?" (SAT). TMA also emphasized the relevance and importance of co-production workshops, describing that "it seems like we need more platforms to involve more stakeholders … some kind of awareness seminars and workshops should be conducted to them. Otherwise, we will just produce and then no one is going to use our information."

However, stakeholders had different expectations and understandings of the possible outcomes of the COGENT workshop. Miscommunication and a lack of transparency between stakeholders about the potential outcome of the workshop and capacity of researchers and TMA thus seemed to decrease perceived trustworthiness (credibility) in the co-production process and in TMA. Two examples from extension officers illustrated such miscommunication. Grace, a village extension officer in Mvomero district, described that the extension officers in her district used to receive location-specific seasonal advisories via text message through the Farm SMS program.[21] The text messages had, however, disappeared in the seasons before the workshop. During the COGENT workshop, Grace discussed the issue with TMA representatives, who promised to add her to the list of recipients again. She described that she had received the forecast for the *vuli* season directly following the workshop, in October 2022. However, during an interview in January 2023, she had not received a text forecast for the *masika* season and was therefore under the impression that although TMA had said they would deliver continuously following the workshop, they had not kept their promise. TMA, however, indicated that the message had not yet been sent out for the *masika* season, and that they were experiencing issues with funding the Farm SMS service and could therefore not add any further phone numbers to the list.

A second example was given by Agnes, a village extension officer in Mlimba district, who similarly stated that *TMA promised us that they'll have weather information for each village. But still they didn't do as they promised.* Agnes felt that during the COGENT workshop, they had been promised a more downscaled weather forecast. However, TMA expressed that although they are working on downscaling the forecasting, they lack funding to do so quickly. The stories from Agnes and Grace highlight a lack of transparency, miscommunication, and differing expectations between TMA and extension officers before, during, and after the workshop, influencing the perceived usefulness of climate services at a local level. When not perceived as useful by farmers and extension officers, climate services and TMA were perceived as less trustworthy (credible).

[21] The Farm SMS system was implemented under the GFCS APA program and is described in further detail in West et al. (2018).

5.2.2 Participation at the workshop

Feedback from participants after the workshop indicated that attendance by relevant stakeholders is an important determinant of the perceived fairness (legitimacy) of the process as well as the potential practical outcome it may have. In the case of COGENT, researchers leading the project chose the workshop participants. Joyce (farmer) expressed that it is important for farmers to be involved in these types of workshops so that they can share their experiences of the seasons. The workshop organizers (COGENT project research leads) and several participants, including extension officers, reported that there were some actors who were not able to attend or not invited to the workshop, including district level government officials. A comment by Agnes, (extension officer) summarized potential issues and practical implications of higher-level government officials not attending: *The executive district director, who holds the highest leadership level, wasn't present … It would be easier to implement the things that they learned from the workshop if the director was also there.*

Other stakeholders who, according to study participants, should have been involved included: private companies (specifically sugarcane companies), agricultural seed agents, agricultural cooperatives ("they are the ones who have the farmers at their back", TARI), and according to Halima, a farmer in Mlimba district, *human rights agents* also should have been present. When asked to elaborate why, she described that there are many violations of the rights of women that occur during the farming process, which should be addressed at workshops focused on access and use of climate information. Regarding co-production processes generally, NORCAP highlighted potential mistrust in the process based on who is chosen to participate: "you'll find the same person who is a community volunteer, who is a lead farmer … I don't know how much the community is involved in choosing who participates in the co-production process" (NORCAP expert 2).

5.2.3 Long-term benefits of co-production

Across study participants, co-production was highlighted as educational, good for networking, and an opportunity for raising awareness and gaining inspiration. Farmers who attended the workshop and were interviewed afterwards expressed increased trust in received seasonal forecasts, because they now know where it comes from: *now we rely more on the information we get from the extension officers because the extension officers themselves, they get* *it from the TMA…and then they share it with the farmers* (Joyce, farmer). For extension officers, the workshop was influential in their understanding of the importance of sharing and communicating climate and weather information. On understanding of weather information, Agnes (extension officer) stated: *I have more understanding of the climate and weather. We were trained on, maybe if you see this, it means maybe you have this kind of rainfall … Now I know more about the weather.* Both extension officers also described the benefits of networking and meeting other stakeholders at the workshop: *It enabled us to meet TMA. It brought us together with TMA instead of hearing from the news* (Grace, extension officer).

Among participants from NGO and research backgrounds, it was commonly emphasized that co-production could serve as an opportunity for networking with other stakeholders as well as to discuss the challenges posed by climate and weather and ways to address them. Many participants highlighted that it was an opportunity to better understand climate terminology such as "climate services, risk, adaptation, the climate adaptation… [the workshop gave] us the clear understanding of those terminologies" (MVIWATA).

Reflections also included that co-production is a good place for all stakeholders to "carry out self-evaluation" and a space for TMA to see that farmers are still using indigenous knowledge (SUA researcher 4). Grace (extension officer) further commented on how it influenced her use and further communication of weather and climate information: *It inspired us to seek more weather information so that we can make sure that the farmers are well informed and they don't [continue with]the business-as-usual farming [methods], so they will do farming that is based on the information that they had from the TMA.*

Despite recognizing benefits of co-production, the farmers and extension officers interviewed described that they are currently not involved in any such processes. A description from Rehema, a farmer in Mkindo, was common among farmers and extension officers: *We only get information that [we] are told. We communicate it with our fellow farmers in our communities…But we don't get any chance of giving our opinion of how [the agencies] have to go about and create the product that will suit us or ways of giving us information.*

5.3 Local farming and adaptation contexts

To gain a deeper understand of the decision-making contexts that climate services need to address if they are to be relevant and salient and support smallholder climate adaptation, the findings in this section highlight the diverse experiences of farmers and extension officers regarding changes in the weather and climate, including the timing of seasons, rainfall amount and distribution, and ways in which climate, weather, and seasons are currently forecast.

5.3.1 Perceived changes in weather and climate

It is clear from the interviews that the increasingly unpredictable timing and amount of rainfall play a central role in agricultural decision-making processes and constitute a central adaptation challenge for farmers in the studied villages. However, the findings also show that there are differing methods used to predict and understand seasons and seasonal changes at local levels.

When asked about the consequences of varying climate and weather patterns at local levels, farmers and extension officers mentioned conflicts over water resources, both between pastoralists and farmers as well as between farmers within irrigation schemes (*The low rainfall … makes people quarrel over water. So, there are some who are coming with the machetes to protect their place to be irrigated first,* Juma, extension officer). Pests and diseases were also reported to be a problem in years with less rainfall *(whenever there is low rainfall the pests become a problem,* Agnes, extension officer). Flooding and drought, a lack of arable land, later timing of harvests, and reduced ability among farmers to adjust the timing of their farming practices due to the weather were also reported as consequences of seasonal and rainfall changes and increasing unpredictability of rainfall.

Timing of the seasons

All interviewees (independent of site) reported changes in the onset, end, and duration of the rainy season(s). This was supported by a similar consensus at the COGENT workshop and in focus group discussions (FGDs). Farmers and extension officers described that in the past they had relied on seasonal calendars or their own experience to know when to prepare their crops and when to expect the season to begin. It was reported that over the past 3–5 years, the *vuli* season has become either non-existent or begins late, and that the timing of rainfall onset is now less predictable than it was before. Although some respondents said there had been no change in the onset timing of the *masika*, or long rainy season, others claimed that it was increasingly difficult to know when the season itself had started, or was instead out-of-season showers, and not, in fact, the seasonal rain. A typical answer across interviews was provided by Samwel, a farmer and village chairman in Mlimba district. He described: *In the past it used to rain very early, but now it starts to rain very late. Also, the weather pattern is unpredictable. It isn't easy for us to know when it will rain or when it won't rain.*

Similarly, Halima (farmer) shared that *the distribution is not the same as in the past. Now it rains heavy for one or two days, then it stops to rain.* Farmers' experiences were corroborated by a scientific researcher at TARI, who noted: "For example, in Morogoro we expect all the year maybe [to have] 100 days [of rain]. But now this whole area you can get maybe 30 days … and we are not sure [of the pattern], maybe very heavy rainfall today and after [that] up to two months, one month, no rainfall."

Changes in rainfall amount and distribution were reported to have led to lower yields among all farmers interviewed, however, the reported influence on their households' food security was noted to depend on factors such as the farmers' access to irrigation as well as relative income levels, gender, and geographical location (described in further detail in section 5.4). An extension officer summarized the consequences for farmers as follows: *In the past, [the farmers] were expecting to have showers in August. So, they were able to harvest a lot. But this season … they did as they [have] done in the past expecting that there will be showers. But we didn't receive any. We had very little rainfall, so even the harvest was very little.* (Agnes, extension officer)

5.3.2 Diversity in ways of forecasting seasons

Differences in the perceived trustworthiness and relevance of forecasting techniques were found across study participants. The importance of focusing not only on scientific accuracy but also on farmers' experiences was highlighted by a NORCAP expert when she stated,

> Scientifically, the forecast might be very good, and it might be talking about a good cassava season, but they [farmers] might tell you that based on the dynamics they've seen in the environment, pests are going to be an issue because the mangoes are flowering, so planting cassava might not be sustainable. (NORCAP expert 2)

The quote further illustrates the close ties between perceptions of credibility and salience to a farmer's experience.

Farmers reported different ways of determining how and when the rainy season would begin. These were based on the TMA forecast, locally observed indicators, experiences of weather patterns, or specific experiences from past seasons. As highlighted in the quote above, the use of climate and weather information depended not only on the scientific accuracy of a forecast, but also on the trusted methods for forecasting in the community. Many farmers in both Mvomero and Mlimba districts described using indigenous and traditional knowledge (ITK) in the form of local indicators, such as bird sounds, insect movement, or weather changes, to indicate the beginning and end of seasons. One farmer described that the local indicators are used as a *checks and balance system* together with the TMA forecast. At the COGENT workshop, it was stated by multiple participants that many of these local indicators were no longer reliable.

Farmers in both districts expressed that they did not trust indigenous forecasters and forecasts by elders. The reason for the lack of trust differed between farmers but included a belief that the indigenous forecasting methods were a "scam" by village elders trying to get money from the farmers for their service, or that the indigenous forecasts were no longer actually their own knowledge but simply based on the forecast delivered by TMA.

Furthermore, at the COGENT workshop, indigenous forecasting methods were presented and met with skepticism from the group, where multiple farmers stated that the indicators had changed in the past years and were no longer reliable. TARI and TMA were also dismissive of indigenous forecasting methods, including ITK in the form of local indicators. NGO and NORCAP interviewees, however, emphasized the importance of gaining the farmers' trust through integrating indigenous forecasting methods with the scientific forecast issued by TMA.

5.4 Assessing the potential usefulness and usability of co-produced climate services

Finally, this section addresses the extent and ways in which smallholders and extension officers access and use existing seasonal forecast information, as well as potential barriers and enablers of co-produced CS. It explores the challenges that contribute to the identified disconnect between the heterogenous decision-making contexts of farmers and the capacity of producers and intermediaries of CS to adequately tailor to the various contexts. The findings are divided into three sub-sections: 1) Practical challenges faced by TMA in communicating CS; 2) Pathways of communication; and 3) Factors that influence the potential and actual use of climate information and services for farmers.

5.4.1 Challenges faced by TMA in communicating climate services

A lack of consistent human and financial resources was highlighted as a big challenge to producing and disseminating climate information and climate services both in an interview with a TMA agent and at the COGENT workshop. A NORCAP expert described the challenge as: "The resources are limited…and then you have MET services that are traditionally not very well resourced from the [government]" (NORCAP expert 2). Further highlighting a lack of flexibility when reliant on donor funding, she continued: "Then, of course, if I come in as a donor, you know, whoever gives the money plays the music and we dance to it." These challenges were highlighted not only within meteorological services, but also by the NGOs and research institutes, SAT and TARI. SAT indicated that although they are seeing initial success in pilot projects that focus on participatory methods, they are limited by reliance on donor-determined funding, priorities, reporting, and timelines. TMA described that they rely on project funding in order to offer any sort of training or educational opportunities regarding climate services to extension officers. As mentioned in section 5.2, the Farm SMS system that is currently used to communicate directly with farmers was initiated and funded by an externally funded project, not using continuous funding from the government. A meteorologist from TMA explained that "you cannot add more to the system because it was just a trial…now to implement it and to make it sustainable is costful. That's why up to now we don't do anything. We don't add more stakeholders in the system because it's costful [sic]."

Also highlighted by TMA were issues in providing information that is scaled down to a Ward or village level. It was noted by both extension officers that the information they received via TV and radio was not specific to their district but covered the whole region and was therefore less useful. The lack of a scaled forecast also led farmers and extension officers to report that they did not find the forecasts relevant (salient) because it was not accurate to their village, or that the forecasters (TMA) were wrong (decreased credibility) because the forecast for the district had not been accurate in their village in the past.

5.4.2 Variations in communication of climate information and services

Communication pathways that lead to farmers receiving information and advice about weather and seasonal changes involved many different stakeholders. Reported pathways were not consistent across interviewees. Based on the feedback at the COGENT workshop and from researchers familiar with the study context, *climate service* was not a known term among smallholders and extension officers, thus interview questions for farmers and extension officers did not include the term itself but were instead divided into questions regarding access to and use of climate information in the form of seasonal forecasts, and separately, access to and use of agricultural advice related to climate and weather predictions.

Despite variation in the role of extension services in communicating climate information, all farmers interviewed reported that they had access, in some form or another, to external weather forecasts and information. Farmers accessed weather forecasts using sources including TV, radio, cell phone (text), neighbors, and online. The extension officers interviewed access information about seasons mainly from TV, radio, or via text message directly from TMA. Depending on their location and access to farmer groups (such as irrigation scheme groups), farmers also received information from farming organizations such as MVIWATA, either via their radio channel or directly at meetings, or through meetings and communications from research organizations such as TARI. For example, TARI communicates the seasonal forecast to all rice irrigation scheme members in order to inform them of when the water in the scheme will be accessible and sets up demo plots for the farmers already in the irrigation scheme.

Regarding advice accompanying the weather and climate information, sources of agricultural advice included agro-supply shops, extension officers, fellow farmers, and trainings on new farming techniques led by universities, NGOs, or international projects. However, when asked if the seasonal weather forecast was issued together with advice about when and how to change a farming practice to adjust to the forecast, most farmers interviewed said they did not receive this type of advice together with the forecast. Extension officer responses varied, with some indicating that they did receive agricultural advice together with the weather forecast (this was the case in Lungo village), whereas others claimed that they only receive the forecast. For example, an extension officer described that: *the [climate and weather] information they come as they are. There isn't any climate service [sic]. It's only the climate information* (Agnes, extension officer).

Furthermore, the extent to which the extension officers were aware of and carried out their role as communicators and translators of climate information varied between villages. For example, in Mvomero, one extension officer (who did not participate in the COGENT workshop) claimed that he *did not* receive any information about the weather other than on the TV, which was not specific to his Ward. They therefore did not communicate any information about climate and weather to the farmers in their village or district. In the neighboring village (also in Mvomero district), however, the extension officer (who had participated in the COGENT workshop) reported that it was their responsibility to communicate information and advice about season onset and other weather and climate events, and that farmers relied on them for it.

The findings thus suggest that it is not only an issue of receiving information, but also an issue of awareness and who is believed to have the responsibility of communicating a weather service. A TMA meteorologist argued that the extension officers need better education in order to effectively communicate climate information to farmers; however, funding for this type of education effort remains project based and lacking at the TMA level:

> The best way [to communicate climate services] would be to go through the extension officers… So maybe [at] TMA, we have to make sure we capacitate those extension officers. Capacitate them so they understand and interpret weather and climate information and know how to interpret it to their farmers.

Despite efforts by TMA, extension officers may not see it as their role to communicate climate information. As described by an SUA researcher (1),

> Extension officers [are not] seeing connecting farmers with these meteorological stations as it is their obligation. They don't think that it is part of their job. They think part of their job is teaching their farmers what crop you have to grow, which animal you have to raise, how to raise that animal, and now we are gonna [teach] at least a bit on where you can sell and buy [sic]. But we are not factoring in the information related to the conditions that are necessary for their crop to grow.

These differences are examples of how communication pathways for climate information vary not only at a district level but between villages within the same district, as well as the varying understandings and expectations of who should be responsible for communicating climate information and associated advice.

The above challenges related to the communication of climate services in Morogoro and were compounded further by barriers to information access reported by farmers. These included a disconnect between the timing of demands by farmers and the climate information and services available: *After witnessing the changes [on the farms of] the farmers who attended those workshops and the trainings … they [other farmers] saw that their fellows have succeeded, now* *the demand is big but there [aren't] any services* (Samwel, farmer). Agnes (extension officer) described similarly that: *During the years [when the project is ongoing] it's easier to contact [the NGOs] to get more training. If the project phases out, then there's no way I can get more trainings.*

Furthermore, farmers in Vigaeni experienced that externally funded projects related to climate services were not impactful due to their short time span and a lack of follow up: projects normally lasted one or two years, and when the project period ended, access to information or advice related both to climate, weather, and new agricultural practices related to climate adaptation disappeared. Samwel (farmer) described such a service: a sign that had been posted near a commonly used road was updated with bulletins and information about seasonal weather, but that *after the contract with the government [ended] and [USAID] didn't renew, the service stopped … we cannot demand more projects or [that the time of the project] should be extended.*

5.4.3 Varying access to and usability of climate information and services across participants

Although farmers express trust in the weather and climate information from TMA, the extent to which they find it relevant (salient) to them depended largely on their own and fellow farmers' past experiences of using such information in practice. In this section, the ways in which farmers described not only their access to, but the operational use of seasonal information about climate and weather are highlighted. All six farmers and four extension officers interviewed highlighted that increased access to weather information was important to their practice and ability to plan and that more information about the seasonal timing and rainfall amount would be beneficial. However, in the six interviews with farmers, access to irrigation (whether formal or informal) was noted as most important in determining their ability to adapt to the changes in rainfall and seasonal timing.

Factors such as access to infrastructure, income level, geographical location, and gender influenced how farmers described the severity of weather and climate change impacts. The consequences included decreased food security, livelihood opportunities, and the ability to save money across seasons. Furthermore, whether based on information from TMA or local indicators and ITK, the perceived usability of climate and weather information was also dependent on the farmers' willingness and ability to take risks in planning their season. Farmers described that without access to irrigation, they were forced to begin planting as soon as there was any indication of the seasonal onset: *in the past we started [preparing the land according to] the weather [patterns] in the past. But now if we see we're about to receive any rainfall, then we start to plant* (Halima, farmer). Similarly, one farmer described that even with access to information about climate and weather, deciding when to plant one's crop still involves *a lot of guesswork* (Joyce, farmer).

Thus, although the perceived relevance (salience) and trustworthiness (credibility) of climate information and associated advice were important to its perceived usability, other factors limited farmers' actual ability to make decisions based on the information they had access to. Many different reasons came up for why and when farmers would be able to use the climate information and advice related to climate adaptation. In this study, initial categories including gender, income, size of the farm, and irrigation access were chosen based on prior research within the COGENT project as well as being focus areas within development projects and studies such as GFCS APA (Kijazi et al., 2021, Yanda et al., 2015). During the data collection, however, the categories of *labor and cost associated with farming techniques* and *market influence* also came up as important factors.

Access to irrigation

All farmers and extension officers said that irrigation was one of the determining factors for how well they were able to adapt to increasingly unpredictable weather. This was mainly because access to irrigation meant security in their water access, rather than being reliant on rainfall, which in turn allowed better planning for the season. Irrigation access was either through a *formal* (government established) irrigation scheme or *informal* through use of wells or irrigation from rivers.[22] In both Mlimba and Mvomero, formal irrigation schemes had been introduced in some villages for rice paddy. Farmers also used informal irrigation systems to irrigate both rice and other crops, such as maize and vegetables.

Although information about climate and weather was described as useful and important, without irrigation they relied on having enough (but not too much) rain over the course of the

[22] Only one of the six farmers interviewed (Rehema) was actively farming in a formal irrigation scheme (farming rice paddy). One other farmer (Joseph) indicated that he owned land in an irrigation scheme but rented it out and instead farmed on rainfed plots of land. Three farmers (Joyce, Joseph, and Samwel) had access to informal irrigation – either a well or land near a river. Two farmers (Amina and Halima) relied entirely on rainfed farming with no access to irrigation.

season, which in a bad season could lead to little or no harvest. For example, farmers in both Mvomero and Mlimba described that *if the rain stops, then the crops will die. [The crops will also die] if the rain doesn't come in time* (Amina, farmer). Having access to irrigation was described as directly related to increased income, which farmers could use to pay for things such as schooling, investment in other small businesses, and increased food security. This was similarly reported by farmers during both the COGENT workshop and in FGDs in Njage and Mkindo villages.

Gender considerations

Of the ten interviews conducted with farmers or extension officers, eight respondents claimed that gender was not an overarching determinant for who adopted meteorological or seasonal forecast advice and why. However, two interviewees claimed that women were more likely to participate in agricultural trainings than men. A female extension officer explained that women were more aware of climate change and the importance of adapting to it, and therefore more engaged in trainings and workshops. In Morogoro town, a TARI representative (male) described that more women attend their trainings because the women were more likely than men to own land outside of an irrigation scheme (due to having lower income), and therefore were more adversely impacted by climate change, leading them to seek out advice from NGOs and extension officers.

Income as a barrier to accessing and using seasonal forecast information

Regarding income, answers highlighted that a differentiation should be made between whether income affected farmers' access to climate information or a climate service, or whether it instead impacted their ability to act on the climate information and climate services. Furthermore, it could be important to distinguish between a farmers' access to and use of weather forecasts to make changes in preparation for or during the ongoing season (such as when and which crop to plant), and the farmers' financial capacity to make long-term changes to their farming practice to follow advice, such as shifting to a different seed variety, farming technique, or accessing formal or informal irrigation.

Responses to the importance of income showed that income was not perceived as a determinant of access to climate and weather information, but that it did significantly influence who was able to use the information and advice they accessed. Most farmers claimed that income did not directly influence who had access to climate information and advice, because farmers had exposure to the information through some form or combination of communication channels, such as extension systems, community meetings, neighbors, or media channels. If a farmer did not themselves own a cellphone, TV, or radio, they would get the information from one of their neighbors.

Extension officers emphasized that although farmers had access to some form of climate and weather information, income significantly impacted their ability to maintain changes in farming practices made according to the advice given to them by outside experts or extension officers. This was mainly due to the increased labor and/or lack of educational follow-up on new techniques. For example, when asked about the adoption of farming techniques promoted as *climate smart*, [23] an extension officer replied that some farmers might not adopt or maintain them, stating: *The reason is cost…if you advise them to do more of the practices that can allow them to adapt to the weather changes, they'll do it [for a] short time. But the reason they go back to their old practices, they say, is the expenses, it's costful* (Agnes, extension officer). Another extension officer, Hadija, observed *that the big difference is the income. So those who listen to our advice and use our advice to adapt to climatic change or the weather changes tend to have more income than those who don't.*

<u>*Land ownership*</u>

The farmers interviewed owned or rented farmland that ranged from 2 to 10 acres (Appendix 2, Table 2). Extension officers primarily also owned or rented farmland, with a wider variety in size among the interviewees, ranging from about 5 acres total to over 100 acres. Most interviewees said that the size of farm did not impact a farmers' access to or use of climate information and associated advice. Samwel (farmer) explained that the size of the farm did not influence access to inputs, because for a farmer with more land, *they have to give him more seed samples than the one with the smaller farm.* However, SUA researchers and COGENT project

[23] The World Bank described "Climate Smart Agriculture (CSA)" as "an integrated approach to managing landscapes—cropland, livestock, forests and fisheries—that addresses the interlinked challenges of food security and accelerating climate change." In Tanzania, CSA is increasingly promoted in both research and practice to sustainably increase productivity, income, community resilience, and enhance food security in agriculture (CIAT; World Bank, 2017).

researchers described that the size of farm is an indirect reflection of the farmers' income, and thus can influence their ability to adopt new techniques, such as modified seeds and increased use of fertilizer or pesticides.

Labor and other costs associated with adopting improved farming techniques

Another factor that farmers indicated was a determinant of whether they adopt proposed farming technologies was how labor intensive the proposed adaptation solution was. Farmers and extension officers reported needing to increase use of pesticide and herbicides to address increasing pests; however, this also increased the labor intensity of preparing and maintaining the land. For example, for maize crops, Amina, a farmer in Mvomero, described that the pesticide, to be effective, needed to be applied to each stem of the maize throughout the field, which was time consuming and labor intensive. She described further that hiring someone to do the work introduced new issues, because they just *do it quickly so that they can get the money*, rather than taking the time to do it properly. Therefore, she emphasized, *to be certain you have a good yield, then you have to do it yourself*.

A further example is an increase in fertilizer use. Samwel (farmer) described applying liquid fertilizer (called *booster*) to rice paddies early on to make the rice grow more quickly. However, this has introduced a tedious, complex, and labor-intensive process. Not only in the process of preparing the seeds but also in transporting the seeds soaked in fertilizer to their plot of land, given that often there are large distances between plots of land and the farmers' house*: it becomes double work, to carry the seeds from here to where the plots are located. That's one of the main challenges*. A final example given by many farmers was the increasing shift away from broadcasting rice seeds towards transplanting seedlings.[24] This was promoted especially for farmers in irrigation schemes. However, farmers reported that they might not choose to do this because of the increased time it took to re-plant each seedling individually, with very specific amounts of spacing required between seedlings, the labor of transporting seedlings from a nursery to the field (given large distances between plots), and the risk of low yields if the proper techniques were not followed. Consequently, farmers expressed skepticism towards hiring

[24] Broadcasting is the main technique used in rice farming in Tanzania. Broadcasting involves scattering seeds directly into a field by hand. Fewer farmers practice transplanting, which refers to the act of planting seeds in a nursery and later re-planting each plant in the intended field (Aune et al., 2014).

outside labor to help, even in cases where they had the funds to do so. Farmers and extension officers in Mlimba reported that the high labor costs associated with new techniques led to an initial uptake in the promoted farming techniques, such as transplanting, but a drop off or return to traditional methods, and local seeds, after a few years.

Market aspects

All farmers interviewed grow their crops both for consumption and for sale. Therefore, in addition to using the seasonal forecast, most farmers and extension officers interviewed described that the influence of external factors related to the market for their crops influenced their choices as well. For example, predictions of low rainfall led farmers to plant drought-resistant crops or use faster maturing seed varieties, but an equal consideration was of which type of crop would fetch the highest market price. Amina (farmer) stated that she *grows three and a half acres for sugar cane because of the prices that now are better than in the past.* As described by Rehema (farmer) this income could then be used towards other businesses: *farming is my main source of income, but during the harvest I sell some of the crops to get capital to do other small businesses.*

All farmers who were interviewed reported that they increasingly use improved seed varieties. Interviewees, workshop participants, and FGD participants discussed the nuances and reasons for using either the short-maturing (and short-in-stature) or long-maturing (and tall-in-stature) rice varieties in the study region. Factors that determined the decision to change the choice of variety included market preference (which variety would fetch the higher price), differences in expected yields, labor requirements, how long the crop would take to mature, susceptibility to pests, etc. Local preferences, such as taste of the rice, were less important. For example, Amina (farmer) used to plant the long-term varieties of rice but recounted that she no longer does so: *I recently started using the local seeds. In the past years, I used the improved variety, but I found that they are [more] easily susceptible to the pests than the local variety. So now I decided to grow the local variety.*

A potential conflict between the influence of market prices and other factors considered by farmers was described by a SUA researcher:

> [Smallholder farmers] are failing now because we are putting pressure on them, we are putting more demand on them… in the past, we would know if I produce this by this time, it

will be ready. And then I'll plant something else, and this would be sufficient for my household. But as a nation we are putting pressure, [you] cannot just produce for your own household. There's a huge chunk of people in urban areas, they need that as well and that's why we are even more pressurizing them to use chemical fertilizers so that they produce more. (SUA researcher 2)

The market influence was not only described as important in farmers' decision-making, but also in the trust farmers had in researchers, projects, and advice given related to weather and climate. A researcher at SUA described it this way:

Next time it is very hard to convince them because the last time you came and you had a lot of potatoes here, no one was there to buy it. Now you are coming with bananas. Maybe the same will happen. So, kind of interventions that preceded the ones we are we're introducing now cause bad memories among the farmers. (SUA researcher 4)

Trust in information accompanying the forecast

Finally, farmers and extension officers expressed varying levels of trust not only in the climate and weather information or advice provided to them, but in the institution, organization, or expert who provided it. Agnes (extension officer) described that regardless of factors such as income or gender, many farmers don't follow advice *until they receive the advice from their fellow farmers.* The description from Agnes highlights a common point raised in interviews with both extension officers and farmers: although gender, income, and the market influence (etc.) may influence if and how farmers change their farming practices in response to weather and climate information and advice, most farmers base their choices either on their own experience from past seasons or the experience and advice obtained from fellow farmers. One SUA researcher described it this way:

I think farmers would rely on experience. They would rely on experience, [and] not necessarily on the information that they are being told [by TMA], because TMA they have been telling them [for example] … it's going to be heavy rainfall and all of a sudden there is nothing. So, do you expect them to trust [that information]? (SUA researcher 2)

A NORCAP expert further highlighted the consequences when the forecast from TMA is not perceived as accurate: "next time when you issue another information they will not use [it] because now these people are lying. [Last time] they said the rain will start in the second week and it didn't start. [So] we don't trust them. We will go with our own" (NORCAP expert 1). Farmers and extension officers highlighted a need to witness results (in terms of increased yield) before they would trust or believe the advice given to them by trainings or extension officers. Agnes (extension officer) claimed farmers need to *witness the success of other farmers. If they see that the farmer who followed the advice of the extension officer has then she or he will try to do the same as the other farmer.* This was typical of responses across farmers, extension officers, and NGO agents.

Other factors that influenced perceived trust in forecasts included both religious beliefs and a mistrust in government and business. As Rehema (farmer) described: *If it doesn't rain as … expected then we just sit around and wait. Because God has decreed it. So, we just have to wait until it rains…the way we wait for Jesus to come back and we're just waiting and waiting and waiting.* Describing mistrust in business, Joseph, a farmer in Mkindo, described that the experienced increase in pests *might be the climate change, but also, they're brought by businessmen for us to buy the pesticides because we had [pests] a lot.*

Results thus indicated that there are many factors leading farmers to use the information that is delivered to them, regardless of whether climate and weather information and associated advice is accessible in a timely and understandable manner. Trust in the institutions that deliver the forecast, trust in the information itself and past experiences of its accuracy, market considerations, costs related to labor and land use, and access to reliable water are some of the factors which influenced whether farmers adopted advice given through climate services, even when accessible to them. Furthermore, the considerations made by farmers are interconnected (for example, access to irrigation meant a better ability to generate income) but not consistent across the studied locations, showing that not only are there multiple and compounding factors farmers must consider, but that these factors play out in different ways depending on the site-specific context of potential end-users of a climate service.

6. Discussion

Through in-depth interviews with farmers, extension officers, NGO, government, and research representatives, findings in this study have shown that the quality and potential impact of co-produced climate services and their link to agricultural climate adaptation is perceived differently not only across stakeholder groups but within these groups as well. Climate information and services were perceived as important by all study participants, yet depending on factors such as gender, income, access to irrigation, market influences, and the labor and time costs associated with implementing improved agricultural techniques in the face of uncertain weather and climate, stakeholders, even when in the same village may have very different needs and capacities to access, use, and adopt associated advice. A lack of consistent access to seasonal forecasts and associated advice by smallholders on the ground, variable user perceptions of the quality and skill of the forecasts, and practical barriers faced both by the intended users and the perceived producers of climate information and services prevented climate information and services from being more widely used in practice. Furthermore, experiential and local knowledge were found to be key determinants for which information farmers trusted, while outside experts were perceived as less trustworthy and relevant.

The discussion explores the study's findings in relation to the knowledge quality criteria of *salience* (relevance to decision-making), *credibility* (trustworthiness), *legitimacy* (inclusiveness of process), *usefulness*, and *usability*. In 6.1, I discuss salience and credibility of existing climate information (seasonal forecasts) and, when relevant, perceptions of CS. Building on this, section 6.2 explores stakeholder expectations and experiences of the co-production process, which showed heterogenous ways of perceiving and assessing climate information and services in terms of its legitimacy. Section 6.3 elaborates on the challenges and opportunities to address usefulness and usability of CS that emerged in this study, where the knowledge quality criteria may fall short, and recommended directions for future research.

6.1 Salience and credibility of existing climate information and services

This section explores stakeholder perceptions of climate services, climate adaptation, and how co-production processes align and differ. These perceptions are then related to the established knowledge quality criteria of salience and credibility. Salience, credibility, and legitimacy have been established as metrics to evaluate scientific knowledge based not only on scientific accuracy but on usefulness in societal decision-making (Bremer et al., 2021; Cash et al., 2003). Yet, what exactly constitutes appropriate societal decision-making was found to be different based on the decision-making contexts of various stakeholders. Given its relevance in the transparency and fairness of the process of developing knowledge (Cash et al., 2003), legitimacy is elaborated on further in the next section (6.2).

Even within a small-scale co-production workshop setting, where most participants in attendance were from the same region in Tanzania, diverse experiences, expectations, priorities, and realities were expressed. Discussions of the product and process of co-producing CS revealed different approaches and expectations. In some cases, these differences led to confusion and mistrust among smallholders and extension officers (section 5.1). Inconsistent terminology used in the co-production of CS has been documented as a challenge both in communicating across stakeholders with varying worldviews, realities, and experiences (i.e., Porter & Dessai, 2017) and as a barrier to scaling up co-production across different contexts (André et al., 2021). Norström et al. (2021) argue that this is in part due to a lack of reflection on how the concept, and associated terminology, is used and applied.

6.1.1 Salience

Salience refers to the relevance of information to the smallholders' decision-making context. Findings in this study support the much-documented observation that increasing unpredictability of rains and changes in season timing pose challenges for smallholder farming practices on the ground in Tanzania. Shaffer (2014) found that when discussing the impact of weather and climate changes with farmers, observations of seasonal changes were described in relation to their livelihoods, those of farming, fishing, or herding.[25] In this study, the need to develop better ways of both predicting and adapting to the increasingly unpredictable rainfall was made clear by all interviewees.

While, in general, climate information in some form was salient to all participants, different understandings and definitions given of CS can highlight important nuances in how different

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[25]The observations made by farmers are supported by similar findings in research on variability in seasonal weather and its drivers in Tanzania and across East Africa. Strong associations between large scale climatic drivers (such as the El-Nino Southern Oscillation (ENSO)) and the timing, length, and intensity of the rainy seasons in Tanzania and wider East Africa have been known for decades, with recent studies showing increasing interannual variability in both the Vuli and Masika rainy seasons, often leading to increased drought and flooding (i.e., Chang’a et al., 2017; Kolstad et al., 2022).

actors think about, prioritize, and form expectations for what CS projects should do, and on what timeline. Perceived understandings of terminology as well as expectations and past experiences of climate information and climate services allow insight into what and when climate information is perceived as salient (Norström et al., 2021; Vincent et al., 2020). The perceived salience of information was critical to whether smallholders expressed willingness and an ability to use seasonal forecasts – when information was not relevant to a farmer or extension officer's experience and contextual knowledge, it was largely ignored or even led to increased confusion and mistrust. Salience was found to be closely tied to whether the forecast was delivered to smallholders in an understandable and timely manner, and whether the forecast was downscaled enough to be relevant to their location (section 5.4).

Terms – such as climate adaptation, risk, vulnerability – are often assumed to have clear and commonly held meanings yet are in practice specific to unique and diverse contexts (Daly & Dilling, 2019; Eriksen et al., 2021). Within CS, terms such as *value chain, end-user, and co-production* are commonly used in research; however, while their definitions and implication are debated across the literature, they are not widely used or understood outside of research and development spheres (i.e., Howarth et al., 2022; Porter & Dessai, 2017; Vincent et al., 2018; Vogel et al., 2019; Vogel & O'Brien, 2006). Furthermore, terms are practiced and understood differently by the intended recipients, the co-producers, of research. The resulting misalignments and misunderstandings serve to further widen the gap between research and practice (Norström, 2021).

When discussing the relevance of climate information and services with farmers and extension officers, three important points arose that can be related to the salience of information they currently, or would like to, receive. First, climate information that is overly technical may serve to confuse rather than help the intended users. Second, there is a mismatch in the timing of information and services provided with the needs and demands of farmers. Third, perceived salience was lower when information was introduced in a top-down manner by outside experts who did not have context-specific understanding.

Overly technical information

Technical language used in reporting weather and climate information has been widely recognized as a barrier to user understanding as it is often inaccessible to non-specialists (Porter

& Dessai, 2017; Vincent et al., 2020). At the COGENT workshop, Joyce, a farmer from Mvomero, described how she didn't understand the information, so ignored it (section 5.2). Although communication of CS in an understandable manner is increasingly a focus of CS projects, informants such as Joyce highlight that overly technical language is still an issue in Morogoro, supporting a finding by Yanda et al. (2015:14), in a study of perceived salience, credibility, and legitimacy of CS in Tanzania, that "the language used to communicate this information is too technical for users without technical specialization in meteorology or climate-related disciplines to understand."

At the COGENT workshop, the definitions of season onset (beginning) and cessation (end) were discussed and shown to vary between TMA (who use a technical, meteorological definition) and smallholders, who often based their predictions on experiential knowledge and local indicators. The indicators in turn varied between different smallholders (SUA and TMA, n.d.). Barriers to communication are broadly discussed in recent CS literature. For example, in their aptly named paper "Mini-me: Why do climate scientists' misunderstand users and their needs?", Porter and Dessai (2017:9) discuss the potential assumption by climate scientists that intended users are "mini-me's": that is, highly technical, specialized, and numerate actors like themselves. The information provided by scientists, although potentially relevant to the user context, is not perceived as such by users who do not understand the technical language. In a study conducted among pastoralists and smallholders in Kiteto and Longido districts in Tanzania, Coulibaly et al. (2015:38) found that because the majority of respondents had only primary school education, or none at all, "scientific probabilistic forecast and the uncertainty concept" was not comprehended clearly enough to be reliable in their decision-making. As pointed out by Joyce, overly technical language can act as a barrier to CS use among smallholders, because when not understandable, the information is not considered salient.

A NORCAP expert described the issue in more general terms when she said that CS providers should replace the technical language with commonly understood terminology or easily understood symbols (section 5.1). In some projects, co-production is being used as an opportunity to do so. For example, the projects under the United Kingdom Meteorological Office funded CS program "Weather and Climate Information Services" (WISER) have used co-production workshops to facilitate interaction between farmers, fisherfolk, researchers, and meteorologists in developing indicators that are understandable to end-users and their communities, for example through using color codes to indicate the severity of a weather advisory (Carter et al., 2019).[26] The projects have reported success stories in which farmers and fishers are better able to understand the forecast because they participated in developing the indicators themselves. Although the COGENT workshop served to raise awareness and enhance understanding of the seasonal forecasts delivered by TMA (as described by Joyce, above), TMA voiced their inability to reach all end-users or limited funding opportunities for educating extension officers. Findings in this study showed that although the workshop was a useful platform, it was limited to a relatively small audience. The approach taken in the WISER project, through using co-production to improve and develop communication of climate information using indicators that are understandable to a wider audience offers a possible way to reach more potential users with the benefits of co-production, potentially addressing the issue of limited capacity and resources described by TMA and researchers.

A mismatch in demand and delivery

Even when communicated in an understandable way, the timing and scale of information delivery impact whether climate information and services are perceived as salient or not. TMA described practical challenges related to the consistency of funding for CS projects and dependency on donors, rather than being able to rely on a government-funded budget. Furthermore, challenges in downscaling led to weather forecasts that were not necessarily locally relevant (section 5.3); study participants described forecasts as covering too large an area to be perceived as salient locally. Not only did this cause mistrust in the weather forecast (a lack of credibility), but also in the authority of TMA and the process of CS production itself (further explored in section 6.2). Farmers also reported mismatches in the timing of CS projects generally and the demand in their communities, where externally funded CS projects did not have a lasting impact because of their short time span and lack of follow-up, or ending of any CS that had been provided once the project period was over (section 5.4).

CS, including both seasonal forecasts and advice related to climate adaptation are an important part of decision-making processes for smallholders, yet only part of the entire picture

[26] The WISER project aims to build capacity of TMA to produce and develop usable climate services. For more information on the WISER program and projects: https://www.metoffice.gov.uk/about-us/what/working-with-other-organisations/international/projects/wiser/completed-projects .

and not an adaptation solution in and of themselves (Carr, 2023). The assumption that CS enable adaptation in isolation from other factors may lead to a mismatch between when farmers need CS information and when this information is available, making otherwise useful information less salient (and perceived as less credible), because it is untimely or contradicts other considerations necessarily made by a smallholder. Ensuring that information is useful requires an understanding of decision-making contexts and the needs and metrics of user preference – in other words, ensuring the salience of information to smallholders (Figure 2, Vincent et al., 2020). In this study, the local context of the smallholders and extension officers interviewed meant that, although technically a more efficient solution, there were many reasons that advice did not work in a particular context, both specifically related to climate change or related to factors such as the distance between plots of land, market influences and other resources. As pointed out by Samwel, a farmer in Vigaeni, the introduction by outside experts of procedures that *aren't based on the condition of the farmland* leads to confusion amongst farmers, who ultimately may not follow the advice (section 5.3). Thus, just as overly technical information can cause a barrier to perceived salience, information that is not driven by the needs of smallholders or based on their seasonal timeline and other considerations may not be considered salient and therefore not used.

Salience is closely tied to the so-called "usability gap", the disconnect between what climate scientists and CS producers consider *potentially* usable and what is *actually* usable for smallholders or other intended users has been widely documented across multiple contexts (i.e., Lemos et al., 2012; Vincent et al., 2020). To address the gap, scholars, such as Findlater et al. (2021:732), distinguish between "data-driven" versus "demand-driven" approaches to climate service provision. When the focus is first on developing data and then tailoring it to user needs, it risks not meeting the actual demands of users, both in terms of relevant content and timeline. The data-driven approach further supports a distinction between experts and recipients – a distinction that, in practice, risks presenting solutions that are perceived as neither salient nor credible (Daly & Dilling, 2019).

Top-down delivery of CS decreases perceived salience

Globally, the production and dissemination of CS are often shaped by a technocratic model to climate adaptation, in which the stakeholders who produce weather and climate information also package, disseminate, and provide it to identified recipients to use as needed (Carr, 2023).

This is depicted in Figure 1, the commonly understood "value-chain" of CS and is the pathway for delivering a climate service described by TMA (Section 5.3). Climate services production and dissemination were largely seen by study participants as a top-down process driven by researchers and scientists at TMA.

The top-down approach means that information is not always driven by the context in which farmers (or other users of CS) operate and make decisions, nor is it always relevant to ongoing ways in which smallholders are already adapting to the impacts of climate change. Farming often involves considerable uncertainty, where farmers must react and cope with multiple stressors of unknown and unpredictable impact (Vogel & O'Brien, 2006). Under these conditions, what constitutes high-quality knowledge cannot be universally agreed upon across CS stakeholders; and although scientifically accurate, forecast information may not be perceived as usable by users because of wider risks and influential socio-cultural factors associated with its adoption (Bremer et al., 2021). For example, farmers described that without access to irrigation, they had no choice but to plant as soon as the rains started even if they were going against advice to wait and see if this was, in fact, the start of the seasonal rains (section 5.3). The decision-making context and associated risk perception for a smallholder is thus different from that of, for example, a meteorologist working in an office or the funder of a CS project; predicting rainfall and the subsequent choices made by a farmer about when to plant and harvest can determine a successful crop or a failed one, with the consequent and direct impact on the farmer's livelihood. Porter and Dessai (2017:10) describe that when scientists make assumptions about user needs and user understandings that do not match the reality of the users, the users may "ignore new information because it does not fit with existing working practices". When smallholders described that they did not choose to follow TMA's forecast or advice on new farming techniques delivered by so-called experts (whether outside experts or extension officers), it was often because it was not perceived as relevant (salient) to their capacity to make changes.

Top-down approaches to knowledge production have been criticized for failing to accurately meet user needs, thus widening the gap between scientific research and practice (André et al., 2021). Recent literature focuses on the diversity in needs among users of CS, pushing scientists to question how the end-user actually perceives salience rather than following the pattern of defining salience for the end-user in a top-down manner (André et al., 2021). This switch is achieved through a focus on the decision-making context (Vincent et al., 2018). In their study of

CS use among agro-pastoralists in Tanzania, Daly and Dilling (2019:76) found that dominant modes of scientific production and a focus on the technological end product led to definitions of co-production that focused solely on "tailoring" the forecasts through downscaling, despite the fact that the forecast itself was still not salient to the intended users. This prohibited "more meaningful exploration of how salience could be improved". The extent to which producers of CS (such as TMA) engage with the literature is limited (Vincent et al., 2018). The findings in this study show that, in practice, sustained CS efforts in Tanzania follow the dominant model described above (and by Carr, 2023) and as depicted in the value-chain schematic (Figure 1).

6.1.2 Credibility

Credibility refers to the trustworthiness of information and is closely related to its perceived salience and legitimacy (Cash et al., 2003). Smallholder perceptions of the trustworthiness of seasonal forecasts were influenced by the extent to which forecasts were perceived as accurate in their given location, for both current and past seasons. Findings showed that it was not only that the climate information and services were not salient to farmers' decision-making context due to challenges in downscaling and capacity of TMA, but that the perceived credibility of the science itself as well as the research and government institutions involved in producing and disseminating the forecast were called into question. This has caused a documented challenge in many contexts, including Morogoro, because of a lack of resources and funding of CS producers (i.e., Kijazi et al., 2021; West et al., 2018). Providing high-resolution climate information that captures local climate requires sustainably expanding and enhancing the climate observation network, which in turn requires consistent funding (Kijazi et al., 2021). A mismatch between decision-making timelines and institutional, policy, and research timescales and capacity have thus been shown to hinder CS from being driven by demand and oriented to the appropriate spatial scale needed by users (André et al., 2021; Vincent et al., 2018). Furthermore, seasonal forecasts are a probabilistic prediction of precipitation and temperature, and cannot be taken as definite, yet are often so by recipients (Muema et al., 2018). At the COGENT workshop, smallholders described that when they experienced that the forecast was "wrong" in their village, they did not trust it the next year (section 5.4). Nonetheless, TMA reported that, although they can scale the weather forecast for the district level, they lack the funds needed to build weather stations so are unable to provide more location-specific forecasts (section 5.3).

Perceived credibility was also related to farmers' experiences of local dynamics, both related and unrelated to the seasonal forecast. A NORCAP expert provided this example: the scientific forecast might indicate a "good cassava season" based on predicted rainfall, yet the farmers might notice dynamics in their local environment, such as pests, that indicate that cassava would "not be sustainable" (section 5.3). Stories from smallholders and extension officers revealed similar contradictions between the recommendation associated with the seasonal forecast and the local observations made by a farmer, which could in turn decrease the perceived credibility of scientific information. In their study of CS use among smallholders and pastoralists in Tanzania, Daly and Dilling (2019:72) found that respondents were reluctant to state whether information was credible, preferring to "empirically verify the outcome of the forecast through personal observation and in terms related to livelihood activities and household well-being". This contrasts the calculation of credibility based on metrics of scientific accuracy often used by TMA and in project reporting. Thus, as discussed by Porter and Dessai (2017), the ways in which smallholders determine credibility may not be as a scientific "mini-me", but rather based on their own experiences. Accounting for different ways of determining credibility (as well as acknowledging that they may be contradictory), can potentially increase the perceived trustworthiness of seasonal forecasts and other types of CS among smallholders.

6.2 Perceived legitimacy of co-production process

The factors that influence perceived salience and credibility of climate information and services help in understanding the decision-making context of farmers, and thus the perceptions, expectations, and experiences they bring with them to the co-production process. Co-production is increasingly seen as a way to enhance legitimacy, the third of the knowledge quality criteria. Legitimacy is defined as the extent to which the production of knowledge is perceived as fair, unbiased, and respectful of stakeholders' values and beliefs (Cash et al., 2003). The perceived legitimacy of climate information and services are therefore closely related to the processes and types of knowledge used to produce them. For example, a deliberate focus on involving both men and women smallholders of different socio-economic strata can enhance the legitimacy of both the process and its product (West et al., 2018).

Through involving multiple stakeholders, the process of co-production is intended to create space for alternative worldviews and to facilitate a two-way interactive process (Bremer & Meisch, 2017). However, co-production is often found to be influenced by the dominance of scientific perspectives and entrenched norms around scientific research and production. Furthermore, possible outcomes of co-production are not only limited by different and potentially contradictory understandings and uses of the term, but also by the existing legal structure and capacity of those facilitating the co-production efforts (Daly & Dilling, 2019). Despite increasing emphasis on co-production of CS, findings in this study showed that a one way, technocratic, flow of information about climate and environmental changes is the current reality for most smallholders in Morogoro (section 5.2).

6.2.1 Factors that influence legitimacy of co-production process

In this study, perceptions of legitimacy in the co-production of climate information and services were related mainly to three factors: a difference in understanding of the aim or ultimate outcome of co-production among stakeholders; differing expectations among workshop participants about the timeline of any potential outcome and who should be participating in the workshop; and, differences in ways of knowing and predicting weather by smallholders and by scientists.

The aim of co-producing climate services: product vs. process

Legitimacy is closely related to the process of developing knowledge. Based on interviews with experts across CS research and practice, Findlater et al. (2021) find that the terms climate services, co-production, and associated concepts are often used in malleable and divergent ways. They identify tensions between *process-focused* and *product-focused* definitions of both CS and co-production. Process-focused services prioritize "translation, engagement, use and evaluation" whereas product-focused services prioritize "production, data quality, distribution and tailoring" (Findlater et al., 2021:732). The approach that is taken and prioritized often depends on the background, aim, or considerations taken by those leading the process (Bremer & Meisch, 2017). A distinction between the *product-* and *process-*focused approaches could be seen in this study, where some interviewees, particularly researchers and NGO representatives, focused their definitions on the process by which co-production and climate adaptation interventions are developed and take place – with more emphasis on the translation of information, engagement of users, and feedback processes. Some described co-production as a two-way learning opportunity and a space to create new ideas or ways of understanding certain phenomena. For example, one SUA researcher described the aim in co-production as facilitating common understanding by giving space for "affected people to take part in generation and in implementing the actions" (section 5.1) When seen as an educational opportunity, co-production may enhance the legitimacy and credibility of CS, making the climate service more usable (Vincent et al., 2020). Focusing on the process of co-production can also increase legitimacy through outcomes such as shared learning, networking, capacity building, and establishment of long-term relationships (André et al., 2021). As emphasized by another SUA researcher, however, the educational opportunity, if perceived only as unidirectional (researcher or scientist to farmers), may overlook important knowledge held by the farmers and further widen the gap between research and practice. He described how the farmers have a lot of knowledge which, "if you allow them…they are going to demonstrate" but that they otherwise will "keep quiet" (section 5.1).

Climate service experts and TMA representatives, on the other hand, emphasized instead data quality (how accessible it is, whether it is delivered at an appropriate scale, etc.), its distribution, and relevance to the intended user. They highlighted that CS should be tailored to perceived or measured user needs, emphasizing the outcome of co-production in terms of a product, such as a forecast or model (sections 5.1 and 5.2). For example, TMA described the consultation process with relevant sectors once the seasonal forecast is developed as co-production (section 5.2). In this study, outcomes, such as networking, awareness raising, and educational opportunities, were brought up by various stakeholders when asked about their experience of the COGENT workshop (section 5.2). Without transparent communication on capacity and timeline, however, findings in this study showed that perceptions of the legitimacy of both product, process, and the institutions involved decreased.

Legitimacy related to timeline and workshop participants

Two factors crucial to legitimacy are (1) clear communication between researchers and stakeholders and (2) broad representation of stakeholders in the production process (André et al., 2021). The first goal of the workshop, from the point of view of facilitators, was to "increase the usability of climate services through a better understanding of intra-household climate-agriculture-health vulnerabilities and decision-making dynamics at the grassroots" (SUA and TMA, n.d.:5). Although participants emphasized that the workshop was beneficial for networking and establishing connections, as well as increasing their understanding of climate and weather information (as explored in section 6.1), farmers and extension officers interviewed as part of this study also expressed disappointment and confusion at the outcome of the workshop. Their expectation was that the workshop would have immediate results through better communication pathways or opportunities for accessing climate services. An SAT representative summarized the tension between *talk* and actual outcome, highlighting a discrepancy between the *talk* at the workshop, how this talk is *actualized* at a community level, and whether the solutions are *feasible* or not (section 5.3). Building on the proposition by Vincent et al. (2018:53), that "a focus on the decision context as opposed to the end-product can facilitate the co-production of a more usable climate service", a possible way to bridge the gap in the workshop's aim and practice could be through a shift in focus from the outcome as a product to the outcome as a process. However, to do so in a way that enhances perceived legitimacy requires clear communication among those facilitating co-production and those participating about the timeline of any outcome as well as a realistic view of what is feasible within the specific decision-context of each participant (section 5.3). West et al. (2018) found similarly that in order to co-produce meaningful knowledge with decision-makers, the varying time-horizons for decision-making, stakeholder diversity, and expectations should be considered.

The legitimacy of co-production in this study was further linked to perceptions of who was not, but perhaps should have been, present at the COGENT workshop. Participants expressed that key decision-makers in their communities were missing, which, in turn, made them skeptical of the potential outcomes for the workshop. For example, Agnes (an extension officer) voiced disappointment at the absence of her executive director, who is typically involved in the communication of climate information and related decisions (section 5.3). Inclusion of key stakeholders is thus an important consideration in shifting climate services co-production to focusing more on the process rather than product. This was further elaborated by Vincent et al. (2018:53), in explaining that "the idea of a process-based product is to highlight that a climate service is about more than the product itself, but also the process through which producers and users engage to develop, test, and refine a service, while also establishing long-term relationships and trust" (Vincent et al., 2018: 53). The outcomes of the COGENT workshop as highlighted by participants indicate thus that a focus on the process of co-producing climate services could serve to establish networking and relationship building opportunities also in Morogoro.

Integration of alternative forms of knowledge in the co-production process

Creating usable climate services, whether through co-production processes or not, is largely seen as a technical problem and the task of climate scientists (Porter & Dessai, 2017). However, the value of "integrating" indigenous and traditional knowledge (ITK) with scientific forecasting methods has been highlighted in Tanzania. In a survey published following the GFCS-APA project, TMA meteorologists identified a "reliance of farmers and pastoralists in Indigenous Knowledge (IK)" and stated that there is a need therefore "for integration of IK with scientific forecast that will enhance area specific climate information" (Kijazi et al., 2021:761). In this study, NORCAP climate services experts emphasized *integrating* ITK into CS to improve legitimacy among users, while researchers at SUA and local NGOs also emphasized the importance of ITK in gaining the trust of farmers. However, smallholders reported different ways of predicting the weather, often combining local indicators with the forecast from TMA. The reliability of local indicators, and the extent to which they had changed over the past years, also varied between smallholders, suggesting that the integration of ITK and scientific forecasting might increase the salience, credibility, and legitimacy of the information for some, while decreasing it for those who no longer use or use different methods of forecasting (Section 5.3). This finding builds on studies such as West et al. (2018), who reported that action to integrate ITK and create "hybrid" forecasts through combining scientific and local knowledge should be approached with care, as attempts to do so have previously been unsuccessful due to a lack of sustained collaboration from TMA or project funders. Instead of increasing the perceived quality and use of climate and weather information, efforts may thus have in fact decreased smallholders' trust in scientific authorities and thereby led to less use of existing services (West et al., 2018: 52).

Furthermore, despite calls to integrate ITK and scientific forecasting, the feasibility of doing so in practice remains limited (Daly & Dilling, 2019). While co-production gained enthusiastic support from smallholders, extension officers, and NGO representatives, the country's legal framework and the authoritative position held by TMA as the primary source of knowledge regarding climate and weather information impose limitations on the potential for reshaping the production and distribution of information. Consequently, the influence of smallholders' perspectives on the actual development of CS remains constrained. In the realm of co-production literature, scholars, such as Norström et al. (2021), emphasize the necessity for a "pluralistic" approach, which acknowledges the diverse ways of knowing held by various stakeholders. Beyond challenges stemming from resource scarcity and funding issues, prior investigations into CS usage among Tanzanian smallholders conducted by Daly and Dilling (2019) and West et al. (2018) found that the prevailing legal structure, with TMA holding exclusive authority over climate and weather communication, inhibits the potential outcomes of co-producing CS through participatory means.

Rather than adhering to the equitable and inclusive pluralistic model advocated by Norström et al. (2021), the enacted co-production often takes the form of "tokenistic consultation", where knowledge differing from scientifically accepted norms can be dismissed as unauthorized. This approach may maintain a high level of legitimacy within circles that prioritize scientific research as the epitome of credible knowledge; however, participants possessing alternative perspectives may be denied their status as "knowledge holders", potentially alienating them and consequently limiting the perceived legitimacy of both process and product (Daly & Dilling, 2019: 77).

The legal framework and authority of TMA thus leaves little space for "integration", as promoted in literature and by NORCAP experts in this study, to be done in a formalized and scaled manner. According to Daly and Dilling (2019:72), "despite claims about inclusion, in practice IK was only included in a way that would not threaten the dominance of scientific approaches to understanding climate". In this study, representatives from TMA and the research institute TARI were both skeptical of ITK and dismissed it as inaccurate, supporting the findings of Daly and Dilling (2019).

6.3 Moving beyond salience, credibility, and legitimacy

Although salience, credibility, and legitimacy have been used in research determining the quality of knowledge for society across both Tanzanian and other contexts, it is widely acknowledged that meeting these criteria does not alone ensure that CS are useful and usable (Lemos & Morehouse, 2005; Vincent et al., 2020; West et al., 2018 and others). Findings in this study showed that smallholders and extension officers had varying access to climate and weather information, with the majority reporting that they did not receive adequate information indicating that the criteria associated with salience, credibility, and legitimacy are moot without the added criteria associated with useful and usable. Similar findings have been documented both in the Tanzanian context and elsewhere. For example, Kijazi et al. (2021), in a review of the GFCS APA project implementation in Tanzania between 2017–2019, found that challenges remain in the access to, uptake, and sustainability of climate and weather information among smallholders (Kijazi et al., 2021).

Even when climate information was accessible, smallholders were not always willing or able to use it in decision-making. This finding challenges a widespread assumption held across CS scholarship and practice that if climate information and services are perceived as salient, legitimate, and credible, as well as being useful (delivered at an appropriate scale and time) and accessible, they will in turn be used (André et al., 2021; Vincent et al., 2020). Findings show that the "usability gap" between potentially usable knowledge and knowledge that is actually *used* (Lemos et al., 2012) is a prevalent barrier to CS uptake also across Morogoro. Vincent et al. (2020:3) assert that to address the usability gap, the characteristics of the existing environment must be considered: useful and usable information may not be operationally *used* unless the environment has supportive institutions, appropriate policy frameworks, and "capacity and agency [that] exist at all stages of the value chain" (Figure 2). Descriptions from stakeholders across the CS value-chain revealed that there is a lack of capacity both at the level of and extension services, as well as a lack of agency among smallholders and extension officers in the co-production process (supported by the existing policy-framework and norms around scientific knowledge), making alternative forms of knowledge generation difficult and ultimately influencing its perceived quality and usability (as explored in section 6.2.1).

Therefore, although the knowledge quality criteria were helpful in assessing the extent to which farmers and extension officers accessed, or wished to have access to, seasonal forecasts and other climate information and services, other factors such as past experiences, access to irrigation, market influence, cultural practices, and costs or labor associated with changing farming techniques were also important in determining whether climate information was, when accessible, actually used in practice. Findings echo a description by André et al. (2021:10), who argue that the knowledge quality criteria "are not sufficient to understand whether the knowledge is indeed perceived as actionable by actors responsible for its implementation". Instead, the actual use of information "hinges on other factors beyond the scope of the co-design process".

The decision-making context, which includes factors beyond climate change adaptation specific decisions, should be taken into consideration when trying to understand how climate information goes from being accessible to being "actionable", both in short- and longer-term use of CS. Not only did the decision-making context of smallholders determine whether accessible information and services were initially used, but furthermore why and when farmers might go back to old techniques or stop using advice given by researchers, NGOs, or TMA after having adopted this advice earlier on (section 5.3).

6.3.1 Challenges to creating useful climate services

The challenges faced by producers and intermediaries of CS in providing useful information are multiple. The need for useful information is clearly acknowledged by researchers and stakeholders at every level. Using the Lemos and Morehouse (2005) definition of useful information as meeting the needs, expectations, and practices of users at appropriate temporal and spatial scales creating a climate service that is useful requires an understanding of the end-users' decision-making contexts, their climate information needs and associated understanding of climate metrics, and the ability to deliver these identified metrics (Vincent et al., 2020). Furthermore, the information needs of users are rarely static, but will likely change over time (Carr, 2023; Vincent et al., 2020) and may be different based on factors, such as gender (West et al., 2018), age, or previous exposure to extreme weather events (Muema et al., 2018).

Participants in this study reported that climate and weather information was, or would be, useful in their efforts to adapt to the impacts of climate and weather changes and as a way to complement their use of local indicators to predict seasonal rainfall, but most participants lamented that they did not receive enough climate and weather information and would like more. Both smallholders and extension officers also reported that even when they did receive information about climate and weather, it was often not delivered together with advice about what to do (section 5.3). Existing studies elsewhere in Tanzania have shown similarly that the usefulness of climate information for smallholders may be constrained when it is not disseminated together with advice (Coulibaly et al., 2015).

Dilling and Lemos (2011) argue that both formal and informal institutional rules can hinder the usefulness and usability of CS. They describe formal institutional barriers as including rules, policies, and a limited resources for production and distribution of CS, while informal institutional barriers include the norms and preferences of intended users and intermediaries. For example, they found a preference among intended users of CS "for established and tested practices instead of unproven innovations such as seasonal forecasts" (Dilling & Lemos, 2011:682). Formal and informal institutional barriers were highlighted by participants in this study, including low funding and resources at the level of CS production and dissemination, which influenced the ability of TMA to provide timely information at an appropriate scale. As discussed above, TMA reported that they can scale the weather forecast to the district level but lack the funds for weather stations so are unable to provide more location-specific forecasts (section 5.3). Such practical challenges have been documented in other contexts as well. For example, providing high-resolution climate information that captures the local climate requires sustainably expanding and enhancing the climate observation network (Kijazi et al., 2021). Complex bureaucratic communication channels and procedures have also been identified as a barrier to CS dissemination in Tanzania (Yanda et al., 2015). Informal institutional barriers were also found to limit the usefulness of CS. As found by Dilling and Lemos (2011), smallholders in this study described that they were more likely to trust past experiences and practices rather than information introduced by external experts, limiting their willingness to trust the scientific forecast if they perceived it had been wrong in the past (section 5.4).

6.3.2 Factors that influence the operational usability of climate services

Usability, how accessible and usable knowledge is in the form provided (Lemos & Morehouse, 2005), is considered the second of three components to overcome the usability gap in the conceptualization (Figure 2, Chapter 3) by Vincent et al. (2020), who argue that usability goes beyond the availability of information and requires that information is both accessible and understandable for the intended users. In addition to ensuring that information is accessible through functional communication channels and communicated in an understandable manner and language, factors such as socio-economic status, gender, and farm size are known to be important in determining the usability of information among smallholders in Tanzania (Kijazi et al., 2021; Yanda et al., 2015).

Despite access to climate and weather information, choices about when to plant and harvest based on seasons were still described as *guesswork* by smallholders dependent on rain-fed farming, who expressed that consistent access to water through irrigation systems was more beneficial than consistent access to climate and weather information and would enable them to operationally use the climate and weather information in their planning (section 5.4). Furthermore, although initially adopted, CS and associated agricultural advice or adaptation strategies might be dismissed over time by smallholders as too expensive, labor intensive, or as not producing the yields promised. Therefore, determining whether CS are in fact used in practice requires longer-term follow-up and, in these cases, not based only on initial perceptions of potentially high-quality knowledge.

Findings in this study indicate that overcoming the usability gap for CS use among smallholders requires going past ensuring accessible and understandable information and factors of gender, income, and farm size to considering the heterogeneous decision-making contexts of smallholders as well as the factors that shape them. Furthermore, it is not only the decision-making context of the smallholders that should be considered. Extension officers serve as key intermediaries of climate and weather information. Therefore, ensuring that CS meet the context of intermediaries as well as end-users (contexts which may differ from village to village) is an important step in moving from high-quality knowledge that is potentially useful and usable to knowledge that is actually used. As summarized by André et al., (2021):

> The climate information itself is only one of many considerations for practitioners and understanding whether knowledge is actionable requires an assessment of the broader planning and decision-making contexts, typically looking beyond climate change adaptation issues per se.

6.3.3 Addressing the usability gap: recommendations for further research

This study has shown ways in which the link between access to climate and weather information and its use in decision-making is more complicated and context-specific than often assumed by development practitioners, funding agencies, and researchers. If not acknowledged, assumptions about common understandings and expectations across all stakeholders involved in CS co-production may overlook context-based factors that influence the actual use of climate information and services, limiting both their perceived quality and ultimate uptake by smallholder farmers. A focus on longer-term impacts of co-production (not solely the final product) can arguably “play a key role in supporting adaptation planning and action beyond an individual project” and help bridge the usability gap between scientific research and societal action (Wall et al., 2017: 10). To go from climate information and services that are usable to those that are operationalized, the intangible, longer-term outcomes of co-production should therefore also be considered in future research.

While detailed investigation of farmers' decision-making contexts was beyond the scope of the current study, further research into longer-term use of CS in agricultural planning among smallholders could connect individual perspectives to the larger, often institutional barriers faced in adapting to climate change and its compounding impacts, such as differences across gender and access to irrigation. Building on studies such as West et al. (2018) and Kijazi et al. (2021), the wider COGENT project has shown that gender is an important factor in CS use among smallholders in Tanzania. It was outside the scope of this study to directly address how perceptions of CS differed based on gender, yet further research could build a more nuanced understanding of smallholder needs by specifically considering how and why men and women smallholders may perceive knowledge quality differently. Similarly, smallholders in this study highlighted irrigation access as a key factor in their ability to use climate information and services, an important practical limitation to CS uptake that should be further explored.

Future research could also address assumptions inherently made when applying the knowledge quality criteria of *salience, legitimacy, credibility, usefulness, and usability* to an array of contexts. In addition to these pre-identified knowledge quality criteria, Bremer et al. (2021) suggest incorporating quality criteria identified by the study participants themselves within their unique decision-making context. This study begins to do so by linking organically produced experiences and perceptions to the established criteria; yet this should be done more explicitly through co-developing such linkages with the research participants themselves.

As argued by Carr (2023), climate services will, in and of themselves, not catalyze transformational adaptation. Nonetheless, providing timely, understandable, and relevant CS to farmers is widely argued to improve their decision-making, leading to increased production, ability to make a profit, food security, and generally better livelihoods (Harjanne, 2017; Vaughan & Dessai, 2014). Although this study found that climate variability impacts and constrains farmers' livelihood opportunities (Section 5.3), the assumption that CS, in their current form, can enhance climate adaptation among smallholders in developing countries should be further examined. As highlighted within critical climate adaptation literature, scholars should examine the implicit and explicit assumptions made about relationships between development, modernity, and progress in adaptation interventions (Eriksen et al., 2021). Within the field of CS, further research should specifically address the role of CS in such adaptation interventions and explore the ways in which an overly weighted focus on creating more timely, accurate, and understandable CS may in fact entrench existing roles and norms about scientific knowledge and overlook opportunities for alternative ways of knowing and experiential knowledge in shaping adaptation approaches. Exploring ways in which CS co-production could create space for such opportunities, through a focus more on the process of co-production itself and its potential longer-term impacts, could in turn re-imagine the role and meaning of CS for climate adaptation.

7. Conclusion

Through in-depth interviews with stakeholders involved in climate services production, communication, and use, as well as observation of a stakeholder workshop on CS co-production, findings in this study counter the assumption that more information, if delivered in a timely, accessible, and understandable way, necessarily leads to better decision-making. Instead, the study showed that the perceived quality of information in terms of its relevance to the decision-making context (*salience*), its trustworthiness (*credibility*), and the inclusiveness (*legitimacy*) of the production process are all important aspects in assessing its potential usefulness and usability for the intended context. However, to move from *potential* usefulness and usability to *operational* and sustained use, a singular focus on the quality of knowledge may overlook important factors that limit the usefulness and usability of climate information and services. Access to seasonal forecasts varied widely across stakeholders in the studied contexts, indicating that although CS are perceived as potentially useful and usable, many smallholders and extension officers in Morogoro still do not have adequate access to climate and weather information, let alone involvement in producing such information.

Smallholders face complex and compounding adaptation risks, which, combined with unique ways of knowing, information needs, and ability and willingness to apply information to decision-making, influence how and when they are able to operationalize the advice delivered in a seasonal forecast. Barriers such as limited institutional capacity, the existing legal framework, and infrastructural challenges were found to hinder sustained usefulness of co-produced CS. Smallholders also faced challenges that include access to irrigation, market fluctuation, and the cost, time, and resources needed to adopt adaptation recommendations associated with CS. Gaining the trust of smallholders requires understanding their experiences of past seasons, farmers witnessing results from other farmers, and close relationships between farmers and village extension officers – indicating that experience and relationships may influence whether or not CS are used in practice.

The process of co-production could serve to establish such trusting relationships. However, different expectations and experiences among stakeholders with regards to the timeline, capacity, and practical barriers faced by CS producers, if not adequately discussed during the co-production process, led to miscommunication and misunderstandings. This in turn decreased the trust (credibility) of both the process, trust in figures of authority, and the credibility, legitimacy, and salience of potential outcomes for some participants. Stakeholders across all levels who were involved indicated that there were other important outcomes of the workshop that were less tangible – providing opportunities for learning, networking, increased awareness, and motivation to communicate weather and climate information to others in participants' communities, in turn increasing the legitimacy of both the process and future CS.

Although scientific accuracy is an important component in establishing legitimacy and credibility, the quality of CS is ultimately reflected in whether the information is used operationally to achieve a desirable outcome. To be perceived as salient, credible, legitimate, useful, and usable, and in turn ultimately to be operationalized, the existing knowledge systems and past experiences, as well as factors constraining and determining decision-making among smallholders, should be considered to a larger extent. As described by a study participant, it's not the farmers who are the problem, *it's us*: the management, the researchers, the extension officers. In theory, co-production of CS can serve as a space to restructure understandings of scientific expertise and determinants of knowledge quality – perhaps simply through listening more closely to those with local and experiential knowledge. But practical challenges exist, and the question remains: can the co-production of CS, when constrained by the current institutional and practical limitations, truly bridge the gap between talk and action?

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9. Appendices

Appendix 1: Vuli Seasonal Forecast 2022

Below are excerpts from the 2022 Vuli seasonal forecast, specifically relating to Agriculture. The full seasonal forecast can be found at: https://www.meteo.go.tz/publications/single/184

(I) SEASONAL RAINFALL OUTLOOK FOR OCTOBER – DECEMBER, 2022

The *Vuli* rainy season is specific for bimodal rainfall areas which include north-eastern highlands (Arusha, Manyara and Kilimanjaro regions); northern coast (northern part of Morogoro region, Pwani (including Mafia Island), Dar es Salaam and Tanga regions, Unguja and Pemba isles); and Lake Victoria basin (Kagera, Geita, Mwanza, Shinyanga, Simiyu and Mara regions) and the northern part of Kigoma region (Kibondo and Kakonko districts).

Based on the current and expected climate systems (as indicated in part III of this statement), generally, below normal to normal rains are expected over most parts of bimodal rainfall areas. The season is likely to be characterized by late onset accompanied by poor temporal and spatial rainfall distribution. Prolonged dry spells are expected during October and November with noticeable rainfall improvement during the third and fourth week of December, 2022. Normally, the *Vuli* rainy season ceases during December. However, during this season rains are expected to extend in January, 2023.

(II) LIKELY IMPACTS AND ADVISORY

The impacts and advisories of the outlook were jointly developed with experts from respective sectors during the stakeholders meeting that was held on 30th August, 2022.

(a) AGRICULTURE AND FOOD SECURITY

"During Vuli, 2022 rainy season, reduced soil moisture is expected to occur in many bimodal rainfall areas. The situation is expected to affect agricultural activities such as land preparation, planting and use of agricultural inputs. Moreover, an increase in crop diseases and pests such as ants, armyworms, locusts and rodent are expected to occur during the season and thus affect crops and production in general.

Farmers are advised to practice timely planting, plant early maturing and drought tolerant crops such as cassava, sweet potatoes, sorghum and legumes. Farmers are further advised to apply climate smart agriculture practice and technologies. In addition, farmers are advised to seek technical advice from extension officers on the application of good agricultural practice.

The relevant authorities are advised to provide awareness and agricultural advisory on effective use of available water and adoption of good rain water harvesting practice.

The community is advised to use food sustainably at household level and National at large."

Appendix 2: Details regarding Data Collection, Timeline and Interviewees

Table 1. Category and number of interviewees

Category	**Organization (and number of interviews)**
1. Intended users of Climate Services	Smallholder farmers (6). *See details in Table 2.*
2. Intermediaries of Climate Services	*Research institute:* TARI (1) *NGO:* SAT (1) and MVIWATA (1) *Extension officers:* Ward level officers (2) and village level officers (2)
3. Producers of Climate Services	TMA (1)
4. Key-informants	NORCAP Climate Services Experts (2) Academic researchers at SUA (4)

Table 2. Smallholder farmers: Gender, Age, Size, Ownership and Crops Grown

Location (pseudonym)	**Gender**	**Size of farm**	**Ownership status (rent/own)**	**Irrigation access:(formal/ informal/ rainfed)**	**Main crops grown**
Lungo (Joyce)	Female	2 acres	Rent	Informal (well)	Maize, cassava, rice paddy
Lungo (Amina)	Female	7.5 acres	Owns 5.5 and rents 2	Rainfed	Sugarcane, maize, rice paddy
Mkindo (Rehema)	Female	2 acres	Owns	Formal irrigation (rice) and rainfed (vegetable plots)	Rice paddy
Mkindo (Joseph)	Male	5 acres	Owns/rents	Informal irrigation (river) and rainfed	Rice paddy, maize
Vigaeni (Halima)	Female	8 acres	Owns	Rainfed	Rice paddy, cocoa
Vigaeni (Samwel)	Male	5 acres	Owns	Informal (river) and rainfed	Rice paddy, maize, cocoa

Table 3. Timeline of interviews and language used

Date	**Interview (number)**	**Language**
22.12	NORCAP Climate Services Expert	English
05.01	NORCAP Climate Services Expert	English
18.01	SAT and MVIWATA	English
19.01	SUA researchers Agricultural Extension (2)	English
23.01	SUA researchers Health/Nutrition and Development (2)	English
26.01	Mkindo Ward extension officer, Lungo village extension officer and observation of FGDs (2) in Mkindo village	Swahili

27.01	Lungo village smallholders (2)	Swahili
28.01	Mkindo village smallholders (2)	Swahili
28.01	Tari	English
30.01	Vigaeni village extension officer and Mbingo ward extension officer	Swahili
31.01	Observation of FGDs in Njage village	Swahili
01.02	Vigaeni village smallholders (2)	Swahili
02.02	TMA meteorologist	English

Appendix 3: Interview guides

1. INTERVIEW GUIDE FOR DISCUSSIONS WITH PRACTITIONERS

Thank you for joining this discussion. My name is Emma, and I am a master's student at the Norwegian University of Life Sciences in Oslo, Norway. I am conducting this interview to learn more about your experiences of climate change and how weather patterns impact your livelihood and farming practices. I expect that the discussion will last around 1-2 hours. Your participation today is voluntary, and your responses will only be shared with the researchers who are involved in this project. I will not be using your names in any publication associated with the information that we collect today. You are of course free not to answer any question and to leave the discussion whenever you like. Before we begin, I would like to request your permission to tape record the discussions. Do you object to this? Do you have any other questions before we begin?

Introduction: Questions about respondent and their background:

- Please tell me a little bit about yourself, including your name, age, and ethnicity.
    - How long have you been living in _____ district?
    - Is farming your main source of income? If so, how long have you been farming on this land?
    - Please tell me about your family. How big is your household?
        - *number of adults >18; number of elderly >50, number of children <5, number of children between 5-18; number of infants <1; number of household heads (single, 2 or more)*

Topics:

1. **General farm characteristics**
    a. Please tell me about your farm. How big is the farm?
    b. Is this a highland vs. a lowland area?
    c. Do you own the land?
        i. Do you farm on one piece of land? If more, how many?
        ii. Do you rent out any land?
    d. What are your main crops? Do you grow any other crops?
        i. Household consumption vs. cash crops
    e. Is the area you farm connected to an irrigation scheme? (formal)?
        i. If yes, is all your land irrigated?
        ii. Does access to irrigation help with adjusting to any climate changes you experience? Probe: Do you get reliable water, or does this depend on rainfall amount?
2. **Experiences of Weather and Climate**
    a. Can you describe what a normal season is like?
        i. What is "normal" rainfall?
        ii. When do you plant and harvest your crops?
    b. How did you prepare your crops (or main crop) for the Vuli rains this year? *[use specific crop prep as entry point here]*
        Probes:

   i. Could you tell me about the activities you do during the season for the certain crop
   ii. Did the season turn out as you expected? Can you give an example?
   iii. Do you have access to modified seeds or other inputs?
      1. Where and when do you get seeds?
   iv. What was the biggest challenge you faced this agricultural season?

3. **Access and use of Climate Information**
   a. What methods/tools do you use to predict and prepare for changes in weather?
   b. How would you define the beginning and the end of the rainy season(s)?
   c. Who gives you information about the weather and climate?
      Probe for:
      i. Do you use information from TMA? If so, how do you get it? If not, why?
      ii. Do you use indigenous or traditional methods for forecasting?
   d. If given information about weather that is specific to farming (for example, seasonal forecast, recommendation on when to plant), does this change your planning?
      Probe for:
      i. Is this information consistently available? If not, what information would you need?
      ii. Does the information arrive on time?
   e. Other than information about the weather, what else would help you adapt to climate and weather changes?
      i. Is this available?
   f. Have you participated in trainings/field schools/adopted new technologies in your farm?
      Probe for:
      i. If yes, could you give an example?
      ii. If no, why not?
      iii. Are there other types of technology – ie. (Pest resistant/early maturing crops) etc. that you would wish for?
4. **Engagement in developing climate services**
   a. Have you been engaged in developing climate services projects? Through, for example, participatory projects with researchers, government organizations (ie TARI, TMA), NGOs?
      i. If yes, can you give an example? Has it increased your use of climate information?
      ii. If not, would you like to be? Would it increase the likelihood that you would benefit from the information?
5. ***(If participant was part of COGENT workshop):***
   a. How did you experience the workshop?
   b. Did it relate to your farming practices? If so, how?
   c. Did the workshop change, in any way, what information about climate and weather you might use in farming? If so, how? If not, why not?

2. INTERVIEW GUIDE FOR DISCUSSIONS WITH BOUNDARY AGENTS

Thank you for joining this discussion. My name is Emma, and I am a master's student from Norway studying International Environmental Studies. I am conducting this interview to learn more about your experiences in working with climate services and climate adaptation for farmers. I expect that the discussion will last around 1 hour. Your participation is voluntary, and your responses will only be shared with the researchers who are involved in this project. I will not be using your names in any publication associated with the information that we collect today. You are of course free not to answer any question and to leave the discussion whenever you like. Before we begin, I would like to request your permission to tape record the discussion. Do you object to this? Do you have any other questions before we begin?

Introduction: Questions about respondent and their background

- Please state your name, occupation and describe work.
- What is your role in the community? Does your role extend beyond your formal occupation? *(ie. If extension officer – only agriculture or other roles as well?*
- How many years have you been living in this community?
- Do you work directly with farmers? If so, could you describe the farmers in this village? What is the main crop, size of farm, source of income?
    - Are the farms in this village/ward/district mainly rain-fed or irrigated?
- Do you yourself have a farm (own or rent land)?

Section 1: Perception of changes in weather and climate over the past years

a) Please explain how the weather changes with the seasons over a typical year in Morogoro
b) What changes in weather patterns have you and your community experienced over the past 10 years?
c) How did the seasons change this past year? Did it follow the pattern expected in your community? *(timing of seasonal onset, rain intensity, out of season rains?)*
d) How do you define the beginning and end of the rainy season(s)?
    a. Is this different from how farmers define the beginning/end? TMA?
    b. Has this definition changed over the past 10 years?

Section 2: Climate adaptation: definition and main challenges

a) Please define climate adaptation *(Probe for local, farmer level if not specified)*
b) Why do you think climate adaptation is important, if so?
c) What factors are important to determine the farming household's ability to adapt to climate change?
    a. Ie. Gender, size of household, size of farm, economic status etc?
d) How do you address climate change in your work?
e) Who is/are responsible for climate adaptation efforts?
f) What are the biggest challenges experienced by smallholder farmers in your community?
g) Could you give an example of a challenge you faced from the past season?
    a. Were you able to overcome this challenge?

Section 3: Definition and delivery of climate information/climate services

a) Where do you receive information about weather and climate?

b) How would you define a climate service? Is it different from information about climate and weather?
c) Who produces climate services? Why?
    a. Have you engaged with TMA to provide climate services to farmers?
d) If applicable, who is/are the intended users of the climate services/information you communicate?
    a. How and why do they use climate services?
e) Are farmers able and willing to follow the information you provide?
    a. If yes, could you give an example from the past season?
    b. If no, why not?
    c. Do you notice differences based on gender, economic status, location, size/type of farm in who uses or does not use your advice? Why do you think this is?
f) Which factors do you see as most important in the production and communication of climate services?

Section 4: Tools for predicting weather

a) What are the main tools farmers use to predict and prepare for the weather? How do they access these tools?
b) Do farmers use indigenous methods of forecasting? Do science-based forecasts usually agree or disagree with indigenous methods?
    a. Over the past five years, has the use of science-based climate and weather forecasts among farmers changed?
    b. What more do farmers need in order to adapt?
c) In your experience, are the farmers enthusiastic about trying new technologies based on advice from your organization/TMA/other organizations or the government?
    a. If so, can you describe an example?
    b. If not, why not?
    c. What factors influence whether they adopt new technologies? (ie. Income, size of farm, location, etc.)

Section 5: Co-production

a) Have you been engaged in developing climate services? For example, through participatory workshops, research, trainings or the like?
    a. If yes, could you describe the impact it had?
    b. If no, would you like to be?
b) Who should be involved?
    a. Should there be equal involvement of men and women? Why/why not?
    b. What about small and larger-scale farmers?

***(Section 6: Specifically relating to the COGENT workshop in October 2022*)**

a. How did you experience the workshop?
b. Did the workshop change how you or the community you work with will prepare for future seasons? Why/why not?

3. INTERVIEW GUIDE FOR DISCUSSIONS WITH CLIMATE INFORMATION PRODUCERS

Thank you for joining this discussion. My name is Emma Wheeler, and I am a student at the Norwegian University of Life Sciences. I am currently writing my master's thesis as part of a study program in International Environmental Studies. I am conducting this interview to learn more about your experiences in producing climate and weather information services used by farmers. If you agree to participate in this interview, we will be talking about topics such as how the past agricultural season, how you define key climatological terms, and how you view the co-production process for climate services. I expect that the discussion will last around 30-40 minutes. Your participation today is voluntary, and your responses will only be shared with the researchers who are involved in this project. I will not be using your names in any publication associated with the information that we collect today. You are of course free not to answer any question and to leave the discussion whenever you like. Before we begin, we would like to request your permission to tape record the discussions. Do you object to this? Do you have any other questions before we begin?

Introduction: Questions about respondent and their background

- Which organization do you represent?
- What is your occupation and specific role in the organization? How long have you been working in your current role?
- Do you work directly with farmers or extension officers (for example to conduct trainings)
- Do you or your immediate family have a farm?

Section 1: Perceived impacts of climate change and climate adaptation

a) Please describe how the weather is expected to change in areas that experience bimodal rainfall over a typical year.
    a. In the past, how many seasons were there, and when did they begin/end?
    b. Now?
b) Please describe the weather over the past year. Did it follow the pattern that was forecast? *(Timing of seasonal onset, rain intensity, out of season rains)*
c) How do you define the beginning and end of the rainy season(s)?
d) In what ways has the changes in seasonal onset, rainfall amount etc changed the process of forecasting at TMA, if at all?
e) In your opinion, what is the biggest impact of these changes in weather and climate at the local level?
f) What more do farmers need in order to adjust to these increasingly unpredictable seasons? Who's responsibility is it?
g) What, in your opinion, is most important in helping farmers adapt to climate change? Who's responsibility is it?

Section 2: Co-production of climate services

a) Do you provide only information about climate and weather, or do you also give advice about what farmers should do?
    a. If advice, who is/are the intended user(s) of the climate service(s) you provide?
        i. Farmers/industry/organizations (ie TARI or NGO etc)/extension officer..etc?
    b. Do you feel they trust the information you provide?

b) In your opinion, what factors may determine whether a farmer trusts or does not trust the forecast from TMA?
    a. For example, does the size of land the farmer owns/gender of head of household/income of farmer/contact with extension officer…etc.
c) Which factors do you see as most important in the production of climate services?
    a. What is TMA's role in the production of climate services?
d) Please describe the process of co-production/co-development of a climate service.
    a. What does successful co-production mean to you?
e) Who should be involved in the production of climate services?
    a. *If community involvement:* has the capacity for community involvement in co-production of climate services improved, declined or stayed the same over the past five years? Please explain
    b. *If no community involvement:* why not? Should there be community involvement, what would this look like?
f) *Specifically relating to the COGENT workshop in October 2022*: What do you think was the most important outcome for the farmers who participated in the workshop?
    a. What was the outcome of the workshop for you? Did you change anything in your production or communication of climate services following the workshop?
    b. How, if at all, do you think the workshop impacted farmers' decision-making for the 2022 Vuli rainy season?
    c. What could have been done differently at the workshop, either prior to, during, or after?
    d. Was there anyone who should have been included in the workshop who was not there?
g) What are the main challenges TMA faces in forecasting and communicating weather and climate information?
    a. What can/will you do to address these challenges?

4. INTERVIEW GUIDE FOR DISCUSSIONS WITH CLIMATE SERVICES EXPERTS

Date:

Name of participant:

Characteristics of participants (gender, occupation, role in the community/at the district, and others as relevant):

INTRODUCTION:

Thank you for joining this discussion. My name is Emma Lea Wheeler. I am a student at the Norwegian University of Life Sciences. I am currently writing my master's thesis as part of a study program in International Environmental Studies. I am conducting this interview to learn more about your experiences working internationally within climate services and climate adaptation. The main data collection for this study will take place in Morogoro Region, Tanzania. I will be talking to farmers, agricultural extension officers, NGO representatives and meteorologists from TMA about their opinions and perspectives on the intersection of climate services and climate adaptation of smallholder farmers. If you agree to participate in this interview, we will be talking mainly about what you see as most important, and most challenging, in local level climate adaptation for agricultural practitioners. I expect that the discussion will last around 45 minutes.

Your participation today is voluntary, and your responses will only be shared with the researchers who are involved in this project. I will not be using your names in any publication associated with the information that we collect today. You are of course free not to answer any question and to leave the discussion whenever you like. Before we begin, I would like to request your permission to record the discussion. Do you object to this? Do you have any other questions before we begin?

Introduction: Questions about respondent and their background

- Which organization do you represent?
- What is your occupation and education? How long have you been working in your current role?
- Please describe any prior occupation/roles you have had in the field of climate services and/or climate adaptation?
- Do you have any experience working directly with smallholder farmers in East Africa?

Interview Questions:

1. How would you define local-level climate adaptation?
    a) Is your personal definition different from definitions you experience
        i. in your work with NORCAP/ UN organizations and
        ii. in your work with national meteorological institutes?

2. How would you define climate services?
    a) What is the role of climate services in local level adaptation?

3. As a researcher and global expert in climate services what do you think about smallholder farmers' ability to adapt to the impacts of climate change?
    a) Given the information they are provided?
    b) What more do they need to better adapt?

4. From your experience, either in Tanzania or other countries in East Africa, what are the biggest challenges in climate adaptation for smallholder farmers in rural areas?

5. What role do you play, as a NORCAP expert and with ______ organization, in local level climate adaptation?

6. If any, what changes in their practice do you think farmers will have to make in the coming decade to adapt to climate change?

7. Please define co-production of climate services
    a) How would you describe successful co-production?
    b) What is necessary for co-production to be impactful for local level adaptation?
    c) Who should be involved in co-production?
    d) What are the biggest challenges in co-production?

8. Lastly, are there any ways in which your answers to these questions might differ if you answer based on your personal experience vs. your role as a researcher or representative of NORCAP/UN?

If time, further discussion will be centered around the experience of the expert in East Africa and any advice they have for my field work.

Appendix 4: COGENT Workshop Program

Time	Topic / Activity	Outline	Facilitator
SESSION 1: OPENING			
0830-0900	Registration	Registration	Secretariat
0900-0915	Welcome	• Participants introduction • Welcome remarks from PI (W/s objective) • Word from CMI/CICERO • Word from TMA	SUA/TMA/CICERO
0915-0935	Opening	• Remarks from Director RPTC • Official opening remarks from DVC A SUA • Group photo	Director RPTC DVC A SUA All
SESSION 2: Introduction to COGENT work on Climate Services in Morogoro – Background to Workshop			
0935-0955	Presentation by SUA and CICERO.	• Overview of COGENT research in Mlimba and Mvomero districts, Morogoro • Preliminary impressions from COGENT fieldwork	SUA/CICERO
0955-1020	Discussion on research findings		SUA/CICERO
10120-1045	Tea break		
SESSION 3: World Café Breakout Sessions 1 & 2			
1045-1245	World Café-style break-out group discussions at three tables.	Breakout session 1&2	Facilitated by SUA, CMI, NORCE and CICERO
1245-1345	Lunch break		
SESSION 4: World Café Breakout Session 3 & Plenary			
1345-1445	World Café-style break-out group discussions at three tables.	Breakout session 3	Facilitated by SUA, CMI, NORCE and CICERO
1445-1600	Presentations and plenary discussion		With facilitation by SUA and TMA
End of day 1			
DAY 2: 22ND SEPTEMBER 2022			
0830-0900	Registration		Secretariat
	Recap		
SESSION 1: OND SEASONAL FORECAST & PRESENTATION ON CLIMATE SERVICES AT TMA			
0900-1000	Presentations and plenary discussion of key points from Day 1 group work		Group Representatives All
1000-1030	TMA Presentation 1	The role of TMA in provision of climate services in Tanzania	TMA
1030-1100	**Tea break**		
	SESSION 2: Sharing of CS Use & OND Forecast, Mock Workshop/OND Scenario Discussion		
1100-1145	Plenary Discussion:	• SUA	SUA/TARI/FARMERS

	Sharing of practical experience of climate information use	• TARI • Farmers Association (SAT, MVIWATA) • Health & Nutrition (TFNC) • Agricultural extension officers	ASSOCIATIONS/HEALTH REPRESENTATIVES
1145-1205	Indigenous Knowledge Group presentation	Forecast for OND season 2022 from Njage and Mkindo	Fredrick Ndikwege Nasib Mzange
1205-1235	TMA Presentation 2	OND seasonal forecast for 2022	TMA
1235-1330	Mock Workshop - Break-out group discussions focusing on "use scenarios" of the OND forecast		Facilitated by SUA, TMA, NORCE, CMI
1330-1430	**Lunch**		
SESSION 3: Continued OND Scenario Discussion, Final Plenary and Closing			
1430-1530	Plenary discussion on the mock workshop		Facilitated by SUA, TMA, NORCE, CMI
1500-1600	Closing Remarks & post-workshop 'way forward'		

Appendix 5: Thematic Analysis Process

Table 4. The Six Step Thematic Analysis process (Braun and Clarke, 2006)

Phase	Description of the process
1. Familiarizing yourself with your data:	Transcribing data (if necessary), reading and re-reading the data, noting down initial ideas.
2. Generating initial codes:	Coding interesting features of the data in a systematic fashion across the entire data set, collating data relevant to each code.
3. Searching for themes:	Collating codes into potential themes, gathering all data relevant to each potential theme.
4. Reviewing themes:	Checking if the themes work in relation to the coded extracts (Level 1) and the entire data set (Level 2), generating a thematic 'map' of the analysis.
5. Defining and naming themes:	Ongoing analysis to refine the specifics of each theme, and the overall story the analysis tells, generating clear definitions and names for each theme.
6. Producing the report:	The final opportunity for analysis. Selection of vivid, compelling extract examples, final analysis of selected extracts, relating back of the analysis to the research question and literature, producing a scholarly report of the analysis.

Appendix 6: Informed Consent

Are you interested in taking part in the research project

Bridging science and practice: narratives of climate adaptation in co-producing climate services in Morogoro Region, Tanzania

This is an inquiry about participation in a research project where the main purpose is to engage with narratives of adaptation to climate change among agricultural users in Morogoro, Tanzania to discuss what successful co-production of climate services means to the groups involved. In this letter I will give you information about the purpose of the project and what your participation will involve.

Purpose of the project

In this study I aim to understand if and how some of the local understandings of climate and weather patterns are currently reflected in co-production of climate services. Specifically, I will be looking at participant experiences of the COGENT project workshop, held in Morogoro, Tanzania in October 2022. I will explore scientific and common perceptions and understandings of some of the meteorological, climatological, agricultural and development terminology that is central in communicating climate information targeting smallholder farmers in Tanzania. This will be done mainly through in-depth interviews targeting a select group of stakeholders involved in the production, communication and use of climate and weather information in Tanzania, and through thick description of background literature surrounding the linkages between co-produced climate services and their impact on local adaptation.

The main research question for this project is:

What are some of the narratives of climate change among groups involved producing, communicating, and using climate services in Morogoro, Tanzania, and how are these narratives reflected in the process and outcome of co-production?

This project is a master's thesis in fulfilment of the master's degree in international environmental studies at the Norwegian University of Life Sciences. The project is also part of an ongoing, interdisciplinary research project titled "Co-producing Gender Responsive Climate Services for Enhanced Food and Nutrition Security and Health in Ethiopia and Tanzania" (COGENT), funded under the Norwegian Research Council NORGLOBAL2 program.

Who is responsible for the research project?

Norwegian University of Life Sciences is the institution responsible for the project.

Research is in collaboration with CICERO Center for International Climate Research and Sokoine University of Agriculture (SUA).

Why are you being asked to participate?

Initial participants in this study have been selected based on follow up with from the COGENT project workshop at the Sokoine University of Agriculture (SUA). Further participants will be selected based on snowballing techniques. Participants have been selected in three groups:

Group 1: Key informant interviews with approximately 2-3 small-holder farmers in Morogoro Region, Tanzania. Farmers will be selected based on the following criteria: 1) have participated in the COGENT workshop in October 2022 or have prior knowledge and participation in co-producing climate services. 2) Smallholder farmer where the size of the farm is <2 hectares. 3) Farming is their main source of income. 3) Speak English or are willing to communicate through a translator

Group 2: "Boundary agents" (approximately 6-8). This group includes those involved in communicating climate information and/or facilitating the co-production of climate services between national and sub-national levels. The group may include agricultural extension officers, district commissioners, professors at SUA, and NGO representatives in Morogoro, Tanzania. Participants will be selected based on the following criteria: 1) Work closely with local farmers in selected districts in Morogoro Region, Tanzania. 2) Have knowledge of climate services and their use in Tanzania 3) Speak English or are willing to communicate through a translator.

Group 3: National or international level producers or communicators of climate and weather information (approximately 4). This group involves staff at the Tanzania Meteorological Agency (TMA), NORCAP climate services experts, or selected persons involved in implementing the Global Framework for Climate Services in Tanzania. Participants will: 1) Be involved in producing and communicating climate services at the national or international level. 2) Have been involved in participatory workshops on co-producing climate services. 3) Speak English or are willing to communicate through a translator.

What does participation involve for you?

Group 1: If you agree to participate in this interview, I expect our discussion to last for about 1-2 hours. It is a 1-1 interview, including a translator if necessary. We will be discussing your experience of the 2022-2023 season so far, what changes in weather and climate patterns you have experienced over the past decade, and how you are adapting to these changes. If you agree, written notes and an audio recording will be used to document the interview.

Group 2: If you agree to participate in this interview, I expect our discussion to last for about 45-60 minutes. It is a 1-1 interview, including a translator if necessary. We will be discussing your experience of the 2022-2023 season so far, what changes in weather and climate patterns you have experienced over the past decade, and how this impacts your own livelihood and work, as well as that of the farmers you work with. If you agree, written notes and an audio recording will be used to document the interview.

Group 3: If you agree to participate in this interview, I expect our discussion to last for about 30-40 minutes. It is a 1-1 interview, including a translator if necessary. We will be discussing your experience of the 2022-2023 season, what changes in weather and climate patterns you have experienced over the past decade, and how you view the connection between climate services and local climate adaptation among agricultural practitioners. If you agree, written notes and an audio recording will be used to document the interview.

Participation is voluntary
Participation in the project is voluntary. If you chose to participate, you can withdraw your consent at any time without giving a reason. All information about you will then be made anonymous. There will be no negative consequences for you if you chose not to participate or later decide to withdraw. It will not affect any relation with SUA or the COGENT project.

Your personal privacy – how we will store and use your personal data
We will only use your personal data for the purpose(s) specified in this information letter. We will process your personal data confidentially and in accordance with data protection legislation (the General Data Protection Regulation and Personal Data Act).

- Your personal data will only be accessible to myself (Emma Lea Wheeler), my supervisors for this project, Jennifer West and Mathias Venning, and professors Dismas Mwaseba and Sylvester Haule at SUA. I will not be using your names in any publication associated with the information that we collect today.
- I will store sensitive data collected on a NMBU university research server, which is not accessible to unauthorized persons.
- In any shared documents, I will replace your name and contact details with a code. Names, contact details and codes will be stored separately from the rest of the collected data.
- Non-sensitive interview notes will be stored on a password-protected computer. Any hand-written notes will be stored in a locked room or cabinet.
- In publications related to this project I will share only information about your age, gender, occupation, and district, along with opinions and experiences you have shared. I will not share your name or any other personal details that might identify you.

What will happen to your personal data at the end of the research project?
The project is scheduled to end in May 2023. Following this, data will be anonymised and archived. Your data may be used for future academic research conducted by the main researcher (Emma Lea Wheeler).

Your rights
So long as you can be identified in the collected data, you have the right to:
- access the personal data that is being processed about you
- request that your personal data is deleted
- request that incorrect personal data about you is corrected/rectified
- receive a copy of your personal data (data portability), and
- send a complaint to the Data Protection Officer or The Norwegian Data Protection Authority regarding the processing of your personal data

What gives us the right to process your personal data?
We will process your personal data based on your consent.

Based on an agreement with Norwegian University of Life Sciences, Data Protection Services has assessed that the processing of personal data in this project is in accordance with data protection legislation.

Where can I find out more?
If you have questions about the project, or want to exercise your rights, contact:

- Norwegian University of Life Sciences via
  - Emma Lea Wheeler (main researcher): emma.lea.wheeler@nmbu.no or +47 40299752
  - Jennifer Joy West (supervisor): jennifer.west@nmbu.no or +47 67231315
  - NMBU Data Protection Officer: Hanne Pernille Gulbrandsen, personvernombud@nmbu.no or +47 402 81 558
- NSD Data Protection Services, by email: (personverntjenester@sikt.no) or by telephone: +47 53 21 15 00.

Yours sincerely,

Emma Lea Wheeler (Researcher)

Jennifer West (Supervisor)

Consent form

I have received and understood information about the project *[insert project title]* and have been given the opportunity to ask questions. I give consent:

- ☐ to participate in *(insert method, e.g. an interview)*
- ☐ to participate in *(insert other methods, e.g. an online survey) – if applicable*
- ☐ *for my/my child's teacher to give information about me/my child to this project (include the type of information)– if applicable*
- ☐ *for my personal data to be processed outside the EU – if applicable*
- ☐ *for information about me/myself to be published in a way that I can be recognised (describe in more detail)– if applicable*
- ☐ *for my personal data to be stored after the end of the project for (insert purpose of storage e.g. follow-up studies) – if applicable*

I give consent for my personal data to be processed until the end date of the project, approx. *[insert date]*

(Signed by participant, date)

Appendix 7: SIKT Ethics Approval

Sikt

Notification form / Unpacking assumptions in co-produced Climate Services for ... / Assessment

Assessment of processing of personal data

Reference number	**Assessment type**	**Date**
573413	Standard	15.05.2023

Title
Unpacking assumptions in co-produced Climate Services for agriculture in Morogoro, Tanzania: Bridging theory and practice

Data controller (institution responsible for the project)
Norges miljø- og biovitenskapelige universitet – NMBU / Fakultet for landskap og samfunn / Institutt for internasjonale miljø- og utviklingsstudier

Project leader
Jennifer West

Student
Emma Lea Wheeler

Project period
01.01.2023 - 15.08.2023

Categories of personal data
General

Legal basis
Consent (General Data Protection Regulation art. 6 nr. 1 a)

The processing of personal data is lawful, so long as it is carried out as stated in the notification form. The legal basis is valid until 15.08.2023.

Notification Form

Comment
Data Protection Services has assessed the change registered in the Notification Form.

We find that the processing of personal data in this project is lawful and complies with data protection legislation, so long as it is carried out as described in the Notification Form with dialogue and attachments.

The project end date has been extended to 15.08.2023.

FOLLOW-UP OF THE PROJECT
We will follow up the progress of the project underway (every other year) and at the planned end date in order to determine whether the processing of personal data has been concluded/is being carried out in accordance with what is documented.

Good luck with the project!

Norges miljø- og biovitenskapelige universitet
Noregs miljø- og biovitskapelege universitet
Norwegian University of Life Sciences

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