The Role of Local Knowledge in Climate Change Research

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Digital Object Identifier: https://doi.org/10.13023/etd.2024.107

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THE ROLE OF LOCAL KNOWLEDGE IN CLIMATE CHANGE RESEARCH

DISSERTATION

A dissertation submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy in the College of Arts and Sciences at the University of Kentucky

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ABSTRACT OF DISSERTATION

THE ROLE OF LOCAL KNOWLEDGE IN CLIMATE CHANGE RESEARCH

This dissertation addresses the growing need within climate research for improvements in regional and local climate information. I argue that knowledge gaps in regional climate information constitute a form of climate injustice in which harm largely falls on regions most vulnerable to climate change. Moreover, I show that our current methods for garnering regional climate information fail to provide information on place-specific factors, such as local culture, socio-economic systems, and ecology, which mediate climate change impacts. In order to address these knowledge gaps, as well as provide information necessary for effective mitigation and adaptation, I argue for the inclusion of local knowledge in climate change research. In addition to this normative argument, I address the ethical and epistemological issues surrounding local knowledge inclusion. This includes concerns relating to exploitation and 'data mining', as well as how to navigate differences in ontological, epistemological, and value commitments between local communities and academic researchers. In addressing these concerns, I argue that we adopt a “partial overlaps” approach in order to facilitate knowledge inclusion and co-production without overlooking important differences between these epistemic communities. Drawing on field work conducted with Michigan farmers and extension personnel, I show how this framework can be applied within the context of climate-agricultural research, as well as facilitate the implementation of climate-smart agricultural practices.

KEYWORDS: philosophy of science, climate change, transdisciplinary research, local knowledge, agricultural science, climate-smart agriculture

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THE ROLE OF LOCAL KNOWLEDGE IN CLIMATE CHANGE RESEARCH

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DEDICATION

To Arlo and Sarah

ACKNOWLEDGMENTS

The following dissertation is the product of many different hands and minds, and would not have been possible without the community and support of my mentors, colleagues, friends, and family. First of all, I would like to thank my dissertation chair, Julia Bursten, for her guidance during the completion of this work, as well as for the opportunity to work together in Michigan as part the National Science Foundation funded project, "The Epistemology of Agricultural Science." This project, and Julia's work in general, has radically changed my view of what is possible within philosophy and the kind of engagement our discipline can have with the world. Moreover, her willingness to support students in and outside of the classroom sets a standard for mentorship that I hope to emulate as I continue in academia. I cannot thank her enough for her friendship, and the role that it has played in my development as a scholar and as a human being.

I would also like to thank each of the members of my committee for their support in bringing this project into fruition. In particular, I am indebted to Lauren Cagle whose influence can be found throughout this work. I am also grateful to Cagle for the opportunity to collaborate with her on a number of projects during my time at the University of Kentucky, including the Kentucky Extension Climate Needs Assessment, Kentucky Climate Oral History Project, and as a research assistant and executive committee member for the Kentucky Climate Consortium. Her leadership and work to grow climate research and collaboration in Kentucky has been inspiring. In addition, I am grateful to Bob Sandmeyer for his mentorship and guidance with this project and throughout my time at Kentucky. Working with Bob as a teaching assistant in his Food Ethics class had a profound impact on my interests in environmental ethics and introduced me to literature that would later become foundational to the research in this dissertation. I would also like to thank Tim Sundell for his insightful comments and conversations throughout the development of this project. His seminars and courses in philosophy of language served as an introduction to literature in conceptual engineering and gave me the opportunity to explore the conceptual development of climate and climate change—ideas which influenced this project and which I plan to develop in future research.

In addition to the members of my committee, I would like to thank the many collaborators who I have had the opportunity to work with during my time at Kentucky. In particular, I would like to thank Catherine Kendig at Michigan State University, who served as a collaborator and host during the Epistemology of Agricultural Science project. I am grateful for her feedback on earlier drafts of this work, as well as her continued mentorship and support. I am also grateful to Kevin Elliot and other members of the Socially Engaged Philosophy of Science group at Michigan State University for their feedback, as well as the farmers and extension personnel in Michigan who took the time to speak with us. I would also like to thank Amanda Gumbert, Lee Moser, and Michael Corio, who I have had the pleasure of working with on the Kentucky Extension Climate Needs Assessment. Moreover, I would like to thank Chad Risko and Rebekah Duke-Crockett for the opportunity to collaborate with them on an article for the *Journal of the American Chemical Society*. Lastly, I am grateful to my colleagues at the USDA Midwest Climate Hub who have graciously allowed a philosopher into their ranks and given me the opportunity to put many of the ideas in this dissertation into practice.

I would also like to acknowledge the mentors and friends over the years who have been integral in my development as a philosopher and human being. At Belmont

University, I would like to thank Andy Davis, Mark Anderson, Mélanie Walton, and Charmion Gustke for their mentorship during my time as an undergraduate and for instilling in me a love of reading and philosophy. I am also thankful to my friends here in Lexington and abroad who have been a source of community in and outside of academia. In particular, I am grateful to M.C. Cunningham, Topher Lutz, Tyler DeMunbrun, Sam Willard, Katherine Nelson, Ouree Lee, Jed Debruin, John Walker, Jason Renner, Josiah Hedges, and David Parks.

Lastly, none of this would be possible without the support, care, and love from my family—my wife Sarah, son Arlo, parents Ken and Beth, my sister Kate, brother-in-law Mohit, and nephew Archie. I am so grateful for their encouragement and the many ways they have helped me throughout and beyond the writing of this dissertation. I am especially grateful to Sarah who, in addition to completing a major project of her own, single-handedly managed a toddler and three unruly pets while I was away doing fieldwork in Michigan—and who, alongside Arlo, has been a daily source of joy and love throughout this process.

TABLE OF CONTENTS

INTRODUCTION

Global climate modeling and international efforts by organizations like the Intergovernmental Panel on Climate Change have made great strides to show that the climate is changing and that this poses an existential threat to those around the globe. While these efforts have driven public and scientific consensus, there remain significant knowledge gaps in how these changes will impact communities on a regional and local scale. These knowledge gaps not only include uncertainties about biophysical processes, but also other mediating factors of climate change impacts like local culture, values, and socio-economic systems. In turn, these knowledge gaps in regional and localized climate information pose a problem for implementing effective adaptation and mitigation strategies.

In the following dissertation I take up this epistemological problem, namely, the need for regional and localized climate information, as well as the social and ethical issues that arise from this need. In particular, I focus on how transdisciplinary approaches that include the local knowledge of Indigenous and local communities can improve our understanding of climate change, as well as improve adaptation and mitigation strategies. Within a narrower philosophical context, local knowledge inclusion encompasses both epistemic issues relating to the possibility of knowledge co-production between differing knowledge frameworks, as well as normative issues for how this research should be carried out. While this makes these areas ripe for philosophical contribution, philosophy of science has played “only a peripheral role” within these debates (Ludwig, et al. 2023). This is likewise the case within the philosophy of climate science, which has in part focused exclusively on modeling approaches to climate change research (e.g. Winsberg

2018; Frigg, et al. 2015a, 2015b). As such, this dissertation aims to both build on the growing literature within the philosophy of transdisciplinarity, as well as broaden areas of research within the philosophy of climate science.

In Chapter 1 I provide an analysis of knowledge gaps in climate research, as well as a methodological argument for how to address them through local knowledge inclusion. In particular, one of the proposals for improving regional and local climate information has been to improve the resolution of regional climate models (RCMs). I argue that while improving the resolution of RCMs is a worthwhile endeavor, there are limitations to the kinds of information these models can provide, as well as limitations for their widespread use. For example, RCMs fail to provide information on factors that mediate the severity of climate impacts. Moreover, they require longstanding historical weather data and are computationally intensive. This has meant that many parts of the globe lack adequate access to quality climate information, particularly the Global South and other communities most vulnerable to climate change. I argue that this constitutes a form of climate injustice, given the unequal distribution of climate information, as well as how this impacts these communities' ability to apply for relief and international aid.

In order to address these knowledge gaps, as well as provide information necessary for effective mitigation and adaptation, I argue for a transdisciplinary approach that includes local knowledge of Indigenous and local communities. Drawing on Collins and Evans (2002), I argue that local knowledge constitutes a form of experience-based expertise that can in certain contexts become contributory expertise. That is to say, this experience-based expertise becomes directly relevant to a given issue or research initiative, and furthermore both can and should play a contributory role within such efforts. In turn, I highlight areas in which local knowledge can play a contributory role within climate research. These areas include: (1) providing finer grained data on climate variability than is capable of current modeling efforts, (2) tracking and addressing impacts on biophysical and socio-economic systems, as well as (3) filling spatial and temporal gaps in instrumental climatic data.

While Chapter 1 highlights knowledge gaps in regional and local climate information, as well as provides a methodological argument for local knowledge inclusion, Chapter 2 addresses the epistemological and ethical issues involved in this transdisciplinary climate research. This includes concerns relating to exploitation and 'data mining', as well as how to navigate differences in ontological, epistemological, and value commitments between local communities and academic researchers. On the one hand, these differences might lead one to adopt a pessimistic attitude by regarding these knowledge frameworks as incommensurable. On the other hand, an overly optimistic view of local knowledge might overlook important differences between these frameworks, leading to assimilatory or exploitative practices. In order to navigate these two extremes, I argue for what Ludwig (2016) and Ludwig and El-Hani (2020) have called a "partial overlaps" framework for transdisciplinary collaboration. Such a framework assumes partial overlaps in commitments between academic researchers and local communities, and importantly recognizes that while there are salient differences among actors, they do not live in entirely separate worlds and some common ground can be had. In turn, these partial overlaps provide starting points for facilitating knowledge inclusion and co-production without overlooking important differences between these epistemic communities.

Having addressed the role local knowledge can play in climate research, as well as the barriers for its inclusion, in Chapter 3 I show how a partial overlaps framework can be applied within the context of climate-agricultural research and the implementation and development of climate-smart practices. For instance, agriculture is both a contributor to climate change as well as highly vulnerable to its effects. Moreover, climate change impacts on agriculture present a broader social risk through disruptions to food systems. These factors in turn underscore the need for climate-smart agricultural practices aimed at climate adaptation and mitigation. While there is a clear need for climate-smart agriculture, there are significant barriers to both implementing these practices, as well as understanding their effectiveness within particular agricultural contexts. Included among these challenges are economic constraints, barriers to communication and outreach given differences in beliefs about climate change, as well as knowledge gaps in regional and local climate information that inform decision-making. Drawing on field work conducted with Michigan farmers and extension personnel, I argue that a partial overlaps framework importantly illustrates how collaboration is possible even in light of deep differences among actors, particularly differences in beliefs about the existence of climate change. Moreover, I argue that facilitating knowledge co-production through this collaboration can help to address knowledge gaps in regional and local climate information that are integral for decision-making.

CHAPTER 1. THE CONTRIBUTORY ROLE OF LOCAL KNOWLEDGE IN CLIMATE RESEARCH

1.1 Introduction

In recent years climate researchers have expressed the need for more accurate, as well as relevant, climate information at the regional scale (IPCC 2023a, Gutowski, et al. 2020). Not only is this information important for our general understanding of the climate and climate change, but it is also an invaluable resource for policymakers and other stakeholders seeking to mitigate and adapt to a changing climate. That is, while rises in sea level and global mean surface temperature might alarm us in their own right, policymakers and stakeholders continue to need information at smaller and smaller scales that will allow them to act effectively in their respective localities.

Within these domains pragmatic concerns and questions abound and yet cannot be quelled or answered by our best global climate models. For example, policymakers not only need to know that their particular region will be affected by climatic changes like drought or increases in precipitation, but also what specific localities will be most vulnerable to these changes. Again, the more information we can provide policymakers and stakeholders at regional and localized scales, the better equipped they are in making decisions about allocating resources to vulnerable areas, as well as adapting to and mitigating climatic changes. Ultimately, underlying these concerns are the safety and well-being of human lives and life more generally.

While there are clear pragmatic and epistemic concerns for improving regional climate information, the sheer costs for performing regional climate model (RCM) simulations have prohibited them from being performed in great number. Moreover, there are still issues surrounding the uncertainties introduced in statistical and dynamical model downscaling, as well as gaps in the instrumental data used to evaluate model performance (Reyes-García 2020: 187). Lastly, there is the additional concern that climate research provide information not typically produced by RCMs: namely, information regarding biophysical and socio-economic impacts.

In order to address some of these concerns above, researchers have advocated for initiatives that engage directly with local communities as a way to better understand climate change at regional and local scales (Reyes-García, et al. 2016; López, et. al. 2017; Kieslinger, et al. 2019). For example, the Local Indicators of Climate Change Impacts (LICCI) project has argued that Indigenous peoples and local communities (IPLCs) possess a long history of interaction with their environment, and are thus capable of detecting local changes in climate variability. As a result, these communities are a well-spring of knowledge for advancing our understanding of climate change, as well as facilitating mitigation and adaptation efforts (Reyes-García 2020: 184).

While local knowledge represents a new avenue for aiding our understanding of climate and climate change, it is also a source of knowledge that has been traditionally excluded from this research. In surveying both the philosophical and scientific literature relating to climate and climate change, there are both implicit and explicit rejections of the view that local observations are a valid source of data for understanding the climate. Many of these rejections call into question the validity of local observation given biases that are present in judgments of climate change attributions (e.g. Swim, et al. 2009; Li, et al. 2011; Zaval and Cornwell 2016). For example, evaluations of global climate change often overemphasize extreme weather events and are often shaped by antecedent beliefs concerning climate change, as well as increases in local temperatures, the actual outdoor temperature at the time of elicitation, and other short-term weather events.

In spite of these objections and its exclusion, in the following chapter I make a case for why local knowledge should be included within climate change research, as well as how such knowledge can fruitfully contribute to climate research and policy. In addition to this normative argument, my aim in this chapter is to broaden discussions within the philosophy of climate science that have thus far largely focused on modeling approaches to climate change research. In doing so, I hope to show that while local knowledge inclusion within climate research has yet to receive much attention within the philosophy of climate science, it is both a topic ripe for philosophical discussion and relevant to existing philosophical literature on Indigenous and local knowledge.

In section 1.2 I discuss this need for higher resolution climate data, as well as the deficiencies and limitations within current methods for garnering regional climate information. Importantly, I argue that while climate change is both a global and regional phenomenon, its impacts are local and place-specific. Because of this, they are mediated by cultural values, socio-economic systems, geography, and a litany of other local factors not typically addressed in regional climate modeling. This makes clear the need for new research approaches not typically employed by traditional methods, both from the perspective of climate researchers as well as policymakers and stakeholders. I then introduce local knowledge as an alternative and discuss some of the reasons why it has received little attention within climate research.

In section 1.3 I turn to the question of what local knowledge is and argue, following Collins and Evans (2002), that it constitutes a form of experience-based expertise that can in certain contexts become contributory expertise. That is to say, this experience-based expertise becomes directly relevant to a given issue or research initiative, and furthermore both can and should play a contributory role within such efforts. In order to illustrate this contributory role of local knowledge, I draw on Collin and Evans (2002) reading of Wynne's (1989) case study of sheep farmers in the Cumbrian Fells. This case study not only makes clear the contributory role that local knowledge both can and should play in scientific research, but also provides an analogue for local knowledge inclusion in climate research.

Finally, in section 1.4 I discuss some of the specific areas and examples in which local knowledge can play a contributory role within climate research. These areas include: (1) providing finer grained data on climate variability than is capable of current modeling efforts, (2) tracking and addressing impacts on biophysical and socio-economic systems, as well as (3) filling spatial and temporal gaps in instrumental climatic data. Not only do these areas improve our understanding of the climate at local and regional scales, but they also address the place-specific needs of policymakers and stakeholders in responding to climate change.

1.2 The Need for Higher Resolution Climate Data

Over the last few decades there has been a continual push for higher resolution climate data and projections which has led to the development and improvement of regional climate models (RCMs) and high-resolution global climate models (GCMs) (Gutowski, et al. 2020, IPCC 2013). From the perspective of climate researchers, this information allows us to better understand climate processes at smaller and smaller scales. For example, high resolution modeling carried out by RCMs allows us to hone in on key features of a climate system like orographic processes and atmospheric rivers, as well as simulations of heat extremes, drought, and extreme weather events typically unavailable at the resolution of coarse GCMs (Gutowski, et al. 2020, 666).

Beyond improving our general understanding of the climate for researchers, from the perspective of policymakers and stakeholders this information is invaluable for adaptation and mitigation in response to climate change. While rises in sea levels and global mean surface temperature projected by GCMs might alarm us in their own right, this information does little to answer those questions faced at the local and regional level. For example, policymakers and stakeholders not only need to know that a given region will be susceptible to climate impacts like drought or increased precipitation, but also what specific localities are most vulnerable to these impacts. Furthermore, for policymakers and stakeholders, this information is not limited to biophysical processes but also includes socio-economic impacts. For example, key issues for policymakers and stakeholders include concerns like food security, infrastructure, and the effect that climate change might have on agricultural production in a given region. Ultimately, the need to address these vulnerabilities is grounded in preserving important social functions and human lives.

In the following section, I discuss two of the most common methods for garnering regional climate information, as well as their deficiencies: statistical and dynamical downscaling. Following this, I turn to a preliminary discussion of how local knowledge might address these deficiencies, as well as why local knowledge has traditionally been excluded from climate research.

1.2.1 Issues for Regional Climate Modeling

While RCMs, and more recent high-resolution GCMs, like those participating in the High Resolution Model Intercomparison Project (HighResMIP), can help provide policymakers and stakeholders with information that can inform decisions at the regional and local level, there remains certain issues with the functioning of these models themselves, as well as limitations to the kind of information they can provide (e.g. Roberts, et al. 2018).

One of the largest issues for producing regional climate information concerns the method of downscaling. In general, downscaling is a procedure that uses large-scale climate models in order to make predictions at finer temporal and spatial scales. Downscaling has been characterized as a ‘top-down’ approach to producing regional climate information, and is ‘top-down’ in the sense that it takes global models as the starting point of inquiry into local and regional impacts (e.g. Dessai and Hulme 2004, Conway, et al. 2019). As Conway, et al. (2019: 503) have argued, understanding the impacts of climate change “to date has primarily been addressed through top-down modelling approaches.”

While there are a litany of different methods, the two most common forms of downscaling are statistical and dynamical downscaling. For statistical downscaling (also referred to as Empirical Statistical Downscaling or ESD), regional climate information is garnered by drawing inferences about a future climate from the statistical relationship between observed climate data taken from local weather stations and the large-scale predictors of a given climate model, typically a GCM. Some of the benefits of performing statistical downscaling is that it is not computationally intensive and can be performed without the computational resources required for high-resolution modeling while still allowing finer spatial resolution and variables not typically rendered by GCMs.

However, the quality of the information produced by statistical downscaling is largely dependent on the quality of weather data for a particular region. In other words, the longer duration and quality of historically observed weather data translates into higher quality regional information. This, of course, poses an issue for regions most vulnerable to climate change like the Amazon, Central Africa, Southern and Southeast Asia, as well as the Arctic where weather data is both spatially and temporally sparse. Furthermore, the process of statistical downscaling introduces anomalies that, as Lanzante, et al. (2018) have argued, can produce erroneous results in projecting future climates, particularly in the case of coastal and mountainous regions. While these examples in no way invalidate statistical downscaling, they do point to certain limitations in their applications for studying regional and local climates.

Another method for garnering regional climate information is through dynamical downscaling. Dynamical downscaling simulates local climates by utilizing the boundary conditions and physical principles of lower resolution GCMs but at a finer-grid scale, typically 50 km or smaller. Again, the benefit of using dynamical downscaling to produce RCMs is that it allows us to simulate and study important features of a given climate like extreme weather events, drought, precipitation, and orographic processes that influence these features. However, given that RCMs are typically nested within GCMs, they are still susceptible to any biases or errors present within their global counterparts. For example, as Giorgi, et al. (2019: 5712) notes, uncertainties in RCMs are introduced through differences in forcing scenarios, global models, as well as the internal variability present in the RCMs themselves. Again, while these uncertainties in no way invalidate RCMs, they require that we take the regional information gleaned from these models in measure.

Moreover, in contrast to statistical downscaling, dynamical downscaling is computationally intensive. Because of the sheer computational resources needed to carry out such simulations, the number of RCMs produced through dynamical downscaling is limited even for countries in the Global North. This problem is even more pronounced in the Global South where there is limited RCM data and where communities lack the adequate computing power to carry out these simulations (Giorgi, et al. 2019: 5708).

This lack of RCM data paired with the lack of observed weather data required for statistical downscaling has meant that in certain contexts we possess little regional climate information for many parts of the world. For example, in looking at the IPCC's most recent report for policymakers, the synthesis of observed change in heavy precipitation shows limited data in many of the regions mentioned above, preventing any judgments on this impact's likelihood in those regions (IPCC 2023c: 10). Moreover, a similar statement is echoed in the full assessment report where the authors write, "Limited observational records of extreme events and spatial data gaps currently limit the assessment of some observed regional climate change" (IPCC 2023b: 47). From the perspective of policymakers and stakeholders in these regions, this lack of observed data presents an obstacle to adaptation and mitigation efforts, as well as to applying for international aid. As Jebeile and Crucifix (2021) have argued, these gaps constitute a form of 'epistemic inequality' and climate injustice on the part of climate modeling and research. This is because those countries with fewer data are disadvantaged in trying to prove adverse climate conditions given that they lack longstanding weather data.

Furthermore, questions have been raised as to whether or not top-down modeling approaches like dynamical and statistical downscaling provide useful information for countries in the Global South that are particularly vulnerable to climate change. For example, Dessai and Hulme (2004) argue that there is often an asymmetry in the benefits of top-down approaches between developed and developing nations. Given their access to resources and established infrastructure, developed nations tend to be more resilient to climate change impacts. Hence, longer-term projections (e.g. projections over a 30 year period) tend to be of more benefit in planning and adaptation efforts. In contrast, in developing areas facing more immediate climate vulnerabilities "it makes more sense to look at the processes that create this vulnerability rather than make predictions of the (long-term) future" (Dessai and Hulme 2004: 113).

In addition to the lack of regional information for many parts of the world, as well as questions about the usefulness of top-down modeling approaches in developing countries, there are further limitations to the kinds of information that can be gleaned from regional models, much of which is relevant to policymakers and stakeholders. For example, in the IPCC's fifth assessment report, the authors note that while understanding climate change impacts on biophysical and socio-economic systems is of the utmost importance for policymakers and stakeholders, adequate information regarding these impacts is largely scarce (IPCC 2013). One of the key challenges to better understanding these impacts is the lack of *observed data* on biophysical and socio-economic systems (e.g. Kilroy 2015; Reyes-García, et al. 2020). In other words, better understanding these impacts require ‘on the ground’ information rather than just model projections.

Lastly, climate change impacts, though both global and regional in scale, are also place-specific. The significance of this claim is that these impacts are mediated by things like local culture and values, geography, ecology, and socio-economic systems—much of which are typically absent from climate models and things for which we lack observed data. For instance, rising sea-levels stand to affect millions of people. Not only are these impacts dependent on certain biophysical conditions such as tidal magnitude and island size, they are also mediated by place-specific factors like available resources to cope with sea-level rise or dependence on fisheries (Reyes-García 2023: 2).

Moreover, it is important to note that while information pertaining to these mediating factors are typically absent, this is not to say that models themselves do not bear the mark of values and culture. For example, much has been written on the influence of non-epistemic values in both climate modeling and IPCC assessments (e.g. Winsberg 2012, Frisch 2013, Intemann 2015, Parker and Winsberg 2018, Jebeile 2020, and Jebeile and Crucifix 2021). My point here is rather that these methods themselves fail to provide insight into *local* culture and values that mediate these impacts. When enacting policies for mitigation and adaptation, as well as understanding the severity of climate change impacts, these factors inevitably play a role in crafting effective policy and action. For example, Conway, et al. (2019: 508) writes,

> The embeddedness and interplay between climate and society (and hence difficulty with attributing causality) underscores the critical need to situate climate adaptation within the context of broader socio-economic,

environmental and political processes; something that top-down approaches often fail to consider.

Again, while this far from undermines the significant role that regional modeling plays in understanding the climate, it shows areas of complexity that are underserved by these traditional methods.

1.2.2 Local Knowledge: An Alternative?

In the previous section I surveyed some of the typical methods for garnering regional climate information, as well as pointed to areas of improvement in the need to better understand the climate and climate change. Uncertainties introduced in downscaling methods, as well as the lack of observed weather data for many regions of the world, have limited the usefulness of this information within certain contexts. Moreover, I addressed the limitations that these traditional, top-down methods face in providing policymakers and stakeholders with information related to information on socio-economic and biophysical impacts, as well as other place-specific factors of climate change impacts. Again, these limitations underscore the need for different data sources and approaches not employed by the usual methods for understanding the climate and climate change at the sub-regional level.

My aim within the present section is discuss some of the alternatives to these traditional methods, sometimes referred to as ‘bottom-up’ approaches. In particular, I focus on a recent proposal from researchers at the Local Indicators of Climate Change Impacts (LICCI) research project, which advocates for engaging with local knowledge as an alternative source for regional and local climate information. In doing so, I address some of the issues surrounding the inclusion of local knowledge: namely, its history of being excluded from scientific research, ethical considerations for inclusion, and more general questions about the reliability of local observations.

In contrast to top-down approaches, which take GCMs as the starting point for inquiry, bottom-up approaches typically begin at a local scale in order to assess physical, ecological, and social processes (Dessai and Hulme 2004). They are often characterized as 'people centered' given that they "attempt to derive and generate knowledge based on peoples' understandings of present and changing conditions, risks, and responses" (Conway, et al. 2019: 504). Unlike top-down approaches, bottom-up assessments tend to provide researchers with more data on biophysical and socio-economic impacts, as well as other place-specific factors in climate impacts. Furthermore, as Dessai and Hulme (2004: 113) have argued, because these studies often begin with present impacts and conditions, bottom-up approaches often provide more useful information for developing areas that face more immediate climate vulnerabilities.

Again, bottom-up approaches provide an alternative to the typical methods for understanding climate at a regional scale, and seem promising for addressing some of the complexities of climate change that are underserved by top-down modeling approaches. Among recent calls advocating for bottom-up approaches, researchers have emphasized the need for transdisciplinary initiatives that engage directly with the knowledge of local communities and their observations of climate change impacts (Reyes-García, et al. 2016; López, et. al. 2017; Kieslinger, et al. 2019). As an example, I would now like to focus on one particular proposal from members working on the LICCI research project.

The LICCI is a citizen science initiative formed in 2018 and funded by the European Research Council. The project is comprised of researchers working within the physical and social sciences, as well as a broader network that includes input from the general public. Fundamentally, the project advocates for the inclusion of local knowledge within climate science and policy-making processes, particularly of Indigenous peoples and local communities (IPLCs) (Reyes-García 2020: 184). Researchers at the LICCI have proposed that communities who possess a long history of interaction with their local environments are capable of detecting local changes in climate variability, as well as direct impacts on the environment on which they depend. In short, these researchers have argued that local communities, through long-term observation of their local environments, can help to advance our understanding of how climate change impacts local socio-economic systems, ecology, as well as livelihoods and culture, and furthermore address these issues with garnering adequate regional information noted in the previous section.

While there has been a growing number of advocates for local knowledge inclusion (e.g. Reyes-Garcia, et al. 2016; López, et. al. 2017; Kieslinger, et al. 2019), local knowledge has historically been excluded from traditional climate data sets. As Ford, et al. (2016) have noted, while the IPCC increased their engagement with Indigenous and local knowledge systems from their fourth assessment (AR4) to their fifth assessment (AR5), this engagement remained limited in length and general in its scope. For example, local knowledge engagement in these IPCC assessments was mostly restricted to Working Groups II and III, which pertain to climate adaptation and mitigation respectively, and was largely absent from the Working Group I assessment that focuses on the physical basis of climate change. While the most recent assessment (AR6) has seen a further increase in engagement with Indigenous and local knowledge systems, the situation remains much the same. For example, while noting the significance of local knowledge for understanding the physical basis of climate change, the authors admit the following:

> Indigenous and local knowledge includes information about past and present climate states. However, assessing this knowledge, and integrating it with the scientific literature, remains a challenge to be met. This lack of assessment capability and integration leads to most WGI [Working Group I: The Physical Science Basis] chapters still not including Indigenous and local knowledge in their assessment findings. (IPCC 2023a: 243)

This statement from the IPCC authors points to one of the issues regarding the inclusion of local knowledge and perhaps helps to explain its absence within climate research: namely, how to integrate knowledge from epistemic communities that are seen as holding vastly different epistemological, ontological, and value commitments.

The issue of integration between differing epistemic communities is not new nor is it restricted to the inclusion of local knowledge within climate science. As Persson, et al. (2018) have argued, the issue of integration between various epistemic communities is one that ranges across transdisciplinary research and evidence-based public policy in general. For example, Jerneck and Olsson’s (2013) case study of a Saharan community in Kenya highlights the slow adoption of agroforestry initiatives seeking to integrate trees and shrubs within subsistence farming practices. In this case adoption was largely constrained by ontological and value differences between agroforestry agencies and local farmers. For example, while academics working in agroforestry were concerned with long-term and intangible benefits like biodiversity and carbon sequestration, members of the community dependent on subsistence agriculture looked to more immediate needs.

Historically these differences in commitments between local knowledge and academic frameworks have led Western scientists to regard local knowledge as ‘too subjective’ or ‘unscientific’ (Ludwig 2017: 4710). As a result, many have viewed local knowledge as largely incommensurable with Western scientific knowledge (Dickison 2009: 171).

One poignant example of how local knowledge has been disregarded as ‘unscientific’ can be found in Nadasdy’s (2003, cited in Ludwig 2017) study of the Ruby Range Sheep Steering Committee (RRSSC). The RRSSC was a Canadian committee established in 1995 after people of the Kluane First Nation voiced concerns over declining populations of Dall Sheep in the Southwest Yukon. The committee itself was composed of members from the Kluane First Nation, as well as scientists and other stakeholders, and was tasked with developing strategies for Dall Sheep management. While all parties agreed that the population of Dall Sheep had declined, they differed in their accounts of the causes and severity of the decline, in addition to proposals for management practices. For example, First Nations hunters saw the decline as both long-term and catastrophic, and advocated for a temporary ban on hunting in the region. In contrast, wildlife biologists viewed the decline as merely a temporary drop, and furthermore considered the ban too drastic of a proposal. In debates between members of the committee, the knowledge of the Kluane First Nation peoples was often disregarded, especially when it was at odds with the wildlife biologists on the committee. For example, one biologist remarked that the knowledge of the Kluane was "'too fluid and dependent upon individuals' to be integrated with science" (Nasady 2003: 195). This example highlights both how local knowledge has been viewed as incommensurable with Western science and furthermore how the norms of scientific knowledge production often dictate what counts as knowledge.

Likewise, in addition to questions about the commensurability between academic and local knowledge frameworks, there are significant ethical concerns for local knowledge inclusion. Chief among these concerns is that research that includes local knowledge has the potential to be extractive in nature. For example, as Kimmerer (2012) argues, there is a worry here that local knowledge frameworks might be viewed as just another data source to be exploited by researchers. In turn, this knowledge is integrated into research only insofar as it is "useful" and accords with the ontological, epistemological, and value commitments of scientific practitioners. This form of "integration" has been likened by El-Hani, et al. (2022) to a form of assimilation, given that it decontextualizes local knowledge from its cultural, spiritual, and place-based context. In short, local knowledge inclusion requires that we walk a fine line between complete division, on the one hand, and assimilatory practices, on the other.

While the issue of integration helps to explain in part the absence of local knowledge from traditional climate data sets, there are concerns about the credibility of local observations more generally. For example, climate is most usually defined as an average of variables typically over a 30 year period, and in this sense is typically thought of as a *mathematical distribution*. The significance of this claim is that if the climate is fundamentally a mathematical distribution, it is simply not a phenomenon that can be witnessed by the naked eye or from local observation. For example, in the case of attributing certain extreme weather events to climate change, local observers seem able to only detect short-term weather events, e.g. droughts, tornadoes, hurricanes, etc., and not long-term trends of global climate, i.e. climatic changes over 30 year periods or longer. This concern largely echoes that of integration: namely, there are concerns here that local knowledge is incommensurate with this mathematical understanding of climate.

Moreover, there are additional concerns regarding the fallibility of local observations. For example, work in experimental psychology has indicated that local observations of climate change have tended to be biased (Swim, et al. 2009; Li, et al. 2011; Zaval and Cornwell 2016). For example, evaluations of global climate change often overemphasize extreme weather events and are often shaped by antecedent beliefs concerning climate change. In addition, these evaluations can be shaped by increases in local temperatures, the actual outdoor temperature at the time of elicitation, as well as other short-term weather events. What this seems to indicate is that, again, local perceptions tend to only detect these short-term weather events and not long-term trends of global climate. Given the unreliability of local perceptions to determine long-term climate trends, these scholars argue that climate change is ultimately undetectable from the standpoint of local observation.

While these are legitimate concerns and furthermore help to explain why local knowledge has often been excluded from climate research, Rudiak-Gould (2013) has also added that that these concerns are in many ways not so much scientific as they are political. Ultimately, what they point to is a tension playing out between scientific knowledge and what is typically referred to as lay knowledge (2013: 120). For example, stemming from these concerns is the idea that giving credence to local observations by non-scientists would have the effect of creating "a problematic new zeitgeist in which global warming can be both confirmed and refuted in one's backyard" (2013: 127).

In the following sections I address some of these concerns for local knowledge inclusion, as well as how local knowledge can play a contributory role within this research. In doing so, I first clarify what local knowledge is. Following Collins and Evans (2002), I argue that local knowledge constitutes a form of expertise in its own right. In order to further illustrate this point, I outline Wynne's (1989) case study on sheep farmers in the Cumbrian Fells, which makes clear the contributory role that local knowledge can play in scientific research. Lastly, I address the direct implications that this has for local knowledge inclusion in climate research.

1.3 What is Local Knowledge?

Local knowledge is broadly defined as knowledge that develops out of regional and local culture, ecology, and socio-economic contexts, and consists of both factual knowledge and skills (e.g. Antweiler 1998, Thrupp 1989). As Ludwig notes, "local knowledge is typically used as an umbrella term to engage with vastly different epistemic practices that are not institutionalized as science" (2017: 4706). For example, the term has been used to characterize the knowledge of a diverse range of epistemic communities from local communities in Southern Appalachia (Rice, et al. 2015), urbanites in Sunyani, Ghana (Adusu, et al. 2023), traditional fishing communities in Brazil (El-Hani, et al. 2022), and Indigenous communities broadly (Ludwig 2017).

Within the context of policy, definitions of local knowledge remain equally broad. For example, the United Nations Food and Agriculture Organization defines local knowledge as knowledge endemic to a given community which is furthermore "based on experience, adapted to local culture and environment," and is "embedded in community practices, institutions, relationships and rituals" (FAO 2004). The authors add,

> Local knowledge is a collection of facts and relates to the entire system of concepts, beliefs and perceptions that people hold about the world around them. This includes the way people observe and measure their surroundings, how they solve problems and validate new information. It includes the processes whereby knowledge is generated, stored, applied and transmitted to others. (Ibid.)

As the authors explain, the definition given here is meant to include not only traditional knowledge of rural peoples and Indigenous knowledge, but stipulates that "all communities possess local knowledge—rural and urban, settled and nomadic, original inhabitants and migrants" (Ibid.). Likewise, the IPCC has defined local knowledge as "the understandings and skills developed by individuals and populations, specific to the place where they live" (IPCC n.d.).

What these definitions share in common is that local knowledge is broadly held by a diverse range of communities, and furthermore encompasses a variety of differing epistemic practices, ontological commitments, and values specific to the place where a given community lives. While these definitions are perhaps intentionally broad in order to capture the wide variety of cases in which local knowledge is exhibited, they leave something to be desired by way of precision. As Ludwig (2017: 4706) has noted, the term 'local knowledge' is, in this sense, "hopelessly ambiguous."

This presents a problem when we consider one of the worries mentioned in section 1.2: namely, that giving credence to local observations from non-scientists would allow climate change to become an issue of individual perception and whim. While this worry over a kind of climate change relativism might be overstated, it points to a more general issue about what constitutes local knowledge as well as the scope of its inclusion within matters related to climate change. For example, local knowledge would fail to be a meaningful category if it were to mean that all local observations constitute local knowledge. In short, in order for local knowledge to be a meaningful term here, we need some way to distinguish from mere observations of the local environment.

Given this ambiguity, I would like to suggest that we consider local knowledge within the framework of Collins and Evans' (2002) study of expertise and experience: namely, that local knowledge constitutes a form of "experience-based expertise," or expertise not conferred or recognized formally by things like "degrees or certificates" (ibid. 238). I argue that doing so extends the scope of expertise beyond academic and scientific communities, and has the benefit of being inclusive of local knowledge across a diverse range of communities like those mentioned at the beginning of this section. Furthermore, framing the discussion of local knowledge in terms of expertise resolves this ambiguity of what constitutes local knowledge and distinguishes it from local observations in general.

1.3.1 Local Knowledge as Experience-Based Expertise

In their paper addressing what they call the "Third Wave" of science and technology studies, Collins and Evans (2002) firstly recognize the growing need to extend the scope of technical decision-making beyond the scientific community or those formally certified as experts. That is to say, issues like energy production, industrial development, and climate change have direct relevance to the general public, and as such, communities should be involved in decision-making regarding these issues. However, there remains the question of how far this involvement should extend for both the public and scientific and academic communities. In light of this issue, they suggest focusing on expertise and experience.

For Collins and Evans, inclusion within decision-making is done on the basis of expertise. Candidates for inclusion who fall outside the academic and scientific community possess what they call *experience-based expertise*. Again, experience-based expertise is defined as expertise not conferred or recognized formally by "degrees or certificates" (Ibid.: 238). While not formally recognized as such, those who fall within this category are themselves experts on a par with their scientific and academic counterparts. However, like the ambiguity of local knowledge, there is an issue of scope here regarding what constitutes such expertise. For example, they write,

> Experience, however, cannot be the defining criterion of expertise. It may be necessary to have experience in order to have experience-based expertise, but it is not sufficient. One might, for example, have huge experience of lying in bed in the morning, but this does not make one an expert at it (except in an amusing ironic sense). Why not? Because it is

> taken for granted that anyone could master it immediately without practice, so nothing in the way of 'skill' has been gained through the experience. (Ibid.: 251-2)

In short, what distinguishes experience-based expertise from mere experience, or in other terms, local knowledge from local observation, is the skill and expert knowledge acquired through such experience.[1]

Moreover, as Collins and Evans address, there are cases in which expertise, both experience-based and formally recognized expertise, becomes *contributory expertise*. That is to say, a given expert can "contribute to the science of the field being analyzed" (Collins and Evans 2002: 254). To illustrate how experience-based expertise specifically functions in this contributory role, Collins and Evans use an example from Wynne's (1989) case study of sheep farmers in the Cumbrian Fells, which I briefly outline below.

1.3.2 Contributory Expertise: Cumbrian Sheep Farmers

As part of their efforts to reduce contamination following the 1986 Chernobyl disaster, government officials in Britain, at the advice of scientists, enacted what eventually became an indefinite ban on sheep sales and movement within the Cumbrian Fells. In addition to the devastating economic effects on the livelihoods of sheep farmers, the incident highlighted tensions between the expertise of scientists and the expertise of sheep farmers in the region.

[1] El-Hani, et al.'s (2022) ethnographic study of Brazilian fishing communities in Bahia provides a good example of how one might practically determine expertise. For example, in their study expertise was determined on the basis age (being 30 years or older) and high fishing frequency (greater than or equal to 4 times per week), echoing the conditions here of both experience and skill.

In this case, sheep farmers in the Cumbrian Fells knew quite a lot about the local ecology, including the behavior of both sheep and rainwater. As Wynne (1989) argues, this knowledge was certainly relevant to discussions being had concerning how to conduct research and minimize contamination from the radioactive fallout. However, scientists involved were skeptical of the sheep farmers' knowledge and expertise, and disregarded their input towards these efforts.

For example, scientists conducted experiments using bentonite to absorb radioactive cesium in soil and vegetation (Wynne 1989: 287). As part of the experiment, scientists spread different concentrations of bentonite across several plots and compared these at intervals with control plots. However, this required fencing sheep that had been accustomed to roaming the fells freely. Farmers protested that these conditions would adversely affect the health of the sheep and ruin the experiment. While their criticisms were ignored, scientists eventually abandoned the experiment for these very reasons.

While just one of the several examples from the case study, it highlights ignorance on the part of researchers that could have very well been informed by the expertise of the local farmers. For example, scientists were ignorant of basic facts about sheep diets, the significance of sheep movement for sustainable grazing, the types of soil found in upland areas, as well as the effects of the ban on sheep health brought on by overpopulation. As a result, this ignorance and unwillingness to include the knowledge of sheep farmers stalled both research and interventions taken to address the emergency. In short, what was needed for effective research and interventions was not just scientific expertise on the radioecology of cesium, but also the expertise of local farmers. It is in this sense, given its relevance to addressing the problems at hand, that the local knowledge, or experience-based expertise, of the farmers was contributory.

For Collins and Evans, what this case study highlights is the broader normative point that there are instances where experts within local communities should be included in research and decision-making. That is to say, there are cases where the knowledge of members within a local community has direct relevance to a given issue, and it is in this sense that such knowledge constitutes a form of contributory expertise. Again, the contributory expertise of the farmers would have improved both research and interventions, and helped to mitigate the socio-economic and cultural harms caused by the British government's policy to ban the sale and movement of sheep in the region. Moreover, while what the farmers could have contributed in this instance is largely factual knowledge related to sheep and the fells, I think it is also important to note that local knowledge is not reserved to mere facts. For example, as El-Hani, et al. (2022) have shown in their study of Brazilian fishing communities in Bahia, local knowledge can rise to the level of genuine explanation and understanding of complex ecological processes. This particularly relevant considering when considering local knowledge's role in climate change research, given its potential to not only provide necessary factual information but also understanding of complex natural processes.

1.3.3 Implications for Local Knowledge and Climate Change Research

One of the benefits of framing local knowledge in terms of expertise is that it recognizes that certain members of local communities are experts in their own right. This in turn extends the scope of expertise beyond just members of academic or scientific communities. This is particularly important when we consider the history of local knowledge and its marginalization by Western scientists. Recognizing that local knowledge constitutes a form of expertise disrupts the traditional distinction between academic and local knowledge frameworks, in which the latter has historically been viewed as subordinate or inferior to the former. Moreover, as Wynne's (1989) case study highlights, there are instances in which local knowledge can function in a contributory role, and as such should be included within scientific research.

Both this framing and broader normative claim are applicable to local knowledge inclusion in climate change research. For example, climate change is an issue that has relevance beyond just scientific and academic communities. Again, climate change impacts are mediated by a number of factors such as cultural values, socio-economic systems, geography, etc., and like the case study of the Cumbrian sheep farmers, climate change stands to disrupt the livelihoods of those impacted in a variety of different ways. Given the risks posed for various communities, I think that following Collins and Evans (2002), there is an analogous case to be made that climate research and policy should include those within local communities who possess this contributory expertise. Moreover, the Cumbrian Fells case study shows how beneficial cooperation between scientists and local experts can beneficial to both epistemic communities: namely, by facilitating research on the part of scientists and mitigating both ecological and economic harms of a given community. Likewise, better understanding these localized factors of climate change can help improve research, as well as mitigation and adaptation strategies that directly affect local communities.

In tandem within this broader normative point for inclusion, I think it is also necessary to clarify what it means for local knowledge to play a contributory role in climate research. One worry here is that contributory expertise might entail a one-sided and extractive relationship between local and scientific communities. For instance, interest in the knowledge of local communities might extend only insofar as it is useful to the researchers and accords with research practices. In this sense, "contributory" would mean knowledge that already accords with the epistemic, ontological, and value commitments of scientific researchers.

While Collins and Evans (2002) often define "contributory" in terms of contribution to a science, which perhaps implies the worry above, the case study of the Cumbrian Fells highlights that we need not think of "contributory" in this way.[2] For example, there were clear value differences between the farmers and scientists, particularly concerning the economic and social impacts of the sales and movement ban on sheep. Likewise, the ontological differences concerning the ecology of the fells, particularly as it relates to sheep diet and movement, are another area in which farmers differed from scientists. Moreover, the scientists and farmers clearly differed in their epistemic practices. For example, as Wynne notes, the expertise of sheep farmers was not something codified or written, but "passed down orally and by apprenticeship from one generation to the next, as a craft tradition, reinforced in the culture of the area" (1989: 295).

Importantly, these differences in commitments in large part shape why the knowledge of the local farmers was particularly relevant to the issue of mitigating

[2] Elsewhere, Collins, et. al. (2016: 105) define contributory expertise as expertise that is relevant to a given domain or issue, rather than in terms of contributing to a given science. I think this definition is more suitable for both being inclusive of differences in commitments between epistemic communities, as well as broadening the range in which expertise can be said to be contributory to include not only research but policy and decision-making more broadly.

radioactive contamination. For example, differences in epistemic practices allotted farmers an intimate understanding of the fells and sheep. Moreover, farmer values highlight what was at stake in various outcomes. In short, these differences supplemented knowledge gaps on the part of scientists involved. Inclusion within these efforts would have not only benefitted the research of the scientists, but also the sheep farmers given their stake in the outcome of these efforts. Ultimately, what is worth noting here is that in order for local knowledge to function in this contributory role, it need not conform to the epistemic practices or ontological and value commitments of scientists, nor do the benefits of inclusion need to be one-sided. In fact, these differences in commitments are what lead to new insights within transdisciplinary research (Ludwig 2016; El-Hani and Ludwig 2020; El-Hani, et al. 2022).

Having clarified what constitutes contributory expertise, as well as addressed this ethical concern for local knowledge inclusion, I would now like to turn to some of the specific areas in which local knowledge can function in this contributory role.

1.4 Local Knowledge and Climate Change

In section 1.2.1 I discussed the many issues faced by current methods for garnering regional climate information, as well as the impact that these issues have on developing effective policies for mitigation and adaptation. Among these issues were the lack of observed weather data for many parts of the world, as well as observed data on biophysical and socio-economic impacts. In the case of the former, this has hindered the ability to adequately perform regional modeling for many areas, and in the case of the latter, this has hindered the ability to both gauge the severity of these impacts in light of local factors and craft effective policies in the face of climate change.

In the previous section I argued that local knowledge, following Collins and Evans (2002), is a form of experience-based expertise and can in cases serve as form of contributory expertise in the context of a given issue. This was further illustrated by Wynne's (1989) case study of sheep farmers in the Cumbrian Fells which serves as an example of how local knowledge can constitute contributory expertise. Moreover, I highlighted how this notion of contributory expertise is relevant to our understanding of local knowledge inclusion in climate research: namely, the broader normative point that stakeholders impacted by climate change, with relevant expertise, should be included within this research.

My aim in the present section is to show how local knowledge can perform this contributory role in the context of climate science, as well as respond to some of the issues faced by current methods for garnering regional climate information. I focus on the following areas of contribution:

(1) Local knowledge can provide data on climate variability that is much more fine-grained than is capable for regional climate modeling.

(2) Local knowledge can be used to track and address impacts on biophysical, ecological, and socio-economic systems.

(3) Local knowledge can fill spatial and temporal gaps in instrumental climatic data.

Ultimately, this will make clear both how and why local knowledge can play a significant role within climate change research.

1.4.1 Fine-Grained Data on Climate Variability

As I noted above, there are a litany of issues surrounding the resolution of global and regional climate models. Model downscaling introduces a host of uncertainties and anomalies. Moreover, performing simulations at such high resolutions requires significant computing power and the sheer costs of doing so has prohibited a large number of these simulations from being carried out. Yet there is still the need for more fine-grained regional and local climate data that can be used to both guide societal responses to climate change by policymakers and stakeholders, as well as provide independent data used to measure the adequacy of climate modeling.

As Reyes-García, et al. (2016: 2) have argued, local knowledge can importantly help to address these issues, particularly in regards to better understanding climate variability. For example, in pilot testing for the LICCI, researchers conducted surveys with farmers and shepherds living in the Sierra Nevada region of Spain (García-del-Amo, et al. 2022). Participants reported climate change indicators related to lack of water, loss of traditional irrigation systems, less predictable weather, and fewer pastures during the summer months. Researchers found that the intensity of these impacts differed depending on livelihood strategies. Additional surveys conducted in the region found that reports of climate change impacts varied according geographic areas, lending further support to the idea that climate change impacts vary at small geographical scales (García-del-Amo, et al. 2022).

What these studies ultimately points toward is that climate change impacts are often far more nuanced than regional models are able to accurately project. Thus, surveys like those conducted at the LICCI can provide us with rich and fine-grained data concerning climate impacts by including input and knowledge from local communities. In turn, this data can be used to guide societal responses to climate change, as well as broaden our understanding of climate variability at a localized scale.

1.4.2 Impacts on Biophysical, Ecological, and Socio-Economic Systems

Beyond providing us with richer data on climate variability than is capable of regional modeling, researchers at the LICCI have argued that this information allows us to better understand not only impacts on climate systems, but also impacts affecting biophysical, ecological, and socio-economic systems. As the IPCC noted in their fifth assessment report, understanding climate impacts on biophysical and socio-economic systems is of the utmost importance for policymakers and stakeholders, and adequate information regarding these impacts is largely scarce (IPCC 2013). Thus research that incorporates local knowledge has the benefit of broadening our understanding of these often overlooked impacts.

For example, a literature review conducted by Kilroy (2015) shows the prevalence of knowledge gaps in our understanding of biophysical impacts for climate change ‘hotspots’ in certain regions of Africa and Central Asia. These areas are particularly significant given their inhabitants’ vulnerability to climatic pressures. Kilroy notes that what is largely responsible for these knowledge gaps are a lack of observed data (2015: 777). As Reyes-Garcia, et al. (2020: 189) have argued, local knowledge can become an important source for information regarding the cryosphere and hydrological systems through observations of changes in snow cover and ice, soil moisture and erosion, as well as changes in sea-levels in coastal regions. In this respect local knowledge can play an important role in narrowing these knowledge gaps.

Regarding ecological impacts, a litany of studies seem to indicate that local knowledge can play a fruitful role in providing information on the effects of a changing climate on a given locality's ecology. For example, in Chapagain, et al. (2009), researchers conducted surveys of local observations in Nepal regarding climate variability, precipitation and floods, vegetation, as well as farming and disease. These observations were not only consistent with studies related to climate change impacts, but also addressed important changes in ecology like plant growth that directly affect the lives of the people in Nepal. Moreover, separate studies done by Primack and Miller-Rushing (2012) and Heberling, et al. (2019) have utilized historical phenological observations, e.g. plant flowering and leaf unfolding, from Henry David Thoreau that indicate how anthropogenic climate change has affected the ecology of Concord, Massachusetts, particularly through reductions in carbon budgets and wildflower fitness.

In tandem with these biophysical and ecological impacts are further impacts on socio-economic systems. As I mentioned previously in section 1.2.1, the impacts of rising sea-levels are not only dependent on biophysical conditions such as tidal magnitude and island size, but also vary depending on the socio-economic systems of a given locality. For example, the severity of climate impacts can depend on available resources for coping with rising sea-levels, such as resources for constructing seawalls or bulkheads along vulnerable coastlines. Moreover, severity of impacts might be greater for communities dependent on fisheries for food production, given that climate change stands to affect not only fishing infrastructure but also wetlands that serve as hatcheries for juvenile fish (Mendenhall, et al. 2020). This is likewise the case with agriculture where climate change stands to impact access to food and economies dependent on agriculture. Again, taking steps to address these impacts, as well as assess their severity, requires a better understanding of local conditions and mediating factors.

In short, what these examples show is the diverse role that local knowledge can play in furthering our understanding of climate impacts that are typically absent from global and regional modeling. Again, the severity of climate change impacts are both place-specific and mediated by a multitude of factors. Thus, understanding these factors at the local level provides policymakers and local communities the means for effective action and policy.

1.4.3 Filling Spatial and Temporal Data Gaps

Lastly, local knowledge from Indigenous and local communities can help us fill spatial and temporal gaps in climatic data. In assessing the adequacy of global and regional climate models, researchers typically compare simulated trends from the models against independent data oftentimes from weather stations. As Reyes-Garcia et al. (2020) point out, a major issue that has arisen in assessing the adequacy of these models is the sparseness, both temporally and spatially, of climatic data from weather stations (187). In addition, a similar sentiment has been echoed in the most recent IPCC assessment. There, the authors write, “Spatial and temporal gaps in both historical and current observing networks, and the limited extent of paleoclimatic archives, have always posed a challenge for IPCC assessments” (IPCC 2023a: 243). Given the uneven distribution of weather stations, particularly in areas like Central Africa, the Amazon, Southern and Southeast Asia, and the Arctic, there are often spatial gaps in the data we possess. In addition, we lack historical records of climatic data for much of the world which has created a temporal gap that introduces new uncertainties in modeling (Brohan et al. 2006).

As I mentioned in previous sections, one of the critical issues surrounding this lack of observed data is how it affects the ability to glean regional climate information using modeling practices, particularly in regards to statistical downscaling. The practical consequences of this is that policymakers and stakeholders lack relevant information for effective policy and action, and furthermore, are less equipped to prove adverse conditions for their region. For this reason, Brönnimann and Wintzer argue, “Unequal spatial coverage is not just a data problem, but also one that affects climate justice” (2018: 4).

Local knowledge can assist these issues by providing information that can fill data gaps both spatially and temporally. For example, one method of reconstructing historical climate trends has been to employ data sources that are prior to instrumental records, e.g. newspapers, ships’ logs, and weather diaries (Whitfield 2001). Like these data sources prior to instrumental records, local knowledge could serve as an alternative data source that could assist in reconstructing historical climate. In short, such data could greatly improve assessments and construction of climate models. Similar projects have already taking place in Australia and New Zealand, where researchers have worked alongside Indigenous communities to reconstruct historical climates from oral history and weather mapping (Green et al. 2010; King et al. 2008).

In short, local knowledge can provide richer and more fine-grained data on climate variability than is capable of regional climate models, and furthermore, improve our understanding of biophysical, ecological, and socio-economic impacts of climate change, as well as help fill spatio-temporal gaps in climatic data. What I believe these points indicate is that local knowledge can and should be taken seriously by climate researchers. As a result, I hope to have shown that local knowledge can play a diverse and contributory role in understanding climate and climate change.

1.5 Conclusion

My aim within the present chapter has been to both highlight current deficiencies in regional and local climate information, as well as argue how the inclusion of local knowledge within climate change research can address some of these issues. Not only can the inclusion of local knowledge improve our understanding of climate and climate change, but by providing relevant information on mediating factors of local climate impacts, assist policymakers and communities in their adaptation and mitigation efforts. In tandem with this aim, I have sought to broaden discussions within the philosophy of climate science that have focused predominantly on top-down, modeling approaches to climate research.

In framing the discussion of local knowledge in terms of Collins and Evans (2002) notions of experience-based expertise and contributory expertise, I have argued that local knowledge constitutes a form of expertise which can function in this contributory role when relevant to a given domain or issue. In turn, I have highlighted several areas within climate change research that are relevant to the kind of information that local knowledge can provide. However, I think it is important to note that there still remain questions as to how climate research that is inclusive of local knowledge both can and should be carried out. While I noted in my discussion of contributory expertise that this notion need not entail an extractive and one-side relationship between academic and local communities, and furthermore that local knowledge need not conform to the commitments of researchers in order to be contributory, issues pertaining to the ethics of local knowledge inclusion and how to navigate these differences in epistemological, ontological, and value commitments between epistemic communities deserve a fuller treatment. With this in mind, I think it is important to highlight in brief some of the current work on Indigenous and local knowledge frameworks that is particularly relevant to these issues, as well as future research on local knowledge inclusion in climate change research.

For example, while it might be acknowledged that members of Indigenous and local communities possess expertise in a given area, this expertise is often coupled with various ontological, epistemological, and value commitments that differ from academic knowledge frameworks. On the one hand, these differences in commitments might be viewed as an insurmountable obstacle to including local and Indigenous knowledge in research and policy. One the other hand, there is the additional worry that failing to acknowledge these differences might lead to "a superficial fusing of incompatible frameworks" (Buroway 2013: 13). Regarding the importance of maintaining these differences, Whyte, et al. (2018) have argued that Indigenous insights into sustainability should not simply be viewed as lessons "for all humanity" but should rather be considered in the context of cultural identity and preservation in the face of settler colonialism and other forms of oppression. Furthermore, maintaining these differences in commitments are important because they serve as alternatives to settler colonial discourses, desires, and needs (Whyte et al. 2018: 163).

In response to navigating these risks of both division and assimilation, within the context of ethnobiological research, Ludwig (2016), as well as Ludwig and El-Hani (2022), have provided a framework for what they call a "partial overlaps" approach to navigating differences in epistemological, ontological, and value commitments between academic and local communities. Importantly, this framework can be used as a tool to highlight areas where the commitments of local and academic knowledge systems partially overlap. In turn, these partial overlaps can provide common ground for dialogue between these knowledge systems, as well as directly acknowledge these differences in epistemological, ontological, and value commitments. For example, Ludwig and Poliseli (2018) have highlighted that while there are differences in the ways that these respective epistemic communities produce and validate knowledge, they also share in epistemic resources like causal, inductive, and mechanistic reasoning. As they argue, attending to the areas where these knowledge systems overlap provides common ground for interaction and mutual learning, needs which are particularly relevant to local knowledge inclusion in climate change research.

Again, while the inclusion of local knowledge within climate change research stands to benefit both research and communities alike, it also requires navigating these issues of both the ethics of inclusion and differences in commitments between academic and local communities. As I have highlighted in a preliminary fashion, there is fortunately work already being done on Indigenous and local knowledge systems that can provide helpful avenues for future research in the philosophy of climate science.

CHAPTER 2. BETWEEN PESSIMISM AND OPTIMISM: LOCAL KNOWLEDGE INCLUSION IN CLIMATE CHANGE RESEARCH

2.1 Introduction

While climate change is often thought of as a global phenomenon, its effects and impacts are felt at the local level and are mediated by things like local culture, socio-economic systems, and geography (Reyes-Garcia, et al. 2016; Kettle, et al. 2014). Traditional 'top-down' approaches to climate research, which utilize global models as the starting point for garnering regional and sub-regional climate information, often fail to incorporate information on these mediating factors (Dessai and Hulme 2004; Conway, et al. 2019; Adger, et al. 2013). As such, in recent years there has been a growing interest in developing 'bottom-up' approaches to climate research, which begin at a local scale to analyze these place-specific factors and seek to include the knowledge of Indigenous and local community members (Reyes-García, et al. 2016; López, et. al. 2017; Kieslinger, et al. 2019).

As the IPCC has noted in their most recent report, local knowledge has the potential to provide information regarding past and present climate states, as well as facilitate behavior changes necessary for adapting to and limiting global warming to 1.5°C (IPCC 2023a: 243). Moreover, it can play an important role in improving knowledge of climate at a local scale, as well as these mediating factors. This knowledge in turn helps stakeholders and communities develop adaptation and mitigation strategies relevant for combatting climate change.

While local knowledge has the potential to play this important role, assessing and including local knowledge within this research, according to the IPCC, "remains a challenge to be met" (IPCC 2023a: 243). This has led to the exclusion of local knowledge in assessment findings. While the authors of the report give little detail on the specific challenges faced in including local knowledge, literature on Indigenous and local knowledge frameworks, as well as transdisciplinary approaches to research, highlight relevant difference between these respective frameworks (e.g. Kendig 2020, El-Hani and Ludwig 2020, El-Hani, et. al. 2022, Koskinen and Rolin 2022).

On the one hand, while Indigenous and local communities possess expertise in a given area, this expertise is often coupled with various ontological, epistemological, and value commitments that differ from those undergirding academic research programs (Ludwig 2016). These differences in commitments have led some to conclude that local knowledge is largely incommensurable with academic knowledge (Dickison 2009, 171). That is, differences in ontology, epistemology, and values create a clear and insurmountable division between these two frameworks—in short, excluding local knowledge from academic research.

On the other hand, there are concerns that even when recognizing the expertise of local knowledge, the process of integration itself strips such knowledge of valuable contextual information and fails to acknowledge key differences between these knowledge systems (El-Hani and Ludwig 2020; Kendig 2020). In turn, integrating local knowledge within an academic research framework is akin to assimilation; local knowledge is included insofar as it accords with the epistemic, ontological, and value commitments held by scientific researchers. Thus, as El-Hani, et al. (2022) note, facilitating genuine dialogue between local knowledge and academic research frameworks require that we walk a fine line between complete division, on the one hand, and assimilatory practices, on the other.

In short, local knowledge inclusion encompasses both epistemic issues relating to the possibility of knowledge co-production between differing knowledge frameworks, as well as normative issues for how this research should be carried out. While this makes these areas ripe for philosophical contribution, as Ludwig, et al. (2023) have argued, philosophy of science has played “only a peripheral role” within these debates. This is likewise the case within the philosophy of climate science, which has in part focused primarily on ‘top-down’ modeling approaches to climate change research (e.g. Winsberg 2018; Frigg, et al. 2015a, 2015b; Werndl 2016). As such, this chapter aims to both build on the growing literature within the philosophy of transdisciplinarity, as well as to broaden areas of research within the philosophy of climate science.

I begin by outlining two general attitudes towards the inclusion of local knowledge within academic research frameworks: pessimism and optimism. On the one hand, extreme pessimism ultimately precludes the inclusion of local knowledge by seeing differences in ontological, epistemological, and value commitments as insurmountable. While on the other hand, extreme optimism fails to account for important differences between local knowledge frameworks and academic research frameworks. I argue that while these two views taken in their extremes are ultimately untenable, each highlights important concerns regarding knowledge inclusion. Following this, I address why maintaining and acknowledging these differences in commitments is vital to the inclusion of local knowledge. In addition, I explore various strategies for the inclusion of local knowledge within academic research frameworks. In particular, I examine El-Hani, et al.'s (2022) "partial overlaps" approach as a juncture for dialogue between the two frameworks. Lastly, I conclude with how such strategies can be used as guidelines within the context of incorporating local knowledge in climate change research.

2.2 Attitudes Towards Local Knowledge Inclusion: Pessimism and Optimism

The IPCC's most recent report acknowledges both the potential of local knowledge within climate change research, as well as the challenges faced for its inclusion. For example, the authors write,

> Indigenous and local knowledge includes information about past and present climate states. However, assessing this knowledge, and integrating it with the scientific literature, remains a challenge to be met. This lack of assessment capability and integration leads to most WGI [physical science basis] chapters still not including Indigenous and local knowledge in their assessment findings. (IPCC 2023a: 243)

While these challenges are not explicitly noted in the report, this issue of local knowledge inclusion is one that ranges across transdisciplinary research and evidence-based public policy in general (Persson, et al. 2018; Tengö, et al. 2014). Thus within this literature there is ample evidence to spell out these potential obstacles.

Transdisciplinary research is typically characterized as research that brings together heterogeneous experts and actors among academic and non-academic communities in order to co-produce knowledge (Pohl 2011). This research is motivated by the recognition that complex social issues, ranging from climate change to public health, require a diverse range of perspectives in order to both understand and address these challenges. In practice, this means not only bringing together a diverse range of collaborators, but allowing the research itself to be shaped by all participants often through formulating research questions, design, and agendas (Pohl and Hadorn 2007). One of the challenges for transdisciplinary research is that it brings together a host of actors who possess different ways of understanding the world and the things in it, different methods for producing knowledge, and also differences in what they are concerned about (Ludwig 2016). At its core, the issue of inclusion here concerns how we can reconcile differences in ontological, epistemological, and value commitments and if such reconciliation is even possible. In other words, to what degree is knowledge co-production possible in transdisciplinary research?

Following Persson, et al. (2023), in this section I outline two ends of the spectrum regarding the inclusion of local knowledge and knowledge co-production in transdisciplinary research: namely, pessimism and optimism in regards to inclusion. If taken in their extremes, I argue that these views are ultimately untenable. On the one hand, extreme pessimism ultimately precludes inclusion of local knowledge, while on the other, extreme optimism fails to account for important differences between local knowledge and researcher frameworks. Yet, viewing them in this way highlights important concerns and implications for the inclusion of local knowledge within transdisciplinary research, as well as climate science more specifically.

2.2.1 Pessimism

Both interdisciplinary and transdisciplinary research attempt to work across disciplinary and academic boundaries. In doing so, this research brings together a variety of different ontological, epistemological, and value commitments, and is furthermore faced with the challenge of navigating these differences. For example, even among different academic disciplines there are different methods for producing knowledge, areas of concern, and ontological commitments about what exists in a given research framework. This is likewise the case when non-academic collaborators are introduced within the contexts of transdisciplinary research projects. As Persson, et al. (2023) have argued, one attitude that we can adopt towards these differences is pessimism. That is to say, given these differences in commitments, academic and local knowledge frameworks are largely incommensurable.

Notions of incommensurability between knowledge frameworks can be found within the philosophy of science (e.g. Kuhn 1970; Hoyningen-Huene 2004; Psillos 2008; Sankey 2019), as well as debates within anthropology concerning the "radical alterity" of Indigenous knowledge (e.g. Kohn 2013; Graeber 2015). For example, as Ludwig, et al. (2023) have argued, this assumption of incommensurability between local and academic knowledge frameworks in many ways mirrors debates within philosophy of science in the 20th-century concerning the demarcation of science from non-science. That is to say, the inclusion of local knowledge hinges on whether or not it qualifies as scientific knowledge.

As evidence for this claim, Ludwig, et al. (2023) cite recent debates surrounding the inclusion of Indigenous knowledge within university settings between philosopher Massimo Pigliucci (2021a, 2021b) and ecologist Root Gorelick (2021a, 2021b). During this exchange, Pigliucci asserts that science is distinct from local and Indigenous knowledge, given that the former makes "universal statements about how the world works", while the latter "is always local" (2021b, 224). Moreover, he goes on to add, “Inuit knowledge does not qualify as ‘science’ by any standard understanding of the word: science isn’t just local knowledge. My local knowledge of the New York subway system [...] doesn’t mean that I am doing subway science” (2021a, 204).

As Ludwig, et al (2023: 7) rightly argue, demarcating science and local knowledge in this way is both pragmatically and epistemically misleading, particularly within the context of transdisciplinary research. For example, many of the heterogeneous actors involved in transdisciplinary research are not scientists and do not claim to be scientists. As a result, the question of whether their knowledge is ‘scientific’ fails to grasp the point of their inclusion. Moreover, claims that science is concerned only with universal statements about how the world works is not only a mischaracterization of how diverse scientific disciplines work (e.g. Galison and Stump 1996; Cartwright 1983), but likewise misunderstands one of key reasons for doing transdisciplinary research: namely, better understanding local systems. For example, within the context of agricultural science, many of the research goals are highly place-specific (Bursten and Kendig 2021), e.g. researchers developing crop varietals for agricultural use are not concerned with universal application but rather varietals that will grow well in a particular area. Furthermore, statements like Pigliucci’s, equating Inuit knowledge to knowledge of a city subway network, fail to recognize the complex knowledge systems and expertise of local communities which have developed out of their relationship to their respective environments.

While this demarcationist framing is ultimately misguided for these reasons, it highlights a key aspect of pessimism: namely, pessimism views local knowledge as fundamentally incommensurable with academic knowledge, given differences in both the aims and methods of these respective knowledge frameworks. Moreover, it shows the ways in which what counts as valid knowledge is often evaluated in terms of idealized epistemic and normative criteria of academic research.

In addition to these theoretical arguments for incommensurability, there are likewise practical ways in which these differences between local and academic knowledge frameworks are at odds. For example, in order to illustrate some of these difficulties for transdisciplinary research, Persson, et al. (2023) cite Jerneck and Olsson's (2013) case study of a Saharan community in Kenya and their slow adoption of agroforestry practices.

Agroforestry is an agricultural practice which integrates trees and shrubs within an agroecological system. This includes planting trees and shrubs for fruit and vegetable production, "fertilizer trees" to increase soil fertility, and fodder shrubs for animal feed and erosion control (Kiptot and Franzel 2011). The benefits of agroforestry also include climate mitigation through carbon sequestration (Ramachandran Nair, et al. 2009), as well as adapting to increases in climate variability (Verchot, et al. 2007). While agroforestry can serve to mitigate climate change, as well as improve farmers' capacity to adapt to climate change, adoption of these practices has been notably slow, particularly within the context of subsistence agriculture (Jerneck and Olsson 2013).

Drawing from their work with farmers in sub-Saharan Kenya, Jerneck and Olsson (2013) note that adoption has largely been constrained by commitment differences between global agroforestry initiatives and the everyday practices and livelihoods of local farmers. On the one hand, researchers working in agroforestry are concerned with long-term and intangible benefits like biodiversity and carbon sequestration, which are largely seen as a global public good. On the other hand, community members dependent on subsistence agriculture have more immediate needs like adequate food production and income. Given the costs of implementing agroforestry practices, as well as constraints from more immediate needs like food and income, there is often little incentive to adopt these strategies.

Although these differences do not preclude agroforestry initiatives in their entirety, they point to just some of the difficulties faced in collaboration between academic and local communities. If we adopt a pessimistic outlook of inclusion, we might be concerned that adoption of one ontological framework over the other would pose a risk to the functioning and concerns of either community. For example, privileging long-term concerns of agroforestry would neglect the short-term concerns of subsistence farmers, and catering to local concerns might in turn run contrary to the interests of agroforestry research. As Persson, et al. (2023) note, this kind of pessimism seems to posit an inverse relationship between the differences in these commitments and transdisciplinary potential.

2.2.2 Optimism

As I argued in the previous section, a pessimistic attitude towards local knowledge inclusion views differences in ontological, epistemological, and value commitments between academic and non-academic knowledge frameworks as incommensurable. On the one hand, philosophical frameworks that demarcate science from non-science often provide a theoretical justification for these claims of incommensurability. On the other hand, the case study above of the Kenyan farmers' slow adoption of agroforestry practices provides an example of how these differences can impede collaboration between academic and non-academic actors in practice. Both the theoretical justification for incommensurability, as well as the example of how these differences can impede collaboration, perhaps give some credence to this pessimistic stance.

However, one might object that the case study of Kenyan farmers presents in part an asymmetrical relationship between the agroforestry agencies and local communities. That is to say, in the initiative credence is largely given to the knowledge of agroforestry agencies which is to be imposed on the practices of the local community. In light of this, rather than adopt a pessimistic stance, we might instead fault the division of engagement and take a more optimistic outlook regarding these differences in commitments. That is to say, we might hold an optimistic view: namely, that knowledge co-production is possible even across differing commitments, so long as the engagement between researchers and local communities is largely reflexive and avoids privileging one knowledge framework over the other.

Consider, for example, participatory plant breeding (PPB) programs in seed systems research. PPB encompasses a variety of approaches for farmer and researcher collaboration in order to select and develop new or genetically improved plant varieties for a local community (Weltzien and Christinck 2011). In practice farmers and community members are included at each stage of the selection process—bringing together the local knowledge of the community and knowledge of seed systems researchers. These stages include setting objectives for the studies, including goals like increasing yield or drought resistance, selecting plant varieties that potentially meet the community needs, and running both field and, if applicable, culinary tests to ensure the efficacy of these varietals.

Importantly, PPB addresses the growing need for plant varieties that are tailored to a given agroecological system, as well as community member preferences and culture. Despite the development of “high-yielding” plant varieties from formal plant breeders, such varieties can at times be inferior to traditional plant varieties. This can be because the “high-yielding” varieties are not adapted to a given agroecological system, might be unavailable to those with limited resources, or fail to possess certain qualities desired by a given community (Weltzien and Christinck 2011: 260).

For example, a study by Rattunde, et al. (2018) notes the slow adoption of new sorghum varieties bred for intensified production in Mali. Interviews conducted with farmers by Yapi, et al. (2000) found that farmers preferred landrace-derived varietals, i.e. those produced locally through traditional agricultural methods, over new varietals. The farmers’ rationale for this preference included things like better grain quality from landrace-derived varieties, better adaptation to the farmers’ environmental conditions, as well as constraints from low soil fertility. In order to facilitate the adoption of improved varieties, researchers began to work closely alongside farmers in a PPB initiative.

Not only did this process include farmer participation in setting study objectives and varietal selection, but also led to a reevaluation of stakeholders typically included within such studies. As sorghum in Mali is typically considered a “men’s crop,” the role of women within sorghum production and processing had largely been overlooked (Rattunde, et al. 2008: 96). In light of this and at the suggestion of a research team member working in the social sciences, the study adapted its procedures to include women led field testing and specific working groups. Not only did adoption of new varieties significantly increase following a more robust inclusion of women within varietal testing, but also indicated that these women possess important knowledge for assessing grain quality given their role in processing sorghum. For example, losses through grain decortication can nullify increases in grain harvest from higher yielding varieties. The role of women in processing sorghum gives them the unique vantage point to assess these losses in different varietals as they process grains. Furthermore, it shows how the diversity of viewpoints included within transdisciplinary research can lead to important insights within a given field of study, as focusing solely on production and yield neglects losses in useable product through processing.

The success of the study above lends credence to optimism in regards to reconciling different commitments in transdisciplinary research. Not only is the study inclusive and attentive to the preferences of the local communities involved, but it takes seriously their knowledge alongside research members. This is perhaps an important lesson to draw when discussing the transdisciplinary potential of a given project: namely, the degree to which local communities are involved in a given research process, both in setting objectives and testing, and the value that their knowledge is given in respect to their researcher counterparts. In short, as Koskinen and Rolin (2022: 197) argue, research design plays a critical role in ensuring this potential for success collaboration by including a diverse array of stakeholders throughout the research process.

However, as a study from Suldovsky, et al. (2018) has shown, the relative epistemic authority that science possesses within transdisciplinary research often undercuts any attempts at epistemic diversity. That is to say, while epistemic diversity is often one of the goals of transdisciplinary research, the perception of science as an epistemic authority within these projects subdues and constrains other ways of knowing. This can come about through certain discursive rules for knowledge legitimation within scientific practice to which other forms of knowing must adhere in order to be seen as legitimate, as well as the influence epistemic authority can have on behavior and decision making (Kruglanski, et al. 2005). As a result, the degree to which other ways of knowing most closely follow these discursive rules and practices merit their legitimacy. In short, the case study of PPB approaches in Mali seems to avoid this issue largely through its inclusion of local community members and the value given to their local knowledge.

However, one might object from the standpoint of pessimism that the successful inclusion of local knowledge within the PPB initiative, in contrast to the agroforestry initiative in Kenya, was due in part to limited differences in commitments between researchers and community members. That is to say, both community members and researchers had a vested interest in increasing the adoption of new sorghum varieties for the sake of improved food security and agricultural production. This is perhaps markedly different from the aims of the agroforestry initiative where community members and researchers differed in regards to research outcomes and benefits like carbon sequestration and biodiversity. Moreover, one might again argue that the difficulties that resulted from these differences in commitments in the agroforestry initiative also bear similarities to potential issues for the inclusion of local knowledge within climate research.

What is important to note here is that both optimism and pessimism express two different but significant concerns when we consider the inclusion of local knowledge within academic research frameworks. While pessimism addresses the concern that we should not underestimate these differences in commitments, optimism leaves open better ways of designing research to include stakeholders and local communities to overcome these differences. As I will argue in the following section, we can be overly optimistic or pessimistic to the detriment of knowledge inclusion, and that taking these concerns into account and in tandem can improve transdisciplinary research, as well as provide insights into local knowledge inclusion within climate science.

2.3 Between Pessimism and Optimism

In the preceding sections I have outlined two case studies that help illustrate two attitudes towards the reconciliation of different ontological, epistemological, and value commitments: pessimism and optimism. A pessimistic approach might see reconciling these differences as a difficult or even insurmountable task, while an optimistic approach sees reconciliation as a possibility, so long as collaboration entails a reflexive relationship between researchers and local communities. In their extremes, we have, on the one hand a view that potentially precludes the inclusion of local knowledge, and on the other, a view that potentially overlooks significant differences in ontological, epistemological, and value commitments.

As El-Hani, et al. (2022) note, facilitating genuine dialogue between local knowledge and academic research frameworks require that we walk a fine line between complete division, on the one hand, and assimilatory practices, on the other. It is with this in mind that I discuss in the present section why these differences in commitments matter in discussing transdisciplinary research. Far from precluding the inclusion of local knowledge, being attentive towards and maintaining these differences can help to improve transdisciplinary research initiatives.

2.3.1 Why Differences Matter

One worry in engaging in transdisciplinary research is that bringing together multiple disciplines and stakeholder groups can lead to “a superficial fusing of incompatible frameworks” (Buroway 2013: 13). That is to say, one can overlook significant differences in commitments among the parties involved. In doing so, several problems can arise. For example, dissolving differences among frameworks can lead to their identity being subsumed by some other, more dominant discipline. Moreover, as Kimmerer (2012) argues, there is a worry here that traditional and local knowledge frameworks might be viewed as just another data source to be exploited by researchers and furthermore integrated into this research only insofar as it is “useful” and accords with the prior commitments of academic practitioners. This form of “integration” has also been likened by El-Hani, et al. (2022) to a form of assimilation, given that it decontextualizes local knowledge from its cultural, spiritual, and place-based context. Likewise, as Klenk and Meehan (2015) have argued, overly optimistic views of integration can cover over antagonisms and power dynamics at play in collaborative research.

These commitments are of importance to both knowledge holders and this knowledge itself. For example, Kendig (2020) has examined Indigenous naming practices of lichen for the Samí of Northern Finmark, the Sherpa of Nepal, and the Okanagan First

Nation. Among this diverse range of communities, what these naming practices reveal are a whole host of ontological, epistemological, and value commitments. For example, many of the names given to lichen by the Samí reflect their husbandry and relationship to reindeer, and allow them to differentiate between those lichen that are preferred and avoided, their nutritional content, as well as practices for ecosystem management and conservation (Kendig 2020: 5). Thus, information pertaining to things like local ecology, community practices, and culture are embedded within these naming practices.

This source-specific, contextual information and knowledge is important when we begin to consider integration and comparison among differing frameworks. As Kendig argues, comparison and integration is not as simple as adopting a pluralistic approach of 'the more the merrier' (2020: 9). Not only do we have to consider the ontological, epistemological, and value commitments of the frameworks to be compared or integrated, but we must also look at the reasons for comparison and integration. This is because our reasons for doing so delimit what is of interest in a particular study. As a result, while comparison among frameworks is possible, Kendig writes, "[it] often leads to substantial information loss if the epistemological and ontological commitments relied upon to make the comparison do not reflect the interest in comparing these names in the first place" (ibid.).

While Kendig's argument pertains specifically to integration and comparison among nomenclatures in ethnobiological research, there are some general considerations that are applicable to discussing local knowledge inclusion. The first is that ontological, epistemological, and, in particular, value commitments are not unique to local and Indigenous knowledge frameworks. That is to say, these same kinds of value-laden and ontologically-laden commitments can be found in scientific research. One implication of this is that it disrupts the traditional demarcation between local and academic knowledge, where the 'universality' or applicability of scientific and academic knowledge might lead us to think that it is somehow less value or ontologically-laden. Moreover, as Persson, et al. (2023: 7) have pointed out, these differences in commitments can be found even within singular disciplines.

Secondly, the inclusion of local knowledge within academic research requires that we examine our reasons and interests for this inclusion in the first place. Again, these reasons for inclusion, alongside ontological, epistemological, and value commitments, delimit what is of interest in a particular study. Moreover, when our reasons for inclusion and commitments fail to reflect the commitments and interests of those involved, this can hinder inclusion and knowledge co-production, as well as lead to substantial information loss. The case studies outlined in sections 2.1 and 2.2 seem to reflect this: namely, the success or failure of a given initiative seemed in large part dependent on whether the interests of researchers coincided with those of the local community. In short, understanding these differences in interests and commitments allows us to better assess the suitability of a given transdisciplinary initiative.

2.3.2 The Importance of Local Knowledge for Communities

In addition to examining the differences in both the commitments of those involved as well as the interests and rationale for inclusion, assessing the suitability of knowledge inclusion requires that we look into the role that it plays within a given community and for whom this knowledge is intended. For example, Whyte, et al. (2018) in their discussion of Indigenous sustainability initiatives, like those being conducted at the College of Menominee Nation's Sustainability Development Institute (SDI), have argued that Indigenous insights into sustainability should not simply be viewed as lessons "for all humanity" (175). Rather Indigenous insights into sustainability should be considered in the context of cultural identity and preservation in the face of settler colonialism and other forms of oppression.

As Whyte et al. note, for many Indigenous peoples, concepts like 'sustainability' are rooted in community practices, spiritual beliefs, and conceptions of ecology that are far broader and more holistic than their Western scientific counterparts. For example, the Māori concept of "mauri," which posits the inter-relatedness of all living things, has been used to design a model for environmental assessment in Aotearoa/New Zealand (Morgan 2004, cited in Whyte et al. 2018). In contrast to relying solely on settler notions like economic costs and health impacts, on this model, actions of the New Zealand settler state are assessed in terms of increasing or decreasing mauri. Likewise, the Akwesasne Mohawk Nation's Environmental Department have developed a climate change plan organized according to ecological categories of the Mohawk Thanksgiving Address, which includes categories like, "The People, Mother Earth, The Waters, The Fish, Small Plants and Grasses, The Berries, Three Sisters, Medicine Herbs, Animals, Trees, The Birds, The Four Winds, The Thunderers, Grand Mother Moon, The Sun, The Stars, the Four Beings and the Creator" (Regis Mohawk Tribe 2013, cited in Whyte, et al. 2018).

Not only are these examples reflective of differences in ecological concepts, categories, and knowledge that are endemic to these Indigenous communities, but they also play an important role in Indigenous resistance and cultural preservation. While Whyte, et al. (2018) note that aspects of Indigenous knowledge regarding sustainability might in many ways be compatible with Western science, these insights are, again, not specifically geared towards that end. As a result, maintaining these differences in ontological, epistemological, and value commitments that underlie these insights are important because they serve as alternatives to settler colonial discourses, desires, and needs (Whyte, et al. 2018: 163). As Ludwig (2016) has argued, the significance of these differences highlight the political dimensions of local knowledge inclusion: namely, the role local knowledge plays in the self-determination of a community.

In short, attending to these differences in ontological, epistemological, and value commitments can help prevent the "superficial fusing of incompatible frameworks" mentioned at the opening of this section. Moreover, maintaining these differences and better understanding our interests and reasons for knowledge inclusion can additionally allow us to avoid assimilative or exploitative practices that decontextualize local knowledge. Again, these differences are not only important to local communities themselves, but can also serve to improve local knowledge inclusion in collaborative research.

2.4 Strategies for Local Knowledge Inclusion

As I have argued in the preceding sections, both pessimism and optimism taken in their extremes present undesirable outcomes for local knowledge inclusion: namely, by precluding inclusion in the case of the former, and overlooking significant differences in commitments for the latter. What these concerns importantly point to is that while we want to maintain the possibility of local knowledge inclusion, we must also be attentive to these differences in ontological, epistemological, and value commitments. This means both examining the reasons and interests for inclusion, as well as the significance that local knowledge has within a community and for whom and what this knowledge is intended. Again, doing so can help mitigate assimilatory and exploitative practices on the part of researchers.

With this in mind, I now turn to what I consider an approach that brings together and addresses these concerns: namely, Ludwig (2016) and El-Hani, et al.'s (2022) "partial overlaps" approach to transdisciplinary research.

2.4.1 A Partial Overlaps Approach

In broad terms, a partial overlaps framework is both a methodology and model for knowledge integration among heterogenous actors in transdisciplinary research (Ludwig 2016; Ludwig and El-Hani 2020; El-Hani, et al. 2022, Renck, et al. 2022). Again, transdisciplinary research involves bringing together academic and non-academic actors, all of whom have different ways of understanding the world and the things in it, different methods for producing knowledge, and also differences in what they are concerned about. A partial overlaps framework analyzes these different ontological, epistemological, and value commitments in order to discover overlaps as well as tensions between these knowledge frameworks.

Given the criticisms of optimism that I have outlined in the preceding sections, the assumption of overlaps among actors might at first glance seem overly optimistic. However, it is important to note that on this framework these overlaps are taken to be only partial. For example, researchers and local communities might differ in their methods for knowledge production but still maintain overlapping observations. Likewise, these communities might have overlapping concerns and values but differ in their normative and ethical frameworks. In addition, these epistemological and value commitments might also be a part of differing ontological commitments concerning how the world works and the things that exist within it. However, assuming partial overlaps in these commitments is not only practically necessary for there to be any collaboration at all, but also recognizes that while there are salient differences among actors, they do not live in entirely separate worlds and some common ground can be had. In this sense, a partial overlaps framework importantly bridges the gap between pessimism and optimism by forgoing notions of incommensurability while also recognizing important differences in commitments.

Likewise, a partial overlaps framework recognizes that there are limitations to knowledge integration and collaboration. For example, partial overlaps can be either complementary or conflicting (Ludwig and El-Hani 2020). For example, Indigenous knowledge related to forest management might include spiritual and religious notions foreign to academic researchers. Nevertheless, there can still be a shared recognition of expertise and collaboration between these epistemic communities (Ludwig and El-Hani (2020). In other cases, local and academic knowledge can be conflicting. For example, Nasasdy's (2003) case study of the Ruby Range Sheep Steering Committee, mentioned in section 1.2.2, shows how conflicts between the knowledge of wildlife biologists and the Kluane First Nation peoples led to divergent views on how to best manage Dall sheep in the Southwest Yukon. While Kluane hunters saw the decline of Dall sheep as both long-term and catastrophic, wildlife biologists viewed the decline as merely a temporary drop. In this case Indigenous expertise was disregarded in favor of the academic knowledge of wildlife biologists, largely on pessimistic grounds that the knowledge of Kluane hunters did not meet the standards of scientific knowledge (Nasady 2003: 195).

Such examples of conflict highlight an important issue for transdisciplinary collaboration: namely, how to adjudicate between conflicting knowledge and resulting courses of action. As Ludwig and El-Hani (2020) admit, decisions to give preference to one knowledge framework over another are context and problem dependent. That is to say, some knowledge frameworks are better for solving certain problems than others. However, as they argue, creating abstract hierarchical relationships between academic and local knowledge frameworks, in which one form of knowledge is viewed as subordinate to another, are counterproductive, given that they fail to account for these contextual differences (Ludwig and El-Hani 2020). As such, an important aspect of a partial overlaps framework is that it does not assume a hierarchy between knowledge frameworks. Likewise, this avoids 'data-mining' practices whereby knowledge is integrated only insofar as it adheres to a given academic or scientific criteria.

While a partial overlaps framework eschews pre-established hierarchies, this does not mean that placing academic knowledge and local knowledge frameworks on a par eliminates unequal power relations between collaborators (Ludwig and Boogaard 2022: 30). As such, conflicts and tensions additionally highlight the political and normative aspects of transdisciplinary research. In particular, concerns like community self-determination might come into account when negotiating conflicting courses of action. For example, in the case of Dall sheep management, not only is there the question of adjudicating between the knowledge of wildlife biologists and Kluane peoples, but also questions relating to the self-determination of the stakeholders involved (Ludwig and El-

Hani 2020: 16). That is to say, there are also concerns that those impacted should have a say in determining these outcomes and policies. Again, decisions such as these are to be negotiated within the context of collaboration, and it might also be the case that tensions remain unresolved. While a partial overlaps framework is not a panacea for adjudicating these decisions, it does provide a framework for analyzing these differences that can help to facilitate negotiations.

2.4.2 Relevance for Climate Change Research

Again, differences in commitments present an obstacle for local knowledge inclusion within climate change research. In turn, a partial overlaps framework can be a helpful tool for analyzing these differences, as well as tensions between local and academic knowledge frameworks. For example, there are conceptual and ontological differences in the way that researchers and locals regard climate. Within climate change research, climate is considered to be an average of variables over a thirty year period and climate change is in turn a shift in this distribution. In this sense, climate is largely a mathematical entity, arrived at through large swathes of data and modeling. In contrast, local observations of climate occur at much smaller temporal and spatial scales, and they can depend on first-hand observations or even those passed down from generations of community members (e.g. Green, et al. 2010, King, et al. 2008). On a partial overlaps framework we might analyze these conceptual differences for climate as ontological differences, while differences in how we come to know climate can be regarded as epistemological. In turn, overlaps might found through shared observations of climate change.

In addition to these ontological and epistemological differences a partial overlaps framework can help parse through important value differences. For example, for a local community, more immediate economic concerns might outweigh long term or more global benefits of practices like carbon sequestration and other mitigation or adaptation efforts. While this presents an issue for implementing mitigation and adaptation strategies, a partial overlaps framework can help to highlight overlapping values and concerns. For example, collaborators working to implement climate smart agricultural practices for climate change adaptation and mitigation might differ in their concerns over carbon sequestration, but find shared concerns pertaining to the economic benefits of such practices. Again, a partial overlaps framework seems promising for analyzing these differences in order to highlight areas of common ground, as well as negotiate tensions that arise in transdisciplinary research.

Another important aspect of a partial overlaps framework relevant to climate change research is its emphasis on context and problem dependency in adjudicating tensions between knowledge frameworks. For example, while global and regional climate modeling projections can provide useful and relevant information related to climate change, there are important aspects of climate that fall outside of their purview—in particular, information on mediating factors of climate change impacts like culture, values, socio-economic systems, as well as more fine-grained geographic variability of climate change. As I noted in the introduction, local knowledge is well-suited to address many of these deficiencies. Rather than view these knowledge frameworks as incompatible, a partial overlaps framework can be helpful for thinking about areas in which these different methods for garnering climate information are complementary.

That is to say, both top-down modeling and bottom-up approaches are suited to address specific problems, and as such, we need not construct abstract hierarchical relationships between the two.

All the same, a partial overlaps framework emphasizes that placing academic and local knowledge frameworks on a par does not eliminate existing power relations and inequalities between researchers and local communities. As such, the inclusion of local knowledge within climate change research requires that we address these normative and political issues, both within the context of specific transdisciplinary research projects, as well as climate research more broadly. For example, as Ford, et al. (2016) notes, local and Indigenous knowledge has been largely absent from major climate change assessments like the IPCC, even in areas where there is significant research and documentation of such knowledge. In particular, they note that chapters outlining climate change impacts in the arctic in the IPCC's Fifth Assessment rarely consider Inuit perspectives, despite these perspectives being well-documented (Ford, et al. 2016: 350). What this highlights is the way that local knowledge is often taken to be subordinate or supplementary to academic research within these assessments.

Likewise, Elabbar (2023) has argued that the absence of marginalized perspectives within IPCC assessments, particularly as it pertains to countries in the Global South, is pervasive. For example, a study by van der Geest and Warner (2020) found that reporting of observed climate change impacts in the IPCC's fifth assessment mention developed countries far more than developing nations, despite general consensus that countries in the Global South are currently experiencing the bulk of climate change impacts (e.g. Huggel et al. 2016). They note, "Germany is mentioned in connection to loss/damage more often than the entire Caribbean and almost twice as often as an extremely vulnerable country like Bangladesh" (van der Geest and Warner 2020: 10). Elabbar (2023) attributes the omission of climate change impacts for developing nations to "stringent" evidentiary standards in IPCC assessments which require multiple peer-reviewed publications and studies for singular climate events. These evidentiary standards in turn privilege 'data rich' countries and communities in claiming loss and damage from climate change impacts. In turn, Elabbar (2023) argues that these power inequalities constitute a form of climate injustice and that relaxing these evidentiary standards can help to mitigate these inequalities. As he suggests, this might require looking beyond peer-reviewed literature to local observations of climate change (Elabbar 2023: 20).

What these examples indicate are the ways in which scientific knowledge is privileged over other perspectives within these assessments and climate research more broadly. Furthermore, they show the political and normative issues at stake in doing so, given the underrepresentation of vulnerable communities within this research. Again, a partial overlaps framework is not a panacea for these issues, and there are instances where inclusion might be difficult given commitment differences or power inequalities. However, as I hope to have shown, it does provide a useful framework for analyzing these differences between academic and local knowledge systems that can help facilitate local knowledge inclusion within climate change research.

2.5 Conclusion

As I noted at the outset of this chapter, local knowledge has been largely absent from major climate change assessments like the IPCC and climate research more broadly. Using examples from transdisciplinary research, I have argued that part of the difficulty of inclusion lies in navigating differences in ontological, epistemological, and value commitments between local and academic knowledge frameworks. Moreover, I have outlined two dominant attitudes towards these differences: namely, pessimism and optimism. A pessimistic attitude views these knowledge frameworks as incommensurable and in turn precludes inclusion altogether. While optimism leaves open the possibility of inclusion, it runs the risk of overlooking important differences between these knowledge frameworks. Maintaining and recognizing these differences are important both from the standpoint of collaboration and knowledge co-production, but also for knowledge holders and communities themselves. In light of this, I have argued that a partial overlaps framework provides a promising approach for navigating these two extremes, particularly within climate change research. Not only does it provide a framework for analyzing differences in commitments between academic and local knowledge systems, but also helps to address political and normative issues for local knowledge inclusion.

CHAPTER 3. IMPLEMENTING CLIMATE-SMART AGRICULTURAL PRACTICES: A PARTIAL OVERLAPS APPROACH

3.1 Introduction

Agricultural production in the United States is both a contributor to climate change and yet also stands to be severely impacted by it. As is noted in the most recent National Climate Assessment, climate change not only increases agricultural production risks through changes in growing zones and growing days, but presents a broader social risk by disrupting food systems—the impacts of which disproportionately impact low-income communities and communities of color (Bolster, et al. 2023). In light of these risks, implementing climate-smart agricultural practices are both critical for climate mitigation and adaptation, as well as ensuring resilient and just food systems. However, farmers, researchers, and other stakeholders are faced with unique challenges in implementing these practices. Included among these challenges are economic constraints, barriers to communication and outreach given differences in beliefs about climate change, as well as knowledge gaps in regional and local climate information that inform decision-making.

Building on the application of a partial overlaps framework (Ludwig 2016; El-Hani and Ludwig 2020) for climate research developed in chapter 2, I show how this framework can be used to analyze these barriers and differences, as well as provide entry points for adopting climate-smart agricultural practices. Such a framework assumes partial overlaps in ontological, epistemological, and value commitments among heterogenous actors. In turn, identifying these overlaps provides common ground for collaboration and knowledge co-production. In the case of implementing climate-smart agriculture practices, I argue that this framework importantly illustrates how collaboration is possible even in light of deep differences among actors, particularly differences in beliefs about the existence of climate change. Moreover, I argue that facilitating knowledge co-production through this collaboration can help to address knowledge gaps in regional and local climate information that are integral for decision-making.

In doing so, this chapter builds on areas within the philosophy of science that have thus far received limited engagement: namely, transdisciplinary research (e.g. Ludwig, et. al 2023) and agricultural science (e.g. Bursten and Kendig 2021). Moreover, it provides a new perspective within the philosophy of climate science concerning the intersections of climate change and agriculture.

I begin in Section 3.2 by giving an overview of climate-smart agriculture practices as a subset of sustainable agriculture, and make clear the need as well as the challenges for implementing these practices. Following this in section 3.3, I describe the features of a partial overlaps framework, the context of its development within transdisciplinary research, and its applicability within the context of agricultural production and research. In order to illustrate this framework's application within this context, in section 3.4 I draw on case studies from field observations and semi-structured interviews with farmers, researchers, and Cooperative Extension personnel in Michigan that were conducted as part of National Science Foundation Award 2132038, "The Epistemology of Agricultural Science." In these studies I focus on climate change impacts on potato crop storage in Michigan, adaptation strategies taken in response, as well as climate mitigation efforts in potato production.

3.2 Climate Change and Agriculture

In this section I discuss the aims of sustainable agriculture and the development of climate smart agriculture (CSA) as a subset of these aims. Moreover, I make clear the need for CSA in light of potential impacts to food systems, as well as some of the challenges faced in implementing CSA practices. In discussing these topics, my focus here and throughout the chapter will primarily be on agricultural production and research within the United States, particularly within the Midwest and Michigan.

3.2.1 Sustainable agriculture and the need for climate smart practices

Sustainable agriculture is often used as an umbrella term for a variety of different practices within agricultural production. The term can apply equally to conventional and organic farming practices, plant and animal agriculture, as well as all of the activities and technologies that result in agricultural products. For example, within United States agricultural policy, as defined first in the 1990 Farm Bill, sustainable agriculture is an integrated system of production practices that over the long-term will:

(1) Satisfy human food and fiber needs.

(2) Enhance environmental quality and natural resources.

(3) Efficiently use non-renewable resources, and where appropriate, integrate natural biological cycles and controls.

(4) Sustain economic vitality of farm operations.

(5) Enhance the quality of life for farmers and society as a whole. (Food, Agriculture, Conservation, and Trade Act of 1990)

As Thompson (2007) has argued, such a definition leaves open what specific practices are considered sustainable. However, it does highlight the goals of sustainable agriculture which typically fall within three main categories: environmental, economic, and social. Environmental sustainability concerns the long-term stewardship of environmental resources and often includes practices like crop rotations, cover cropping, and no-till or reduced till methods that promote soil health and biodiversity. In addition to these environmental aspects of sustainability, there are economic and social concerns that include ensuring profitability for farms of all sizes, fair labor practices, as well as other issues of equity and justice which include broader social access to healthy food.

While the goals of sustainable agriculture have remained much the same since their initial definition given in the 1990 Farm Bill, they have been further complicated by growing concerns over climate change and its impacts on agricultural production. This has led to the development of climate-smart agriculture. As a subset of sustainable agriculture, CSA recognizes that ensuring the long-term sustainability of agricultural systems now requires attention to practices that will help mitigate carbon emissions, as well as adapt these systems to climate change (Lipper and Zilberman 2018). CSA applies to a variety of different practices that are characterized as promoting a "triple-win" scenario: increasing agricultural production, enhancing resilience through adaptation, and reducing emissions through mitigation (FAO 2010). These include overlapping practices with sustainable agriculture such as crop rotations, cover cropping, and no-till farming, as well as a variety of other practices ranging from developing climate-resilient cultivars to crop storage techniques (Bhattacharyya, et al. 2020). In short, CSA recognizes climate change adaptation and mitigation strategies are key components for meeting the environmental, economic, and social aims of sustainable agriculture.

As noted in the most recent National Climate Assessment, failing to do so has dire consequences for food availability, accessibility, and usability (Bolster, et al. 2023). For example, climate change impacts like heat domes and wildfire smoke can make harvesting unsafe and disrupt food supply chains. Extreme weather events can destroy or damage crops and food distribution centers. Food can become inaccessible through physical barriers caused by extreme weather such as flooding, as well as economic barriers due to decreases in food production and high food costs. In addition, higher levels of carbon dioxide can reduce food quality and nutrition. And while one might imagine these as future scenarios, it is important to note that similar events have already begun to occur within the United States. For example, in August of 2020 a line of severe thunderstorms known as a "Derecho" swept through the Midwest causing $11 billion dollars in damages and significant crop loss just before harvest. Likewise, wildfires during the same year in California saw farm laborers working in unsafe conditions due to smoke and heat.

Lastly, these disruptions to food systems and unsafe working conditions resulting from climate change present further issues of equity and justice as they stand to have the greatest impact on already vulnerable low-income communities and communities of color (Bolster, et al. 2023). Given these impacts on agricultural production, implementing climate-smart adaptation and mitigation practices will help to ensure both resilient and just food systems.

3.2.2 Challenges for implementing climate-smart agricultural practices

Although climate-smart practices are critical for ensuring resilient food systems, farmers, researchers, and other stakeholders involved in agricultural production face unique challenges in implementing these practices. Included among these challenges are economic constraints, barriers to communication and outreach, as well as knowledge gaps in regional and local climate information.

For example, as Sassenrath, et al. note in their study on the adoption of sustainable agriculture practices in the Northeastern and Southeastern United States, economic factors such as capital to implement changes in production, as well as net-return on these changes, are among the key drivers in farmer decision-making (2010: 690). This has likewise been reiterated in a survey of farmers attitudes in Michigan regarding climate change where economic concerns were largely the most decisive factor in farm decision-making (Doll, et al. 2017). For example, in the same study, researchers found that high commodity prices for corn led to a reduction in sustainable practices like crop rotations. As one farmer remarked, “If it makes you more money, you’re going to plant only one crop” (ibid. 748). The need to capitalize on commodity increases is in large part due to the way that agriculture is susceptible to “margin squeeze,” given the prevalence of fixed costs within agricultural production (Gloy, et al. 2015). That is, land rents, equipment, and labor remain the same regardless of changes in commodity prices. In short, even in cases where there is a willingness to adopt CSA practices, economic constraints can prevent their implementation.

In addition to these economic constraints, skepticism or outright denial of climate change remains prominent among farmers and other personnel within agricultural production (Chatrchyan, et al. 2017). Given differing political views and beliefs about climate change, this in turn creates difficulties for climate change communication and outreach. For example, the Extension Foundation, a partner to Cooperative Extension Services in the United States, note that some of the biggest challenges for climate change communication and outreach have been terminology choice and message framing, as well as censorship among colleagues and institutions (Kipp, et al. 2020: 48). This ultimately creates a barrier for disseminating climate change information relevant for adaptation and mitigation, as well as a barrier for understanding the specific needs of stakeholders.

Furthermore, gaps in regional and local climate information present a challenge both for developing and implementing appropriate CSA practices, as well as understanding the impacts of climate change on agriculture. For example, the fifth National Climate Assessment notes that in regions like the Midwest there is a high degree of uncertainty regarding variations in intensity and seasonality of precipitation in the region, as well as the impact of rising annual temperatures on agriculture (Wilson, et al. 2023, Wilson, et al. 2022). Moreover, more detailed information is still needed for other climate parameters relevant to agriculture like soil moisture and vapor pressure deficit, which impact plant nutrient uptake and photosynthesis (Rigden, et al. 2020). In addition, research has largely focused on climate impacts on crops like corn, soy, and wheat (Partridge, et al. 2019, Lui and Basso 2020). This has left a gap in knowledge of impacts on specialty crops which make up nearly a quarter of agricultural production in places like the Midwest (Johnson and Morton 2015).

Moreover, while there has been a growing interest in developing CSA practices, there remain uncertainties about the effectiveness of these practices within specific agricultural contexts (Chandra, et al. 2018). Taking into account farmers' economic constraints, these uncertainties about local impacts of climate change are a further obstacle to implementation. For example, a study of farmers perceptions on climate adaptation in the upper Midwest found that farmers there believe there is too much uncertainty of climate impacts to justify changes in farming practices (Morton, et al. 2017). In other words, in the absence of adequate climate information, there is the concern that implementing certain practices might prove more costly than beneficial. In short, these knowledge gaps present challenges for both assessing climate change impacts on agriculture, as well as providing farmers with information on appropriate practices for adaptation and mitigation.

3.3 A Partial Overlaps Approach to Climate-Smart Agricultural

In the previous section, I highlighted the importance of CSA practices, as well as some of the barriers for their implementation. I would now like to discuss how a partial overlaps framework developed in Ludwig (2016) and El-Hani and Ludwig (2020) might help to better understand these challenges. In doing so, I give an overview of what a partial overlaps framework is and its development within transdisciplinary research. Moreover, I argue that given the heterogeneity of actors involved as well as the role of knowledge co-production, a partial overlaps framework is particularly applicable within the context of agricultural production and research, and by extension, understanding and implementing CSA practices.

3.3.1 An overview of partial overlaps frameworks

Ludwig (2016) and El-Hani and Ludwig's (2020) partial overlaps approach is a framework within the philosophy of science developed in response to issues of knowledge integration within transdisciplinary research. Rather than merely collecting data or communicating scientific results, transdisciplinary research is a method that seeks to meaningfully engage stakeholders throughout the research process in order to co-produce knowledge. This often involves the collaborative development of research agendas and problems to be addressed, and is done so in order to include knowledge and values from a variety of different stakeholders. The popularity of this method of research has in part grown out of the recognition that complex societal problems, such as climate change, require a diverse range of expertise for both understanding these problems as well as developing strategies to address them (Whyte and Thompson 2012). In particular, as Ludwig (2016) has argued, the inclusion of non-academic stakeholders can provide epistemically relevant information on local conditions and practices.

While transdisciplinary research can help to address complex societal problems, it faces several challenges. Key among these challenges is how to navigate epistemological, ontological, and value differences between collaborators. That is to say, transdisciplinary research brings together a host of actors who possess different ways of understanding the world and the things in it, different methods for producing knowledge, and also differences in what they are concerned about. Given these differences, knowledge integration and collaboration within transdisciplinary research can be challenging. On the one hand, failing to attend to differences among collaborators can lead to "a superficial fusing of incompatible frameworks" (Buroway 2013: 13). On the other hand, focusing exclusively on these differences can create artificial divides. In turn, as El-Hani, et al. (2022) note, transdisciplinary research must navigate between, on the one hand, overly simplistic narratives of knowledge integration and, on the other hand, focusing on insurmountable differences between collaborators. In order to address this dilemma, Ludwig and El-Hani have proposed what they call a partial overlaps framework.

In broad terms, a partial overlaps framework is a methodology and model for assessing barriers and drivers for collaboration between heterogenous actors. Such a framework first assumes overlaps in commitments between these actors, and analyzes these commitments within three main categories: epistemology, ontology, and values. For example, ecologists working alongside an Indigenous community on forestry management might diverge in their methods of knowledge production but might nonetheless have overlapping observations of ecosystem dynamics. Likewise, in terms of values, researchers and community members might have overlapping concerns and yet come to these concerns through different normative frameworks. Lastly, there might be key differences in their ontological commitments, or how these actors view or relate to the world. For example, certain epistemological or value commitments might be embedded in spiritual beliefs and practices (e.g. Kohn 2013). Acknowledging these overlaps implies that while there may be important differences among actors, they do not live in separate worlds and some common ground can be had. That is, while there are salient differences, there is no strict division, for example, between academic and non-academic knowledge frameworks.

As a result, a partial overlaps framework runs contrary to discussions in philosophy regarding the incommensurability of knowledge frameworks (e.g. Kuhn

1970; Sankey 2019), as well as anthropological discussions of “radical alterity” (Graeber 2015). There are philosophical reasons for assuming these overlaps, ranging from Davidson’s (2001) assertion that all languages are inter-translatable, or Putnam’s (1981) argument that notions of incommensurability, whereby terms from differing cultures cannot be equated in meaning and reference, are incoherent. Just as well, there are also practical reasons: namely, collaboration among heterogenous actors hinges on there being some common ground between them. That is to say, some overlap is necessary for there to be any possibility of collaboration at all. All the same, these overlaps in ontological, epistemological, and value commitments on this approach are only partial. As a result, a partial overlaps framework both recognizes important differences between actors, while also providing a starting point for collaboration.

3.3.2 Partial overlaps in an agricultural context

Although it has been applied primarily within the context of transdisciplinary ethnobiological research alongside local and Indigenous communities (e.g. El-Hani, et al. 2022), I would like to argue that a partial overlaps framework is well-suited for analyzing collaboration within agricultural production and research.

Firstly, agricultural production in the United States involves a heterogenous group of actors. While an exhaustive list of these actors exceeds the scope of this chapter, stakeholders in agriculture range from farmers, laborers, academic researchers, governmental and non-governmental organizations, to members of private industry. As Bursten and Kendig (2021) have argued, collaboration between these various stakeholders has largely been shaped and supported by Cooperative Extension Services (CES). CES was created through the 1914 Smith-Lever Act as a means of disseminating relevant research and information from researchers working at land-grant universities to farmers and other community members. It includes institutions at the federal level, such as the United States Department of Agriculture (USDA) and the National Institute of Food and Agriculture (NIFA), the state-level, including academic departments and experimental research stations at land-grant universities, and at the local-level, with offices traditionally in each county that interface with local organizations, businesses, and other stakeholders.

Secondly, while the mission of CES is to disseminate research relevant to farmers and communities, how this is done in practice is by no means a top-down affair. That is to say, it is not just the one-sided communication of academic research, but rather stakeholders themselves play a crucial role in shaping this research. For example, county-level extension personnel might consult farmers on what particular problems they are facing in order to seek out or develop research agendas that can meet their needs. Understanding these needs and values plays a crucial role in developing research that is relevant and applicable to the communities CES serves (e.g. Elliott 2022: 1019-20, Parker and Lusk 2019). Moreover, this role of stakeholders goes beyond the inclusion of needs and values, and in fact shapes how knowledge is produced in agricultural research (Bursten and Kendig 2021). For example, experiments in agronomy utilize what are called growers standards. These standards are meant to imitate typical growing conditions and practices within a given agricultural context. In turn, these standards set the protocol for agronomic experiments. In short, grower standards serve as an example of how knowledge within agricultural research is co-produced between farmers and researchers.

Given the interactions of heterogenous actors and the way in which knowledge is co-produced, a partial overlaps framework is a suitable tool for analyzing collaboration within the context of agricultural production and research broadly. By extension, it is likewise applicable for many of the challenges mentioned in section 3.2.2 regarding the implementation of adaptation and mitigation practices: namely, it provides a framework for assessing drivers and constraints in implementation, as well as facilitating communication between various groups. Doing so can in turn help facilitate knowledge co-production and collaboration—particularly in regards to better understanding climatic changes at local and regional scales, as well as best practices for CSA within these contexts. For example, on a partial overlaps approach, differences in climate change beliefs can be analyzed as ontological differences regarding the existence of climate change, which in turn shape and are shaped by the epistemological and value commitments of actors. Identifying overlaps among these different categories can provide starting points for collaboration even in light of ontological differences between actors.

3.4 Climate Adaptation and Mitigation Strategies in Michigan Agriculture

In order to illustrate this framework's application within the context of climate change adaptation and mitigation in agriculture, in the present section, I draw on previous surveys conducted with farmers in the Midwest and Michigan, as well as case studies collected from field observations and semi-structured interviews conducted with farmers, researchers, and Cooperative Extension personnel in Michigan between January and October 2023. All case studies were collected by myself and other members of the research team for the National Science Foundation (US) Award #2132038: The Epistemology of Agricultural Science (principal investigator: Julia Bursten). These surveys provide a broad picture of climate change beliefs and attitudes towards mitigation and adaptation, while the case studies highlight some of the barriers and drivers for implementing climate adaptation strategies, including economic constraints for farmers, as well as strategies for communication given differences in beliefs regarding climate change. Moreover, the examples drawn from this research help illustrate how adaptation and mitigation strategies have been implemented despite these differences. For example, by attending to epistemological overlaps in observations of climate impacts, as well as value overlaps regarding economic concerns, farmers, researchers, and Extension personnel have found common ground despite ontological differences in their beliefs regarding climate change.

3.4.1 The Complexity of Climate Change Belief

Beliefs about climate change can include a variety of different commitments (Haltinner and Sarathchandra 2021). For example, there is climate change denial, or the view that climate change does not exist. There is also climate change skepticism, which can include skepticism that the climate is changing and/or that such change is anthropogenically caused. Moreover, climate skepticism might also entail the belief that there is too little information to be committed to either the existence or non-existence of anthropogenic climate change. Lastly, there is climate change acceptance, which typically entails that climate change exists and that it is anthropogenically caused.

Alongside these different beliefs are varying degrees of concern about climate change. For example, the Yale’s Six Americas Survey categorizes these concerns as Alarmed, Concerned, Cautious, Disengaged, Doubtful, and Dismissive (Leiserowitz, et al. 2021). On one end of the spectrum, the Alarmed category represents those who believe that anthropogenic climate change is occurring and support strong measures to mitigate it. On the other end, there is the Dismissive category who view climate change as either a non-issue or non-existent. In turn, the categories in between represent a continuum of less certainty and support for action.

While there is a strong relationship between belief in anthropogenic climate change and concern, there can also be exceptions (Crawley, et al. 2020). For example, one might believe that climate change is occurring but that it is largely natural, i.e. not primarily due to anthropogenic causes, and still might be concerned over its impacts. Likewise, one might hold that anthropogenic climate change exists, but might be unsure of its impacts and the need for immediate action. In short, contrary to the binary of climate change belief and denial often present in public discourse, there are a variety of different beliefs about climate change, as well as levels of concern and knowledge about climate change (Chryst et al. 2018).

When considering those involved in agricultural production in Michigan and the Midwest broadly, the complexity and variety of commitments is no different. For example, a survey conducted with nearly 5,000 farmers in the Midwest found that of the 66% of farmers who believed climate change is occurring, only 8% held that these changes were anthropogenically caused, while 24.5% believed they were natural, and 33% believed these causes to be equally anthropogenic and natural (Arbuckle, et al. 2013). Those who did not believe there to be sufficient evidence for climate change and those who denied its existence encompassed 31% and 3.5% respectively.

Despite the majority of farmers holding some level of skepticism or denial toward anthropogenic climate change, additional analysis from this survey found that farmers were mostly in support of adaptation measures (Arbuckle, et al. 2014). While these studies indicate a strong correlation between belief in anthropogenic climate change and support for implementing adaptation measures, such belief is neither necessary nor sufficient for doing so. Likewise, while farmers who believe in anthropogenic climate change are more likely to notice weather variability and view these changes as risks (Mase et al. 2017), a 2017 focus group study with farmers in Michigan further complicates this picture (Doll, et al. 2017). For example, farmers who participated in these groups largely denied the existence of climate change, while also describing changes to climate and weather, e.g. extended growing seasons, increases in temperature, and increases in the severity of rain events (Doll, et al. 2017: 745).

Given that climate change denial and skepticism are the dominant beliefs among farmers in the Midwest and Michigan, both support for adaptation as well as awareness of climatic changes might be surprising. However, such examples seem to indicate that there is a much more complex relationship between climate change belief, knowledge, and responses to climate change. In light of this complexity, I show in the following section how a partial overlaps framework is particularly helpful for providing a more nuanced analysis.

3.4.2 Climate Change Beliefs as Ontological Differences

On a partial overlaps framework, one way to analyze these differences in climate change belief is as ontological differences. That is to say, farmers and other stakeholders within agriculture are committed to the existence of certain entities, e.g. climate, weather, potatoes, etc., as well as these entities having certain properties. For example, one might be committed to the existence of climate, as well as a variety of different properties of climate, e.g. that it is changing, that it is not, that it is largely or solely natural, or that it is anthropogenic. Analyzing these differences in a “top-down” manner might at first reveal deep ontological differences between actors: namely, climate change exists or it does not exist. However, as Ludwig (2016: 28) has argued, top-down analyses are not particularly helpful if one’s aims are understanding and collaboration as they often highlight the most intractable differences. Instead, taking a bottom-up approach by parsing through and discretizing these ontological commitments can help to reveal certain overlaps that facilitate collaboration.

As it applies to farmers’ support for adaptation and observations of impacts, while there might be differences in ontological commitments concerning the existence of climate change, there are also a host of overlapping commitments to climate related entities. For example, a commitment to the existence of climate change is not necessary for being committed to the existence of droughts or extreme levels of precipitation. While these differences in commitments certainly impact causal explanations of events, e.g. that heavy rainfall or drought is caused by climate change, they do not necessarily preclude observation of perceived risk. This is not to downplay the relationship between belief in anthropogenic climate change and adaptation and mitigation responses, nor how these differences can be an obstacle to communication. However, focusing on differences in belief, particularly within a binary framework of acceptance and denial, might not be the most relevant or useful strategy for thinking about communication and collaboration with farmers. Moreover, in doing so it fails to capture the complex relationship between climate change belief, knowledge, and concerns among actors.

For example, during field observations in Michigan at a field day for potato growers in Montcalm County, members of the Epistemology of Agricultural Science research team witnessed extension personnel navigate these differences by utilizing terminology that was neutral to the existence of climate change in order to discuss the impacts of alternating periods of drought and heavy precipitation in the 2023 growing season. At the beginning of one of the presentations on how to adjust fertilizer applications in light of these patterns, an extension agent remarked to participants that while they might not all agree that climate change is happening, they can at least admit that over the past few years they have been experiencing “weird weather.” Most in attendance laughed and nodded in approval of these remarks as they began a candid discussion on how to adapt fertilizer use to changes in precipitation patterns.

This brief case study highlights how appealing to partial overlaps in ontological commitments can help to facilitate collaboration. In addition, it highlights that while collaborators might disagree over the cause of impacts like drought and heavy rainfall, there can still be overlaps in their observations of these events. These epistemological overlaps are particularly important when we consider knowledge gaps in regional and local climate information as it relates to agricultural production. For example, while researchers might understand these trends through models and tools like the U.S. Drought Monitor, there remains the need to understand observed impacts for how these patterns are affecting farmers at a local level. To this end the inclusion of farmers’ expertise and observations become particularly helpful in filling those gaps.

In addition to these ontological and epistemological overlaps, there are overlapping values to consider. Again, adopting climate-smart practices for climate change adaptation and mitigation help to ensure the long-term sustainability of food systems and farmers' own operations. Farmers, researchers, and extension personnel all have, in part, overlapping interests related to these goals. To illustrate this using the example above, implementing more efficient practices for fertilizer application can appeal to a variety of different concerns and values. Firstly, it is a measure that serves to both adapt to changes in precipitation patterns, as well as helps to mitigate carbon emissions by reducing nitrogen fertilizer use (Stuart, et al. 2014). Secondly, reducing fertilizer use also provides an economic benefit to farmers by reducing fertilizer costs. While farmers who are skeptical or in denial of climate change might not be concerned with mitigation, both adaptive and economic benefits can provide common ground for implementing such practices.

Taking into account these concerns and shared observations of changes perhaps helps to explain how there might be support for certain adaptation practices among farmers, despite the prevalence of climate change denial and skepticism. Moreover, utilizing a partial overlaps framework to examine differences in ontological, epistemological, and value commitments helps to clarify the complex relationship between climate change beliefs, knowledge, and concerns. Again, while differences in belief and ontological commitments might be a barrier to implementing climate-smart practices, they are not insurmountable—particularly when attention is given to overlaps in these commitments.

In order to further illustrate this point, in the following section, I turn to an example from interviews and field observations conducted in Michigan by members of the Epistemology of Agricultural Science research team. In particular, I focus on current climate impacts for potato growers in the state, as well as responses to these impacts.

3.4.3 Case Study: Adaptation and Michigan Potatoes

Potatoes play a significant role in Michigan agriculture and its economy. For example, nearly a quarter of all potato chips in the United States get their start in Michigan, making it the largest producer of "chip-processing" potatoes in the United States (Winkler, et al. 2018). Moreover, potatoes overall generate nearly $1.24 billion to Michigan's economy (Michigan Potatoes). The prominence of potato production in Michigan is in part due to sandy and loamy soil conditions, as well as a climate that has historically been cool and moist (USDA NIFA 2000). Not only have these climate conditions been ideal for production but also potato crop storage. However, changes to Michigan's climate in recent years threaten both production and storage. In particular, as one extension specialist working with potato producers pointed out during interviews conducted by members of the Epistemology of Agricultural Science research team, rising temperatures in the region have increased the risk of crop spoilage in storage facilities and now present a challenge for adapting these facilities to climate change.

Harvest of potatoes for storage typically begins in September and accounts for 70% of Michigan potato crops (USDA NIFA 2000). Potatoes are stored throughout the winter and spring, typically above ground in bulk piles in insulated concrete or corrugated metal storage facilities (Olsen 2010). Given Michigan's historically cool climate, the majority of these facilities are not refrigerated and instead use forced-air ventilation equipped with controls that monitor conditions like temperature and humidity. Monitoring and maintaining certain levels of temperature and humidity are integral for potato storage, given their impact on sugar content, weight, as well as susceptibility to disease, spoilage, and even bruising. Moreover, these conditions vary for specific potato cultivars, as well as the end use of the product, e.g. chips, fries, or "table" potatoes. For example, consistently low temperatures during the storing process can result in an accumulation of sugars, and for chipping potatoes, this can result in undesirable consumer characteristics like browning (Sowokinos, et al. 1987). In contrast, higher temperatures can lead to shrinkage, sprouting, and spoilage (Nourian, et al. 2003).

Given the role that temperature plays in potato storage and given that the majority of storage facilities lack refrigeration equipment, potato storage in Michigan is particularly susceptible to the impacts of climate change. For example, the extension specialist interviewed pointed out recent climate projections from Winkler, et al. (2018) which indicate that reliably cool temperatures for winter storage are expected to decrease by 11 to 17 days in Michigan's primary area of production by the mid-century. In other words, changes in Michigan's climate are projected to narrow the window for unrefrigerated storage and shorten the length of time potatoes can be stored. This has several implications for potato production, including the need to shift storage facilities from ventilation to refrigeration, as well as develop new potato varietals that are resistant to higher temperatures (Winkler, et al. 2018: 285). Moreover, it introduces new costs to farmers both in terms of purchasing refrigeration equipment, as well as fuel costs to operate this equipment.

While these greater changes are projected for the mid and late-century, the extension specialist pointed out that potato growers in Michigan are already experiencing crop loss in storage facilities due to higher temperatures. For instance, an article in the

Detroit Free Press details this loss, as well as how farmers have already begun purchasing refrigeration equipment (Flesher 2021). Moreover, while the extension specialist described that farmers were in general skeptical of attributing this to climate change, they largely recognized the need to adapt storage facilities.

What is interesting about this example is that it again shows farmers' willingness to adapt to these changes despite largely being skeptical of climate change. Analyzing this willingness through a partial overlaps frameworks helps to explain why this might be the case, as well as provide insights into implementing adaptation and mitigation practices. For instance, while there are ontological differences in climate change belief, there are also overlapping values, particularly economic concerns, as well as epistemological overlaps from complementary observations of impacts to crop storage. For example, given the role that potatoes play in Michigan agriculture and its economy, there are shared concerns between researchers, farmers, extension, and industry personnel for ensuring food system resiliency and farmers' operations. Climate impacts on crop storage present a huge risk to all actors involved. Hence, while adapting potato storage presents new costs to farmers, it is outweighed by the costs of spoilage or the need to end operations entirely.

Likewise, there are important epistemological overlaps at play. For example, while researchers have projected changes to Michigan's climate and the number of reliably cold storage days, many growers have observed these impacts first-hand. This is significant when we consider knowledge gaps in regional and local climate information and the need to better understand the impacts of climate change on agriculture. Again, agricultural knowledge is in many ways highly context specific and not just a matter of “simply applying universal rules for deriving knowledge from facts” (Bursten and Kendig 2021: 89). As Morton et al. (2015) have argued, global trends are often of little use to farmers, as they need information on how climate patterns play out on a local level. For example, in their projections for cold storage days, Winkler, et al. (2018) admit that while these projections show a general trend, there is significant variability in these impacts based on the geographic location of a farmer’s operation. This was likewise reiterated by another extension specialist at the potato growers field day mentioned above: namely, impacts vary not only among different grower operations but from field to field within them. As a result, adaptation practices need to be tailored to a particular agricultural context. In short, not only can farmers’ observations provide insights into local climate change impacts, but they also contribute to what is a unique and understudied area of how climate change affects agricultural production: namely, food storage (Winkler, et al. 2018; Lesinger, et al. 2020).

3.5 Conclusion: Lessons for Implementing CSA Practices

In the previous section I highlighted the complexity of climate change beliefs and their resulting ontological commitments. By adopting a partial overlaps framework, I argued that parsing through these ontological commitments from the bottom-up can help to highlight overlaps between collaborators. Moreover, I argued that beyond these ontological overlaps, there are additional epistemic and value overlaps that help to explain how there might be support for adaptation among farmers, despite climate change skepticism and denial being prominent beliefs. Lastly, I focused on cases studies from fieldwork in Michigan in order to further illustrate how collaborative work has been carried out despite these differences.

While the examples above show successful collaboration in cases of implementing adaptation focused practices, mitigation is perhaps a more difficult and complex problem in the face of ontological differences in climate change belief. For instance, in the example above of adapting potato crop storage, there are observable impacts of these changes shared by collaborators: namely, crop spoilage. Mitigation, on the other hand, seeks to reduce carbon emissions in order to prevent future impacts which are not observable in the same manner. In turn, the need to implement these practices might not have the same immediacy for farmers as adapting to present impacts. As a result, in contrast to adaptation, mitigation seems to highlight the significance of climate change belief for implementing these practices.

Just as well, there are important lessons for mitigation that can be drawn from a partial overlaps approach. Analyzing this issue in terms of a partial overlaps framework, we might find that where there are fewer epistemological overlaps in observations, these ontological differences become more pronounced. In turn the adoption of certain practices for mitigation might hinge on overlaps in other areas, particularly value overlaps. Again, given the role that economic factors play in farmer decision-making, these overlaps might largely be economic. For example, at the field day for potato growers in Montcalm County, an extension specialist giving a presentation on managing fertilizer run-off remarked that practices for improving nutrient retention in soil might require economic subsidies and incentives, given the costs of implementing these practices. Likewise, another extension specialist interviewed discussed how sustainability standards from corporate potato processors, like Frito-Lay, have played a key role in shifting potato growers towards more sustainable farming practices. In short, implementing mitigation strategies might require emphasizing the economic benefits of certain practices.

Another lesson applicable to mitigation practices is the role that farmers' knowledge can and should play within their development. As I mentioned in section 2.2, while there has been growing interest in developing climate-smart agricultural practices, there are still knowledge gaps in understanding their effectiveness within specific agricultural contexts. Moreover, Chandra, et al. (2018) have argued that national and global policy for climate-smart agriculture has to date overlooked the complex socio-economic and environmental considerations for implementing these practices at a local scale. Farmers' knowledge can in turn be critical for better understanding the feasibility of these practices as well as their effectiveness. This likewise would provide further insights into farmers values and potential overlaps for collaboration and implementation.

In this chapter I have aimed to highlight both the need, as well as some of the barriers, for implementing climate-smart agricultural practices. Differences in climate change beliefs, economic constraints, and knowledge gaps in regional and local climate information complicate both collaboration and implementation of these practices. In light of these difficulties, I have argued that a partial overlaps framework can be useful for analyzing these differences, as well as finding starting points for collaboration and implementation. In particular, focusing on case studies of successful adaptation practices can help to show that while ontological differences in climate change beliefs can impact the implementation of CSA practices, they are not insurmountable. Again, this is not to downplay the role that climate change belief plays in adopting adaptation mitigation strategies. However, it does importantly show how this is possible by attending to overlaps in commitments among stakeholders in agricultural production.

CONCLUSION AND FUTURE DIRECTIONS

Throughout this dissertation I have focused on the need for improving regional and local climate information, including factors that mediate the severity of climate change impacts. These knowledge gaps not only present an epistemic problem, but also result in social and ethical issues that impact mitigation and adaptation efforts. In order to address these knowledge gaps, I have sought to give a methodological argument for transdisciplinary approaches to climate research that include the knowledge and expertise of Indigenous and local communities. Moreover, I have highlighted the difficulties in conducting such research: namely, differences in commitments between local knowledge and academic research frameworks. While not a panacea for the issues that arise in transdisciplinary research, a partial overlaps framework can be an important tool for analyzing these differences in commitments and facilitating collaboration in a manner relevant to climate and ag-climate research.

An upshot of this work is that it broadens the scope of philosophical engagement with climate research that has focused exclusively on 'top-down' modeling approaches. While climate modeling plays an important role in climate research, I have aimed to show that there are limitations to such approaches—particularly in light of the kinds of information models can provide, as well as how this information impacts mitigation and adaptation efforts. By showing how transdisciplinary approaches can help address these needs, this work likewise contributes to growing literature within the philosophy of transdisciplinarity. Furthermore, it expands the application of partial overlaps frameworks to both climate and climate-ag research, and also builds on fairly limited philosophical engagement with agricultural science. In doing so, my hope has been to show how philosophical work can importantly intervene and contribute to issues within climate research, agricultural science, and transdisciplinary research more broadly.

While this dissertation provides a methodological argument for local knowledge inclusion and addresses many of the normative and epistemic issues involved in this research, there are several adjacent areas to build on this work in future research. For example, while climate is usually defined as an average of variables over a 30 year period, and climate change is a shift in this mathematical distribution, there are questions about the usefulness of 30 year climate projections for communities most vulnerable to climate change (Dessai and Hulme 2004), as well as how this mathematical notion seems to preclude local observations of climate change. Future research might make more explicit both the historical development of this notion of climate alongside scientific practices like climate modeling, as well as considerations of scale that might better suit the needs of vulnerable communities and local knowledge inclusion. This research might likewise be relevant for the development of Climate Services—which involve the production, translation, and utilization of climate information to aid in decision-making.

Moreover, in this dissertation I have largely relied on notions of climate justice as distributive, e.g. as the equitable distribution of climate burdens and climate information. Future research might develop a more holistic notion of climate justice that builds on critiques of distributive justice. For example, in the context of food justice, Whyte (2015) has argued for a notion of food justice that takes into account the self-determination and collective relations of a community. In doing so, he argues that we are not only concerned with the equitable distribution of goods, but also the communal activities associated with these goods and their role in self-determination. In turn, injustice can occur when these collective relations are interfered with or disrupted. Such a notion of injustice seems particularly relevant to the impacts of climate change, and would make clear why disruptions to local culture and livelihood strategies constitute a form of climate injustice.

Lastly, another avenue for future research might involve extending the application of a partial overlaps framework to issues of Just Transition. Just Transition is a movement that involves the equitable transition of labor from fossil fuel intensive industries to those that are sustainable, e.g. converting fossil fuel energy sources to renewable systems. Like the implementation of climate-smart agricultural practices, Just Transition initiatives, particularly in coal producing regions, face similar challenges in light of community and cultural identities built around fossil fuel industries, as well as economic constraints. A partial overlaps approach seems applicable within this context as a means of analyzing differences in commitments and providing a framework for collaboration with local communities.

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