CO-PRODUCTION AND THE POLITICS OF USABLE KNOWLEDGE FOR CLIMATE ADAPTATION IN TANZANIA

by

MEAGHAN ELIZABETH DALY

B.A., Colorado College, 2005

M.A., Columbia University, 2009

A thesis submitted to the

Faculty of the Graduate School of the

University of Colorado in partial fulfillment

of the requirement for the degree of

Doctor of Philosophy

Environmental Studies Program

2016

This thesis entitled:
Co-production and the Politics of Usable Knowledge for Climate Adaptation in Tanzania
written by Meaghan Elizabeth Daly
has been approved for the Environmental Studies Program

____
Lisa Dilling (Chair)

____
Mara Goldman

Date_________________

The final copy of this thesis has been examined by the signatories, and we find that both the content and the form meet acceptable presentation standards of scholarly work in the above mentioned discipline.

IRB protocol # ____________________

Daly, Meaghan Elizabeth (Ph.D., Environmental Studies)

Co-production and the Politics of Usable Knowledge for Climate Adaptation in Tanzania

Thesis directed by Dr. Lisa Dilling and Dr. Mara Goldman

ABSTRACT

The concept of 'co-production' is increasingly offered as an approach to enable more responsive and inclusive processes of knowledge production across a range of disciplines. While it is recognized that uneven power relations play a significant role in shaping co-production processes, how these dynamics affect, and are affected by, intentional efforts to 'co-produce' usable knowledge is not well understood. In this dissertation, I examine the multiple ways in which power is exercised within efforts to 'co-produce knowledge' for climate adaptation decision-making in Tanzania, and with what effect. I do so through a multi-scalar mixed methods case study. To begin, I conduct a systematic literature review to illustrate the lack of conceptual clarity around the term co-production and argue that there is a need to distinguish between 'strong constitutive', 'strong interactional', and 'weak interactional' interpretations of the term. Then, I present results from a survey examining the production, circulation, and use of climate knowledge across institutional scales in Tanzania. I find that existing landscapes of climate knowledge are complex, with both formal and informal pathways for knowledge production and circulation playing an important role. Next, I conduct a modified Actor-Network analysis to understand the 'constitutive' dimensions of co-production. I find that current efforts to co-produce climate knowledge in Tanzania rely on stable science-society configurations in which there is a clear demarcation between 'producers' and 'users' of knowledge. This may have the unintended effect of delimiting the full participation of some actors within instrumental co-production efforts. Finally, using a critical application of the Knowledge System Criteria (KSC) framework (credibility, salience, legitimacy), I examine the politics involved in the production of 'usable' knowledge. I find that how actors relate to and employ these criteria within instrumental co-production efforts represents a political move that can reinforce existing power differentials. In sum, I find that uncritical usages of the concept of co-production may contribute to the very problems they are intended to solve. These findings are offered as part of an effort toward developing more critical, yet integrative and productive, understandings of co-production.

ACKNOWLEDGEMENTS

This dissertation is dedicated to my brother, James. His sharp wit and sense of humor have been greatly missed. I'm sure that it would have made him laugh to learn that I am now Dr. Daly. It is also dedicated to my grandmother, Patricia Daly. Her unending optimism and fortitude in the face of many obstacles taught me so much.

At many moments, completing a Ph.D. feels like a fundamentally lonely and individual task. I suppose that it is only in retrospect that one can look back to fully realize that there were so many people enabling your progress, so many giving you that extra nudge, so many propping you up, and so many cheering you on at all points along the way. It is difficult to capture the depth of gratitude that I feel to all those who have helped me in just a few, meager words. It feels wholly insufficient. But I suppose I must consider these words as just the beginning of trying to repay my debts. I must admit – there are so many people that I owe thanks to, it is entirely possible that I may miss someone. I apologize in advance for any lapses.

I will start with the many people in Tanzania who made this research possible. Without their patience, tolerance, and generosity, this dissertation could not have been written. In the districts of Monduli and Longido, I start with the people in Arkaria and Kiserian, who were continually curious about my presence, but always welcoming. In particular, I would like to thank Ndoika Sakita, and his wife, Narikosaro. They, and other members of their household, made me feel like part of their family and I am deeply grateful for the many things they taught me – both the large and the small. It was always sad to see their boma fading from my rearview mirror as I reached the top of the hill and dropped down into the valley on my way back to Arusha. I would also like to thank Daniel and Neema Oldorop, who graciously welcomed me into their home for delicious meals during my field stays. I am grateful for the evenings of candlelit conversation and good company. I must also thank Mepukori Mollel, Chairman of Arkaria Village, and Alais Yohana, Executive Officer of Kiserian Village, for granting me permission to conduct research in their villages. I am also grateful to Ally Msangi and Joseph Rutabingwa, who were my focal points in the Longido and Monduli district offices. They were always willing to meet with me and to support my research, despite their busy schedules.

There are also many individuals and organizations in Arusha and Dar es Salaam that I am indebted to. I thank COSTECH for supporting the research project and granting me permission to conduct research in Tanzania. Importantly, I must thank Dr. Elifuraha Laltaika, Lecturer of Law at Tumaini University – Makumira, who acted as my academic affiliate in Tanzania, but also became a good friend. I am consistently inspired by his commitment to supporting indigenous rights around the world. His enthusiasm and support for my research was always greatly valued. I am also thankful for the support of Alais Morindat, who was a key collaborator in this research from the very start and provided me with essential guidance throughout. He always made time to chat with me and to impart some of his wisdom! He and his wife, Maria, also welcomed me into their home in during the early days of the project, while I was still finding my bearings. I am also grateful for Munka Killerai and his family who provided me with a roof over my head and transport both within and outside of Arusha. I am also grateful to Rosemary Mchihiyo and Augustine Kanemba, who were my first contacts at the Tanzanian Meteorological Agency (TMA) back to 2010. I also thank Dr. Ladislaus Chang'a, Helen Msemo, and Mecklina Merchades, who were always generous in supporting the project. I am grateful to Dr. Agnes Kijazi, Director General of TMA, who granted me permission to spend time in the agency's offices and the opportunity to learn from her very able staff. I also thank the many other individuals in national government offices, as well as non-governmental organizations, who made this research possible. I also thank

Renatus Mkaruka of the Tanzanian Red Cross Society and Juvenal Kisanga of the World Food Programme, who were always willing to let me to tag along. I would also like to appreciate the contributions of the many staff members and local government officials who participated in the inception meeting and several feedback meetings throughout the project. Your knowledge and experience greatly improved the quality of this research. In particular, I would like to thank Esupat Ngulupa and Jopha Kakanyi whose strong voices were always a welcome addition to any meeting. I also thank my dedicated team of survey enumerators – Majembe ya Kazi daima! In particular, I thank Simon Lepilal and Herry Matinda, who I now consider good friends. I would also like to thank Sarah Lenkai and Samaito Ole Kopitoo, who provided additional research assistance at critical junctures in the project. Finally, I must thank Shayo Alakara Lemoloo, who was my primary research assistant for three years. His sense of humor and knack for story-telling made field work much more enjoyable – even during our 'death-marches' to and from distant sub-villages, markets, and watering holes and, also, when the car (inevitably) broke down. A large portion of the data presented in this dissertation is the result of his hard work and dedication. I am also extremely grateful for the friendship of Fokas Nchimbi, who introduced me to the Swahili language during my first visit to Tanzania in 2008. He, his wife, Suze, and daughter, Paula, along with James and Krista, were always ready to provide me with a much needed escape from the Peninsula.

Next, it is important to acknowledge that without a great deal of assistance and guidance from many individuals and organizations in the U.S., my forays to Tanzania would not have been possible. First, I need to thank my advisors, Lisa Dilling and Mara Goldman. This research would not have been possible without their combined support. From the day I arrived at CU, Lisa was incredibly supportive of my desire to conduct my research in Tanzania – even though this often meant taking the more difficult route! She was willing to go above and beyond the call of duty on many, many occasions to help me along the way – and, for that, I am extraordinarily grateful. She has also provided me with invaluable academic, as well as personal, guidance over the years. Her clear and consistent communication style, critical (but always constructive) feedback, and continual positivity have set an example that I can only hope to emulate one day. I am also deeply grateful to Mara, who convinced me on my third day at CU that I should stay in her class – which is where I was first introduced to the fields of Science and Technology Studies and Political Ecology. My view of the world has never been the same since. I also thank her for challenging me intellectually, for providing invaluable practical and logistical guidance, and for bringing me into her Tanzanian networks. I would also thank my other committee members who have provided me with key advice and direction along the way. I thank Max Boykoff for creating a supportive and collaborative academic environment at CU and for welcoming me within his research group, both of which have fostered my intellectual growth. I am very grateful to Terry McCabe, who helped to steer me on the right path early on in my fieldwork and who was always generous in sharing his deep knowledge of Tanzania. I am also grateful to Bruce Goldstein whose insightful comments have continually pushed me to consider the practical implications of my research. I would also like to thank Pablo Suarez from the Red Cross / Red Crescent Climate Centre, who first convinced me that I should pursue a Ph.D. I also need to thank Penny Bates in the Environmental Studies Program and Andrea Dietz at CIRES for managing the many complexities of my funding and field work arrangements. I also thank Robin Moser at CSTPR for being a much needed ray of sunshine. I am extremely grateful to the National Science Foundation – Science, Technology, and Society Division, USAID Climate Change Resilient Development – Small Grants Program, and the University of Colorado Boulder – Innovative Seed Grant for providing financial support for field work, data analysis, and writing. I am also grateful to CIRES for awarding me a Graduate Student Fellowship that allowed me to focus on data analysis.

There are also many friends that I also need to thank. First, I am grateful my best friend, Amanda Fixsen. Her consistent support and loyal friendship have meant the world to me. I will always be deeply indebted to her, her husband, Andrew Schaper, and (of course) Toby, for welcoming me into their home during a particularly difficult stretch. I also need to thank John Putnam, who was always ready to help in a pinch or give me a shoulder to cry on. I am also grateful to him for housing me during my various short stints in Boulder, as well as taking care of my 'life administration' while I was out of the country. My time at CU would not have been the same without the Lunch Club – John Berggren, Alex Lee, and Tyler Kohler. Thanks for the laughs and the philosophical debates. I also thank Arielle Tozier de la Poterie, who has been both a good friend and valued collaborator. I am also grateful to the many adventure buddies that made Boulder an amazing place to live – Rory Cowie, Margi Dashevsky, Alice Hill, Lydia Lawhon, Christian Martin, Shawn Olson Hazboun, Malcolm and Carmel Ulbrick, and Ethan Welty. I would also like to thank Eric Lovell for his help running the survey in Tanzania and for producing a beautiful map of the survey sites. I also thank Alicia Davis, Julie Santella, and Anna Estes for being inspiring researchers and friends in Tanzania. I am indebted to Sigrun Marie Moss, Eivind Fjeldstad, and Storm Fjeldstad for welcoming us with open arms to Norway and providing much-needed advice and encouragement over the years. I also thank Grete Benjaminsen, Hajj Mohammed Hajj (and little Sofian too!) for opening up their home to us. I am also grateful to Jennifer Joy West, who has been both a wonderful colleague and friend in Norway. Warm gratitude also goes to Rasmus Røder-Jensen and Linda Mathisen, who I hope to (finally) do more adventuring with, now that I am finished. I also thank Jesse Marsolais, Heather Rockwell, and Rosemarie Santos-MacPherson for teaching me at a young age that I needed to follow my own path.

It goes without saying that I would never have made it this far without the unquestioning love and support of my family. I am very grateful to my mother- and father-in-law, Connie and Peter Roop, who were always interested in my work and also put up with me when I went into 'barnacle' mode in order to write. I appreciated their patience and good humor! I thank my grandmother, Mabel Clear, for teaching me what it means to be from 'tough Vermont stock.' I am also grateful to my great aunt, Joan Minnis, whose encouragement, along with continual queries about when I would finish, inspired me to keep pushing forward. I thank my sister, Shannon Daly Gorr, and her husband, Michael Gorr, for always providing me with a warm welcome home. I am especially grateful to Shannon for sending me the best and most perfectly timed emails, which were always guaranteed to elicit a giggle just when I needed it most. I am also grateful to my niece and nephew, Sadie and Simon, who were a reminder that there is *always* time to play. And to my parents – I cannot begin to thank them enough for their seemingly endless well of love and encouragement. While they do not like having me so far away and were (at times) disconcerted by my less-than-linear path toward completing my Ph.D., they never wavered in their unquestioning support. I am grateful to my father for being a constant voice of reason and for giving me the confidence to believe that I could accomplish whatever I put my mind to. I thank my mother for being the most generous person I know. She was always there for me whenever I needed her help – *always*. I am forever grateful. And, finally, I thank my partner, Sterling Roop. It was he who first introduced me to Tanzania. His love for the country was infectious and my experiences there have been greatly enriched by all that he has taught me about its people, its language, and its culture. Over the years, he has supported me in so many ways. In order for me to undertake my Ph.D., it meant that we would have to spend many years apart., but he never hesitated once in backing my decision. During the course of writing this dissertation, he constantly attended to all of the little day-to-day things – laundry, cooking, bills – so that I could focus on my work. He was also my sounding board, my confidante, and my most unabashed advocate. And he was unbelievably patient with me throughout. Quite simply, I could not have done this without him by my side.

CONTENTS

APPENDIX

TABLES

FIGURES

CHAPTER 1: Introduction

1.1: Overview of the Problem

Climate change, both as a global physical phenomenon and as a 'traveling' concept, is now unavoidable (Hulme, 2009). In response, there has, over the last decade, been a growing emphasis on the need for adaptation in order to mitigate the worst impacts of climate change on both humans and the environment (Pielke et al., 2007). However, exactly what should be done, where, how, and by who are thorny questions that societies around the globe are currently grappling with. Within debates about how best to adapt to climate change, a common feature is the emphasis on the need for appropriate knowledge about the climate to inform decision-making — including, what the climate was like in the past, how this compares to the present, and what this might mean for the future.

To date, Western-scientific approaches to understanding climate have dominated discourses in both the political and practical realms. However, despite technological advances, scientific knowledge about climate change has not been able to resolve difficult and often intractable questions about how best to adapt to climate change. There are several reasons for this. First, the "scale, complexity, and interconnectedness" of climate change has challenged existing models of both scientific and democratic decision-making (Jasanoff & Wynne, 1998, p. 2). Second, top-down, global, scientific representations of climate are often at odds with the place-based ways in which climate is understood, experienced, and lived (Brace & Geoghegan, 2011; Hulme, 2010; Jasanoff, 2010). In response, there has been a growing emphasis on the need for more open and collaborative approaches to producing and using knowledge for climate change adaptation decision-making.

The concept of co-production has been increasingly invoked within academic literature and put in to practice as a way of producing knowledge that is more inclusive ways and sensitive to the social, political, and cultural contexts in which knowledge is used and applied (Armitage et al., 2011; Dilling & Lemos 2011; Morehouse & Lemos, 2005), as well as a practical model for producing more efficient and effective public services (Ostrom, 1996; Parks et al., 1981). Co-production has also been presented as an analytical cognitive frame to examine the ways in which knowledge, power, and social orders are mutually constituted (Jasanoff, 2004). As co-production has gained traction across a wide range of disciplines, these varying conceptualizations have often resulted in a lack of theoretical clarity about how the concept is interpreted and applied.

Ensuring that we have a good grasp on what is meant by 'co-production' is important for several reasons. To start, there is currently a great deal of stock being put into the concept of co-production as a means of making scientific knowledge more 'usable.' However, if co-production is applied uncritically without acknowledging the theoretical underpinnings coming out of science and technology studies (STS) scholarship, it risks undermining the potential of the concept to enable reflexive and transformative ways of understanding relations between knowledge, power, and society. More importantly, the various ways in which co-production is defined and understood have very different ontological and epistemological starting points with implications for how they will be enacted. While co-production can be used to understand and address differential relations of power, there is an increasing trend toward uncritical instrumental uses of the term can ignore, or even exacerbate, power imbalances. This can serve to further marginalize particular perspectives, knowledge, and ways of being — with real and important consequences on people's lives and well-being.

1.2 Overview of the Project

In recent years, Tanzania has been the focus of multiple efforts to enhance the 'usability' of scientific knowledge for climate adaptation at both national and 'local' scales. This has been accompanied by an increasing interest in fostering pathways to bring indigenous knowledges to bear on adaptation decision-making. Within this context, there has been a growing interest in the development of 'climate services' through instrumental co-production processes, in which 'users' and 'producers' are intended to collaboratively produce knowledge. In this case study, I seek to understand the role of power relations in shaping these efforts to develop climate services in Tanzania through instrumental co-production efforts, with a particular emphasis on how these efforts have taken shape in pastoral communities in the semi-arid areas in the northern portion of the country. Thus, this study has three primary objectives, with the following related research questions:

Objective 1: Understanding production, circulation, access, and use of knowledge:

1. What kinds of knowledge are currently being incorporated within adaptation decision-making across institutional scales and for what kinds of decisions?
2. Who is producing this knowledge, through what processes, and for what purposes?
3. How is this knowledge circulated and how does this shape who is able to access and use this knowledge?

Objective 2: Examining how knowledge gains salience, credibility, and legitimacy among actors

within and across epistemologies and scales:

1. Do actors across epistemologies and institutional scales have differing perceptions of the salience, credibility, and legitimacy of various climate knowledges?

2. How do perceptions of the salience, credibility, and legitimacy of various knowledges influence *actual practical use* within decision-making?

3. What are the tradeoffs between credibility, salience, and legitimacy? Do these vary among actors within and across different epistemologies and institutional scales?

Objective 3: Interrogating power relations between actors within and across scales and the ways in which this influences processes of knowledge production:

1. How are relations of power perceived and enacted by actors at different institutional scales and/or within different epistemological settings?

2. How do differential power relations among actors within and across epistemologies and scales influence the perceived salience, credibility, and legitimacy of various knowledges, and how does this influence knowledge production and use?

3. How do power relations influence the production and use of knowledge within particular epistemological communities and across institutional scales?

To address these questions, I employ two analytical approaches within a mixed methods case study. First, I employ a modified Actor-Network analysis (Rocheleau & Roth, 2007) to understand the ways in which knowledge is produced and how it gains and maintains social authority. In the second, I critically apply the Knowledge System Criteria (KSC) framework to understand how perceptions of the credibility, salience, and legitimacy of knowledge vary among various actors at different institutional scales, as well how these are deployed as part of the knowledge politics involved in the production of 'usable.' These two approaches present a novel means of understanding both the macro- and micro-processes that enable some knowledges to gain and maintain authority at the exclusion of others. Such insight enables an approach to understand the diffuse ways in which power is exercised and expressed within various co-production settings.

1.3 Contribution to Scholarship

This dissertation aims to provide contributions to the broader scholarship in several areas. First, I seek to add value to the rapidly evolving literature around the theoretical basis of the concept of co-production. Second, I contribute to dialogues and debates about how relations between knowledge and power, specifically within instrumental co-production activities, might be studied. Third, I apply the Knowledge Systems Criteria (KSC) framework (Cash et al., 2003) in a potentially innovative way that is more attuned to the politics involved in producing 'usable' knowledge. Lastly, I put forward the argument (made in Chapter 3), which emphasizes the need for 'strong' co-productionist analysis (following Jasanoff and other STS scholars) in order to understand instrumental attempts toward co-production of knowledge and to unpack the ways in which power is exercised through them. I will discuss each of these in more detail.

In recent years, co-production has rapidly gained traction across many divergent areas of scholarship and practice. However, it is often apparent that there is a lack of clarity with regard to how the term is understood and applied, both across research domains, as well as within applied or practical settings. An initial review of the literature made it evident that there are multiple distinct theoretical origins of co-production; however, these various interpretations are merged without sufficiently recognizing the differences. This theoretical muddle created new questions. First, it was necessary to ask, where did the concept of co-production originate and how did it get 'here' — meaning, how has it gained such intense attention across such a wide number of disciplines and streams of scholarship concurrently? Second, it raised the question of how have these different theoretical origins more recently been incorporated within the literature and what does this mean for how the concept of co-production is taken forward, both in theoretical and practical terms? Given the increasing frequency with which co-production is called upon within both policy and practice and its oft-cited potential to remedy complex issues — from sustainable development, to the role of science in society, to public service provision — this is not trivial. How we conceive of and deploy the idea of co-production will have real impacts (for better or worse) on people's lives. For this reason, I hope to contribute to the conversation by helping to provide a broad overview of the term — including its origins, evolution, and its present articulations — with the aim of more critically (yet productively and integratively) engaging with the concept in the future. I do so by reviewing and tracing the antecedent literature that has preceded recent usages of the term co-production (in Chapter 1). I follow this with a systematic review of co-production over the last decade to synthesize the current state of the literature (in Chapter 2).

There are no clear sign posts about how one might go about examining relations of knowledge and power. There has been much said about uneven power relations within instrumental co-production efforts, but what does this mean in practice? And how are such power imbalances created and maintained? As I discuss further in subsequent chapters, the ways in which power is manifested are not always visible. It is often as much about what topics, actions, or ways of being that are constrained or excluded, as about those that are actively promoted, expanded, and included. Thus, I contribute to debates about how concepts of co-production might be studied, through the development and testing of a methodological approach that enables the observation of knowledge production, circulation, and use across scales. While it is acknowledged that co-production can address both micro- and macro-scale processes (Jasanoff, 2004), it is less often that these are considered concurrently. A key aim of my approach was the principle of symmetry, which demanded that I employ the same data collection methods across all scales and participants. This in itself is a departure from the majority of research approaches. Multi-scalar studies are quite rare, for obvious reasons. They are time-consuming to carry out and require the negotiation of access and building of relationships and networks in multiple sites. Yet, such a cross-scalar approach helps to attend to the diffuse ways in which knowledge is produced, picked up, and applied — which occurs both formally and informally, explicitly and implicitly, and across standard notions of scale. While this approach presented many challenges, as well as benefits (as will be discussed in the next section), it is my hope that what can be learned from this experience (the good and the bad) can contribute to the broader scholarship on co-production.

Additionally, I apply the Knowledge System Criteria (KSC) framework (Cash et al., 2003) in an innovative way. The KSC framework was developed as a means of understanding how scientific knowledge can be made usable or to increase its influence within policies to address complex socio-ecological issues. The KSC framework claims that in order for knowledge to be usable for decision-making, it must be sufficiently credible, salient, and legitimate among various actors involved. While the KSC framework is a potentially useful entry point for understanding how knowledge and politics interact in contentious knowledge debates, it is also problematic for several reasons. The KSC framework embraces a normative stance in which the use of scientific knowledge is considered fundamentally beneficial — most notably, it asserts the potential of science to resolve the challenge 'sustainable development,' if it could only be 'harnessed' correctly. This risks ignoring many of the insights coming out of STS and Political Ecology literatures, which have shown that the application of scientific knowledge is far from neutral. In this way, the KSC framework pays insufficient attention to relations of power. In contrast, I adopt a stance that recognizes the *potential* value and contribution of scientific knowledge to informing key environmental issues, while acknowledging that scientific knowledge is not equally beneficial to all and has been used as a powerful tool to undermine the livelihoods and existence of marginalized communities in many locations throughout the world. I seek to use the KSC framework to better understand the interactions between politics and knowledge that inevitably play out in contentious policy settings. The ways in which the criteria of credibility, salience, and legitimacy are advanced or silenced is not neutral. Rather, these are in themselves deeply political moves.

Finally, this dissertation simultaneously attends to the multiple facets of co-production, both the analytical and descriptive dimensions, as well as instrumental interpretations. These are, of course, always intertwined. But, there are few studies that try to simultaneously track these two interpretations simultaneously in practice. As will be discussed in Chapter 3, there is only a small segment of the co-production literature that concurrently attends to instrumental co-production and also with *how these attempts themselves* "loop back" (Jasanoff, 2004) to reshape ontological and normative conditions. This study contributes toward expanding this body of literature.

1.4 Outline of the Dissertation

This dissertation is organized into 6 main chapters, preceded by this introduction (Chapter 1) and followed by a conclusion (Chapter 8). Chapter 2 reviews the antecedent theoretical lineages that have shaped current understandings and usages of the term co-production. I illustrate how these different strains of literature have evolved concurrently, sometimes in parallel, sometimes often with interacting, to arrive at the seemingly 'common' ground that has produced the current widespread interest in co-production across a range of scholarship and practice. I argue that greater attention needs to be paid to the ways in which the term co-production is used.

In Chapter 3, I conduct a systematic review of the co-production literature between 2005 -

2015. This review illustrates the diversity of ways in which the concept of co-production is currently being deployed, though the majority of scholarship has only focused on either weak or strong variants of co-production. There is a small number of studies that incorporate both. I conclude to suggest that strong interpretations of co-productive analysis are needed to ensure that instrumental co-production does not reproduce the problems it was intended to solve.

In Chapter 4, I describe the case study location, in semi-arid regions of northern Tanzania, and detail the research design and methods. I detail each of the data collection methods, including: quantitative surveys, semi-structured interviews, planned group discussions, and non-participant observation. I conclude by reflecting on the research design and methodological choices, and how these relate to the aspirations of co-productionist analysis.

In Chapter 5, I present quantitative survey results assessing the landscape of climate knowledge production, circulation, and use across multiple institutional scales in Tanzania, with village scale data collected in two districts in northern Tanzania. Results show that there are already complex webs of knowledge and that most respondents at all scales already rely on multiple sources of knowledge about weather and climate. These survey results also emphasize the importance of both formal and informal modes of sharing knowledge, along with the need to recognize the dynamic and socially situated nature of all knowledge.

In Chapter 6, I describe the constitutive dimensions of co-production involved in attempts to promote instrumental co-production of climate services in Tanzania using a modified Network-Analysis. I show that climate services agenda and processes of instrumental co-production produce particular subjectivities of 'end-users' of climate information that conform to idealized notions of a 'modern' Tanzanian citizen.

In Chapter 7, I examine the interactional dimensions of co-production through the critical application of the Knowledge System Criteria (KSC) framework, which theorizes that knowledge must be sufficiently credible, salient, and legitimate among a range of actors to be ‘usable’ or influential within policy-making. I instead use the framework analytically to illustrate the politics of ‘usable’ knowledge that take place within instrumental co-production.

CHAPTER 2: Theoretical Antecedents Contribution Toward Current Usages of Co-production

2.1 Introduction

In recent years, the concept of co-production has garnered increasing attention across many different areas of research, policy, and practice. It has become a key tenet of several large global agendas and international programs. For example, Future Earth, the post-2015 Sustainable Development Goals, and the Global Framework for Climate Services have all embraced co-production as a component of governance structures, research activities, and agendas. Additionally, co-production has recently been the topic of several special issues in academic journals (e.g. Environmental Science and Policy in 2014 and Ecology and Society in 2015), as well as the theme of conferences (e.g. the Royal Geographical Society in 2014). Given this recent surge of interest in co-production across a range of disciplines and domains, one might reasonably ask why and how co-production has rapidly become such a popular topic. In other words, how did we get 'here' with co-production?

In order to try to answer this question, I conduct a review of the literature to identify the various theoretical antecedents that have contributed toward the current co-production 'fervor.' I find that the current research on co-production stems largely from two areas of scholarship — 1) public services administration / common pool resources and 2) science and technology studies (STS). Yet, these concepts did not emerge contemporaneously. While co-production in the public services literature emerged in the late 70's and early 80's, it was not until the late 90's and early 2000's that the term became widespread in the STS literature. However, it is through the interactions of these two conceptualizations of co-production with each other, and with other concurrent trends in theory and practice in the last decades (e.g., participatory development, transdisciplinarity), that has resulted in an evolution toward seemingly – though perhaps deceptively – common ground. I also discuss how influential work on global environmental assessments and knowledge systems, along with a growing emphasis on the role of knowledge in adaptive management and co-management, have created a turn toward instrumental conceptualizations of the *co-production of knowledge* in particular. As this review will show, these (sometimes parallel, sometimes overlapping, and sometimes divergent) theoretical contributions have been increasingly intermixed, such that there are now very different interpretations of what is actually meant by the term 'co-production.'

These multiple interpretations are potentially problematic for several reasons. First, the integration of concepts of co-production derived from these two primary streams of co-production scholarship, along with other conceptual developments, often occurs without sufficient recognition of the important differences in the ontological foundations, epistemological commitments, and theoretical origins of each. This can result in uncomfortable disjuncture and contradictions that may detract from the original contributions of these theorizations. Additionally, this intermixing has resulted in a lack of conceptual clarity around the term co-production. As the concept of co-production has been rapidly picked up and assimilated within and across a range of disciplines, little attention has been paid to the ways in which the term has been altered in these multiple translations. Instead, the concept of co-production risks being assimilated, transported, and modified, in ways that might be antithetical to underlying principles of co-production theorization. Approaching co-production from a vantage that does not adequately deal with the politics and power of knowledge production, co-production can serve to close off, rather than open up (Stirling, 2007), important ontological questions that can better inform science-society relations in the future.

This has important implications for how we might understand and apply the concept within research and practice. This is not to say that there cannot be useful interactions between differing concepts of co-production, or other related theories. I would argue that there is a great deal of potential for interaction and debate among these various areas of scholarship. Rather, I argue that in order to enable more beneficial engagement between these concepts, there is first a need to better understand their roots.

The review will be presented in the following structure. I will first review the early literature on co-production of public services. This will be followed by a review of concurrent or follow-on theoretical developments in the areas of common-pool resource management, participatory development, 'local' knowledge, decentralization, co-management, and adaptive management, which have interacted with or shaped current conceptualizations of co-production. I then turn to contributions from the STS literature, including the social construction of knowledge, boundary work, mode-2 knowledge production, and transdisciplinarity. These have variously contributed to the comprehensive articulation of the "idiom of co-production" (Jasanoff, 2004). I then provide a detailed accounting of the idiom of co-production — including the constitutive and interactional dimensions. I end with a discussion of the interactions and divergences between these literatures and dangers of uncritical usages.

2.2 Antecedent Concepts and Theories from Public Services and Commons Literatures

This section will illustrate the complex interweaving between the earliest conceptualizations of co-production in the public services and later developments in the literature, to show how this was then indirectly picked up within natural resource management literatures through Elinor Ostrom's later work on common pool resources. While public services and natural resources might seem to be quite different realms, Ostrom (2010) has shown how her early thinking around public services was fundamental to her later theoretical contributions to natural resource management in the form of adaptive management and polycentric governance systems. While the term 'co-production' itself was not reflected in the commons and natural resource management literatures and other related trends (such as participatory development and decentralization) until the early 2000's, the conceptual thrusts of the early work on co-production of public services can be seen within these various theoretical threads. By tracing how these strands of literature have interacted and evolved in similar trajectories over the last decades, it can help to explain how we have arrived at the focus on co-production across such a wide range of scholarship and practice in recent years.

2.2.1 The Rise of Co-production of Public Services

The earliest comprehensive usage of the term co-production was developed largely through the work of Elinor Ostrom and colleagues at the Workshop in Political Theory and Policy Analysis at Indiana University in the late 1970's (Brandsen & Pestoff, 2006; Kiser & Percy, 1980; Ostrom, Parks, and Whitaker, 1978; Parks et al., 1981). Based on empirical studies, this research developed new conceptualizations of public services administration that disrupted traditional economic theories explaining the production of goods and services, in particular public services (e.g., safety, health, education). The concept of co-production emerged largely in response to budget constraints that demanded a cut in budget expenses, while maintaining the same level of public services (Brudney & England, 1983). Co-production was also seen as a means of facilitating 'post-neoliberal policy' that encouraged increased citizen participation within public services (Dunston Lee, Boud, Brodie, & Chiarella, 2009), reflecting other critical perspectives related to citizen participation and empowerment (e.g. Arnstein, 1969) and in parallel with a growing participatory turn within international economic development in the early 1980's (Chambers, 1992).

According to Ostrom (1996), co-production is the "process through which inputs used to produce a good or service are contributed by individuals who are not 'in' the same organization"

(p. 1073). Early work on co-production was often presented narrowly in economic terms (e.g., framed in terms of 'inputs' and 'outputs', e.g. Kiser & Percy, 1980), as well as focused on efficiency (e.g. Warren, Rosentraub, & Harlow,1984). The basic idea of co-production was simple, yet had far-reaching implications: it dispelled the myth that there was a clear distinction between the 'producers' and 'consumers' of public services and asserted that the successful production of public services required the participation of citizens in both their consumption and production. The implications of this finding also challenged dominant theories of urban governance at the time, which argues that centralized bureaucratic structures were best positioned to provide efficient and effective services (Brandsen & Pestoff, 2006). The primary proposition was that for public services to be both efficient and effective, citizens must play a role as hybrid 'consumer producers.'

Drawing on these early conceptualizations, Brudney and England (1983) highlighted two definitions of co-production. The first involves the notion that citizens are active participants in the provision of public services, as well as the notion that both citizens and government officials create the setting in which services are delivered through their joint activities. Under this definition, citizens are always implicitly involved in co-producing the public services, since they themselves are a vital component that helps to shape the context (i.e. ontological conditions) in which services can either fail or succeed. While not expressed in such terms, this represents a relational ontological perspective of how public services 'come into being.' The second is from an economic perspective highlighting the frequent overlap between 'producers' and 'consumers' of goods and services, which necessitates the participation of publics in the production of services. A primary component of both of these conceptualizations was the recognition that the dynamics of public services production were complex and unlikely to succeed without the active participation of the intended recipients of services (Ostrom, 1996). As such, co-production was a new way of describing relationships between traditional ‘producers’ and ‘consumers’ of services and products that challenges the notion that these are distinct categories (Ostrom, 1996).

Beyond this initial groundbreaking work on co-production, the theoretical backing for co-production of public services remained relatively undeveloped for several decades (Alford, 2014) even as the concept began to proliferate. In recent years, this approach to co-production has gained increasing traction across a range of both public and private services, including: healthcare, education, public safety, architecture, urban planning, industry and production, and many others (Boyle & Harris 2009; Cepiku, 2014; Kiser &Percy, 1980; Otsuki, 2016; Warren, Rosentraub, & Harlow, 1984; Steen, Nabatchi, & Brand 2016; Whitaker, 1980).

2.2.2 Co-production, Institutions, and Common Pool Resource Management

There is relatively little explicit discussion of co-production by Ostrom between her earlier work on co-production and her later contributions through her comprehensive and well-known frameworks. Yet, it is possible to see the various linkages manifest through the ‘design principles’ (Ostrom, 1990) that form a key aspect of arguments for institutional diversity and polycentric systems within her broader work on adaptive governance. In essence, Ostrom concluded that there are certain principles that can inform the organizing of institutions and governance that increase opportunities for learning under uncertain conditions, such as ecological change (Ostrom, 2009). Alford (2014) has argued that despite the fact that Ostrom’s theorization of co-production was not well developed, subsequent development of the Institutional Analysis and Development (IAD) and Social Ecological Systems (SES) frameworks resonate with co-production such that it could be applied to collective action problems within adaptive governance of social-ecological systems (in particular themes related to learning, collective action, and institutional design). For example, this includes findings with regard to the need for a diversity of actors and institutional arrangements within governance systems and decision-making across multiple scales, as well as the goal of creating synergistic relationships that enable actors to jointly achieve outcomes that would not have been possible individually.

Ostrom's comprehensive IAD framework, was further developed and integrated within her SES framework in the 1990's and 2000's. While there is not the scope to fully detail Ostrom's expansive work here, it is important to note that participation was deemed a key evaluation metric of outcomes within the framework, with co-production being a particular 'form of participation' that is likely to be more successful in terms of producing desirable outcomes (Cox et al., 2010; McGinnis, 2011; Ostrom, 1996). The concept of co-production is reflected in Ostrom's calls for "synergies" across different sectors, scales, and levels of governance that can be manifested through different institutional forms (Ostrom, 1996; 2011).

It is also through Ostrom's work on institutions and the management of common property (i.e. common pool resources) that the concept of co-production has been reflected in discussions of self-regulation and community-based institutions. For example, one of the eight design principles proposed for community-based natural resource management (Ostrom, 1990) includes institutional arrangements for collective choice. The design principles specify that within these institutional arrangements, individuals who are affected by particular management schemes have legitimate authority to take part in making and modifying the rules for managing the resource (Ostrom, 2005). The principles also state that it is important for 'local' knowledge to inform decision-making, especially under conditions of environmental change, since more distant actors may not perceive or detect local changes as quickly (Ostrom, 2005). A key aspect of Ostrom's framework is that different participants have comparative advantages at different scales. This is a notion that is applied to knowledge production, where local communities are considered to be best situated to contribute knowledge about their situation that can more effectively inform the development of appropriate rules and strategies for resource management in a particular location. Likewise, managers at other levels may have knowledge production capacities that are suited to different levels of governance and decision-making (Cox et al., 2010).

2.2.3. Sustainable Development, Participation, and 'Local' Knowledge

In parallel to the developments within the public services and commons literatures, there were growing critiques of 'top-down' approaches to planned economic development starting in the 1980's, which resulted in wide-spread calls for participatory models that encouraged the involvement of 'beneficiaries' within development interventions (e.g. participatory rapid appraisals) (Cooke and Kothari 2001, see Chambers 1983 as one of the fundamental texts behind this movement). While these participatory approaches did not use the language of 'co-production', this line of thinking would go on to shape how co-production would later be conceived of within the common pool resources and natural resource management spheres. Participatory development was heralded as a means of challenging the dominance of bureaucratic planning systems by reversing the roles and relationships between the 'outsiders' attempting to facilitate 'development' and the 'local' people who are the intended 'beneficiaries' (Mosse, 2001). Embedded within many of the debates about top-down managerial approaches with sustainable development were issues related to control or management of natural resources, particularly common-pool resources, such as forests. The participatory turn in development was intended to counter technocratic tendencies within development agendas that relied heavily on 'experts' and adopted a narrow definition of expertise, a move that held broader questions and implications for democratic decision-making. Thus, the trend was perceived to simultaneously contribute toward debates about issues of environmental governance and the role of expertise in public decision-making.

The turn toward participatory development was consistent with Ostrom's emphasis on enhanced involvement of 'local' perspectives, knowledge, priorities and skills; however, some of these approaches also sought to make explicit the political and ethical dimensions of participation and 'local' knowledge. Building on the early work of Chambers (1983) and others, such as Brokensha et al. (1980), there was an increased interest in indigenous knowledge (IK), traditional ecological knowledge (TEK), local expertise, lay expertise, etc., during the late 1980's and 1990's (Huntington 2000). Within the last decades, the practice of sustainable development has become almost inseparable from the application of participatory methodologies (Pritchett & Woolcock, 2004). There has, however, been a powerful and ongoing critique of the rapid proliferation of participatory methods (Cooke & Kothari 2001; White, 1996; Ribot et al., 2010; Masaki, 2010), which contends that such methodologies may not only fail to bring about the positive outcomes that are claimed, but in many instances serve to perpetuate or worsen conditions of inequality.

2.2.4 Concurrent Trends and Intersections: Decentralization and Co-management

Reflecting both the institutional perspectives advanced by Ostrom and the trend toward participatory development, decentralization emerged as a dominant approach within economic development and environmental policies (Agrawal & Gupta, 2005; Batterbury & Fernando, 2006). Reflecting some of the economic foundations of the early presentation of co-production, decentralization was often justified based on anticipated improvements in efficiency, equity, and responsiveness to citizen demands through open and accountable forms of governance (Batterbury & Fernando, 2006). Yet, the dominance of early models of citizen participation (e.g. Arnstein, 1969), which equate participation with power, have more recently come under much scrutiny (Collins & Ison, 2009; Cooke & Kothari, 2001). It has been recognized that remitting full decision-making authority to local actors, which was previously seen as the penultimate form of empowerment, is overly simplistic, problematically depicting a hierarchical, apolitical, and linear view of empowerment. Decentralized governance efforts sought to move from just soliciting local knowledge as an input, to actually linking that knowledge with devolved decision-making to empower local actors. Critiques of decentralization have highlighted the need for downward accountability, as well as the need for more complex arrangements with regard to the decision-making powers allocated to various actors and further consideration of how these influence the potential for increased participation and empowerment (Agrawal & Ribot, 1999).

Co-management emerged out of the commons literature and offered ways of addressing some of the evident problems with the more simplistic approaches to participatory and decentralized models of conservation, natural resource management, and development. Co-management addressed the need for vertical institutional linkages evident in decentralization and, thus, sought to overcome the unidirectional conceptualizations of participation and empowerment (Carlsson & Berkes, 2005) and is seen as a win-win in which control is shared among actors at various scales. Co-management has taken different forms, some of which have also sought to address issues of power sharing, institution building processes of trust building, deliberation, negotiation, problem solving, and governance and has evolved from an early emphasis on structural dimensions toward a process-based conceptualization that seeks to better address complexity (Whaley & Weatherhead, 2014).

2.2.5 Adaptive Management and a Shift Toward Knowledge as a Resource

Co-management's emphasis on the complexity of socio-ecological systems has highlighted the need for iterative planning and policy arrangements that enable processes of muddling through, learning-by-doing, and social learning. Yet is also through co-management that an emphasis on the role of *knowledge* as a key resource emerges. Berkes (2009) states that "successful co-management is a knowledge partnership" (p. 1699), thus affirming the central role that knowledge plays in co-management arrangements. Along with the emphasis on process, co-management has also resulted in the emergence and evolution of a variety of institutional forms, such as: epistemic communities, policy networks, polycentric systems, and institutional interplay (Berkes, 2006). A key element across all of these new institutional arrangements is that all seek to involve knowledge contributions from a range of stakeholders, often at a variety of scales or across multiple disciplines. Thus, the shift toward adaptive management and co-management resulted in calls for diverse perspectives and multiple knowledges to inform ecosystem management. For example, it has been argued that traditional ecological knowledge (TEK) and other non-scientific knowledges (e.g., indigenous, local) have been "rediscovered" as a form of adaptive management in and of themselves, due to the "holistic" perspectives they embraced and the tendencies toward the evolution of "traditional" knowledge, practice, and beliefs (Berkes et al., 2000).

Evident overlaps between concepts in adaptive management, which include a focus on problem-solving and learning-by-doing, have resulted in a coalescence and, in recent years — as co-management has broadened its scope — a merging with adaptive governance in many areas, particularly social learning (or co-learning). Such moves have also highlighted the importance of issues of scale, critical perspectives of context, and power and relationships with the behavior of SES (Berkes, 2009; Whaley & Weatherhead, 2014). The adaptive perspective within co-management has problematized the simplistic dichotomies between homogeneous 'communities' and the 'government' (Carlsson & Berkes, 2005). This is one area where we can clearly see linkages between Ostrom and colleagues' original conceptualizations of co-production, which similarly questioned the possibilities of homogeneous, unified, and distinct groups falling under the general categories of citizens (i.e., 'consumers') and government (i.e., 'producers'). Her later work and more recent trajectories in adaptive governance explicitly call for the inclusion of a multiplicity of actors and knowledges.

This is in part how the definition on the term co-production seems to become blurred. While Ostrom's discussion remained fundamentally concerned with the contributions of the knowledge and capacities of various groups of actors within *co-production of public services* (e.g. Ostrom, 1996), scholars working more specifically on co-management, became more overtly focused on the role of *co-production of knowledge* as a means of better supporting co-management and/or governance. Indeed, learning generally, and social learning more specifically, is now recognized as a central component of co-management and adaptive management approaches (Fabricius & Cundill, 2014). Directly reflecting Ostrom's earlier assertions about the scalar nature of comparative advantages, but now in reference specifically to knowledge, Berkes (2009) concludes, "different levels of organization have comparative advantages in the mobilization and generation of different kinds of knowledge" (p. 1699).

2.3 Antecedent Theories and Concepts from STS Literature

Within the public services, we have seen how the term co-production was introduced early on and then traced how it eventually emerges, somewhat indirectly, within the literature on adaptive management and co-management. Within the STS literature, there is an opposite trend. The term co-production itself was not used extensively until the late 1990's and 2000's, but there were several earlier theoretical antecedents which, together, help to form the fundamental basis for Jasanoff's comprehensive introduction of the idiom of co-production in 2004. Examining the theoretical underpinnings of STS formulations of co-production is important, since this helps one to understand the potential for theoretical dissonances when conceptualizations of co-production from the public services/commons and STS literatures are deployed simultaneously. Thus, while in this early literature, the term co-production does not appear explicitly, these are the key developments that informed its development later on.

2.3.1 The Construction of Scientific Knowledge

At the same time that the concept of co-production was being developed by Ostrom and colleagues, scholars in the nascent field of Science and Technology Studies (STS)[1] began examining of the relationships between the production of scientific knowledge, politics, and societal decision-making. Early approaches toward explaining the processes of production of scientific knowledge, which challenged idealized models of scientific rationality that characterized the post-war era, emerged in the 1960's (Kuhn, 1962; Polanyi, 1967). It was during the 1980's and 1990's, when the field of STS began to proliferate rapidly, that sociological and ethnographic study of science began to highlight the particular practices involved in the construction of scientific knowledge (Edge 1995). In particular, 'laboratory studies' (Knorr-Cetina, 1983; Latour & Woolgar, 1986) described in detail the particular work involved in creating stabilized facts, through social practices and microprocesses observed in laboratory settings, which had otherwise been taken as given and 'black boxed' as objective (Knorr-Cetina, 1995). Others argued that Western scientific knowledges, which are equated with universality, rationality, and objectivity, are themselves 'local', warranting the treatment of scientific and all other knowledge systems on equal footing (Watson-Verran &Turnbull, 1995). Furthermore, work in this area has emphasized the performativity of all knowledge practices, which has challenged the supposed 'universal' nature of scientific knowledge, as well as the notion that 'local' knowledge necessarily remains lodged at particular spatial or temporal scales (Turnbull, 2000). Along with recognition of the constructed nature of science, growing concern about relations between science and society were fueled by the emergence of new technologies which were accompanied by greater uncertainty and risk (Beck, 1992), as well as the increasing deference to scientific evidence and expert advice within policy-making (Jasanoff, 1990). These studies included examinations of the relations between knowledge and power, the role of expertise in societal decision-making, and increased scrutiny of 'standard' modes of knowledge production (M. Goldman, 2004; Jasanoff, 1990).

2.3.2 Boundary Work and Epistemic Authority

Studies illustrating the constructed nature of scientific (and all) knowledge spurred important debates about epistemic authority – or the "legitimate power to define, describe, and explain bounded domains of reality" (Gieryn, 1999, p. 1). The distinctions between 'science' and 'society' that are often invoked as the defining feature of 'modern' times (Latour, 1993) were not always taken for granted. Rather, these distinctions were created through elaborate methodologies of validation and accompanying social practices and norms that defined boundaries and relationships between science and politics, as well as imbuing science, over other ways of 'knowing', with the authority to represent nature (Jasanoff, 2004; Shapin &Schaffer, 1985). Indeed, such studies have helped to problematize perspectives that seek to assign essential characteristics to set science apart from social activities (e.g., politics, culture) to show that science gains its authority. Gieryn (1999) defined boundary work as the "discursive attribution of select qualities to scientists, scientific methods, and scientific claims for the purpose of drawing a theoretical boundary between science and some less authoritative residual non-science" (p. 5).

The concept of boundary work opens up new questions and also has important theoretical implications. The first of these was the idea that no ontological domain should be attributed with unquestioned privilege as an authoritative way of knowing (Gieryn, 1999). Rather, epistemological authority must be constructed. From this vantage, science only gains its legitimacy and cognitive authority through continual negotiation of flexible and contingent boundaries. In this way, science gains its authority through the exclusion of other knowledge, only 'coming into being' in relation to that which is 'non-science' (Gieryn, 1995, p. 405). Boundary work occurs in sites or situations when the authority or legitimacy of science is challenged as a means of enabling science to (re-) establish its privileged position, and the credibility and power that come along with it.

2.3.3 Mode-2 and Transdisciplinary Knowledge Production

A critical view of boundaries between science and society had important implications for how research and other knowledge production activities were fundamentally viewed. The concept of "Mode-2" knowledge production emerged in response to the shortcomings of 'traditional' research models (termed "Mode-1") and disciplinary constraints preventing effective response of research to societal needs (Gibbons et al., 1994). The proposition of Mode-2 knowledge production is characterized by production of knowledge within the context in which it will be used or applied (Gibbons et al., 1994; Nowotny et al., 2001). There have been similar moves in the social sciences, where there have been calls for "interactive research" in which "interconnections and back-and-forthness" between social scientists and a range of actors is called for in order to help ensure the use of research (Weiss, 1979, p. 428, see also Baldwin, 2000). Because mode-2 knowledge and other interactive models seeks to address complex problems that supersede the capacities of individual disciplines, it is frequently considered to be transdisciplinary, or involving a heterogeneous set of skills and expertise that may change over time in relation to various aspects of the problem-solving process. Further, Mode-2 knowledge also sought to address social accountability, reflexivity, and new ways of assessing the validity of knowledge (Gibbons et al., 1994, pp. 2-5).

Crucial to the evolution of conceptualizations of co-production, Mode-2 requires the participation of multiple actors in the exploration and production of knowledge. The ways in which such participation is organized is a key aspect of ensuring that the knowledge that is produced is socially distributed. Gibbons (1994) highlights this shift: "The goals of participation are no longer simply to secure some national advantage, commercial or otherwise. Indeed, the very notion of what constitutes an economic benefit, and for who, is at the root of many debates…" (p. 15). Mode-2 is a challenge for governments in the sense that centralized government or national institutions that were once the primary centers of knowledge production must become more flexible, de-centered/distributed, and diverse (Gibbons et al., 1994). Notwithstanding many critiques of the over-simplifications and problematic boundaries that are (somewhat ironically) reproduced and perpetuated within the theorization of Mode-2 model of knowledge production, it has been highly influential in reshaping idealized conceptualizations of research and knowledge production (McNie et al., 2016) and spurred early exploration of the "co-evolution of science and society" and gave credence to the notion that "coincidences and correspondences between the development of science and society suggest that a process of co-evolution is at work" (Nowotny et al., 2001, p. 30).

2.3.4 Rethinking Linkages Between Science and Society: Democratization of Science

There have been a range of propositions that aim to reexamine relations between 'science' and 'society,' including renegotiating the role of publics within knowledge production processes (e.g. Wynne 1993), the role of expertise and policy decision-making (e.g. Jasanoff, 1990), and, ultimately, reconsidering the relationships between knowledge, citizenship, governance, and democracy and how these fundamentally shape the world that we live in (e.g., Ezrahi, 1990; Latour 1993; Shapin & Shaffer, 1985). A common strain within these disparate approaches to studying the interactions between knowledge, science, and society is the notion that there is a need to 'open up' the processes through which knowledge is produced and deployed in order to democratize science and policy making decisions (e.g. Jasanoff & Wynne, 1998; Kleinman, 1998). The implications of such calls are far-reaching and force us to grapple with fundamental questions about the relationships and 'boundaries' between science and society.

2.4 The Idiom of Co-production

Although she was not the first to use the term, the concept of co-production was first comprehensively and cohesively introduced by Jasanoff (2004) in an effort to bring many of the insights coming out of the emergent field of STS into conversation with other fields concerned with the relationships between knowledge, society, governance, culture, and power. The idiom of co-production (Jasanoff, 1996, 2004) was introduced as a way of understanding the relations between how we know about the world (epistemology) and how this in turn shapes how we exist in the world (ontology). Building on the previous insights of STS, including growing insights related to the practices and politics involved in the construction of scientific knowledge, co-production sees relationships between the production of scientific knowledge and social orders as mutually dependent. Notably, this removes any primal determinacy from both 'science' and 'the social.' In this way, co-production refuses claims that science is a purely social product, while also avoiding scientific or technological determinism as the sole driver of social systems. As Jasanoff succinctly summarizes: "increasingly the realities of human experience emerge as the joint achievements of scientific, technical, and social enterprise: science and society are, in a word, *co-produced*, each underwriting the other's existence" (Jasanoff, 2004, p. 17). This is essentially to say that how we produce knowledge has material consequences for how citizens and societies experience and 'know' about the world and, conversely, how these worlds are in turn 'known' and organized. In this way, science and technology are seen as legitimating and mediating the power of the state, institutions, and other social orders.

2.4.1 Constitutive Co-production

Jasanoff identifies two strands of co-production: the constitutive and the interactional. In large part, constitutive co-production is concerned with how and why demarcations between what counts as 'natural' and 'social' have come about in the first place, rather than treating these as settled matters. This aspect of co-production simultaneously interrogates the ways in which this separation shapes human experience and observations of 'reality' and the consequences of this on political and social orders (Jasanoff, 2004). This "constitutional guarantee" is essential to Jasanoff's argument. The authority of scientific knowledge is based on the premise that it is the one authoritative means of understanding true 'nature.' A key underpinning of constitutive co-production is the lack of causal primacy of either the 'social' or 'natural' worlds (Jasanoff, 2004). This stance draws in large part on the insights of Michel Foucault and Bruno Latour.

Foucauldian conceptualizations of power are created, circulate, and continually re-inscribed through knowledge production processes (Foucault, 1982). Similarly, Latour has pointed to the separation between 'nature' and 'culture' (non-humans and humans) as a human creation which has become so pervasive in "modern" Western thinking that it forms the basis for all other ways of knowing the world (Latour, 1993). As such, this duality between nature and culture forms the constitution of a new relationship between epistemology and social order: scientists are given the authority to represent nature/non-humans, while society/humans are represented through the construction of social and political spheres. Together, these movements act in tandem to "invent" the separation between scientific representation and political representation, in what Latour calls "purification" (Latour, 1993). It is in this way that 'natural' and 'social' orders co-produce each other — 'nature' only becomes possible in relation to 'cultural' or 'social' domains. It is through this separation that scientific and political representation gain power over their respective domains, thereby forming a new 'constitutive' order in which science-society relations are formed (Jasanoff, 2004; Latour, 1993). And, it is this guarantee of the modern constitution that enables the separation of science and society. It is with this movement that constitutive co-production is concerned: in understanding the simultaneous ways in which the divide between science/society is created and maintained, how this fundamentally shapes our understanding of the world, and what this implies for social order.

This perspective results in at least two crucial insights. First, the indeterminacy between the 'natural' and the 'social' demands symmetry in the treatment of human and non-human actors and the role they play in shaping how we know about the world. Secondly, this realization also has significant implications about conceptualizations of expertise and who is authorized to represent nature and to "mediate" (in Latour's terms) between the natural and social worlds. This provides a lens to more aptly examine existing relationships between science and social worlds, opening up important questions about representation, deliberation, and notions of expertise. Simultaneously trying to understand the shuttling between the activities of translation and purification as presented by Latour forces us to interrogate the ways in which these divisions are both mutually dependent and created together — or, in other words, co-produced.

2.4.2 Interactional Co-production

The idiom of co-production is not only concerned with ontology, but also addresses conflicts about the social authority, credibility, and legitimacy of knowledge. This is referred to as interactional co-production, in reference to the co-production that takes place at the interface of science and politics. Epistemological conflicts within interactional co-production accounts tend to operate within pre-established determinations about what counts as 'social' and 'natural' (Jasanoff, 2004). This does not mean that interactional co-production understands such demarcations as being permanently fixed or innately determined or that there are uni-directional causal relationships between the two. Rather, it is a constant process of 'boundary work' (Gieryn, 1999) through which the distinctions between natural and social orders (i.e. science and society) are continually negotiated, stabilized, and reinforced. Demarcations between scientific and social domains are intrinsically related to questions about who possesses the expertise, credibility, and authority to speak in these domains, as well as how this translates to the accumulation of power through knowledge practices (Jasanoff, 2004). In this way, "social and cultural commitments are built into every phase of knowledge production and consequent social action, even though enormously effective steps are often taken to eliminate the traces of the social from the scientific world" (Jasanoff & Wynne, 1998, p. 16). Assessments of the credibility of knowledge claims involves evaluating the trustworthiness and authority of the individuals and/or institutions making those claims, a process which draws upon rules of social order. In this way, "problems of knowledge" are able to resolve "problems of social order" (Shapin & Schaffer, 1985, p. 332, as quoted in Jasanoff, 2004).

Importantly, within Jasanoff's conceptualization of co-production, *these two strands of co-production are inseparable and continuously reinforcing and remaking the other*. The ways in which we talk about knowledge will influence the ways in which we seek to go about producing it, and vice versa. In this way, Jasanoff envisions co-production as being a starting point to help us to understand relations between knowledge and power and what this implies for our own capacities to reflexively, but intentionally, intervene within these processes. It does not, however, make prescriptions about what engagements and interventions should look like *per se*. In fact, this can only be contemplated in a meaningful way by *first* seeking to tease apart the relations between science and social orders, how they have come to be, how they have been maintained, and why they continue to endure. For this reason, neither variant of co-production 'supersedes' the other; rather, they both interact to form an endless dialectic.

2.4.3 The Instrumental Turn and the 'Co-production of Knowledge'

In the last sections, I have reviewed two primary antecedents of current understandings of co-production coming from public services (and common pool resource) and STS literatures, which have interacted with many other concurrent conceptual developments in related fields. This is particularly important since these various conceptualizations draw on very different theoretical orientations, and it is beneficial to understand how this shapes current uses of co-production. The growing shift toward the notion of the *co-production of knowledge* presents a useful example of the potential tensions that may exist when the two primary conceptualizations of co-production — drawing on the work of Ostrom and Jasanoff — are merged. In Section 2.1.5, I illustrated the shift in adaptive management and co-management in which knowledge comes to be seen as a key resource to facilitate more effective resource management systems toward conceptualizations in which co-production is seen as a participatory or joint means of producing knowledge. Yet, this was not the only thread in the literature that resulted in a specific turn toward the co-production of *knowledge* as an increasingly dominant way of interpreting the concept of co-production.

In the early 2000's, there was also a growing interest in determining how to better link scientific knowledge and assessments with environmental policy action and sustainable development through several large projects based at the Kennedy School of Government at Harvard University (Global Environmental Assessment Project and the Knowledge Systems for Sustainable Development). Similar to the rationale supporting co-production as a component of co-management (see Armitage et al., 2011), such scientific assessments were intended to support knowledge generation across various scales at which environmental management decisions and actions take place (Cash and Moser, 2000). These new ways of conceptualizing the need for cross-scalar knowledge production drew explicitly on Ostrom's (2005) assertion that knowledge that is produced at the scale of management decisions has a distinct comparative advantage and also incorporated related thinking coming out of the common pool resources and institutions literature. At the same time, these efforts drew specifically on concepts coming out of the STS literature, in particular, boundary work (Gieryn, 1995; Jasanoff, 1987) — and related ideas around boundary management, boundary organizations (Guston, 1999) and boundary objects (Star & Griesemer, 1989) (see, for example, Cash & Moser, 2000; Cash et al., 2003; Polsky & Cash, 2005).

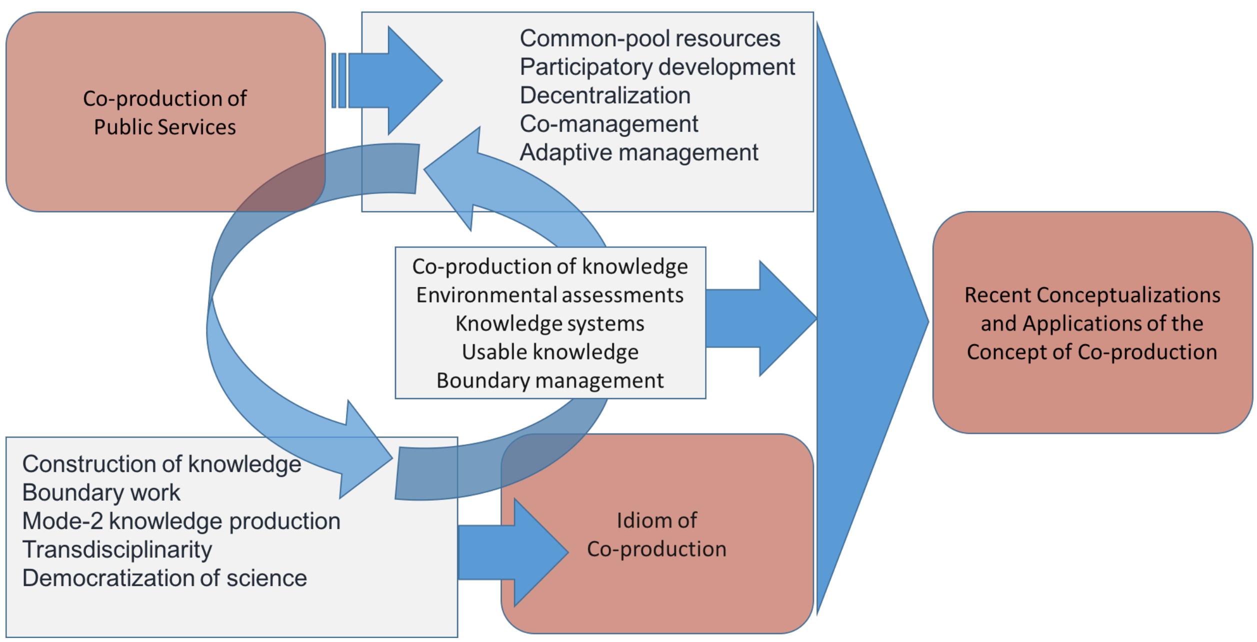

Figure 1: Theoretical antecedents and related concepts that have contributed to current interpretations and applications of the concept of co-production

It is through the interactions of these various concepts, along with other conceptual contributions (e.g. participatory development), that one clear example of the "co-production of knowledge through participation" (Mitchell, Clark, Cash, & Dickson, 2006) emerges. Mitchell et al. (2006) conclude that "the effectiveness of assessment processes depends on a process of *coproduction of knowledge* between assessment user groups in which the boundaries among these groups are bridged" and also that assessments are influential to the degree to which "they are bidirectional, with science shaping politics but also politics shaping science" (p. 325, emphasis mine). They go on to define co-production of knowledge as a process through which "producers and potential users of an assessment have long-term interactions that foster communication and mutual understanding" (p. 326).

This is a clear example in which precepts coming out of the idiom of co-production —namely the notion that science and policy are mutually constitutive — are *intentionally* employed to achieve a particular desired outcome. This is one example of an instrumental turn in the co-production literature in more recent years, with a particular emphasis on *co-production of knowledge* as a means of achieving desired goals or outcomes, such as increasing the use of scientific knowledge or producing better policies and outcomes (see, for example, Lemos & Morehouse, 2005; Pohl et al., 2010). However, it is necessary to question what this shift toward instrumental interpretations means.

2.5 Interactions and Divergences

It is not surprising that many studies have picked up on the potential power of the concept of co-production and seek to use this strategically. The problem is when this is done in a way that is detached from deeper understandings of how historical and current configurations of science and society might shape possibilities for doing so. Thus, it is not that instrumental interpretations of co-production are necessarily problematic. Rather, it is when these are undertaken without critical perspectives on the linkages between knowledge and power that there is the potential for problems.

What is key, is the ability, to simultaneously tend to the ways in which we are enacting particular normative visions through the instrumental versions of co-production. Research programs that demand collaborative knowledge making but fail to enable the spaces that allow radical questioning, reflexivity, and interrogation of the normative implications may undermine the goals of co-production.

2.5.1 Divergent Normative and Ontological Starting Points

It is clear that the two primary streams of scholarship that have informed the current interest applications of the co-production concept are premised on different ontological, epistemological, and theoretical foundations. While at times recognizing that there are normative implications for the ways in which citizens (publics) are involved as participants in the polycentric governance systems, co-production coming out of the public services and commons literatures are premised on the fundamental goals of efficiency and effectiveness. Ostrom herself recognized that emphasis on these aspects might come at the expense of equity (Ostrom, 1996), but this is not a concern that is fully explored or addressed. Because of Ostrom's ontological assumptions (e.g. separation between nature and society, fixed scales), there is little space to consider the underlying reasons of why and how scientific knowledge was assumed to be the preferred form of knowledge at all scales in the first place. Such omissions make it exceedingly difficult to 'see', and problematic to address, the fundamental roots of power imbalances in many of these systems. Ostrom's work on co-production sought to break down the theoretical "great divide" that kept public interest decisions separate from economic incentives, as well as to complicate conceptualizations of homogenous and distinct groups of 'producers' or 'consumers' by introducing the notion that often there are hybridized 'consumer producers.' This also recognized the implicit dimensions of co-production of public services, in the sense that there is necessarily a relational element to public service. Without the expression of needs and desires for services, they would not be produced in the first place. Paradoxically, while Ostrom's work sought to dissolve boundaries in some areas, it reproduced and multiplied them in others - including the divisions between social and ecological components SES (i.e. boundaries between nature / culture).

2.5.2 Differing Conceptualizations of Power

Another area of tension is the divergent ways in which power is conceived of between the public services and STS conceptualizations of co-production. Within co-production variants coming from public services, common resources, and co-management, power is conceived primarily in terms of 'power over' in terms of who is authorized to do what and to whom (e.g., rules, norms). The result is that these approaches tend to pay very little attention to the ways in which ontological categorizations (e.g. what counts as 'natural' or not), and the discourses, practices, and enactments that sustain them, play an important role in shaping relations between knowledge and power. This lack of attention to the ways in which ontological categories come about in the first place ignores the historical legacies of the use of scientific knowledge as a tool to classify and sort people according to physical, mental, and social characteristics to enact far reaching social agendas, to control populations, and to normalize and erase the practices through which these occur (Foucault, 1980; Jasanoff, 2006). Relationships between knowledge and power can serve to solidify entrenched ontological commitments, norms, and values — as well as leave the fundamental roots of power imbalances unquestioned. In contrast, it is through understanding these relationships, which are continually reproducing existing pathways for the circulation and distribution of power, that strong co-production asks us to attend to. As this review has shown, many of those who employ the concept of co-production acknowledge that their use is different than that first described by Jasanoff and does not deal with the constitutive dimensions of co-production.

2.5.3 Accessibility to Non-STS Scholars and Other Audiences

Wyborn (2015) makes an important point in that fundamental precepts of the idiom of co-production are much more difficult for scholars outside of STS, as well other non-academic audiences, to productively engage with. First, the specialized vocabularies that are often used in STS literature are often inaccessible for those who do not engage in STS scholarship. Second, fully engaging the analytical capabilities of the co-production idiom often requires dismantling some fundamental constructs that are part of the 'modern' Western worldview, a process that can be uncomfortable for some actors. For example, engaging co-productive analysis requires questioning normalized practices and norms, as well as deeper engagement with normative and metaphysical considerations and worldviews. Yet, within most contexts in which co-production is currently discussed (and 'applied'), these debates are well outside of the comfort zone.

It will be necessary to recognize and continually interrogate the relations between science and society that have been made 'invisible' through entrenched practices and normative assumptions. In questioning these boundaries, we can open up the space to question the rightful place of science in society, as well as unquestioned notions that it should serve as the singular means of accessing 'truth' about the world. This is the kind of space that is needed to enable co-production processes. Thus, important questions remain about how to conceive of and create configurations of science-society relations that better enable the analytical insights of constitutive co-production perspectives to effectively engage with and shape (and reshape) research, policies, and practical implementation. Such questions should not be answered in the form of rigid prescriptions.

2.6 Dangers of Uncritical Applications of Co-production

Not only can the singular focus on instrumental interpretations of co-production fail to achieve the desired outcomes, it can also serve to reinforce existing power dynamics. Noxolo and Featherstone (2014) argue that because the concept of co-production itself is in flux as a discursive construction, it may easily be co-opted to deny the political and historical determinants of power imbalances and vulnerability, with the potential to increase insecurity for disadvantaged individuals and groups. It is true that instrumental co-production has been shown in a growing number of examples to improve relationships and foster trust (Armitage et al., 2011; Hegger & Dieperink, 2014; Kirchoff et al., 2013; Puente-Rodriguez et al., 2015). But care must be taken to ensure that the success of co-production is not solely measured by its ability to avoid controversy or to enable the dominant discourse or framing of the problem to proceed unchallenged. Indeed, co-production can be used to decrease resistance to particular framings of a problem or to promote a particular 'solution.' For example, Reyers et al. (2015) use instrumental co-production to promote the use of 'ecosystem services' within disaster risk reduction planning and implementation in South Africa. In this way, co-production can be used as a vehicle to advance pre-established solutions and ways of framing and understanding problems. This can have the effect of burying or papering over divergences in how various actors think problems should be defined and addressed. Yet, avoiding controversy or conflict within participatory forums can be counterproductive to enabling the authentic dialogue (Innes & Booher, 2010) that is essential to facilitating the open and transparent processes that are often the justification for instrumental co-production efforts.

The growing emphasis on the need for 'scaling up' co-production, including the drive for 'guidelines', 'best practices', and other prescriptions to guide instrumental co-production are particularly concerning, not only because the concept was never intended to promote a universal answer, but also because it shuts down, narrows, and redirects organic manifestations of the interfaces between science and society in ways that indicate that there might be singular, best form of science-society configurations that work in all settings. Van Kerkhoff and Lebel (2015, p. 14) note that recent calls for co-production within platforms such as Future Earth have implied that the imperative for instrumental co-production is often presented in homogeneous and universalizing terms.[1] Even if we had more experience with the concept of co-production as a practical 'strategic' approach (see Armitage et al. 2011 for a notable exception) upon which to base such 'guidelines,' the notion of rigid prescriptions is antithetical to the analytical and normative aims of co-production, which pushes us to expand the scope of our search for explanations. According to Lemos (2015), the finding from "the relatively sparse empirical literature is that just designing participatory institutions and putting people together are not enough to foster the creation of usable knowledge in support of adaptive governance" (p. 51).

Both Jasanoff and Ostrom strongly warn against the tendencies to reduce and simplify the complexities of governance and institutions. As Van Kerkhoff and Lebel (2015) highlight, the richness of contextual, place-based, critical analysis may be lost if we seek to frame co-production as a panacea. Ostrom's work has emphasized the role of diversity in allowing sustainable institutions to emerge in various SES. She warns strongly against the use of "blueprint thinking" in which "policy makers, donors, citizens, or scholars propose uniform solutions to a wide variety of problems that are clustered under a single name based on one or more successful exemplars" (Ostrom, 2009, p 274). In a prescient warning, she goes on: "Even with all of the lessons learned

[1] At the same time, Van Kerkhoff and Lebel state the need for concepts and approaches that prevent science from being "marginalized," a statement that does not resonate with the co-productionist perspective, which questions the hegemonic dominance of scientific knowledge.

in the last three decades about the dangers of blueprint thinking, the temptation to fall into this trap continues unabated" (Ostrom, 2009, p. 275). The question is, can instrumental co-production resist this trap?

Similarly, Jasanoff (2014) is clear that co-production in her terms is not just about "strategic moves" that seek to make more useful or robust knowledge. Nonetheless, co-production was not intended to remain a static or inaccessible concept. Rather, co-production can move from being an "analytical tool to a strategic instrument in the hands of knowledgeable social actors, through reflexive moves that open doors to new forms of engagement" (Jasanoff, 2004, p. 281). However, what these forms of engagement should look like remains a key question. It is one that should *in itself* be informed by analyses employing a strong co-productionist lens.

The danger within current approaches to collaborative engagements is that they tend to be divorced from these key insights that might be drawn from strong co-production – for example from normative foundations – as well as the deeper interrogation of science-society relations in particular locations in space and time, and still leave much that is taken for granted. In earlier works, Jasanoff elaborated the need for democratic participation of publics in science policy, advice, and risk decision-making and a reconceptualization and redistribution of expertise. In many cases, this would require new models of engagement between scientific knowledge and the range of publics that move beyond the frequently narrow designations of who is authorized to speak about issues related to science and technology (Jasanoff, 1990; 2003; 2004). For example, regular or systematic engagements between policy-makers and 'experts' is seen as building sufficient mutual confidence in the motivations and credibility of other participants (Jasanoff, 1990) *but only when the underlying ontological and epistemological assumptions about the rightful role of science within society are made explicit*. Further, work in this area has highlighted that efforts to *exclude* publics from these debates undermine credibility of scientific advice and policy-making processes (Jasanoff, 1990, not a direct quote – emphasis mine). A fundamental premise of these new forums is the need for increased reflexivity, accountability, and humility (Jasanoff, 2003).

It is not surprising that many of studies that have focused solely on less politicized dimensions of co-production — thus closing off the more descriptive, critical, and normative aspects of co-production from the more practical prescriptive dimensions. Indeed, as Jasanoff wryly acknowledges: “Looking again at what seems settled history is a non-trivial thing to do” (Jasanoff, 2014). The instrumental components of knowledge co-production offer a pathway to action that is attractive to practitioners who are faced with the pragmatic concerns of decision-making and policy formulation. The problem is when this is done in a way that is detached from deeper understandings of how historical and current socio-technical configurations shape entrenched power relations, as well as possibilities for countering these in the future. Thus, it is not that the instrumental approaches to co-production are necessarily problematic. Rather, what is needed is to keep the interactional and constitutive dimensions of co-production front and center within instrumental efforts in order to simultaneously tend to and follow the ways in which these enact particular visions in the world and how this in turn reshapes our ability to know about and act in the world.

Furthermore, the act of studying co-production itself is also meant to rely on a breadth of theoretical and analytical approaches. Jasanoff (2004) explicitly states that co-production “aims neither to be a universal grand theory, not to be univocal in the sense of commanding all who adopt this perspective to invoke it in precisely the same ways, using the same units of analysis, and with the same interpretive or critical intent.” Rather, the scope of topics and analysis that may be examined using a co-productionist lens means that "no set of prescriptions can possibly do justice to the infinite plasticity of the forms of governance in a globalizing world. These conclusions [about aspects that are key to all governance arrangements: institutions, expertise, and democracy] should be seen at best as moveable guideposts, not as a finished architectural blueprint" (Martello & Jasanoff, 2004). In this way, the idiom of co-production leaves space for exploring and creatively engaging the basic foundations of the concept, but strongly maintains that there is no correct 'starting' place — no ontological position being privileged above others as more representative of reality. Indeed, it is recognized that various starting points of analysis can result in completely "different stories" that emerge (Nightingale, 2015).

While both Jasanoff and Ostrom call for efforts to avoid blueprints, there are significant differences between how they go about understanding the world. In contrast to Jasanoff, the premise of much of Ostrom's life's work has been to build generalizable frameworks that can enable a defined entry point for analysis in order to *narrow and simplify* the range of possible factors that contribute to successful management outcomes, rather than *broadening or complexifying* explanations in the ways that strong co-production might. We can see echoes of the "design principles" (Ostrom, 2009) that have become the hallmark of Ostrom's contribution to institutional analysis within recent efforts to understand instrumental co-production (e.g., Hegger et al., 2012; van Kerkhoff & Lebel, 2015). Such efforts seek to identify a generalizable set of factors that may either pose barriers or opportunities to instrumental co-production. For Jasanoff, co-production represents an opening up and a detailed describing, rather than a closing off, of both the potential explanatory factors influencing the relations between science and social order, as well as the normative framings and possibilities emerging from these. Jasanoff (2004) states that "what distinguishes co-productionist analysis from conventional metaphysical or epistemological inquiry is its constant rejection of a priori demarcations” (p. 274). Thus, as co-production gains ground in a range of public concerns, it will be crucial to recognize the different starting points for these two visions of co-production and what this entails for imagining science-society relations in the future.

Many of the examples of co-production in this review employ an instrumental conceptualization of co-production that is primarily concerned with the implementation of pre-determined policy decisions, either by reducing ‘negative’ responses or by enhancing trust in institutions or processes that formulate these processes. In this sense, it may be useful to move beyond ‘invited’ forms of participation that are the basis of the majority of co-production efforts discussed in the literature in the last decade, to explore the ways in which participation can be more broadly conceived as a form of ‘citizenship’ that is based on hybrid, rather than static, identities (i.e., through engagement with law, media, activism, and implicit and explicit protest) and, at the same time, to consider how these interact with more deliberate, or facilitated, forms of participation (Stirling, 2007). The concept of “technologies of humility” (Jasanoff, 2003) also directs research toward normative and substantive dimensions of co-productive activities. Indeed, through the combined gaze of constitutive and interactional co-production(s), the idiom of co-production offers the potential to understand whether and how instrumental forms of co-production may influence ontological states and more fluid and responsive pathways for science and technology. Jasanoff and Martello (2004) conclude:

> It is the *ideology* of global governance that we wish to influence more than the design of specific institutions or processes. For this larger purpose, we have argued throughout, practice needs to join hands with theory and close empirical studies must ground themselves in deeper conceptual analysis (p. 348, emphasis in the original).

2.7 Conclusion

It is clear that these two streams of literature — public services and STS — have not evolved in complete separation. In particular, scholarship on commons, adaptive management, polycentrism, and institutions, which have their roots in the early public services administration scholarship, and concepts such as boundary management, boundary organizations, and boundary objects, coming out of STS literature, have gravitated toward what appears to be common themes and ideas. At this critical juncture when the term co-production is rapidly gaining global prominence as a catch-all term within and across a range of disciplines, it is crucial to ask, *what are the implications of merging various conceptions of co-production coming from different ontological, epistemological, and theoretical foundations*? While it is much easier and expedient to envision and 'operationalize' instrumental co-production, what does this exclude *and at what (and whose) expense*? Without accounting for the constitutive aspects of co-production, there is not the same imperative to place current configurations of science-society configurations in historical perspective and thus ask: *how did things come to be this way in the first place?* Without such questions, there is a risk of depoliticizing – and, thus, failing to acknowledge and address – the root of power imbalances that are inherently part of any instrumental co-production process.

CHAPTER 3: A Systematic Review of Co-production Literature

3.1 Introduction

Amidst increasing calls for 'scaling up' co-production and embedding it as a basis for a wide range of research agendas and implementation, it is important to understand how the term co-production has evolved, as well as how it is currently being interpreted and applied. The concept of co-production has moved through several waves of development, spanning multiple disciplines and streams of research (Cepiku & Giordano, 2013). In the last chapter, I have identified and reviewed multiple theoretical origins of the concept of co-production in order to understand how these have contributed to current understandings. Given the rapid and widespread uptake of the concept across a range of disciplines, tracing the theoretical antecedents of current usages of co-production helps to understand why the term has gained traction in so many different areas. Such understanding is important, since these varying interpretations have significant implications for how the concept of co-production will be interpreted and applied, particularly as there is growing interest in defining what constitutes 'successful' co-production.

In this chapter, I seek to answer a different question. After answering the question of how we have arrived 'here' — which is to say, at the current prominence and popularity of the concept of co-production — it is also important to ask: what does 'here' actually look like? What are the different ways in which co-production is being currently understood? How is the idea of co-production being applied, both in research and in practice? While there have been several comprehensive reviews of co-production, they have generally focused on one or the other of the two primary streams of literature identified in the previous chapter (i.e. public services / commons and STS literatures). For example, there have been several comprehensive reviews of co-production theory, research, and practice from a public services administration perspective in the gray literature (see for example, Boyle & Harris, 2009; Durose, Beebeejaun, & Rees, 2011) and also in the academic literature (Brandsen & Pestoff, 2006; Verscheure et al., 2012; Voorberg & Bekkers, 2015). Others have reviewed approaches to co-production in research, environmental management and transdisciplinary settings (Harris & Lyon, 2013; Maclean & Cullen, 2009; Meadow et al., 2015). There has not, to date, been a comprehensive review of the concept of co-production across disciplines and research areas. This paper seeks to address this gap by taking stock of the current co-production landscape through a systematic review, with the goal of identifying trends across the literature.

Given the wide range of contributions and intersections between different disciplines and streams of co-production scholarship, there are a growing number of ways in which co-production has been defined. Additionally, the uncritical merging of different versions of co-production has, at times, resulted in a theoretical muddle and created confusion about what exactly co-production *is* or *should be*. A more detailed understanding of the various usages of the concept of co-production will enhance theoretical clarity in the future, and may also help to foster a more integrated and reflexive approach to the concept of co-production. Such efforts could potentially help to prevent the concept of co-production from becoming another empty buzzword or normalized 'box-checking' activity. This is particularly crucial amidst increasing interest in how to 'scale up' co-production (e.g. Hegger et al., 2014) and concern about the potential for co-production to become obligatory (Ryan, 2012). Indeed, without greater attention to theoretical underpinnings, co-production risks falling into the very same essentializing and ordering tendencies it was intended to counteract. Through this review, it may be possible to identify issues of both epistemological and ontological import, which, if left unaddressed, may diminish the value of the concept of co-production in the future.

In this chapter, I present the findings of a systematic and comprehensive review of co-production literature. I develop a three-part typology building on the constitutive and interactional dimensions of co-production (Jasanoff, 2004), differentiating between 'strong' and 'weak' interpretations of co-production (Jasanoff, 2014): strong constitutive, strong interactional, and weak interactional. The reviewed literature was analyzed to identify the theoretical basis of co-production presented in the article and how this was used or operationalized. I then categorize the literature by grouping it according to the typology — (1) strong constitutive / interactional, (2) weak interactional, and (3) a combination of strong / weak (instrumental) interpretations of co-production — and then I organize these articles within emergent themes.

This review illustrates that there are several trends in the literature that are pertinent to how co-production may be taken forward in the future. First, I find that there have been explicit efforts to side-step constitutive co-production. This represents an explicit move to depoliticize the practice of co-production and fundamentally ignores the roots of power imbalances within instrumental co-production efforts. Such moves may, in some cases, be an attempt to delimit the scope of co-production to make it manageable by depoliticizing it and enabling the *status quo* to continue. A second trend is the emergence of 'spin-off' concepts, which utilize the basic idea of co-production to develop related, but different, concepts, often involving merging it with other existing concepts. This can create conflict and redundancies among various interpretations of co-production. Third, I identify a 'paradox' in the co-production literature, which is the fact that the growth of weak interactional co-production processes itself represents an ontological shift that is not recognized in the literature.

This review illustrates that while the majority of the co-production literature has focused on weak or strong interactional co-production interpretations in isolation, there are a growing number of studies that examine instrumental approaches to co-production using a strong co-production lens. Such approaches may help to simultaneously attend to the weak and strong conceptualizations of co-production in a more reflexive and productive way.

3.2 A Typology of Co-production

The fact that co-production has become such a widely adopted concept across a range of disciplines has resulted in confusion about the meaning of the term. As this review will illustrate, the term co-production has been used in a variety of different ways, often with very different meanings. A list of some of the definitions from the literature reviewed is below in Table 1. In order to differentiate between these conceptualizations, I build off of the two strands of co-production presented by Jasanoff: interactional and constitutive. Constitutive co-production is concerned with ontology and deals with questions of how knowledge and other emergent categories (e.g. nature, society) gain and maintain stability. Interactional co-production is concerned with epistemology and deals with knowledge debates at the interface of science and politics. There has also been a tendency to apply the term co-production in more utilitarian or instrumental interpretations of the term (Lövbrand, 2011, see also discussion in Section 3.4.5).

Definitions of Co-production Across the Literature	
Sancino 2015	"...the involvement of citizens, clients, consumers, volunteers and/or community organizations in producing public services as well as consuming or otherwise benefiting from them." p. 414, citing Alford, 1998, p. 128
Bovaird 2007	"the provision of services through regular, long-term relationships between professionalized service providers (in any sector) and service users or other members of the community, where all parties make substantial resource contributions." p. 847
Brandsen and Pestoff 2013	"…in the restricted use of the term [i.e. differentiated from co-management and co-governance] refers to an arrangement where citizens produce their own services at least in part. This is a specific interpretation of user involvement, although there are of course other types." p. 497
Brugnach et al. 2014	"...the co-production process consists in redefining the problem in a way that is compatible and inclusive of those that participate, based on which actionable knowledge...can be derived." p. 8
Cash 2006	"...the act of producing information or technology through the collaboration of scientists and engineers and nonscientists, who incorporate values and criteria from both communities." p. 467

Coburn 2007	"…a way of interpreting and accounting for complex phenomena so as to avoid the strategic deletions and omissions of most other approaches to understanding the role of the public in science policy." p. 151
Edelenbos et al. 2011	"...ongoing interactions between experts, bureaucrats and stakeholders in developing usable knowledge...involves exploration, discussion and negotiation on the relevance of the different knowledge domains...." p. 677
Enengel et al. 2012	"…a collaborative process of knowledge production that involves multiple disciplines and actors of other sectors of society." p. 107
Franteskaki and Kabisch 2015	"...the active involvement and engagement of actors in the production of knowledge that takes place in processes either emerging or being facilitated and designed to accomplish such active involvement." p. 2
Hegger et al. 2012	"...direct collaboration between scientists, policymakers, and other societal actors in specific projects." p. 54
Meadow et al. 2015	"...the process of producing usable, or actionable, science through collaboration between scientists and those who use science to make policy and management decisions." p. 3
Muñoz-Ericson 2012	"...the mutual construction between knowledge and forms of social organization…concerned with the macro societal processes that shape and are shaped by the production of knowledge."
Nel et al. 2016	"...a more interactive, multi-dimensional mode of iterative knowledge co-production in a participatory arena that puts researchers, decision makers, and other users of knowledge on equal footing." p. 177
Palomo et al. 2016	"...how human agency (i.e. institutions such as tradition, belief systems, markets or state planning) determines the services provided by means of physical resources, energy, labour and money." p. 245
Pellizoni 2014	"...the mutual constitution of epistemic and ontological states." p. 851
Pohl 2008	"...a collaborative process of knowledge production that involves multiple disciplines and stakeholders of other sectors in society." p. 47
Robinson and Wallington 2012	"…knowledge as a process of relating that involves negotiation of meaning among partners." p. 2
Roux et al. 2006	"...collaborative learning between "experts" and "users" […] which can be achieved through knowledge interfacing and sharing, which requires a shift from a view of knowledge as a "thing" that can be transferred, to one of a "process of relating" that involves careful negotiation of meaning among partners." p. 4
Schuttenberg and Guth 2015	"...a collaborative and dynamic knowledge generation process that more fully grounds scientific understanding in a relevant social, cultural, and political context […] an explicit intention to create usable knowledge that influences decision making" p. 15
St. Clair 2006	"...the interrelated constructions of both knowledge and governance systems, taking a comprehensive view of the relations between knowledge, culture, and power." p. 66

Table 1: Definitions of co-production from across the literature

This has created a tension between those who would seek to make co-production a practical tool for resolving knowledge conflicts within contested policy settings, and those who see co-production primarily as a descriptive and analytical resource that enhances understanding of the intertwining of knowledge, politics, and power. Jasanoff has loosely referred to these variants as "weak" and "strong" co-production, respectively (Jasanoff, 2014). Using this, I differentiate between strong constitutive, strong interactional, and weak interactional variants of co-production (see Table 2). Constitutive co-production is implicit and analytical in all cases, so can be referred to as 'strong constitutive' co-production. There are two ways in which interactional co-production can be interpreted. First, there is 'strong interactional co-production' described above. Then there are the utilitarian and instrumental interpretations, which I argue can be considered a sub-set of interactional co-production, since these often deal with epistemic controversies and debates but often in superficial ways — meaning that it does not address questions related to power or the social authority of knowledge and treats the boundaries between science and society as fixed. I will refer to this as 'weak interactional' co-production, but will often use this term interchangeably with the term 'instrumental co-production.'[2] This typology helps to create means of more clearly distinguishing between variants of co-production.

[2] For the purposes of this paper, I will refer to intentional or deliberate attempts at co-production (e.g., of knowledge, policy outcomes, to achieve specific normative goals, etc.) as "instrumental co-production" to differentiate these from strong constitutive and strong interactional interpretations and applications of the term. This is not meant to be a derisive or diminutive term and not all instrumental co-production is detached from co-productive analysis (as will be discussed in Section 6). Rather, the term merely illustrates that co-production is often employed intentionally in relation to a range of (either implicit or explicit) normative goals or outcomes (e.g., democratizing technical decision-making, making knowledge production more 'participatory', developing socially robust policy options, etc.) and is, thus, fundamentally conceived of as a means of achieving a particular end. Instrumental co-production can be undertaken in a deeply reflexive manner — but it can also be applied indiscriminately or as a means of co-opting or silencing dissent.

Constitutive Co-production	Interactional Co-production	
Strong	**Strong**	**Weak (Instrumental)**
Concerned with ontology (what we can know)	Concerned with epistemology (how we know)	Concerned with epistemology (how we know)
Implicit	Both Implicit and Explicit	Explicit
Descriptive / Analytical	Descriptive / Analytical	Instrumental / utilitarian
Explanatory	Explanatory	Prescriptive
Nature / society are mutually constituted, neither has primacy	Science / society are distinct / divided – boundaries are fluid	Science / society are distinct / divided – boundaries are fixed
Deals with questions of how knowledge(s), categorizations, socio-material configurations, etc. gain and maintain stability	Deals with debates about the social authority of knowledge at the interface of science / politics / society (i.e., social order)	Deals with conflicts between different knowledges, but does not interrogate how / why knowledge gains authority

Table 2: Attributes of constitutive, interactional, and instrumental co-production

The growth of approaches that are seeking to apply a strategic and intentional form of co-production may stem in large part from the uptake of normative and prescriptive conclusions that have in fact arisen from constructivist and co-productionist analysis by STS scholars. Such studies have produced numerous calls for more inclusive, multi-directional, deliberative, and reflexive approaches to the development and deployment of science and technology (see Section 2.2, also e.g., Gibbons et al., 1994; Jasanoff & Wynne, 1998; Jasanoff, 2003; Nowotny et al., 2001; Wynne, 1993). The potential for "strategic uses" (Jasanoff, 2004) of co-production have been recognized, though cautiously. The increasing emphasis on co-production as direct interaction between scientists and non-scientists (e.g., Edelenbos, 2004; Lemos & Morehouse, 2005) may be seen as a logical extension of these calls and other trends, but are also related to the growing imperative for science to produce knowledge that is useful for societal decision-making (e.g., Cash et al., 2003; Gibbons et al., 1994). The upward tick of instrumental co-production can also, in part, be explained by the growing prominence of the concept of co-production within the public services domain (Brandsen & Pestoff, 2006) with emphasis on outcomes, impacts, and effectiveness, which is now being increasingly intermixed with STS-informed conceptualizations of the term in complex policy settings and international research platforms.

3.3 Methods

This review was an attempt to seek out literature about co-production to broadly examine the various ways in which the concept is being presented, understood, and applied over the last decade through the systematic gathering of literature through the use of commonly used search engines. This literature was compiled using the broad search parameters to survey publications including the words "co-production", "coproduction", "co-production of knowledge", or "co-produce" in either the title, key words, or abstract in both Google Scholar and Ebscohost search engines. Because this broad search resulted in a large number of results pertaining to co-production as a chemical process (e.g., within the biological, biochemical, and medical sciences) and the services management sector, search results were further screened to filter out these results. The result was 122 publications, which were reviewed and coded to identify and analyze: 1) antecedent literature and definitions of co-production that formed the basis of analysis (i.e. public services, STS, or other) and 2) the approach to co-production employed in the article's justification, methods, analysis, and/or discussion. Articles were then categorized according to the typology of co-production in Table 2 and grouped into emergent themes under each of these typologies.

While this approach is not exempt from omissions, it is sufficiently comprehensive to provide an overview of the variants of co-production that have been put forth within the literature in the last decade, how these have interacted, and to better understand how these have been shaped by the antecedent formulations of co-production coming from the two distinct theoretical lineages presented in Chapter 2. Coding of the antecedent literature cited and definitions of co-production used draws on the primary discussion of co-production in each of the papers. However, this was often complicated when multiple definitions were offered. For example, some studies acknowledged or made reference to definitions, theoretical perspectives, or aspects of co-production (e.g. strong constitutive co-production), even when this was not the driving theoretical orientation for the study. In these cases, it was necessary to assess the primary ways in which the concept of co-production was applied by analyzing the application of the concept of co-production within the justification, methods, analysis, or discussion sections of the paper. It is necessary to recognize that these typological designations are not black and white, and there is frequently overlap. In some cases, conceptual interactions and theoretical blurring has occurred, making it difficult to definitively put some articles in one category or another. Thus, rather than serving as a concrete designation, sorting the literature in this manner was intended as a heuristic to help identify trends, trajectories, similarities, and disparities within the literature.

3.4 A Review of Weak Interactional (Instrumental) Applications of Co-production

As the notion of co-production has gained significant traction in a range of other fields outside of STS scholarship, there has been an increasing shift toward selectively applying the concept of co-production in instrumental ways, often while severing linkages with the strong constitutive dimensions of co-production. In this section, I review the literature that is concerned primarily with resolving epistemological debates, as well as providing solutions to decision-making, policy implementation, and public services production. Such approaches can be seen as engaging with concepts falling under the interactional strand of the co-production idiom. Indeed, some of this literature does rely on a co-productionist lens to understand how the boundary between science and society is demarcated and maintained. However, such efforts are generally undertaken with the starting point of seeking to 'harness' scientific knowledge for decision-making and policy formulation (e.g. Cash et al., 2003) or toward 'efficient' public services provision (e.g. Alford, 2014). Much of the literature therefore employs co-production in a primarily instrumental fashion to achieve a particular goal with relation to pre-established normative framings. As mentioned previously, I will refer to instrumental and weak interactional co-production interchangeably to enable ease of reading.

Very few of the studies question how and why scientific or expert knowledge has acquired such a firm grip on epistemic authority in the first place and what this implies for intentional efforts to open up knowledge and practice to a wider range of actors. This is not to say that all of these studies *only* recognize one aspect of co-production; rather, the point is that even when nuanced understanding and application of these various conceptualizations of co-production are presented, there is a tendency for conceptual slippage and a narrowing toward framing co-production as a 'tool' or 'method' that may address epistemological conflicts within decision-making or policy processes. This serves to highlight the difficulties and tensions that have arisen as the concept of co-production has grown in popularity in the last decade. As argued in Chapter 2, this stems from the multiple origins of the term, as well as the permutations stemming from these as it has travelled and been assimilated within a wide range of research areas.

Reflecting the multiple antecedent traditions through which co-production has evolved, as well as new engagements in other areas of research and practice, there were several emergent themes within studies employing weak interactional (instrumental) interpretations of co-production, including: 1) public services provision, 2) co-management, adaptive governance, and adaptive co-management, 3) Integration of multiple knowledges (drawing primarily on literatures on traditional ecological knowledge (TEK), Indigenous knowledge (IK), 'local' or lay knowledges), 4) participatory, community-based, and transdisciplinary research, and 5) science policy and usable knowledge.

3.4.1 Public Services Production

In recent years, there have been efforts to return to the foundational concepts of co-production, drawing on Ostrom and colleagues' early formulation in the context of public services administration and common pool resources (e.g. Parks et al., 1981). This has included efforts to expand the potential participants in co-production beyond simple binaries (e.g. public vs. private participants) to more specific categorizations that define participants by their role in the production process (such as: suppliers, public sector organizations, partners, and consumers) to enable deeper analysis of what participants are contributing, as well as what they are getting out of the process (Alford 2014).

Remaining true to the economic roots of the concept of co-production of public services, Alford (2014) argues that this can better enable analysis of both the motivations and capacities of various participants within co-productive processes. From this perspective, some primary motivations of co-production include fear of sanctions, material self-interest, intrinsic rewards, sociality, and normative values. Furthermore, the value of co-production can be conceived of in terms of private, group, or public benefit, though these may sometimes be at odds (Alford, 2014; Cepiku & Giordano, 2013). This indicates that advancing the benefits of co-production to participants based on utilitarian justifications may not always be effective, even in purely economic terms.

While the development of co-production did not go on to play a central role in the conceptualization of much of Ostrom's and colleagues' later work, it is evident that the notion has had a deep and lasting impact on a wide range of public services production (Cepiku & Giordano, 2013). This is true particularly in the UK and several European countries, where the concept has been widely taken up in a variety of sectors of public services, including health, education, safety, and has been invoked by policy-makers and included within public policy strategy documents and reports as a means of reforming the delivery of public services (Boyle & Harris, 2009). In this literature, co-production is a deemed a "means of delivering public services in an equal and reciprocal relationship between professionals, people using services, their families and their neighbors" (Boyle & Harrism 2009). Mitlin (2008) defines co-production as "states and citizens working together" toward the "joint production of public services between citizen and state, with any one or more elements of the production process being shared" (p. 339). Co-production is seen as involving four key activities: 1) recognizing people as assets, 2) valuing work differently, 3) promoting reciprocity, and 4) building social networks (Boyle & Harris, 2009).

Co-production in the public services seeks the knowledge and experience of 'users' of public services (or citizens more broadly), which might otherwise be 'wasted resources,' as a means of improving the efficiency of the system. However, some approaches emphasize that co-production is not just about efficiency, but also about "humanizing" public services. In other instances, co-production is seen as requiring fundamental changes in public service delivery that fundamentally rework relations between citizens and state institutions and shift balances of power (Boyle & Harris, 2009).[3] This can enable more collaborative relationships and can be seen as a political process, as well as an instrumental approach focused on outcomes, as it enables a shift towards substantive changes and enables greater emphasis on local issues (Mitlin, 2008). In this way, co-production is seen as a means of improving state accountability.

[3] It is worth noting that some early conceptualizations of co-production of public services recognized the relational ontologies required within processes of all public services production. Furthermore, while they are not referred to as such, many processes of co-production of public services imply the needs for shifts or changes in institutional and governance structures that are themselves co-productive. This could be considered what Jasanoff has called "naïve co-production" (Jasanoff 2014).

The notion of co-production has also been embraced within public services provision in developing contexts, where co-production is seen as having two drivers: 1) failure of government to provide services (governance drivers), and 2) the context makes it difficult (logistical drivers) (Mitlin, 2008). Cepiku and Giordano (2013) advance understanding of the application of co-production in health services among community health workers in Ethiopia. The study concludes that co-production must be integrated within all stages of the policy cycle to enhance impact and sustainability. Additionally, it highlights the importance of representativeness and influence of participant selection on the equity of services provided, the need for supervision, logistics, support, and resources, and the need for engaging users in more collaborative institutional environments. More problematically, it has been asserted that co-production processes can serve as a secondary strategy for service delivery in developing contexts when governments lack the will and capacity to provide services (Ostrom, 1996; Mitlin, 2008). This assertion is built upon troubling assumptions about developing contexts that claim that "the labor of low-income residents is under-utilized," suggesting that "the opportunity costs of citizen labor are low, and hence the economics of co-production will favor high inputs from citizens" (Mitlin, 2008, p. 346).

Much of the current public services literature fails to acknowledge that the origins of co-production were often employed in tandem with neoliberal policies that resulted in budget shortfalls for public service provision in urban areas in the U.S. and reflected a reaction to ensure that public services could be provided more efficiently and effectively at decreased cost. There is very little discussion of the implications of what this shift in terms of expectations of public contribution toward the provision of services, as well as increased government accountability, should entail. Indeed, the justification for co-production is framed in terms of delivering better outcomes, preventing problems, encouraging self-help, *as well as* better use of scarce resources

(Boyle & Harris, 2009).

While this may seem incompatible with other approaches to co-production, it is important to note that there has been little examination of the reasons why people may choose to participate (or not) in participatory knowledge production. Ostrom's work on institutional analysis may offer some potential insights understanding how and why people might participate in co-production by understanding the evolution of social norms in relation to processes of co-production (Alford, 2014). The notion of synergies, or "win-win" outcomes, in which different actors' varied knowledge, capacities, and skills are combined to provide a greater level of benefit to all participants, is also key to Ostrom's conceptualization of co-production (Alford, 2014; Ostrom, 1996). Some have argued that the same design principles (Ostrom, 1997) that are applicable for designing adaptive governance could similarly be used to govern processes of co-production (Alford, 2014). In this sense, much of the co-production on service provision sees co-production as a complementary or synergistic activity, in which various actors respectively possess particular knowledge, skills, or resources that would not be as effective in enabling the outcomes on their own.

3.4.2 Co-management, Adaptive Governance, and Adaptive Co-management

Co-management is a "sharing of power or responsibility between the government and local resource users" (Berkes, 2009, p. 1692) and was conceived as a means of overcoming the problems associated with 'top-down' managerial approaches. Coming from a very different literature based in non-equilibrium understandings of ecosystems (Holling, 1978), adaptive management was seen as a more appropriate way to approach environmental policy decision-making as a way to deal with uncertainty and complexity inherent in social-ecological systems, in contrast to sets of management prescriptions (Armitage et al., 2011; Berkes, 2009). In recent years, these approaches have been seen to increasingly share common ground, in which learning and knowledge generation are central (Berkes, 2009).

The linkages between Ostrom's work on adaptive management and co-management theorization has resulted in an emphasis on the key role of knowledge. Adaptive co-management, a blending of these two concepts, has been considered a "knowledge partnership", in which various participants have "comparative advantages" in generating and mobilizing knowledge at different scales. Armitage et al. (2008) argue that co-management is particularly suited to enable transformative learning processes that facilitate spaces to share goals, reflect on intentions, and to discuss values held by actors or embedded within particular courses of action. Transformative processes most often "reach beyond the local" and require coordinated strategies or interventions at multiple scales. Co-management arrangements, which seek to link actors/groups and facilitate knowledge synthesis and transfer across 'vertical' and 'horizontal' scales, are seen as enabling the needed cross-scalar approaches. Within this context, "adaptive experimentation" (or learning by doing) is presented as a means of fostering adaptive co-management that more expediently fosters learning and feedback (Berkes et al., 2009).

Learning has been hailed as a normative goal within core concepts and approaches of a range of environmental management approaches, including adaptive co-management, adaptive governance, and co-management. Indeed, learning has been promoted as the basis for joint action and an essential component of collaborative forms of governance within SES (Armitage et al., 2008). In this literature, co-production is seen as a means of facilitating social learning. Social learning is defined as "iterative action, reflection, and deliberation of individuals and groups engaged in sharing experiences and ideas to resolve complex challenges collaboratively" (Armitage et al., 2011). Similarly, Medema et al. (2015) conceptualize social learning as a multilayered and iterative process of examining actions, assumptions, values and learning processes. Roux et al. (2006) advance a version of co-production that focuses on "collaborative learning between 'experts' and 'users'…which can be achieved through knowledge interfacing and sharing, which requires a shift from a view of knowledge as a 'thing' that can be transferred to one of a 'process of relating' that involves careful negotiation of meaning among partners" (p. 16).

In this way, discussion of co-management becomes enmeshed with instrumental co-production through a range of related concepts, including: bridging or boundary organizations, social learning, and (in the long-term) adaptive co-management (Berkes, 2009). Based on a case study of sustainable water governance in Quebec, Medema et al. (2015) conclude that innovative tools for the co-production of knowledge are needed to overcome challenges to multi-loop learning, including limited capacity, credibility of water governance organizations, and mismatches between discourses and participation among participants at different scales. In this way, co-production is seen as a sub-activity that falls under broader processes of multi-loop learning and social learning. Similarly, Armitage et al. (2011) see co-production as being a key contributing activity toward the successful deployment of co-management. In this sense, co-production is viewed as an "institutional trigger or mechanism to enable learning and adapting" (Armitage et al., 2011, p. 996) that can enable successful co-management processes.

The role of institutions and governance arrangements in enabling instrumental co-production are considered crucial in the co-management context. It is not sufficient to have processes of "mere consultation or ad hoc public participation" to be labeled 'co-production'; rather it requires institutionalized arrangements that allows for authentic and intensive participation in decision-making (Berkes, 2009, p. 1693). In the context of Ostrom's work on institutional analysis and SES, Homsy and Warner (2013) apply the concept of co-production of knowledge to climate change adaptation in polycentric governance systems in rural U.S. Communities. Here, co-production is seen as a process that "…involves two directions for knowledge flows and learning (top-down and bottom-up)" (Homsy & Warner, 2013, p. 292). From this perspective, multi-level governance is key to facilitating multi-directional knowledge flows, coordination, and compliance that are needed to implement climate adaptation policies that are owned and respected at the 'local' level.

3.4.3 Integration of Multiple Knowledges

In much of the recent literature on co-production, the idea of 'integration' of multiple knowledges is central to conceptualizations of co-production. For example, Pohl et al. (2010) define two 'modes' of knowledge co-production, with the first involving boundary organizations that uphold the boundaries between science and policy to facilitate interactions between "academic" and "non-academic" knowledges, and the second being a more fluid collaboration of "academic" and "non-academic" actors involving the "interactive and dynamic endeavor of multiple actors where conventional epistemological realms and roles of different actors are blurred" (Pohl et al., 2010, p. 269). According to Armitage et al. (2011), co-production is "the collaborative process of bringing a plurality of knowledge sources and types together to address a defined problem and build an integrated or systems-oriented understanding of that problem" (p. 996). Within this conceptualization of co-production, the process can be broken down into 5 stages: knowledge gathering, knowledge sharing, knowledge integration, knowledge interpretation, and knowledge application (Armitage et al., 2011; Dale & Armitage, 2011). Cash (2006) defines co-production as "the act of producing information or technology through the collaboration of scientists and engineers and nonscientists, who incorporate values and criteria from both communities" (p. 467). Mauser et al. (2013) analyze dimensions of integration of various knowledges within global research platforms, in particular Future Earth, with the goal of integration being to ensure "joint, reciprocal framing, design, execution, and application of research, science and society approach the transformations towards the sustainability in a structured and knowledge-driven way" (p. 426). Mauser et al. (2013) see knowledge integration consisting of a three part, linear process of co-design, co-production, and co-dissemination, along with iterative processes of reflection among all stakeholders. Within the co-production process, "the transdisciplinary focus is on scientific integration" (Mauser et al., 2013).

Similarly, there have been calls for greater integration across physical and social sciences through co-production that is seen as "an explicit vision of basic research in continuous dialogue with critical society-facing functions" and "rests on the collaboration and dialogue between scientists (of all disciplines) and practitioners, aimed at producing knowledge that is practically relevant, usable, credible, legitimate, and actionable" (Weaver et al., 2014, p. 656). Schuttenberg and Guth (2015) define co-production as "a collaborative and dynamic knowledge generation process that more fully grounds scientific understanding in a relevant social, cultural, and political context […] (with) an explicit intention to create usable knowledge that influences decision making."

A large portion of weak interactional co-production studies which frame co-production as an issue of 'integration' deal explicitly with IK, TEK, or 'local' knowledges. Brugnach et al. (2014) argue that multi-scalar negotiations and power-sharing structures are needed to facilitate the co-production of "blended knowledge." They conclude that collaboration is needed as a governance mechanism in which problem and direction setting are a joint responsibility and critical self-reflection and questioning of implicit assumptions and values is included as part of the process (Brugnach et al., 2014). Reflexivity is further needed to be wary of the "participation paradox" (Brugnach et al., 2014), which can result in attendant knowledge, structures, and practices reproducing the very exclusion of indigenous peoples they sought to mitigate. Drawing on a case study of efforts to integrate indigenous and scientific knowledges of climate change in Tanzania, Shaffer (2014) employs a conceptualization of co-production in which community-based participation in climatic data collection was seen as enabling grounded, placed-based engagement between people and their surrounding environment, thus providing the opportunity to "create new narratives."

Some of the co-production literature that addresses integration of multiple knowledges seeks to also address important questions about designations of expertise and democratization of science, in essence reflecting issues related to the politics of expertise. Such questions, and attending concerns, are reflected in earlier debates in STS about the existence (or not) of the "problem of extension" (e.g., Collins & Evans, 2002, 2003; Wynne, 2003) within efforts to broaden participation in the production of scientific knowledge. Some have argued that without safeguards, science risks becoming 'too democratic,' thereby eroding social boundaries that 'protect' science from politics, as well as opening up an epistemic free for all. From this vantage, Carolan (2009) examines the co-production of knowledge by 'local' and 'non-local' experts, which he argues requires "interactional expertise" (Collins & Evans, 2002), or "enough expertise to allow for interesting interactions between contributory experts of both abstract/generalizable and local/practical knowledge domains" (Carolan, 2009). The study seeks to show that co-production of interactional expertise serves to enable broader public participation within science (and in agriculture in particular) without sacrificing the cognitive authority of experts to make legitimate knowledge claims. From this perspective, the co-production of expert knowledge requires individuals in one domain to attain sufficient levels of particular forms of expertise that enable them to be knowledgeable, or at least conversant, in the other's domains. Similarly, Cash (2006) highlights that a critical component of co-production involves managing the boundaries between science and policy, as well as across disciplines, scales, and epistemologies, to produce knowledge that is credible, salient and legitimate. This can involve four activities: 1) convening various actors / participants, 2) translation of core sets of assumptions into mutually understandable terms, 3) collaboration to jointly produce knowledge, and 4) mediation between divergent interests and values.

3.4.4 Participatory, Community-based, and Transdisciplinary Research

Other studies have sought to distinguish various approaches to conducting research that broaden the participation and role of various stakeholders. Such approaches draw in large part on the 'mode-2' conceptualizations of research in which the relations between knowledge production and use in an effort to better link knowledge with problem-solving capacities (Gibbons et al., 1994). Ford and Pearce (2012) highlight the need for new research approaches to understand climate change vulnerability and adaptation that move away from research that is "conducted *on* communities" toward research "conducted *with* communities" (p. 276). They argue that 'community based' research, in which there is early and ongoing communication in all stages of project design, development, implementation, and dissemination of findings, can help to facilitate the co-production of knowledge and empower adaptation.

However, there are varying conceptualizations about what 'stage' in the research process should be opened up for broader participation and what this implies for ways in which designations of expertise are renegotiated at different points in the research process. This is reflected, for example, in discussions about 'upstream' or 'downstream' participation in research activities. Akpo et al. (2014), focus on the potential for 'joint experimentation' between researchers, farmers, nursery-owners, and policy makers to facilitate the co-production of knowledge in Benin, which challenged scientific knowledge and created a productive means of bringing ‘local’ knowledge into decision-making. Joint experimentation is seen as a social process that enables a variety of actors to participate in the knowledge production process, and includes “co-designing, co-implementing, and co-analyzing” the research itself, as well as the outputs (Akpo et al., 2014). Puente-Rodriguez et al. (2015) present the role of ‘participatory research’ in enabling particular arrangements to facilitate the co-production of knowledge for environmental management systems in Dutch ports. This case does strive to highlight some of the processes of strong co-production through which technical practices of standardization emerge and how this may influence interactive modes of co-production. Yet, the article at the same time refers to co-production as a “practice” that involves participatory methodologies to mobilize and integrate various knowledges and the treatment of “gathering relevant knowledge” and “organizing encounters for sharing knowledge” (Puente-Rodriguez et al., 2015, p. 8). For example, the article sums up: “To conclude, knowledge from different actors and sources was mobilized and integrated into the process, and key stakeholders were consulted at different moments” (Puente-Rodriguez et al., 2015, p. 7). MacLean and Cullen (2009) present research methodologies that seek to facilitate the co-production of knowledge among co-researchers to enable “multi-directional learning” and mutual benefit among all participants. They argue that co-production is not solely about the knowledge itself, but more importantly, is concerned with the processes involved in co-production, including relationship-building and authentic dialogue about embedded epistemological and methodological assumptions.

Co-production has also been seen as a key component of transdisciplinary research that strives to incorporate knowledge from actors spanning academia, policy, and practice. Alongside discussions of co-production, the concept of transdisciplinarity has surged as a catchall term for ‘new’ forms of knowledge production. In some cases, transdisciplinarity is used synonymously with co-production (e.g. Amber hard and Rist, 2009). Transdisciplinarity is considered a means of integrating knowledges from various disciplinary domains, as well as involving actors across the academic, public, and practitioner (both public and private) spectrum, with an emphasis on solving real-world problems (Costanza, 1996).[4] According to Weischelgartner and Truffer (2015), transdisciplinary research has the following characteristics: addresses complex problems; encompasses cooperation between academic disciplines, as well as non-academic knowledge holders; prioritizes shared learning among various actors; and enables integration of multiple knowledges. Others have noted that participatory research and integration of disciplinary programs are key components of transdisciplinarity (Hirsch Hadorn et al., 2008). Aeberhard and Rist (2009) employ the term “transdisciplinary co-production of knowledge” which merges concepts of transdisciplinarity and co-production. It has been posited that transdisciplinary research has four distinct features: it provides a clear but flexible framework to guide problem-solving, it does not necessarily contribute to disciplinary knowledge, its results are communicated to participants in both formal and informal ways throughout the course of the production process, resulting in diffusion of knowledge as it is taken up in other spheres, and it evolves in dynamic ways, with

[4] Max-Neef (2005) argues that transdisciplinarity is not only a means of combining various disciplinary knowledge, but rather a new way of seeing the world that requires concomitant adjustments in the “three pillars” of values, normative commitments, and pragmatic capacities. A fundamental aspect of achieving ‘strong’ transdisciplinarity (Max-Neef 2005) involves a radical reconceptualization of knowledge that is able to account for complexity through recursive thinking, feedback loops, and dialectic relationships that help to break down the binary thinking that results in reductionism in knowledge production processes. In essence, this is a call to incorporate multiple worldviews and ontologies, not only epistemologies, within knowledge production practices. Thus, before any substantive collaborative research can take place, an understanding of the ontologies, epistemologies, methodologies, and the way that they serve as the building blocks of research, as well as tools to locate and overcome existing barriers, is needed. This perspective of transdisciplinarity reflects elements of strong co-production, but is often not addressed or applied within the majority of transdisciplinary literature.

‘answers’ often becoming the starting point for further exploration (Gibbons et al., 1994, pp. 2-5).

3.4.5 Science Policy and Usable Knowledge

Others have focused more specifically on the instrumental ‘co-production of knowledge’ within science policy. In this conceptualization, co-production of knowledge is primarily a function of the iterative interactions between scientists and ‘users’ of knowledge. Such instrumental approaches are considered essential to addressing the push-pull dynamics between supply of scientific knowledge with the demand for knowledge that can inform policy-making. These conceptualizations often focus on issues of accountability within science-society interactions. Some of the key literature in this area originates in efforts to improve the usability of climate data and information to inform societal adaptations to climate variability and change. In a widely cited study of co-production in the context of integrated climate assessments in the U.S., Lemos and Morehouse (2005) highlight the key role of iterativity in supporting co-production of usable science for policy, with iterativity referring to the extent to which interactions between scientists and stakeholders influence how scientists conduct scientific studies and the ways in which publics understand the strengths and limitations science, including potential applications and practical value of resulting knowledge. Edelenbos et al. (2011) define co-production as “ongoing interactions between experts, bureaucrats and stakeholders in developing usable knowledge that crosses different actor domains” that can lead toward “common ground that can be used as a starting point for assessment and decision-making" (p. 677). Similarly, Furman et al. (2014) focus on the benefits of co-producing climate information through long-term partnerships and development of learning communities, to better enable use of climate information with viable adaptation options. The study emphasizes the need for user participation through a “co-production of knowledge approach" as a means of increasing the salience, credibility, and legitimacy of knowledge.

Other studies in this area have sought to develop specific guidance, methods, and metrics for implementing instrumental co-production. Meadow et al. (2015) examine various modes of engagement and collaborative research approaches that might help to alleviate gaps between the demand for and availability of usable climate science. Drawing on extant literature, the article presents five approaches as a set of guidelines and activities that can be used to structure co-production processes. Similarly, Hegger et al. (2012) seek to develop success conditions for analyzing the merits and limitations of project-based instrumental coproduction. Their framework asserts that there are four key conditions that affect success in joint knowledge production: actors involved, contents of dominant discourses, presence of rules, and the availability of resources. They suggest that this framework can be used for retrospective analysis of projects to provide an empirical basis for future "joint knowledge production" — a term they employ following Edelenbos et al. (2011) to distinguish weak interactional (instrumental) co-production from the idiom of co-production — as well as a tool for promoting reflection to enable social learning. This framework has been tested (see Hegger & Dieperink, 2014; Hegger et al., 2012b) in the context of regional climate adaptation projects and land-use and urban planning in the Netherlands. However, it has been noted that within institutionalized calls for 'usable' knowledge, there has been little explication of what 'usable' knowledge entails and how this should be evaluated (Hegger et al., 2012b).

The concept of "joint knowledge production" as put forth by Hegger et al. (2012) (following others, especially Edelenbos et al., 2011 and Pohl et al., 2010) has been applied in other recent work. For example, Hegger et al. (2014) present a prescriptive three-stage framework to provide specific guidance on "how and to what degree science should contribute and be embedded" within processes of adaptation (p. 81). In another example, Kniveton et al. (2014) focus on multiple tools to facilitate enhanced collaboration and shared understandings between 'providers' and 'users' of climate information in order to integrate 'local' and 'scientific' knowledges, with the emphasis on co-producing "user-useful" information.

3.5 A Review of Strong Constitutive and Strong Interactional Co-production

According to Jasanoff (2012), knowledge practices always have ontological ramifications in that they simultaneously perform and alter the 'realities' that they seek to represent. STS scholars often focus on "procedural approaches" that focus on the "practices, strategies, and devices" that endow particular knowledges with epistemic authority (Beck et al., 2014, p. 6). Indeed, a primary aim of strong constitutive / interactional co-production approaches is to help explain the ways in which power originates, circulates, is held, and distributed within particular networks of social-scientific relations. Jasanoff highlights four primary sites of constitutive co-production in the making of: 1) identities, 2) institutions, 3) discourses, and 4) representations. In this way, the development of categories and boundaries are a powerful means through which both epistemological possibilities and ontological 'realities' are enacted. This constitutive aspect has been reflected in a range of the co-production literature. In broad terms, work dealing with the ontological dimensions of co-production have sought to explore the mutual constitutive relations between knowledge and 1) institutions, policies, and legal frameworks, 2) politics of scale, and 3) socio-materiality, with some touching on multiple of these.

3.5.1 Institutions, Policies, and Legal Frameworks

Another key area in which co-production scholarship has focused is on the ways in which science-society relations fundamentally shape, and are shaped by, institutions, policies, and legal frameworks. Corburn (2007) presents a case study of residents in a low income neighborhood of New York City who are able to mobilize 'local' knowledge to assert their right to participate in an Environmental Protection Agency exposure assessment, which required the fundamental reworking of existing institutional assessment processes. The study claims that new institutional approaches to research can open up key epistemological debates about the processes through which knowledge is produced and who has the right to speak credibly as an expert. In this way, the outcomes of 'community' intervention, and the consequent co-production of knowledge and institutional configurations, influenced ontological states to demand more accountability and to develop solutions that emphasized the role of individual agency alongside social determinants of risk. This highlights that much more than 'participation' is needed to re-make the "substance, not just the mechanics, of science governance," but that through the overflows of standardized participatory processes, the role of institutions overseeing science can be constructively reframed (Corburn, 2007, p. 152). In this way, the paper shows how co-production can simultaneously contribute both to more technically credible knowledge and democratic accountability.

Other approaches have sought to integrate the literatures on usable knowledge and co-management and adaptive management literatures, by examining the interactions between the (co-)production of usable knowledge and existing governance systems (Lemos, 2015). Such work tests theoretical claims that adaptive governance and social learning are essential elements of adaptation in the water sectors, and highlights that implementation of both concepts is fraught with challenges in practice. Lemos (2015) found that climate knowledge can have negative impacts on democracy and deliberation despite perceptions that it led to better decisions. This case illustrates that the material outcomes of epistemological approaches to co-production are just as essential as the knowledge ‘product’ that is envisioned within instrumental framings. Such findings highlight that co-production of ‘usable’ knowledge, while potentially transformative in terms of shaping the institutional structures and policy mandates, does not fully disentangle the complexities of how and why science has established authority in the first place.

Institutional discourses and practices are often treated as a-political, yet a co-productionist lens illustrates how they both reflect and create social orders. In the example of sustainable development discourse, Elgert (2010) calls for the politicization of the concept of sustainable development through the recognition that it is co-produced as part of broader power politics and social orders. This recognition emphasizes that the ways in which environmental problems are framed and enacted is innately tied to knowledge politics, with effects on both material and discursive spaces for addressing them. Rather than the continued reliance on “evidence-based” approaches to sustainable development, Elgert argues that deliberative governance that is “not exclusively controlled by privilege” should serve as the “gold-standard” for environmental governance and decision-making. However, while this argument employs the idiom of co-production to examine the sustainable development discourse, it stops short of applying this critical perspective to the particular normativities that are embedded within visions of deliberative processes and the publics that participate in them.

Others have looked at the politics of knowledge surrounding research institutions. In their dissection of the development of the Montserrat Volcano Observatory, Donovan and Bravo (2013) illustrate how institutions can be a key site of co-production of science and society. This case illustrates how inter-dependencies between science and society have resulted in particular modes of knowledge production. At the same time, it reflects the complex historical, cultural, and political messiness that defined the expectations placed on the observatory, which served as a nexus where “the mixing of laws, politics, cultures, subjectivities, and science in pursuit of social order under natural threat transformed the social relationships with science on the island” (Donovan & Bravo, 2013, p. 184). Stryker et al. (2012) provide a co-production perspective on employment discrimination and industrial psychology. This in turn emphasizes the mutual constitution of legal and social-scientific knowledge and institutions. In this way, the institutionalization of reliance on science within legal argumentation has resulted in important shifts in the legitimacy of law.

The interface between institutions and science policy is also an important focus of strong co-productionist analysis. Doubleday (2007) shows how in the case of nanotechnology, the co-production of natural and social orders is reworked through emphasis on accountability within science policy. This illustrates that the enmeshed relations between science and society are not only embodied in “micro-social orderings of knowledge” that take place in the laboratory, but that these must be considered in the broader sphere of their political implications in terms of the kinds of citizenship they demand and construct (Doubleday, 2007, p. 167). Jasanoff (2014b) illustrates how international regulatory standards are co-produced, reflecting the messy processes of negotiation between the various histories, political cultures, and modes of public reasoning that are embedded within legal practice as part of risk governance. She concludes that: “Legal and technological orders are in this sense co-produced; particular locally and historically situated sensibilities of rightness and governability are built into the very design of technological systems, including the standards that control their risks” (Jasanoff, 2014b, p. 139).

3.5.2 Politics of Scale, Expertise, and Social Authority

Another variant of the strong co-production work in the last decade focuses primarily on the mutual constitutive relations between knowledge making and the institutions, governance, policy arrangements, legal frameworks, and other social orders that shape the workings of our everyday lives. Social order not only shapes how we know about the world, but has implications for how we are able to exist in it. For example, epistemological commitments to particular conceptualizations of scale have important ramifications for how we approach processes of knowledge making and fundamental ontological implications for the institutions and governance arrangements that exist as a result. Rather than being 'natural' or 'fixed', scalar configurations are constantly "in the making" and fundamentally shape understanding and representations of problems, as well as the ways in which we choose to solve them (Beck et al., 2014). The politics of scale point to critical junctures through which knowledge production practices serve to co-produce epistemic authority and the ontological conditions in which it operates. Tuinstra et al. (2006) and Tuinstra (2008) use a co-productionist lens to examine how air pollution assessments hold together as credible, legitimate, and relevant when they are applied in differing institutional, political, and policy settings, moving from a UN arena to the European Commission. With a particular focus on the boundary work involved in defining scientific and political arenas, this shows that constructed boundaries between science and policy are not pre-determined and that this influences both policy- and knowledge-making processes. This is a clear example of the strong interactional strand of co-production, focusing primarily on how boundaries between science and policy are negotiated. However, the emphasis on producing "effectiveness" of assessments (Tuinstra et al., 2006, p. 350) framed uncritically in terms of producing credible, relevant, and legitimate knowledge, fails to touch on the deeper ontological and normative questions surrounding the mutual constitution of science and society. In contrast, Wehrens (2014) employs the concept of boundary work to consider the intertwined relations between researchers, policy-makers, and professionals in the provision of public health services in the Netherlands with attention paid to the particular *purposes* that are served by boundary-making efforts, thus making the normative aspects of science-policy interactions more explicit.

Another key entry point for strong co-production analysis is knowledge practices through which expertise is designated. This has implications for relations with the state or other structures, institutions, norms, or practices that are endowed with authority. These conceptualizations work to make visible the otherwise 'black boxed' processes through which scientific and technological knowledge becomes taken as 'truth.' For example, St. Clair (2006) examines the co-production of knowledge and politics by examining the circular strategies through which the World Bank legitimizes its expertise in conducting poverty assessments by invoking audiences that are already dependent upon it for knowledge to validate their claims. In this way, the epistemic authority of knowledge is co-produced by the particular institutions and practices, and the discourses it creates, which in turn shape the ontological conditions that shape possibilities for acting.

Co-productionist analysis seeks to understand the ways in which particular categorizations come about, how they are sustained, and how these are deployed as a means of exercising power within socio-natural worlds. The construction and enactment of identities is one way in which individuals and groups can seek to differentiate themselves. Such categorizations can serve to mark differences and can be used as tools of exclusion, but these are always relational and responsive to the socio-natural conditions in which they are enacted. Several authors have highlighted the particular spatialities involved in the co-production of identities (Grabbatin, Hurley, & Halfacre, 2011; Landolt, 2013). Landolt (2013) examines the spatial geographies of the co-production of youth identities on the periphery of high-crime areas in Zurich, Switzerland through the simultaneous tracking of spatial movements and how this interacts with social categories in the creation of youth identities. Frequently, particular conceptualizations of 'the public' are invoked within debates about science and technology. Stilgoe (2007) illustrates how constructions of 'the public' were reworked in relation to changing states of uncertainty around the health risks of mobile phone technologies in the U.K., with consequences for what was deemed appropriate public engagement. Thus, rather than being a static entity, ideas about 'the public' were co-produced alongside scientific designations about what scientific issues should be of public concern. This can result in the co-option of definitions of what counts as a public concern and attendant instrumental construction of publics that correspond with them (Stilgoe 2007). Cherrier (2007) examines the co-production of identities and social values by interrogating the normative underpinnings involved in the consumption decisions made by consumers who are part of the "voluntary simplicity" movement. Using a co-productive lens, she illustrates the ways in which both collective and individual identities are shaped by, and in turn shape, the ethical consumption practices that help to determine understandings and meanings of "ethical" behavior in society.

Jasanoff has stated that strong co-production requires not only "constructing a representation of the world as it is, but also concurrently a representation of the world as you want it to be in various ways." In other words, it must also grapple with normative visions for the future of society. In an edited volume dedicated to issues around the co-production of science, technology, and society, Harbers (2005) draws on actor-network analysis to expose the ways in which "normativity and morality are incorporated into technological artifacts", as well as the normative assumptions implicated within notions of deliberative democracy that underpin many efforts to rework socio-technical relations. Considering both human and non-human agency, Harbers argues that the framework of deliberative democracy is contestable as the singular desirable means of opening up science and technology to more accountability. Following this, "democratic politics in a technological culture requires not so much an extension of participation in public deliberations, but a proliferation of rivaling socio-technical networks. Not closing off existing worlds by moral regulation, but opening up new worlds via heterogeneous (cognitive, technical, social, political, and moral) experimentation – that is what is meant here by the democratization of science and technology" (Harbers, 2005, pp. 268-69).

3.5.3 Socio-materiality and Relational Ontologies

Relational ontologies assert that "things become what they are in relation to other things that emerge through an overall process of mutual becoming" (Linton & Budds, 2014, p. 174). There has been a growing movement to apply relational and dialectic approaches in political ecology as a means of examining politics and power relations, as well as resulting social inequalities (Linton & Budds, 2014). This approach addresses ontological, epistemological dimensions, as well as the ways in which these can create and perpetuate social relations and power differentials. Reflecting a different approach to strong co-production, there is a greater emphasis on socio-material relations, meaning that they extend the conceptualization of co-production to describe the ways in which knowledge and resulting social orders can in turn shape physical environments and other non-human entities (and vice versa).

The interactions between livelihoods, environment, and land use change have been the focus of several studies of co-production. In their study of livelihoods and land use change in Ghana, McCusker and Carr (2006) argue that livelihoods are shaped by, as well as shape, the landscapes in which are undertaken. Similarly, Grabbatin et al. (2011) explore the ways in which social relations co-produce land use and livelihood changes among sweet-grass basket makers in North Carolina, with a particular emphasis on the spatialities and socio-material determinants that shape resource access and use among basket-makers. The study illustrates that there is a continual need to renegotiate relationships at the interface of dynamic social and material changes in order to maintain and remake customary livelihood activities. However, contrary to other conceptualizations of strong co-production, which assert that it is not possible to assign primacy to the 'social' or 'natural', the authors in this study begin with social relations of power as the starting point to illustrate relations between knowledge, livelihood decisions, and material impacts on land use change. Further, unlike much of the STS literature employing strong co-production concepts, McCusker and Carr seem to leave presumed boundaries between 'social' and 'natural' worlds unquestioned and unexamined, thereby neglecting crucial dimensions of how the unidirectional causal relationships between livelihoods and land-use change that they refute were able to proliferate so widely in the first place. This may fail to fully realize the potential of material environments to mutually (re-)shape social relations in contingent and dynamic ways.

In contrast, other approaches to socio-material co-production focus more explicitly on the concept of hybridity in shaping socio-natural categories. For example, the study of the physical and human dimensions of water has also proven a rich area for considering the socio-material co-productive relations. Bouleau (2014), employing Syngedouw's (1999) concept of the "hydrosocial" cycle, or the ways in which water science and social orders have material impacts on hydrological systems and 'waterscapes', exemplifies this approach. Such work illustrates the ways in which discursive categories (e.g., "social", "natural") become institutionalized to stabilize and maintain particular social orders and processes of knowledge production, with concomitant impacts on physical environments. However, this perspective takes the conceptualization further to assert that, in turn, material changes in physical environments can loop back to open up windows through which ontologies and categories can be reconsidered and potentially remade, thus changing the basic framings of water institutions and management regimes. This has been called a relational-dialectic approach (Bouleau, 2014; Linton & Budds, 2014). A key tenet of this approach is the notion that water and social power are *internally* related, meaning that they are mutually constitutive (in the sense of strong constitutive co-production) and also result in the proliferation of hybrids. In a similar vein, Budds and Hinojosa (2012) treat water as a “hybrid nature,” in which materiality and social relations are fundamentally bound up in the making of the other. As a key starting point, the authors interrogate the particular role that the “politics of scale” plays in defining the ways in which water resources and related issues are understood and mobilized and, in turn, how this legitimizes particular epistemic claims and social authority. Consequently, “this requires attention to a range of ‘moments,’ such as physical flows, patterns of access, technologies, institutions, practices, legislative reforms, governance frameworks, and discourses around water, which are mediated by social and political processes and collectively constitute the waterscape of a given context” (Budds and Hinojosa, 2012, p. 120). In this way, the authors call for us to consider not only the ways in which water is shaped by social processes, but also about the ways in which water shapes social processes. In the example of the construction of modern highways in India, Nepal, and Tibet, Murton (2013) explores the role of roads as technological objects in co-producing networked relations between borders, livelihoods, land use, and trade relations, with simultaneous implications for the re-ordering of material environments. In yet another example, Palomo et al. (2016) argue that ecosystem services are co-produced through a “mixture of natural capital and various forms of social, human, financial, and technological capital” (p. 245). This perspective seeks to blur the boundaries between the ‘social’ and the ‘natural’ by arguing that ecosystem services require relational and hybrid ontologies in the sense that humans are necessary to bring the ‘services’ into being. However, the very notion of ecosystem services and the framing of socio-natures in terms of ‘capital’ presents a particular normative framing that remains wholly unexamined and does not question pre-given demarcations of what counts as ‘natural’ and ‘social’ and how society perceives and values nature, even as it seeks to argue for the need to rethink this binary divide.

Socio-material approaches to co-production have also been recently applied in the sphere of public services. Fenwick (2012) argues that attempts toward co-production of public services are bound up in the particular socio-material conditions in which these efforts take place. Rather than delimiting 'co-production' to singular or discrete arenas, this perspective opens up the notion of the co-production to much more than just the development of services or products to focus on "a broad range of co-productive enactments and patterns" that take place in and around sites of instrumental co-production. This requires attention to the particular relational ontologies that services bring into being. From this vantage, practices and social relations involved in knowledge making depend on particular "sociomaterial configurations," thereby extending the idea of co-production far beyond the binary of professional 'producers' and community 'users' (Fenwick, 2012). While some studies of public services overtly address the normative dimension, others do so implicitly. For example, Lundin and Makitalo (2016) present a case of instrumental co-production of health services, but recognize that material technological artifacts play a key role in shaping interactions and discourses between participants to negotiate processes of meaning-making and to challenge existing enactments of expertise. However, while the role of materiality is acknowledged as shaping the discursive space in which deliberate co-production occurs, the normative implications of this are not fully acknowledged or explored.

3.6 Using Strong Conceptualizations of Co-production to Examine Instrumental Approaches

In the previous two sections, I have reviewed the literature illustrating variations on two different interpretations of co-production that have been presented in the literature over the last decade. In the first instance, co-production is applied as a tool or method, always intentionally and often instrumentally, to negotiate epistemic conflicts in a range of policy-making contexts in an effort to foster more inclusive knowledge production practices. The second interpretation of co-production relies on the descriptive idiom that exposes the ways in which how we know about the world helps to define the ontological conditions that shape how we are able to exist and act. While some of these articles do seek to address, or at least acknowledge, both interpretations of co-production, this is generally in passing. Less frequent are examples of scholarly work that has attempted to address how the strong interpretations of co-production can be used to deconstruct the impacts of the increasing prevalence of instrumental forms of co-production within a range of research, policy, and practice. This is problematic for several reasons.

The first is that instrumental co-production approaches that become detached from normative and theoretical foundations may fail to grasp the ways in which power comes about and is exercised within knowledge production, circulation, and use. This fundamentally neglects the role that power plays within instrumental co-production. A primary strength of the co-production idiom is that it refines understandings of the knowledge-power nexus by showing that: 1) knowledge is often concentrated in centers of control and power, 2) power is expressed as much through what is excluded from knowledge-making, as much as what is included, and 3) stability of particular political and cultural configurations are the result of the intertwining of knowledge and power structures (Jasanoff, 2004, p. 280). Without interrogating the practices through which scientific knowledge has become dominant and how this dominance is maintained and exercised, it is not possible to fully understand how to break down power differentials within instrumental co-production activities, as is often called for. Thus, this is crucial for considering how to approach issues of power within contested knowledge settings, but is often ignored within instrumental co-production. The second is that instrumental co-production often delimits what counts as ‘participation,’ reducing this to a pre-determined performative exercise that can undermine agency and impose identities in ways that constrain the possibility of reworking power dynamics to enable authentic dialogue between actors.

This section will provide an overview of some efforts to engage an analytical co-productionist perspective within the context of instrumental co-production activities. In *States of Knowledge* (2004), Jasanoff notes that it should be expected that the introduction of the concept of co-production itself should be expected to be picked back up within new discourses that can shape new possibilities for reworking social and political orders. Further, she notes that co-production does not need to remain only an analytical tool but can also be used to inform interventions that may disrupt existing relations between knowledge and power. Thus, there is the potential to “bridge the gap between co-production as an analytic approach and co-production as a strategic instrument” (Jasanoff, 2004, p. 281). The literature reviewed in this section attends to this possibility, by illustrating some of the ways in which the strong co-production analysis has been used to either inform the design instrumental co-production, or else to better understand the dynamics of the processes or outcomes associated with them.

3.6.1 Public Services Provision

Dunston et al. (2009) examine co-production of public health services provision and system reforms in Australia. Drawing on Ostrom’s conceptualization of co-production of public services, in which citizen consumers are considered necessary and expert partners in the production of services, as well as outcomes, they go further to state that instrumental co-production involves a fundamental reworking of relations between the state and citizens. In this way, co-production is seen as requiring ideological and material change concurrently. Rather than seeing the challenges of co-production of public services as “instrumental matters to be resolved in purely technical ways", the authors argue that they should be seen as "profound cultural and practice changes" that must be negotiated (Dunston et al., 2009, p. 44). In this way, co-production requires "radical discursive, as well as organizational, work" (Dunston et al., 2009, p. 44). Further, it is noted that there is also a need to attend to the "deep entrenchment and ongoing reproduction of expert-based identities and practices" (p. 44) if there is to be meaningful engagement between citizens and service providers. This points toward the need for increased understanding of the ways in which discourses about instrumental co-production in turn shape conceptualizations of identities of 'citizens' and 'service providers,' and how this simultaneously shapes politics of expertise and knowledge-making. This is in contrast to the emphasis on building resource and skills capacities or particular conditions of success as is emphasized by some approaches to co-production (e.g., Bowen et al., 2015; Hegger et al., 2012). This also illustrates that reflexive approaches to instrumental co-production of public services can account for the constitutive dimensions of co-production to productively engage with both the epistemological and ontological dimensions of co-production as envisioned by STS scholars.

In another example, Otsuki (2016) examines participatory processes of sanitation infrastructure development in informal settlements in Nairobi, Kenya. While the study employs a public-services perspective to ground its stance on co-production (e.g. Ostrom, 1996), it also incorporates considerations of the interlinkages between the social, political, and material processes to understand the ways in which these iteratively shape "place-making" processes (Otsuki 2016) employed by settlement residents and the possibilities for enabling inclusive governance and the co-production of public services, thus employing a constitutive co-production lens. That is to say, material infrastructures both shape and are shaped by the everyday activities of settlement residents in ways that fundamentally affect relations between residents and the state agencies who are enrolled in the process of co-producing public services. In this case, unpredicted outcomes from intentional efforts to co-produce sanitation services resulted in new demands on state and non-state actors coming from residents of the settlements, thus reworking both notions of place, as well as social and political identities of all the actors involved.

3.6.2 Science, Policy, and 'Usable' Knowledge

There have been several attempts at strong co-productionist analysis in the context of instrumental co-production of (usable) knowledge for policy; however, these differ in the extent to which they have done so. Seeking to broaden the concept of "co-productive capacity" (Van Kerkhoff & Lebel, 2015), Bowen et al. (2015) examine the concept of instrumental co-production (which they refer to as "knowledge co-production", following Mitchell et al., 2004) within project settings, while also acknowledging that such processes are "shaped by a multitude of external factors" (p. 1). In the example of instrumental co-production of knowledge for climate adaptation in the health and water sectors in Cambodia, the authors assert that instrumental co-production "requires the recognition that knowledge is value-laden and that science-practice interface involves complex negotiations" (Bowen et al., 2015, p. 13). This is an important contribution, since much of the instrumental co-production literature only peripherally acknowledges (or ignores altogether) broader linkages between 'local' processes of knowledge-making and broader social and political configurations. However, in attempting to explore these relationships, the authors present the "context" of climate change adaptation, governance and policy as separate, settled, and a-political domains. In this way, the "external factors" that are claimed to shape instrumental co-production remain just that; rather than being considered as integral components that fundamentally shape knowledge production and use, they are detached and seemingly outside of the actual processes of knowledge-making. Furthermore, while the paper examines how knowledge production practices are shaped by these factors, there is little examination of how processes of knowledge production reshape these in turn. For example, the authors conclude that scientific capability and governance resources — both in terms of financial assets and skills — and the inclusion of indigenous knowledge are important for instrumental co-production. However, this glosses over the ways in which the knowledge-power nexus has created the particular ontological conditions in which there are global imbalances in the capacity to produce scientific knowledge or, more importantly, why scientific knowledge has come to maintain such a powerful grip on determining what counts as knowledge in the first place.

In contrast, Lövbrand (2011) pays particular attention to the ways in science is shaped by policy (and vice versa) and also explicitly addresses the tension that exists between the critical and normative dimensions of strong co-productionist perspectives, which call for reflexivity, and instrumental co-production, which generally focuses on social accountability in the form of the utility of the information. In a case study examining the production of knowledge for European climate policy formulation, the author shows how efforts to provide 'useful' information for policy decisions may close off opportunities for reflexive knowledge production practices. She further shows that even when co-production is undertaken for utilitarian purposes (e.g., to support existing policy goals) the knowledge that is produced still plays a constitutive role in shaping the definition, and thus ontology, of the issue being investigated. In this way, the knowledge produced in the case study simultaneously shapes and is shaped by how the issue of climate change adaptation is defined, as well as decisions about what can or should be done about it. However, the case also illustrates that while instrumental co-production resulted in 'closing down' possibilities for new interpretations of the problem of climate adaptation, it was still successful in 'opening up' limited opportunities for reflection. This paints a more complicated picture of instrumental co-production rather than more simple interpretations that assume that co-production is beneficial in all cases. In this way, a strong co-productionist analysis helps to elucidate the epistemic politics that are involved within processes of instrumental co-production.

However, not all attempts at accounting for instrumental co-production through strong interpretations are able to successfully avoid falling into a reductionist perspective. For example, Puente-Rodriguez et al. (2015) draw explicitly on Jasanoff's conceptualization of co-production through the examination of the emergence, standardization, and legitimation of the phenomenon of "environmental management systems" in Dutch ports. The study strives to examine strong co-productive relations through which technical practices of standardization emerge and how this may influence interactive modes of co-production. However, there are several problematic aspects. The article refers to co-production narrowly and prescriptively as a "practice" that involves participatory methodologies to mobilize and integrate various knowledges and the treatment of "gathering relevant knowledge" and "organizing encounters for sharing knowledge" (Puente-Rodriguez et al., 2015, p. 8). Co-production is further referred to as a "participatory methodology" and "tool" that can be used to incorporate divergent knowledge within policy-making processes, thereby "triggering co-production knowledge practices" (Puente-Rodriguez et al., 2015, p. 4). For example, the article sums up: "To conclude, knowledge from different actors and sources was mobilized and integrated into the process, and key stakeholders were consulted at different moments" (Puente-Rodriguez et al., 2015, p. 7). This portrays an overly simplistic and decontextualized account of negotiations of knowledge production and use that is at odds with analytical precepts of strong co-production. Just as concerning, the authors conclude that instrumental co-production of knowledge should "become mandatory in the near future" to help "stabilize" the environmental management system phenomenon, thus black-boxing and reproducing the very processes that their co-productive analysis strives to unpack.

There are also several examples in the literature that do not draw explicitly on either STS or public services literature, but nonetheless exemplify strong constitutive co-production analysis in the context of instrumental co-production. For example, Aeberhard and Rist (2009) examine the evolution of transdisciplinary knowledge production processes that have shaped, and been shaped by, predominant social orders. The study illustrates how production of knowledge about organic farming in Switzerland went from being rooted in self-organizing transdisciplinary "thought collectives" to more segregated and specialized knowledge production as part of transitions toward formal agricultural policies and market development, as well as the development of 'modern' research institutions, which perpetuated particular forms of expertise and boundary-making. The study treats all knowledge as constructed and reflective of social and historical context, yet it tends to oversimplify the relations between science and society, which are seen as being fully segregated in a push toward modernization. STS literature, in contrast, asserts that these are separate only to the extent that social practices have successfully established the appearance of fixed boundaries between these domains.

3.6.3 Politics of Expertise and Identities

Identities are also as a key site of co-production (Callon & Rabeharisoa, 2009; Jasanoff, 2004) and debates about what constitutes expertise are often intimately tied to the formation of identities within knowledge production processes. Muñoz-Erikson (2014) examines knowledge-action systems, defined as "the networks of actors, their visions and expectations for the future, and the practices and dynamics underlying the production of knowledge to advance specific policies, decisions, and actions related to sustainability" (p. 182), and their role in shaping knowledge politics within land use governance regimes in San Juan, Puerto Rico. The goal of the study is to better understand the power dynamics that shape the production, circulation, and use of knowledge and how this creates the particular visions and capacities of various actors who are involved in decisions about sustainable land use planning in the city. Integral to this analysis are concepts related to instrumental co-production, including epistemic cultures and boundary work, which help to expose epistemic commitments and the practices required to establish authority over knowledge in particular contexts. A key finding from this study is that the fundamental problem of linking knowledge and action is not the need for more knowledge or strategies to better 'harness' scientific knowledge. Rather, key barriers are those of social and political order, which determine how the knowledge is perceived and validated within public arenas (Muñoz-Erikson, 2014, p. 189).

Drawing on theoretical contributions from STS and geography, Pallett and Chilvers (2015) seek to link normative interventions of researchers aiming to rework the practices of organizations at the science-policy interface with analytical approaches that simultaneously view such organizations as continuously co-produced and 'in-the-making' within dynamic networked spaces. From this vantage, organizations are seen as "externally networked, responsive, and actively being co-produced with other phenomena through practice and contestation" (Pallett & Chilvers, 2015, p. 159). Failed attempts at changing organizational practice and learning are seen as stemming from assumptions that organizations are fixed, as well as the reduction of such interventions to 'instrumental procedural fixes'. In line with constitutive dimensions of co-production, the authors note that "simply the act of studying and understanding organizations in a different way has implications for forms of action, even in the absence of directed interventions" (Pallett & Chilvers, 2015, p. 154). The authors conclude that taking the unfixed and contingent nature of organizational practices and learning seriously requires new methodological approaches that acknowledge their constitutional ability to help create the worlds describe and also aim to "destabilize the relationship between the researched and researcher" (Pallett & Chilvers, 2015, p. 158) to capture the everyday and transient aspects of organizational practice and learning.

3.6.4 Socio-materiality and Relational Ontologies

Co-productionist analysis has shown how the politics of scale are a key determinant of manifestations of power in the production of knowledge. Drawing on STS, political geography, and critical state theory, Beck et al. (2014) examine the ways in which decisions about scale within global scientific assessments represent normative judgements that privilege particular epistemologies over others. Using the example of the creation of the Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES), the authors show how explicit efforts to value regional and local knowledge within global assessment processes is "not politically neutral"; rather, how boundaries are drawn between what 'counts' as local or global are inherently power-laden processes that have ontological implications in how problems are defined and addressed (Beck et al., 2014, p. 2-3). In this way, epistemic and political authority — as a form of social order — are co-produced. As such, this is an example of how a strong co-productionist lens can provide valuable explication of efforts to bring multiple knowledges to bear on policy decisions. Graham (2012) also tackles issues of scale within instrumental co-production of museums in the UK. In this case, the problem of scale within instrumental co-production is viewed in terms of how micro / macro processes (e.g., institutional politics, policy) correspond to each other — which is to say, the ways in which specific interactions and encounters within museum co-production are shaped by broader circulations of power and, conversely, how change in broader social and political systems may be related to micro-scale practices within museums. This particular conceptualization of scale also draws on Latour's proposition that all action is "dislocal" in that specific interactions take place in particular locations, but at the same time are comprised of networks of actors that cannot be contained by one particular site, thereby reworking Euclidean notions of scale and space.

Drawing primarily on post-colonial, international development, and race theory, Lynch and Alberti (2010) examine the role of museums in reproducing institutionalized racism in the UK. In this case, the authors show that efforts to facilitate instrumental co-production of museum exhibits can perpetuate particular social orders through the maintenance of categories such as race. The article illustrates how the intertwined acts of knowledge-making and representation shape social structures, with important impacts on the potential for reflexive engagement within instrumental co-production processes. Importantly, this perspective illustrates the potential danger of instrumental co-production to reinscribe boundaries and categorizations that form the basis of disparities in authority and power that exist among the participants in the first place. The authors conclude that there is a need for "radical trust" that can be built through the acknowledgement of the specific positionings and prejudices embedded within museums, as well as through unlearning these to enable genuine negotiations of knowledge and power (Lynch & Alberti, 2010, p. 30).

Applying a political ecology of education framework, Meek (2016) illustrates how educational institutions are a crucial arena for co-production of knowledge, social order, and physical environments. In the example of a vocational high school in Brazil that was linked to a landless workers' movement, Meek shows how intentional efforts to rework school curricula and related knowledge practices to reflect the problems that students encounter in their settlements can have important ramifications for sociopolitical and environmental change. Applying strong constitutive dimensions of co-production, schools and educational systems are seen as "important pathways and instruments for the co-production of environmental knowledge, because they are where conceptions of what constitutes scientific methodologies and knowledge are continually inscribed, thus affecting how students create boundaries between the social and natural" (p. 413). Furthermore, schools also have the effect of demarcating what counts as valid knowledge through the creation of spatial and temporal boundaries within which knowledge can be obtained (e.g., certain hours of the day, within a classroom). However, for this reason, schools can also be seen as a key site to spur transformation. When local workers' organizations demanded new curricula to advance new forms of agroecological knowledge that were more consistent with local experiences, this was also viewed as a means to create alternative possibilities for the ordering of society, as well as new possibilities for environmental stewardship, land use, and livelihoods. In the process, discussions of the resulting hybridized knowledge were consistently linked with the broader vision of interrupting the dominant social productions that devalued rural, agricultural livelihoods and knowledge. This study illustrates how goal-oriented co-production of knowledge can be consciously linked with reflexive processes that are attuned to the ways in which the production and recognition of alternative knowledges can be a tool in perpetuating the transformation of dominant political and economic systems.

3.7 Discussion: Trends in the Literature

Through this review, there are several key trends that can be observed across the various interpretations of co-production:

3.7.1 The Co-production 'Paradox'

There is a paradox within the recent co-production literature that highlights the tensions between various ways in which the ontological aspects of co-production are conceptualized. In this first case, several of the studies recognize that there are essentially two strands of co-production that address epistemological and ontological questions respectively, drawing in large part on Jasanoff's original presentation of the idiom of co-production. Yet, despite acknowledging the existence of these two 'faces' of co-production, these approaches work to isolate the weak interactional interpretations from strong co-production to focus on the instrumental implementation of co-production (e.g. Hegger et al., 2012; Puente-Rodriguez et al., 2015). Others have been less explicit about their attempts to distill the 'practical' components of co-production for instrumental purposes. For example, Armitage et al. (2011) citing Guston (2001, p. 401) highlight that co-production involves "the simultaneous production of knowledge and social order," yet go on in the same article to articulate fundamentally instrumental definition of co-production (see full definition in Section 4.3). This, in essence, implies that it is possible to separate the epistemological from the ontological within processes of co-production.

Yet, even when the constitutive aspects of co-production are ignored (either intentionally or unintentionally), the growing body of work advocating for interactive co-production processes in itself represents an ontological shift in how organizations, governments, and scientists approach issues of facilitating more 'inclusive' processes of knowledge- and decision-making. This includes basic assumptions that inform expectations of citizens and their role in producing knowledge, as well as making and evaluating decisions that have consequences for their lives. This is what Jasanoff has termed a form of "naïve co-production" (Jasanoff, 2014). Indeed, co-production is a cognitive frame that can itself loop back to remake the world we live in (Jasanoff, 2004). This makes sense from a co-productionist perspective: the very introduction and circulation of the concept of co-production has discursive effects that can re-organize the ways in which we conceptualize and grapple with relations between knowledge and power (Jasanoff, 2004, p. 276). Co-production describes mutually constitutive socio-scientific relations. Yet, the concept itself is not immune to these very effects. The specific language and concepts that emerge from such an analysis play a role in shaping norms and behaviors and, thus, ontological states. This, however, not only asks us to think about ways of producing useful or robust knowledge, but also to enact normative decisions about the way the world should be.

In the second case, approaches to co-production implicitly recognize the linkages between epistemological and ontological debates, but often in a very limited or linear fashion. For example, co-production as conceived within some adaptive co-management framings recognizes the material impacts emanating from issues of representation of knowledge. However, this is generally on a singular or bounded aspect of the system and does not address other less visible aspects of social order. For example, co-management can be seen as relying on learning, interplay, and two-way feedback between government and local institutions (Berkes et al., 2009). This alludes implicitly to constitutive co-production feedbacks but only in the institutional realm – ignoring other areas of social order. Similarly, co-production in public services administration is seen as requiring fundamental transformation and innovation, including "reconstituting the state" through new kinds of organizations and structures (Boyle & Harris, 2009). However, the ways in which such material outcomes then serve to influence how we know about the world, as well as the new ontologies that result, are left to dangle. The issue of co-production is still cordoned off as a fundamentally operational issue. In these conceptualizations, co-production is thus seen as a means to an end — namely as a vehicle for enabling collaborative knowledge production processes or social learning that is needed to affect a desired outcome (e.g., implementation of adaptation to climate change). In contrast to Jasanoff's conceptualization, however, the changes brought about through such knowledge and learning are not considered to fall under the umbrella of "co-production" in their terms. This creates a strange narrowing of the concept of co-production that is at odds with the expansiveness of the co-production idiom, one that aligns more readily with the co-production concepts coming out of institutional analysis approaches following Ostrom.

3.7.2 Spin-off Concepts

As the concept of co-production has gained popularity, there have also been a variety of 'spin-off' concepts that have been developed with the intention of better understanding how to implement instrumental co-production. In a special issue in *Ecology and Society* devoted to the topic, van Kerkhoff and Lebel (2015) present the concept of "co-productive capacity", which is defined as the "combination of scientific resources and governance capability that shapes the extent to which a society, at various levels, can operationalize relationships between scientific and public, private, and civil society institutions and actors to effect scientifically-informed social change" (p. 2). In other words, co-productive capacity is "the foundation from which co-production takes place" (van Kerkhoff & Lebel, 2015, p. 2). In this conceptualization, capacity refers to: 1) capacity to produce, access, and employ scientific knowledge and 2) capacity to combine science with 'local' knowledge within existing practices and governance structures in order to bring about change. While the concept of co-productive capacity is backed by a strong recognition of both strands of co-production (i.e., constitutive and interactive, see van Kerkhoff & Lebel, 2015, pp. 1-2 for discussion), the definition of capacity provided remains fundamentally attuned to epistemological issues, with little space to consider ontological dimensions. For example, rather than focusing on the interrelations between knowledge-making and ontological states, the article states that co-productive capacity focuses on the "social, cultural, and political dimensions that explicitly and implicitly affect the *relationships between knowledge making and decision making"* (van Kerkhoff & Lebel, p. 2, emphasis mine) rather than considering relations between knowledge-making and ontological conditions and broader epistemological issues.

This unnecessarily narrows the scope of the co-productive analytical gaze to epistemological conflicts, rather than the complex interrelations between how these debates are enacted and the ontologies they produce. In this way, the notion of co-productive capacity fits awkwardly with the idiom of co-production, which highlights that neither scientific nor social factors have primal determinacy (Jasanoff, 2004). Employing the concept introduced by van Kerkhoff and Lebel, Schuttenberg and Guth (2015) see the 'knowledge co-production process' itself being a determinant of co-productive capacity. While this might reflect perspectives that may be a problematic assertion from a strong co-productionist perspective, they do draw valuable insights about the need for and value of unquestioned integration of knowledges, while also emphasizing that collaborative knowledge production alone is not enough to eliminate entrenched power disparities in many instances. Reflective processes have the potential to help identify types of structural or institutional changes that are needed, thus creating linkages between the epistemological and ontological.

Similarly, Wyborn (2015) acknowledges two broad, yet divergent, views of co-production: a prescriptive approach with pre-determined normative goals (Mitchell et al., 2004) and the explanatory, analytical lens defined in the co-production idiom (Jasanoff, 2004). Seeking to provide an alternative conceptual framing that integrates these two approaches, Wyborn presents the concept of "co-productive governance" to reconceptualize adaptive governance as a process of co-production that articulates "the context, knowledge, process, and vision of governance" (Wyborn, 2015, p. 57). The study usefully applies Jasanoff's co-production idiom in the context of connectivity conservation as both examples of adaptive governance and co-production in action. While the study presents a theoretical basis drawing on strong co-production interpretations, the analytical scope of co-production is more concerned with knowledge production and decision-making (see Wyborn, 2015, p. 57) rather than examining linkages between knowledge, meaning-making, and ontology. Furthermore, from a co-productionist perspective, any form of governance will necessarily have co-productive effects, particularly in the realm of knowledge production and use. Thus, the term ‘co-productive governance’ is itself redundant.

3.7.3 Side-stepping Constitutive Co-production

As the surge in literature on the topic of co-production has illustrated, there are many ways in which the interactive component of co-production has been conceptualized. Co-production has frequently been interpreted as being synonymous with practices to facilitate ‘integration’ of various perspectives, disciplines, knowledges, and epistemologies (e.g. Cash, 2006; Meadow et al., 2015; Schuttenberg & Guth 2015; Weaver et al., 2014). In many instances, the term co-production is used to refer specifically to knowledge generation activities (e.g. ‘co-production of knowledge’), but the lasting influence of Ostrom and colleagues is also evident in the many references to the co-production of public services and goods (e.g., Boyle & Harris, 2009; Cepiku & Giordano, 2013). In other instances, new terms were created *specifically* to enable differentiation between interactional forms of co-production and the constitutive dimensions elaborated by Jasanoff. For example, both Edelenbos et al., 2011 and Hegger et al., (2012) have embraced the term “joint knowledge production” to differentiate “more direct” and “purposeful” interactions between scientists and non-scientists (Hegger et al., 2012), in order to avoid confusion with the idiom of co-production as presented by Jasanoff. Similarly, Pohl et al. (2010) talk specifically about “knowledge co-production” (following Cash et al., 2003) to emphasize the goal of developing participatory knowledge production practices and Meadow et al. (2015) seek to distinguish implicit forms of co-production from those that are explicitly undertaken, through the use of the term “deliberate co-production.”

Part of the challenge noted by Hegger et al. (2012) is that constitutive co-production can be difficult to discern and, consequently, they opt to focus on a "direct and more easily recognizable form of co-production" that can be directly observed, measured, and fit within frameworks or evaluative tools. Yet, processes of constitutive co-production "happen whether you like it or not" (Jasanoff, 2014) and do not reside within the artificially determined boundaries of projects or programs. Such bounded and simplified co-production narratives are not sufficient to fully address the issue of power in knowledge production processes. It is *precisely because science has become so enmeshed in our society* such that it has become completely naturalized, that we need the analytical breadth of strong analytical dimensions of co-production to help understand these interrelations and processes. As such, the desire to dissociate strong constitutive and weak interactional dimensions of the co-production idiom from the more instrumental interpretations of the term represents a political move that willfully ignores the deep intertwining of knowledge and power, of science and social orders, which create uneven power dynamics between participants in instrumental co-production in the first place. Such a deflection illustrates an unwillingness to question the authoritative position of scientific knowledge, since this would result in difficult and charged debates that may not result in a smooth trajectory toward consensus. The result is that efforts to understand instrumental co-production become reductive and completely depoliticized. For example, Hegger et al. (2012) have created a set of 'design principles' that are intended to guide instrumental co-production efforts. This severely constrains the focus of analytical efforts at the interface of science and society and risks co-opting the concept of co-production in ways that can perpetuate existing power dynamics.

3.8 Conclusion

In practical terms, and within most contexts in which instrumental co-production is currently discussed (and 'applied'), debates about the boundaries between the social and natural and the authority of science are difficult. This requires breaking down fundamental assumptions and world views. This can be directly challenging or even threatening to some participants. However, as Latour (1993) and others have shown, these very debates form the basis of the authority of scientific knowledge. Science gains its ability to act as the sole designated mediator between the social world and the natural world through the constant and active drawing and re-inscribing of boundaries (Gieryn, 1995).

Thus, it is necessary to recognize and continually interrogate the relations between science and society that have been made 'invisible' through entrenched practices and normative assumptions. In questioning these boundaries, we can open up the space to question the rightful place of science in society, as well as unquestioned notions that it should serve as the singular means of accessing 'truth' about the world. This is the kind of space that is needed to enable deeper reflexivity within instrumental co-production. Important questions remain about how we conceive of and create science-society relations that better enable the analytical insights of constitutive co-production perspectives to effectively engage with and shape (and reshape) research, policies, and practical implementation. Such questions cannot be answered in the form of rigid prescriptions.

This review shows that it is possible to take the normative calls for more reflexive and open processes of knowledge production that arise out of STS literature seriously without having to cast aside the descriptive and analytical strengths that the idiom of co-production provides. Instead, this illustrates that each attempt at instrumental co-production represents the intention to rework the extant social order to enable more inclusive and accountable knowledge production practices. When instrumental approaches become detached from strong interpretations of co-production, there is the risk of conceptualizing power in pre-defined and often overly narrow terms that do not fully acknowledge the role of knowledge itself as a key determinant of power. In contrast, strong co-production asks us to consider more pervasive forms of power embedded within normalized and invisible practices of knowledge production, representation, circulation, and application. Instrumental co-production is valuable only in as much as it enables us to see these, make them explicit, and create useful debate about these practices in ways that seek to reflexively examine these structures and dynamics in ways that can better.

Approaching co-production from a vantage that does not deal with the politics and relations of power involved in knowledge production, instrumental interpretations of co-production can serve to close off, rather than open up, important ontological questions that can better inform science-society relations in the future (Stirling, 2008). Just as importantly, it must be recognized that *all* instrumental co-production necessarily shapes new discourses, representations, and understandings, which will ultimately have impacts on the ontological conditions under which science and social orders are co-produced — a "looping back between analysis and behavior" in which "the words and concepts with which we describe society become part of the self-conscious apparatus of reflection" (Jasanoff, 2014). However, the key question is: *are these changes actually desirable in relation to the normative aspirations that we have set out to achieve?* It is this kind of question that the lens of constitutive co-production may help to answer.

CHAPTER 4: Research Design and Methods

4.1 Case Study Location

The East African country of Tanzania presents an ideal context within which to study the features of knowledge production and use within climate adaptation decision-making for several reasons. Adapting to climate has been a long-standing issue in East Africa, where there have historically been high levels of interannual variability. There is high confidence that East Africa has already undergone significant warming (Trenberth & Jones, 2007) and future impacts of climate change are expected to be significant. Yet, a great deal of uncertainty remains regarding future climatic conditions, with significant variation among scientific studies looking at trends and projections in precipitation. For example, there is evidence of an overall slight upward trend in precipitation in the region since 1900 (Hulme et al., 2001). However, other studies indicate that over the last several decades, a significant drying pattern has been observed in some parts of East Africa (Williams & Funk, 2011) and new studies highlight the role of multi-decadal variability in the region (Tierney et al., 2013). Climate models project that East Africa may experience an increase in mean annual precipitation of between 5 – 15% by the end of the century (Trenberth & Jones, 2007).

The uncertainty of these broad-scale climatological trends and projections are complicated by the localized heterogeneity of semi-arid ecosystems, in both time and space (Homewood, 2009). Semi-arid regions are considered particularly vulnerable to the first line of impacts of climate change, due to the tightly coupled nature of ecosystem productivity and precipitation, and increasing fragmentation of landscapes through changes in land use and institutions (Galvin, 2008; M.J. Goldman & Riosmena, 2013). Further, historically-derived social and economic factors have resulted in the marginalization of pastoralists in northern Tanzania, making them particularly vulnerable to the effects of climate change (Galvin et al., 2001; Hodgson, 2001).

There have been multiple and on-going efforts to facilitate production and use of knowledge for adaptation across scales in East Africa. Yet, despite these many efforts to link knowledge with decision-making, scientific climate knowledge is often produced at spatial and temporal scales that tend to be at odds with scales at which decisions are made and where impacts and adaptations might occur (Wilbanks & Kates, 1999; Liverman, 2004). Further, the social and ecological impacts that changes in climate might entail depend upon numerous factors that increase the uncertainty associated with predictions and, therefore, how they might effectively be used to inform decisions (Dessai et al., 2009). Such challenges have been widely documented in the use of meteorological data and seasonal forecasts (Roncoli, 2006; Gearheard et al., 2009; Speranza et al., 2010; Orlove et al., 2010).

At the same time, it has been recognized that 'local' populations possess a vast wealth of knowledge that may be helpful to informing climate adaptation—locally, nationally, and perhaps globally—but how to incorporate such knowledge within formal adaptation planning is still an open question for research (Green & Raygorodetsky, 2010). There has been a great deal of interest in indigenous knowledge regarding climate change in the region (Green & Raygorodetsky, 2010; Orlove et al., 2010; Eguru, 2012) and in Tanzania specifically (Chang'a et al., 2010; Kijazi, 2014; Mahoo et al., 2015; UNEP, 2008). However, most of these efforts have emphasized the need to 'collect', 'gather', or 'document' indigenous knowledge, without considering the underlying socio-material processes that are involved in its production, circulation, and use.

There have been explicit efforts across East Africa to deliver scientific climate knowledge for use within localized adaptation planning, but Tanzania specifically was chosen for national scale data collection for several reasons. First, there have been explicit calls for localized climate adaptation planning, along with efforts to deliver relevant scientific knowledge for adaptation decision-making (see, for example, United Republic of Tanzania [URT] Climate Change Strategy, 2012). This reflects broader national trends of decentralization in Tanzania since the 1970s and a renewed push for devolution of decision-making powers since the mid-1990s (Mollel & Tollenaar, 2013), including increased community participation in the planning and implementation of development projects – though such efforts have notably had mixed results (Venugopal & Yilmaz, 2010). The trend toward decentralization is bolstered by projects facilitated by community-based organizations and national and international NGOs to strengthen local adaptive capacities in relation to climate risks (see, for example, Tanzania Natural Resource Forum [TNRF], 2012).

In particular, Tanzania has been the focus of two internationally sponsored initiatives that explicitly aim to strengthen linkages between scientific knowledge and climate adaptation decision-making at multiple scales, including: 1) the Devolved District Climate Financing (DDCF) Project which was funded by the U.K. Department for International Development (DfID) and coordinated by the International Institute for Environment and Development (IIED) and 2) the Global Framework for Climate Services Adaptation Program in Africa (GFCS-APA) which is funded by the Norwegian Ministry of Foreign Affairs (MFA) and coordinated by the World Meteorological Organization (WMO).

Tanzania thus, presents an ideal context to examine cross-scalar knowledge production and use for climate adaptation. At the same time, agro-pastoral and pastoral populations in semi-arid areas of northern Tanzania are directly reliant upon natural resources for the majority of their livelihood activities and climate knowledge is already an established resource for informing coping and adaptation strategies. For these reasons, East Africa, with a focus on local dynamics in semi-arid rangelands of northern Tanzania, is an ideal location to study how various knowledges are produced and used across scales within adaptation decision-making.

4.2 Research Design

In the previous chapter, I reviewed the current literature on co-production to elucidate both the analytical and instrumental usages of the term. Based on this review, I argue that in order to understand the crucial 1) science-society configurations, 2) relations of power, and 3) knowledge-politics that fundamentally shape and constrain efforts of instrumental co-production, it is necessary to draw on both the descriptive and analytical insights of the idiom of co-production. How to do so, however, presents a number of significant research design and methodological challenges. In the first, constitutive dimensions of co-production do not adhere to commonly understood (socially constructed) notions of scale — including spatial, institutional, administrative, and (even) temporal scales. This means that co-production analysis must employ approaches that are not bound to a particular scale of analysis, but are rather able to work within and across a range of scales, recognizing that scale is always fluid and relational. In the second, while co-production is fundamentally concerned with examining the interlinkages between knowledge and power, 'observing' these interactions in practice is not necessarily straight forward. This requires tracing the interrelations of material and discursive practices and the ways in which these simultaneously constitute particular science-society configurations, as well as understanding how they shape current and future possibilities for new science-society interfaces that can enable new pathways and opportunities for addressing issues related to climate change.

In addition to the methodological considerations stemming from a co-production theoretical orientation, there are two additional lines of reasoning that justify a cross-scalar case study design. First, the literature tells us that environmental management decisions, including those concerning climate adaptation, are complex and exhibit pervasive cross-scalar socio-ecological interactions (Berkes et al., 2006). Building upon these findings, scale-related challenges have been widely acknowledged within the climate adaptation literature, and it has been argued that more attention to cross-scalar dynamics within adaptation research is warranted (Wilbanks & Kates, 1999), but how exactly this should be done is an open question. While there have been a number of efforts to empirically tease apart cross-scalar dynamics of adaptation decision-making (e.g., O'Brien et al., 2004; Leichenko & O'Brien, 2002; Belliveau, Smit, & Bradshaw, 2006; McDowell & Hess, 2012) the majority of scholarship has remained theoretical in nature. Differing perspectives among actors across epistemologies and scales with regard to what constitutes credible, salient, and legitimate knowledge is a constraint to including multiple knowledges within climate adaptation decision-making in Tanzania. Further, the ways in which knowledge gains credibility, salience, and legitimacy among actors is a process that is bound up in power dynamics and differentials that exist among actors. However, there has been little empirical study to examine how these criteria and relations of power are perceived and performed among actors across epistemologies and scales and how this influences knowledge production, circulation, and use — as well as what this entails for the lived experiences of individuals and the possibilities for responding to impacts of weather and climate.

Importantly, a co-productionist perspective also requires reflexivity on the part of the researcher. To start, this involves acknowledging that the researcher is herself situated in a particular set of ontological conditions and epistemological assumptions that fundamentally shape and constrain what questions are asked, how, and why, as well as the understanding that all knowledge is partial and situated (Haraway, 1991). Wynne has similarly argued that knowledge is "partial, temporally contingent, conflicting, and uncertain to a degree that is rarely acknowledged"

(Wynne, 1991, p. 119). Importantly, a co-productive stance also recognizes that research methods not only describe the world in which we live, but they also help to create it (Law, 2004). Thus, it is also important to recognize that the ways in which research is approached is not neutral, but has important consequences for the versions of 'reality' that researchers may create and sustain. According to Law (2004), this requires methodological bundles that acknowledge the importance of 'standard' research methods (as well as the normativities attached to these) but also a humility in recognizing that there are always complexities that cannot be known or understood through standard research methods.

4.3 Research Questions and Objectives

This research examines the production of knowledge for climate adaptation, as well as the ways in which different knowledges circulate and gain recognition as 'valid' or 'usable' among actors within and across epistemologies and institutional scales. This analysis applies the knowledge system criteria (KSC) framework (i.e., salience, credibility, legitimacy, see Cash et al., 2003) in combination with a modified ANT analysis (Rocheleau & Roth, 2007) to delineate the processes through which different knowledges are produced, travel, and become recognized as valid among various actors across institutional scales and how this, in turn, either reconfigures or reinforces existing science-society relations. I argue that such an analysis can provide insights about the ways in which knowledge gains authority, how this shapes the production, circulation, and use of knowledge, and how this may (or may not) reconfigure relations between knowledge systems and actors. Specific research questions, as related to the three main project objectives, are outlined below.

The research reflected three primary objectives. First, it sought to understand the ways in which different knowledges are produced, circulated, accessed, and used within adaptation decision-making. The second goal was concerned with understanding how knowledge gains salience, credibility, and legitimacy among actors across epistemologies and scales. Third, research aimed to interrogate power relations between these actors, to better understand how differentials in power shape knowledge production and use, as well as possibilities for reworking science-society arrangements. Each of these objectives has several guiding research questions.

Objective 1: Understanding production, circulation, access, and use of knowledge

1. What kinds of knowledge are currently being incorporated within adaptation decision-making across institutional scales and for what kinds of decisions?
2. Who is producing this knowledge, through what processes, and for what purposes?
3. How is this knowledge circulated and how does this shape who is able to access and use this knowledge?

Objective 2: Examining how knowledge gains salience, credibility, and legitimacy among actors within and across epistemologies and scales:

1. Do actors across epistemologies and institutional scales have differing perceptions of the salience, credibility, and legitimacy of various climate knowledges?
2. How do perceptions of the salience, credibility, and legitimacy of various knowledges influence *actual practical use* within decision-making?
3. What are the tradeoffs between the various knowledge system criteria? Do these vary among actors within and across different epistemologies and institutional scales?

Objective 3: Interrogating power relations between actors within and across scales and the ways in which this influences the processes of knowledge practices:

1. How are relations of power perceived and enacted by actors at different institutional

scales and/or within different epistemological settings?

2. How do differential power relations among actors within and across epistemologies and scales influence the perceived salience, credibility, and legitimacy of various knowledges, and how does this influence knowledge production and use?

3. How do power relations influence the production and use of knowledge within particular epistemological communities and across institutional scales?

4.4 Data Collection and Analysis

Recognizing the need for a bundle of methods that pay attention to cross-scalar dynamics of knowledge production, circulation, and use within climate adaptation, this research utilized a mixed-method case study design, with multiple embedded units of analysis situated at multiple institutional scales. Case studies are particularly useful for empirical studies in which "the boundaries between the phenomenon and context are not clearly evident" and enable the in depth examination of contemporary phenomena (Yin, 2009, p. 18). A single case study can offer a useful structure for organizing data collection and analysis when attempting to test an established theoretical frame that has a clear set of propositions, thereby enabling the development of theoretically grounded research questions (Yin, 2009). For analytical clarity, my case study design is situated at distinct and bounded institutional scales defined in relation to the Tanzanian nation state; however, it is recognized that these scalar designations are constructed and relational and that in practice boundaries between them are fluid and porous, with both knowledge and actors often operating within, between, and across a multiplicity of scales (sometimes concurrently). The three institutional scales that framed data collection activities were: international, national, and village scales. Four methods were used symmetrically at all scales: surveys, planned group discussions, semi-structured interviews, and ethnographic observation. A summary of the data collection is provided in Table 3 below. Data was collected during four trips to Tanzania: June – December 2013, April – December 2014, February – April 2015, August – September 2015.

METHOD	Quantity / Duration	Dates
Village Scale		
Survey	n=198	June – July 2013
Planned Discussion Groups	n=11	September – December 2013
Semi-structured Interviews	n=36	September – December 2013, August – December 2014
Ethnographic Observation	6 months in villages (unstructured) n=6 (structured meetings)	September – December 2013, August – December 2014
National / International Scale		
Survey	n=30	April – December 2014
Planned Discussion Groups	n=2	April 2015, September 2015
Semi-structured Interviews	n=12	April – December 2014
Ethnographic Observation	3 weeks in national offices (unstructured) n=26 (structured meetings)	April 2015, August – September 2015

Table 3: Overview of methods

4.4.1 Surveys

Surveys were administered at each unit of analysis, with surveys conducted at the village scale in June – July 2013 and at the national/international scales from April – December 2014. Because of differing sizes and attributes of survey populations at each scale, different sampling techniques were applied. Transitions to agro-pastoral livelihoods have occurred in recent decades among Maasai in the semi-arid regions of northern Tanzania in response to state efforts to encourage sedentarization and cultivation (McCabe, Leslie, & DeLuca, 2010). Therefore, villages were purposively selected in the districts of Monduli (predominantly agro-pastoral, less arid, higher elevation) and Longido (higher proportion of pastoral, more arid, lower elevation) to capture a range of agro-pastoral and pastoral contexts. Five villages in each district were selected in consultation with the district Climate Change Focal Points. These were individuals appointed as the project contact person in each of the district offices under the Devolved Climate Change Adaptation Fund project (which was one of the projects used as an entry point for this research). Specific villages were selected in relation to two criteria. Recognizing that distance from paved / primary roads plays a significant role in determining livelihood strategies and mixes in Maasai areas (Homewood et al., 2011), villages were selected to include both those that are close to and far from paved roadways. For the second criteria, sample villages were selected to ensure a mixture of locations that were both moderately and severely impacted by the 2008/2009 drought to avoid perception bias.

Surveys were conducted at the household level (Swahili: *Boma,* pl. *Maboma*, Maa: *Olmarei*, pl. *Ilmareita*), which is here defined as a polygamous unit including a man, his wives, children, and other dependents (see M.J. Goldman & Riosmena, 2013). Sampling was conducted using a cluster sampling approach in which a total of n=20 surveys were conducted in each village across a total of 10 villages (5 in each district). A map of the survey sites is provided in Section 5.2. A total of 200 responses were collected and 2 were discarded due to data quality issues. Responses were weighted to account for variation in the total village populations (see Chapter 5 for additional detail). Respondents were selected using a randomized walk pattern with replacement, alternating between male heads of household and female heads of household (when this was the case) or senior females in the household (first wife of head of household). While the heads of household in Maasai communities are predominantly men, who also manage the most valuable household assets (the majority of cattle and livestock), it is increasingly recognized that women are playing a growing role in diversifying livelihood strategies (Homewood et al., 2009). Additionally, women are also highly impacted by variations in climate since they remain at the homestead and manage food and water resources for household consumption. Surveys at the village scale were administered by local enumerators, under the supervision of myself and another University of Colorado graduate student, along with two head research assistants who were fluent in English, Swahili, and Maa to assist with translation as needed.

At the international and national scales of analysis, sample frames were developed based on professional roles, affiliations, and organizational or group membership, (e.g., adaptation working groups, technical committees, etc.). Sample frames were developed around three categories of actors: government officials, NGO practitioners, and climate experts/scientists. These frames were developed through the combination of two approaches. The first involved consultations with several key informants within the Tanzanian Meteorological Agency (TMA) to develop a comprehensive list of individuals from: 1) national ministries, departments, and agencies, 2) national and international non-governmental organizations who are the intended beneficiaries of weather and climate services they produce, and 3) climate scientists or other technical experts. The second approach was to use a comprehensive online compendium of non-governmental organizations in East Africa compiled by the World Association of Non-Governmental Organizations (WANGO, http://wango.org/resources.aspx?section=ngodir&sub=region&regionID=14&col=ABC875, accessed October 2013) to identify appropriate organizations to include in the sampling frame. Because of the large number of NGOs operating in Tanzania and the breadth of the respective scope of activities, it was necessary to filter the organizations according to the following criteria, to ensure relevance: 1) conduct of at least some activities / programming in the Arusha Region (where Longido and Monduli districts are located), and 2) primary focus of programming included work on climate change, natural resources, conservation, or development. Savings and Credit Co-Operatives (SACCOs) were excluded from the sample frame. The results of these two approaches were combined to generate a master sampling frame. Because this resulted in relatively small survey populations (<50 at each scale), all individuals in the survey frame were included in the sample, rather than conducting randomized sampling (see Dillman et al., 2008, p. 59). A summary of the survey universe, population, and respondents for the national and international surveys is included in the table below. Respondents were contacted first by email, with 2 rounds of follow up. If respondents did not reply to email recruitment, they were contacted by telephone whenever possible.

Respondent Category	# of Respondents in Survey Frame	# of Respondents	Response Rate
National Ministries, Departments, and Agencies	12	6	50%
Climate Experts / Scientists	15	6	40%
National NGOs	30	11	36.7%
International NGOs	19	7	36.8%
Total	**76**	**30**	**39.5%**

Table 4: Summary of national and international survey frames, number of respondents, and response rates

Survey questions include questions about: general demographic information (e.g., level of education, wealth indicators), role of climate in livelihood or professional responsibilities, access to and use of climate knowledge (past and present) including what sources of knowledge are used, where they come from, and how these are communicated. Additionally, a number of questions in the survey operationalized the KSC framework to assess what information is considered ‘usable’ by respondents at different scales and why. Survey responses were translated from Swahili to English (by the author) and digitized from hand-filled paper survey forms (by myself and another

University of Colorado graduate student). They were then formatted, when necessary (i.e., put in ordinal or numerical formats), and cleaned to input into STATA statistical data analysis software by myself.

4.4.2 Planned Discussion Groups

In general terms, Planned Discussion Groups (PDGs) bring a number of participants together (generally between 4 and 12) to discuss a certain topic of interest and are most frequently conducted in a field site or otherwise familiar settings (O'Reilly, 2005). A group setting as created by PDGs can offer the opportunity to allow ideas to emerge, identify areas of consensus, as well as negotiate divergences, allowing topics that may not have otherwise been considered to emerge – a process likely to provide deep insight about opportunities and challenges to knowledge co-production. PDGs were conducted at each unit of analysis (village, national, international) and focused on exploring perceptions of: 1) what climate knowledge they currently have access to, 2) where the knowledge comes from, 3) how they use the knowledge, and 4) what they consider to be 'valid' knowledge and why using the KSC framework.

Groups at the village level were stratified across gender, age, and class to elicit multiple perspectives, allowing for in depth exploration of similarities and differences across them. Four focus groups were conducted in each village (Kiserian and Arkaria, total n=11) in September – December 2013. A focus group was conducted for each of the following social groups to assure freedom of expression of participants: 1) male elders, 2) male youth, 3) female elders and youth, and 4) a mixed participant group. With the help of key informants in each village (Village Chairman and Village Executive Officer), participants were selected to represent a range of socio-economic status within each of these groups, and participants were drawn across all sub-villages in both villages (there are 4 sub-villages in each of the villages). I facilitated the focus groups with the assistance of a translator to help from translation from Maa to either Swahili or English. Focus groups were conducted in a mixture of Swahili and Maasai.

At the national and international scales, two PDGs were conducted (n=2). Participants in the groups were comprised of 1) national NGO staff members and 2) a mixture of government officials, climate scientists / experts, and international NGO staff members. I facilitated the focus groups, which were conducted in a mixture of Swahili and English.

Data from PDGs was recorded through field notes, which were taken by hand during the group discussions and written up electronically following the group meetings. Additionally, meetings were audio recorded with the permission of participants to allow for additional analysis. Village scale recordings were transcribed and translated with the assistance of a local research assistant (this was the same research assistant who assisted with translation during the actual focus groups, so he was present for all of these). National and international scale recordings were transcribed and translated by myself. Transcripts were then coded to identify: 1) what knowledge is produced and how it is accessed, 2) who it is produced by / where it comes from, 3) how knowledge is used. Transcripts were further coded in relation to the KSC framework, to identify the various ways in which salience, credibility, and legitimacy were perceived among respondents and to analyze both convergences and divergences in opinions.

Scale	# of PDGs	Participants
Village	11	Female elders, female youths, male elders, male youths, mixed age/gender (at least one focus group was arranged for each of these categories, with representation of different socio-economic status in each)
National	1	Relevant staff members at national NGOs
National / International	1	Relevant staff members at: national ministries, research institutes / universities, national and international NGOs

Table 5: Overview of planned discussion group sampling at all scales

4.4.3 Interviews

An initial round of mixed individual and group interviews were conducted with elders in each of the 10 villages (at least one interview in each of the villages) included in the survey in both Longido and Moduli districts in June – July 2013. Respondents were selected through opportunistic sampling. This included both mixed groups of male and female elders, as well as separate groups in several locations, resulting in a total of n=12 interviews. Interviews focused on 1) the impacts of weather and climate on livelihoods, 2) understanding of seasonality, 3) ways in which weather and climate are predicted, 4) ways in which changes in weather, seasons, or climate affected their decision-making, and 5) receipt of scientific or other 'outside' information.

Additional semi-structured interviews were conducted in 2 villages (Kiserian – Longido District, Arkaria – Monduli District) to enhance understanding of: 1) what kinds of climate knowledge are currently produced, accessed, and used and by whom, 2) who has access to what types of knowledge and how, and 3) how such knowledge is used within decision-making, both currently and in the past, 4) specific attributes of knowledge that relate to the KSC framework, and 5) exploration of the tradeoffs between knowledge system criteria and how this influences knowledge use. In each village, 3 elder men, 3 elder women, 3 male youths, and 3 female youths were interviewed (n=12 interviews per village) with respondents being opportunistically sampled, although respondents were from different sub-villages. Questions included within the interview protocols were developed based on survey and discussion group data, in order to further interrogate conceptions of credibility, salience, and legitimacy of knowledge, as well as tradeoffs among these. Interviews were conducted at multiple scales (village, national, and international) with n=12 interviews in each of the 2 villages (total n=24). Interviews at the village scale were stratified across age and gender. A total of n=12 interviewees total for both national and international scales of analysis, with n=4 interviews conducted among 1) government officials, 2) climate experts / scientists, and 3) NGO staff members. Interviews were conducted until 'saturation' was reached, such that interviews began to cover same data repeatedly or else do not offer new data, see Dillman et al. 2009, p. 67). A total of n=36 semi-structured interviews were conducted across all scales combined.

Scale	Interviews (n)	Interviewees
Village	24 (n=12 Kiserian – Longido, n=12 Arkaria, Monduli)	6 elder males, 6 male youths, 6 elder females, 6 female youths
National / International	12	4 national government officials, 4 climate experts / scientists, 4 international NGO staff members
Total	**36**	

Table 6: Overview of semi-structured interviews conducted at all scales

An additional 38 non-structured interviews were conducted throughout the course of the data collection, with n=26 interviews among government officials, n=9 interviews among NGOs, and n=3 among climate experts / scientists.

4.4.4 Ethnographic Observation

Power relations and epistemological orientations are crucial determinants in shaping knowledge production and use, and are frequently expressed through everyday interactions between individuals, groups of individuals, and institutions. Such interactions are not easily explained through direct modes of inquiry (such as surveys or formal interviews) and require ethnographic methods to observe and record details of how events unfold and change within the course of daily life (Lofland et al., 2006). Two types of ethnographic observation were employed in this project: 1) non-structured observation — to understand how knowledge is produced and used within everyday contexts and 2) structured observation — to understand how relations of power are expressed across epistemological and institutional scales within explicit processes of adaptation planning that bring together actors across epistemologies and scales (e.g., workshops, meetings, trainings, conferences).

Non-structured observation was undertaken at village scale through participant observation for a cumulative duration of 6 months between June 2013 and September 2015 in the villages of Kiserian (Longido) and Arkaria (Monduli). I am relatively fluent in Swahili so was able to conduct many conversations and much of the observation on my own. However, because I do not speak Maa, I had a local research assistant with me to help with translation from Maa to English or Swahili as needed. The research assistant was Maasai, but was not a resident in either of the research sites. While visiting the villages, I stayed with two particular households, sometimes staying inside their home, but more often pitching a tent directly adjacent to the household. I ate all meals with these families. This enabled both the opportunity and freedom to conduct observations, but also the privacy needed to be able to write up notes, etc. During this time, I accompanied individual village residents at the village scale to observe how they manage assets and allocate resources (e.g., buy/sell livestock, migrate cattle, plant supplementary crops). Observation at the village scale included participating in day-to-day activities, such as moving cattle, searching for pasture, and going to markets. This was supplemented with informal interviews regarding the ways in which pastoral/agro-pastoral community members make decisions about managing their assets and what type of knowledge is used, when, and how to inform these decisions, within the context of broader social and environmental change (e.g., changes in institutions, legal constraints on resource access). Observation was timed around key annual decision-making points related to weather and climate patterns, such as the beginning of the short-rains, and also to observe livelihood practices throughout the course of the year.

Non-structured observation was conducted at the national scale through non-participant observation of the production of scientific climate knowledge primarily at the Tanzania Meteorological Agency (TMA), with shorter visits to other government offices for meetings related to forecast interpretation and use. This involved shadowing the professional activities of climate experts and scientists for a total of three weeks in August – September 2015. This was conducted to coincide with the production of the seasonal forecast for the October, November, December 2015 season, as well as forums for government and NGO decision-makers to discuss and decide how the climate forecast should be used to inform practical decisions.

Structured observation at the national and international scale entailed participation in events designed to facilitate knowledge exchange across scales. This included events such as the meetings of District adaptation planning groups, adaptation conferences, and training workshops, which brought individuals rooted in varying epistemologies or who are operating at different scales together to facilitate dialogue on the topic of climate knowledge. A full list of the types of meetings, locations, and dates is provided in Appendix 2. Data from structured observation was recorded in field notes, which were taken by hand myself and then written up electronically, or else typed directly into the computer when possible.

4.5 On Reflection and Reflecting

Earlier in this chapter, I made several assertions about the conduct of research, and the methods involved therein: 1) researchers themselves must recognize their own situatedness and entanglement in webs of relations and power, 2) all knowledge, even the most 'rigorous' or 'well-designed' research, is partial, and 3) research methods not only describe the phenomena they study, they also produce it. During the course of this research, the importance of these was repeatedly illustrated.

As a white, American, female Ph.D. student, relatively fluent in Swahili I was allowed access to an array of research settings, from household kitchens in the village, to high level international meetings. Indeed, conducting this research revolved around my ability to negotiate access to these different settings. However, acquiring such access was itself bound up with complex relations that sometimes made for uncomfortable realizations about my privileged position. Conducting the research involved both emphasizing my status as 'just a student', while also taking measures to shore up my standing to be seen as a knowledgeable expert who should be granted respect.

Differential relations of power are a fundamental consideration within instrumental efforts toward co-production. Of course, observing how these dynamics manifest through practices, enactments, positionality, speech, written words, material objects, etc. is a complex enough task. Yet, it would be wrong to assume that it is possible for me to be a neutral or invisible observer of these interactions. Rather, I was always part of the constellation of actors implicated in how these interrelations were expressed and how this translated to the exercise of power. My perceived role was, of course, variable depending on the setting in which I was observing – or rather, the ways in which my role was perceived and how this influenced my own identity was dependent upon the shifting sets of relations that I found myself entangled in, which shifted over time in various ways.

For example, near the end of my data collection, I was hired to conduct some research for the Norwegian Center for International Climate and Environmental Research – Oslo (CICERO) to contribute toward policy and institutional analyses, as well as conducting evaluations to assess 'user' satisfaction with climate services produced under the GFCS-APA. While my role was still as a researcher (rather than an implementing partner), this new affiliation resulted in a distinct shift in how I was viewed and received within meetings and other interactions within the project. Because the program was Norwegian-funded, and because of Norway's well-known affluence and generous development aid budget, my affiliation with a Norwegian research institute led many actors involved in the program to believe that I 'held the purse strings.' As such, I was instantaneously embedded within a new set of associations, both real and presumed. This resulted in several tense interactions during meetings in which multiple program partners sought to push for me to provide additional funding to the program or to divert some of my institute's funding to support national level partners – despite the fact that I had no control over budget allocations and that our institution had the smallest portion of budget allocation among any of the international program partners. Yet, during similar meetings the year prior, I was barely even acknowledged as an observer and was granted no authority as a participant.

Furthermore, because of the way in which the GFCS-APA program governance was structured, I, as a junior researcher without a Ph.D., was responsible for sub-contracting and overseeing research deliverables produced jointly with a senior Tanzanian researcher. This was uncomfortable for several reasons. First, I was acutely aware of the fact that because I was an *mzungu* (foreign, white person) and came from a rich, developed country and was affiliated with an international research institution, I was automatically granted a disproportionate level of status relative to my credentials and experience. The arrangement smacked of neocolonialism. At the same time, because of the extremely hierarchical and gendered nature of Tanzanian society and the fact that I was a (relatively) young female, I was also frequently dismissed or ignored in formal settings. This illustrated my own intersectionality and the fluidity of how power relations were expressed. I found myself simultaneously situated within a multiplicity of networks composed of differing social and material components, which resulted in multiple identities which were at times imposed, at other times actively projected – and which I was at times able to use to my own benefit.

The second assertion put forth at the beginning of this chapter was that as researchers, we must recognize that all knowledge is partial – even our own. I will admit that at the outset of this project, I firmly believed that through the triangulation of multiple well-designed and rigorously implement research methods, I would be able to access a single 'true' depiction of the worlds I was seeking to study. However, the more data that I accumulated, the more cracks, fissures, and gaps became evident. As some parts of the picture came into focus, others were obscured or blurred. This is not to say that my understanding of these issues did not increase over time. Rather, it is to say that the more I learned, the more I gained a sense of humility. I recognized that not everything that I was observing would necessarily fit into the well-defined and 'systematic' research plan I had devised. There needed to be room for overflows and contradictions, as well as a recognition that there would always be absences in what I might be able to translate into transcriptions – words on a page. Thus, while I hope that this dissertation can shed light on the issues I've sought to examine, I recognize that it can never be more than a partial accounting.

Finally, it is necessary to recognize that the ways in which we conduct research not only describe the world(s) we seek to study, but they also play an active role in *bringing them into* *being*. For example, while this study recognized the need to move within and across 'traditional' notions of scale, in its very design, it often drew or reinscribed boundaries it sought to overcome. Part of this was the sheer practicality of needing to identify a starting point, even it if it was a relative one. I started with institutional scales to orient data collection strategies. Yet, from the very outset, this required 'locating' individuals, events, material objects, phenomena at particular scales. This became an immediate challenge. How do you categorize a Tanzanian who grew up in a village, but works for the country-level office of an international NGO? What is to be made of a Tanzanian climate scientist who spent twenty years in Geneva, who has brushed elbows with world leaders and eats his *ugali* (starchy staple food) with a fork rather than his fingers? Is he 'national' or 'international'? What can be said about an organization that receives most of its funding from international donors, but operates at the 'grass roots' level? How do you distill the production and flow of knowledge down to simple or linear pathways, when such translations are often diffuse and meandering, with the need for both material and discursive practices to fully take shape?

Despite recognizing these complexities, it was often necessary to make a decision about where these actors were deemed to 'fit' in order to determine what 'position' they were representing. Yet, these determinations have ramifications. They solidify particular subjectivities and propagate them through representations in the form of research findings. While I have sought to question and add complexity to these designations in the following chapters, there are also lapses.

CHAPTER 5: Knowledge Production, Access, and Use Across Institutional Scales

5.1 Introduction

'Gaps' in knowledge are frequently cited as barriers to effective climate change adaptation (e.g. Mastrandrea et al., 2010). Additionally, because climate change adaptation is a complex issue that spans physical, environmental, social, political, and cultural realms, there is often discussion of the need to 'bridge the gap' between science and action, as well as between different 'kinds' of knowledge (Alexander et al., 2011; Buizer et al., 2010). Increased delivery of improved scientific climate knowledge and processes of knowledge co-production are often cited as a means of addressing this two-fold problem (Mitchell et al., 2006). Yet, in most cases, these 'gaps' are assumed rather than fully assessed and explored and there is little understanding of what kinds of knowledge are already being produced, how this circulates and is accessed, and what it is used for (or not).

This is problematic considering the significant amount of resources that are being dedicated to improving 'flows' of existing climate information, as well as the creation of new climate services, decision-support tools, and modes of engaging 'end-users'. This is reflected, for example, in the significant financial investments being made in the climate services more broadly, as well as the emphasis on the development of 'user interface platforms' within the Global Framework for Climate Services (GFCS) (WMO, 2011). In this chapter, present a snapshot of the broader knowledge landscape for climate adaptation in Tanzania and present the results of a multi-sited survey. This survey assesses what knowledge is available for climate adaptation decision-making, how it is produced, how it is received or accessed, whether or not it is used, and for what purposes, among a range of actors situated at different institutional scales. Specifically, this chapter addresses Research Objective 1 and related research questions (see Chapter 1), which aim to examine the current production, circulation, access, and use of knowledge for climate adaptation in Tanzania.

The chapter will be structured as follows: I will first provide a brief overview of the methods (see Section 4.5.1 for additional detail) and description of the analysis. Next, I will present results, which will be organized in terms of the: 1) production, 2) circulation and access, and 3) application and use of knowledge. Further, findings are presented along scalar designations (i.e., international, national, and village). While this structure was adopted for purposes of clarity and readability, it is necessary to recognize that, following Goldman et al. (2011), processes of the production, circulation, and application of knowledge are inseparable — a feature that will be discussed in more detail in Chapters 6 and 7. Further, designations of scale are problematic, since survey respondents cannot necessarily be definitively labeled as 'being' at just one scale. Rather, all respondents embody a multiplicity of identities (both explicitly and implicitly) that transcend clear-cut notions of who might be considered an 'international', 'national', or 'village' scale respondent. This will be followed by a discussion and interpretation of results and conclusion.

Findings illustrate that while there are some 'gaps' in knowledge about climate change, these exist amidst existing flows of multiple knowledges, whose relationships are complex and enmeshed. This knowledge travels through both formal and informal pathways, resulting in 'assemblages' of knowledge that reflect the multiple and diffuse ways in which knowledge is produced, circulated, and applied. This complicates standard depictions that tend to assume that 'different' knowledges are compartmentalized, with strict boundaries between 'scientific' and 'other' knowledges (i.e., local, indigenous, lay, tacit), and that knowledge travels in linear, domesticated, and standardized ways. Instead, these findings show that the knowledge of actors at all scales is drawn from a multiplicity of sources and reflects the socialized processes of knowledge production, circulation, and use. At the same time, these findings highlight that there are disparities in access to knowledge that are rooted in social, cultural, and political — as well as material and physical — determinants. I will conclude by reflecting upon these findings in relation to the dominant ways in which instrumental co-production is currently framed.

5.2 Data Collection and Analysis

5.2.1 Data Collection

The survey was conducted at the village and the national scales in Tanzania, with village scale surveys collected in July – August 2013 and national and international scale surveys collected between December 2013 – August 2014. Survey questions focused on the production, transmission, access, and use of knowledge about weather and climate change (see Appendix 1 for the full survey protocol). Surveys also included questions about basic demographics and socio-economic status. The village level surveys were conducted in the districts of Longido and Monduli. In each district, 5 villages were selected for inclusion in the survey, in consultation with district officials (see Figure 2). Villages were selected based on 2 criteria: 1) distance from a major paved road and 2) level of impact experienced during the 2008/09 drought. Villages were selected to include locations that were near to and far from major roads. Villages were selected to include both locations that were moderately and least affected by the 2008/09 drought to minimize response bias. Surveys were translated from English into Swahili[5] by an independent translator and were then back-translated to ensure consistency and accuracy of meaning. Surveys were administered by 8 enumerators (7 males, 1 female) who were fluent in both Swahili and Maa.

[5] Because Maa is not typically used as a written language, translating to Swahili was preferable, since many of the enumerators had difficulty reading Maa and most respondents understand at least some Swahili. Enumerators jointly discussed translations to Maa, which helped to ensure consistency of translation across surveys.

Surveys were administered in Swahili, or translated orally to Maa, depending on the preference of the respondent.

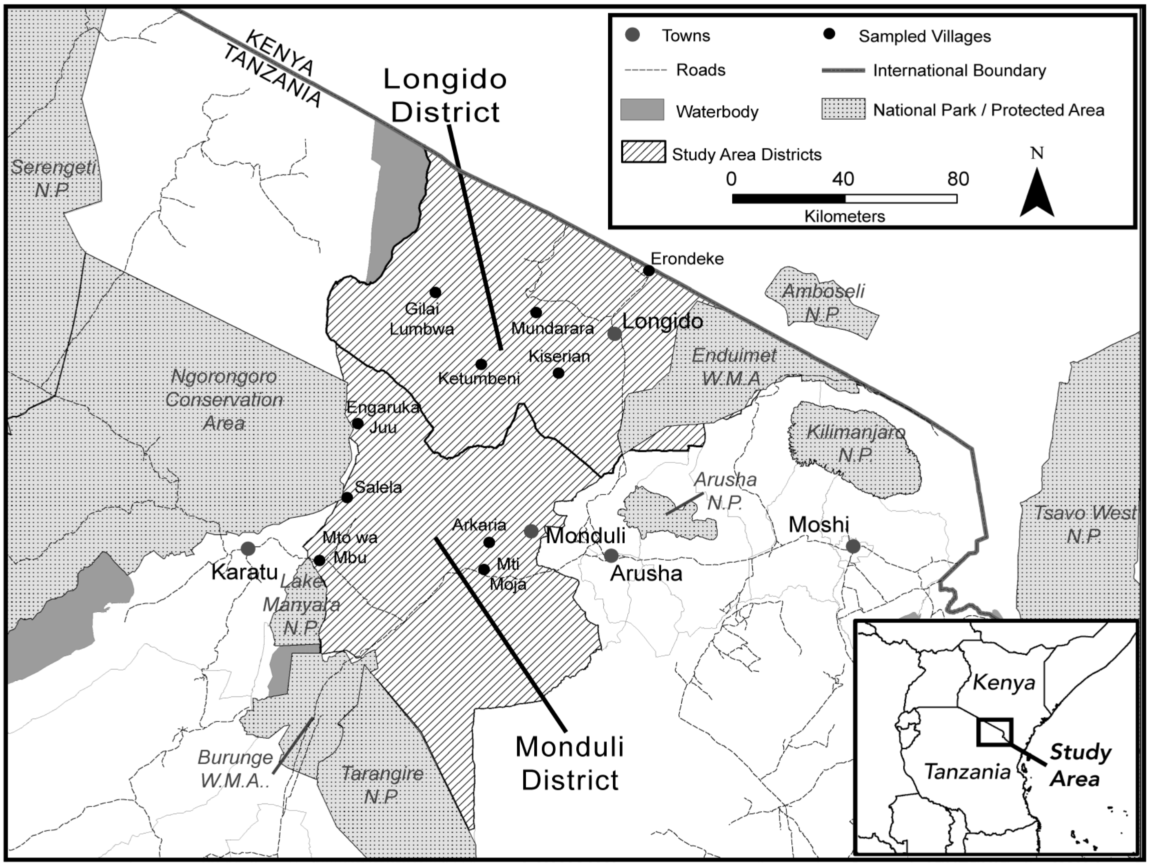

Figure 2: Map of villages in Monduli and Longido Districts included in the survey (Map: Eric Lovell)

A clustered sampling methodology was used, with 20 respondents in each village. Cluster sampling was used instead of simple random sampling for practical and logistical purposes, since in these semi-arid locations the distances between households is large and there is often inaccurate or incomplete data available to generate reliable sample frames needed to conduct simple randomization. Within clusters, data was randomly collected by surveying heads of household through a random walk pattern. Enumerators alternated between male and female heads of household, with replacement.

At the international and national scales of analysis, sample frames were developed based on professional roles, affiliations, and organizational or group membership, (e.g., adaptation working groups, technical committees, etc.). Sample frames were developed around three categories of actors: government officials, NGO practitioners, and climate experts/scientists. Because this resulted in relatively small survey populations (<50 at each scale), all individuals in the survey frame were included in the sample, rather than conducting randomized sampling (see Dillman et al., 2008, p. 59).

5.2.2 Data Analysis

Survey responses were translated from Swahili to English (by the author) and digitized from hand-filled paper survey forms (by the author and another graduate student) and were then formatted when necessary (i.e., put in ordinal or numerical formats) and cleaned to input into STATA statistical data analysis software. Village scale surveys were weighted to account for the two-step (multi-stage) sampling strategy: 1) selection of villages from the total number of villages in each district and 2) selection of individuals from the total number of individuals in each village. Sampling fractions (proportion of the population being sampled) were calculated for each of these steps. Sampling fraction 1 (sf1) was calculated by dividing the total number of respondents sampled in each district (n=100) by the total population of the district. Sampling fraction 2 (sf2) was calculated by dividing the total number of respondents sampled in each village (n=20) by the total population of the village. Sampling fractions were used to calculate probability weights (p-weight) which are the inverse of the probability of being included in the sample due to the sampling design. Thus, the p-weight = 1 / (sf1 * sf2). The p-weight was applied to all village-level responses to adjust for different population size across sampling units. National and international scale surveys did not require similar adjustments, since they were purposively selected and cannot be assumed to be representative in strict statistical terms. Further, because the sample frames at the national and international scales were small, responses from these scales were combined (total combined n=30). Across the two scales, there was a combined 39.5% response rate. Descriptive statistics were generated using STATA basic commands.

5.3 Results: Knowledge Production

5.3.1 National and International Scale

Respondents were asked to discuss what individuals, institutions, or other entities that they are aware of that produce information about weather or climate change. Responses indicate that individuals at national and international scales generally rely on several sources to inform their knowledge about weather and climate change. Only 3% relied solely on one source of information, while 67% and 27% relied on 2 or 3 sources of knowledge production to information respectively (see Figure 3). The most frequently cited sources of climate knowledge production were TMA and international organizations (see Figure 4). A full list of all of the organizations or sources identified as producers of information about weather and long-term climate change are found in Tables 6 and 7.

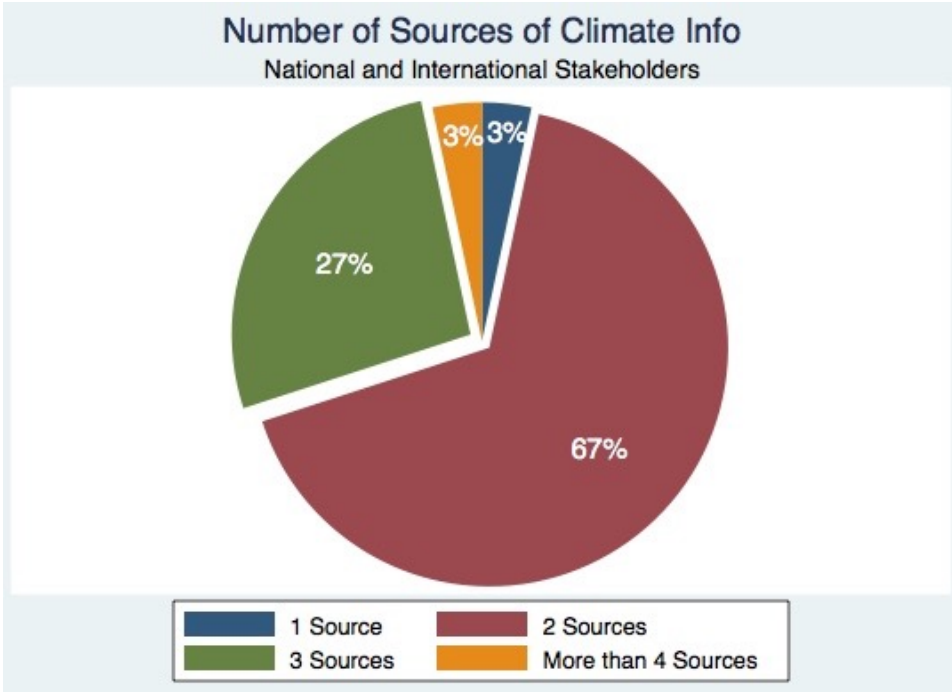

Figure 3: Total number of sources of climate information among national and international participants

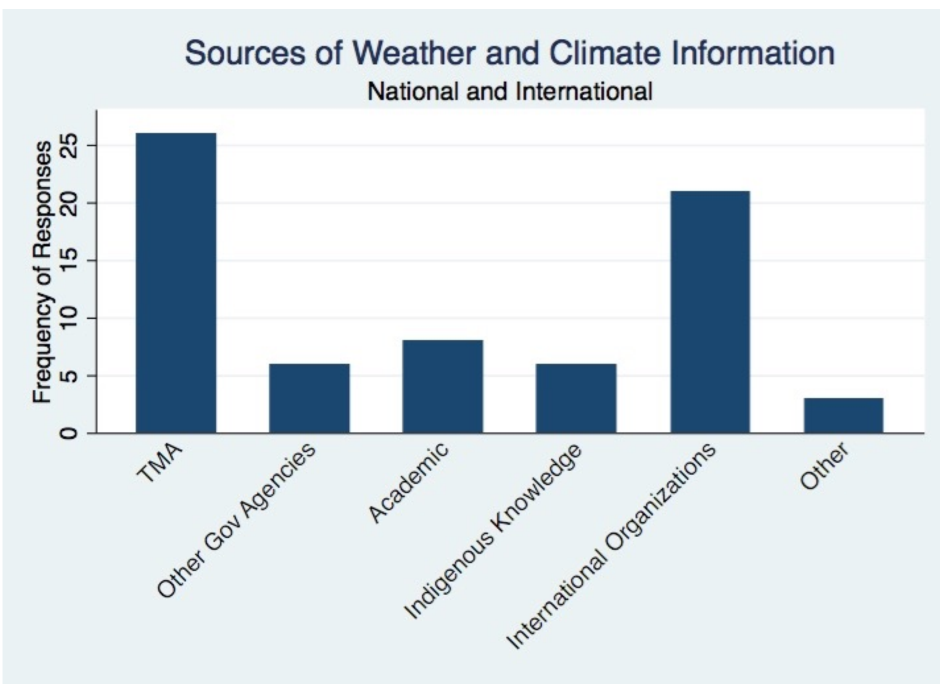

Figure 4: Sources of weather and climate information among national- and international-scale respondents

Sources within Tanzania	Sources Outside of Tanzania
Community-based Reports / Observations	Al Jazeera Weather
Early Warning Unit – Ministry of Agriculture and Food Security Cooperatives	BBC Weather
Indigenous Forecasters	CNN Weather
River Basin Authorities: various offices nationwide	European Centre for Medium-range Weather Forecasting (ECMWF)
Tanzania Meteorological Agency (TMA)	Famine Early Warning System Network (FEWS NET)
Tropical Pest Research Institute – Arusha	IGAD Climate Prediction and Applications Centre (ICPAC)
Zonal Agricultural Research Centers: various offices nationwide	International Research Institute for Climate and Society (IRI)
	Meteo France
	SADC Climate Services Centre
	South Africa Weather Service (SAWS)
	UK Meteorological Office (UK Met)
	US National Oceanographic and Atmospheric Administration (NOAA)
	Weather.Com

Table 7: Producers of weather and seasonal information for national and international stakeholders (in alphabetical order)

Sources within Tanzania	Sources Outside of Tanzania
Academic Institutions: University of Dar Es Salaam (UDSM) – Institute for Resource Assessment, Sokoine University of Agriculture (SUA)	Australian Bureau of Meteorology (BOMS)
Community-based Reports / Observations	Famine Early Warning System Network (FEWS NET)
Indigenous Knowledge	International Institute for Environment and Development (IIED)
Tanzania National Environment Management Committee (NEMC)	International Institute for Tropical Agriculture (IITA)
Tanzania National Resource Forum (TNRF)	International Livestock Research Institute (ILRI)
Tanzania Vice President's Office (VPO)	International Research Institute for Climate and Society (IRI)
	International Panel on Climate Change (IPCC)
	NASA – Goddard Institute for Space Studies
	Norwegian Meteorological Institute
	World Meteorological Organization (WMO)
	UK Department for International Development (DFID)
	UN Development Program (UNDP)
	UN Framework Convention on Climate Change (UNFCCC)
	UN International Strategy on Disaster Reduction (UNISDR)

Table 8: Producers of climate change information for national and international stakeholders (in alphabetical order)

When national and international scale respondents were asked specifically whether they felt that they themselves were producers or holders of indigenous knowledge, 50% indicated that they either possessed IK or that they received IK from others, which directly informed their own knowledge of weather and climate. There were many respondents who noted that they themselves were able to formulate indigenous predictions in their home place, but not necessarily in the location where they now reside. While the majority (60%) of national and international respondents no longer live in their home locations, most make frequent visits. On average, respondents' ancestors have lived for 80 years in the respondents' place of origin. 73% of respondents indicated that they visit a place of origin that is different than their current (urban) dwelling location, with an average of 8 visits home per year.

Respondents were also asked to assess the difficulty of predicting seasons currently, relatively to the past. In response, 25 out of 30 respondents (83%) indicated that they perceive it to more difficult to predict seasonal conditions than it was in the past. Those who felt it was more difficult to predict seasons described both scientific and indigenous predictions as being less effective now than they were in the past. Most believed that this is due to rapid changes associated with climate change, which have, consequently, made the seasons more difficult to predict. Those who felt that it was easier to predict seasons in the past stated that scientific and technological advances have made it easier to predict seasonal weather conditions presently.

5.3.2 Village Scale

At the village scale, a large percentage of respondents rely on a greater number of sources of information and observations to inform their knowledge of weather and climate change in the past; however, there was a larger variance in responses. For example, 60% of respondents rely on between 2 – 4 sources of information, while 18% of respondents rely on 5 or more sources of information (see Graph 3). Interestingly, 22% of respondents indicated that they relied on one source of information to inform their knowledge of weather and climate in the past, a much higher percentage than for national and international stakeholders.

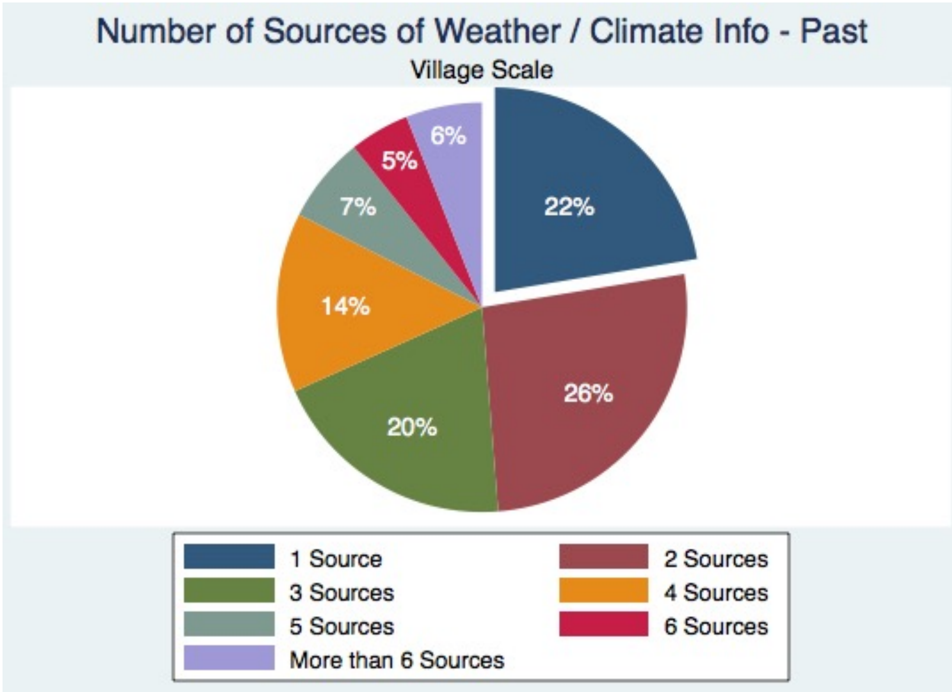

Figure 5: Total number of sources of climate information among village scale participants in the past

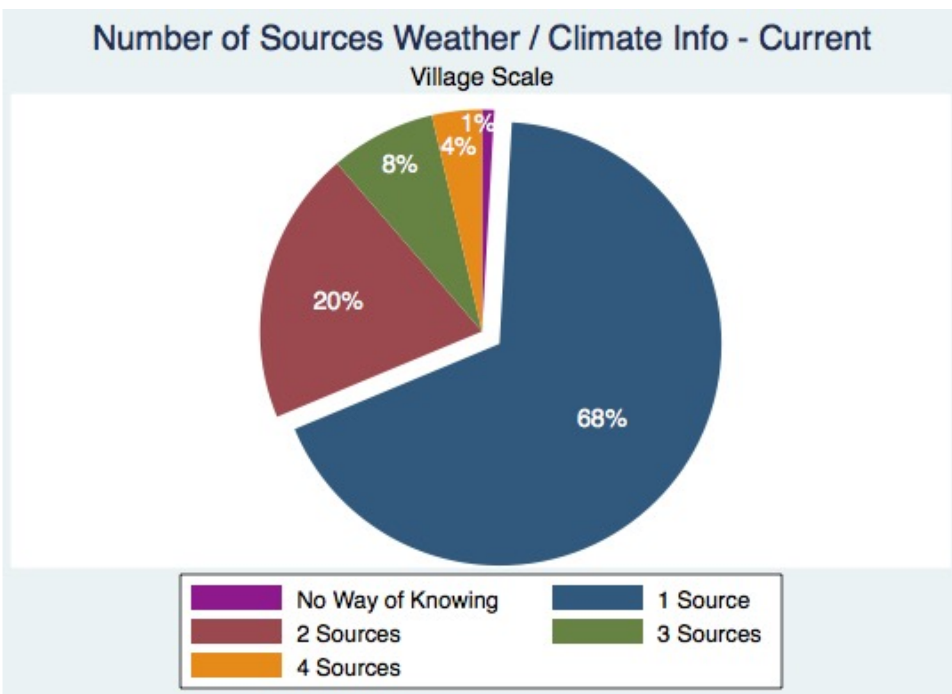

Figure 6: Total number of sources of climate knowledge relied upon among village participants currently

Village respondents were asked to list the specific ways of predicting weather that informs their knowledge, both in the past and currently. By far, the most frequent responses for ways of prediction that were used in the past were changes in patterns in the stars and moon and observed changes in plants. Changes in animals and animal behavior and advice from elders were tied as the next most frequent response for past prediction (see Figure 7). While many have argued that, due to issues of in-migration and relocations during the Ujamaa era, indigenous might not be applicable. However, respondents indicated that they and their families had lived in the region for 120 years on average. It is important to note, however, given recent tensions over land between pastoralists and farmers, there may have been an incentive to overstate the duration of their family's historical connection to a place or parcel of land.

Changes in patterns in the stars and moon and changes in plants were also the most frequent responses selected for ways of predicting weather used currently. However, the overall number of ways of predicting weather has decreased significantly compared with the past. In the case of stars and moon the frequency of responses decreased from 129 to 83 and changes in plants from 126 to 53 responses (see Figure 8). Similarly, reliance on observed changes in animal behavior and advice from elders also decreased significantly. Other producers of climate information that were mentioned in the survey were *oloiboni* (prophets), traditional calendars, counting months (using customary methods), and modern calendars.

What is clearly illustrated in the comparison of the pie charts comparing past and current sources of knowledge about weather and climate change (Figures 5 and 6), is that the total number of sources of knowledge that people are relying on have decreased dramatically. This decrease can be accounted for almost exclusively through the decreased used of particular sources or indicators used within IK, especially changes in observations of the stars and moon, changes in plants and animals, changes in animal behavior, and advice from elders. Outside sources of information included information delivered from mass media, as well as through other modes of transmission, including mobile phones, information from people coming from other places, seminars and workshops, etc. Additionally, reliance on weather in other places and common knowledge as ways of predicting weather has also decreased significantly.

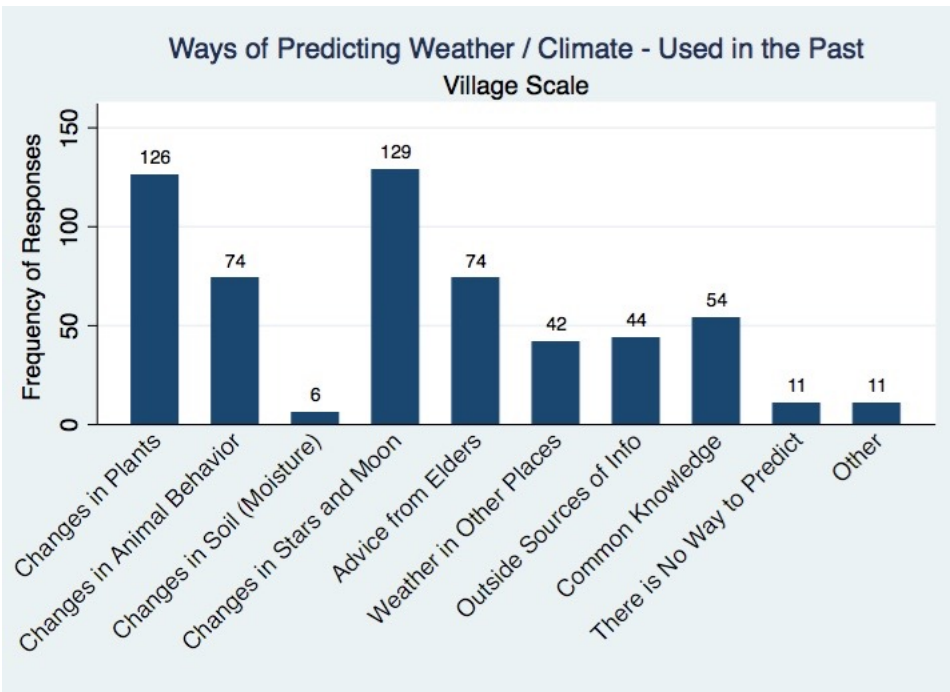

Figure 7: Ways of predicting weather used in the past by village participants

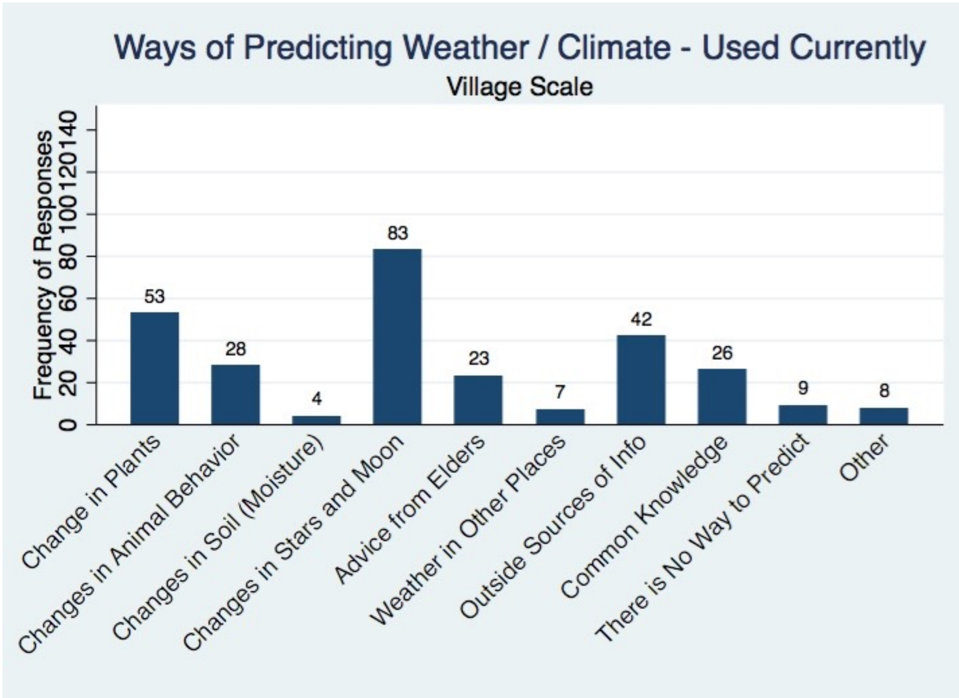

Figure 8: Ways of predicting weather used currently by village scale participants

At the same time, reliance on external sources of information to inform knowledge remained about constant (with a small decrease compared to the past). This indicates that while reliance on some indigenous ways of producing knowledge may be falling out of use, this gap is not being readily filled by scientific or other knowledge. This indicates an overall decrease in the sources informing knowledge of weather and climate change among village scale respondents. This result was robust across villages in both Longido and Monduli.

50% of respondents at the village scale have received external information about weather and climate at some point in the past. This is in contrast with only 24% who say that they actively incorporate this information within their general knowledge of weather and climate, meaning that a large portion of those who may have heard this information in the past either no longer receive it or they disregard it, issues which will be discussed further in Sections 2.2 and 2.3.

Despite the decrease in the production of indigenous predictions of weather and climate, there was large agreement among respondents in terms of observed changes in climate over the last several decades (approximately over the last 30 years). 92% of village scale respondents noted that it is now more difficult to predict the seasons than it was in the past, while 5% said that it was about equally difficult to predict the seasons now relative to the past. In addition, 87% of respondents reported that they had observed major changes in the seasons. 10% reported that they had observed slight changes in the seasons. Notably, none of the respondents reported that they had observed no change at all. The difficulty in predicting the seasons can largely be accounted for due to the perceived change in drought frequency and intensity. 92% of respondents stated that drought is now more frequent than it was in the past. Similarly, 92% of respondents stated that droughts are now more severe than they were in the past. In contrast, very few respondents reported experiencing an increase in the frequency (<10%) or severity (<10%) of flooding events.

The perceived changes in seasonality, as well as in frequency and severity of drought events, reported in the survey data across Monduli and Longido districts were corroborated by focus group discussion and interview data collected in the villages of Arkaria and Kiserian, as well as within interviews conducted with traditional leaders across all 10 survey data collection sites. There was wide agreement among respondents across location, gender, and age that the short rains (Swahili: *Vuli,* Maa: *Olkisirata*) were now considerably delayed (or sometimes failed completely) more often than in the past, while the long rains (Swahili: *Masika,* Maa: *Engakwai*) were also delayed and were also cut short relative to the past. For example, the vast majority of respondents reported that in the past, the short rains could be expected to begin in October and continue through December or January, when there would be a break in rainfall (Maa: *Oladalo*) through February. The long rains would then begin again in March and last through the end of May or early June. Nearly all respondents reported that the dry season generally used to last only three months – July, August, and September. However, some rain could be expected in highland areas as early as September. There was some debate about when the 'real' dry season used to begin, since July was often considered as part of the early dry season (Maa: *Koromare*). Many respondents did not judge the start of the 'real' dry season (Maa: *Alimei*) by the cessation of rainfall alone, but rather by a lack of milk, pasture, and water. There were, however, varying opinions about when these changes began. Most respondents reported observing these changes as long as 30 years ago. A fewer number reported observing significant changes in the early 1990's. Several respondents also noted that 1998, which was considered a "very hot year" (and also the strongest El Niño on record at the time of these interviews), was the beginning of noticeable changes in seasonality and drought.

Historical observations were very different than the currently observed conditions. While many respondents noted that in the past the rainy seasons were equal to or longer than the dry seasons, the situation has been reversed. It is now perceived that there are more dry months out of the year than rainy months. In both focus groups and interviews, it was reported that these days, the short rains do not begin until November or December – or that sometimes they do not come at all. It was also reported that in many cases, the long rains would not begin until the end of March or early April and would cut off by the end of May. Thus, rather than having 3-4 months of rain occurring between March – June, April and May were reported to be the only months where there was likely to be sufficient amounts of rainfall to support agriculture or pasture growth. Overall, the shorter duration of the both the short and long rainy seasons has resulted in a perceived decrease in the total annual amount of rainfall received.

5.4 Results: Knowledge Circulation and Access

5.4.1 National and International Scales

Respondents at the national and international scales reported receiving climate information through multiple modes (see Figure 9). Meetings, conferences, and written reports were most frequently listed as ways of receiving information about weather and climate change. This was closely followed by television and email. Additionally, many respondents reported receiving information through colleagues (70%) and friends and family (63%). This indicates that while the prominent means of receiving climate information may be through formal mechanisms, such as organized meetings, mass media, or institutional protocols, informal delivery also plays a strong role.

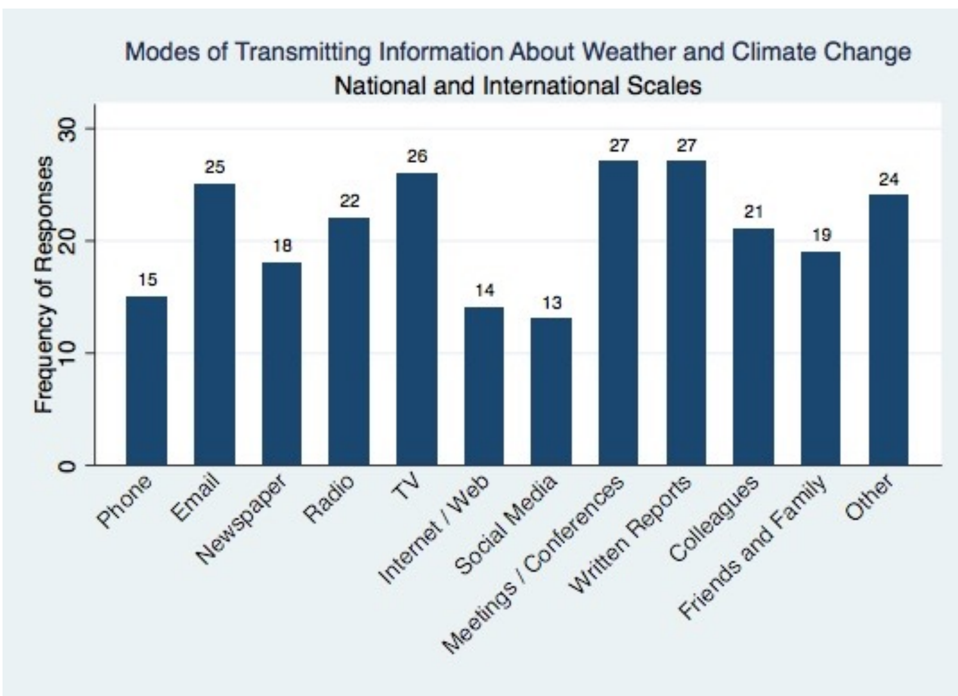

Figure 9: Modes of transmitting climate information among participants at the national and international scales

With regard to access of climate knowledge, the most frequent response was that individuals actively look for this information themselves (see Figure 10). Beyond that, delivery by colleagues and delivery by TMA directly were the next most frequent responses. In addition, 83% of respondents indicated that they are actively looking for new sources of information about weather and climate change. Other responses included the delivery through climate change networks and list-serves and through implementation of projects and programs. This indicates that much of the circulation of climate knowledge among national and international respondents is due to their own efforts to look for information.

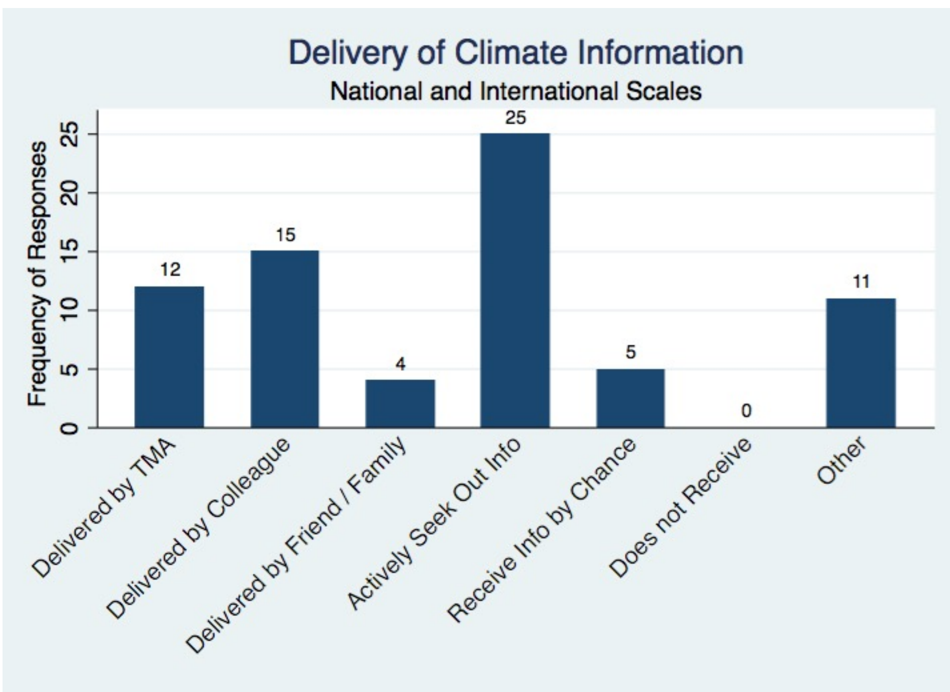

Figure 10: Delivery of climate information among participants at the national and international scales (Note: Respondents were asked to indicate if information was delivered to them and, if so, how. If they did not receive this information, they were also asked whether they actively sought out this information.)

Nearly half (48%) of respondents stated that they receive information about weather or climate change on a daily basis (see Figure 11). 10% received such information once a month, while 14% received it once a week. The remaining respondents (28%) stated that the frequency with which they received climate information was variable.

All respondents had received some information about climate change. However, many respondents indicated that while they have received a lot of information about the potential impacts of climate change, they have received little training about the scientific explanations of climate change. One national scale survey respondent stated that “Everyone is talking about climate change, but they don’t know what it means.” Most individuals indicated that the information they receive about climate changes is almost exclusively with regard to adaptation, with little attention to mitigation.

Additionally, many respondents indicated that while they have received information about climate change, they are also themselves observing and experiencing it through impacts on their personal and professional lives. For example, 33% of respondents engage in farming activities themselves, while over 50% keep livestock themselves and thus engage in climate-sensitive livelihood activities through which they gain experiential knowledge of weather and climate, even if their primary profession was an office-based job (see Figure 12). Nearly all respondents had someone in their immediate or extended family who farms or keeps livestock (see Figure 12).

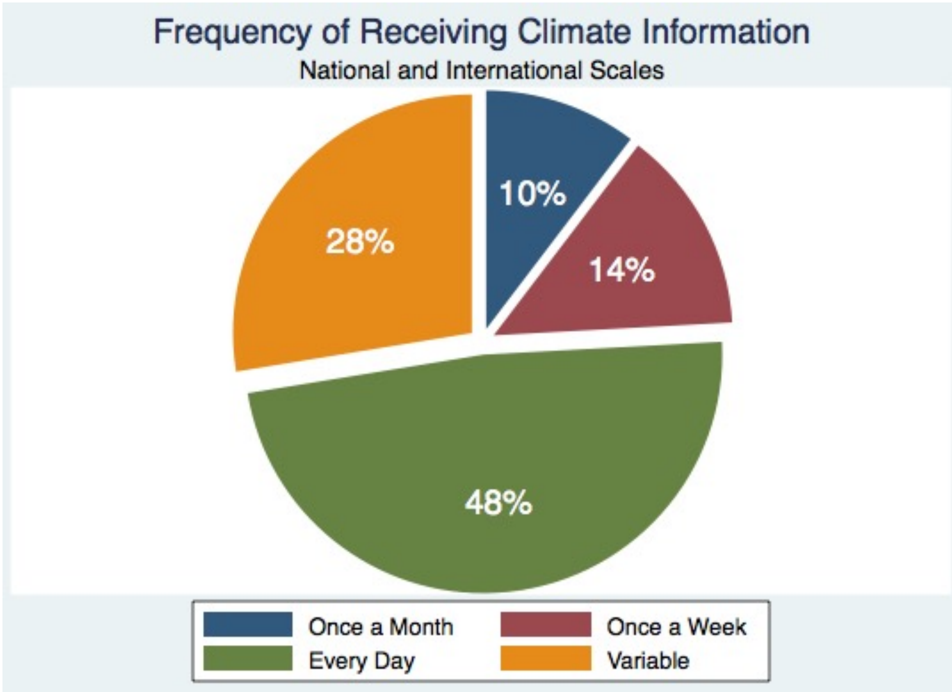

Figure 11: Frequency of receipt of climate information among respondents at the national and international scales

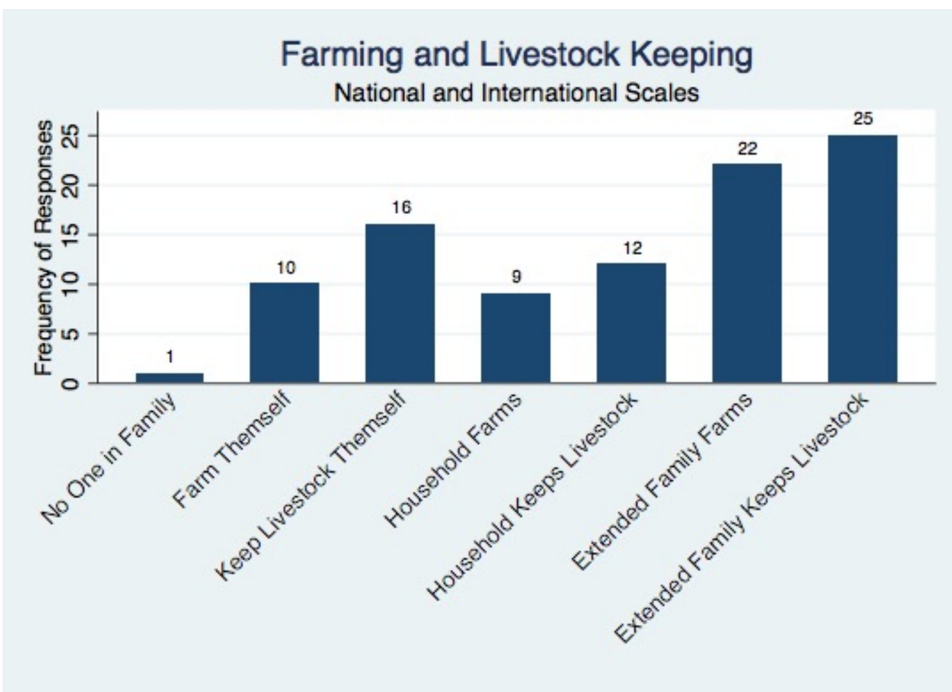

Figure 12: Farming and livestock keeping (personally and among family) among respondents at the national and international scales

In other examples, respondents noted that their day to day professional activities are affected by weather and climate. For example, the commute to the office may be hampered by heavy rains or the availability of electricity may be reduced when there is low rainfall. Many organizations with which respondents are affiliated work directly with communities and therefore experience the impacts of weather and climate indirectly, since this can affect the planning and implementation of their work. For example, many respondents discussed the difficulty of implementing trainings or workshops during heavy rains or extended drought. Others cited the difficulty of testing new development or adaptation strategies, such as improved agricultural techniques, since the 'success' of these trials might be evaluated during a particularly bad year.

Nearly all respondents at the national and international (97%) level indicated that they seek to share information about weather and climate with particular communities that they work with, or in some cases, the general public. Similarly, 97% of respondents also indicated that they have received information about weather and climate change from the communities they work with. The majority of this information is about the impacts of weather and climate change on livelihoods, rather than about weather conditions specifically (i.e. rainfall amounts).

Half (50%) of respondents at the national and international scale reported directly receiving reports of indigenous knowledge from communities. This knowledge was generally with relation to seasonal and short-term weather forecasts and historical knowledge. The receipt of this knowledge was in most cases reported to occur intermittently. However, several respondents noted that their organizations are undertaking research to better understand indigenous knowledge of weather and climate. When they do receive indigenous knowledge, respondents indicated that they share it with a wide range of stakeholders, generally informally. This includes: national government and ministry officials, regional and district governments, village early warning committees, researchers, and NGOs.

5.4.2 Village Scale

Among respondents at the village scale, radio is by far the most frequently cited means of receiving external or scientific information about weather and climate (see Figure 13). Other government agencies and NGOs were the most frequent responses, after radio. Extension agents were the least frequent way of receiving such information. Additionally, when asked to report the frequency with which climate information is received, 44% of all respondents said that they had never received such information (see Figure 14). 25% of respondents reported receiving information every day and 13% once per year. 5% reported that they have received external climate information just once. As such, the data indicates that nearly half of village respondents are not receiving external climate information on any regular basis. Thus, while radio was the most frequent means of receiving external information about weather, in total only 50% of the village scale respondents receive information this way. Together these various factors illustrate that receipt of scientific knowledge remains generally low across both districts, with significant variability in the frequency with which people receive information.

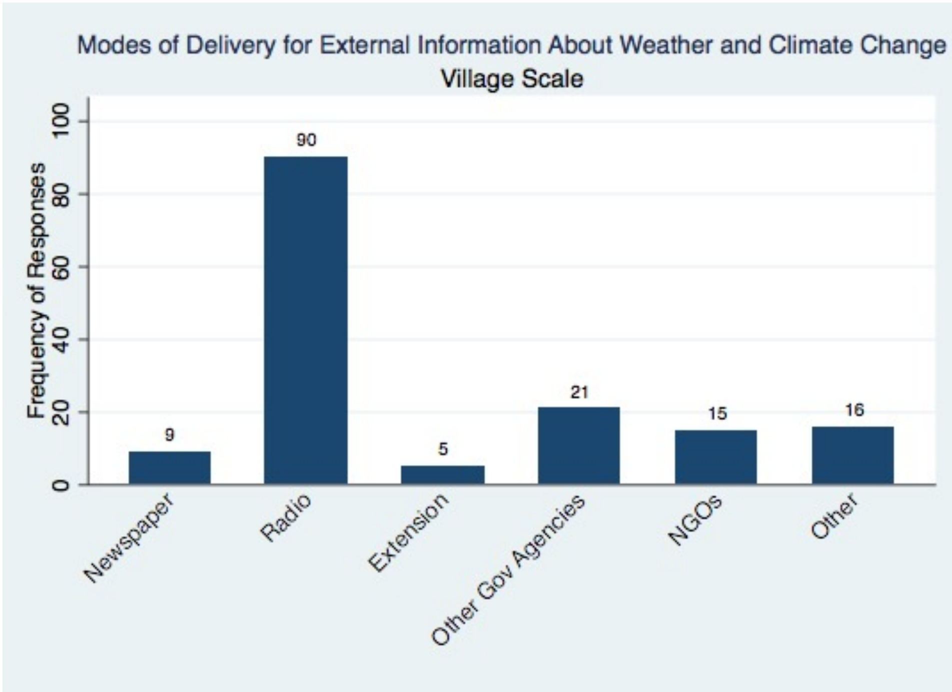

Figure 13: Modes of transmitting external information about weather and climate change among respondents at the village scale

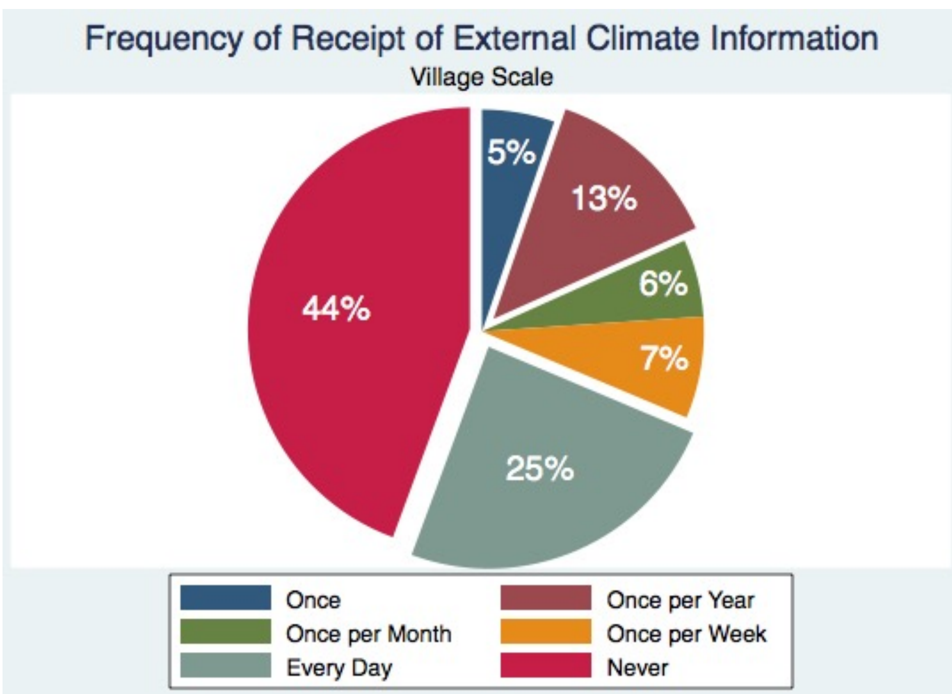

Figure 14: Frequency of receipt of information about weather and climate among respondents at the village scale

There were, however, some differences within these populations, with the receipt of information differing significantly between the districts and also based on gender across the districts. For example, while 53% of respondents in Longido reported never receiving climate information, only 41% said the same in Monduli (see Figure 15). Furthermore, there is a sharp divide along gender lines in terms of receipt of external information about weather and climate change. While 74% of men have received external climate information at some point in the past, only 45% percent of women reported the same (see Figure 16).

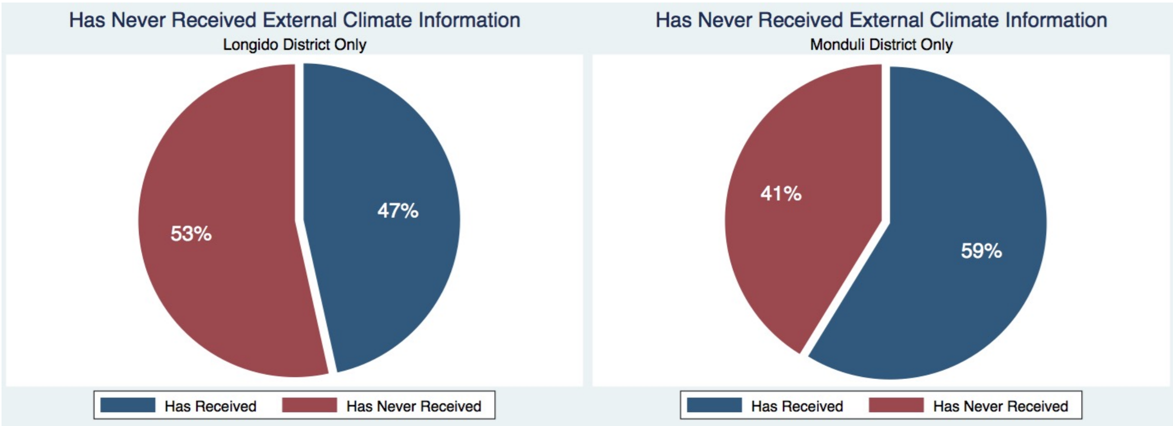

Figure 15: Percentages of respondents reporting they have never received external climate information among villages in Longido vs. Monduli districts respectively

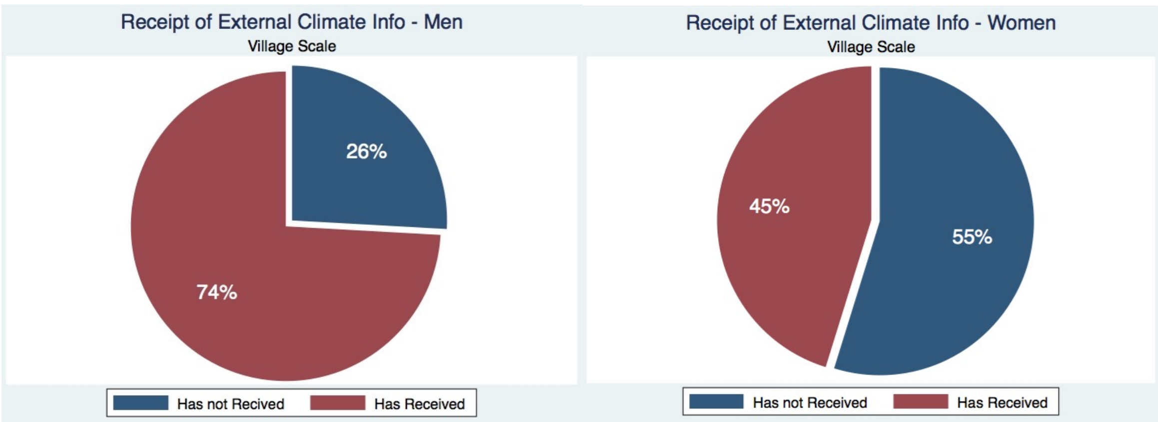

Figure 16: Receipt of external climate information among men and women respectively in Longido and Monduli

The majority of village scale respondents (69%) did not feel like there was a way to communicate impacts of weather and climate change to institutions at other scales (see Figure 15). Similarly, 72% of respondents at the village scale felt that there was no way to communicate indigenous knowledge about weather and climate change to governmental institutions at other scales so that it could, for example, be included in policies. For those who did feel that they were able to communicate indigenous knowledge, the vast majority were able to do so through customary, village government, and project implementation meetings. Some respondents said that the inability to communicate indigenous knowledge at other scales was in part due to the fact that there is no formal mechanism for communicating this knowledge.

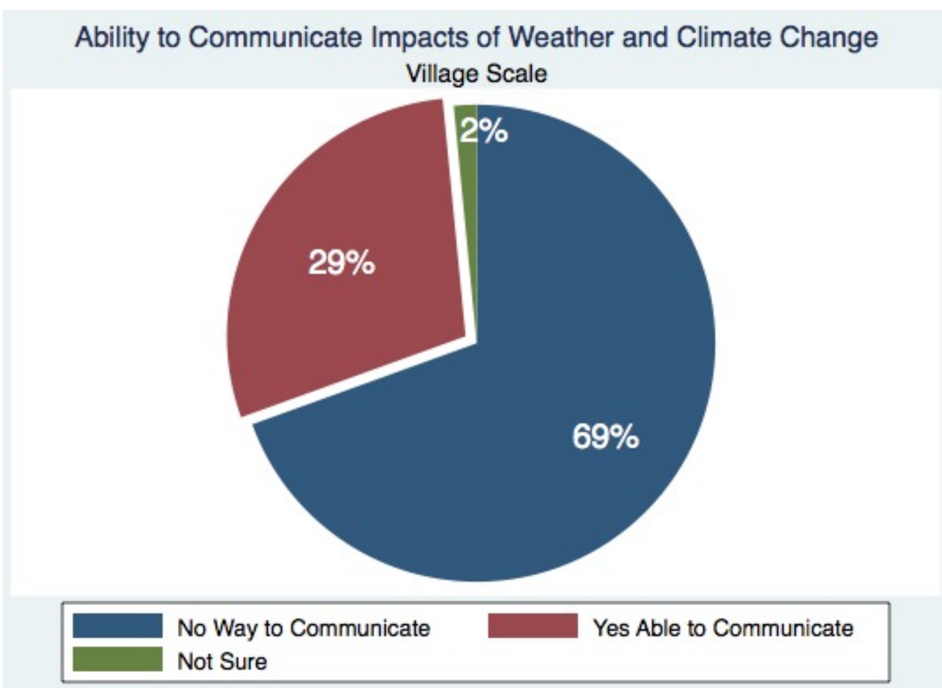

Figure 17: Perceptions of village scale respondents about their ability to communicate impacts of weather and climate change to institutions at other scales

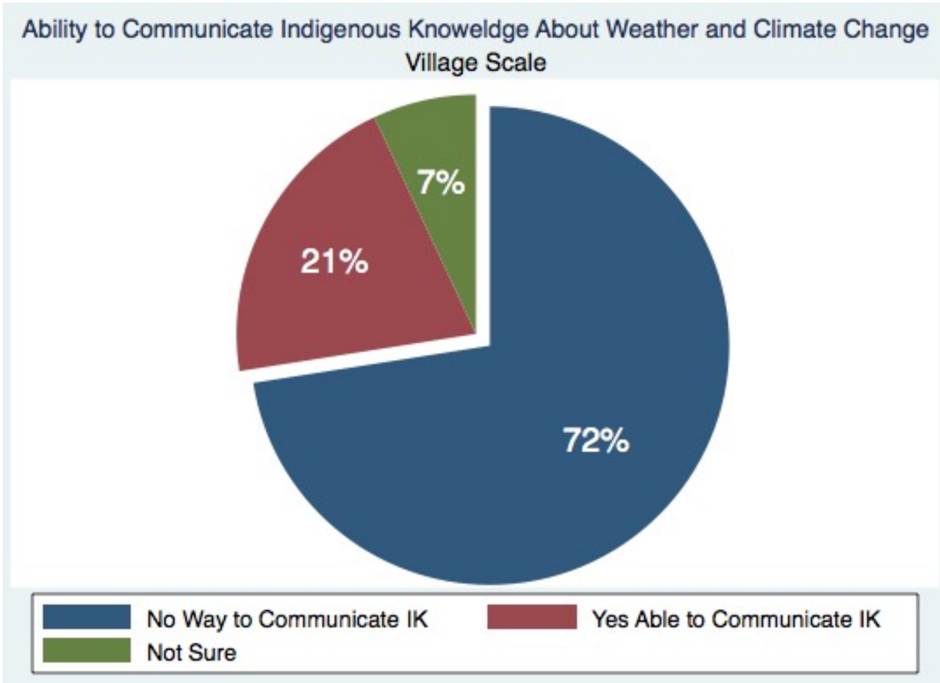

Figure 18: Perceptions of village scale respondents about their ability to communicate indigenous knowledge to institutions at other scales

5.5 Results: Knowledge Application and Use

5.5.1 National and International Scales

At the national and international scales, most respondents relied on a combination of multiple knowledges about weather and climate change to make decisions. The most frequently used information was scientific weather forecasts, followed by information about El Niño or La Niña and scientific seasonal forecasts (See Figure 19). Indigenous seasonal and weather forecasts, as well as indigenous knowledge of historical trends, were also used, but by fewer respondents. Nonetheless, two-thirds of respondents (67%) said that they, or the organization that they work for, try to include indigenous knowledge about weather and climate change in their planning and activities. This often occurs on an informal and intermittent basis. Nonetheless, the majority of respondents (60%) said that they did not believe that indigenous knowledge was effectively included in government policies (See Figure 20).

National and international respondents were also asked why they chose to use knowledge. They were able to select all options that applied (See Figure 21). Past experience using the information and whether or not the information was relevant to specific decisions or needs were the most frequently listed reasons. The perception that the information is easily available and not biased also played a role in determining whether many participants at the national and international levels chose to use information. About one-third of respondents indicated that one reason they choose to use particular information is because it is the only information available.

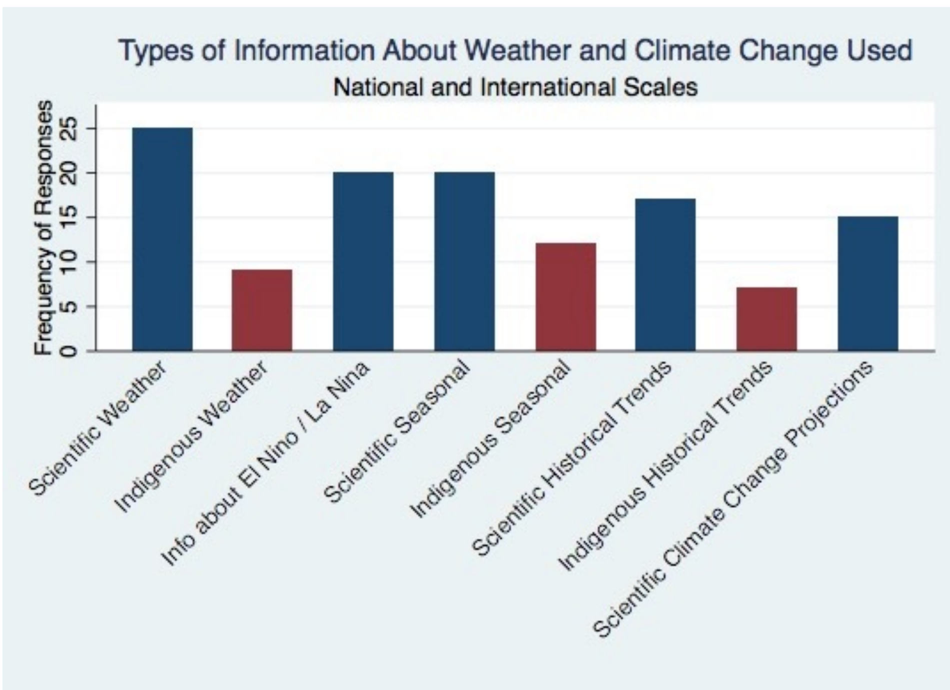

Figure 19: Types of forecasts and other information used with regard to present, past, and future weather and climate change among respondents at national and international scales (Note: blue bars indicate scientific sources of knowledge and red bars indicate indigenous sources of knowledge

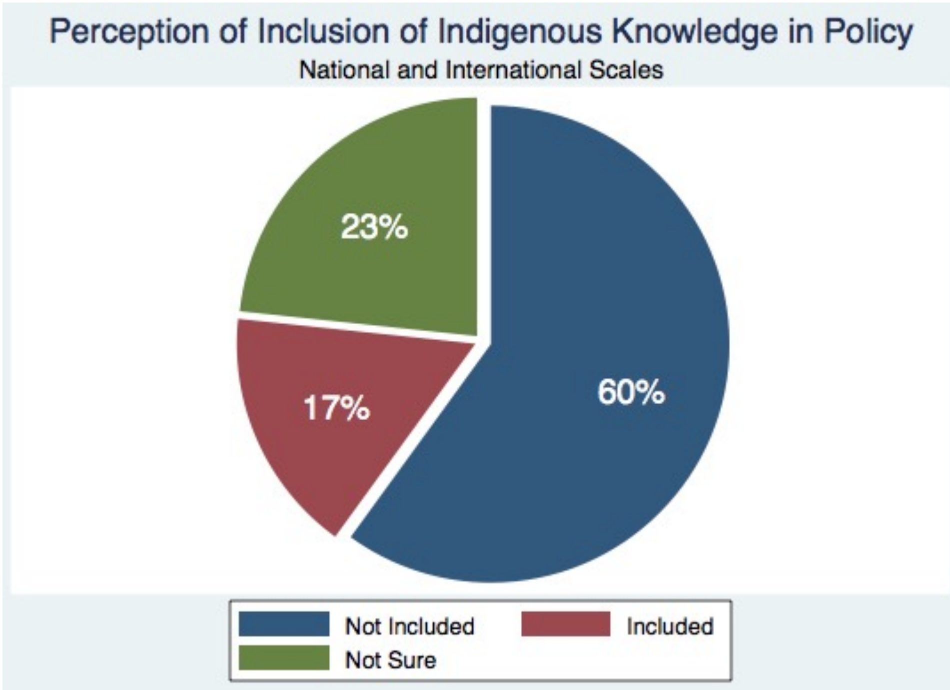

Figure 20: Perception of inclusion of indigenous knowledge in planning and policies among respondents at the national and international scales

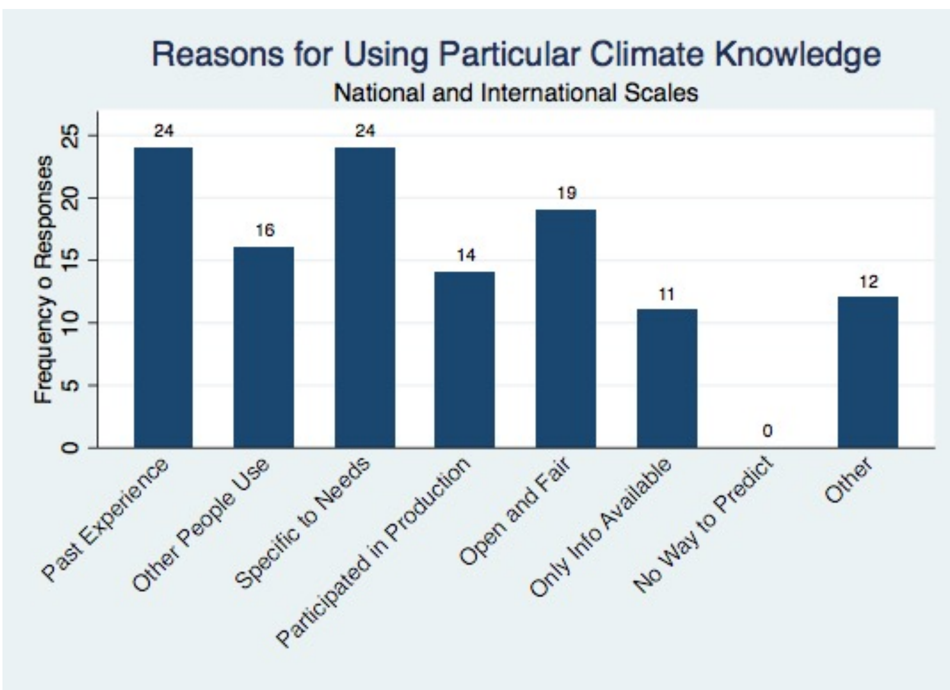

Figure 21: Reasons for using particular climate information and knowledge among national and international scale respondents

5.5.2 Village Scale

Respondents were also asked to discuss what types of weather and climate had the greatest impact on their livelihoods. This can serve as a proxy to understand what kinds of information about weather and climate might be more relevant to the decisions that people make on a day-to-day basis. At the village scale, drought was considered to be the weather or climate event that had the greatest impacts on livelihoods, with over 90% respondents choosing this (see Figure 22). Extreme rainfall was considered to have the greatest impact by only 5% of respondents.

Respondents were also asked to select what aspects of seasonality were most important to their decision-making in relation to 5 seasons commonly identified by Maasai population (See Figure 23). The *Olkisirata* and *Engakwai* correlate to the Vuli and Masika rainfall seasons. The *Oladalo* describes the short break between the Vuli and Masika usually experienced in January. *Koromare* marks the beginning of the dry season, but while there is still plenty of water and pasture available. *Alimei* is the equivalent of the full dry season, or kiangazi. See Goldman (2006) for a more detailed description of Maasai understanding of seasons. Respondents were able to choose all responses that applied. Based on these responses, *Alimei* (kiangazi) is the most important seasonal attribute for decision-making. The beginning and end of the *Engakwai* (Masika) were rated the second most important time during the year for making decisions, followed by the start/stop of the *Olkisirata* (Vuli). In general, the timing of the start and stop of both rainy seasons was more important that the total amount of rainfall.

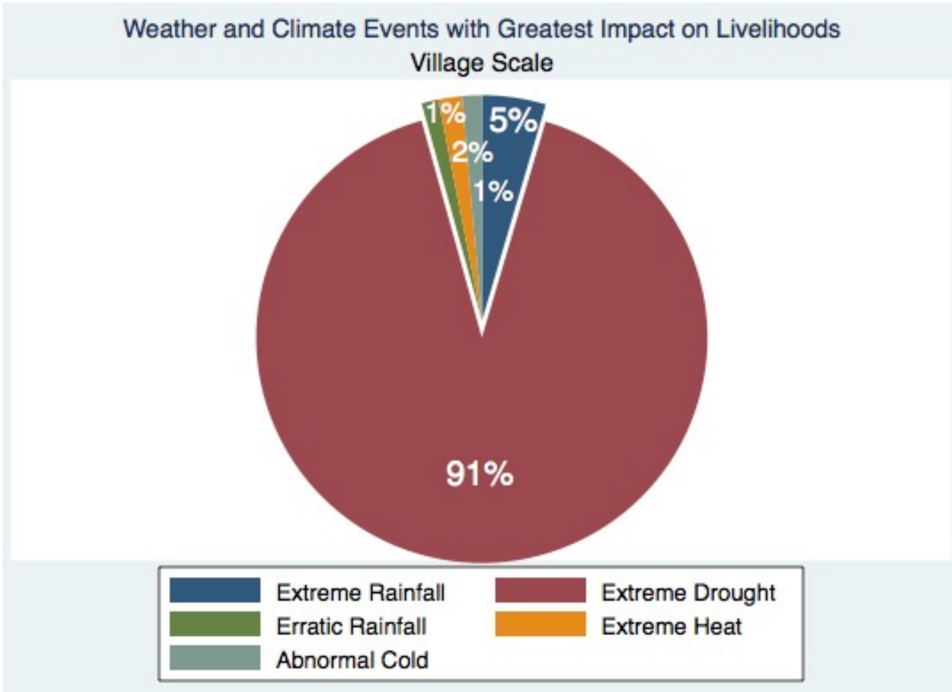

Figure 22: Weather and climate events with greatest impact on livelihoods among respondents at the village scale

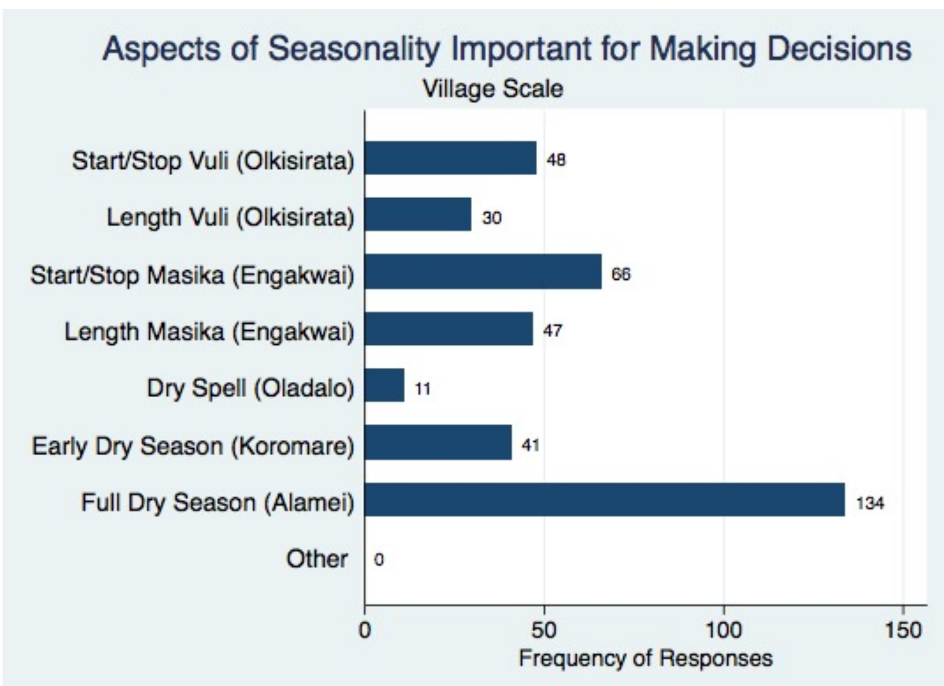

Figure 23: Aspects of seasons important for making decisions among respondents at the village scale (Note: Maasai terms for the various seasons are included in parentheses)

Respondents at the village scale were asked to list the 5 most important sources of information about weather and climate change that they use in their decisions. When looking at the first choice only, the most important information about weather and climate came from observations of the surrounding environment, including observations of things such as plants, animals, clouds, etc. (see Figure 24). Advice from elders and respondents' own common knowledge were also cited as top choices, followed by mass media (e.g., television, newspaper, and radio). Very few participants selected extension officers or government agencies as the most important source of information.

When considering all 5 most important sources of information listed by respondents, similar patterns emerge (see Figure 25). Environmental observations are still the most frequently used source of information. Advice from elders is the second most important source of information. Notably, information coming from travelers was the third most important source of information when evaluating the top 5 selections together. Information coming from travelers about conditions in other places was the first choice for very few respondents. However, it was frequently listed as one of the top five important sources of information. This shows that this source of information is still considered important, but is generally used in combination with other primary sources of information. Past experience and common knowledge were seen as equally important after news coming from travelers. Information from extension officers and government agencies remained the least frequent responses among the top 5 sources of information, confirming that this is information that is not commonly used. This highlights an important point. Even though information coming from TMA (a government agency) is delivered through mass media, many of the recipients at the village scale do not associate the information about weather and climate that they receive through the radio with government.

Village level respondents indicated that the most common reason they use information is because other people are also using it (see Figure 26). Past experience using information was next most common, followed by the specificity of information to decision making. This is in contrast to the top reasons listed by respondents at the national and international scale, where the specificity of information was the most frequent response. 69% of respondents indicated that in their village, decisions about how to respond to the impacts of weather and climate change were decided communally (see Figure 27). This is important for considering whether and how people may choose to use information and for what purposes.

Respondents were also asked to express their opinion about whether or not they felt like their knowledge was included in policies about climate change. 31% said that they did not feel like their knowledge was included in policy, while 19% did. Interestingly, 50% of respondents were not sure whether their knowledge was included in planning and policies related to climate change. Among those who felt like their knowledge was excluded from policies about climate change, there was strong belief that the government was not interested in including indigenous knowledge within policies, for a variety of reasons. Quotes included in Table 8 illustrate some of these opinions.

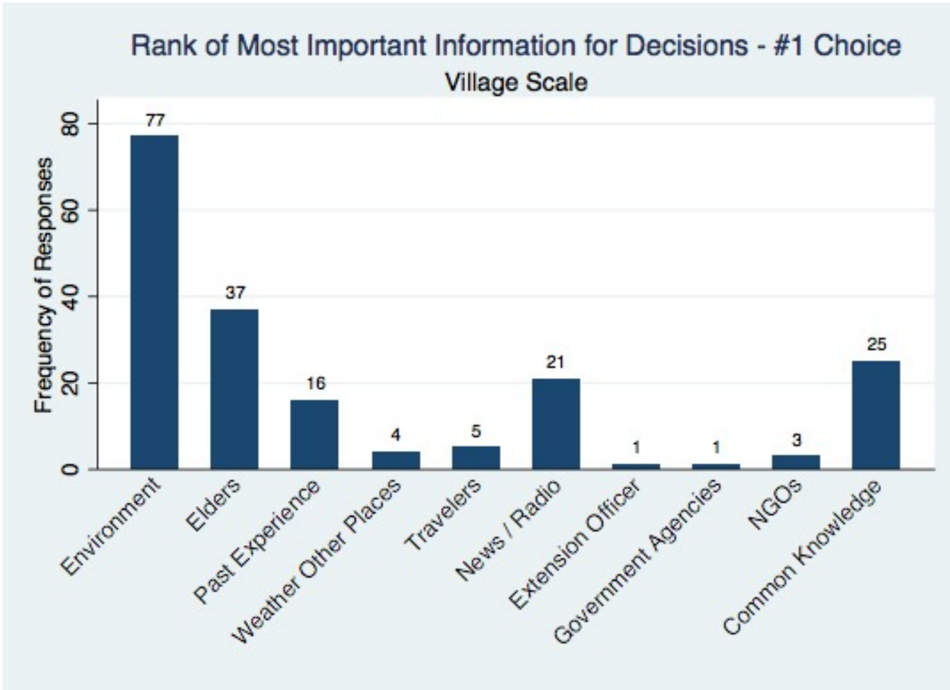

Figure 24: Respondents were asked to rank the most important information they use for decision-making (Note: This graph indicates the frequency of selection for the first choice (most important) source of information among respondents at the village scale)

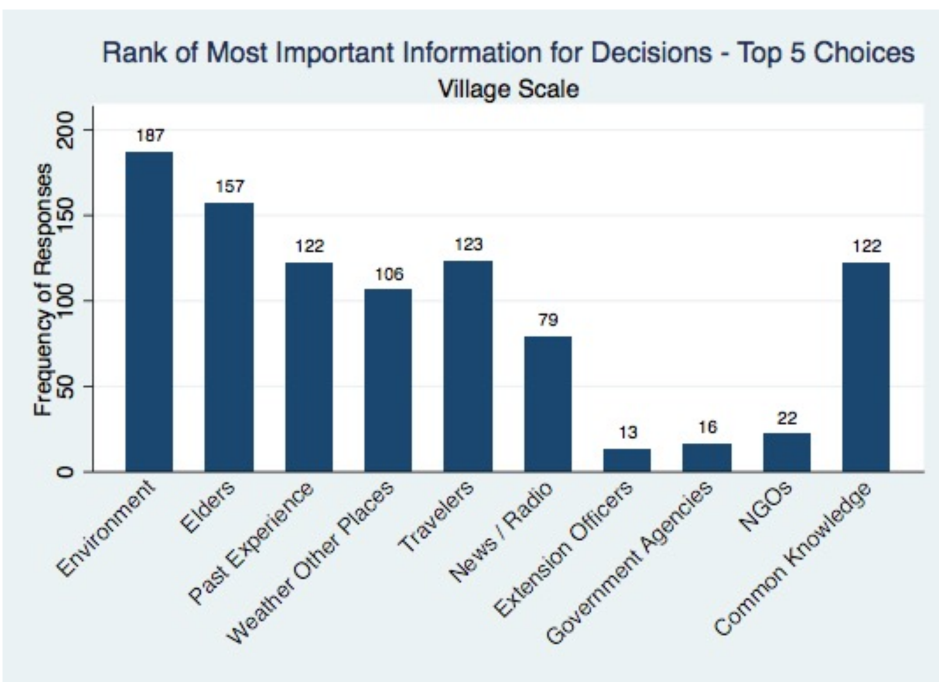

Figure 25: Top 5 most important sources of information for decision-making (Note: this graph indicates the frequency of selection for top five choices selected among respondents at the village scale)

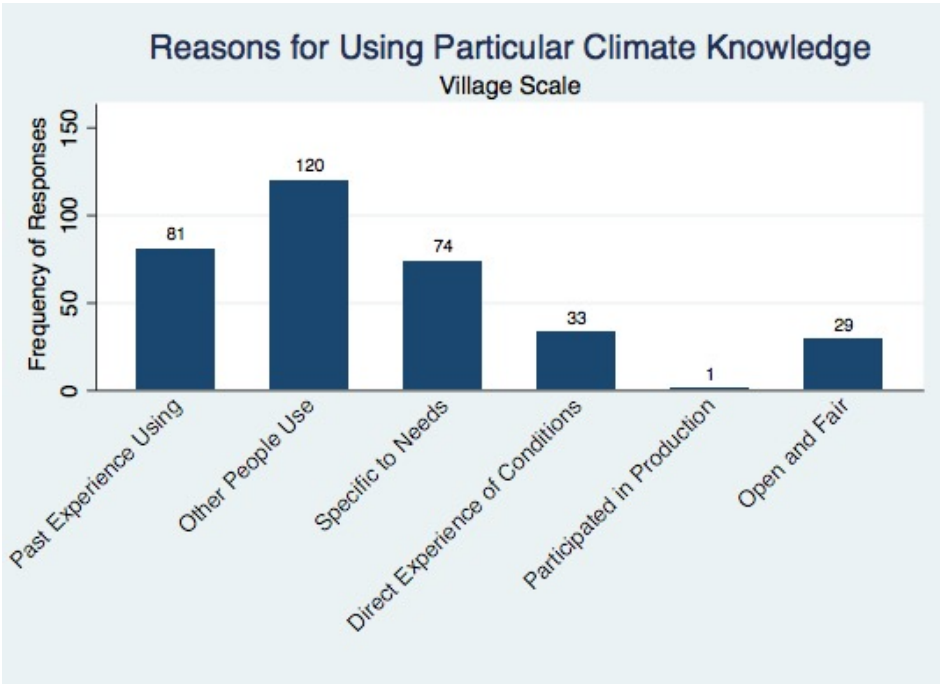

Figure 26: Reasons for choosing to use particular information or knowledge about weather and climate among respondents at the village scale

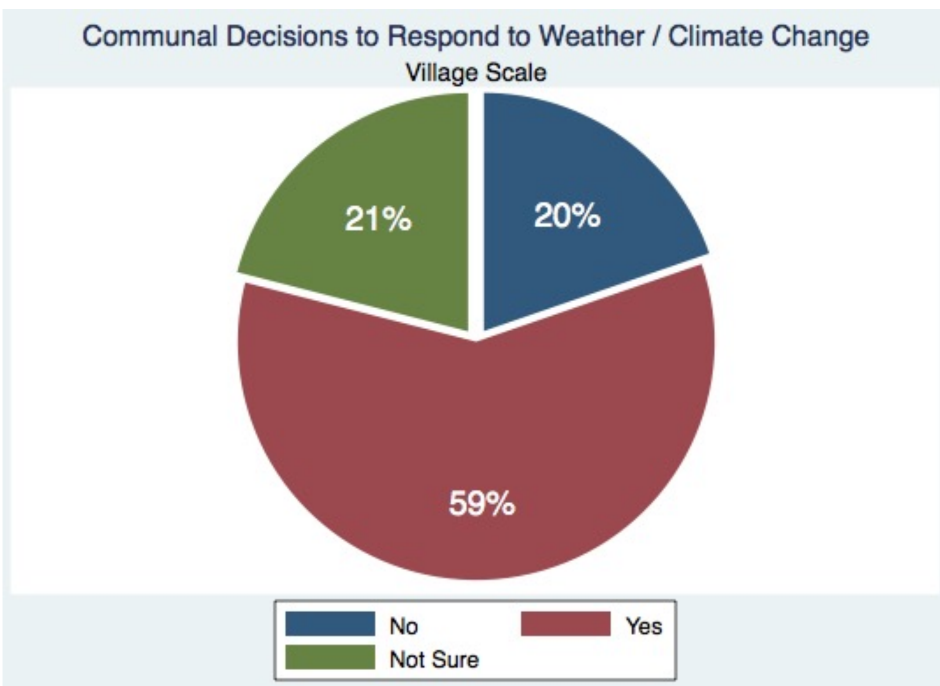

Figure 27: Communal decision-making about responses to the impacts of weather and climate change among respondents at the village scale

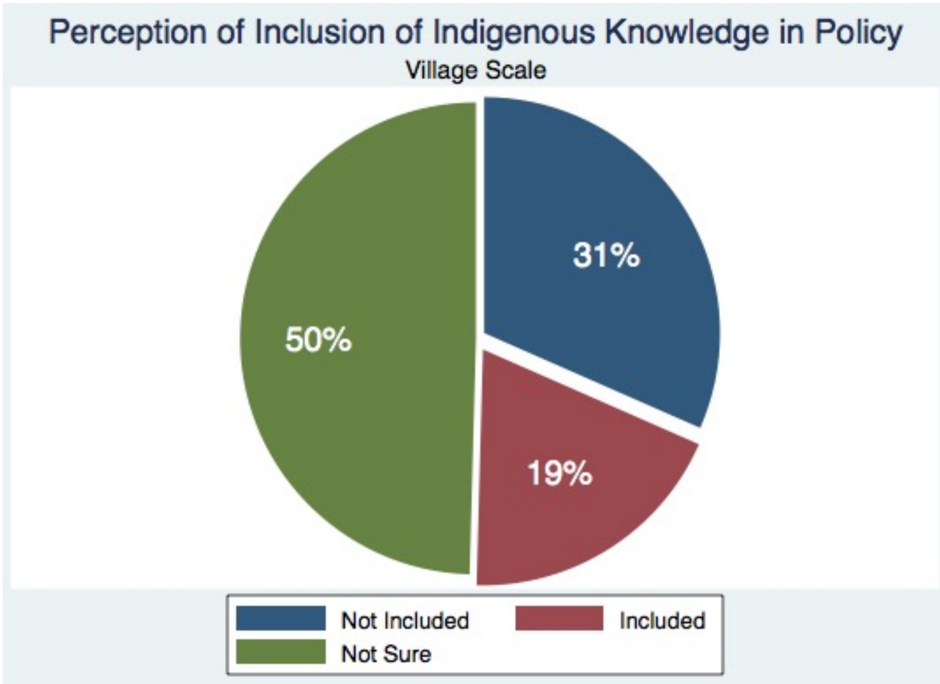

Figure 28: Perception of inclusion of indigenous knowledge in planning and policy among respondents at the village scale

Quote 1	“Serikali hawashirikishi wanajamii katika upangaji wa sera zake zote.” / “The government doesn’t involve the community in the planning of any of their policies.” Female Respondent from Longido District, Age 44
Quote 2	“Serikali imekuwa ikishuhulika na wataalamu zaidi kuliko wana mila.” / “The government thinks it should be done by experts more than traditional people.” Male Respondent from Longido District, Age 58
Quote 3	“Wanafikiri sio muhimu kutumia mawazo ya watu ambao hawajasoma.” / “They think it’s not important to use the ideas of people who haven’t gone to school.” Female Respondent from Longido District, Age 60
Quote 4	“Serikali haikuwahi kuonesha nia na haitaki kujumisha mambo ya kimila katika sera zao.” / “The government has never shown any interest and it doesn’t like to include traditional things in their policies.” Female Respondent from Longido District, Age 50
Quote 5	“Serikali kutotambua ufahamu wa kimila.” / “The government doesn’t recognize traditional knowledge.” Male Respondent from Longido District, Age 42
Quote 6	“Kwa sababu mila na serikali ni tofauti.” / “Because the traditions and the government are different.” Male Respondent from Monduli District, Age 27
Quote 7	“Serikali haitusikilizi.” / “The government doesn’t listen to us.” Male Respondent from Monduli District, Age 38
Quote 8	“Wana jamii wa kimaasai hawajawasilisha ufahamu wao katika serikali.” / “Maasai community members have not presented their knowledge in the government.” Female Respondent from Monduli, Age 50
Quote 9	“Serikali haiamini sana ufahamu wa kimila unaohusika sana na hali ya hewa.” / “The government doesn’t really believe traditional knowledge concerning the weather.” Male Respondent from Monduli District, Age 44
Quote 10	“Kwa sababu serikali inaamini kuwa ufahamu wa kimila hauna maana yoyote.” / “Because the government believes that traditional knowledge has no meaning.” Male Respondent from Monduli District, Age 48
Quote 11	“Hatushirikishwi kuandaa sera na mipango ya serikali ya kukabiliana a tabia nchi.” / “We are not involved in preparing governmental policies and plans to adapt to climate change.” Male Respondent from Monduli District, Age 70
Quote 12	“Serikali haiamini sana katika ufahamu wa kimila.”/ “The government doesn’t believe in traditional knowledge at all.” Female Respondent from Monduli District, Age 53

Table 9: Quotes from interviewees in villages across Longido and Monduli districts, expressing their opinion about why indigenous knowledge is not included in government planning and policies related to climate adaptation.

5.6 Discussion

Contrary to simplistic depictions of knowledge 'gaps' and linear models of knowledge production, dissemination, and use, these survey results show that there are much more complex dynamics at work. First, these findings illustrate that many respondents already rely upon a multiplicity of knowledges and that these are considered within a bundle of knowledges that shapes their experiences, understandings, decisions, and practices. Second, 'flows' of knowledge do not necessarily follow formal channels and are often overlapping and diffuse. However, it is worth noting some respondents were much better able to access and use certain types of information, illustrating how social dimensions of knowledge production, access, and use are intertwined with relations of power. For example, less than half of women were able to access external climate information, while nearly three quarters of men were able to do the same. Similarly, there were differences between the two districts that were sampled, with access greater among residents in Monduli district when compared with Longido. Third, these results illustrate the dynamic and socially situated nature of all knowledge. This challenges common assertions about the need to 'document', 'standardize', or 'harness' indigenous knowledge according to Western scientific rationalities so that it can be applied within adaptation decision-making. Rather, it is the very situatedness of IK that often makes it so usable. Additionally, the knowledge that individuals choose to use is not a constant, but varies depending on the context in which it is used, as well as the identity of the 'user' of knowledge in that context. Importantly, what knowledge is projected in particular settings reflects social and institutional determinants (e.g., respect, norms, mandates). Last, these findings challenge common assumptions about the ability of scientific climate knowledge to inevitably 'fill the gaps' in indigenous understandings of weather and climate. I will discuss each of these points in greater detail below.

5.6.1 Multiplicity and the Production of Knowledge

The findings of this research illustrate that the landscape of knowledge about weather and climate across all scales is complex and this is evident in the multiple sources and overlapping systems of knowledge that informed respondents' understandings of weather and climate. While most discussion of creating knowledge for climate adaptation decision-making focuses on formalized and sanctioned processes of knowledge-making, these results highlight that people rely on assemblages of knowledge that reflect both formal and informal processes of knowledge-making. Respondents at the national and international scale, even those who relied primarily on scientific sources of information, generally relied on two or three sources of information to learn about weather and climate change. Contrary to the frequent assumption that the only people who hold indigenous knowledge are those who live 'in the village' (Swahili: *kijijini*), many national level participants also indicated that they possess indigenous knowledge about weather in the places where they grew up. Even for respondents who do not live in the places where they were raised, they still maintain close connections with their original homes, both through frequent visits and communications with friends and family in those locations. Thus, they were still able to remain connected to this knowledge, either because they were knowledgeable about indigenous forecasting themselves, or were able to access this knowledge through family or friends. While most respondents indicated that such knowledge was not relevant to the location where they live currently, this continues to have an important effect on their views of indigenous knowledge more generally. This shows the importance of informal communication networks and ways of producing and circulating knowledge. Thus, while it may not often be recognized officially, this can often be an important source of knowledge for 'modern' actors within governmental and non-governmental agencies at the national and international scale.

While national and international respondents most frequently relied on information coming from TMA as their top source, this was almost always alongside other sources of information from both domestic and external organizations (e.g., other government agencies, international organizations, foreign news agencies). Many of the sources that people relied on were 'mandated' as part of their professional responsibilities, but these were invariably accompanied by supplementary sources of knowledge. These supplementary sources often reflected less formal or standardized efforts to gather knowledge —such as calling home to family members, checking a new weather app on a smart phone, talking to a neighbor in the street, or just knowing which way the wind is blowing. Thus, TMA is the primary and authoritative source of information about weather and climate in Tanzania for national and international stakeholders, but it is not the only contribution toward people's overall knowledge. Similarly, at the village scale, people relied on multiple sources of information, with most people relying on 3-4 sources, but some relying on up to 7 sources or indicators to inform their knowledge. This exposes the complex and overlapping networks that shape people's knowledge, as well as the fact that the production of knowledge is far from a linear process. At all scales, the production of knowledge was intertwined with people's lived experiences as they go about their daily activities (e.g., heavy rains can mean being stuck in traffic jams in Dar es Salaam, lack of rain can mean shortages of pasture in Kiserian). But this is often combined with knowledge coming from 'external' sources (such as scientific weather forecasts), which may be produced in locations that are quite far away. This shows how knowledge production, circulation, and use do not adhere to standard conceptualizations of scale, but rather 'flatten' and 'compress' them.

There were also observed trends in respondent's perceptions about the ability to produce predictions of seasons currently, as compared to the past. The vast majority of respondents at all scales agreed that it is more difficult to predict seasons now. Much of this difficulty was attributed to changes in seasonality — in terms of delayed start of the rains, more erratic rainfall throughout the season, as well as shorter rainy seasons overall (which most people also associated with overall decreases in annual rainfall). Current challenges to predicting weather and climate were most frequently considered to be impacts of climate change. Indeed, this was considered a dominant barrier to predicting weather and climate across all scales, for both scientific and indigenous knowledges. But it would be a mistake to think that climate change is the only reason that people perceived increased difficulty in predicting weather and climate. These challenges were also explained through social and cultural determinants. For example, increases in the numbers of children attending school, the growing pervasiveness of formalized religion, and a high reliance on sending family members away to seek wage labor in urban areas were all seen as factors that make it more difficult to be able to produce predictions about the seasons. Some also expressed the sentiment that these social changes were *themselves* the direct cause of the observed changes in seasons, particularly in terms of the increased prevalence of formalized religion. Some felt that shifting away from customary spiritual beliefs and practices was the reason for the observed changes in the seasons and decreases in rainfall. There were also much smaller group of respondents (at all scales) who felt that it was easier to predict the seasons now compared to the past. This can be explained through the expression of a 'technological optimism' that assumed that advances in science and technology are incrementally, but continually, improving the ability to predict weather and climate.

5.6.2 Knowledge Flows: Circulation and Access

Respondents at all scales reported receiving climate information through many different pathways. As with the production of knowledge, the ways in which knowledge circulates among sites of production is both through explicit channels for delivering information (e.g. government-backed climate change communication strategies), as well as through more diffuse and informal modes of knowledge sharing. The result is that many respondents at all scales receive (or possess) multiple knowledges through a variety of means. Nonetheless, there were some similarities in the ways in which actors accessed information. In the case of scientific information, most respondents at the national and international scales said that they needed to look for this information themselves in order to receive it, rather than having it directly sent to them. This in and of itself is important, as it indicates that individuals are searching for new sources of information about weather and climate and that scientific and indigenous knowledges are often considered valuable enough to seek out explicitly (i.e. there is demand). However, this may also illustrate that institutionalized efforts to distribute scientific information may not be as effective as assumed or hoped.

Formal mechanisms for transmitting and receiving information about weather and climate change, such as through the government, extension officers, or non-governmental organizations, were considered much less important sources of information. This indicates that many of the formal mechanisms that are in place to distribute weather and climate change information are not very effective in the study locations. For example, despite the various governmental efforts to communicate scientific information about climate variability and change (e.g. under Tanzania's National Climate Change Communications Strategy), very few respondents at the village scale were familiar with the Swahili term for climate change (Swahili: *mabadaliko ya tabia nchi).* Further, given the low numbers of respondents who reported receiving climate information through extension agents, these modes of transmission are currently ineffectual. Yet, extension services are often cited as the primary vehicle for disseminating climate information. Significant efforts are currently being undertaken under the Global Framework for Climate Services program in Tanzania to funnel climate information and structured trainings through agricultural extension officers, despite the fact that extension networks are weak and poorly resourced.

The frequency with which people receive information about weather and climate is also helpful to understand how and why some knowledge circulates (or not) and through what means. As indicated in the results, the frequency with which respondents received information varied considerably. For example, nearly half of national and international respondents indicated that they received information on a daily basis. This indicates that many people are able to receive daily weather forecasts through mass media, such as television, radio, and newspaper, or else to look for this on other digital media, such as websites, social media, or through phone apps. Similarly, among village scale respondents, the most common responses in terms of frequency of receiving 'external' or 'outside' (primarily scientific) climate knowledge was on a daily basis; however, there was an almost equal number of people who reported that they never receive external or scientific information about weather or climate. At first glance, this might seem like a paradoxical finding. However, considering that daily weather forecasts are widely distributed through mass media and that the majority of village scale respondents who do receive external climate information receive it through the radio, this very likely reflects differences in radio ownership, or else the ability to listen to radio broadcasts on someone else's handset. That is to say, ownership or access to a radio is likely a key determinant in enabling access to climate information. But this is not the only relevant factor. Even among those who own radios, the language in which the forecast was delivered was also an issue. Nearly all of the forecasts were delivered in Swahili (with the exception of broadcasts from the Orkonerei Radio Service (ORS), which broadcasts in Maa language).

What this also highlights is that other kinds of scientific climate information, such as seasonal forecasts or information about climate change, were not accessed nearly as frequently. This makes a great deal of sense, since weather forecasts are distributed every day, while seasonal forecast information is only distributed a few times a year and information about climate change is disseminated on an irregular and unpredictable basis (e.g., workshops, seminars, special radio programs). Also, given that seasonal forecasts are generally cited as the most desired scientific climate information and that there are already concerted efforts to transmit them widely, it also requires deeper consideration of the structural and material determinants that may constrain access to information. For example, many women reported that they did not have time for activities like listening to the radio, since forecasts are generally aired during meal preparation times, and also that they don't have access to or control of radios, as these generally belonged to their husbands. Additionally, villages located in Monduli District were more likely to receive information than villages located in Longido District. Monduli is a more densely populated district and there is generally more access to urban and quasi-urban centers such as Arusha, Karatu, and Mto wa Mbu. There is also better radio reception and mobile phone network in much of Monduli when compared to Longido.

There is often an assumption that indigenous knowledge cannot circulate outside of local settings, and this is often accompanied by assertions about the existence of fundamental differences between scientific and other kinds of knowledge. Results from this survey show that it is difficult to make such generalizations. The productions and flows of knowledge do not adhere to strict conceptualizations of scale. Both scientific and indigenous knowledges travel by formal and informal means and become intermixed along the way. For example, several NGO staff members highlighted that they are able to communicate their own informally produced IK through formal mechanisms. National scale government officials reported using informal channels to access formally produced information, for example through phone calls to personal contacts at

TMA. Despite the opinion of many respondents across all scales that the lack of formal pathways to deliver IK was a barrier to use, it is clear that this knowledge travels effectively, if unpredictably, through informal networks. Thus, there is a need to consider both formal and informal ways in which knowledge is circulated, as well as the interactions between these.

5.6.3 Knowledge Application and Use

With regard to the use of information, credibility was considered a key consideration among all respondents. Yet, it is clear that there are different ways of evaluating the credibility of knowledge. In general, participants at the national and international scales believed that the standardization of knowledge was an important way of making knowledge credible. Additionally, experience using the information in the past was important to the credibility of information. In contrast, participants at the village scale believed that the ability to empirically observe the real outcome of the information was the most important way of establishing the credibility. Nearly all respondents included in interviews and focus groups stated strongly that they would be unlikely to trust information about the weather until they were able to observe the outcomes over time. Personal observations of the environment (i.e., plants, animals, clouds) was the top choice of information. However, this was often complemented by the use of other kinds of information, such as animal behavior, past experience using information, information about other places coming from travelers, advice from elders, common knowledge, and information from the radio. This shows that one of the important ways in which indigenous knowledge gains credibility is that it can be validated through a larger number of observations and sources of information. Furthermore, even when sources of information are highly trusted, such as environmental observations, nearly all respondents said they would not make important livelihood decisions (such as where to move cattle or when to plant crops) until they saw physical evidence that there was enough rainfall, pasture, or water resources. This indicates that even when people receive high quality weather and seasonal forecasts, this alone will be unlikely to significantly change people's decisions. Despite these differences in how credibility was perceived among the different actors, these divergences are rarely discussed or addressed within discussions of co-production, including various efforts I've observed in Tanzania.

Instead there is a predominant emphasis on the need to 'tailor' scientific weather and climate forecasts to specific contexts in order to make it 'usable' for decision-making. Most frequently, these efforts prioritize the need to deliver forecasts at the right spatial or temporal scales, or to make sure that forecasts are timely so that they align with important decision-making timelines. These are all key features of the decision-making context, which addressed, would be expected to improve the relevance, and therefore 'usability,' of climate forecasts.

However, there are also mismatches in what are considered the most important determinants of the relevance of the forecast to livelihood decision-making and what the science is currently able to provide. The results of this survey indicate that aspects of weather and climate that are most relevant to livelihoods in Longido and Monduli districts are not well represented within current scientific forecasting. At the village scale, the most important time of year for making decisions is during the full dry season (Swahili: *Kiangazi,* Maa: *Alimei*). The long rainy season (Swahili: *Masika*, Maa: *Engakwai*) season was seen as the next most important period for making decisions, since people are able to evaluate whether there will be enough rainfall for the year based on its performance. Additionally, knowing when the seasons will start and stop is also more important than knowing the full length of the seasons. However, currently available seasonal climate forecasts focus primarily on the expected total amount of rainfall over the course of the short (Swahili: *Vuli,* Maa: *Olkisirata*) and long rainy seasons respectively. This means they provide little information about the expected duration of the *kiangazi* dry season, which was generally of most interest to village scale respondents. This indicates that the currently available information about weather does not fit the seasonal decision-making among pastoral populations in these districts.

There are also technical limitations to what the forecasts can provide. For example, while the Masika is considered much more important for determining overall livelihood security, the scientific seasonal predictions of the Masika have much less skill than those for the Vuli (see Mason &Chidzambwa, 2008). Furthermore, while the start and the stop of the season are of most interest to most respondents, this is a climate feature that is much more difficult for scientists to predict. Currently, seasonal forecasts issued by TMA include a prediction of the week during which the rainfall is expected to start based on a combination of statistical analysis and subjective expert assessment. However, other forms of prediction of start and end dates of the season, which might be more precise, would also be likely to be less accurate. Thus, producing this kind of information would require tradeoffs between the relevance of the information and the scientific credibility. These kinds of tradeoffs are generally not fully addressed in many discussions about how to 'tailor' climate information to better suit 'user' needs (see Chapter 7).

Perhaps more importantly, however, is that due to the narrow emphasis on refining the technical dimensions of the forecasts (e.g., enhanced spatial resolution through 'downscaling') there are many social aspects of decision-making contexts that are not taken into account within the development of scientific climate information. For example, nearly 60% of village respondents indicated that decisions about how to respond to the impacts of climate were made communally — for example, this includes decisions about allocating reserve pasture areas and regulating access to these, as well as access to water resources. Yet, most of the discourse around scientific climate services creates a fundamentally individualized conceptualization of actions that can be taken at the household level. Following Lemos et al. (2012), these results show that making forecasts usable within local decision contexts may require considering more than just the technical 'fit' of forecasts, but also the interplay between knowledges (i.e., knowledge already in use and knowledge that is newly 'introduced') and the need for development of trust, relationships, and legitimate processes.

It is often assumed that in cases where use of indigenous knowledge may be declining, there will be a corresponding increase in the use of scientific knowledge. However, the results of the survey contradict this presumption. The inclusion of scientific information within knowledge of weather and climate change was reported to be relatively constant when comparing the current use of scientific knowledge to use in the past. This is despite the fact that many people reported relying on fewer sources of information overall. For example, there was dramatic increase in the number of people who are relying on only one source of information currently when compared to the past. This reflects an overall decrease in the use of many indigenous prediction methods. This decrease is significant because IK was often seen as more credible and trust-worthy than other knowledge because it relies on multiple indicators that are often readily observable to village residents, rather than a single source of information that is not directly verifiable, such as a scientific climate forecast. Thus, the observed decrease in the number of sources of knowledge that village scale respondents draw on is a concerning trend, considering that it is a valued and trusted resource among many respondents.

The natural question would be to ask why such a decrease was reported. While these surveys did not fully answer this question, I bring in some findings from interviews and focus groups that were conducted later on (additional findings from these are discussed further in Chapters 6 and 7), to help contextualize the findings about changes in the production and usage of IK. While this decrease in the use of IK is often solely attributed to changes in climate or to rapid deforestation, which are purportedly occurring too rapidly for IK to keep pace, this only captures one contributing factor. Respondents attributed this decrease in the use of indigenous prediction to social changes, including the increased influence of formal religion, education, urban migration, and the availability of new technologies (such as television and mobile phones), as well as changes in the physical environment related to land use, environmental degradation, and weather or climate. Respondents reported that for those who participate in organized religion or attend school, there are active efforts within these institutions to discourage or ban the use of customary practices and indigenous knowledge, including indigenous weather forecasting and related rituals (e.g., offerings, prayers). Both urban migration and the influx of new technologies, such as smart phones, were also seen as eroding the ability of IK to be reliably generated and transmitted. Both of these dynamics disrupt social ties between elders and youth that have historically enabled oral transmission of prediction practices. These social and cultural shifts have also reduced the amount of time that younger community members spend directly observing their environment — since they were either frequently in the city or else, when they were home, they were too busy looking at their mobile phones.

Despite the growing challenges to the production and use of IK, this survey shows that this was not accompanied by a marked increase in the number of respondents who chose to rely on scientific information about weather and climate. This challenges overly simplistic assumptions that individuals will automatically fill ‘gaps’ in IK with available scientific information. This is not to say that there was not an expressed desire among some village respondents to receive more scientific information. Indeed, many village level respondents stated directly that they would like to have better access to scientific information (but usually on the condition that it was ‘true’).

Instead, it demonstrates that whether or not scientific climate information will be used in practice and in particular places is a more complicated story, one that is about much more than just ‘filling gaps.’

Finally, there were mixed perceptions about whether or not indigenous knowledge is included within policies to address climate change and climate adaptation in Tanzania among respondents at different scales. The majority of respondents at the international scale did not believe that indigenous knowledge was included, but many thought that this would improve in the future due to concerted efforts by policy-makers to make processes more open to citizens and other stakeholders. In contrast, nearly half of respondents at the village scale were not sure if their knowledge was included in policies. This in and of itself is telling. It illustrates that most village residents are not aware of or do not have access to policies that oversee climate adaptation and are, thus, unable to assess whether these align with their own knowledges and experiences, thereby decreasing the legitimacy of climate adaptation planning processes. Among the 31% of village respondents who felt that IK was not included in government planning and policies to address climate change, there were strong sentiments that the government did not recognize or appreciate the value of indigenous knowledge (see Table 8). Beyond feeling that they were not invited or that there was no way to participate in these processes, there was a more fundamental sentiment that the kinds of knowledge that village residents might be able to bring to the table are not what the government is looking for. At the very least, there was a sense that the government prefers knowledge coming from experts or other educated persons. At the worst, respondents felt that the government actively discredits and disrespects IK, since this knowledge does not align with government agendas. Thus, the perceived inclusion or exclusion of IK within policy-making revealed a general mistrust and deep-rooted skepticism on behalf of residents in Longido and

Monduli about the willingness of the government to include their knowledge within planning and policy-making to address climate change impacts in the future. This indicates that superficial efforts to implement instrumental co-production, such as one-off consultation processes, will do little to address the most pervasive root causes of power differentials between village residents and national and international actors.

5.7 Conclusion

This chapter has presented the findings of a multi-scalar survey, which provides an overview of the landscape of knowledge for climate adaptation across institutional scales in Tanzania. These results focus on multiple aspects of the production, circulation, access, and use of knowledge for climate adaptation. This 'snapshot' presents an overview of current knowledge flows within and across institutional scales in Tanzania and helps to identify disjuncture between the production of knowledge and the ways in which knowledge circulates and is applied (or not). Such findings can potentially help to identify opportunities for enabling more inclusive knowledge production processes, as well as the potential for increasing the equitable access and use of information. At the same time, these findings also highlight pervasive barriers to the flow and application of knowledge, such as deeply entrenched power differentials, relations of mistrust, and conflicting visions and goals. Given the growing emphasis on the need for 'co-produced' climate information and services as a basis for climate change adaptation decision-making in Tanzania, and beyond, such findings provide a useful vantage from which to consider the possibilities for and implications of the growing number of instrumental co-production efforts.

These results highlight several findings that should be considered within all efforts toward instrumental co-production in Tanzania, and perhaps in other locations as well. First, these results challenge calls to overcome 'gaps' between scientific and other knowledges; instead, there is a need to recognize the complex contours of knowledge production, circulation, and use which result in hybridized understandings of weather and climate change. This will necessitate more complex representations of how individuals engage with knowledge about climate and that such interactions are shaped by much more than deliberate efforts to disseminate knowledge through formal (linear) delivery channels. Second, and following the first point, there is a need to pay attention to both formal and informal flows of knowledge. The results of this survey show that informal means of receiving or accessing knowledge were often essential. Even when knowledge was received through formal mechanisms, these other informal knowledge pathways were crucial to enabling individuals to evaluate and contextualize the information they had received.

Lastly, these findings point toward the need to take power differentials between actors seriously (a topic which will be discussed in depth in Chapters 6 and 7). The sentiment expressed by nearly a third of respondents that the government did not welcome IK within policy-making illustrates that there is a lack of mutual respect between village residents and actors at the national scale. Such dynamics pose significant barriers to enabling trust and respect among various actors who might be engaged in instrumental co-production of climate knowledge and have their roots in long-standing historical exclusions and science-society interactions that have played a part in producing (and reproducing) uneven power relations among participants in instrumental co-production (this is discussed further in Chapter 6). Thus, it will not be sufficient to merely 'get everyone in the same room' (Lemos, 2015) as has been suggested by some proponents of co-production of climate information. When relations of power are already imbalanced, attempts to facilitate dialogue may often reproduce these dynamics, rather than address them. Thus, it will be important to understand the historical roots of existing science-society relations to gauge whether and how processes of instrumental co-production should be undertaken at all — and, if so, how to proceed. In the next two chapters (6 and 7), I illustrate some of the multiple ways in which power was exercised within instrumental co-production of knowledge for climate adaptation in Tanzania – at both macro- and micro-scales. These findings illustrate that there is a need to approach instrumental co-production cautiously. This is not only because of potential to 'oversell' the potential of co-production to solve problems – although, I argue strongly that it should be viewed neither as a panacea, nor appropriate, in all contexts. It is also because instrumental co-production can actually re-create and reinforce the troubling power dynamics it was deployed to resolve. Building on the assertion that co-production should not be considered a silver bullet, in the conclusion of this dissertation (Chapter 8) I offer a set of questions that may help to inform instrumental co-production efforts in ways that pay more explicit attention to the importance of addressing power relations.

CHAPTER 6: 'Co-producing Knowledge', Producing End-Users

6.1 Introduction

Knowledge is frequently considered a vital component of enhancing adaptive capacities to climate change (Yohe & Tol, 2002; Smit & Wandel, 2006) and in most adaptation discourse and practice, this is generally assumed to mean Western scientific knowledge. Yet, the limitations of scientific understandings of climate change have been increasingly recognized. Disjuncture between scientific ways of knowing climate change and the ways in which is it lived and experienced on the ground (Brace & Geoghegan, 2011; Hulme, 2009; Jasanoff, 2010; Miller, 2004) have spurred calls for more inclusive processes of knowledge-making and decision-making with regard to adaptation. This has resulted in both increased efforts to expand production of information about climate change that is more responsive to societal needs, as well as growing emphasis on the incorporation of other knowledges (e.g., 'local', 'indigenous', 'lay', 'tacit') along with 'scientific'[6] knowledge.

In the last decade, the concept of co-production has been increasingly invoked within a wide range of contested knowledge contexts, both as a practical tool and as a descriptive analytical approach. "Co-production of knowledge" (see Mitchell et al., 2006), has been increasingly put forth as a means of 'integrating' scientific and indigenous knowledges in a range of environmental management and sustainable development efforts, including climate change adaptation. In contrast, scholars in the field of Science and Technology Studies (STS) refer to the "idiom of co-production," as a way of illustrating how knowledge, power, and social order are inseparable and

[6] It has been argued that the use of terms such as 'scientific' and 'indigenous' to describe knowledge implies that knowledge possesses particular or essential attributes and perpetuates the constructed boundaries that enable some knowledge to be privileged over others. Following Agrawal (1995) I will use these terms 'scientific' and 'indigenous' without parentheticals for the remainder of the article to enhance readability and fluency, while recognizing that these terms are "deeply problematic" when used uncritically.

mutually constituted (Jasanoff, 2004). From this perspective, co-production is seen as an interdependent process through which the legitimacy of knowledge works to reinforce particular social and political arrangements, and vice versa. To distinguish between these differing applications of the term, I will refer to deliberate efforts of knowledge co-production as 'instrumental co-production.' I will use the term 'co-production' (or alternatively 'co-productionist') to refer explicitly to conceptualizations drawing from Jasanoff's idiom of co-production.

Relations of power are fundamental in shaping the possibility for authentic dialogue and iterative engagements that are envisioned within many instrumental co-production processes. While it has been recognized that power relations play a key role in shaping what is considered 'valid' knowledge within instrumental co-production processes, these dynamics are usually acknowledge only peripherally. In contrast, the idiom of co-production is constantly and fundamentally concerned with accounting for the interlinkages between knowledge and power. For this reason, I argue that in order to make sense of attempts at instrumental co-production, and in particular to understand how power is exercised through knowledge-production practices, it is necessary to draw on theoretical insights coming from the idiom of co-production.

To do so, I draw explicitly on Actor-Network Theory (ANT) and other post-ANT material-semiotic perspectives (e.g., Barad, 2003; Latour, 2005; Law, 2002; Law and Hassard, 1999; Rocheleau & Roth, 2007) to conduct a co-productionist analysis of knowledge and climate adaptation in Tanzania, to explain how knowledge gains and maintains social authority in historically contingent ways. The co-production idiom helps to elucidate how power is a distributed within these networks through practices of differentiation and exclusion and exposes how and why some distributions of power are able to remain more durable than others. This analysis illustrates how instrumental co-production efforts in Tanzania currently rely on stable science-society configurations in which there is a clear demarcation between 'producers' and 'users' of climate services. For this reason, contrary to the what may be intended, this may result in the perpetuation, or even exacerbation, of existing power differentials between the 'producers' and 'users' of climate services that are enlisted within instrumental co-production.

6.1.1 Climate Services and 'Co-production'

This study is situated within the rapid uptick of instrumental co-production efforts globally, which is concurrent with significant activity to mobilize scientific climate knowledge for adaptation decision-making, such as those included under the Global Framework for Climate Services (GFCS). For example, the focus on 'user interface platforms' within the GFCS (GFCS, 2013) has resulted in greater emphasis on the role of instrumental co-production in producing climate information and services.

There have been multiple and on-going efforts to facilitate production and use of scientific climate knowledge for adaptation across scales in East Africa. To date, Global Circulation Models (GCMs) have been the predominant means of gauging potential magnitude of climate change, as well as multi-decadal variability (e.g., Graham et al., 2011; Tierney et al., 2013). At the same time, there has also been great interest in generating seasonal climate forecasts that might help to reduce climate impacts on livelihoods and wellbeing on inter-annual timescales at the regional and national scales (Goddard et al., 2010; Patt et al., 2007).

While there was a great deal of early optimism about the potential for climate information to play a key role in reducing climate risks, particularly in developing countries, it was soon recognized that merely distributing climate information in a linear fashion would not have the desired result; in many cases the information was not widely used (Broad & Agrawala, 2000; Patt

& Gwata, 2002; Vogel et al., 2006) or had unanticipated or negative impacts (Broad & Orlove, 2007; Pfaff et al., 1999). Much of the discourse surrounding climate services over the last decade has centered around the need to produce information in relation to 'user needs', with a particular emphasis on 'tailoring' forecasts for use in particular sectors or decision-making contexts. In response to this shift, the term 'climate services' has been developed to indicate the need for the production of information that is more attuned to the particular contexts and needs of those who might use the information. The shift from climate information to climate services represents an explicit effort to produce 'usable' scientific knowledge.

Many of these efforts, both within the context of the GFCS and otherwise, have emphasized the prerequisite of characterizing the information 'needs' of small-holder farmers, building on the notion that the utility of forecasts is dependent upon formulating generalizable attributes of potential 'users' that can determine who may take up and benefit from climate services and information in Sub-Saharan Africa (e.g., Amissah-Arthur, 2003; Coulibaly et al., 2015). Most recently, the World Meteorological Organization, along with other UN agencies, international research institutes, and international humanitarian organizations, have launched the Global Framework for Climate Services Adaptation Program in Africa (GFCS-APA), which has emphasized the need for instrumental co-production of climate knowledge to "facilitate the enabling environment for the end-users and climate service providers [to] interface at all levels" (Proposal to the Norwegian Ministry of Foreign Affairs, obtained on the GFCS website). As part of this program, Tanzania is one of two countries in East Africa to be 'fast-tracked' to develop a National Framework for Climate Services (GFCS, 2013).

This paper will examine the particular practices involved in current climate knowledge production, circulation, and use to show how within the discursive space of existing science-society relations, the focus on instrumental co-production and efforts to develop climate services in Tanzania create and deploy particular categorizations and boundaries about who knows about climate change, who is affected by it, and what should be done. All of these reflect attempts to impose particular subjectivities of 'producers' and 'users' that correspond with the project of 'co-producing' climate services in order to provide stability to the arrangement. This is often reliant on the work of creating dualisms and boundaries between who is considered a 'producer' and who is considered an 'end-user' within scientific climate knowledge production and circulation and how these designations are produced, measured, and enforced. However, these efforts to create subjects is complicated by the multiple and hybrid identities of those who are the 'target' of such efforts.

In Tanzania, these conceptualizations of who are considered 'producers' and 'users' are inherently tied up with questions about what is considered 'traditional' versus what is 'modern', what is 'scientific' and what is not, who is or is not 'qualified' to speak about climate change, who should use such knowledge and for what purposes, and what 'counts' as adaptation. These tensions are not unique to climate knowledge, but are embedded within a long history of socio-technical relations in Tanzania. The subjectivities of actors involved do not remain fixed and efforts to impose them are often countered by competing networks and relations. Efforts to create particular subjectivities are held in tension with the identities that are both internalized and enacted by individuals. There are many overlapping and contradictory ways for identities to emerge or to be strategically and actively projected, sometimes in agreement with, and sometimes in opposition to, the idealized subjects that were intended. Thus, rather than being powerless to resist, actors are able to contest these processes by mobilizing identities that are emergent, hybrid, and relational, enmeshed within (sometimes multiple) networks. In these contestations, scaling up 'co-production' may only serve to solidify and deepen the very divisions such processes were intended to overcome.

6.1.2 Co-production, Knowledge/Power, and Identities

The idiom of co-production (Jasanoff, 2004) was introduced as a way of understanding the relations between how we know about the world (epistemology) and how this in turn shapes how we exist in the world (ontology). In this way, co-production serves as a heuristic to refer to ways in which knowledge and human experience are intertwined. Jasanoff refers to the constitutive and interactional strands of co-production. The first describes the ways in which the stability of the duality between 'nature' and 'culture' is created and maintained, thereby accounting for how people perceive elements of nature and society and relations between them. Interactional co-production is fundamentally concerned with epistemic conflicts about the social authority and political legitimacy of knowledge (for further discussion of interactional and constitutive strands of co-production, see Chapter 1). Importantly, within Jasanoff's conceptualization of co-production, *these two strands of co-production are inseparable and continuously reinforcing and remaking the other*.

Yet, within the recent literature about co-production, many have actively sought to distinguish between the co-production as an analytical lens, as described by Jasanoff, and "deliberate co-production" (Meadows et al., 2015), which are also synonymously referred to as joint knowledge production (Edelenbos, 2011; Hegger et al., 2012), co-creation of knowledge (Voorber et al., 2014), and a variety of other terms (see Chapter 1 for further discussion). In some cases, these efforts may address the power-laden roots of debates about epistemic authority (see, for example, Armitage et al., 2011; Corburn, 2007). However, in many cases these approaches may instead serve to advance highly instrumental goals and to obscure the ways in which knowledge gains epistemic authority. Additionally, there has been increasing emphasis on the development of standardized analytical frameworks that strive to direct the analyst's gaze toward particular and standardized sets of 'factors' or 'variables' that may either enable or challenge attempts at deliberate 'co-production' (See Chapter 1, for example, Hegger et al., 2012, van Kerkhoff & Lebel, 2015). Yet, such approaches risk reviving a reductionist approach to understanding the complexities of science-society relations. In contrast, this paper seeks to build on the proposition that in order to begin making sense of attempts at instrumental 'co-production,' or any other explicit attempts at reshaping science-society relations, it is necessary to situate these within a "strong" co-productionist analysis that accounts for the ways in which knowledge-making and being-in-the-world are mutually constituted (Jasanoff, 2014a).

While much treatment of power relations within environmental management and climate adaptation emphasize episodic or coercive forms of power, Foucault (1982) describes power as something that is pervasive and embodied in all aspects of life, rooted and circulating through 'social networks' and relationships to discursively to shape what counts as acceptable knowledge. While participatory processes, including those aimed at enabling the 'co-production' of knowledge, often aim to address visible forms of power (e.g., state authority, elite capture), others have argued that it is necessary to address less visible manifestations of power which serve to delimit what knowledge is considered valid (Jasanoff, 2006). Scientific knowledge has played a key role in efforts to standardize and classify both human and environmental subjects, including the climate (Jasanoff, 2010; Hulme, 2009), so that they may become more legible and, therefore, easier to exploit or control (Jasanoff, 2004b). In this way, "knowledge production practices are strategic sites of power" (M. Goldman, 2005, p. 179), where the scope and nature of environmental issues are framed, defined, and bounded, along with the range of possible responses. Thus, it is important to examine how discursive practices determine not only what is discussed and how, but also what is not discussed (i.e., what topics are 'off the table'), how this shapes material possibilities and the particular *practices, actors, and networks that endow certain knowledges with authority, while excluding others* (Latour, 1987; Haraway, 1991).

Jasanoff (2004) has identified the "making of identities" (p. 39) as one of several common sites of co-production. This can include the formation and maintenance of identities of expertise, as well the ways in which collective identities are negotiated within shifting socio-technical configurations. According to Jasanoff, an important question then becomes: "what role do knowledge and its production play in shaping and sustaining these social roles or in giving them power and meaning" (Jasanoff, 2004, p. 39)? For Foucault (1982), subjectivities are created not only in accordance with dominant discourses, but also simultaneously in *resistance* to these. It is in this relational and oppositional space in which subjectivity can be renegotiated to enable the performance of particular identities, which are never quite settled, but are continually remade across time and space. In this way, discursive practices also create the space for the emergence of multiple identities, which can be performed in ways that can resist or strategically re-direct the exercise of power.

The importance of identities has been recognized both within processes of climate knowledge production, as well as 'new' forms of co-productive engagements. Carr and Owasu-Daaku (2015) have argued that the particular ways in which climate services 'users' are defined and categorized constructs particular versions of 'vulnerability' that overlook the complexities of 'user' identities and the inherent tensions arising out of these. The ways in which the climate services community comes to "know" the presumed 'users' of climate services results in the essentialization of subjects that disregard the multiple and overlapping ways in which hybrid identities are variously expressed in specific settings and locations and at particular times (Carr & Owasu-Daaku, 2015). Miller (2005) has noted that using climate predictions for decision-making requires changes in how people conceptualize their lived experience and entails a reliance upon “making the local and the global interdependent” thereby “co-producing ‘global information’ and ‘local users’ that fit together in stable arrangements” (p. 91). In a different context, Callon and Rabeharisoa (2003) have made the argument that new knowledge production arrangements in which ‘scientists’ work with ‘non-scientists’- what they term “research in the wild” - results in the co-production of new identities and knowledge. Importantly, identities are formed through assemblages of human and non-human components, which in turn shape determinations about what processes of knowledge making ‘non-scientists’ are ‘qualified’ to speak to. In this way, these identities, which are variously created, imposed, and enforced, can simultaneously increase connectivity and interdependencies, while also being used as tools of exclusion. However, such exclusions are productive in the sense that they can also create new identities, thus leaving open the possibility of new forms of connectivity, entanglement, and agency, resulting in a “never-ending movement in the reconfiguration of identities, inclusion, and exclusion…” (Callon & Rabeharisoa, 2003, p. 202).

6.1.3 Material-semiotics and Relational Networks Metaphors

I draw on relational network metaphors to illustrate the ways in which power is exercised through knowledge production practices, recognizing the rooted and historical nature of networks, as well as their various mobilities (Rocheleau & Roth, 2007). Relational network approaches also incorporate notions of materiality in ways that blur the lines between the ‘social’ and the ‘natural,’ as well as various other dualisms that serve as categorizing devices of exclusion. Such approaches reflect “a disparate family of material-semiotic tools, sensibilities, and methods of analysis” (Law 2009, p. 2) that are most frequently associated with Actor-Network Theory (ANT) and post-ANT approaches, that understand ‘social’ and ‘natural’ realities as being constituted by sets of relations between heterogeneous (i.e. human and non-human) entities (Latour 1987, 1999; Law, 2009; Law & Hassard, 1999). ANT was originally concerned with the ways in which scientific knowledge was able to gain authority in locations far from where it was produced. A crucial insight of early ANT theory was that scientific knowledge does not travel without enlisting a range of both actors (humans) and actants (non-humans) to construct the networks that allow science to be meaningful in different locations.

By tracing and exposing the processes involved in creating relational networks, it is possible to show why and how networks hold together, how this shapes and reshapes various components of the network, and how difference is created through these processes (Law, 2009). For example, in his seminal account of Pasteur’s discovery of the cause of anthrax and development of vaccines, Latour shows that these innovations were the consequence of networked relations between diverse entities, including: farmers, veterinarians, bacteria, laboratories, farms, and statistics (Law 2009). In the network described by Latour, all of the entities enrolled in the network were also changed through these associations, since all had to be “domesticated” in order for the network work to hold together. Similarly, Law (1986) shows how the Portuguese became a dominant imperial power through the assemblage of networks of actors and actants – ships, monarchs, spices, ocean currents, wind stars, merchants – and enacted through particular practices and technologies. In this case, Law illustrates how networks are fundamental in creating difference (i.e. between the Portuguese and others) and that this difference is what enables political power to be exercised. These moves to assert boundaries are important to understanding stories of the co-production of knowledge, power, and social order. An important implication is that entities do not have essential characteristics, but gain relative attributes through associations with other entities (Law 2009). In this way, materiality is intimately tied up with the making of "contemporary subjectivities" (Moser & Law, 1999).

Material-semiotic approaches have also sought to pay attention to power, space and scale, and political history and how these shape the formations of networks (Law, 1986, 2009). As stated by Latour (2005, p. 64), "power and domination have to be produced, made up, composed. Asymmetries exist, yes, but where do they come from and what are they made out of?" Such an approach seeks to understand how power circulates in the associations, connections, and relational ontologies that compose such networks. It has been recognized that there exist various imbalances in the 'weight' of particular elements within the network, both individually and systemically, that reflect particular relationships that form socio-natural histories (Rocheleau & Roth, 2007).

Such analysis helps to illustrate how knowledge making requires relations between a variety of human and non-human actors, which has implications for how certain knowledges gain strength, but also illustrates their fragilities, discontinuities, multiplicities, and interferences (Law, 1999, 2002; Mol, 2002). Furthermore, an actor-network perspective helps to illustrate the inseparability between the production, circulation, and application of knowledge (M.J. Goldman et al., 2011). Thus, the effort here is to try to understand how power becomes distributed within networks in particular ways through a politics of knowledge and how and why some distributions are able to remain more durable than others. In this way, identities and other social aggregates are the object of performative definitions, meaning that such categories or groupings "have to constantly be made, or remade" and that further, social aggregates are performed as socio-material relations that help to achieve stability within these networks (Latour, 2005, p. 34).

Law and Singleton (2014) argue that post-ANT approaches that incorporate feminist material-semiotic perspectives can help to reveal particular possibilities (and impossibilities) within particular political and policy settings, while also helping to create space for change. Within this realm, the concept of agential realism (Barad, 2003, p. 823) is helpful. Agential realism provides a perspective on materiality that "takes account of both discursive and material constraints, without reinscribing traditional empiricist assumptions about the transparent or immediate given-ness of the world." Key to Barad's conceptualization is "intra-activity," a process in which material and discursive practices are mutually constituted, both playing an active role in producing the world, as well as our ability to 'know' it. Barad calls for "thinking the 'social' and the 'scientific' together" in ways that blur boundaries and highlight that the relations between these are not static, but rather involve a "doing" or enactment of boundaries that "always entails constitutive exclusions" (p. 803). In this way, discursive practices are boundary-making processes that are continually enacted through material entanglements that shape the "conditions, constraints, and practices" and, thus, possibilities for the future. Neither material nor discursive practices are blank slates, but rather reflect historical contingencies. In this way, Barad's work helps to show that for subjectivities to come into being, both material and discursive work is necessary.

Building on these insights, this paper will illustrate how various discursive practices are engaged in the effort to draw boundaries between 'users' and 'producers' of climate services, but how this is complicated by the emergent and relational enactments of the multiple identities of actors that reflect the networked intertwining of material and discursive practices, ontological conditions, and the meanings that emerge from these in particular places. As will be discussed in the remainder of this paper, producing subjects in the form of 'users' of climate services requires processes of boundary-drawing, but such demarcations are only recognizable within a set of networked relations between heterogeneous actors. Difference must be created. At the same time, identities emerge through dynamic material and discursive entanglements that are historically contingent, but not deterministic, in their continual re-enactment (and hence reconfiguration). For this reason, the ability to create 'users' of climate services is not always successful. In short, networks can be fragile. Networks can fail. But it is always much more complex than that. These emergent and networked identities can sometime interfere, sometimes complement, the efforts of other actors at other scales to build new or strengthen existing networks.

6.2 Methods

Findings presented here are based on mixed-methods data collection conducted at multiple institutional scales in Tanzania between 2013 - 2015. First, it is important to note that in an attempt to follow knowledge production, circulation, and application across scales, it was necessary to delineate what was meant by each 'scale.' This was done in correspondence with institutional scales designated in reference to bureaucratic and administrative structures in relation to the Tanzanian state, with data collected at the village, district, national, and international 'scales.' However, it is recognized that conceptualizations of scale are constructed and fluid in practice (Marston 2000). In terms of knowledge production and flows, notions of scale were quite slippery. For example, individuals designated as 'national scale' respondents often maintain close linkages with their home places to learn about the most recent weather. Village level respondents can often 'jump' scales to create associations with international NGOs to gain access to knowledge about climate change. Thus, the purpose here was not to strictly classify responses based on these constructions of scale, but rather to help illuminate how positionality and associations within the relational networks shape particular views of climate knowledge production, circulation, and use.

District and village level data was collected in the Districts of Longido and Monduli, located in northern Tanzania. Both are districts in which the majority of residents self-identify as pastoralists, but have significantly different socio-ecological conditions, to allow comparison.

Quantitative surveys (n=198) were conducted in 10 villages (5 in each district). Ethnographic data collection included non-structured observation conducted for a total of 6 months during the research period in the villages of Kiserian, Longido District and Arkaria, Monduli District. Semi-structured interviews (n=36), and planned group discussions (n=11) were also conducted at the village scale. Quantitative surveys (n=30) were conducted among national governmental and non-governmental actors, as well as international non-governmental actors, whose job responsibilities were related to topics of climate change, environment and conservation, or development. At the national and international level, ethnographic data collection included both structured and non-structured observation within organized meetings and events (n=22) and informal settings (total of 3 weeks), semi-structured interviews (n=8), and planned group discussion groups (n=2). All observations, national/international interviews, national/international group discussions, and informal conversations were transcribed and translated from Swahili into English by the author. Village interviews and group discussions were transcribed and translated from Maa or Swahili to English with the help of a local research assistant.

6.3 The Nexus of Knowledge Production/Application/Circulation within Co-production of Climate Services: Setting the Scene

What counts as 'valid' knowledge and the ways in which such demarcations influence debates about epistemic authority and material outcomes are inherently political processes (Jasanoff, 2004; M.J. Goldman et al., 2011). As noted by M.J. Goldman and Turner (2011, p. 2), "knowledge politics" often make it impossible to separate out processes of production, application, and circulation of knowledge. Rather, what are needed are approaches that recognize the "inseparable nexus of production, application, and circulation" of knowledge (M.J. Goldman & Turner, 2011, p. 4) and the co-productive webs of relations that constitute these enmeshed processes.

The following vignette, drawn from observations at the Africa Climate Conference, held in Arusha Tanzania in 2013[7], illustrates the overlaps between the ways in which knowledge is constructed, how it circulates and is used, and how this produces particular socio-material configurations:

> *The Africa Climate Conference (ACC), held in Arusha, Tanzania in October 2013, was hailed at the "first conference of its kind" and brought together nearly 400 participants from across Africa and the world aiming to "narrow the communications gap currently existing between African decision-makers and climate scientists" and to set a coordinated climate research agenda for the continent in the future (Africa Climate Conference 2013). The conference was backed by a range of international organizations and regional climate centers, as well as development banks and several countries in the global North. The main plenary session was titled "Grand Challenges and Frontiers of African Climate Research to Inform Adaptation Decision-making in the 21st Century in Africa", in which the focus was on emphasizing the need to "fill gaps" in knowledge that pose fundamental challenges to integrating scientific knowledge about climate variability and change within decision-making in Africa — which was frequently referred to as the "most vulnerable continent" to climate change. Throughout the conference, it was repeatedly noted that the availability of meteorological data was a key issue, with most of the data used in climate projections and other*

[7] I was both a participant and an observer at the conference. Material in quotations above are direct quotes made by panel members and participants within plenary sessions during the conference.

modeling efforts being generated by "groups external to the continent." Speakers also raised questions about technical capacities in many locations in Africa to "produce" the needed knowledge, due to sparse data, limited computing resources, and insufficient modeling capabilities. A social science researcher on the plenary panel noted that "there is a limit to what knowledge can provide" and, consequently, that decisions about climate adaptation ultimately become decisions about risk and values. Nonetheless, this point was sidelined by more prevalent and pervasive discussions about the need to produce more complex and detailed climate models. Along with discussion of the "state of knowledge" regarding the "African climate," the session stressed the need to link such knowledge with adaptation decision-making. A particular emphasis was placed on the need to "interact with end-users" and "involve stakeholders" to produce "user needs-based science." An audience member directed a comment to the panel stating that, given there had been a lot of talk about "end-users," it would be important to "define who the end-users are." In response to this comment, an official from the World Meteorological Organization responded: "There can be a range of different users. The definition [of the user] is subject to the type of [climate] service and product."

The excerpt above illustrates the entangled dynamics of climate knowledge production, circulation, and application, despite claims made about the "gap" between the science and politics of climate change adaptation. It is clear that the particular ways in which research agendas about the 'African climate are established are the outcomes of implicit epistemological and ontological commitments, as well as particular conceptualizations of how such knowledge should circulate and be used for the purposes of adaptation through constructions of a 'vulnerable' African continent and 'end-user' subjects who are the intended beneficiaries.

This vignette further illustrates the political nature of debates and contestations about framing the problem of climate adaptation. While alternative ways of framing and 'knowing' the issue were proposed, these must compete with the dominant framings of climate change as a technical problem to be solved through enhancing observation networks and models. The use of relational networks as an analytical tool may be one way of helping to expose the convergences between the production, application, and circulation of climate knowledge — as well as a means of helping to explain how ontological and epistemological politics play out in practice.

To begin, I first provide a description of the historical roots of current science-society relations in Tanzania to illustrate how these shape power relations within instrumental co-production of climate services (see Section 6.4). Doing so, I emphasize that the relational networks that are involved in producing climate knowledge – both scientific and indigenous – are 'rooted' in places, with particular histories, politics, and cultures. I then go on to describe the various (multiple and overlapping) networks that are involved in the production and circulation of climate knowledge – both scientific and indigenous.

This network analysis highlights several key points about the production and circulation of climate knowledge, as well as about processes of instrumental co-production. First, I show that all knowledge is made up of networks of heterogeneous elements – both social and material – and that these networks often take a great deal of effort to build and maintain. I demonstrate that, despite the different strategies used to produce them, both scientific and indigenous knowledges were 'brought into being' through networked assemblages of human and non-human entities (e.g., policy makers, meteorologists, satellites, monitoring stations, hand-written climate data, cattle, droughts, pasture) that draw on connections, associations, and relations with other entities in different locations — both near and far — in ways that transcend conventional notions of Euclidean space (Mol & Law, 1994). This deep analysis of the complex networks involved in the production and circulation of climate knowledge also shows that scientific knowledge gains its social authority by black-boxing the vast amount of work that is required to produce it. A relational network approach also illustrates that social authority of scientific climate knowledge is created *through its linkages with and in relation to social worlds* – such as through the provision of scientific advice for international climate negotiations or the mandate for to protect life and reduce poverty in Tanzania. Second, I show how the multiple identities of actors relates to the overlaps, interferences, and failures of these multiple climate knowledge networks (Section 6.7). Being able to tap into multiple networks, as well as being able to apply these hybridized knowledges, reflects the multiple identities of the actors themselves. Importantly, these identities are not static, but can be strategically projected in particular contexts, which enables flexibility. I conclude by discussing three different examples of how the co-production of climate knowledge relies on the production of particular subjectivities (end-users, 'modern' citizens, and holder of indigenous knowledge) that help to bring into being particular configurations between knowledge and social order that enable the climate services agenda to successfully take root. However, because of the dynamic ways in which the identities of actors are expressed and enacted, such efforts are not always successful, meaning that the broader project of climate services is not always able to successfully be stabilized.

6.4 Examining the Historical Roots of Science-Society Relations in Tanzania

Science-society relations reflect the histories and politics of particular cultural domains, such as nation-states, with important implications for the ways in which knowledge is produced, evaluated, and taken up, including societal choices with regard to scientific and technological alternatives (Jasanoff, 2004). Inevitably, any attempt at instrumental co-production of knowledge will be superimposed upon the existing historical, political and cultural understandings. The ability to control material and discursive knowledge practices has been fundamental in enabling the formation and production of the Tanzanian state as a recognizable and authoritative entity. This section illustrates that efforts to implement instrumental co-production of climate services do not happen on a blank slate, but rather take place within the context of well-established and competing discursive and material practices.

There are several historical shifts in the socio-political landscape that have served to fundamentally shape current science-society relations and knowledge politics in Tanzania, with particular effect on the pastoral and agro-pastoral populations in northern Tanzania: the legacy of colonial rule, the post-colonial socialist movement of 'Ujamaa', and the subsequent shift toward economic liberalism and neoliberalism. In different ways, each of these shifts has asserted and solidified the role and ideals of scientific rationalities, with a particular emphasis on the role of 'modern agriculture' supported by technological and scientific advancement, as a pathway toward 'development.'

What is now mainland Tanzania was first colonized by the Germans and then placed under British colonial rule following World War I until independence in 1961 (Chachage, 1988). Colonial policies were primarily concerned with enhancing the productivity of agricultural activities in Tanzania, often through relocation of local residents, shifts to more centralized agricultural practices, introduction of cash-crops introduced by "scientifically" educated agricultural officers, and integration within a capitalist economy (Hyden, 1990). A consistent trend was that indigenous knowledge was consistently denigrated, as regulations put in place under British rule attempted to require local populations to discard indigenous knowledge in favor of colonial knowledge to comply with the demands of these new modes of production (Hyden, 1990, p. 49).

For the pastoral populations in northern Tanzania, and in particular with the semi-nomadic Maasai[8], the advent of colonialism resulted in the demarcation of new political and administrative boundaries which had significant impacts on mobility, a fundamental pillar of their livelihood strategies. Under British rule, Maasai movements were constrained and in many cases forced relocations occurred, under which Maasai were removed and placed in designated settlement areas in order to accommodate agricultural and conservation interests (Hodgson, 2001). In general, British colonial policies toward the Maasai reflected a desire to control the Maasai by 'modernizing' them, while at the same time neglecting basic needs such as access to health care and education through strategic processes of economic and social segregation and marginalization (Hodgson, 2001).

In 1961, mainland Tanzania gained independence under the leadership of Julius Nyerere, ushering in the 'postcolonial' period. While Nyerere and other leaders sought to eschew the colonial domination of the past, the new government's activities were often continuations of the colonial administration as they sought 'rapid development' and 'modernization.' The Arusha

[8] Often, the 'Maasai' are referred to as a singular ethnic group, a tendency that was strongly promulgated through colonial practices that established ethnic categories (i.e. "tribes") as a means of establishing and maintaining control (Hodgson 2001). However, the 'Maasai' were never composed of a single political or ethnic entity, but were rather composed of at least a dozen independent groups, with significant historical intermixing with other groups in Tanzania (Fratkin 1997, Hodgson 2001, Homewood et al. 2009). Despite the complex realities of Maasai ethnic attribution based on economic or cultural categories, the terms 'Maasai' and 'pastoralism' are often so closely linked such that 'Maasai' are viewed as prototypical pastoralists, both in the literature and by Maasai pastoralists themselves (Spear 1993, p. 2). I will use the term Maasai to refer to a heterogeneous group of Maa speaking people who engage in interrelated practices of pastoralism and agro-pastoralism. In this text, I will use the terms Maasai, pastoralists, herders, and agro-pastoralists somewhat interchangeably.

Declaration, delivered by Nyerere in 1967, officially departed from colonial systems of rule through the introduction of Ujamaa (Swahili: literally translated as "community" or "family-hood", but is now more commonly understood as "socialism") but often employed tools of colonial rule (Scott, 1998). Under Ujamaa, Tanzanians were collectively called upon to work for the good of all members of society in collective farms, at first voluntarily and then increasingly under coercion (Jennings, 2008; Scott 1998), thus eroding existing systems of communal land tenure and cultural linkages with livestock keeping. In deference to ideological principles, there was no consideration of indigenous knowledge and practices within the design of Ujamaa policies (Scott, 1998). Rather, during this period, questions of technical competence became central in public discourse in Tanzania, such that the use of the word expert (Swahili: *mtaalamu*) is now common (Feierman, 1990).

Ujamaa socialist policies were a failure both nationally, and in Maasai areas particularly (Fratkin, 1997; Scott, 1998). In addition to the "livestock villages" that were planned by the national government, programs initiated by international development agencies aimed to promote improvements in livestock production. Much of this was focused on the market integration of pastoralists through the creation of Western-style ranches and infrastructure improvements (Fratkin, 1997; Fratkin & Mearns, 2003; Parkipuny, 1979). Many of the changes that were designed to increase livestock productivity (e.g., construction of dams, wells, and roads) only served to contribute to the influx of large numbers of immigrant farmers from other areas and resulted in Maasai being forced into marginal areas or concentrated near water sources, resulting in rapid overgrazing of surrounding pastures (Fratkin, 1997). Furthermore, under Ujamaa, the notion of customary land rights, which fundamentally underpinned Maasai resource access and livelihoods, were abolished under new mandates that gave all Tanzanians the right to apply to live in any area in Tanzania (Homewood et al., 2009).

At the same time, efforts to provide basic services to Maasai were scarce and efforts to bring development to pastoral areas that have been backed by scientific evidence have had detrimental impacts on access to natural resources. What little efforts to educate Maasai populations did take place reflected broader contempt for pastoralist ways of life by overtly promoting the uptake of agriculture within education curricula, while dismissing pastoralism as backward (Bishop, 2008). In this way, knowledge delivered through formalized education, often associated with 'modernization', worked against both pastoral livelihoods and their knowledge. The emphasis on the use of 'modern' knowledge had the effect of reinforcing Western interpretations of relations between 'development' and the environment, with particular effect on understandings of pastoral livelihoods and ecological conservation in the rangeland areas of northern Tanzania (M.J. Goldman, 2006; Hodgson, 2001). 'Scientific' interpretations of ecological dynamics that viewed local livelihoods as antithetical to conservation goals, have resulted in massive conversion of land in Tanzania to various forms of 'protected' conservation areas, such that now over 30% of the country has some sort of protected status (Brockington, 2002; M.J. Goldman, 2009), thus drastically changing the material conditions and relations through which Maasai are able to enact their livelihood practices.

For pastoralists, the emphasis on technological modernization has been concomitant with shifts in forms of governance and their own relations to the state. The modernizing, socialist agenda of Nyerere was not able to produce the significant increases in agricultural outputs as hoped, and, by 1984, the socialist model was increasingly replaced with economic liberalization and privatization. By the early 1990's neoliberalization had resulted in the near complete privatization of most areas of the Tanzania economy (Due, 1993). For pastoralists, neoliberal efforts toward 'modernization' represented another key shift in land tenure policy, under which communal lands were sold by central government agencies with very little consultation with customary users before doing so, often to foreign investors or conservation interests (Homewood et al., 2009). However, as Igoe and Brockington (2007) have pointed out, neoliberalization (in the conservation domain and elsewhere) also entailed important changes in governance, resulting in 'hybrid' governance arrangements in which states, NGOs, private enterprise, and 'communities' are drawn into new networks that purport to provide greater opportunities for increased 'democracy' and 'participation.' At the same time, these arrangements have resulted in the creation of "new state forms" that have increased dependence on external funds, technology, and expertise, making them more vulnerable to external control (Igoe & Brockington, 2007, p. 432). Gardner (2016) has also highlighted the complex ways in which neoliberal shifts have both undermined and empowered Maasai communities in northern Tanzania in the last several decades.

Thus, discursive emphasis on the need for modernization has had important impacts on Maasai identities in Tanzania. Neoliberalism is both a political discourse about the nature of rule and a set of practices that facilitate the governing of individuals from a distance that fundamentally changes the relations between citizens and governance, with consequent reformation and understanding of self-identities (Larner, 2006). This is a process that is evidenced by the rise of fractious indigenous identity politics among Maasai in Tanzania, as well as the resulting reworking of citizen-state relations brought about in large part by the ability of pastoralist civil society organizations to effectively tap into and link with global indigenous movements (Hodgson, 2011). This also creates an inherent paradox: within these new networked configurations, self-identified indigenous groups, such as the Maasai, are successfully able to gain recognition as 'indigenous' on the international stage, but continue to fail to gain recognition from the nation-states that have denied their full citizenship through rights abuses, including unauthorized resource grabs, as well as a general denigration of their livelihoods and cultures (Hodgson, 2001).

This historical overview illustrates the ways in which broader international and national trends have served to shape interactions between scientific and expert knowledge, forms of governance, citizen-state relations, and pastoral and agropastoral livelihoods in Tanzania — all of which have important socio-material consequences. These trends collectively illustrate the politically fraught history of colonial and state interventions aimed at 'developing' the Maasai that have tried to incorporate them within dominant visions of a 'modernization,' while at the same time neglecting or disenfranchising them (Hodgson, 2001). These attempts have reconfigured the webs of relations between Maasai, their material surroundings, technology and scientific knowledge, the Tanzanian state, and non-governmental entities.

In general, these reworking have resulted in increasingly marginal (and marginalized) pastoral livelihoods (Homewood et al., 2009). To make matters worse, when these efforts fail, blame is generally placed on the Maasai themselves, rather than deficiencies in the schemes (Hodgson, 2001). Not surprisingly, continued efforts to employ technocratic and scientific managerialism approaches that in the name of delivering the 'benefits of development,' are viewed with a great deal of skepticism among Maasai (Hodgson, 2011). As will be further discussed in this paper, one outcome of these shifting relations is the multiple ways in which Maasai communities have positioned themselves, and in particular their knowledge and perspectives, in conflict with 'modern' approaches, but also — a process that has brought new practices, understandings, and uses of Maasai identities into being. At the same time, Maasai have been able to strategically leverage their identity as 'holders' of indigenous knowledge and practices as a means of gaining access to knowledge and resources (Hodgson, 2011), including climate services, that simultaneously make them more 'modern.' Thus, while instrumental co-production arrangements within the context of climate services rely on the formulation of a particular type of 'end-user' subject, Maasai may at times conform to or resist this. In these tensions and shifts, it is possible to trace the various ways in which power is exercised within instrumental co-production.

6.5 Socio-material Networks and the Assemblage of Climate Knowledge

6.5.1 Assembling Scientific Climate Knowledge

Scientific weather and climate prediction relies on long-term data for particular sets of variables collected through observation networks and systems around the globe, relying on both *in situ* observations and space-based satellites (Zillman, 2014). At the global scale, efforts to bolster the prediction of weather and climate have relied on extensive efforts to collect, standardize, and aggregate data, as well as systematic coordination, under the Global Climate Observing System (GCOS), which was initiated in 1992 and is situated under multiple United Nations System organizations, under the primary leadership of the World Meteorological Organization (WMO) (Edwards, 2013; Houghton et al., 2012). The GCOS is intended to support all facets of the World Climate Program, which currently includes the Global Framework for Climate Services (GFCS), the IPCC, and the UNFCCC (Houghton et al., 2012) — meaning that it is the primary pillar to support for how we 'know' the climate scientifically, as well as what should be done with such knowledge, in terms of actions to address both mitigation and adaptation. Yet, despite continual expansions in the number and amount of instrumentation, such as synoptic stations, weather buoys, and other technical tools, much of the focus of the GCOS has been to continue to identify 'gaps' in the observation network, which is perpetually framed as lacking. The sufficiency of the GCOS observing networks is evaluated specifically in terms of its capacity to support the UNFCCC to address the needs of the Parties to the Convention (see Houghton et al., 2012).

Much of the effort to collect climate data has relied on processes that can 'fit' weather and climate events into standardized parameters that can represent the 'true nature' of the climate – what ANT scholars might refer to as 'domesticating' (e.g. Callon, 1984) the climate so that it can be 'known' scientifically. The rationale behind the GCOS, while important to global processes, also includes the desire to "characterize the state of the global climate system" in order to enhance understanding of climate change and support prediction of climate variability and change — including to project climate change information "down to local scales" and to "develop adaptive responses to reduce vulnerability to climate and climate change" (Global Climate Observation System [GCOS], 2015, p. 5). In this way, observations are essential to the implementation of climate services, which are presumed to contribute to sustainable economic development and public well-being (GCOS, 2015). Yet, the GCOS relies on more than just atmospheric measurements — rather, it is also dependent upon observations of oceans, land, and ice — and thus is not just a singular system, but rather a "system of systems" in which the atmosphere, ocean, and land are observed as separate "spheres" (GCOS, 2015, p. 2). There are considerable challenges to merging these data, however, since they reflect "distinct observing traditions and cultures" (Houghton et al., 2012).

What quickly becomes evident is that the GCOS and global modeling efforts, as well as the knowledge they produce through the production of climate services, requires both the rooted observations of climate in particular places as well as 'dislocated' observations made from space. Neither of these sets of observations would make sense without the other – they are dependent upon one another to 'ground' satellite data and to link *in situ* observations together in way that fills the gaps in the observational network. There have been recent efforts to merge these sources of data to create comprehensive national climate data sets at high resolutions for countries in Africa with previously insufficient point station data availability, including Tanzania (International Research Institute for Climate and Society [IRI], 2014). Yet, the various forms of data are often valuable for modeling and prediction efforts only in as much as they are *mobilized* and *networked* to provide smoothed and aggregated data about the atmosphere, ocean, and land, in which 'the climate' is translated and transcribed into material outputs that allow it to travel.

Climate data and modeling gains and asserts its authority in particular venues in which scientific knowledge is assumed to be the basis of solving problems of global decision-making about what to do about climate change. Yet, this authority is also reliant on the interactions between climate science and the social processes that regulate, produce, and apply it. Collection of climate data is not only based upon scientific assumptions about what would produce the best possible models; rather, the data collection conducted under the GCOS is a process shaped both by the needs of various programs under the World Climate Program, including the politically oriented UNFCCC,[9] as well as *what is feasible* within the messy process of attempting to establish and systematize data collection efforts at a global scale. So it is not just the technical instruments upon which the data and observations rely; there is a need to enlist actors in various nation states to

[9] Part of the GCOS mandate is to provide support to the UNFCCC in the areas of: development of observational networks, research and observations, climate change adaptation, and providing support to the Annex-I UNFCCC Parties to the Convention. The Essential Climate Variables (ECV) that are collected through the GCOS observation system are designed specifically to meet the needs of the Parties to the UNFCCC. (http://www.wmo.int/pages/prog/gcos/index.php?name=UNFCCCandGCOS, accessed 6 June 2016).

participate in these data collection efforts, there is the need to mobilize financial resources to build and maintain the network, and there is the need to be able to adequately transmit the data. The bulk of these efforts are spearheaded by the WMO, which serves as the secretariat of the GCOS, but are complemented by several other UN and international agencies.[10] Without holding all of these pieces of the network together, there would be no scientific capacity to produce scientific information about the climate, past or future, or the accumulation of authority that goes along with this. Further, the knowledge must enlist the 'vulnerable' populations at 'local scales' in order to become usable toward the goals of implementing 'development' or bring about 'public well-being.'

National level predictions in Tanzania similarly rely on the aggregation of data. While at the global scale, new coordination mechanisms have been developed for the purposes of aggregating data, often separate from where predictions are produced, in Tanzania the processes of collecting, aggregating, cleaning, and transcribing data and producing the model 'outputs' occur in the same space. Again, the observation networks are the foundation for predictions, but here, the process of transcription and translation bumps up against a different set of challenges, a different set of relations to be negotiated.

The production of meteorological data is bound up in the colonial and post-colonial histories of Tanzania. Formal meteorological services for Tanzania were first produced under the British East African (EAMD) Meteorological Department beginning 1929, with the sole emphasis on providing data for military and civil aviation (East African Community [EAC], 2004). By 1977, the Directorate of Meteorology was created in Tanzania, which then assumed the responsibility of

[10] The GCOS is co-sponsored World Meteorological Organization (WMO), Intergovernmental Oceanographic Commission (IOC) of UNESCO, United Nations Environment Programme (UNEP), and International Council for Science (ICSU). The GCOS secretariat is seated at WMO.

conducting all meteorological activities in Tanzania. In 1997, the Tanzanian Meteorological Agency (TMA) was formed as a semi-autonomous agency (Timiza, 2013), thereby institutionalizing the TMA as the authoritative agency designated by the Government of Tanzania (GoT) to produce meteorological and climate services.

With the creation of the TMA, we also see an important shift and an expansion of the mission of meteorological services; whereas the early production of meteorological services in Tanzania were undertaken for the aviation sector, the mission of the TMA was adapted to emphasize the role of weather and climate information as contributing to "*the protection of life, property, environment, and poverty reduction*" (Timiza, 2013, emphasis mine), as well as to provide for and meet the expectations of "various users" in the sectors of agriculture and food security, surface transport, and others. Thus, we can see that the production of climate knowledge in Tanzania is already discursively enmeshed with its intended uses and the particular ontologies that are desired.

As at the global level, the capacities to produce meteorological and climatological predictions are often framed in terms of the existence and strength, as well as 'gaps', in the existing observation networks. In Tanzania, the Ministry of Transport conducts an inventory of current, operational equipment and stations in order to identify needs and shortages in terms of capacities to collect data. Here it becomes evident that while the TMA's ability to produce authoritative predictions relies on a continual process of expanding and maintaining observation networks, this is not such a simple task. The observation networks must be taken care of. Sometimes they wear out and need replacement. Sometimes they are interfered with by local residents. Sometimes severe weather events themselves can disable the stations. Sometimes there are issues related to recording, transmitting, and collating the data. Observation networks have been eroded in many locations, particularly during the 1980's and 1990's, when the impacts of structural adjustments took full effect in Tanzania. Indeed, while there are 2,056 rainfall stations in Tanzania, only 500 of these are operational (United Republic of Tanzania [URT], 2014).

All of these issues require additional human and financial resources, which generally does not have available in its own budget, due to generally insufficient funding (EAC, 2004). As a consequence, there is a need to obtain funding from an already strained government budget or from external donors interesting in funding such investments. This requires making the case that Tanzania is 'in need', a case that often invokes the country's status as a less developed country but also in particular reference to being a country that is 'most vulnerable' to climate change. The successful deployment of the observation stations involves much more than just the stations themselves — but the need to seek out other associations to build the networks that enable the climate to be 'known'. The issue is not only of collecting the data.

The production of climate knowledge is dependent on the ability of observations to be inscribed in particular ways so that it becomes transportable and standardized data. Yet, this is not a simple task. The process of transmitting the data takes additional work, multiple interdependencies, and varied assemblages of human and non-human entities. For the observation stations that are functioning, some have the capacity to automatically send data electronically. More frequently, there is a need for the station data to be read and recorded by TMA staff members or local residents who are trained as volunteers. Sometimes, these observations are called in to TMA headquarters by mobile phone. In most cases, however, the data is recorded by hand and sent in hard copy by mail to TMA on a monthly basis. However, this creates an additional step or challenge of digitizing the data, both for current and past records, something that has been a major challenge in WMO's efforts to collect globally comprehensive data.

We have seen that the networks that are established to accumulate scientific climate knowledge at global and national scales rely on elaborate practices and extensive materials, instruments, and technologies to 'domesticate' the climate in a way that can be captured in transcriptions (e.g. transportable, standardized data sets). It is these socio-technical configurations that enable the establishment between what is considered 'scientific' climate knowledge and what is not. There has been a growing movement to recognize indigenous knowledge (IK) of climate change alongside scientific modes of inquiry (e.g. Green & Raygorodetsky, 2010). Yet, the majority of efforts to incorporate IK within climate services have focused primarily on extractive processes of cataloguing the various 'indicators' that are used within IK predictions (e.g. Mahoo et al., 2015).

There were recurrent patterns in the way in which indigenous climate knowledge was discussed among national and international stakeholders. For example, in the only session devoted to examining the social dimensions of the application of climate science during the Africa Climate Conference, IK was repeatedly portrayed as something that needed to be documented, indexed, and preserved. One researcher remarked that: "indigenous knowledge has not been captured and stored in a systematic way and therefore are [*sic*] endangered with extinction" (Researcher 1 ACC). Further, there was a great deal of concern that there is currently a "lack of data to validate IK and their environmental indicators" (Researcher 2 ACC). Final recommendations coming out of the session, which were presented during a plenary, stated that "very little IK is shared and documented" and that what IK that has been collected "via surveys" should be fed into a "more holistic system." For example, it was noted that "the [indigenous] knowledge is there, but we don't have a good source…IK differs from one area to another" (Government #19). There have been efforts to "coordinate" scientific forecasts with IK, but there is currently no structure in which to do so — a point also made by Mahoo et al. (2015) in a report documenting efforts to link scientific and indigenous knowledges in Lushoto, Tanzania.

6.5.2 Assembling Indigenous Climate Knowledge

The production of knowledge about weather and climate at village scales requires a new set of associations. In contrast to the ways in which indigenous climate knowledge was framed within national and international discourses, perspectives of IK in the villages of Arkaria and Kiserian reflect a more dynamic and complex set of interactions that enable the climate to be 'known.' Respondents noted the simultaneous and overlapping use of observations of the moon and stars, plant phenology, animal behavior, weather in other locations, changes in soil conditions, as well as advice from elders, reports from travelers, phone calls from relatives in other locations, their own tacit knowledge, and knowledge from 'outside' sources, to inform their understandings of weather and climate – reflecting a complex set of networked relations, often involving entities that would be discounted from Western conceptualizations of climate knowledge (see also de Wit, 2015; M.J. Goldman, Daly, and Lovell, 2015). It is in this way that networks can serve as tools of exclusion and boundary-making, to determine what should count as climate knowledge and, indeed, to 'produce' a climate in the first place. Tellingly, in the languages of both Swahili and Maa, there is no word for climate.

However, the networks that enable indigenous understandings of climate are at the same time enmeshed and overlapping with, as well as interfered by, other sets of relations and historical contingencies. Residents of the villages of Kiserian and Arkaria rely on multiple ways of knowing the climate simultaneously and reflect a reliance on both human and non-human elements as a means of assembling their overall knowledge. When asked to identify the top 5 sources of knowledge and information about weather and climate variability, respondents reported that their own observations of the natural environment, information from elders, and their own 'common' knowledge were the most important sources of knowledge for predicting weather and climate. These ways of knowing were also embedded within daily practices (e.g. observing the behavior of cattle in the mornings) and social relations (e.g. seeking out advice from knowledgeable elders). This highlights that while much of the knowledge coming from scientific experts is based on a narrow set of indicators to measure change, many individuals 'know' climate change through their daily practices in which they see changes in land use (e.g., increased farming, larger numbers of cattle) and changes in the weather in their places all as part of determine whether or not the 'climate' is changing.

Yet, these are dynamic processes that are sensitive to socio-ecological changes, which have changed how people assemble their own knowledge. Village surveys indicated that the number of sources of observations and knowledge contributing to their own knowledge about weather and climate was declining, particularly with regard to reliance on observations of plants, moon and stars, and animal behavior and knowledge from elders. It was widely expressed that the socio-material relations through which knowledge about weather and climate are gathered are changing. The increasing number of Maasai who were able to access formal education is one important factor. "The challenge is that the younger generation doesn't believe. Schools are changing people…" (NGO #6). People also complained that now, many of the youth do not have time to look at the stars, to observe the behavior of the animals, or to see the changes in plant phenology because "they are too busy looking at their phones. They do not have time to look up."

Additionally, the production and circulation of indigenous knowledge of climate is dependent upon the relations between older and younger generations, which are in turn shaped by broader processes of environmental, technical, and socio-economic changes, as well as processes of globalization. The increasing reliance on goods that must be purchased outside of the household and a desire to avoid selling livestock has resulted in a growing need to search for new ways of tapping into more diversified livelihood strategies, which include sending youth to seek out wage and salaried labor opportunities in urban areas (Homewood et al., 2011). These transitions have resulted in a change in how elders and youth interact. With the youth gone to the cities, there is little opportunity for elders to share their knowledge about the climate and the ways in which they predict weather. Furthermore, many youths felt that because of their work in the cities, they no longer had the opportunity to prove their strength and bravery (e.g. through cattle raiding) as they did in the past. Without opportunities to earn the respect, the youth felt they were increasingly demeaned by elders. This increasing friction has also resulted in breakdowns in the ways in which climate knowledge is produced, circulated, and used. There were fewer opportunities for the youth to learn from the elders since they were more frequently away from the household. At the same time, feeling disrespected made the youth less likely to want to learn from the elders.

In the previous sections, I have shown that the production of all climate knowledge is dependent upon networks of heterogeneous entities. Scientific climate knowledge gains its authority through sets of standardized practices and technical equipment, which are also used to differentiate it from other knowledges. These various networks – those involved in the production of both scientific and indigenous knowledges – sometimes overlap and sometimes contradict each other. This problematizes simplistic narratives that assume that there is a distinct divide between scientific and indigenous knowledges that should be overcome through instrumental processes of co-production that merely seek to 'integrate' or 'combine' different knowledges. Furthermore, it shows how knowledge production both relies upon and is productive of particular science-society relations.

6.6 Socio-Material Networks and the Circulation of Climate Knowledge

In general, much of the circulation of both scientific and indigenous knowledges rely on a combination of formal and informal sets of relations through which these knowledges travel. Yet, in order for this knowledge to 'travel', there is a need to mobilize connections, associations, and relations established through networking in order for the knowledge to circulate.

6.6.1 The IPCC and the Enrollment of Tanzanian Climate Experts

While the IPCC is often touted as the sole authoritative resource to define the causes and potential impacts of climate change, the authority of the IPCC has also been contested in many arenas (Beck et al., 2011). Furthermore, there have been accusations that the reports generated by the IPCC are more widely available in and representative of the global North. In response, the IPCC undertook extensive action to circulate the findings of the new AR-5 report at the national level in many countries in the global South in 2015, a communications and outreach effort that was deemed the "most comprehensive ever taken" (IPCC Acting Chair, IPCC Outreach Meeting).

During an IPCC outreach meeting held in Tanzania in 2015, these efforts to actively disseminate the findings of the IPCC AR-5 report were presented as a "key milestone for the Tanzanian research community, to illustrate the value of the IPCC as an authoritative source of climate information" (IPCC Rep. #1, IPCC Outreach Meeting). Throughout the meeting, there were continuous references made to then numbers of reviews and reviewer comments, people involved, references/studies, pages, and words included in the report - concluding with the statement that "no other document undergoes such a thorough review" - ostensibly to build the credibility of the report findings. As a final gesture to reinforcing the 'boundary' between science and policy, the panel noted that the IPCC does not make recommendations about how to respond to the information, they just compile information. Rather, the recommendation offered by the IPCC representative was that: “you take science seriously and integrate it into decision-making…*that* is the recommendation.”

Not only was this an effort to shore up the epistemic authority of the IPCC, but it was also designed to enroll participants from developing countries through capacity building seminars. Within this context, Tanzanian speakers from the government repeatedly referenced the lack of “diverse participation” within Tanzania and other developing countries. Another minister noted that they should use the opportunity to “convince Tanzanian researchers to publish on climate change” in order to “build our position as Africans” so that “Africans can take charge and benefit” (Gov. Minister #1, IPCC Outreach Meeting). Such arguments, however, are often bolstered by depictions of the impacts of climate change, such as failing crops and dying cattle, which can equally promote depictions of ‘vulnerable populations’ who are at the mercy of climate change. The fact that the entire meeting was prefaced with a “traditional African dance group” to perform for the “honored guests” (i.e. foreigners coming from the IPCC secretariat) solidified the multiple enactments by the Tanzanian meeting participants — at the same time projecting ‘traditional’ and ‘modern’ identities.

6.6.2 Tapping into Multiple Networks to Assemble Hybrid Knowledge

The circulation of information at the national level in Tanzania involves both different networks of human and non-human entities, as well as a rationality of bureaucratic decentralization as the key mode for facilitating knowledge flows. Some actors are able to link up with these networks at certain times, but also are able to fluidly reposition themselves in efforts to seek out other kinds of knowledge and to integrate this in creative (and sometimes covert) ways. Some government ministries and departments and NGOs have also been able to link directly with

TMA, to develop partnerships in which they can access or are directly sent information about upcoming weather and climate.

Often times, the information from TMA is combined with knowledge from other sources. The country office of one international NGO reported working closely with TMA, a relation through which they were able to obtain information more consistently and expediently. But they were also receiving information and technical support from an international climate prediction center in the U.S., as well as data sent to them from local weather stations that they had installed in locations where they work. Thus, while they had a good working relationship with TMA and even formalized relations with an MoU in place, the information produced was perceived to be very general and overly broad to be incorporated into decision-making directly. For this reason, the NGO brought the multiple sources of knowledge together, through the construction of new networks, as a means of creating hybridized knowledges that was seen as credible, but also flexible enough to be adapted to particular sites of application. For example, this same NGO had worked to develop a program through which climate forecasts were translated into songs to be delivered in the villages.

Within the current institutional mandates in Tanzania, TMA must officially distribute its predictions, and other related information, through the bureaucratic structures designated in national policies. These institutional flows rely heavily on the decentralized regional and local government structures, which have remained in place since their advent under Nyerere. However, there are often failures of the network to successfully take root. In some cases, letters do not arrive (or arrive long after they are relevant), in other instances, there may be no one from the District to retrieve the letter from the Regional Offices. In other cases, the letters may arrive to the District, but there may be no way to deliver the letters to the village extension officers, due to lack of transport. It is evident that the process of circulating the knowledge is not a smooth or automatic process; rather, it must enlist a multitude of human and non-human participants within the network in order for the forecasts to 'travel.' There are potential pitfalls and missed connections at every turn. Thus, while the idea of the network exists, this illustrates that it is fragile and precarious and requires constant negotiation to ensure that the network is able to successfully 'work.'

Within efforts at the national level to increase access to climate information, there are many assumptions made about the vital importance of the use of information and communication technologies (ICTs) such as radio, phone, text messaging, social media platforms, and the internet. This embodies an implicit expectation that knowledge delivered via technological means, but coming from 'experts', is likely to be superior to knowledge that is received through common routines and practices, including individuals' own experiences and observations, face-to-face interactions, customary meetings, etc.

While formal systematic networks are designated as the 'official' way of distributing the information, these may not always be effective. As one Met Agency staff member exclaimed "Of course people complain!" when asked about whether or not people are able to get the information that TMA produces – meaning that there is acknowledgement of the challenges of promoting the forecasts. When the formal networks fail, national level actors have built a range of different linkages through less formal conduits, to attempt to 'hook up' to the information. The assumption is that this distribution will trickle down to the local level. This has been combined with more direct delivery via various information communication technologies. However, both of these approaches to distribution are based on one or both of the following assumptions: 1) the notion of an idealized small scale 'farmer' that is receiving information through an extension agent or 2) the idea of a ‘technological citizen’ that is able to access information through radio, television, phone, internet, etc.

6.6.3 Circulation of Knowledge as a Relational Activity

In Maasai culture, extensive greetings and conversation are a central component of day-to-day social life. In particular, there is a custom of “eating news” (Maa: *ainos ilomon*) (M.J. Goldman 2006) in which it is expected that, whenever possible, you engage in conversation that can involve a whole range of matters, but often including inquiries about a person’s health, the well-being of their family, and their general state of affairs at home. This custom is also a key means through which people receive information, since people are often on the move and cross paths. While walking in the villages, when encountering another traveler, you will often be asked a series of questions, including: Where have you come from? Where are you going? What did you do [there] and what do you plan to do when you get where you are going? In these interactions, a frequent topic of conversation can include aspects of herding and farming, including information about the current conditions of weather and water and pasture availability (both locally and in other locations along the way), as well as discussion of what is expected in terms of future weather (based on ethnographic observation). While considered an “informal system” (NGO #3) of delivering information, the process of eating the news highlights the importance of social engagement, as well as mobility, in shaping knowledge flows and illustrates the crucial dimension of face-to-face interactions as a conduit for transferring knowledge in Maasai culture.

Indeed, this was a sentiment expressed by the majority of research participants in Longido and Monduli Districts, who seemed almost baffled by the idea that one could be expected to trust information without being able to see the face of the person who was delivering it. This applied to information coming through the telephone, radio, and television. In an often repeated example, many people noted that they would never trust information someone gave them through the telephone because, for example, a person might tell you that they are in a faraway location, such as Dar es Salaam, where in reality they may be in the very same village as you. Radio and television were also seen as enabling people to speak mistruths without enabling the listener to verify the veracity.

This touches on another key aspect of the circulation of climate knowledge in Maasai areas: the importance of telling the truth — or rather, it might be better to say the strong imperative to not speak mistruths. When asked whether or not they share information about weather and climate change with family, friends, or neighbors, the essential determinant was whether or not the information was "true." Of course, in the case of climate forecasts which are probabilistic, they are neither 'true' or 'untrue', 'right' or 'wrong', thus presenting a major barrier to the circulation of scientific climate information at among village residents. Many village respondents indicated that they often felt like there were already ways through which they could receive climate forecasts, including customary meetings and through village government meetings, if the forecast information was deemed important and 'correct.'

Thus, it is less a matter of pathways for the knowledge to be transmitted, but more an issue that in many cases both human and non-human actors may not 'play their part' in enabling the knowledge to circulate. This can include the lack of 'cooperation' of the seasonal climate to correspond with expected conditions in previous years (thus making the information 'untrue' and thus not worthy of sharing), as well as the resistance of particular actors within the network, such as customary leaders or village government, who may choose not to deliver the information to avoid the negative repercussions on their own reputations and credibility.

6.7 Hybrid Knowledges, Hybrid Identities

The use of climate information at all scales reflects a multi-faceted interaction with different knowledges and engaging with different sets of networked relations. Indeed, there are always and already complex interactions between multiple knowledges always and already taking place. Yet, these dynamics are often ignored or obscured within efforts to facilitate instrumental knowledge co-production. It is often assumed that the only people who use IK are only those who live 'in the village.' National scale actors are considered to be cut off from IK. Conversely, rural residents are generally considered unable to access or understand scientific information. Counter to these common assumptions, this research highlights that different actors are often able to tap into a multiplicity of knowledges, but that how this knowledge is expressed and used is dependent upon the various identities that are strategically enacted and projected by actors. Further, these identities are not static but are dynamic across time and space – reflecting the differing ways in which actors can tap into various networks depending on the situation and context in which they are situated.

6.7.1 Bureaucratic Mandates and Strategic Denial of IK

Many national scale actors possessed, accessed, and used IK in various ways, but they were not always able to admit to doing so because this was contradictory to their need to conform to expectations of being a modern and technologically sophisticated citizen. In the case of many national-level government workers, most are still connected to indigenous knowledge in their home places, which they continue to receive on a regular basis through communications with friends and family, as well as through their own visits. While not always recognized within 'formal' justifications in professional contexts, it was acknowledged that this was often an important dimension of decision-making for both personal and professional purposes. For example, many respondents indicated that they try to compile all the sources of information that are available, rather than relying on only one source of information.

However, there is a strong bureaucratic precedent that dictates the use of scientific climate information within government agencies. As noted by one government worker, they are expected to follow their mandate — meaning that if other individuals or ministries are using particularly kinds of information, you must also do so. Within this context, TMA is viewed as the only agency mandated to provide information about weather and climate in Tanzania, meaning that this is the only source of knowledge that is acceptable to use as a justification for particular decisions. One respondent noted that when determining what information to use, it is necessary to consider the "authority of the people giving the information. They [TMA] are experts and are mandated as an organization" (Government #19).

Different sets of challenges were described by national level actors in the use of IK. Most respondents within national government agencies or NGOs actively attempted to deny using IK within decision-making for their official duties. However, when pressed about whether they might use it for other 'personal' decisions, the answer was often different. Among government workers, there was a strong sentiment that it was not appropriate to use IK for 'government' work. This was a sentiment that was also expressed in some NGO offices. When one NGO staff worker remarked that "of course" he relied on IK, a fellow staff member at the NGO who was sitting at the next desk intervened to mock and scold the respondent for admitting to doing so. (Yet, this is an NGO that is also vigorously working to promote IK within its climate adaptation programming!)

Nonetheless, many NGO staff used a combination of IK and scientific knowledge, though in some cases they relied solely on IK for decision-making. This was attributed to the perception that the scientific forecasts are not credible in general — "they have predicted droughts and then floods come" (NGO #3) — and also reflected a lack of trust in government organizations, including the TMA, particularly among grassroots NGOs.

6.7.2 Network Failures and the Fragility of Scientific Knowledge

Despite the fact that scientific climate knowledge is considered the only sound basis for backing policy-decisions among many national actors, there were many barriers to being able to use the information in practice. One respondent expressed doubt about whether "even conventional scientific knowledge is used" (Expert #15). Rather, as one respondent noted that there is still a lot of work to do to "mainstream weather and climate information" — but the challenge is that "currently, no one knows how to do this." As a result, there is a lack of action at the national level to apply knowledge about weather and climate, even when it is readily available. Even when there is 'good information' available, politicians are generally unable to carry these out due to limited budget resources and lack of fully operational institutional structures to carry actions out. However, this has created a 'jumping of scales' in which international agencies are supporting climate adaptation initiatives at the grassroots, while there is an absence of efforts to mainstream climate change within national development projects (Expert #15).

Similarly, the use of scientific climate knowledge at village scales was challenged by the lack of perceived credibility of the information. One respondent stressed that "if you are a farmer, you need the rain to come, not to be told that the rain will come" (Government #19), highlighting the tension between scientific and other ways of assessing the credibility of knowledge. This was expressed in relation to the challenge that "the science and the actual occurrence are not actually matching" — which presents two challenges. The first is that the government ministries become the target of anger when the forecasts are perceived to be inaccurate. This has resulted in some government ministries looking for 'no-regrets' strategies that do not depend on forecasts — "that way people won't blame you if the forecasts are wrong." Interestingly, one respondent noted that it has become harder for TMA to predict weather and climate than it was in the past because public expectations have been raised and people are paying attention now (Expert #15), illustrating another facet of 'user' identities — those that hold 'producers' of climate services accountable.

The difficulties in creating compliant 'end-users' posed challenges to the establishment of networked relations needed for climate services to 'work' on the ground. Without 'users' who are willing to take up the information on the ground, network-building efforts fall short. Further, it becomes a challenge to regain credibility once it has been lost. As noted by Expert #12, it is difficult to "change the mindsets of the people to think that the forecast is good." This represents the difficulty of enrolling 'end-users' within the networks that endow climate services with authority. Such attempts at enrollment may not be successful for a variety of reasons, including the fact that 'targeted' populations do not neatly correspond to the subjectivities that current conceptualizations of 'successful' production and use of climate services may require — which is to say essentialized 'small-scale farmer' subjects whose decision-making is highly sensitive to climate information.

Complex interrelations between livelihoods, identities, and decision-making are at work in the villages of Arkaria (in Moduli District) and Kiserian (in Longido District) with important implications for how knowledge is used and for what purposes. The reasons expressed about why and how people chose to integrate particular knowledges within their decision-making often reflected highly personalized rationalities, experiences, and beliefs. Indeed, when discussing livestock keeping and farming practices, many people I spoke to throughout the course of my fieldwork were quick to assert that they were "pure" Maasai, a point which served to distinguish them from other neighboring groups, such as the Arusha, who rely to a greater extent on cultivation. Those that did farm emphasized that they mainly relied on livestock, even if they engaged in some agricultural activities. This was both because of perceptions and experiences about the limited benefits of farming, particularly in the more arid Longido District, as well as a means of reinforcing the centrality of cattle to Maasai and their cultural identity. However, there were some important similarities. When discussing the kinds of information that is used for various livelihood decisions, both within quantitative surveys and qualitative interviews, village respondents consistently indicated that the kind of information provided through weather and climate forecasts was generally much more useful for agricultural practices than for activities related to livestock keeping. Very few people expressed a willingness to make decisions about where to move their cattle solely based on predictions of any kind — whether scientific or indigenous. Rather, there is a prevalent norm that requires a family member to be sent as a 'scout' to evaluate water and pasture conditions in other areas, as well as negotiate access, before moving cattle there (see also Goldman & Riosmena, 2013 and Goldman et al., 2015). This is a point made also by Luseno et al. (2003) who has questioned the value of climate services for pastoralist decision-making.

6.8 Co-producing Knowledge, Producing Subjectivities

6.8.1 Producing 'End-Users'

In examining the processes of the production, circulation, and application of climate knowledge, it becomes evident that scientific knowledge cannot be brought into being as a 'climate service' without a particular subject that is able to receive and assimilate them within decisions and practices. Yet, enlisting 'end-users' takes work. There is ongoing debate within climate services about 'end-users' — in terms of who these groups are, what kinds of information they ‘need’, the kinds of livelihoods they engage in, and decisions that they make. A summarized in the proceedings of the Africa Climate Conference (ACC), “more research [is] required to understand and properly characterize existing and emerging needs of users.” An audience member at the ACC remarked that what are really needed are “user needs-based science” which will require “interfacing with local communities.” A scientist from an African regional climate center (Expert #1, ACC) noted that there is a need for a “mechanism to teach the end-users” to ask for climate services, because the products need to be “demand driven.” Thus, not only are users defined by their information needs, in some cases they are actively ‘taught’ how to be engaged ‘end-users’ who demand such products. In essence, this results in a form of subjectivization, in which individuals are ‘known’ and made ‘legible’ in terms of their climate information needs, a point that has also been made by Carr and Owasu-Daaku (2015). This results in a proliferation of attempts to impose particular subjectivities, in which citizens and groups are defined by their ‘information needs,’ as well as in relation to the existing understandings and framings of what it means to be a ‘citizen’ in Tanzania.

6.8.2 Using Co-production to Advance ‘Modernization’

The climate services agenda often implicitly embeds particular visions about progress, prosperity, and ‘development’ that reinforce the dominant framings of modernization that privileges sedentary and technologically connected subjects, rather than those who are flexibly rooted, yet mobile, and thus linked within a different set of relations that opens up alternative ways of knowing about the climate. Given the focus on agricultural livelihoods, climate services have at least an implicit (if not explicit) imperative for ‘end-users’ to see themselves as individualized farmer subjects that are concerned primarily with private well-being — apart from the cultural ties, social systems, and informal institutions, outside of the context of communal decision-making and norms of reciprocity that have been an important part of pastoralist and Maasai society. Furthermore, in this process, responsibility for the consequences of decisions also becomes individualized, without recognizing the particular settings in which such decisions are made and how these are constrained or enabled by inequalities. This serves to erase the political nature of the use of information and its outcomes.

The ‘end-user’ subjects are also supposed to engage in particular forms of climate adaptation which correspond to the kinds of information available through climate services, which embody ‘actions’ that are also legible to the ‘producers’ or other backers of climate information. This is generally characterized in terms of specific adjustments to agricultural practices (e.g. changing crop or seed varieties), livestock keeping (e.g. selling off cattle in advance of a drought), or other changes that mark a departure from ‘standard’ practices that can be attributed to climate information.

6.8.3 Being ‘Indigenous’ to Become ‘Modern’

Additionally, there is a seeming contradiction within the co-production of climate services. In order to gain access and to be part in the co-production of climate services, this often required participants to conform to the ideal of a ‘traditional’ holder of indigenous knowledge in order to be considered authoritative within co-production activities. Yet, the very process of accessing and using climate services is part of a modernist agenda in which ‘users’ of climate information are consistent with idealized visions of what it means to be a ‘modern’ citizen. This process of determining who should be ‘added’ to the production of scientific climate knowledge often sought to include individuals who could represent ‘non-science.’ Such processes require the multiplication of identities, in which the ‘local co-producers’ of climate services are at once supposed to ‘represent’ the ‘traditional’, while at the same time conforming to the ideal of a legible, settled, and technologically savvy citizen. Yet, in pastoral areas, existing relations with the state and promotion of 'modern' expertise has until this point largely marginalized IK, and despite growing recognition of pastoralist issues on the national stage, such relations remain entrenched. Additionally, the process of 'tailoring' climate services to the 'needs' of 'end-users' constricts the validity of indigenous knowledge, ideas, and perspectives to a very narrow and pre-determined portion of knowledge making. Such processes are upheld through first 'protecting' the credibility of scientific knowledge about climate, and then allowing 'other' knowledge and perspectives to be added, but generally only so as to make the scientific knowledge more credible — with less concern about recognizing the value. Such actions serve to actively reinforce the authority of scientific knowledge, even as they are ostensibly opening these up to the public.

6.9 Conclusion

In the attempts to rework existing science-society relations through instrumental co-production of climate services, there has been a shift away from more generalized ideas about 'the public' and a more central concern with 'end-users' as a form of political identity. However, this is not something that was necessarily always imposed; rather, reflecting the legacies of past ways in which citizenship has been made and understood historically in Tanzania, these identities are the result of the interaction between dominant and oppositional claims and, therefore, are not fixed or singular. Much of the promise of climate services has emphasized the role that they can play in supporting smallholder agriculture, particularly in Africa (CGIAR Climate Change and Food Security program [CCAFS], 2014). However, such efforts rely upon essentializing assumptions about the ways in decisions are made (e.g. Amissah-Arthur, 2003), which do not account for the dynamic complexities involved in 'performances' of livelihood activities. Ramisch (2011) sums this up: "Africans don't use simple set of rules and decisions as part of a prior body of knowledge of 'indigenous technical knowledge'…rather these decisions are a contingent response to unfolding events over the season" (p. 282).

It would, however, be a mistake to think that Maasai are unable to resist efforts to impose subjectivities or that they are not able to make changes in their livelihoods on their own terms. These moves, however, also rely on networked and relational ontologies. For example, it is recognized that pastoralists may take up agriculture for many reasons, and that this is not always out of necessity but a reflection of choice (McCabe et al., 2010). Further, livelihood decisions — including whether to farm, whether to move cattle, whether to migrate to the city for wage-labor — are all related within webs of social, political, economic, material, and personal considerations that are not only a reflection of the discursive practices employed by advocates of climate services. For example, while generally not discussed within the discourse about making climate services 'usable' for pastoralists, land tenure and access to resources are key determinants of seasonal decision-making. This corresponds with de Wit's (2015) analysis that the idea of climate change adaptation in pastoral areas is frequently depoliticized in ways that enable dominant discourses to continue unchallenged. Within this context, the trend toward diversification of livelihoods, as well as the use of new strategies, has been noted as a means of continuing the centrality of livestock within livelihoods and, consequently, "staying Maasai" (Goldman & Riosmena, 2013; Homewood et al. 2009; McCabe et al., 2010). In this way decisions about climate are made in reference to relational constellations of many entities that are brought into networks — and are about much more than adaptation to 'climate' alone.

CHAPTER 7: Boundary Work in Co-production Processes: The Politics of 'Usable' Knowledge

7.1 Introduction

Environmental problems, and in particular climate change, has been presented in global terms (Demeritt, 2001; Jasanoff, 2010; Miller, 2004; Wilbanks & Kates, 1999). In response, there have been growing numbers of scientific assessments and expert bodies that seek to measure and monitor conditions, often at multiple geographic and temporal scales (Berkes et al., 2006). Such efforts include the Intergovernmental Panel on Climate Change (IPCC) and more recently formed Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES) (Beck et al., 2014). However, globalized environmental agendas have quickly encountered resistance stemming from the friction at the interface of environmental problems as they are encountered and understood in particular places and the dislocated and ahistorical discourses that are often the basis for and product of global scientific assessments (Brace & Geoghegan, 2011; Martello & Jasanoff, 2004; Jasanoff, 2010).

Paradoxically, this has resulted in the "rediscovery of the local" (Martello & Jasanoff, 2004, p. 7) in which global and international scientific assessments have sought to incorporate 'local' knowledge of environmental problems within assessment processes. Following this, there have been a growing number of calls for inclusion of indigenous, traditional, or local knowledges within scientific knowledge practices and international assessments (Brugnach et al., 2014; Kniveton et al., 2014; Berkes et al., 2006; Sutherland et al., 2013; Tengo et al., 2013) and for science to become more responsive and more inclusive of alternative modes of knowledge production and divergent perspectives (Jasanoff, 2003; Leach, Scoones, and Wynne, 2005; Odora-Hoppers, 2011). This has been the case in the realm of climate change, where there have been increasing calls for the inclusion of indigenous and local knowledges both within assessments of the problem and the decision-making process (Alexander et al., 2011; Brugnach et al., 2014; Cochran et al., 2013; Green & Raygorodetsky, 2010). This has resulted in a growing awareness of epistemological debates concerning what 'counts' as knowledge and how this is determined. Such issues have raised important challenges and questions about processes of deliberation and participation within scientific knowledge practices. These have sometimes been applied with uncritical enthusiasm (Leach et al., 2005; Wynne, 2005) and have also raised questions related to "issues of scale" and "how to embrace different knowledge systems" (Berkes et al., p. 2) in order to make knowledge 'usable' for decision-making and action (Cash et al., 2003).

There have been two important and related approaches that have sought to address challenges of enabling participation within scientific decision-making, which have gained increasing attention within both academic and practice-based literatures in recent years. "Co-production of knowledge", or what I will refer to as instrumental co-production (see Chapter 2 for additional discussion of instrumental co-production), has been offered up as a means of addressing the challenge of including a multiplicity of knowledges within knowledge production, decision-making, and application (e.g., Armitage et al., 2011; Hegger et al., 2012), as well as overcoming barriers to producing scientific knowledge that is 'usable' (Dilling & Lemos, 2011; Lemos & Morehouse, 2005). Additionally, the knowledge systems criteria (KSC) framework has been presented as a way to understand how knowledge can be more effectively linked with action (Cash et al., 2002; Cash et al. 2003; Mitchell et al., 2006). The KSC framework asserts that in order to overcome barriers to integrating and using knowledge across scales and epistemologies, knowledge must be considered sufficiently credible, salient, and legitimate (CSL) among a range of actors (Cash et al., 2003). It has been proposed that instrumental co-production, through iterative and collaborative or joint knowledge production processes, can help to foster the relationships that are necessary to negotiate and improve shared perceptions of CSL among stakeholders who are operating at multiple scales or domains or who have divergent epistemological orientations (Dilling & Lemos, 2011; Hegger et al., 2014; Lemos & Morehouse, 2005). For example, Mitchell et al. (2006) found that salience can be improved through efforts to bring in 'local' knowledge and concerns.

While it is not always recognized explicitly, instrumental co-production efforts are fundamentally concerned with reconciling epistemic debates about what is considered legitimate knowledge. Such debates represent struggles for control over who is authorized to represent nature, a process that is inextricably linked to the exercise of power (M. Goldman, 2006). However, the majority of proposed approaches to instrumental co-production pay scant attention to relations of power — both in terms of the ways in which differential relations of power have come about in the first place, as well as the ways in which these shape the possibility of enabling meaningful dialogue between participants.

In contrast to instrumental co-production, the "idiom of co-production" (Jasanoff, 2004) is an analytical lens that elucidates the inseparability of the ways in which we know about the world and how we live in it. In this way, knowledge production becomes an inherently political activity in which Western science has gained influence as the dominant framing, with attendant allocation of prestige and power to those who produce, possess, or otherwise adhere to it. Co-production can provide "new ways of thinking about power, highlighting the often invisible role of knowledge, expertise, technical practices, and material objects in shaping, sustaining, subverting or transforming relations of authority" (Jasanoff, 2004, p. 4) which are often neglected in efforts to either implement or study attempts at instrumental co-production. I argue here that in order to make sense of instrumental co-production, it is necessary to apply the analytical insights that can be drawn from the idiom of co-production to understand how and why some knowledges have been afforded greater authority in the first place; it is not possible to alleviate imbalances of power if we cannot understand how these have come about in the first place.

7.1.1 Knowledge System Criteria

The knowledge system criteria were developed in response to the challenges posed by new sustainable development paradigms that recognized that the ‘successful’ development in these terms requires attention to cross-scale linkages and attention to the knowledge and agency of the intended ‘beneficiaries’ of sustainable development projects. However, the ability to do so was recognized as a fundamental challenge. In large part, the KSC came out of scholarship conducted under the Global Environmental Assessment Project (GEAP) and Knowledge Systems for Sustainability (KSSP), both based at the Kennedy School of Government at Harvard University, but with affiliated scholars located around the globe. Within the project, knowledge systems were viewed as “consisting of a network of linked actors, organizations, and objects that perform a number of knowledge related functions…that link knowledge and know-how with action.” A key premise of the project is that knowledge systems can be “at least partially understood and manipulated in ways that improve their performance,” with performance being evaluated in terms of the extent to which the knowledge is used, or otherwise has influence, on practical actions at multiple scales.

In their seminal paper solidifying the knowledge systems criteria as an analytical framework, Cash et al. (2003, p. 8086) propose the criteria as a means for better understanding how to “effectively harness S&T (science and technology) for sustainability,” a goal that is underpinned by the notion that “mobilizing and using science and technology (S&T) is increasingly recognized as an essential component of strategies for promoting sustainable development.” The KSC stressed that producers of scientific and technical information must recognize that scientific credibility is not the only (and sometimes not even the most important) reason that information is taken up by potential 'users'; rather, there is recognition that knowledge production is an inherently social process (Mitchell et al., 2006). As such, the salience and legitimacy of the information with respect to existing social and political dynamics in specific locations is crucial to understanding its perceived validity among particular actors.

The KSC has been widely influential, with application among a variety of contexts (Heink et al., 2015). However, the KSC acknowledges that credibility, salience, and legitimacy are *necessary* but not always *sufficient* for linking knowledge with action. In the context of climate information, others have proposed different sets of determinants to the use of knowledge for decision-making. For example, Lemos et al. (2012) have proposed various barriers to the usability of information relative to users' perception of the fit of information, interplay with existing knowledge, and interaction between 'producers' and 'users.' Patt and Gwata (2002) identify the credibility, legitimacy, scale (of information), cognition (or understanding), standard procedures of information use, and available choices as constraints to the use of seasonal forecasts in Zimbabwe. Both of these frameworks seek to incorporate contextual or situational factors that can either contribute to or prevent the use of information in practice. Dilling and Lemos (2011) in a review of the use of seasonal climate forecast information identify both intrinsic and contextual factors that may pose barriers to use.

The KSC framework is framed broadly in terms of understanding the dynamics between various knowledges across settings and scales, which makes it more broadly applicable for understanding efforts to engage multiple knowledge systems. A further strength of the KSC framework is its emphasis on the dynamic and relational nature of perceptions of knowledge usability, which recognizes the tensions and tradeoffs that exist between the criteria. As such, increases in one criterion may result in reductions in others. For example, the legitimacy or salience of knowledge may be improved through the involvement of a wider range of stakeholders, but this may compromise the credibility of the knowledge from the perspective of scientific experts.

The KSC framework literature has highlighted that broad participation of a range of actors through processes of "coproduction of knowledge" are important to improving mutual perceptions of the credibility, salience, and legitimacy of knowledge, while also helping to balance the attendant tradeoffs between them (Mitchell et al., 2006). Through comparative analysis of case studies from around the globe, it was also recognized that such processes require long-term dialogues, as well as interactions between 'producers' and 'users,' in which there are opportunities to mutually evaluate and debate available knowledge in relation to particular problems or settings.

7.1.2 Critical Application of KSC

Climate adaptation efforts have often conceptualized power simply in terms of 'levels' of citizen participation (i.e., at the local scale), with increasing participation associated with higher degrees of empowerment (Collins & Ison, 2009). Such conceptualizations envisage 'citizen control' as the highest level of 'empowerment'. Critics of these approaches argue that such conceptions imply that power is something that can be 'transferred' or 'ceded' in an effort to redistribute power through increased participation of local actors (Cooke & Kothari, 2001). Indeed, calls for 'deeper' participation have often been expressed through efforts to incorporate local or indigenous knowledge within project planning or implementation (Mosse, 2001). However, the treatment of power as a commodity implies a duality in terms of the 'haves' and 'have-nots', those who are powerful and those who are powerless (Gaventa & Cornwall, 2001). This dichotomy can clearly oversimplify power relations, and can even serve to reproduce and entrench power differentials.

In most cases, the knowledge system criteria have been employed as a framework to understand why and how particular knowledge can be made ‘usable’ within particular decision settings. In much of this literature, divergences in how different actors perceive credibility, salience, and legitimacy are seen as barriers to the flows of knowledge. ‘Effectiveness’ of science-policy interfaces in this way either implicitly or explicitly refers to the ability of scientific information to successfully impact policy decision-making. However, from this perspective, it is *taken for granted* that the flow and application of knowledge are necessarily a positive outcome for all actors, without adequately understanding / considering the historical, political, and cultural settings in which these occur. Additionally, there is insufficient attention to the ways in which knowledge fundamentally shapes the landscape of power differential in which such knowledge exchange is intended to take place. However, it has been pointed out that the use of information, including scientific climate knowledge, can be positive or negative depending on the historical, cultural, and political contexts in which they are applied (Lemos, 2003).

The KSC framework acknowledges that perceptions of usability can shift over time and in relation to various ‘audiences’ who may be potential ‘users.’ However, there is also a danger of assuming that some actors or information may have intrinsic qualities that may either make them credible, salient, or legitimate. For example, Patt (2006) claims that some channels of communication for climate forecasts garner more credibility than others. However, Wynne (1992, p. 282) has argued that attributes such as credibility are not inherent or fixed, but are rather relational in terms of the social relationships, networks, and identities that are the basis of such designations. These relationships reflect particular histories, but are also responsive to new interventions and interactions among participants (Wynne, 1992).

The KSC have usefully stimulated discussions of how to transition away from linear models of scientific knowledge production and has emphasized the social nature of knowledge production and use. This has built on other calls to involve a range of actors or stakeholders within knowledge production processes through iterative participatory processes of knowledge production, but in much of this literature, the issue of 'participation' itself has been glossed over (for exceptions to this, see Kearnes & Chilvers, 2015 and Wynne, 2007). While the originators of the KSC recognize that "participation is not a panacea" to remedy problems of credibility, salience, and legitimacy (Mitchell et al., 2006, p. 328), this is acknowledged primarily because of the limitations of participation to address the needs of multiple or cross-scalar audiences. As such, the issue of participation in knowledge production is treated a-politically and controversially.

Thus, the KSC either neglects or oversimplifies the complexities of creating processes that enable multiple knowledges to interact (e.g., Clark et al., 2016). Which aspects of the KSC are addressed with regard to divergent perspectives is in itself a political act, one that is based on and solidifies particular manifestations of power. While participatory processes, including those aimed at enabling co-production of knowledge, often seek to address visible forms of power (e.g., state authority), others have argued that it is necessary to address less visible manifestations of power which serve to delimit what knowledge is considered valid (Jasanoff, 2004). Scientific knowledge has played a key role in efforts to 'standardize' and 'classify' both human and environmental subjects, including those related to climate change (Jasanoff, 2010; Hulme, 2010) so that they may become more legible and, therefore, easier to exploit or control (Jasanoff, 2004). In this way, "knowledge production practices are strategic sites of power" (M. Goldman, 2005, p. 179), where the scope and nature of environmental issues are framed, defined, and bounded, along with the range of possible responses. Thus, it is important to examine not only what is discussed and how, but also what is not discussed (i.e., what subjects are 'off the table'), and, most importantly, the particular practices, actors, and networks that endow certain knowledges with authority, while excluding others (Latour, 1987; Haraway, 1991).

Cash et al. (2002) saw the KSC as variables that were important to the use of knowledge that were independent of the "boundary work" that constructs social barriers between science and society. In contrast, I argue that these criteria are, in fact, intimately bound up in boundary work. I propose to use the knowledge system criteria as a critical analytical lens to understand how boundaries between scientific knowledge and social practices are constructed and maintained within processes of knowledge-making. First of all, it becomes important to ask: 'Usable' for whom and for what purposes? Second, it is possible to use these categories as a means to understand how and why particular knowledges gain social authority, while others are excluded, and how these processes are negotiated. While much of the application of the knowledge system criteria seek to enhance the standing of credibility, salience, and legitimacy of knowledge to enable its application, this research asks, rather, how did these differing perspectives of credibility, salience, and legitimacy come about? How do these reflect the multiple and overlapping ontologies, lived experiences, and futures of various actors? How are some actors able to advance the standing of particular knowledges through the emphasis of some knowledge criteria over other? In asking these questions, it is possible to see how different actors relate to and employ the KSC within instrumental co-production efforts as a form of knowledge politics.

7.1.3 Co-production

The term co-production was first employed by scholars within sociology of scientific knowledge (SSK) and science and technology studies (STS) to refer to the processes through which science and society are mutually constituted (Jasanoff 2003, 2004). Some scholars argue that the co-production of science and society occurs always and everywhere, shaping knowledge in ways that can be difficult to discern (Latour, 1987; Jasanoff, 2004). This occurs through knowledge production practices with "permeable boundaries that not only allow contextual factors to seep in and mold the production of science and technology, but also, and equally, enable scientific and technological achievements to loop back and reorder the organization and self-perception of society" (Jasanoff, 2004, p. 276). However, co-production is both constitutive and interactional. This means that on the one hand, it encompasses the ways in which boundaries between nature and society are created and stabilized such that certain knowledges are "arrived at and held in place, or abandoned" (Jasanoff, 2004, p. 36). On the other hand, it addresses overt questions about epistemology and the ways in which different knowledges conflict in practice. Importantly, the constitutive and interactional dimensions of co-production do not operate independently, but rather continually and mutually shape (and reshape) the other.

The concept of co-production of knowledge has gained increasing traction within science-policy dialogues, but there are differing definitions and interpretations of what co-production is and how it should be undertaken. Some scholars have pointed toward different conceptualizations of 'instrumental' co-production, which focus instead on the need for more explicit forms of participatory knowledge production processes that facilitate direct collaboration between scientists, policymakers and other societal actors (Callon & Rabeharisoa, 2003; Hegger et al., 2012; Landstrom et al., 2011; Lemos & Morehouse, 2005). However, these varying conceptions need not be mutually exclusive; Jasanoff (2004) acknowledges that co-production is not restricted to a theoretical lens and can "move from being an analytical tool to a strategic instrument in the hands of knowledgeable social actors, through reflexive moves that open doors to new forms of engagement" (p. 281).

Following this, others have argued that instrumental co-production can be a deliberate process designed to address specific problems within decision-making or policy processes or as a means of making scientific knowledge more usable for decision-making (e.g., Lemos &Morehouse, 2005; Dilling & Lemos, 2011). Armitage et al. (2011) have defined co-production as "the collaborative process of bringing a plurality of knowledge sources and types together to address a defined problem and build an integrated or systems-oriented understanding of that problem." Hegger et al. (2012) have argued that it is useful to differentiate between implicit co-production (of science and society) and more explicit, directed, or facilitated processes of co-production through use of the term "joint knowledge production". However, instrumental processes of facilitated co-production may neglect the constitutional and interactional aspects of co-production that elucidate how certain knowledges have gained their authority in the first place – thereby neglecting broader relations of power that shape knowledge production and use.

There are additional concerns and debates about the potential of co-production processes to enable the state or international actors to expand the breadth of their networks to the local scale, or to co-opt local knowledges. Often, efforts to bring together various forms of knowledge call for 'bridging' of knowledge systems (e.g., Berkes et al., 2006). However, because of the relations of power caught up in knowledge production, an emphasis on 'incorporation' or 'bridging' of knowledges may actually serve to perpetuate existing power dynamics, by reinforcing the notion that scientific knowledge is distinctly different from other forms of knowledge (Agrawal, 1995; M.J. Goldman, 2007). Further, there is concern that 'integrating', 'combining', or 'linking' knowledges may only result in efforts to try and make indigenous knowledge more 'scientific' (see, for example, Alexander et al., 2011), a process that would allow dominant epistemological constructs to supersede indigenous and other knowledges, thereby disempowering local populations (Agrawal, 1995). For this reason, co-production must be approached cautiously within the context of existing power relations to avoid reinforcing or enhancing these dynamics.

This research will employ a co-productionist lens[11] to understand how the boundaries between scientific and other knowledge are constructed and maintained and how this relates to relations of power within instrumental co-production of climate services in Tanzania. I will use a critical application of the KSC framework to better understand processes of boundary work. This approach helps to illustrate the ways in which actors selectively address some knowledge criteria in order to conform with the ideals of instrumental co-production, while also seeking to reaffirm boundaries in ways that can help to solidify the authority of science within processes of instrumental co-production. Such an approach acknowledges and interrogates the ways in which certain knowledges may gain authority, while also aiming to understand how these influence the possibility of enabling legitimate and inclusive processes that do not reinforce existing inequalities in the ability to control how problems are framed, defined,

7.1.4 Boundary Work

While most treatment of power relations within instrumental co-production tend to emphasize coercive forms of power, post-structuralist scholars understand power as something that is pervasive and embodied in all aspects of life, rooted and circulating through 'social networks' and

[11] Here, I use a co-productionist lens to refer to 'strong' interpretations, which include either or both of the constitutive or interactional strands of co-production presented by Jasanoff (2004). See Chapter 2 for a further detail and a description of the typology of co-production.

relationships to discursively shape what counts as acceptable knowledge (Foucault, 1982). A co-productionist lens as proposed by Jasanoff (2004) can help to expose the ways in which the boundaries between what counts as 'valid' knowledge and what is excluded are constructed. For this reason, it is a useful tool in helping to account for the various ways in which power is exercised within knowledge production, as well as in its uses. Boundary work is a fundamental concept to understand how epistemological debates unfold. Scholars in the field of Science and Technology Studies (STS) argue that social 'boundaries' are established to demarcate science from non-science. While within most approaches to co-production, power is conceptualized in explicit terms (i.e. coercive), the concept of boundary work helps to elucidate the less visible manifestations of power.

Such boundaries are created and maintained through the "attribution of selected characteristics to the institution of science (i.e., to its practitioners, methods, stock of knowledge, values and work organization) for purposes of constructing a social boundary that distinguishes some intellectual activities as 'non-science'" (Gieryn, 1983, p. 782). Put simply, boundary work[12] refers to the allocation of particular attributes to scientists, along with their activities and claims, in order to establish science as a more authoritative means of generating knowledge (Gieryn, 1999). Boundary work is performed to establish what counts as valid knowledge and, thereby, the allocation of prestige and authority that accompanies this. Thus, a key tenet of the notion of the boundary work performed by scientists is that it requires the creation of a binary, which enables 'science' to be placed in opposition to 'non-science.' In this way, boundary work is always relational. Indeed,

[12] Building on the idea of boundary, the concepts of boundary management and boundary organizations have also been put forth as a means of intentionally upholding the boundaries between science and society. In contrast, boundary work is the process of constructing these boundaries through discursive practices.

without this activity of difference-making, it would be impossible for science to gain its social authority, since such positioning is relative to other knowledge.

The epistemic authority of science has both temporal and spatial limitations, meaning that it "exists only in its local and episodic enactment within structural contexts" (Gieryn, 1999, p. 12). This means that the boundaries that uphold science and scientific knowledge as a particular domain are continually contested in specific locations: "The epistemic authority of science is in this way, through repeated and endless edging and filling of its boundaries, sustained over lots of local situations and episodic moments, but 'science' never takes on exactly the same shape or contents from contest to contest" (Gieryn, 1999, p. 14). This indicates that the constitution of science is not only geographically situated, but also temporally.

Scientists can use a variety of strategies to perform boundary work. Gieryn (1999) has noted that there are three types of "credibility contests" through which boundary work is performed to produce and maintain the epistemic authority of science: expulsion, expansion, and protection of autonomy. Expulsion is a means of socially controlling legitimate claims about 'good' science from lesser scientific claims. In contrast, expansion seeks to establish the authority of science relative to other less 'true' or reliable ways of knowing about the world (e.g., religion, tacit knowledge). The protection of autonomy is a strategy used to protect science from political uses in order to maintain its distinction as an 'objective' source of knowledge. All of these strategies are used to designate spaces where science 'is' and 'is not.' These spaces are constantly renegotiated in historically and contextually contingent ways.

It has been recognized that as science has been called upon to address policy-relevant questions, this can pose challenges to maintaining the constructed boundaries between science and other social or political domains (Jasanoff, 1990) thereby threatening the authority of science.

Similarly, efforts to facilitate instrumental co-production implicitly seek to make the constructed boundaries between science and society more porous in order to allow increased communication and interaction. However, this has important consequences. A shift in these boundaries, which many actors may have perceived to be stable and, in many cases, essential, intervenes in the existing social order. When science is asked to speak to specific issues and problems, it can open science up to additional scrutiny, as scientific knowledge undergoes processes of deconstruction to assess whether the data, methods, and conclusions of scientific study are credible and legitimate (Jasanoff, 2003; Sarewitz & Pielke, 2007).

7.2 Instrumental Co-production in Tanzania

This research used two programs as entry points for observing the dynamics of how instrumental co-production in the context of climate services development in Tanzania. The first project was the UK funded 'Promoting Adaptation and Climate Resilience through Devolved District Climate Financing' (DDCF) program implemented by the International Institute for Environment and Development (IIED) in partnership with the Tanzanian NGO HakiKazi Catalyst. The DDCF was launched in June of 2013 in the districts of Longido, Monduli, and Ngorongoro. Building on a preparatory phase to identify institutional barriers to adaption decision-making and implementation, the program sought to develop the districts' capacities to manage a devolved district-level climate finance mechanism to support "public goods investments that promote climate resilient growth and adaptive livelihoods" (International Institute for Environment and Development [IIED], 2013). In order to inform such investments, the program aimed to increase the availability of climate information to local residents and district agencies to support improved climate adaptation planning, including developing plans to improve dissemination and develop community radio. At the same time, however, the program sought to build on customary livelihoods, leadership structures, and resource management systems. It was recognized from the outset that there were ideological barriers to coordinating formal and customary planning processes, including the “lack of value placed on traditional knowledge” and differing perspectives among program stakeholders with regard to the factors that contribute to the resilience of local livelihoods (IIED, 2013). The DDCF program sought to address these barriers through enhanced engagement between local residents, district officials, and national government representatives, including climate experts from the Tanzania Meteorological Agency (TMA).

The second project was the Norwegian funded ’Global Framework for Climate Services - Adaptation Program in Africa’ (GFCS-APA). The GFCS-APA was launched in 2014 and was intended to serve as a ‘proof of concept’ for the development of national climate services around the globe under the Global Framework for Climate Services. The program was made up of a consortium of international agencies – including the World Meteorological Organization (WMO), the International Federation of Red Cross / Red Crescent Societies (IFRC), World Food Program (WFP), the CGIAR Climate Change and Food Security (CCAFS) program, the World Health Organization (WHO), and two Norwegian research institutes, the Center for International Climate and Environmental Research – Oslo (CICERO)[13] and the Christian Michelsen Institute (CMI). Each of these international partners worked with a ‘local’ national partner in Tanzania, creating a two-tiered governance and implementation structure. A primary focus of the program was on assessing the needs of ‘users’ of climate services, as well as developing different capacities to use the information through trainings-of-trainers among extension service officers. There was also a major emphasis on scoping the potential for use of information communications technologies

[13] I was hired by CICERO as a Research Fellow beginning in March 2015 to assist with research activities related to assessing ‘user satisfaction’ with climate services, as well as to contribute to research and reporting related to IK and co-production.

(ICTs) as a means of delivering climate services. Finally, the program provided support for the Tanzanian Meteorological Agency – both in terms of technical instrumentation (e.g. automated weather stations) and also through support for capacity building (e.g. to build capacities to conduct more complex climate modeling).

While these two programs had some important differences in their approaches and organization, they shared a key element in that both had an underlying goal of improving livelihoods and well-being of Tanzanian citizens in relation to climate-related risks and, in particular, residents of semi-arid districts where pastoralism and agro-pastoralism are the dominant livelihoods. Both of these projects viewed climate information and services as a key component to enabling both average citizens and government actors to effectively respond to the challenges resulting from climate variability and change. They also saw increased interaction between climate experts (primarily from the Tanzania Meteorological Agency) and stakeholders as crucial to facilitating the co-production of knowledge that would be useful and actionable within practical decision-making. This offered a valuable opportunity to study multiple efforts toward co-production of climate services occurring simultaneously.

7.3 Results

7.3.1 'Co-production' as a Credibility Contest

In the current neoliberal space in which the two projects in Tanzania are conducted, this also creates a new multiplicity of 'audiences' to which climate scientists are held accountable. Through their legal mandate, TMA is considered the only authoritative agency that is allowed to issue weather and forecast information. In addition to the need to prove their value to the government of Tanzania in order to secure standing and sufficient budgetary resources, the TMA was also now accountable directly to Tanzanian citizens who were the intended beneficiaries of the projects, as well as to international organizations and donors who had sponsored them. These groups of stakeholders have very different demands in terms of what constitutes legitimate processes and credible and salient knowledge (a point which will be discussed in greater detail in the following sections of this paper).

Given the amount of money and resources that have been channeled toward the premise of 'co-produced' climate services, there is also greater pressure on TMA to show that they are responsive to 'user' needs. Importantly, this has put the TMA and its staff in a difficult and vulnerable position of being accountable on multiple fronts and on different terms, but with essentially the same human resources and technical capacities with which to respond to these demands. The GFCS-APA has invested significantly in strengthening the observation networks and in building technical skills capacity among TMA staff, but this does not address the different types of skills (e.g., dialogue facilitation, communication) and the time required to engage in instrumental co-production processes. Additionally, there has been little attention paid to the additional demands involved with responding to the requests of 'users' as expressed through consultative processes in institutional terms.

The approach to 'co-production' and treatment of IK was different within the two projects. The IIED program started with the explicit intention of attempting to build on IK — both of weather and climate, but also importantly of the *particular on-the-ground practices* associated with this knowledge. However, the question remained about how best to do so. The program utilized a multiplicity of approaches, including providing forums where TMA and district-level officials could interact, for example, through trainings and meetings several times a year, such as participatory resource mapping exercises, consultations with customary leaders, and establishment of ‘traditional forecasting groups’. In the last, the intention was to identify individuals who were known to be knowledgeable about indigenous weather and climate prediction in each of the districts and to develop a system for them to meet periodically to develop a ‘consensus’ forecast based on individual predictions. The intention was that these forecasts would be sent to TMA so that they could then be ‘combined’ with the scientific forecast. The GFCS program, on the other hand, did not start out with a clear intention to specifically address issues surrounding the use of IK within its activities; rather, the issue was framed in terms of ‘co-production’ of knowledge with the intention of making climate services more usable for a range of stakeholders. In many cases this took the form of consultative fora. For example, the National Stakeholders’ Consultative Workshop on the GFCS, held in May 2014, was focused primarily on understanding the “needs and gaps” in relation to currently available climate information among (primarily) national scale stakeholders within governmental Ministries, Departments, and Agencies (MDAs) and national and international NGOs. In the course of the project, however, it became quite evident that IK was something that could not be ignored. Research activities conducted under the GFCS-APA found that residents in the pilot districts were heavily reliant on IK, much more so than scientific knowledge (CCAFS 2014a, CCAFS 2014b). It was concluded that more research was needed to better understand IK to better facilitate the processes of co-production.

Despite the different starting points and approaches to instrumental co-production within the two programs, TMA was given the primary responsibility of facilitating instrumental co-production in both instances. Formal meetings and workshops were a key forum through which ‘dialogue’ and ‘interaction’ took place. These types of interactions are intended to be institutionalized through the development of District Climate Information plans and the establishment of District and Divisional Climate Adaptation Committees, though as of writing, this was still in development. While the DDCF project worked to establish regular meetings between TMA and district stakeholders throughout the 2-year project duration, the GFCS-APA primarily facilitated interaction between national-scale stakeholders. The exception to this were district-level inception meetings and 'training-of-trainers' provided to extension officers, with a focus on teaching local residents to interpret historical climate data and seasonal climate forecasts in the context of their livelihood decisions — though the trainings focused primarily on agricultural decision-making. These trainings were followed by a one-day 'review' session in which extension officers could provide feedback.

Each of these meetings represents a "credibility contest" (Gieryn, 1999), which had fundamental implications for how they were organized. Within all of these interactions, discussions were generally presaged by a technical presentation by TMA summarizing the 'state of the science' and the range of available climate information products in Tanzania. These presentations included an array of PowerPoint slides filled with technical charts and graphs of historical climate data and trends, as well as graphics depicting the various components of the global climate observation system, including satellites, in situ weather stations, databases, and communications equipment. While many of the participants were generally appreciative to receive this information, at times it was clear that the presentations contained overly technical information that was not comprehensible for many participants. On one occasion, a participant sitting next to me leaned over to whisper to me to express frustration that he was unable to understand the presentation since it was "too full of graphs" and other technical "jargon" that was "for scientists, not for us."

While perhaps not intentional, these types of presentations at the outset had the effect of establishing the boundaries to make statements about how credible knowledge is (and should be) produced. As noted by Gieryn (1999, p. 15), “Epistemic authority does not exist as an omnipresent ether, but rather is enacted as people debate (and ultimately decide) where to locate the legitimate jurisdiction over natural facts.” As such, epistemic authority is something that is produced in episodic and situated encounters between contested views of what is considered valid knowledge. In this way, each of the meetings between TMA and stakeholders represented a credibility contest, in which there was the opportunity for the authority of TMA’s knowledge to be challenged or accepted. Processes of instrumental co-production, by their very nature, seek to open up the possibility to illustrate the value of alternative sources of knowledge. However, this also increases opportunities to challenge the authority of scientific climate knowledge more generally, as well as the position of TMA to be the sole voice to ‘speak’ on behalf of weather and climate in Tanzania. The technical presentations are simultaneously a means of establishing the ‘correct’ way of observing weather and climate, as well as drawing the boundaries between scientific and other knowledges by defining the particular sorts of practices that are needed to truly observe the climate (i.e., satellites, observation stations) and how this knowledge should be presented (i.e., in scientific figures, graphs, charts, etc.).

7.3.2 Enacting Boundaries: Exclusion and Expansion

The ways in which scientific knowledge is presented within instrumental co-production preemptively establishes science as the starting point, thereby setting discrete bounds around the kinds of knowledge that will be condoned within dialogues about climate knowledge for adaptation decision-making. In terms of the three kinds of boundary work presented by Gieryn (1999), this represents both an exclusion to exclude other knowledges from the realm of science, as well as expansion of the boundaries of scientific knowledge into other ‘non-scientific’ domains.

The desire to distinguish scientific climate knowledge in relation to IK is a strategy to imbue scientific knowledge with authority by illustrating that scientific methods are essentially distinct. According to one climate expert, “For us, indigenous people use different ways of predicting. Ours is much more scientific. Using theirs with ours would be contradicting ourselves. So we keep the different forecasts separate and then we compare them. We do not mix the two” (Climate Expert #3). TMA has already been involved in several projects to incorporate indigenous weather and climate forecasts alongside scientific forecasts to produce a ‘consensus’ forecast. While a great deal of learning was achieved through these projects (see Mahoo et al., 2015), they also illustrated the imbalance in terms of the validity allocated to different knowledge systems within the process. One stakeholder involved in the project noted that the scientific and indigenous forecasts often “aligned” but that “what is missing is scientific validation” (Climate Expert #1). Another respondent noted that it was possible to rely on IK but that there was a need to “understand scientifically how this works” (Climate Expert #4).

These responses also echoed the calls of an international climate expert involved in the GFCS-APA who stated that with regard to IK, it would be necessary to “find the indigenous indicators that are backed by science and promote these” (Climate Expert #7). In general, there were questions about the possibility of IK meeting sufficient “standards of integrity” to be included within decision-making (Climate Expert #7). Nonetheless, there was a desire to conduct further studies to understand the biophysical mechanisms that could explain in scientific terms how the observed indicators helped to predict weather. There was also a push for indicators to be “correlated” (i.e., to conduct a regression analysis) to illustrate the relationships between observations and outcomes within indigenous predictions (Climate Expert #1). It was widely expressed among both national and international climate experts that once correlations were established and scientifically validated, then it would be possible, and even desirable, to include IK within standard forecasting procedures.

In an effort to shore up the epistemic authority of scientific climate knowledge, there were several discursive moves that were commonly employed to situate IK as an inadequate or lesser means of understanding weather and climate. The first move involved discounting IK on the grounds that it was no longer applicable under conditions of climate change. This stance acknowledges the prior value of IK as a source of knowledge, but claims that because of changing weather and climate patterns, such predictions are no longer accurate. In the second, IK was seen as unstandardized and deemed too heterogeneous and location-specific to be valuable for decision-making. In the third, IK was seen as lacking a means of being documented and transmitted. This was both implicitly and explicitly contrasted with scientific climate knowledge, which was seen to overcome all of these challenges. Thus, respondents at the national scale emphasized that IK was indeed an important source of information; however, this was almost always countered with a one of these three rhetorical devices to simultaneously devalue IK and differentiate it from scientific ways of knowing about weather and climate. This results in a double movement that both reifies and undermines IK.

The collection and transmission of scientific climate data in Tanzania represents the assemblage of a complex network of human and non-human actors. Behind the tidy and succinct presentation of the final forecast products, there is a constant and continual need to piece together a bricolage of observational data. In the first sense, all scientific climate knowledge is heavily dependent on observations of the past climate as a means of asserting its authority to represent 'the climate.' Indeed, the primary tool used to produce seasonal climate forecasts in Tanzania is statistical modeling, which uses correlation or regression analyses to identify relationship between key climate drivers (e.g., sea surface temperatures in the eastern Pacific Ocean) and the observed climate behavior in the past. This means that the scientific forecasts are subject to the same criticism of being limited by their ability to ‘keep up’ with climate change, since they are also heavily rooted in past predictions. In order to try and resolve this issue, TMA has periodically updated the time series of the data sets it uses in order to ensure that the baseline data is reflective of the current conditions under more recent conditions of climate variability and change, rather than previous decades, and then conducts a ‘reanalysis’ to determine whether indicators are still valid. While this illustrates the ways in which scientific prediction is seeking to adapt to variability and change, this assumes that indigenous forecasts are not also similarly continually vetted and updated.

Observational data is fundamental to the ability to scientifically predict weather and climate. As noted by one expert, “if you have good climate data, you will be able to have a climatological understanding of the area” (Climate Expert #8). There are very few automated weather stations in Tanzania. This means that all of the other data used to produce forecasts must be physically measured and recorded by a human, frequently a volunteer, in various locations throughout the country. While these volunteers undergo trainings on how to systematically record the data, many climate experts in Tanzania expressed concern that these measurements may not be as accurate. In the absence of automatic or digital transmission of data, the records need to be sent to the TMA headquarters — some of these are sent electronically, some are called in by phone, but most of these are sent as physical records through the postal system at the end of every month. Once these records arrive at TMA headquarters, there is then a need to digitize them and put them in standardized formats so that they can be used within computer modeling. This is not a trivial process. Additionally, many locations in Africa have a backlog of climate data that must be digitized from hand-written or printed records in order to make it useful within prediction. In Tanzania, data rescue is seen as a priority by international actors and is supported by the GFCS-APA, as well as other donors and initiatives.

The messy and often fragmented nature of climate data takes a vast amount of work to assemble and maintain. This is a point which belies the scientists' and other national and international actors' argumentation for discarding IK or to delimiting its use to narrow and pre-determined aspects of knowledge debates. The bricolage that comprises scientific climate knowledge in Tanzania (and climate knowledge in other locations) are naturalized through the concealment of the heterogeneity of the practices and processes, as well as the great deal of resources and effort, that are involved in assembling them (see Chapter 6).

7.4 The Politics of 'Usable' Knowledge

7.4.1 Credibility

Credibility is a central aspect of any knowledge system, though it has been recognized that there are differences in how credibility is perceived and achieved among actors (Mitchell et al., 2006). Within the two projects in Tanzania included in this research, there was little effort taken to understand or include alternative means of assessing credibility within instrumental co-production beyond those used within scientific modes of inquiry. Yet, it was clear that there were varying means of establishing and assessing credibility among the range of actors involved in the projects.

TMA relies heavily on the standards provided by the WMO to evaluate forecasts as a means of verifying the credibility of its own information. These verification standards specify that forecasts should achieve a 'hit rate,' of 70% or higher.[14] Among scientists at TMA, the notion of adhering to scientific protocols was paramount to assessing the credibility of information: "As a scientist, you need to analyze the information. You need to see what criteria they used to achieve credibility. You need to look at the source" (Climate Expert, #5). Hit rates can be calculated both over space, as well as time. However, one climate scientist reflected that with seasonal forecasts, which are produced for various zones throughout the country which cover vast expanses (generally three administrative regions combined), the hit rates are often quite high because the observed outcome can occur anywhere in the zone, without necessarily applying to the whole zone, and still be counted as a successful 'hit' in terms of forecast accuracy (Climate Expert #6). But the fact that there was sufficient rainfall in a portion of a district does not reflect the reality of individuals living in the portion of the district that received too little rainfall. Yet, the 'hit' rate as a measure obscures this.

Technical means of assessing forecasts while useful for establishing credibility among international audiences were often out of synch with the ways in which credibility was assessed on the ground. In Longido, it is well known among the district government, as well as among some average residents, that there is only one weather station for the entire district. This weather station is located in Tingatinga, in the eastern portion of the district on the flanks of Mt. Kilimanjaro, an area that is considered to receive higher rainfall than other locations in Longido, as well as being

[14] WMO provides standardized protocols for assessment and validation of forecasts. Following these protocols, a 'hit rate' of 70% or above is considered 'useful' information, meaning that it provides added value relative to having no information at all. For example, the Heidke Hit Proportion evaluates the proportion of forecast cases in which the forecast category that was the most likely (highest probability) is in fact later observed. This is one of the simplest metrics for evaluating forecast skill and is considered to be easily understood by non-technical users (IRI (No Date) Descriptions of the IRI Climate Forecast Verification Scores).

the location of more concentrated agricultural activities. Village residents in villages located in the western portions of the district rejected the seasonal forecasts because they insisted that the data collected at Tingatinga was not reflective of the weather and climate patterns they experience in their locations and also differed in terms of livelihood activities. Instead, they insisted that the weather conditions that they experience originate and travel from Kenya. So, rather than listening to the TMA forecasts, they relied on indigenous forecasts or scientific forecasts which they receive from weather stations located in Kenya, which are often the only stations that they can receive.

Pressure to engage in instrumental co-production processes, as well as the recognition of the limited ability of climate science to compete with IK in many settings, have prompted TMA to seek out ways to engage with IK. TMA itself has initiated a variety of projects to examine IK about weather and climate in Tanzania (e.g., CCAFS, 2015; Chang'a, 2010; Kijazi, 2014). Indeed, staff members from TMA and other climate experts in Tanzania are quick to acknowledge the widespread use of IK and its *potential* value as a source of knowledge. IK was also seen as a means of bolstering the credibility of scientific predictions. The limited extent of the scientific observational data, as well as limitations in computing capacities, mean that the scientific forecasts are not able to provide information at spatial scales that are relevant to individuals or communities. For this reason, IK was also seen as a means of bolstering the credibility of scientific information, since it could provide additional knowledge at more 'localized' scales and was seen as a means to "help with downscaling" the scientific forecast (Climate Expert #1).

When discussing issues of credibility among village scale respondents, respondents had difficulty stating succinctly what would make information credible. Processes of determining what information to trust and use were also highly individualized. Despite this variability, there was a consistency in responses: "It depends." People were rarely able to definitively say whether information would be credible in and of itself. Rather, the information had to be situated within particular settings to determine whether and how it should be used. In this way, the credibility of information was always in relation to the kind of information being delivered, the situation, the relationship with the person (organization or entity). Credibility was not judged in terms of the information itself. For example, in order to judge the credibility of information, whether it was coming from their mother, their neighbor, or a climate scientist from England, there was a strong desire to be able to have a discussion with the person — to be able to ask questions and to be able to see the person's face. Furthermore, whether or not something was deemed credible also depended on the kind of information being discussed — there was not the same level of transparency afforded to all topics of discussion. The desire to be able to verify the outcome of the forecast through personal observation was ubiquitous — meaning that the credibility of the forecast could only be assessed in relation to the outcomes in terms of factors such as sufficient water for households and cattle, enough high quality pasture, successfully harvested crops, etc.

The ability to publicly vet information through both formal and customary governance structures was also seen as an important means of establishing credibility among some respondents, but not others. Therefore, there was not a 'general rule' that specified what made the information more or less trustworthy. For example, while one set of focus group respondents (Male Elders, Arkaria Village) felt that information that was delivered through village government or customary meetings was likely to be good knowledge, since they felt that leaders in these positions would only share information that they had verified was true. However, other respondents in the same village had different opinions. For example, another set of focus group respondents (Female Mixed Ages, Arkaria Village) were skeptical about knowledge coming from both the village and district government leadership. They felt that there were many things (e.g., information, food aid) "coming from the outside" (e.g., national or international scales) that the district level did not actually bring to them. The village government was also seen as sometimes being deceptive among this group of women. This discredits the idea that there are fixed attributes of trustworthiness or credibility that can be attached to particular 'types' or 'sources' of information or 'channels' of delivery. Rather, trust and credibility are "contingent variables…dependent upon the nature of these evolving relationships and identities" meaning that "the best explanatory concepts for understanding public responses to scientific knowledge and advice are not trust and credibility *per se*, but the social relationships, networks and identities from which these are derived" (Wynne, 1992, p. 282).

Furthermore, village scale respondents were also more willing to recognize that their observations in changes in climate were partial and this was often explained in relational terms. People's perceptions of the 'climate' were only made possible in relation to a host of other changes in the socio-ecological system, including changes in: land use, human and livestock health, customary governance, inter-generational relations, marriage practices, religion, and increases in available science and technology. Reflecting this, there was a general willingness to be open to new sources of information if they were perceived to be an improvement on currently available information:

> When I was young, I saw evidence of women praying, goats being slaughtered, and my father predicted the weather, and these were right many times. So the traditional ways can be true. But at the same time, in 1998 I heard about El Niño on the radio and this came true. There were several other times when the scientific forecasts were true. So in this sense I am not on either 'side' but I believe that both might have some 'truth'. (Male Elder, Arkaria Village, Monduli District)

This quote also reflects the fact that perception among many respondents is that, to some degree, all of the knowledge that they relied upon was partial and that no one source of information was able to capture the whole 'truth.'

Indeed, many respondents acknowledged the imperfections of indigenous predictions, which were also seen as being less accurate than they were in the past. In large part, this was attributed to evolving social dynamics that have significantly transformed relationships between elders and youth. There were changing levels of mutual respect. For example, because of the enforcement of national laws, which had greatly reduced activities of cattle raiding, youth complained that there was no longer any good way to earn the elders' respect. Furthermore, youth are increasingly sent to cities to seek work, so they were not able to acquire the skills to produce the forecasts, which are passed down through oral transmission and through personal observations. Additionally, there was acknowledgment that changes in climate were making it more difficult to trust the indigenous forecasts. Nearly all respondents noted a shift in the seasons in recent decades, primarily in the delay or absence of the short rains. This was also seen as a major challenge to the credibility of indigenous predictions. In this way, the indigenous knowledges are "no more innocent than contemporary scientific knowledge, yet they are a useful counterweight because, as subjugated knowledges, they are less likely to deny the critical and interpretive core of all knowledge" (Watson-Verran and Turnbull 1999, p. 132).

7.4.2 Salience

Within the instrumental co-production processes, issues related to the credibility of the scientific forecasts were frequently sidestepped. In large part, this was because there was little in the immediate term that could be done to remedy some of the challenges underlying the credibility of the knowledge from a scientific perspective. For example, ongoing efforts under the GFCS and other programs to expand the observational network in Tanzania will take time to provide benefit to the overall quality of data available. Similarly, the series of comprehensive trainings supported by the GFCS-APA, which aimed to enhance the capabilities of TMA staff to conduct dynamical modeling (which was seen as a key step to improving the accuracy of the models) need to be matched by institutional capacities (e.g., such as standard operating procedures, computing capacities, etc.). All of these were efforts that are in the pipeline with the end goal of improving the scientific credibility of the forecasts, but there is a significant lag before the impact of these improvements would be manifested in the quality of the majority of the forecasts that TMA produces.

The underlying problems with relation to the scientific credibility of the predictions, such as limited and missing data, were not seen as undermining the basic premise of the utility of the forecasts. An implicit technological optimism assumed that such issues would eventually be resolved and, therefore, there was not a sufficient reason to discredit the activity of forecasting as a whole. In the meantime, however, there was very little transparency or reflexivity within interactions with potential 'users' of the forecasts with regard to the limitations of the information. In this way, the credibility of the forecasts was treated as a settled fact, one that did not have to be opened up for further investigation. Instead, attention was turned to improving the salience of the forecasts, which involved trying to 'tailor' existing forecast information to the specific 'contexts' in which they would be used. There are several ways in which this was approached.

Within its seasonal forecasting activities, TMA has instituted a process to involve stakeholders who may be potential 'users' of the forecasts. After the forecast has been internally vetted, TMA creates a forum for 'users' from various government ministries, department, and agencies to attend a seminar to receive a detailed presentation about the forecast, including information about the indicators that were used in the production of the forecast. Within the public presentation of the forecast, there is a key move that occurs in the translation. While the forecast is produced in terms of 'terciles' of 'above', 'below', and 'average' expected rainfall, the forecast provided to the public compresses these terciles to provide a more deterministic presentation. For example, in a zone where there is a 35% change of above average rainfall, 40% change of average rainfall, and 25% change of below average rainfall, the color coding and caption for the zone reads "normal to above normal" — thereby effectively erasing the 25% probability of below average rainfall, while also presenting the forecast in more deterministic terms.

Once the participants have received the forecast information, they are placed into groups based on the sector in which they work, with each group being comprised of 'related' sectors. For example, livestock and fisheries, agriculture, and wildlife were placed into one group to develop a common message. Energy and water were grouped into another, while health and disasters were put into a third. Within these groups, the various stakeholders are asked to interpret the forecast in terms of the impacts that they would expect within their sector. Within the group discussion, there was very little treatment of the uncertainty associated with the forecasts or the probabilistic nature of the information itself. Rather, the discussion of the potential impacts quickly collapses into deterministic statements such as: "there will be more water available for irrigation", "rice will perform well, but other crops, like *mihogo* [English: cassava] won't do well", and "wildlife will get more foot and mouth [disease]" (quotes from various stakeholders during the national users' forum). The uncertainty of the forecast, which poses a barrier to incorporation within decisions, is effectively ignored in favor of developing tractable messages that are seen as being actionable.

However, this can have negative implications for the perceived credibility (and perhaps legitimacy) of the knowledge should the outcomes turn out differently than the forecast.

While the participants in these meetings have expressed that there is a great deal of value in meeting with TMA officials to receive the forecast and to work with other government officials to discern what the forecasts may entail within their areas of work, it provides very little opportunity for dialogue about the nature of the forecasts themselves and whether these are considered usable. Rather, the utility of the forecast is assumed, as reflected in the following statement during the opening of the session: "There will be a benefit for all countries because the rains will start early. We will announce the forecast on Monday. This will allow people in the ministries to prepare early" (Climate Expert #9). However, there are two issues that arise. First, this effectively allows TMA to bypass any challenges to the authority of the information they are providing. Second, this delimits the kinds of knowledge that non-scientific stakeholders are effectively allowed to contribute toward the development of the forecast. They are only allowed to contribute toward the 'co-production' of the forecast at the tail end of the process, when the forecast has already been effectively settled.

In another example, there have been recent efforts to downscale the seasonal forecasts to move from zonal predictions to forecasts that would be specific to individual districts. This is a request that has been put forth by 'users' for many years, as the coarse resolution of forecasts has been seen as a primary barrier to its usability. Downscaling efforts had not yet been undertaken in Tanzania, which is not surprising since the downscaling of seasonal forecasts is a notoriously difficult task for climate scientists globally (Wilby & Wigley, 1997). There is continuing debate about the best methods for approaching downscaling and, more importantly, how to determine if a downscaled forecast provides improved information.

However, the GFCS-APA program emphasized the need to illustrate how the climate services were responding to the expressed 'needs' of 'users' and the downscaled forecast was considered a tangible product that could be exhibited as evidence of this. Some of the TMA staff members were hesitant about producing the downscaled forecast, recognizing that this was a "new area" with which they did not have prior experience -- meaning that they would need to develop new methodologies. When the forecasts were distributed to the various districts, there was little discussion about the potential to reduce the accuracy of the forecasts in exchange for increased precision (i.e., it may be more specific, but also less reliable), a well-known tradeoff in climate prediction. However, the forecasts were treated as 'experimental,' reflecting that the scientists themselves still felt that there was the need for additional exploratory studies and validation of the results. There was also very little transparency initially provided to stakeholders to describe the methodologies applied within the downscaling process, which would have helped to make the tradeoffs involved in the downscaling more evident. In the end, TMA was pressured to provide a detailed explanation of the downscaling methodology, so that potential 'users' could evaluate this, as this was just seen as part of doing "good science" (Climate Expert #15).

These examples illustrate that the selective emphasis on the salience or relevance of the forecasts, rather than on the credibility or legitimacy, can be seen as both a discursive and political move, which both creates the 'reality' of credible forecasts while at the same time producing evidence of the 'success' of instrumental co-production of climate services.

7.4.3 Legitimacy

It has been recognized that it is often difficult to separate out the perceptions of credibility, salience, and legitimacy, since these are often interdependent. Heink et al. (2015) have found that there is significant conceptual overlap between credibility, salience, and legitimacy. This is particularly the case with regard to credibility and legitimacy, which have many overlapping features. For example, Tang and Dessai (2012) concluded that credibility and legitimacy were so closely related as to make it nearly impossible to differentiate between them. However, these differences in the overlap between credibility and legitimacy may have to do with the extent to which there exists a shared and consolidated civic epistemology (Jasanoff, 2005; Clark, 2008) — or "public knowledge ways or ways of knowing that operate within and across this multiplicity of spaces" in the form of "both formal knowledge systems…[and] informal processes of knowledge making by which states and their citizens arrive at collective settlements regarding the epistemic foundations of public life" (Clark, 2008, p. 1897) — among a sufficient portion of the public. In Tanzania, there exist wide divergences in the epistemologies that form the basis of social contracts that govern how publics engage with scientific and technological realms. Without a shared epistemology, the concepts of credibility and legitimacy are less likely to overlap. In some of the literature on KSC, there is a tendency to want to distill each of these characteristics in order to be able to use them as evaluative metrics (e.g., Heink et al., 2015).

Perceptions of legitimacy were directed both at the processes of governing the development of climate services, as well as whose voices were considered within processes to develop them. Struggles over the legitimacy of the development of climate services were evident from an early stage in the GFCS program. The program developed a Project Delivery Team (PDT), which was a body composed of various program partners and other national-level stakeholders tasked with implementing the program deliverables. Yet, it was recognized that there was a need for a more institutionalized body that was not attached to the program in order to ensure sustainability of climate services development in the future. This was proposed to happen through the development of a National Framework for Climate Services. During the National Consultation for the GFCS, there were debates about how to develop institutional arrangements that could successfully support "dialogue between the users and producers of climate services" that could be "sustained beyond the consultation meeting workshop" (WMO Official #1, National Consultation Meeting).

In the end, it was decided that an existing institution, the Tanzania National Disaster Relief and Emergency Committee (TANDREC), an inter-ministerial disaster response body, would "take the additional responsibility of creating dialogue" among producers (TMA) and users (other governmental ministries) of climate services at the national scale. However, some participants at the meeting questioned whether TANDREC was the best platform for the purpose of developing climate services, since it was composed of high level political appointees at the head of departments, ministries, and agencies (DMAs) and its membership might not be broad enough to reflect the broader constituencies who have a stake in climate services development. This issue was debated with several suggestions made. One suggestion included expanding the membership of TANDREC "to have a few more members" so that other key actors would be included. Others argued for the need for a smaller task force that could be assigned responsibility for overseeing implementation plans and ensuring technical competence. These issues were not further taken up, as it was apparent that the decision to embrace TANDREC as the steering committee of the National Framework had been preemptively decided prior to the consultation meeting and there was no space for real debate around the issue.

The legitimacy of climate services also reflects broader histories of the ways in which science and technological interventions have been employed in Tanzania, particularly among pastoral and agro-pastoral populations. From the very outset of both programs, local respondents in my own research, as well as participants invited to participate directly in the programs, often commented that the forecasts were "for farmers" and "people in the cities." This is important for two reasons.

First, it shows that the local participants felt that the climate scientists and other governmental agencies had little interest in providing information that was compatible with their livelihoods. Many respondents felt that the government saw their livelihoods and customs as completely backward. Given the long history of marginalization of pastoral communities, this was a threat to the credibility of scientific information. Second, the distinction that the kinds of information that were "for farmers" were not the same kinds of information that pastoralists needed was both a practical and a political statement. It was an expression of the kinds of climate services that were desired – or, rather, it was a statement about how the current climate services that were provided didn't fit their decision-making contexts. But it was also a political means of differentiating pastoralists from farmers, thereby solidifying a distinct pastoralist identity. The rejection of the forecasts as being for farmers or urban residents reflects more than just the disjuncture between the forecast and the livelihoods of the residents in Longido and Moduli districts. It also illustrates resistance to a history of attempts to make pastoralists conform to idealized visions of 'citizens' who have sedentary, permanent dwellings and who engage in agricultural activities. Efforts to 'modernize' pastoralist livelihoods were widespread in both pre- and post-colonial periods (Hodgson, 2001), but have provided little actual benefit to many pastoralists (see Chapter 6 for further discussion).

7.5 Discussion

In this case study, I have used the concept of boundary work, combined with a critical application of the KSC, to elucidate the politics of knowledge that have played out within instrumental co-production processes to develop climate services in Tanzania. In theory, instrumental co-production seeks to make the constructed boundaries between science and society more permeable, with the joint goals of including alternative perspectives within knowledge making processes, as well as making scientific knowledge more open, responsive, and usable for decision-making. Through this analysis, it is clear that while some benefits have been realized through increased interaction between scientists and potential ‘users’ of climate services, there is also a strong potential for these interactions to reproduce the problematic power dynamics that they purport to address.

The networks that make up climate science as a recognizable and authoritative domain have not achieved the levels of stability or ‘naturalization’ in Tanzania as they have in other locations globally. There are various reasons for this. In part, this can be explained through the legacy of colonialism and the fallout from post-structural adjustments, which significantly eroded capacities to develop and maintain extensive observation networks to produce the data that forms the basis of climate science’s claims to authority over the ways in which climate change is known and understood. As a result, the collection of data and achievement of desirable levels of standardization are a continual struggle. At the same time, citizens in Tanzania have not always been willing to accept the scientific basis of forecasts. This means that the networks remain fragile and require constant upkeep to maintain the semblance of a solid body of knowledge.

Exposing these unconsolidated connections can have the antithetical effect of provoking climate scientists and other experts to more rigorously reinforce the boundaries between scientific and other knowledges in an effort to maintain their authority. This helps to illustrate that while instrumental co-production was conceived in part to overcome divides and power differentials between scientific and other knowledges, it may in fact sustain or exacerbate the imperative to reassert the singularity of science, particularly in settings where the networks of both human and non-human entities are not sufficiently established to provide scientific knowledge with a secure stronghold on epistemic authority. In this sense, co-production may actually serve to strengthen or accelerate efforts to ensure that science frames the terms of the debate before allowing other knowledge to be 'let in'.

At face value, the willingness to engage in instrumental co-production efforts appears to be a means of validating IK as an equally valuable way of knowing about weather and climate in Tanzania. Upon closer inspection, however, it appears that the acceptance of the need to facilitate instrumental co-production and to incorporate IK was a necessary political move to uphold the standing of scientific climate knowledge — both through the appearance of more inclusive and legitimate processes, as well as addressing perceived deficiencies in the credibility of scientific knowledge (e.g., the inability to provide localized climate forecasts, limited accuracy, etc.). At the same time, climate experts only sanctioned these processes when this was preceded by the subjugation of IK by making it accountable to scientific measures of credibility. While not instrumentally nefarious, this often results in the co-option of IK for the purposes of strengthening the authority of scientific climate knowledge, a process that both diminishes the influence of IK in current debates, but also erodes the resilience of IK systems in the face of change. This can be summed up:

> The view that modern science is capable of providing the solution to 'underdevelopment' is also responsible for the depreciative view of indigenous or local knowledge systems. Furthermore, the focus on objectivity, rigor, control, and testing has helped to develop the perception that S&T are value-free, and that they operate outside of the societies in which they are based. Unfortunately, given the tremendous influence of S&T, this attitude has undermined the capacity of local knowledge systems to innovate and has lowered the status

> of the innovators themselves, especially women whose contribution to technological development has been historically undervalued. (Appleton et al. 2011, p. 212).

The effect of the boundary-ordering to differentiate IK from scientific knowledge is to secure the dominance of a particular knowledge — i.e., scientific weather and climate forecasts — as well as a particular vision of social ordering. This vision enables and perpetuates a "technological determinism" (Odora-Hopper, 2011) in which advances of weather and climate forecasting are seen as a solution to problems of 'development', with the path forward being configured in relation to a specific vision of modernity. Furthermore, this ordering also entails assumptions about improving the well-being and livelihoods of citizens, but particularly those who conform to an idealized 'small-scale farmer' who enthusiastically accepts and embraces technological interventions and is willing to dramatically alter livelihood decisions based on scientific forecasts. As Watson-Verran and Turnbull (1995) conclude, when multiple knowledges are involved, what is at stake is more than just participation; rather it is a "practical politics" that enables contestation, disagreement, and criticism of past relations (Watson-Verran & Turnbull, 1995, p. 132). Importantly, within this critical, yet productive space, it can become possible to realign relationships between actors such that the adequacy of the knowledge is not judged solely on the basis of standard ideas of validity or credibility, but rather on the ways in which this knowledge enables new "possibilities for social action" (Watson-Verran & Turnbull, 1995, p. 132)

7.6 Conclusion

So what can be gleaned from using the KSC as a lens into the ways in which power is exercised in knowledge production, particular within the context of instrumental co-production processes? First of all, it is evident that deliberate choices with regard to which of the KSC are deemed more or less important are political maneuvers that are inextricably bound up in how some knowledges gain dominance and also carry with them judgments, assumptions, and normative stances. Following this, it asks whether the KSC framework can be used as an effective means of mediating epistemic conflicts in situations where power relations are heavily skewed. As illustrated in Tanzania, processes of instrumental co-production primarily revolved around enhancing the standing of scientific knowledge, while there was little space for indigenous knowledge to be included in processes on its own terms.

Mitchell et al. (2006) note that in order to overcome relations of distrust, it requires ongoing interactions over a long duration, *as well as* efforts to reassure potential 'users' that the information they are being provided with is not just the "continuation of policy by other means" (Clausewitz, 1982, p. 119, as cited in Mitchell et al., 2006). This is particularly relevant for pastoralists in northern Tanzania, who have seen persistent efforts to denigrate their livelihoods and to dispossess them of land continue uninterrupted during the colonial and post-independence eras through 'development' projects that relied heavily on technical approaches and scientific information. The delivery of climate information and services is viewed within this lineage of technical interventions that have, in the best cases, had little impact, and, in the worst cases, made people worse off. Therefore, it is not surprising that yet another attempt to promote 'science-informed' development strategies are generally viewed with ambivalence (if not hostility) and that there is little existing trust in scientific information, such as scientific weather or climate forecasts.

It will not be possible to rework entrenched social relations through tokenistic consultation processes that delimit the agency of participants as holders of knowledge in their own right. Rather, there is a need to take seriously the different ways in which credibility of knowledge is achieved in different contexts and to be willing to put these in contention with scientific modes of establishing validity of knowledge. For example, Odora Hoppers (2011) has made comprehensive calls for broader, shared understandings of what constitutes credible and legitimate knowledge:

> The scientific community must, therefore, transform their knowledge legitimation and accreditation cultures in order to build the linkages between excellence in formal scientific systems and innovations in informal knowledge systems, and thus create an inclusive knowledge network to link various stakeholders through applications of information technologies. (p. 395)

Taking this suggestion seriously would have radical consequences for how instrumental co-production might be approached in the future. In contrast to how co-production is currently being deployed – i.e. focused on enhancing the perceived validity and usability of scientific knowledge among 'non-scientists' – this would put the onus on the scientific community to rework their own practices and perceptions in ways that enable more productive engagement with other knowledges. This is not something that could be expected to happen quickly and would require openness on the part of all participants – most of all the scientists. But it does show that there is a possibility to remake instrumental co-production in positive ways.

CHAPTER 8: Conclusion

8.1 A Recap

In Chapters 2 and 3, I reviewed the theoretical origins and current interpretations and applications of the term co-production across a range of literatures. In Chapter 2, I trace the theoretical origins of the term co-production to show that co-production has originated from two primary areas of scholarship — public services administration (Ostrom et al., 1978) and science and technology studies (Jasanoff, 2004). Yet, the story of co-production is not that simple. These two conceptualizations of co-production have, over the last several decades, interacted and intermingled with other strains of scholarship in both direct and indirect ways. These interactions with other broader trends in the literature — including a range of participatory approaches within development and natural resource management, as well as concepts. such as boundary management. coming out of STS literature — have given rise to a particular emphasis on the *co-production of knowledge* in explicit terms. The accompanying premise that knowledge can be cultivated as a resource has led to an instrumental turn in how the concept is used. Tracing the evolution of different conceptualizations of co-production within the literature helps to explain, at least in part, how the concept of co-production has gained interest across a range of disciplines. Perhaps more importantly, it also enables a clearer understanding of the differing epistemological and ontological, as well as normative, commitments embedded within these differing conceptualizations of co-production. I argue that this is a necessary first step in recognizing the need for greater clarity and attention to how the term co-production is applied. This may help to avoid diminishing the potential value of co-production as both an analytical frame and strategic approach.

In Chapter 3, I presented the findings of a systematic review of the co-production literature over the last decade. Given the multiple origins of co-production, and resulting lack of conceptual clarity surrounding the term, this review was intended to provide a better understanding of the various ways in which co-production is currently being interpreted and applied. I developed a typology of co-production, to help make sense of the current landscape of co-production. This typology differentiates between ‘weak’ and ’strong’ co-production, as well as between constitutive and interactional forms (Jasanoff, 2004, 2014). I further analyzed articles included in the review to determine 1) the antecedent literature and definitions of co-production that formed the basis of analysis and 2) the approach to co-production employed in the article’s justification, methods, analysis, and/or discussion. This analysis enabled a means of identifying trends in the literature. I find that while the majority of literature focused either on strong or instrumental co-production, there are a small number of studies conducted in recent years that are using strong co-production analysis to better understand instrumental versions of co-production. First, I find that there are new ‘spin-off’ terms that are building on the original term to combine it with other concepts. I find that some of these spin-offs may unintentionally narrow the scope of co-production meanings, or else produce redundancies. I also find that there are intentional efforts to separate the constitutive and instrumental forms of co-production. This can be seen as a political move to make co-production more manageable and compatible with existing science-society configurations. Lastly, I identify a ‘paradox’: even when the constitutive dimensions of co-production are ignored (either intentionally or unintentionally), the growing body of scholarship calling for instrumental co-production itself represents an ontological shift, in which the introduction of the concept of co-production itself has constitutive effects. I conclude that care must be taken to track the usages of instrumental co-production through strong co-productionist analysis in order to ensure that instrumental co-production does not reproduce the same problems it was intended to solve.

In Chapter 4, I describe my research design and case study location. Indeed, the fact that Tanzania has been the site of multiple and overlapping efforts to facilitate instrumental interpretations of co-production of climate knowledge made it an ideal place to undertake this research. Furthermore, pastoral populations in the semi-arid regions of northern Tanzania are simultaneously invoked as particularly vulnerable to the impacts of climate change and, at the same time, are venerated as custodians of indigenous knowledge that are often seen as an essential 'ingredient' within co-production efforts. I argue that a mixed methods research approach at multiple scales is highly appropriate for understanding issues of knowledge and power, particularly in the context of co-production and climate adaptation. These processes are inherently multi-scalar, reflecting constant interactions between localized processes and those occurring at broader scales. I detail each of the data collection methods, including: quantitative surveys, semi-structured interviews, planned group discussions, and ethnographic observation. I conclude by reflecting on my own situatedness within and across these different research settings and how my own privileged status related to my ability to be able to carry out this research. I further conclude that no matter how systematic or rigorous a research design might be, the findings are can never be more than a partial, situated accounting that will inevitably result in creating the world it seeks to describe.

In Chapter 5, I presented the results of a quantitative survey examining the production, circulation, and use of climate knowledge at multiple institutional scales in Tanzania. Findings illustrate that complex networks of knowledge exist among actors at all scales, despite the assumptions and rhetoric that are often invoked within climate services development in Tanzania, which frequently refer to the need to overcome 'gaps' in knowledge. These findings illustrate that the landscape of climate knowledge is complex, reflecting webs of knowledge stretching across multiple scales and reflecting already 'hybridized' knowledges that involve multiple sources of information. Another important conclusion is that while most efforts toward climate services development focus on formal ways of transmitting information, this neglects the importance of informal knowledge sharing that is embedded within dynamic social relations. The results indicate that what knowledge individuals choose to use is not constant, but rather varies in relation to the identity of the 'user' and the context (including social norms) in which the knowledge is applied. Lastly, findings call into question frequent assertions that scientific knowledge can (and will) fill 'gaps' in indigenous knowledge about weather and climate. Rather, there is evidence to show that despite declines in the breadth of the indicators used within indigenous prediction of weather, this has not resulted in a concomitant uptick in the use of scientific knowledge. Such results both challenge prevalent assumptions that scientific climate knowledge will automatically increase even in cases where use of indigenous knowledge is declining. Such findings presented a useful entry point for considering the why and how knowledge gains credibility and social authority, which formed the basis of the remainder of the dissertation in Chapters 6 and 7.

In Chapter 6, I describe the constitutive dimensions of co-production (as defined by Jasanoff, 2004) involved in attempts to promote instrumental co-production of climate services in Tanzania. I start by tracing the history of science-society relations in Tanzania, and in pastoral areas in particular, to illustrate how knowledge and power are mutually reinforcing. Using a modified Actor-Network analysis and relational ontological perspective, I illustrated the immense amount of work that is required to assemble scientific climate knowledge through socio-material networks. I show how the erasure and the naturalization of these efforts is used to establish boundaries between scientific and indigenous knowledges, a process that enables scientific knowledge to gain power and social authority. I show how the climate services agenda and processes of instrumental co-production produce particular subjectivities of 'end-users' of climate information that conform to idealized notions of a 'modern' Tanzanian citizen. However, the imposition of these subjectivities is not always successful; it is continuously countered by the complex ways in which individuals and groups express and project multiple identities. Thus, while instrumental co-production in this case study has the effect of reinstating the authority of scientific by reasserting boundaries between 'users' and 'producers' of climate services, this is complicated by the emergent and relational enactments of the multiple identities of actors.

In Chapter 7, I illustrate the interactional aspects of co-production (again, as defined by Jasanoff, 2004), also drawing on efforts to advance the co-production of 'usable' climate services. I do so through the critical application of the Knowledge System Criteria (KSC) framework, which theorizes that knowledge must be sufficiently credible, salient, and legitimate among a range of actors to be 'usable' or influential within policy-making. While most applications of the KSC framework are concerned with how to strategically increase the standing of these criteria among stakeholders, I instead use these criteria analytically, along with the concept of boundary work, to illustrate the politics of 'usable' knowledge that come into place when facilitating instrumental co-production. This analysis highlights the double movement involved within instrumental co-production efforts in Tanzania, which simultaneously seek to integrate and undermine indigenous knowledge. However, through an Actor-Network analysis of the construction of scientific climate knowledge in Tanzania, it is clear that scientific knowledge is subject to many of the same idiosyncrasies and limitations of indigenous knowledge, but that these are overcome through a vast amount of work. Yet, this work is naturalized and made invisible. This erasure enables climate experts to maintain control of when and on what terms indigenous knowledge can be included. This often includes subjecting indigenous knowledge to scientific measures of credibility. I show that which aspects of the KSC framework are addressed is in itself a political act, one that is based on and solidifies particular manifestations of power. For example, by focusing on the salience of knowledge rather than on issues of credibility or legitimacy, this black-boxes the credibility of scientific forecasts.

8.2 Significance of the Research

This research aimed to understand power relations within current approaches toward instrumental co-production of knowledge for climate adaptation decision-making at multiple institutional scales in Tanzania and what this might mean for possibilities toward more open, inclusive, and reflexive knowledge-making practices in the future. In light of the findings presented in the previous chapters, what now is to be concluded about the role of power within instrumental interpretations of co-production?

As a start, this dissertation has emphasized that there is a need for greater attention to the ways in which co-production is conceived of, defined, applied, and put into practice. This is important not just as a theoretical debate, but because this has material impacts on people and the world we live in. If we uncritically combine different conceptualizations of co-production that are rooted in differing epistemological and ontological positionings, we may fail to pay attention to the very processes and interactions that have spurred co-production as a concept to be taken forward in the first place. That is to say, we risk completely neglecting the tight intertwining of knowledge and power. Thus, rather than helping to remake existing relations of power, we may rather serve to entrench and reinforce them. As Stirling (2008) has noted "instrumental perspectives are aimed uncritically at achieving ends that are conditioned by existing power structures and so — intentionally or not — will tend to support these" (p. 223). As I have shown in the previous chapters, how co-production is defined is not just an issue of semantics. It is a political choice —

one that can serve to either recognize or deny the politics and histories that have shaped the current relations between scientific knowledge and existing social orders.

I have also shown through this research the importance of accounting for the variety of ways in which power is manifested concurrently. The conduits through which power is exercised are not limited to a particular site or 'scale' — but is much more about the ways in which interactions within and across these scales take shape, a processing of shuttling back and forth that collapses standard notions of scale. This has involved tracking both the 'macro' processes that have shaped the existing power relations, as well as the 'micro' processes through which knowledge gains social authority. In Tanzania, questions about what counts as valid knowledge are inherently bound up in questions of notions of expertise, visions of what it means to be a Tanzanian citizen, and what counts as 'modern.' Yet, how these constitutive configurations are upheld is the result of innumerable everyday, mundane interactions at the interface of knowledge and politics. For example, the social structures in Tanzania which have marginalized Maasai populations for more than the last century have been the result of an inestimable number of micro-processes of exclusion that can only occur through specific interactions and enactments.

To account for the multiple and overlapping ways in which power is exercised through these cross-scalar and micro/macro interactions, I have tended to both the constitutive (Chapter 6) and interactional (Chapter 7) dimensions of the idiom of co-production (Jasanoff, 2004). Through the examination of the interrelation of the constitutive and interactional it becomes possible to track the complex ways in which knowledge and power are continually and mutually reinforcing the other. While most studies of instrumental co-production are primarily focused on epistemological politics, this highlights that there is a simultaneous need to recognize instrumental co-production as a form of *ontological* politics as well. As I have shown within instrumental engagements between climate experts and pastoralists in Tanzania, co-production is as much about determining what counts as valid knowledge, *as well as* about determining what are considered valid ways of *being in the world.* Efforts to discredit indigenous knowledge in these contexts were not just conflicts over the authority of scientific knowledge, but were also strategies that are employed to undermine pastoralist livelihoods and ways of being.

8.3 Moving Forward with Instrumental Co-production? Questions and Possibilities

During the course of conducting this research, I have been approached numerous times by various organizations who were interested to have me to develop 'best practices' or to write 'guidelines' for instrumental co-production. This is something that I have strongly resisted for several reasons. First, I do not feel like there are any set of guidelines that could possibly encapsulate the innumerable contexts in which instrumental co-production might take place, as well as sufficiently address the constantly shifting sets of relations (both in time and space) that are inherently involved within any attempt to deliberately co-produce knowledges. What constitutes 'best practice' is highly dependent upon the distinct sets of relations existing among actors in each attempt at co-production – and, therefore, cannot be generalized. 'Successful' instrumental co-production can and will take any number of forms. Second, I feel that there is a real danger (one that has already taken shape) that the concept of co-production will be co-opted, in the same way that participatory methodologies have been overtaken in the last decades, to advance any number of goals that do not truly reflect the experiences, ideas, knowledge, and capacities of those who would be the intended beneficiaries. In this way, instrumental co-production can serve to covertly defuse controversy to promote a pre-established agenda (see, for example, Franzeskaki & Kabisch, 2015; Nel et al., 2016; Sitas et al., 2016), while also (re-) entrenching power imbalances. Thus, instrumental co-production can be used in self-serving ways

– both intentionally and unintentionally – that bolster *status quo* relations of power. For this reason, it is my opinion that the creation of a standardized set of guidelines would support the misuses of co-production more than it would help to enable positive change.

As it stands, there have already been several attempts at the creation of systematic guidance to inform instrumental co-production. Hegger et al. (2014) have developed a set of "design principles" for joint knowledge production (see Chapter 3 for additional discussion). In a more recent and direct example, Beier et al. (2016) create a "how-to guide" for the "co-production of actionable science." While Beier et al. (2016) state that readers should focus on the "spirit" of the guidelines understanding that they need to be adjusted to particular settings, the provision of narrow recommendations (e.g., regarding the number / type of meetings to be held, the length of meetings, the types of participants) unnecessarily constrains the ways in which instrumental co-production could organically take shape in different settings. While both sets of guidance acknowledge the need to adapt these frameworks to particular contexts, they embody a narrow set of indictors, prescriptions, and measures of success. It is notable that neither of these attempts explicitly address the role of power in shaping the potential for instrumental co-production.

This is not to say, however, that there are not also positive examples of instrumental co-production efforts that have indeed led to improved relations, shared understandings, common goals, and mutually beneficial outcomes. For example, Armitage et al. (2011) present a rare exception in which the need for long-term commitments is recognized as key to establishing the trust and institutions that can support open dialogue, difficult interactions and disagreements, and multiple modes of deliberation. In this example, the importance of building relations of trust over extended durations of time (i.e. not just over 2-3 year project cycles) is emphasized. However, while they acknowledge the importance of historic inequities among actors participating in instrumental co-production, the authors do not rigorously interrogate the underlying relations of power that are embedded within instrumental co-production and social learning (Armitage et al., 2011, p. 1002).

Thus, there is a need for more critical reflexivity and attention to power within efforts to study and implement instrumental co-production. As Bäckstrand (2004) has pointed out, within the domain of civic science and amidst increasing calls for co-production within sustainability science, the primary focus is on increasing participation for participation's sake rather than reworking rules, practices, and relations involved in the production and application of scientific knowledge (p. 36). This illustrates a need for constant attention to both the theoretical / practical, ontological / epistemological, normative / prescriptive facets of instrumental co-production.

It is still quite rare for studies of instrumental co-production to attend to the tensions between the interpretive, descriptive elements of the co-production idiom alongside the normative, prescriptive bent of instrumental co-production. In particular, few studies have internalized the interrelations between knowledge and power in order to expose the power relations that are necessarily part of any deliberate attempt at collaborative knowledge-making. However, there are a growing number of examples that take seriously the need to address the interconnections between knowledge and power. For example, Erickson-Muñoz (2014) examines the relationships between knowledge, power, and culture by combining a strong co-productionist analysis and social network analysis within the context of the production and use of policy-relevant knowledge for land use governance. The study highlights that producing actionable knowledges is "not solely a matter of harnessing more science, but about the politics of knowledge and visions that emerge from complex governance systems" (Erickson-Muñoz, 2014, p. 182). In another example, Wyborn (2015) examines the co-production of knowledge and social orders around the issue of connectivity conservation in order to better understand the social and normative dimensions of instrumental co-production. These examples show that it is possible to pay attention to and balance the analytical and prescriptive interpretations of the concept of co-production in beneficial ways, even if these are necessarily held in tension. These examples illustrate a promising avenue for taking co-production forward in more critical and integrative ways.

In my own observations of attempts at instrumental co-production of knowledge for climate adaptation in Tanzania, two issues stood out as crucial to understanding attempts at instrumental co-production. The first was concerned with the role of historical science-society relations and how these shaped existing relations of power. Any attempt to understand the dynamics of instrumental co-production in Maasai areas without accounting for the historical uses of scientific knowledge as a means of marginalizing Maasai populations would neglect deep-rooted disparities in power. This erasure would make it very difficult to understand why and how relations of mistrust between Maasai and other actors engaging in instrumental co-production came to exist, as well as how they may potentially be addressed. The second had to do with the ways in which credibility was determined. In this case, credibility of knowledge was always evaluated in strictly scientific terms within observed attempts at instrumental co-production. Scientific knowledge was uncritically taken as the 'base' to which indigenous knowledges could be added 'when appropriate.' This, however, consistently privileged some knowledges and actors over others from the very outset. Without recognition of the need to acknowledge multiple ways of assessing the credibility of knowledge, there was little space to develop shared understandings of what should count as 'valid' knowledge among all actors. Furthermore, this continually reasserted the authority of scientific knowledge over other knowledges. All of this is to say that without attention to both the macro- and micro-processes through which power is exercised within knowledge practices, there can be little hope of redressing underlying power imbalances within instrumental co-production. In order to do so, I argue that it is necessary to employ strong co-productionist analysis to continually and reflexively follow the evolution of instrumental co-production efforts. Therefore, rather than providing a set of guidelines, I instead offer a set of questions that might help to orient or redirect the focus of instrumental co-production efforts below:

- What are the historical science-society relations in the particular area / location in which instrumental co-production is being undertaken? How do these affect power dynamics / differentials and relations of trust among actors?
- Do actors involved in instrumental co-production have a shared ideal about the role of science in society? If not, how will these various divergent normative ideals be acknowledged and / or addressed?
- What are the material and discursive practices that either constrain or enable particular knowledge practices? How do these enable the formation of boundaries and exclusions that endow some knowledges with authority and not others?
- How might instrumental co-production re-assert the social authority / power of some knowledges over others? How does this relate to which actors are able to maintain social authority / power?
- Are some topics, knowledge(s), and experiences privileged or considered the 'starting point' for instrumental co-production? Why?
- What topics, knowledge(s), and experiences are excluded? Why and how?

- Who has initiated instrumental co-production efforts and why? What are the goals of instrumental co-production – both implicit and explicit – and who has determined these?
- Who has decided who should participate in instrumental co-production processes? Who has been included? Who has been excluded? Why?
- What are the different costs of participating in instrumental co-production for the various participants? How does this contribute to power differentials? (e.g., while professional scientists or experts are generally paid to take part as part of their job, villagers will have significant opportunity costs associated with participating)

While these questions do not offer explicit guidance on how to 'do' co-production, they do help to enable a standpoint from which to consider whether and how instrumental co-production might be approached – and, indeed, what it *is* and *could* or *should* be.

8.4 Some Final Words

In *States of Knowledge* (2004), Jasanoff presciently recognizes the potential for the introduction of the concept of co-production to *itself* have co-productive effects and speculates about the ways in which the concept will come back upon itself. Yet, I wonder if anyone would have been able to predict the extent to which the idea of co-production has become so pervasive in both research and practice. The concept of co-production has clearly had an immense and growing influence on the discourse surrounding scientific activity and its relation with society over the last decade and this is only likely to increase as ideas about co-production are becoming increasingly institutionalized, as within Future Earth (van der Hel, 2016). Yet, as this dissertation shows, existing formations of knowledge and power are difficult to dislodge. Transformation does not come easily and it should be expected that there will be resistances, both in explicit and implicit ways. Yet, resistances are themselves productive. There is always both the danger that new and potentially transformational ideas may be co-opted, weakened, or shut-down in ways that were not intentioned at the outset. But these new concepts also have the power to be used in innovative, organic, and emergent ways to affect positive change that may not have been imagined. What is clear is that, either way, ideas that are put out in the world, such as co-production, do not sit still. They travel. And, as they travel they are transformed, in both surprising and predictable ways. If one is to take the relation between knowledge and power seriously, it should not be surprising that the concept of co-production would be remade in, sometimes blatant and sometimes subtle, ways that are more accommodating to extant relations between social orders and knowledge-making. I have shown how this is already occurring in various ways, both within the broader co-production literature, as well as within efforts to put co-production 'into practice' in Tanzania. Such moves represent a politics of knowledge that are certain to persist, no matter how many times and in how many ways practices of knowledge-making are re-envisioned and remade. In this way, co-production is, literally, everywhere you look. And more importantly, the work that can be done through co-productionist perspectives and accounts is never finished. So, while this dissertation feels quite like an end in many ways, it is just the beginning in others.

REFERENCES

Aeberhard, A., & Rist, S. (2009). Transdisciplinary co-production of knowledge in the development of organic agriculture in Switzerland. *Ecological Economics*, *68*(4), 1171–1181. http://doi.org/10.1016/j.ecolecon.2008.08.008

Agrawal, A. (1995). Dismantling the divide between indigenous and scientific knowledge. *Development and Change*, *26*(3), 413–439.

Agrawal, A., & Gupta, K. (2005). Decentralization and participation: The governance of common pool resources in Nepal's Terai. *World Development*, *33*(7), 1101–1114. http://doi.org/10.1016/j.worlddev.2005.04.009

Agrawal, A., & Ribot, J. (1999). Accountability in decentralization: A framework with South Asian and West African cases. *The Journal of Developing Area, 33*(4), 473-502.

Akpo, E., Crane, T. A., Vissoh, P. V., & Tossou, R. C. (2015). Co-production of knowledge in multi-stakeholder processes: Analyzing joint experimentation as social learning. *The Journal of Agricultural Education and Extension*, *21*(4), 369–388. http://doi.org/10.1080/1389224X.2014.939201

Alexander, C., Bynum, N., Johnson, E., King, U., Mustonen, T., Neofotis, P., et al. (2011). Linking indigenous and scientific knowledge of climate change. *BioScience*, *61*(6), 477–484.

Alford, J. (1998). A public management road less travelled: Clients as co-producers of public services. *Australian Journal of Public Administration, 57*(4), 128-137.

Amissah-Arthur, A. (2003). Targeting climate forecasts for agricultural applications in sub-Saharan Africa: situating farmers in user-space. *Climatic Change, 58*, 73-92.

Appleton, H., Fernandez, M. E., & Hill, C. L. M. (2011). Gender and indigenous knowledge. In S. Harding (Ed.), *The Postcolonial Studies Science and Technology Reader*. Durham, North Carolina: Duke Univerisity Press.

Armitage, D., Berkes, F., Dale, A., Kocho-Schellenberg, E., & Patton, E. (2011). Co-management and the co-production of knowledge: Learning to adapt in Canada's Arctic. *Global Environmental Change*, *21*(3), 995–1004. http://doi.org/10.1016/j.gloenvcha.2011.04.006

Arnstein, S. R. (1969). A ladder of citizen participation. *Journal of the American Institute of Planners*, *35*(4), 216–224.

Baldwin, S. (2000). Interactive social science in practice: new approaches to the production of knowledge and their implications. *Science and Public Policy, 27*(3), 183-194.

Barad, K. (2003). Barad (2003) Posthumanist performativity: Toward an understanding of how matter comes to matter, *Signs,* 28(3), 1–31.

Batterbury, S. P. J., & Fernando, J. L. (2006). Rescaling governance and the impacts of political and environmental decentralization: An introduction. *World Development*, *34*(11), 1851–1863. http://doi.org/10.1016/j.worlddev.2005.11.019

Bäckstrand, K. (2004). Civic science for sustainability: reframing the role of experts, policy-makers and citizens in environmental governance. *Global Environmental Politics, 3*(4), 24-41.

Beck, S., Borie, M., Chilvers, J., Esguerra, A., Heubach, K., Hulme, M., et al. (2014). Towards a reflexive turn in the governance of global environmental expertise, *GAIA, 23*(2), 1–8. http://doi.org/10.14512/gaia.23.2.4

Beck, U. (1992). Risk Society. Los Angeles: Sage Publications.

Beier, P., Hansen, L. J., Helbrecht, L., & Behar, D. (2016). A how-to guide for coproduction of actionable science. *Conservation Letters*, *00*(0), 1-9. http://doi.org/10.1111/conl.12300
Belliveau, S., Smit, B., & Bradshaw, B. (2006). Multiple exposures and dynamic vulnerability: Evidence from the grape industry in the Okanagan Valley, Canada. *Global Environmental Change*, *16*(4), 364–378.
Berkes, F. (2009). Berkes (2009) Evolution of co-management: Role of knowledge generation, bridging organizations. *Journal of Environmental Management*, *90*(5), 1692–1702. http://doi.org/10.1016/j.jenvman.2008.12.001
Berkes, F., Colding, J., & Folke, C. (2000). Rediscovery of traditional ecological knowledge as adaptive management. *Ecological Applications*, *10*(5), 1251–1262.
Berkes, F., Reid, W. V., Wilbanks, T. J., & Capistrano, D. (2006). Bridging scales and knowledge systems. *Bridging Scales and Knowledge Systems: Concepts and Applications in Ecosystem Assessment.* Island Press, Washington, DC, USA, 315–331.
Bishop, E. (2008). Schooling and the encouragement of farming amongst pastoralists in Tanzania, *Nomadic Peoples, 11*(2), 1–22. http://doi.org/10.3167/np.2007.110202
Bouleau, G. (2014). The co-production of science and waterscapes: The case of the Seine and the Rhone Rivers, France. *Geoforum*, *57*(C), 248–257. http://doi.org/10.1016/j.geoforum.2013.01.009
Bowen, K., Miller, F., Va, D., & Graham, S. (2015). The relevance of a coproductive capacity framework to climate change adaptation: investigating the health and water sectors in Cambodia. *Ecology and Society,* 20(1), 13, http://doi.org/10.5751/ES-06864-200113
Boyle, D., & Harris, M. (2009). The challenge of co-production. *London: New Economics Foundation*.
Brace, C., & Geoghegan, H. (2011). Human geographies of climate change: Landscape, temporality, and lay knowledges. *Progress in Human Geography*, *35*(3), 284–302. http://doi.org/10.1177/0309132510376259
Brandsen, T., & Pestoff, V. (2006). Co-production, the third sector and the delivery of public services. *Public Management Review*, *8*(4), 493–501. http://doi.org/10.1080/14719030601022874
Broad, K., & Agrawala, S. (2000). The Ethiopia food crisis--uses and limits of climate forecasts. *Science 289*(), 1993-1694.
Broad, K., & Orlove, B. (2007). Channeling Globality. *American Ethnographist*, *34*(2), 285–302.
Brockington, D. (2002). Fortress Conservation. Bloomington, Indiana: Indiana University Press.
Brokensha, D. W., Warren, D. M., & Werner, O. (1980). Indigenous knowledge systems and development. Washington, D.C.: University Press of America.
Brudney, J. L., & England, R. E. (1983). Toward a definition of the coproduction concept. *Public Administration Review, 43*(1), 59-65.
Brugnach, M., Craps, M., & Dewulf, A. (2014). Including indigenous peoples in climate change mitigation: addressing issues of scale, knowledge and power. *Climatic Change*. http://doi.org/10.1007/s10584-014-1280-3
Budds, J., & Hinojosa, L. (2012). Restructuring and rescaling water governance in mining contexts: The co-production of waterscapes in Peru. *Water Alternatives, 5*(1), 119-137.
Buizer, J., Jacobs, K., & Cash, D. (2010). Making short-term climate forecasts useful: Linking science and action. *Proceedings of the National Academy of Sciences*. http://doi.org/10.1073/pnas.0900518107
Callon, M. (1984). Some elements of a sociology of translation: domestication of the scallops

and the fishermen of St Brieuc Bay. *The Sociological Review, 32*(S1), 196-233.
Callon, M., & Rabeharisoa, V. (2003). Research "in the wild" and the shaping of new social identities. *Technology in Society*, *25*(2), 193–204. http://doi.org/10.1016/S0160-791X(03)00021-6
Carlsson, L., & Berkes, F. (2005). Co-management: concepts and methodological implications. *Journal of Environmental Management*, *75*(1), 65–76. http://doi.org/10.1016/j.jenvman.2004.11.008
Carolan, M. S. (2006). Sustainable agriculture, science and the co-production of "expert" knowledge: The value of interactional expertise. *Local Environment*, *11*(4), 421–431. http://doi.org/10.1080/13549830600785571
Carr, E. R., & Owusu-Daaku, K. N. (2015). The shifting epistemologies of vulnerability in climate services for development: the case of Mali's agrometeorological advisory programme. *Area*, *48*(1), 7–17. http://doi.org/10.1111/area.12179
Cash, D. W. (2006). Countering the loading-dock approach to linking science and decision making: Comparative analysis of El Nino/Southern Oscillation (ENSO) forecasting systems. *Science, Technology & Human Values*, *31*(4), 465–494. http://doi.org/10.1177/0162243906287547
Cash, D. W., & Moser, S. C. (2000). Linking global and local Scales. *Global Environmental Change*, *10*(2000), 109–120.
Cash, D. W., Clark, W. C., Alcock, F., Dickson, N. M., Eckley, N., Guston, D. H., et al. (2003). Knowledge systems for sustainable development. *PNAS*, *100*(4), 8086–8091.
Cepiku, D., & Giordano, F. (2013). Co-Production in developing countries: Insights from the community health workers experience. *Public Management Review*, *16*(3), 317–340. http://doi.org/10.1080/14719037.2013.822535
Chachage, C. (1988). British rule and African civilization in Tanganyika. *Journal of Historical Sociology, 1*(2), 199-223.
Chambers, R. (1983). Rural Development: Putting the Last First. Oxford: Routledge.
Chambers, R. (1992). Rural apprasial: rapid, relaxed and participatory, Institute of Development Studies, UK.
Chang'a, L., Yanda, P., & Ngana, J. (2010). Indigenous knowledge in seasonal rainfall prediction in Tanzania: A sase of the south-western highland of Tanzania. *Journal of Geography and Regional Planning*, *3*(4), 1–7.
Cherrier, H. (2007). Ethical consumption practices: co-production of self-expression and social recognition. *Journal of Consumer Behaviour*. http://doi.org/10.1002/cb.224
Christo Fabricius, G. C. (2014). Learning in adaptive management: Insights from published practice, 1–8. http://doi.org/10.5751/ES-06263-190129
Collins, H. M., & Evans, R. (2003). King Canute meets the Beach Boys: Responses to "The Third Wave." *Social Studies of Science, 33*(3), 435-452.
Collins, K., & Ison, R. (2009). Jumping off Arnstein's ladder: social learning as a new policy paradigm for climate change adaptation. *Environmental Policy and Governance*, *19*(6), 358–373. http://doi.org/10.1002/eet.523
Cooke, B., & Kothari, U. (2001). Participation: The New Tyranny? London: Zed Books.
Corburn, J. (2007). Community knowledge in environmental health science: co-producing policy expertise. *Environmental Science and Policy*, *10*(2), 150–161. http://doi.org/10.1016/j.envsci.2006.09.004
Costanza, R. (1996). Ecological economics: Reintegrating the study of humans and nature.

Ecological Applications, *6*(4), 978–990.
Coulibaly, J., Mango, J., Swamila, M., Tall, A., Kaur, H., & Hansen, J. (2015). What climate services do farmers and pastoralists need in Tanzania? *CCAFS Working Paper, No. 110, CGIAR Research Program on Climate Change, Agriculture, and Food Security*, Copenhagen, Denmark.
Cox, M., Arnold, G., & Villamayor Tomas, S. (2010). A review of design principles for community-based natural resource management. *Ecology and Society*, *15*(4), 1–19.
Dale, A., & Armitage, D. (2011). Marine mammal co-management in Canada's Arctic: knowledge co-production for learning and adaptive capacity. *Marine Policy*, *35*(4), 440–449. http://doi.org/10.1016/j.marpol.2010.10.019
de Wit, S. (1448). Changing patterns of rain or power? *German Research Foundation, Working Papers of the Priority Programme 1448*.
Dessai, S., Hulme, M., Lempert, R., & Pielke, R., Jr. (2009). Climate prediction: A limit to adaptation? In Adapting to Climate Change: Thresholds, Values, Governance, eds. W. Neil Adger, Irene Lorenzoni and Karen L. O'Brien. Published by Cambridge University Press.
Dilling, L., & Lemos, M. C. (2011). Creating usable science: Opportunities and constraints for climate knowledge use and their implications for science policy. *Global Environmental Change*, *21*(2), 680–689. http://doi.org/10.1016/j.gloenvcha.2010.11.006
Donovan, A. R., Bravo, M., and Oppenheimer, C. (2012). Co-production of an institution: Montserrat Volcano Observatory and social dependence on science. *Science and Public Policy,* 40. http://doi.org/10.1093/scipol/scs078
Doubleday, R. (2007). Organizing accountability: co-production of technoscientific and social worlds in a nanoscience laboratory. *Area, 39*(2) 167-175.
Dunston, R., Lee, A., Boud, D., Brodie, P., & Chiarella, M. (2009). Co-production and health system reform: From re-Imagining to re-Making. *Australian Journal of Public Administration*, *68*(1), 39–52. http://doi.org/10.1111/j.1467-8500.2008.00608.x
Durose, C., Beebeejaun, Y., Rees, J., Richardson, J., & Richardson, L. (2011). Towards co-production in research with communities. *Connected Communities: Project Report.*
EAC. (2004). Five year meteorological development and investment strategy. *East African Community Working Document*, October 2004, 1–68.
Edelenbos, J., van Buuren, A., & van Schie, N. (2011). Co-producing knowledge: joint knowledge production between experts, bureaucrats and stakeholders in Dutch water management projects. *Environmental Science and Policy*, *14*(6), 675–684. http://doi.org/10.1016/j.envsci.2011.04.004
Eguru, A. (2012). Role of indigenous knowledge in climate change adaptation: A case study of the Teso Sub-Region, Eastern Uganda. *Indian Journal of Traditional Knowledge*, *11*(2), 1–8.
Elgert, L. (2010). Politicizing sustainable development: the co-production of globalized evidence-based policy. *Critical Policy Studies*, *3*(3-4), 375–390. http://doi.org/10.1080/19460171003619782
Ezrahi, Y. (1990). The Descent of Icarus. Cambridge MA: Harvard University Press.
Feierman, S. (1990). Peasant intellectuals: Anthropology and history in Tanzania. Madison WI: The University of Wisconsin Press.
Fenwick, T. (2012). Co-production in professional practice: a sociomaterial analysis. *Professions and Professionalism*, *2*(2). http://doi.org/10.7577/pp/v2i1.323
Folke, C. (2004). Traditional knowledge in social-ecological systems. *Ecology and Society*, *9*(3), 7.

Ford, J. D., & Pearce, T. (2012). Climate change vulnerability and adaptation research focusing on the Inuit subsistence sector in Canada: Directions for future research. *The Canadian Geographer / Le Géographe Canadien*, *56*(2), 275–287. http://doi.org/10.1111/j.1541-0064.2012.00418.x
Foucault, M. (1980). Power/Knowledge: Selected interviews and other Writings, 1972-1977. (C. Gordon, Ed.). New York: Vintage Books.
Foucault, M. (1982). The subject and power. *Critical Inquiry*, *8*(4), 777–795.
Fratkin, E. (1997). Pastoralism: governance and development issues. *Annual Review of Anthropology, 26*(1997), 235-261.
Fratkin, E., & Mearns, R. (2003). Sustainability and pastoral livelihoods: lessons from East African Maasai and Mongolia. *Human Organization, 62*(2).
Freierman, S. (1990). Peasant Intellectuals: Anthropology and History in Tanzania. Madison: The University of Wisconsin Press.
Furman, C., Roncoli, C., Bartels, W., Boudreau, M., Crockett, H., Gray, H., & Hoogenboom, G. (2014). Climate Risk Management. *Climate Risk Management*, *2*(C), 11–25. http://doi.org/10.1016/j.crm.2014.02.002
Galvin, K. A. (2009). Transitions: Pastoralists living with change. *Annual Review of Anthropology*, *38*(1), 185–198. http://doi.org/10.1146/annurev-anthro-091908-164442
Galvin, K. A., Boone, R. B., Smith, N. M., & Lynn, S. J. (2001). Impacts of climate change on East African pastoralists. *Climate Research*, *19*, 161–172.
Gardiner, B. (2016). Selling the Serengeti: The Cultural Politics of Safari Tourism. Athens: The University of Georgia Press.
GCOS. (2016). Status of the global observing system for climate. *Gcos*, (195), 1–373.
Gearheard, S., Pocernich, M., Stewart, R., Sanguya, J., & Huntington, H. P. (2009). Linking Inuit knowledge and meteorological station observations to understand changing wind patterns at Clyde River, Nunavut. *Climatic Change*, *100*(2), 267–294. http://doi.org/10.1007/s10584-009-9587-1
GFCS. (2013). Guideline. GFCS Secretariat, World Meteorological Organization, Geneva, Switzerland.
Gibbons, M., Limoges, C., Nowotny, H., Schwartzman, S., & Scott, P. (1994). The New Production of Knowledge: The Dyanmics of Science and Research in Contemporary Societies. Los Angeles: Sage Publications.
Gieryn, T. (1999). Cultural Boundaries of Science: Credibility on the Line. Chicago: University of Chicago Press.
Gieryn, T. F. (1995). Boundaries of science. In S. Jasanoff, G. E. Markle, J. C. Petersen, & T. Pinch (Eds.), *Handbook of Science and Technology Studies*. Thousand Oaks, California: Sage Publications.
Goddard, L., Aitchellouche, Y., Baethgen, W., Dettinger, M., Graham, R., Hayman, P., Kadi, M., Martínez, R., & Meinke, H. (2010a). Providing seasonal-to-interannual climate information for risk management and decision-making. *Procedia Environmental Sciences*, *1*, 81–101. http://doi.org/10.1016/j.proenv.2010.09.007
Goldman, M. (2006). Imperial Nature. Yale University Press.
Goldman, M.J. (2007). Tracking wildebeest, locating knowledge: Maasai and conservation biology understandings of wildebeest behavior in Northern Tanzania. *Environment and Planning D: Society and Space*, *25*(2), 307–331. http://doi.org/10.1068/d0505
Goldman, M.J. (2009). Constructing connectivity: conservation corridors and conservation

politics in East African rangelands. *Annals of the Association of American Geographers*, *99*(2), 335–359. http://doi.org/10.1080/,DanaInfo=dx.doi.org+00045600802708325
Goldman, M.J. (2011). Strangers in their own land: Maasai and wildlife conservation in Northern Tanzania. *Conservation and Society*, *9*(1), 65. http://doi.org/10.4103/0972-4923.79194
Goldman, M. J. (2006). *Sharing Pastures, Building Dialogues: Maasai and Wildlife Conservation in Northern Tanzania*. PhD Thesis, University of Wisconsin Madison.
Goldman, M. J., & Riosmena, F. (2013). Adaptive capacity in Tanzanian Maasailand: Changing strategies to cope with drought in fragmented landscapes. *Global Environmental Change*, *23*(3), 588–597. http://doi.org/10.1016/j.gloenvcha.2013.02.010
Grabbatin, B., Hurley, P. T., & Halfacre, A. (2011). "I Still Have the Old Tradition": The co-production of sweetgrass basketry and coastal development. *Geoforum*, *42*(6), 638–649. http://doi.org/10.1016/j.geoforum.2011.06.007
Graham, H. (2012). Scaling governmentality: Museums, co-production and re-calibrations of the "logic of culture." *Cultural Studies*. http://doi.org/10.1080/09502386.2012.679285
Graham, R. J., Yun, W. T., Kim, J., Kumar, A., Jones, D., Bettio, L., et al. (2011). Long-range forecasting and the Global Framework for Climate Services. *Climate Research*, *47*(1), 47–55. http://doi.org/10.3354/cr00963
Green, D., & Raygorodetsky, G. (2010). Indigenous knowledge of a changing climate. *Climatic Change*, *100*(2), 239–242. http://doi.org/10.1007/s10584-010-9804-y
Haraway, D. (1991). Simians, Cyborgs, and Women. Los Angeles: Routledge.
Harbers, H. (2005). Inside the politics of technology: Agency and normativity in the co-production of science and society. Amsterdam: Amsterdam University Press.
Harris, F., & Lyon, F. (2013). Transdisciplinary environmental research: Building trust across professional cultures. *Environmental Science and Policy*, *31*, 109–119. http://doi.org/10.1016/j.envsci.2013.02.006
Hegger, D., & Dieperink, C. (2014). Toward successful joint knowledge production for climate change adaptation: lessons from six regional projects in the Netherlands. *Ecology and Society*, *19*(2), art34. http://doi.org/10.5751/ES-06453-190234
Hegger, D., Lamers, M., Van Zeijl-Rozema, A., & Dieperink, C. (2012a). Conceptualising joint knowledge production in regional climate change adaptation projects: success conditions and levers for action. *Environmental Science and Policy*, *18*, 52–65. http://doi.org/10.1016/j.envsci.2012.01.002
Hegger, D., Van Zeijl-Rozema, A., & Dieperink, C. (2012b). Toward design principles for joint knowledge production projects: lessons from the deepest polder of The Netherlands. *Regional Environmental Change*. http://doi.org/10.1007/s10113-012-0382-6
Heink, U., Marquard, E., Heubach, K., Jax, K., Kugel, C., Neßhöver, C., et al. (2015). Conceptualizing credibility, relevance and legitimacy for evaluating the effectiveness of science–policy interfaces: Challenges and opportunities. *Science and Public Policy*, *42*(5), 676–689. http://doi.org/10.1093/scipol/scu082
Hirsch Hadorn, G., Hoffman-Reim, H., Biber-Klemm, R., Grossenbacher-Mansuy, W., Joye, D., Pohl, C., et al. (2008). Handbook of Transdisciplinary Research. Zurich, Switzerland: Springer.
Hodgson, D. L. (2001). Once Intrepid Warriors: Gender, Ethnicity, and the Cultural Politics of Maasai Development. Blomington: Indiana University Press.
Hodgson, D. L. (2011). Being Maasai, Becoming Indigenous: Post-colonial Politics in a Neoliberal World. Bloomington: Indiana University Press.

Holling, C. S. (1978). Adaptive Environmental Assessment and Management. Chichester, UK: John Wiley and Sons.

Homewood, K. (2009). Ecology of African Pastoral Societies. Ohio University Press.

Homewood, K., Kristjanson, P., & Chenevix, P. (2011). Staying Maasai? Livelihoods, conservation, and development in East African rangelands. K. homewood, P. Kristjanson, & P. Chenevix, Eds. New York: Springer.

Homsy, G. C., & Warner, M. E. (2013). Climate change and the co-production of knowledge and policy in rural USA communities. *Sociologia Ruralis*, *53*(3), 291–310. http://doi.org/10.1111/soru.12013

Houghton, J., Townshend, J., Dawson, K., & Mason, P. (2012). The GCOS at 20 years: The origin, achievement and future development of the Global Climate Observing System. *Weather, 67*(9).

Huggel, C., Scheel, M., Albrecht, F., Andres, N., Calanca, P., Jurt, C., et al. (2015). A framework for the science contribution to adaptation: Experiences from science-policy processes in the Andes. *Environmental Science and Policy*, *47*, 80–94. http://doi.org/10.1016/j.envsci.2014.11.007

Hulme, M. (2009). Why We Disagree About Climate Change. Cambridge, UK: Cambridge University Press.

Hulme, M., Doherty, R., Ngara, T., New, M., & Lister, D. (2001). African climate change: 1900-2100. *Climate Research*, *17*(2), 145–168.

Huntington, H. P. (2000). Using traditional ecological knowledge in science: methods and applications. *Ecological Applications*, *10*(5), 1270–1274.

Hyden, G. (1980). Beyond Ujamaa in Tanzania: Underdevelopment and Uncaptured Peasantry. Berkeley: University of California Press.

Ifejika Speranza, C., Kiteme, B., Ambenje, P., Wiesmann, U., & Makali, S. (2009). Indigenous knowledge related to climate variability and change: insights from droughts in semi-arid areas of former Makueni District, Kenya. *Climatic Change*, *100*(2), 295–315. http://doi.org/10.1007/s10584-009-9713-0

Igoe, J., & Brockington, D. (2007). Neoliberal conservation: a brief introduction. *Conservation and Society, 5(*4), 432-444.

Innes, J. E., & Booher, D. E. (2010). Planning with Complexity: An Introduction to Collaborative Rationality for Public Policy. New York: Routledge.

IRI. (2014). Enhancing national climate services: Targeted climate information for decision-makers. *IRI Fact Sheet*, 1–2.

Jasanoff, S. (1987). Contested boundaries in policy-relevant science. *Social Studies of Science*, *17*(2), 195–230. http://doi.org/10.1177/030631287017002001

Jasanoff, S. (1990). The Fifth Branch. Cambridge and London: Harvard University Press.

Jasanoff, S. (1996). Beyond epistemology: relativism and engagement in the politics of science. *Social Studies of Science*, *26*(2), 393–418.

Jasanoff, S. (2003). Technologies of humility: citizen participation in governing science. *Minerva*, *41*(3), 223–244.

Jasanoff, S. (2004). States of Knowledge: Science, Power, and Political Culture. Routledge.

Jasanoff, S. (2006). Designs on Nature: Science and Democracy in Europe and the United States . *Princeton University Press*, 1–374.

Jasanoff, S. (2010). A New Climate for Society. *Theory, Culture & Society*, *27*(2-3), 233–253. http://doi.org/10.1177/0263276409361497

Jasanoff, S. (2014a). A mirror for science. *Public Understanding of Science*, *23*(1), 21–26. http://doi.org/10.1177/0963662513505509
Jasanoff, S. (2014b, July 23). 'To be inclusive, you need more voices'. Retrieved November 22, 2014, from
Jasanoff, S. & Martello, M. L. (2004) Earthly Politics: Local and Global in Environmental Governance. Cambridge: MIT Press.
Jasanoff, S., & Wynne, B. (1998). Science and Decision-making. In S. Rayner & E. Malone (Eds.), *Human Choice and Climate Change: Volume 1 The Societal Framework*. Columbus, Ohio: Batelle Press.
Jennings, M. (2007). Surrogates of the State: NGOs, Development, and Ujamaa in Tanzania. Bloomfield, Connecticut: Kumarian Press.
Kijazi, A., Chang'a, L., Liwenga, E., Kanemba, A., & Nindi, S. (2013). The use of indigenous knowledge in weather and climate prediction in Mahenge and Ismani wards, Tanzania. *Journal of Geography and Regional Planning*, *6*(7), 274–279. http://doi.org/10.5897/JGRP2013.0386
Kirchhoff, C. J., Carmen Lemos, M., & Dessai, S. (2013). Actionable Knowledge for Environmental Decision Making: Broadening the Usability of Climate Science. *Annual Review of Environment and Resources*, *38*(1), 393–414. http://doi.org/10.1146/annurev-environ-022112-112828
Kiser, L. L., & Percy, S. L. (1980). The concept of coproduction and its implications for public service delivery. *Workshop in Political Theory and Policy*
Kleinman, D. L. (1998). Beyond the science wars: Contemplating the democratization of science. *Annual Meeting of the American Society of Public Administration, San Francisco, April 13-16.*
Kniveton, D., Visman, E., Tall, A., Diop, M., Ewbank, R., Njoroge, E., & Pearson, L. (2014). Dealing with uncertainty: integrating local and scientific knowledge of the climate and weather. *Disasters*, *39*(s1), s35–s53. http://doi.org/10.1111/disa.12108
Knorr-Cetina, K. D. (1983). The Ethnographic Study of Scientific Work: Towards a Constructivist Interpretation of Science. In *Science Observed: Perspectives on the Social Study of Science* (pp. 115–140). London: Sage Publications Limited.
Kuhn, T. S. (1962). The Structure of Scientific Revolutions. Chicago: The University of Chicago Press.
Landolt, S. (2013). Co-productions of neighbourhood and social identity by young men living in an urban area with delinquent youth cliques. *Journal of Youth Studies*. http://doi.org/10.1080/13676261.2012.733813
Larner, W. (2006). Neoliberalism: policy, ideology, governmentality. In *International Political Economy and Poststructural Politics,* M. de Goede (ed.) Macmillan Publishers.
Latour, B. (1987). Science in Action. Cambridge: Harvard University Press.
Latour, B. (1993). We Have Never Been Modern. Cambridge: Harvard University, and Nairobi: International Livestock Research Institute Cambridge, MA.
Latour, B. (1999). On Recalling ANT. (J. Law & A. Mol, Eds.). Durham: Duke University Press.
Latour, B. (2005). Reassembling the Social: An Introduction to Actor-Network Theory. Oxford: Oxford University Press.
Latour, B., & Woolgar, S. (1986). Laboratory Life: The Construction of Scientific Facts. Princeton: Princeton University Press.
Law, J. (1986). On the methods of long-distance control: vessels, navigation and the Portuguese

route to India. *The Sociological Review Monograph, 32,* 234-263.
Law, J. (2002). On Hidden Heterogeneities: Complexity, Formalism, and Aircraft Design. In J. Law & A. Mol (Eds.), *Complexities: Social Studies of Knoweldge Practices*. Durham: Duke Univerisity Press.
Law, J. (2004). After Method: Mess in Social Science Research. London and New York: Routledge.
Law, J. (2009). Actor network theory and material semiotics. *The New Blackwell Companion to Social Theory, http://www.heterogeneities.net/publications/Law2007ANTandMaterialSemiotics.pdf.*
Law, J., & Hassard, J. (1999). Actor Network Theory and After. Oxford: Blackwell Publishers.
Law, J., & Singleton, V. (2013). ANT and politics: Working in and on the world. *Qualitative Sociology*, *36*(4), 485–502. http://doi.org/10.1007/s11133-013-9263-7
Law, J., & Singleton, V. (2014). ANT, multiplicity and policy. *Critical Policy Studies*, *8*(4), 379–396. http://doi.org/10.1080/19460171.2014.957056
Leichenko, R. M., & O'Brien, K. L. (2002). The dynamics of rural vulnerability to global change: the case of southern Africa. *Mitigation and Adaptation Strategies for Global Change*, *7*(1), 1–18.
Lemos, M. C. (2015). Usable climate knowledge for adaptive and co-managed water governance. *Current Opinion in Environmental Sustainability*, *12*, 48–52. http://doi.org/10.1016/j.cosust.2014.09.005
Lemos, M. C., & Morehouse, B. J. (2005). The co-production of science and policy in integrated climate assessments. *Global Environmental Change*, *15*(1), 57–68. http://doi.org/10.1016/j.gloenvcha.2004.09.004
Lemos, M. C., Kirchhoff, C. J., & Ramprasad, V. (2012). Narrowing the climate information usability gap. *Nature Climate Change*, *2*(11), 789–794. http://doi.org/10.1038/nclimate1614
Linton, J., & Budds, J. (2014). The hydrosocial cycle: Defining and mobilizing a relational-dialectical approach to water. *Geoforum*, *57*(C), 170–180. http://doi.org/10.1016/j.geoforum.2013.10.008
Liverman, D. (2004). Who governs, at what scale and at what price? Geography, environmental governance, and the commodification of nature. *Annals of the Association of American Geographers*, *94*(4), 734–738.
Lövbrand, E., Pielke, R., & Beck, S. (2010). A democracy paradox in studies of science and technology. *Science*. http://doi.org/10.1177/0162243910366154
Lövbrand, E. Co-producing European climate science and policy: A cautionary note in the making of useful knowledge. *Science and Public Policy*, *38*(3), 225-236.
Lundin, M., & Mäkitalo, Å. (2016). Co-designing technologies in the context of hypertension care: Negotiating participation and technology use in design meetings. *Informatics for Health and Social Care*, 1–14. http://doi.org/10.3109/17538157.2015.1113176
Lynch, B. T., & Alberti, S. J. M. M. (2010). Legacies of prejudice: racism, co-production and radical trust in the museum. *Museum Management and Curatorship*, *25*(1), 13–35. http://doi.org/10.1080/09647770903529061
Maclean, K., & Cullen, L. (2009). Research methodologies for the co-production of knowledge for environmental management in Australia. *Journal of the Royal Society of New Zealand*, *39*(4), 205–208. http://doi.org/10.1080/03014220909510581
Mahoo, H., Mbungu, W., Yonah, I., Recha, J., Radeny, M., Kimeli, P., & Kinyangi, J. (2015). Integrating indigenous knowledge with scientific seasonal forecasts for climate risk

management in Lushoto District in Tanzania. *CGIAR Research Program on Climate Change, Agriculture, and Food Security (CCAFS)*, *CCAFS Working Paper No. 103*, 1–34. Retrieved from http://www.ccafs.cgiar.org
Marston, S. A. (2000). The social construction of scale. *Progress in Human Geography*, *24*(2), 219–242.
Martello, M. L., & Jasanoff, S. (2004). Globalization and Environmental Governance. In S. Jasanoff & M. L. Martello (Eds.), *Earthly Politics: Local and Global Environmental Governance*. Cambridge: MIT Press.
Masaki, K. (2010). Rectifying the anti-politics of citizen participation: Insights from the internal politics of a subaltern Community in Nepal. *Journal of Development Studies*, *46*(7), 1196–1215. http://doi.org/10.1080/00220388.2010.487092
Mastrandrea, M. D., Heller, N. E., Root, T. L., & Schneider, S. H. (2010). Bridging the gap: linking climate-impacts research with adaptation planning and management. *Climatic Change*, *100*(1), 87–101. http://doi.org/10.1007/s10584-010-9827-4
Mattee, A. Z., & Shem, M. (2006). Ambivalence and contradiction: A review of the policy environment in Tanzania in relation to pastoralism. *IIED*, (Issue Paper no. 140).
Max-Neef, M. A. (2005). Foundations of transdisciplinarity. *Ecological Economics*, *53*(1), 5–16. http://doi.org/10.1016/j.ecolecon.2005.01.014
McCabe, J. T., Leslie, P. W., & DeLuca, L. (2010). Adopting cultivation to remain pastoralists: The diversification of Maasai livelihoods in northern Tanzania. *Human Ecology*, *38*(3), 321–334. http://doi.org/10.1007/s10745-010-9312-8
McCusker, B., & Carr, E. R. (2006). The co-production of livelihoods and land use change: Case studies from South Africa and Ghana. *Geoforum*, *37*(5), 790–804. http://doi.org/10.1016/j.geoforum.2005.09.007
McDowell, J. Z., & Hess, J. J. (2012). Accessing adaptation: Multiple stressors on livelihoods in the Bolivian highlands under a changing climate. *Global Environmental Change*, *22*(2), 342–352. http://doi.org/10.1016/j.gloenvcha.2011.11.002
McGinnis, M. D. (2011). An introduction to IAD and the language of the Ostrom workshop: a simple guide to a complex framework. *Policy Studies Journal*.
McNie, E. C., Parris, A., & Sarewitz, D. (2016). Improving the public value of science: A typology to inform discussion, design, and implementation of research. *Research Policy*, *45*(4), 884–895. http://doi.org/10.1016/j.respol.2016.01.004
Meadow, A. M., Ferguson, D. B., Guido, Z., Horangic, A., Owen, G., & Wall, T. (2015). Moving toward the deliberate coproduction of climate science knowledge. *Weather, Climate, and Society*, *7*(2), 179–191. http://doi.org/10.1175/WCAS-D-14-00050.1
Medema, W., Adamowski, J., Orr, C. J., Wals, A., & Milot, N. (2015). Towards sustainable water governance: Examining water governance issues in Québec through the lens of multi-loop social learning. *Canadian Water Resources Journal / Revue Canadienne Des Ressources Hydriques*, *40*(4), 373–391. http://doi.org/10.1080/07011784.2015.1088403
Meek, D. (2015). Taking research with its roots: restructuring schools in the Brazilian landless workers' movement upon the principles of a political ecology of education, *Journal of Political Ecology, 22(0),* 1–19.
Miller, C. (2004). Climate Science and the Making of a Global Political Order. In S. Jasanoff (Ed.), *States of Knowledge: The Co-production of Science and the Social Order*. New York: Routledge.
Miller, C. (2004b). Resisting Empire: Globalism, Relocalization, and the Politics of Knowledge.

In S. Jasanoff & M. Martello (Eds.), *Earthly Politics: Local and Global in Environmental Politics*. Cambridge, MA: MIT Press.

Miller, C. A. (2008). Civic epistemologies: Constituting knowledge and order in political communities. *Sociology Compass*, *2*(6), 1896–1919. http://doi.org/10.1111/j.1751-9020.2008.00175.x

Mitchell, R. B., Clark, W. C., & Cash, D. W. (2004). Science, scientists, and the policy process: Lessons from global environmental assessments for the Northwest Forest Plan. In K. Arabas and J. Bowersox (eds.), *Forest Futures: Science Politics and Policy for the Next Century*, Rowman and Littlefield Publishers.

Mitchell, R. B., Clark, W. C., & Cash, D. W. (2006). Information and Influence, In R. Mitchell (ed.) *Global Environmental Assessments: Information and Influence*. Cambridge: MIT Press.

Mitlin, D. (2008). With and beyond the state: co-production as a route to political influence, power and transformation for grassroots organizations. *Environment and Urbanization*, *20*(2), 339–360. http://doi.org/10.1177/0956247808096117

Mol, A., & Law, J. (1994). Regions, networks and fluids: Anaemia and social topology. *Social Studies of Science*, *24*(4), 641–671. http://doi.org/10.1177/030631279402400402

Mollel, H. A., & Tollenaar, A. (2013). Decentralization in Tanzania: Design and application in planning decisions. *International Journal of Public Administration*, *36*(5), 344–353. http://doi.org/10.1080/01900692.2013.767271

Moser, I., & Law, J. (1999). Good Passages, Bad Passage. In *Actor Network Theory and After*. Oxford: Blackwell Publishers.

Mosse, D. (2001). People's Knowledge, Participation, and Patronage: Operations and Represenations in Rural Development. In B. Cooke & U. Kothari (Eds.), *Participation: The New Tyranny?* London: Zed Books.

Muñoz-Erickson, T. A. (2014). Co-production of knowledge-action systems in urban sustainable development: The KASA approach. *Environmental Science and Policy*, *37*, 182–191. http://doi.org/10.1016/j.envsci.2013.09.014

Murton, G. (2013). Himalayan highways: STS, the spatial fix, and socio-cultural shifts in the land of Zomia. *Perspectives on Global Development,* http://doi.org/10.1163/15691497-12341278

Nel, J. L., Roux, D. J., Driver, A., Hill, L., Maherry, A. C., Snaddon, K., et al. (2016). Knowledge co-production and boundary work to promote implementation of conservation plans. *Conservation Biology: the Journal of the Society for Conservation Biology*, *30*(1), 176–188. http://doi.org/10.1111/cobi.12560

Nightingale, A. J. (2015). Adaptive scholarship and situated knowledges? Hybrid methodologies and plural epistemologies in climate change adaptation research. *Area*, *48*(1), 41–47. http://doi.org/10.1111/area.12195

Nowotny, H., Scott, P., & Gibbons, M. (2003). Introduction: 'Mode 2' revisited: The new production of knowledge. *Minerva*, *41*(3), 179–194.

Noxolo, P., & Featherstone, D. (2014). Co-producing Caribbean geographies of in/security. *Transactions of the Institute of British Geographers*, *39*(4), 603–607. http://doi.org/10.1111/tran.12068

O'Brien, K., Sygna, L., & Haugen, J. (2004). Vulnerable or resilient? A multi-scale assessment of climate impacts and vulnerability in Norway. *Climatic Change*, *64*, 193–225.

Odora Hopper, C. A. (2011). Toward the Integration of Knowledge Systems: Challenges to Thought and Practice. In S. Harding (Ed.), *The Postcolonial Science and Technology Studies*

Reader (pp. 389–402). Durham, North Carolina: Duke Univerisity Press.
Orlove, B., Roncoli, C., Kabugo, M., & Majugu, A. (2009). Indigenous climate knowledge in southern Uganda: the multiple components of a dynamic regional system. *Climatic Change*, *100*(2), 243–265. http://doi.org/10.1007/s10584-009-9586-2
Ostrom, E. (1990). Governing the Commons. London and Cambridge: Cambridge University Press.
Ostrom, E. (1996). Crossing the great divide: coproduction, synergy, and development. *World Development, 24*(6), 1073-1087.
Ostrom, E. (2005). Self-Governance and Forest Resources. In P. Shah & V. Maitra (Eds.), *Terracotta Reader: A Market Approach to the Environment* (pp. 131–155). New Delhi: Academic Foundation.
Ostrom, E. (2009). Understanding Institutional Diversity. Princeton and Oxford: Princeton University Press.
Ostrom, E. (2010). Polycentric systems for coping with collective action and global environmental change. *Global Environmental Change: Human and Policy Dimensions*, *20*(4), 550–557. http://doi.org/10.1016/j.gloenvcha.2010.07.004
Ostrom, E. (2011). Background on the institutional analysis and development framework. *Policy Studies Journal*.
Ostrom, E., Parks, R. B., & Whitaker, G. P. (1978). The public service production process: a framework for analyzing police services. *Policy Studies Journal, 39*(1),
Otsuki, K. (2016). Infrastructure in informal settlements: co-production of public services for inclusive governance. *Local Environment*, 1–16. http://doi.org/10.1080/13549839.2016.1149456
Pallett, H., & Chilvers, J. (2015). Organizations in the making: Learning and intervening at the science-policy interface. *Progress in Human Geography*. http://doi.org/10.1177/0309132513518831
Palomo, I., Felipe-Lucia, M. R., Bennett, E. M., Martín-López, B., & Pascual, U. (2016). Disentangling the pathways and effects of ecosystem service co-production, 1–39. http://doi.org/10.1016/bs.aecr.2015.09.003
Parkipuny, M. L. O. (1979). Some Crucial Aspects of the Maasai Predicament. In J. Coulson (Ed.), *African Socialism in Practice: The Tanzanian Experience*. Nottingham: Spokesman.
Parks, R. B., Baker, P. C., Kiser, L., Oakerson, R., Ostrom, E., Ostrom, V., Percy, S… (1981). Consumers as coproducers of public services: Some economic and institutional considerations. *Working Paper.*
Patt, A., & Gwata, C. (2002). Effective seasonal climate forecast applications: examining constraints for subsistence farmers in Zimbabwe. *Global Environmental Change-Human and Policy Dimensions*, *12*(3), 185–195.
Patt, A., & Winkler, J. (2007). Applying Climate Information in Africa. *NOAA*, 1–133.
Pfaff, A., Broad, K., & Glantz, M. (1999). Who benefits from climate forecasts? *Nature*, *397*(6721), 645–646.
Pielke, R., Prins, G., Rayner, S., & Sarewitz, D. (2007). Climate change 2007: Lifting the taboo on adaptation. *Nature*, *445*(7128), 597–598. http://doi.org/10.1038/445597a
Pohl, C., Rist, S., Zimmermann, A., Fry, P., Gurung, G. S., Schneider, F., et al. (2010). Researchers' roles in knowledge co-production: Experience from sustainability research in Kenya, Switzerland, Bolivia and Nepal. *Science and Public Policy*, *37*(4), 267–281. http://doi.org/10.3152/030234210X496628

Polanyi, M. (2000). The republic of science: Its political and economic theory. *Minerva. 38,* 1-32.
Polsky, C., & Cash, D. W. (2005). Drought, climate change, and vulnerability: the role of science and technology in a multi-scale, multi-stressor world. *Drought and Water Crises: Science, Technology, and Management Issues. Marcel Dekker, New York City,* 215–245.
Puente-Rodríguez, D., van Slobbe, E., Al, I., & Lindenbergh, D. (2015). Knowledge co-production in practice: Enabling environmental management systems for ports through participatory research in the Dutch Wadden Sea. *Environmental Science and Policy*, 1–11. http://doi.org/10.1016/j.envsci.2015.02.014
Ramisch, J. (2011). Experiments as "Performances": Interpreting Farmers' Soil Fertility Management Practices in Western Kenya. In M. J. Goldman, P. Nadasdy, & M. D. Turner (Eds.), *Knowing Nature: Conversations at the Intersection of Political Ecology and Science Studies*. Chicago: University of Chicago Press.
Reyers, B., Nel, J. L., O'Farrell, P. J., Sitas, N., & Nel, D. C. (2015). Navigating complexity through knowledge coproduction: Mainstreaming ecosystem services into disaster risk reduction. *PNAS*, *112*(24), 7362–7368. http://doi.org/10.1073/pnas.1414374112
Ribot, J. (2010). Vulnerability does not fall from the sky: toward multiscale, pro-poor climate policy. *Social Dimensions of Climate Change: Equity and Vulnerability in a Warming World*, 47–74.
Rocheleau, D., & Roth, R. (2007). Rooted networks, relational webs and powers of connection: Rethinking human and political ecologies. *Geoforum*, *38*(3), 433–437. http://doi.org/10.1016/j.geoforum.2006.10.003
Roncoli, C. (2006). Ethnographic and participatory approaches to research on farmers' responses to climate predictions. *Climate Research*, *33*(1), 81.
Roux, D., Rogers, K., Biggs, H., Ashton, P., and Sergeant, A. (2007). Bridging the science–management divide: Moving from unidirectional knowledge transfer to knowledge interfacing and sharing, *Ecology and Society, 11*(1), 1–20.
Ryan, B. (2012). Co-production: Option or obligation? *Australian Journal of Public Administration*. http://doi.org/10.1111/j.1467-8500.2012.00780.x
Schuttenberg, H. Z., & Guth, H. K. (2015). Seeking our shared wisdom: a framework for understanding knowledge coproduction and coproductive capacities. *Ecology and Society*, *20*(1), art15. http://doi.org/10.5751/ES-07038-200115
Scott, J. C. (1998). Seeing Like a State: How Certain Schemes to Improve the Human Condition Have Failed. New Haven: Yale University Press.
Shaffer, L. J. (2014). Making sense of local climate change in rural Tanzania through knowledge co-production. *Journal of Ethnobiology, 34*(3), 315-334.
Shapin, S., & Schaffer, S. (1985). Leviathan and the Air-Pump: Hobbes, Boyle, and the Experimental Life. Princeton and Oxford: Princeton University Press.
Sitas, N., Reyers, B., Cundill, G., Prozesky, H. E., Nel, J. L., & Esler, K. J. (2016). Fostering collaboration for knowledge and action in disaster management in South Africa, 1–9. http://doi.org/10.1016/j.cosust.2015.12.007
Smit, B., & Wandel, J. (2006). Adaptation, adaptive capacity and vulnerability. *Global Environmental Change*, *16*(3), 282–292. http://doi.org/10.1016/j.gloenvcha.2006.03.008
St Clair, A. L. (2006). Global poverty: The co-production of knowledge and politics. *Global Social Policy*, *6*(1), 57–77. http://doi.org/10.1177/1468018106061392
Star, S. L., & Griesemer, J. R. (1989). Institutional ecology, translations, and boundary objects:

Amateurs and professionals in Berkeley's Museum of Vertebrate Zoology, 1907-39. *Social Studies of Science, 19*(3), 387-420.
Steen, T., Nabatchi, T., & Brand, D. (2016). Introduction: Special issue on the coproduction of public services. *International Review of Administrative Sciences*, *82*(1), 3–7. http://doi.org/10.1177/0020852315618187
Stilgoe, J. (2007). The (co-) production of public uncertainty: UK scientific advice on mobile phone health risks. *Public Understanding of Science*. http://doi.org/10.1177/0963662506059262
Stirling, A. (2007). "Opening up" and "closing down": Power, participation, and pluralism in the social appraisal of technology. *Science, Technology & Human Values*, *33*(2), 262–294. http://doi.org/10.1177/0162243907311265
Stryker, R., Filipek, D. D., & Wald, P. (2012). Employment discrimination law and industrial psychology: Social science as social authority and the co-production of law and science. *Law & Social Inquiry, 37*(4).
Tang, S., & Dessai, S. (2012). Usable Science? The U.K. Climate Projections 2009 and Decision Support for Adaptation Planning. *Weather, Climate, and Society*, *4*(4), 300–313. http://doi.org/10.1175/WCAS-D-12-00028.1.
Tierney, J. E., Smerdon, J. E., Anchukaitis, K. J., & Seager, R. (2013). Multidecadal variability in East African hydroclimate controlled by the Indian Ocean. *Nature*, *493*(7432), 389–392. http://doi.org/10.1038/nature11785
Timiza, W. (2013). Status and priority needs of monitoring and predicting climate anomalies and extremes in Tanzania. Presented at the Regional Workshop on Climate Monitoring and Analysis on Climate Variability, Pretoria, South Africa.
TNRF. (2012). Mainstreaming climate change adaptation in drylands development planning in Tanzania. *Quarter 1 Highlights Bulletin*, 1–2.
Trenberth, K., & Jones, P. (2007). IPCC WG1 Ch. 3, 1–102.
Tuinstra, W. (2008). European air pollution assessments: Co-production of science and policy. *International Environmental Agreements: Politics*. http://doi.org/10.1007/s10784-008-9064-8
Tuinstra, W., Hordijk, L., & Kroeze, C. (2006). Moving boundaries in transboundary air pollution co-production of science and policy under the convention on long range transboundary air pollution. *Global Environmental Change*. http://doi.org/10.1016/j.gloenvcha.2006.03.002
Turnbull, D. (2000). Masons, Tricksters, and Cartographers. Sussex: Psychology Press.
UNEP. (2008). Indigenous knowledge in disaster management in Africa. Nairobi: United Nations Environment Programme.
URT. (2012) National Climate Change Strategy, Government of Tanzania, Dar es Salaam
URT. (2006) *National Livestock Policy* (pp. 1–55). Ministry of Livestock Development.
URT. (2014) *Meteorological Subsector Performance Review Paper for Tanzania Meteorological Agency*. Eighth Joint Transport Sector Review Meeting 2014.
Van Buuren, A., & Edelenbos, J. (2004). Why is joint knowledge production such a problem? *Science and Public Policy, 31*(4), 289-299.
van der Hel, S. (2016). New science for global sustainability? The institutionalisation of knowledge co-production in Future Earth, *Environmental Science & Policy*, 1–11. http://doi.org/10.1016/j.envsci.2016.03.012
van Kerkhoff, L. E., & Lebel, L. (2015). Coproductive capacities: rethinking science-governance

relations in a diverse world. *Ecology and Society*, *20*(1), art14. http://doi.org/10.5751/ES-07188-200114
Venugopal, V., & Yilmaz, S. (2010). Decentralization in Tanzania: An assessment of local government discretion and accountability. *Public Administration and Development*, *30*(3), 215–231. http://doi.org/10.1002/pad.556
Verschuere, B., Brandsen, T., & Pestoff, V. (2012). Co-production: The state of the art in research and the future agenda. *Voluntas, 23,* 1083-1101. http://doi.org/10.1007/s11266-012-9307-8
Vogel, C., & O Brien, K. (2006). Who can eat information? Examining the effectiveness of seasonal climate forecasts and regional climate-risk management strategies. *Climate Research*, *33*(1), 111.
Voorberg, W. H., & Bekkers, V. (2015a). A systematic review of co-creation and co-production: Embarking on the social innovation journey. *Public Management Review,* http://doi.org/10.1080/14719037.2014.930505
Warren, R., Rosentraub, M. S., & Harlow, K. S. (1984). Coproduction, equity, and the distribution of safety. *Urban Affairs Review, 19*(4), 447-464.
Watson-Verran, H., & Turnbull, D. (1995). Science and Other Indigenous Knowledge Systems. In S. Jasanoff, G. E. Markle, J. C. Petersen, & T. Pinch (Eds.), *Handbook of Science and Technology Studies*. Thousand Oaks, California: Sage Publications.
Weaver, C. P., Mooney, S., Allen, D., Beller-Simms, N., Fish, T., Grambsch, A. E., et al. (2014). From global change science to action with social sciences. *Nature Climate Change*, *4*(8), 656–659. http://doi.org/10.1038/nclimate2319
Wehrens, R. (2014). Beyond two communities. *Public Health*, *128*(6), 545–551. http://doi.org/10.1016/j.puhe.2014.02.004
Weiss, C. H. (1979). The many meanings of research utilization. *Public Administration Review, 39*(5), 426-431.
Whaley, L., & Weatherhead, E. K. (2014). An integrated approach to analyzing (adaptive) comanagement using the "politicized" IAD framework. *Ecology and Society*, *19*(1), art10. http://doi.org/10.5751/ES-06177-190110
Whitaker, G. P. (1980). Coproduction: Citizen participation in service delivery. *Public Administration Review, 40*(3), 240-246.
White, S. C. (1996). Depoliticising development: the uses and abuses of participation. *Development in Practice*, *6*(1), 6–15.
Wilbanks, T., & Kates, R. (1999). Global change in local places: How scale matters. *Climatic Change*, *43*(3), 601–628.
Wilby, R. L., & Wigley, T. (1997). Downscaling general circulation model output: a review of methods and limitations. *Progress in Physical Geography, 21*(4), 530-548.
Williams, A. P., & Funk, C. (2011). A westward extension of the warm pool leads to a westward extension of the Walker circulation, drying eastern Africa. *Climate Dynamics*, *37*(11-12), 2417–2435. http://doi.org/10.1007/s00382-010-0984-y
WMO. (2011). Climate knowledge for action: A Global Framework for Climate Services - empowering the most vulnerable (pp. 1–248).
Wyborn, C. (2015a). Global Environmental Change. *Global Environmental Change-Human and Policy Dimensions*, *30*, 56–67. http://doi.org/10.1016/j.gloenvcha.2014.10.009
Wyborn, C. (2015b). ScienceDirect. *Environmental Science and Policy*, *51*, 292–303. http://doi.org/10.1016/j.envsci.2015.04.019

Wynne, B. (1991). Knowledges in context. *Science, Technology & Human Values*, *16*(1), 111–121.
Wynne, B. (1992). Misunderstood misunderstanding: Social identities and public uptake of science. *Public Understanding of Science, 1,* 281-304.
Wynne, B. (2003). Seasick on the third wave? Subverting the hegemony of propositionalism: Response to Collins & Evans (2002). *Social Studies of Science, 33*(3), 401-417.
Yin, R. K. (2009). Case Study Research: Design and Methods. Thousand Oaks CA: Sage.
Yohe, G., & Tol, R. S. J. (2002). Indicators for social and economic coping capacity: Moving toward a working definition of adaptive capacity. *Global Environmental Change*, *12*(1), 25–40.
Zillman, J. W. (2014). Weather and Climate Information Delivery Within National and International Frameworks (pp. 201–219). New York, NY: Springer New York. http://doi.org/10.1007/978-1-4614-9221-4_9

APPENDIX 1: Village Scale Survey Protocol (Swahili Translation)

Verbal Consent Script

Hello, my name is [NAME]. I am helping to conduct a survey with researchers from the United States in Tanzania based at the University of Colorado.

The study is about climate change and am examining how climate change affects people's lives and what kinds of information they use now and will need in the future to better manage the impacts of climate change. The goal of the research is to understand what kinds of information are most helpful for you, and people in your community, in helping you decide how to avoid negative impacts of weather and climate.

If you are interested to be part of the study, participating would involve answering survey questions. Participating in the survey will take about an hour.

Please know that your participation is completely voluntary, but your experiences could be very helpful to develop better policies to address the impacts of climate change in Tanzania. You can decline to answer any questions or stop the interview at any time.

There are not any direct benefits to participating in the study, but the goal of the study is to better understand your views of climate change and the challenges you face, so that they might be included in decisions about how to respond to climate change in the future.

All data collected will only be seen by the researchers and your name will not be used in any reports or documents resulting from the study. After the survey is finished, we may ask you about your interest in participating in other research activities, such as an interview. You can decline to participate in additional research activities later on, even if you have participated in the survey.

If you have any questions about this research, you can ask me right now, or you can feel free to contact Meaghan Daly or Eric Lovell at any time. I have a card here with the email addresses and phone numbers of the research team members. You can keep this in case you would like to contact the research team.

Now that you have all the information, do you have any questions? (ANSWER ANY QUESTIONS.)

If you do not have any other questions, do you agree to be interviewed?

NOTE WHETHER RESPONDENT AGREES TO INTERVIEW OR NOT

[ ] DOES NOT AGREE TO BE INTERVIEWED → THANK PARTICIPANT FOR HER/HIS TIME AND END

[ ] AGREES TO BE INTERVIEWED

↓

Is now a good time to talk?
Is this a good place to hold the interview, or is there somewhere else that you would like to go?

TO BE COMPLETED BY INTERVIEWER BEFORE CONDUCTING INTERVIEW:

I CERTIFY THAT I HAVE READ THE ABOVE CONSENT PROCEDURE TO THE PARTICIPANT.

SIGNED:____

DATE OF INTERVIEW: day ________ month ________ , 2013

ENUMERATOR NAME: ____

Mahojiano #:	**Tarehe:**
Mji:	**Wilaya:**
Jina:	
Jinsia:	**Umri:**

Sehemu 1: Maelezo ya Anayehojiwa

UTANGULIZI: Tutajitambulisha sisi ni kina nani na tuko hapa kwa sababu gani, tafadhali tutakuuliza maswali yanayokuhusu wewe na familia yako. Maelezo tutakayopata kutoka kwako yatabaki kuwa ya kwetu na wewe. Maelezo haya yatatumika tu katika uchambuzi wa uchunguzi huu sambamba na nafasi yako na mahusiano yako katika jamii. Habari hii itatuwezesha kuelewa zaidi maswala yahusuyo ukame na hali ya hewa.

1. Wewe ni mjumbe wa serikali?	☐Hapana ☐Ndiyo, katika ngazi ya kijiji ☐Ndiyo, katika ngazi ya kata ☐Ndiyo, katika ngazi ya wilaya ☐Ndiyo, katika ngazi ya mkoa
2. Wewe ni kiongozi wa kimila?	☐Hapana ☐Ndiyo, olaigwanani lengaji (Kiongozi wa kimila wa familia) ☐Ndiyo, olaigwanani lengang' (Kiongozi wa kimila wa boma) ☐Ndiyo, olaigwanani lolaji (Kiongozi wa kimila wa rika) ☐Ndiyo, olaigwanani loloshoo (Kiongozi wa kimila wa jamii ya wamasai) ☐Ndiyo, Vyeo vingine: ____
3. Umesoma shule?	☐Hapana ☐Ndiyo, nimesoma shule ya msingi lakini sikumaliza ☐Ndiyo, Nimemaliza shule ya msingi ☐Ndiyo, Nimesoma shule ya sekondari lakini sikumaliza ☐Ndiyo, Nimemaliza shule ya sekondari ☐Ndiyo, Nimepata elimu ya chuo lakini sikumaliza ☐Ndiyo, Nimemaliza elimu ya chuo ☐Ndiyo, Nimesoma vyuo vya elimu kwa vitendo ☐Ndiyo, Nimesoma elimu ya watu wazima ☐Ndiyo, Nyinginezo: ____
4. Una simu ya mkononi?	☐Ndiyo ☐Hapana
5. Unamiliki pikipiki	☐Ndiyo ☐Hapana
6. Unamiliki gari?	☐Ndiyo ☐Hapana
7. Unamiliki nyumba ya aina gani?	☐Ya udongo iliyoezekwa kwa majani ☐Ya udongo iliyoezekwa kwa bati

	☐Ya matofali iliyoezekwa kwa bati ☐Sementi ☐Nyinginezo: ____

8. Kwa makisio familia yako ina ng'ombe wangapi?	☐ Sina ng'ombe hata mmoja ☐ Hawafiki 10 ☐ Zaidi ya 10 hawafiki 50 ☐ Zaidi ya 50 hawafiki 100 ☐ Zaidi ya 100 hawafiki 500 ☐ Zaidi ya 500 hawafiki 1,000 ☐ Zaidi ya 1,000
9. Je unajua kwa uhakika familia yako ina ng'ombe wangapi?	☐Ndiyo ☐Hapana **KAMA NDIYO,** una ng'ombe wangapi kwa uhakika?: _____
10. Una ngombe wangapi wa aina tofauti zilizo orodheshwa hapo chini?	_____ Zebu (Kienyeji) _____ Borana _____ Sahiwal _____ Chotara (Ahola borana pamoja zebu)
11. Je unajua kwa uhakika kuwa ni ng'ombe wangapi wa familia yako waliopata chanjo?	☐Ndiyo ☐Hapana **KAMA NDIYO**, ng'ombe wangapi kwa uhakika walipata chanjo?: _____
12. Familia yako ina mbuzi wangapi?	☐Sina mbuzi hata mmoja ☐Hawafiki 10 ☐Zaidi ya 10 hawafiki 50 ☐Zaidi ya 50 hawafiki 100 ☐Zaidi ya 100 hawafiki 500 ☐Zaidi ya 500 hawafiki 1,000 ☐Zaidi ya 1,000
13. Familia yako ni wa kulima?	☐Ndiyo ☐Hapana
14. Familia yako ni wakulima kwa muda gani sasa?	☐Chini ya mwaka 1 ☐Zaidi ya mwaka mmoja chini ya miaka 5 ☐Zaidi ya miaka 5 chini ya miaka 10 ☐Zaidi ya miaka 10 ☐Kwa muda mrefu, hakuna mtu anayekumbuka miaka ☐Familia sio wakulima
15. Je ukubwa wa shamba lako umebadilika ndani ya miaka 10?	☐Ndiyo ☐Hapana **KAMA NDIYO,** hekari ngapi zimeongezeka? _____ **KAMA NDIYO,** hekari ngapi zimepungua? _____
16. Je una mashamba mangapi?	_______ hekari

17. Je unalima mashamba mangapi katika maeneo tofauti?	☐Ndiyo ☐Hapana **KAMA NDIYO,** mashamba mangapi katika maeneo tofauti? _____
18. Wewe binafsi unalima mashamba mangapi?	_____

19. Mashamba mangapi yanalimwa na wanawake katika familia yako	_____
20. Mashamba mangapi yanalimwa na wanaokutegemea katika familia	_____
21. Kipato chako kinatokana na nini? **(Chagua hapo chini zinazohusika.)**	☐ Mifugo ☐ Mshahara ☐ Biashara ☐ Biashara ndogo ndogo ☐ Fedha au msaada kutoka kwa mtu wa familia anayefanya kazi nje ya kijiji ☐ Kilimo ☐ Nyinginezo:- ____
22. Una watoto wangapi uliowazaa ambao (hajaoa/hajaolewa)?	_____ hajaoa _____ hajaolewa
23. Una watoto wangapi ambao sio wa kuwazaa (hajaoa/hajaolewa)?	_____ hajaoa _____ hajaolewa
24. Una watu wangapi wanaokutegemea (ukiacha watoto wako)? (Kwa mfano: wazazi wazee na ndugu wa kuzaliwa)	_____
25. Kwa muda gani familia yako na mababu zako wameishi kwenye hili eneo ambalo unaishi kwa sasa?	☐Haifiki Mwaka 1 ☐Zaidi ya mwaka 1 haifiki miaka 5 ☐Zaidi ya miaka 5 haifiki miaka 10 ☐Zaidi ya miaka 10 ☐Kwa muda mrefu hakuna mtu anakumbuka
26. Je unayajua mashirika yoyote yasiyo ya kiserikali (NGOs) au taasisi za kijamii yanayofanya kazi katika kijiji chako, kwa sasa au siku zilizopita?	☐Ndiyo ☐Hapana **KAMA NDIYO,** unajua ni mashirika yapi? ____ **KAMA HUYAJUI HAYO MASHIRIKA,** je unawajua baadhi ya watu wanaojihusisha na mashirika? ____

27. Je wewe au kijiji chako mmekuwa mkijihusisha na mashirika yasiyo ya kiserikali (NGOs) au taasisi za kijamii hapa kijijini? (kwa mfano: semina, mafunzo, mikutano nakadhalika.)	☐ Hapana ☐Ndiyo, kijiji changu kimehudhuria katika shughuli ☐Ndiyo, mimi binafsi nimehudhuria mikutano ☐Ndiyo, mimi binafsi nimeongea katika mikutano ☐Ndiyo, mimi binafsi nimehudhuria katika shughuli

Sehemu 2: Nafasi ya Tabia Nchi kwenye Makazi

UTANGULIZI: Sasa tutakuuliza baadhi ya maswali yanayohusu hali ya hewa na tabia nchi katika eneo lako na mchango wake katika makazi.

28. Unashughulika na shughuli zipi katika makazi yako? **(Chagua hapo chini zinazohusika)**	☐Ufugaji wa mifugo ☐Biashara ya uuzaji na ununuzi wa mifugo ☐Kilimo ☐Biashara ndogo ndogo zisizohusiana na bidhaa za kilimo wala ufugaji ☐Utalii ☐Mshahara na Posho ☐Nyinginezo: ____
29. Shughuli ipi ya msingi kabisa ambayo unashughulika nayo **(Chagua moja hapo chini.)**	☐Ufugaji wa mifugo ☐Biashara ya uuzaji na ununuzi wa mifugo ☐Kilimo ☐Biashara ndogo ndogo zisizohusiana na bidhaa za kilimo wala ufugaji ☐Utalii ☐Mshahara na Posho ☐Nyinginezo: ____
30. Kwa mtazamo wa haraka kwa kiasi gani shughuli hizi za kifamilia/makazi zinategemeana na hali ya hewa moja kwa moja?	☐Shughuli zote za kifamilia ☐Shughuli nyingi za kifamilia ☐Baadhi ya shughuli za kifamilia ☐Hakuna
31. Kama makazi yako yanaathiriwa moja kwa moja na hali ya hewa na tabia nchi, tafadhali elezea ni kwa njia zipi?	____ ___ ____ ___ ____ __
32. Tangu Landiis watahiriwe (takriban miaka 30 iliyopita) ni	____ ___

kwa namna gani hali ya hewa iliyokithiri kama ukame, mafuriko, au joto jingi vimeathiri makazi yenu? (Kwa mfano: Unakumbuka ukame wowote, mafuriko au joto jingi? Je vilikuwa na madhara katika familia yako? hayo madhara yalikuwaje?)	____ ____
33. Ni hali ya hewa ya namna gani inayokuwa na madhara makubwa kwako? **(Chagua moja hapo chini.)**	☐Ni mvua kubwa inaponyesha kwa muda mfupi (mafuriko) ☐Ni ukosefu wa mvua kwa muda mrefu (ukame) ☐Ni mvua inaponyesha kwa muda ambao sio sahihi ☐Ni mvua inaponyesha halafu inakatiza ☐Ni mvua inaponyesha kwenye baadhi ya maeneo na kutonyesha kwenye maeneo mengine ☐Ni kukiwa na joto sana ☐Ni kukiwa na baridi sana ☐Nyinginezo: ____
34. Ni kwa namna gani maswala ya misimu yanachukua umuhimu mkubwa wakati wa kufanya maamuzi yanayohusu makazi yako? **(Chagua hapo chini majibu yote yanayostahili.)**	☐Wakati wa mvua za muda mfupi (olkisirata) zinapoanza na inapoisha. ☐Muda wote wa mvua za muda mfupi (olkisirata) ☐Wakati wa mvua za muda mrefu (engakwai) zinapoanza na zinapoisha ☐Muda wote wa mvua za muda mrefu (engakwai) ☐Panapokuwa au pasipokuwa na vipindi vikavu kipindi cha mvua ☐Muda wote wa kipindi cha ukame wa kawaida (koromare) ☐Muda wote wa kipindi cha kiangazi kikali (alimei) ☐Nyinginezo: ____

Sehemu 3: Uelewa wa Tabia ya Nchi – Wakati uliopita, Wakati uliopo na Wakati ujao

UTANGULIZI: Sasa tutakuuliza baadhi ya maswali kuhusu hali ya hewa na tabia nchi katika eneo lako kwa Wakati uliopita, Wakati uliopo na Wakati ujao.

35. Kwa maoni yako unafikiri misimu ni rahisi, vigumu au ni sawa tu kukisia kwa sasa kama ilivyokuwa hapo zamani (Kwa mfano: Unauhakika	☐Rahisi ☐Vigumu ☐Karibia sawa tu a) Kama ni **RAHISI** zaidi kwa namna gani?: ____ b) Kama ni **VIGUMU** zaidi kwa namna gani?: ____

zaidi au kidogo kuhusu matarajio ya misimu ijayo sasa kama ilivyokuwa hapo zamani?)	
36. Kama imekuwa ☐**NGUMU ZAIDI** ☐**RAHISI ZAIDI** kukisia misimu ijayo, umepangaje mikakati na maamuzi ya familia yako?	____ ____
37. Kama imekuwa ☐**NGUMU ZAIDI** ☐**RAHISI ZAIDI** kukisia misimu ijayo itakuwaje, je umetafuta vyanzo vipya vya kupata habari au ufahamu?	☐Ndiyo ☐Hapana **KAMA NDIYO,** uliza maswali hapo chini: a) Ni habari zipi na ufahamu upi? ____ b) Unapata wapi habari hizi na ufahamu? ____ c) Je unatumia vipi habari hizi mpya na ufahamu? ____
38. Kwa maoni yako unafikiri misimu inabadilika?	☐Ndiyo, imebadilika sana ☐Ndiyo, imebadilika kidogo ☐Hapana, haibadiliki ☐Sina uhakika **KAMA NDIYO,** uliza maswali hapo chini: a) Kwa namna gani? ____ b) Viashiria ni vipi? ____
39. Kwa maoni yako, unafikiri kasi ya ukame imebadilika	☐Ndiyo, kuna ukame zaidi sasa kuliko ilivyokuwa hapo nyuma ☐Ndiyo, ukame umepungua kuliko ilivyokuwa hapo nyuma. ☐Hapana, hakuna mabadiliko katika kasi ya ukame. ☐Sina uhakika, hakuna namna ya kuonyesha kuwepo kwa mabadiliko. **KAMA NDIYO**, viashiria ni vipi?

(Kwa mfano: Vipindi kati ya ukame mmoja na mwingine vimekuwa karibu karibu?)	____
Kwa maoni yako, unafikiri makali ya ukame yanabadilika? (Kwa mfano: Ukame unapokuja, unakuwa wa muda mrefu?)	☐Ndiyo, ukame umekuwa mkali kuliko ulivyokuwa hapo mwanzo ☐Ndiyo, ukame sio mkali kama ilivyokuwa hapo mwanzo ☐Hapana, hapajakuwa na mabadiliko katika makali ya ukame ☐Sina uhakika, hakuna namna ya kuonyesha kuwepo kwa mabadiliko. **KAMA NDIYO**, viashiria ni vipi? ____
41. Kwa maoni yako, unafikiri kuna mabadiliko ya mafuriko ya mara kwa mara?	☐Ndiyo, Kuna mafuriko zaidi kuliko ilivyokuwa hapo nyuma. ☐Ndiyo, kuna mafuriko kidogo kuliko ilivyokuwa hapo nyuma. ☐Hapana, Hakuna mabadiliko kwenye kasi ya mafuriko ☐Sina uhakika, hakuna namna ya kuonyesha kuwepo kwa mabadiliko. **KAMA NDIYO,** viashiria ni vipi? ____
42. Kwa maoni yako, unafikiri makali ya mafuriko yamebadilika?	☐Ndiyo, kuna mafuriko makali kuliko ilivyokuwa hapo nyuma. ☐Ndiyo, mafuriko yamepungua makali, sio kama ilivyokuwa hapo nyuma ☐Hapana, hakuna mabadiliko kwenye makali ya mafuriko. ☐Sina uhakika, hakuna namna ya kuonyesha kuwepo kwa mabadiliko. **KAMA NDIYO,** viashiria ni vipi? ____
43. Kwa maoni yako, unafikiri milipuko ya magonjwa ya mifugo imekuwa ikitokea mara nyingi au mara chache?	☐Ndiyo, kuna milipuko ya magonjwa zaidi ya ilivyokuwa siku za nyuma. ☐Ndiyo, milipuko ya magonjwa imepungua kuliko ilivyokuwa hapo nyuma ☐Hapana, hakuna mabadiliko kwenye milipuko ya magonjwa ya mifugo. ☐Sina uhakika, hakuna namna ya kuonyesha kuwepo kwa mabadiliko. **KAMA NDIYO,** viashiria ni vipi? ____
44. Kwa maoni yako, unafikiri ukali wa milipuko ya magonjwa ya mifugo unabadilika?	☐Ndiyo, milipuko ya magonjwa imekuwa mikali kuliko hapo nyuma ☐Ndiyo, milipuko ya magonjwa imepungua ukali kuliko hapo nyuma ☐Hapana, hakuna mabadiliko katika milipuko ya magonjwa ☐Sina uhakika, hakuna namna ya kuonyesha kuwepo kwa mabadiliko. **KAMA NDIYO,** viashiria ni vipi? ____
45. Kwa maoni yako, unafikiri afya	☐Ndiyo, mifugo ina afya zaidi sasa kuliko ilivyokuwa hapo nyuma ☐Ndiyo, afya ya mifugo imedorora sio kama ilivyokuwa hapo nyuma ☐Hapana, hakuna mabadiliko kwenye afya ya mifugo

ya mifugo imebadilika?	☐Sina uhakika, hakuna namna ya kuonyesha kuwepo kwa mabadiliko
46. Kama afya ya mifugo imebadilika, ni kwa namna gani?	____ ____
Kwa nini unafikiri afya ya mifugo inabadilika? Kama haibadiliki ni kwa nini?	____ ____

Sehemu 4: Fursa na matumizi ya elimu/uelewa wa Tabia Nchi

48. Ni njia zipi zinatumika kutabiri hali ya hewa ya mbeleni au tabia nchi kwa sasa na siku zilizopita? **(Chagua hapo chini zinazohusika.)**	☐Mabadiliko ya mimea ☐Mabadiliko ya tabia za wanyama ☐Mabadiliko ya udongo ☐Nyota na mwezi ☐Wazee waliniambia cha kutarajia Hali ya hewa katika maeneo mengine ni dalili za kipi cha kutarajia hapa tunapoishi ☐Nasikia kuhusu utabiri wa hali ya hewa kutoka kwenye vyanzo vya nje ☐Ni uelewa wa kawaida, najua tu Sina uhakika, hakuna namna ya kuonyesha kuwa hali ya hewa inayokuja itakuwaje ☐Nyinginezo: ____
49. Kwa sasa, ni njia zipi za utabiri wa hali ya hewa na tabia nchi mnazoendelea kuzitumia? **(Chagua njia inayohusika hapo chini.)**	☐Mabadiliko ya mimea ☐Mabadiliko ya tabia za wanyama ☐Mabadiliko ya udongo ☐Nyota na mwezi ☐Wazee waliniambia cha kutarajia Hali ya hewa katika maeneo mengine ni dalili za kipi cha kutarajia hapa tunapoishi ☐Nasikia kuhusu utabiri wa hali ya hewa kutoka kwenye vyanzo vya nje ☐Ni uelewa wa kawaida, najua tu Sina uhakika, hakuna namna ya kuonyesha kuwa hali ya hewa inayokuja itakuwaje

	☐Nyinginezo: ____
50. Kama umewahi kusikia kuhusu utabiri wa hali ya hewa kutoka vyanzo vya nje sasa au siku za nyuma, hiyo habari imetoka wapi?	☐Magazeti ☐Redio ☐Maafisa ugani ☐Taasisi za serikali **TAFADHALI ORODHESHA**:________________________________ ☐Mashirika yasiyo ya kiserikali (NGOs) na taasisi za kijamii **TAFADHALI ORODHESHA**:________________________________ ☐Nyinginezo: ____
51. Kama umewahi kusikia kuhusu utabiri wa hali ya hewa kutoka vyanzo vya nje sasa au siku za nyuma, ni mara ngapi?	☐Mara moja tu ☐Mara moja kwa mwaka ☐Mara moja kwa mwezi ☐Mara moja kwa wiki ☐Kila siku ☐Sijawahi

52. Katika njia mnazotumia kutabiri hali ya hewa, zipi ndizo za muhimu zaidi? Tafadhali onyesha njia tano za juu kwa kuzingatia umuhimu. **ONYESHA KADI YA MAJIBU SASA HIVI.** **CHAGUA MAJIBU MATANO TU na weka 1, 2, 3, 4, na 5 mbele ya kila.** **1 = muhimu zaidi** **: siyo muhimu kuliko majibu mengine**	_______ Kwa kuangalia mazingira ya asili (kwa kila msimu) _______ Wazee na wana jamii _______ Uzoefu wa mtu (wa muda fulani) _______ Habari kuhusu hali ya hewa na tabia nchi ya maeneo mengine _ Taarifa ya moja kwa moja kuhusu hali ya hewa na tabia nchi kutoka kwa waliosafiri kwenye maeneo hayo _______ Utabiri wa hali ya hewa kutoka kwenye magazeti na redio _______ Utabiri wa hali ya hewa kutoka kwa maafisa ugani _______ Utabiri wa hali ya hewa kutoka kwa taasisi nyingine za serikali _ Utabiri wa hali ya hewa kutoka kwa mashirika yasiyo ya kiserikali na taasisi za umma _______ Uwelewa wa kawaida, najua tu _______ Sina namna yoyote ya kujua kuhusu hali ya hewa ya mbeleni _______ Nyinginezo: ____
53. Kwa sasa, kwanini umechagua kutumia njia hii/hizi mahususi kujua hali ya hewa ya siku za mbeleni? **(Chagua hapo chini zinazohusika.)**	☐Naamini kutokana na uzoefu wangu ☐Ndo namna watu wengine wanatumia kufanya maamuzi ☐Inanipatia habari mahususi ambayo nahitaji katika kufanya maamuzi ☐Inatokana na uzoefu wangu wa moja kwa moja ☐Nilihudhuria katika kutengezeneza habari ☐Naona kuwa habari ni ya wazi na kila mtu anaweza kupata kiurahisi.
54. Umewahi kuambiwa kuhusu mabadiliko ya tabia nchi na watu wengine, jamii, mashirika yasiyo ya serikali, taasisi za serikali, au vyanzo vingine?	☐Ndiyo ☐Hapana **KAMA NDIYO,** uliza maswali hapo chini: Watu gani, jamii ipi, mashirika gani yasiyo ya kiserikali, taasisi za serikali, au vyanzo vingine? ____
55. Maneno "mabadiliko ya tabia nchi" yana maana gani kwako?	____ ____

	____
56. Je kijiji chako au viongozi wa kijiji chako, wanafanya maamuzi ya kijamii yanayohusu namna ya kukabiliana na hali ya hewa au tabia nchi? (Kwa mfano: maamuzi yanayohusu haki ya maeneo ya malisho yanafanywa kwenye mikutano ya jamii (enkigeuna)?)	☐Ndiyo ☐Hapana ☐Sina uhakika

57. Je unajihusisha na kuandaa mipango na maamuzi ya kisera katika serikali ya mtaa, kujiandaa au kukabiliana na majanga au mabadiliko ya tabia nchi?	☐Ndiyo ☐Hapana **KAMA NDIYO,** kwa njia zipi? ____
58. Kuna njia yoyote ambayo wewe unatumia kuwasiliana na taasisi za serikali, mashirika yasiyo ya kiserikali au taasisi za jamii kuhusiana na jinsi hali ya hewa inavyokuathiri wewe?	☐Ndiyo ☐Hapana ☐Sina uhakika **KAMA NDIYO,** uliza maswali hapo chini: a) Kwa njia zipi? ____ b) Wewe unajiweka mstari wa mbele kuhudhuria na kuwasilisha? ____
59. Kuna njia yoyote ambayo unaweza kuwasilisha ujuzi wa kimila (mfano: Ujuzi wa kimasai) kuhusu tabia nchi kwa taasisi	☐Ndiyo ☐Hapana ☐Sina uhakika **KAMA NDIYO,** uliza maswali hapo chini: a) Kwa njia zipi?

za serikali, mashirika yasiyo ya kiserikali au taasisi za kijamii?	____ b) Wewe unajiweka mstari wa mbele kuhudhuria na kuwasilisha? ____
60. Je unadhani ufahamu wa kimila umejumuishwa katika mipango ya serikali au maamuzi ya kisera ya mabadiliko ya tabia nchi?	☐Ndiyo ☐Hapana ☐Sina uhakika **KAMA NDIYO,** ni ufahamu gani wa kimila na aina gani ya mipango na maamuzi? ____ **KAMA SIYO,** ni kwa nini? ____