Climate services for society:
Institutional arrangements to support national agricultural climate services in Uruguay

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The candidate confirms that the work submitted is her own, except where work which has formed part of jointly authored publications has been included. The contribution of the candidate and the other authors to this work has been explicitly indicated below. The candidate confirms that appropriate credit has been given within the thesis where reference has been made to the work of others.

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Abstract

This thesis advances our understanding of what it means to create climate services for society, with a particular focus on the institutional arrangements needed to support a national-level agricultural climate service in Uruguay.

Grounded in a broad analysis of the emerging field of climate services, the thesis starts with a bird's-eye-view approach, analysing a global survey of more than 100 services to draw general conclusions about the current state of practice and the persistence of a number of common challenges. This activity is also used to define what might be considered a pattern of attributes that might define a "typical" climate service.

While the analysis of this dataset is useful in providing a historical overview of the field in 2012, it was not able to provide a sense of good practice in this emerging field. To advance this discussion, the analysis finds that case studies must move past a simple accounting of what took place to explore and explain strengths and weaknesses of climate services from a more theoretical perspective. To achieve this, the thesis argues that case studies should explore currently under-researched issues, explaining causal links between specific climate-service interventions and ultimate outcomes. Case studies should also play a role in climate service evaluation, complementing experimental and quasi-experimental methods, and supplementing those methods in cases in which they may be inappropriate or premature.

Building on these recommendations, the thesis develops a case study that follows an "archetypical" climate service, looking at the governance and institutional arrangements that support a national-level agricultural climate service based on seasonal-scale information and provided to the Uruguayan agricultural sector over the Internet. This work reveals six factors that created an enabling environment for investment in Uruguay's National Agricultural Information System (SNIA). These are: institutional support for sustainable agriculture; groundwork on climate change adaptation; the modernisation of the meteorological service; an open data policy; a focus on the near-term; and the role of key individuals.

In particular, the results reveal the role that "innovation systems," "groundwork," and the modernisation of the meteorological service play in fostering investment in climate services. This suggests a number of avenues by which national governments can advance investment

in climate services, even when political factors make the possibility of this kind of investment seem remote. Policy measures – such as Uruguay's requirement that all public data be made available, and the SNIA's policy of focusing on near-term climate variability rather than long-term climate change – were critically important. Key individuals, and the relationships of trust between them, were also found to be central to the decision to invest in the SNIA.

Following this analysis, a second component of the case study explored the governance arrangements that supported the development and use of SNIA. While this analysis found that the team responsible for the SNIA was relatively successful at developing ad hoc solutions to governance challenges associated with delivering the SNIA, it found as well that the team was less successful at addressing the governance challenges associated with defining the SNIA, including by selecting the information products that composed it, and ensuring the sustainable impact of the tool.

As one of the first studies focused specifically on climate service governance, this analysis relied on themes from project governance. In extending these concepts, the thesis suggests that those concerned with the governance of national climate services should be particularly concerned with issues related to (1) prioritization among climate service opportunities, and between climate services and other types of) opportunities designed to further similar goals; (2) balancing needs and opportunities at local and national scales; (3) supporting evaluation; and (4) fostering sustainable impact.

Taken together, the components of the thesis contribute to a larger discussion on the governance and institutional factors that contribute to the success of climate services, and to a better understanding of what determines "good practice" in climate services more broadly. The thesis also consolidates a range of social science literature that has expanded in the climate service field over the past decade and improves a general understanding of what climate services are, how they are funded, and how they are governed.

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PhD Publications

Parts of this thesis have been published in / submitted to the following journals:

Vaughan, C., Dessai, S., and C. Hewitt. 2018. Surveying climate services: What can we learn from a bird's eye view? *Weather, Climate and Society*. 10(2): 225-239.

Vaughan, C., Dessai, S., Hewitt, C., Baethgen, W., Terra, R. and M. Berterreche. 2017. Creating an enabling environment for investment in agricultural climate services: The case of Uruguay's National Agricultural Information System. *Climate Services*. 8:62-71.

Vaughan, C., Dessai, S., Baethgen, W. and C. Hewitt. 2019. Governance of and through climate services. *Climatic Change*. Submitted.

In addition, parts of chapters 1 and 2 are adapted from:

Vaughan, C. and S. Dessai. 2014. Climate services for society: origins, institutional arrangements, and design elements for an evaluation framework. *Wiley Interdisciplinary Reviews Climate Change*. 5(5): 587-603.

The candidate confirms she is the lead author on the articles listed above; that she designed the research questions and the methodology; and that she collected and analysed the data. The papers were co-authored by supervisors and colleagues, whose roles were in the recommendations of revisions and edits to manuscripts.

Rationale for thesis by alternative format

This thesis was motivated by a general question about what it means to create climate services for society. It developed iteratively – and each set of methods, data collection, and results has required rationalization and grounding within the relevant literature, which has been achieved within the separate papers more efficiently than within a traditional monograph.

The first step was to define climate services, which was done both with a literature review and with the empirical analysis of more than 100 descriptions of climate services. It used this work to inform the selection of a case study and the design of research questions. Following priorities identified through the broad analysis, the case study focused on a national-level agricultural climate services based on seasonal-scale information, and the research questions involved exploring the institutional and governance arrangements that support investment and development. Each set of methods, data collection, and results was rationalized and grounded within its own relevant literature.

The thesis begins with an introductory chapter that sets the context and rationale for the research. It is followed by a literature review (chapter 2) and an empirical analysis (chapter 3, Vaughan et al. 2018), both of which make an effort to define climate services. Motivated by the results of previous chapters, chapters 4 and 5 (Vaughan et al. 2017 and Vaughan et al. submitted, respectively) explore the institutional and governance arrangements that support investment and development of Uruguay's National Agricultural Information System.

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Acronyms

ACMAD	African Centre of Meteorological Application for Development
AXIS	Assessment of Cross(X) - Sectoral Climate Impacts and Pathways for Sustainable Transformation
BLUE-ACTION	Arctic Impact on Weather and Climate
C3S	Copernicus Climate Change Service
CCAFS	Climate Change Agriculture and Food Security
CIG	Climate Impacts Group
CIIFEN	International Research Centre for the Study of the El Niño Phenomenon (Centro Internacional de Investigación del Fenómeno El Niño)
CIMH	Caribbean Institute for Meteorology and Hydrology
CLARA	Climate Land Ambition and Rights Alliance
CRESCENDO	Coordinated Research in Earth Systems and Climate
CSAG	Climate Systems Analysis Group
CSP	Climate Services Partnership
DACC	Development and Adaptation to Climate Change (Uruguay) (Desarrollo y Adaptación del Cambio Climático)
DGRN	General Department of Natural Resources (MGAP, Uruguay) Departamento General de Recursos Naturales
DNM	National Department of Meteorology (Uruguay) (Departamento Nacional de Meteorología)
ECMWF	European Centre for Medium-Term Range Weather Forecasting
ERA4CS	European Research Area for Climate Services
EU MACS	European Market for Climate Services
EUCP	European Climate Prediction System
EUPORIAS	European Provision of Regional Impact Assessment on a Seasonal-To-Decadal Timescale
GCM	General Circulation Model
GFCS	Global Framework for Climate Services
GoU	Government of Uruguay
GRAS	Agro-Climate and Information Systems (INIA, Uruguay)
IMO	International Meteorological Organization
INIA	National Agricultural Research Institute (Instituto Nacional del Investigación Agrícola)
INUMET	Uruguay Meteorological Institute (Instituto Uruguayo del Meteorología)
IPCAC	IGAD Climate Prediction and Application Centre
IPCC	Intergovernmental Panel for on Climate Change
IRI	International Research Institute for Climate & Society
MARCO	Market Research for a Climate Services Observatory
MGAP	Ministry of Agriculture, Livestock and Fisheries (Ministerio de Ganadería, Agricultura y Pesca)
NACLIM	North Atlantic Climate

NOAA	US National Oceanic and Atmospheric Administration
NOSCCA	North Sea Climate Change Assessment
OLE2	Latin American Observatory for Extreme Events (Observatorio Latinoamericano de Eventos Extremos)
OPYPA	Office for Agricultural Planning and Policy (MGAP, Uruguay) (Oficina de Políticas y Planificación Agrícola)
PNRCC	National Plan for Response to Climate Change (Uruguay) (Plan Nacional por una Respuesta del Cambio Climático)
RCC	Regional Climate Centre
RENARE	Department of Renewable Resources (MGAP, Uruguay) (Recursos Naturales)
RESCCUE	Resilient Cities Facing Climate Change
RISA	Regional Integrated Science Assessment
SNIA	National Agriculture Information System (Sistema Nacional de Información Agropecuario)
SNIG	National Livestock Information System (Sistema Nacional de Información Ganadera)
SNRCC	National System for a Response to Climate Change (Sistema Nacional por una Respuesta del Cambio Climático)
SPECS	Seasonal-To-Decadal Climate Prediction for the Improvement of European Climate Services
UDELAR	University of the Republic (Uruguay) (Universidad del la Republica)
UTE	National Administration of Power Plants and Electrical Transmissions (Administración Nacional de Usinas y Trasmisiones Eléctricas)
WB	World Bank
WCC	World Climate Conference
WCP	World Climate Programme
WMO	World Meteorological Organization

CHAPTER 1: FRAMING and ORIENTATION

1. Introduction

This thesis advances our understanding of what it means to create climate services for society. It is grounded in a broad analysis of the emerging field of climate services. It starts with a bird's-eye-view approach, analysing a global survey of more than 100 services to draw general conclusions about the current state of practice and the persistence of a number of common challenges. This sampling activity is also used to define a pattern of attributes that define a "typical" climate service. A national agricultural climate service that matches this archetype is selected for further study, allowing for an in-depth case study of both the governance and institutional arrangements that support it.

1.1 Historical and contemporary context of climate services

While the term "climate services" has come into favour fairly recently, climate services themselves are not new. Indeed, the World Meteorological Organization (WMO) – together with its predecessor, the International Meteorological Organization (IMO) – has worked to create a framework for international cooperation on climate research and data exchange for societal benefit since the late 19th century. More recently, the WMO has convened a series of international climate conferences that have been instrumental in generating and sustaining interest in climate-services activities. The first World Climate Conference (WCC 1) was held in 1979 as a "world conference of experts on climate and mankind." Citing the "all-pervading influence of climate on human society and on many fields of human endeavour," the conference statement called on the nations of the world to:

a) To take full advantage of man's present knowledge of climate
b) To take steps to improve significantly that knowledge
c) To foresee and prevent potential man-made changes in climate that might be adverse to the well-being of humanity (World Meteorological Organization 1979)

To further these goals, WCC 1 called for the creation of a World Climate Programme (WCP) to improve our understanding of the climate system and its impact on society (Bruce 1990; World Climate Programme 2019.) . In doing so, the WCP both led and responded to activities around the world. The US National Climate Program, for instance, was created in 1978 to “assist the Nation and the world to understand and respond to natural and man-induced climate processes and their implications” (Hecht 1984; Changnon, Lamb, and Hubbard 1990; National Research Council 2012a). Immediately following the creation of the WCP, the Australian Bureau of Meteorology began exploring opportunities to create a National Climate Centre (NCC) to serve as the national focus for all matters relating to Australian climate and climate data (Coughlan, Walland, and Watkins 2012). In 1988, the UK government announced its intention to create the Met Office Hadley Centre to focus climate science research (History of Met Office Hadley Centre 2014).

These organizations, among others, fostered the activities of the WCP throughout the 1980s. Within the WCP, the creation of the Tropical Ocean-Global Atmosphere research program led, in the late 1980s, to the development of predictive models of the El Niño Southern Oscillation and a relative breakthrough in our understanding of the climate system (Busalacchi and Asrar 2009; Cane, Zebiak, and Dolan 1986). Shortly thereafter, the Intergovernmental Panel on Climate Change (IPCC) was created to assess the impacts of increasing greenhouse gas concentrations on the climate (Agrawala 1998). The second World Climate Conference (WCC 2) was convened in 1990 to review both the first 10 years of the WCP and the IPCC’s first assessment report.

Among other things, WCC 2 endorsed a “Climate Agenda” which focused the attention of governments on improving climate observation, prediction, impact assessment and services (Final statement of the Second World Climate Conference 1991). While formally endorsed, the Climate Agenda did not gather steam until developments within the United Nations Framework Convention on Climate Change (1992) – and the second (1995) and third (2001) IPCC assessment reports – led people to the conclusion that addressing climate change would require a mix of mitigation and adaptation strategies (Zillman 2009).

These developments focused attention on the need to provide comprehensive scientific information to support such actions; it also underscored the continuing importance of earlier initiatives to support the development of climate information and service delivery (Zillman 2009). The WMO organized two conferences that addressed these issues – "Living with Climate Variability and Change," in 2006 (Finnish Meteorological Institute, International Research Institute for Climate & Society, and World Meteorological Organization 2006), and "Secure and Sustainable Living: Social and Economic Benefits of Weather, Climate, and Water Services," in 2007 (World Meteorological Organization 2007) – before its 15th Congress called for a third World Conference (WCC 3). Held in 2009, WCC 3 endorsed the concept of a Global Framework for Climate Services (GFCS) to strengthen production, availability, delivery and application of science-based climate prediction and services (WMO 2009).

It is important to note the radical improvements in climate science that took place between the first and third World Climate Conferences. Over these 30 years, new technologies – including satellites, radar, telecommunications, and supercomputing – helped scientists to dramatically increase their understanding of the climate system (Troccoli 2010; Lynch 2008; Edwards 2011). As a result, increasingly accurate predictions of climate phenomena, such as the El Niño Southern Oscillation, contributed to the production of seasonal-to-interannual climate forecasts that are significantly better than climatology (Cane, Zebiak, and Dolan 1986; Troccoli 2010). Long-term climate projections also improved, as General Circulation Models – models that describe the main interactions between various components of the climate system – have been continually refined and extended, allowing for better representation of the effect of greenhouse gases on the atmosphere, an improved description of the Earth surface and atmospheric properties (Solomon et al. 2007).

The ability to produce better information about future climates naturally led to questions about how to use that information. Improved climate forecasts were a marked improvement over previous efforts at climate-informed decision-making, which generally took into account long-term means of relevant climate variables (Goddard et al. 2010). At the same time, society became increasingly aware of its vulnerability to climate-related impacts. In the face of global change, government planning departments, development agencies, investment banks, and private companies have begun to seek out information that can help protect themselves and their constituents (National Research Council 2009; Changnon and Changnon 2010; Hewitt, Stone, and Tait 2017). An increase in the cost and frequency of climate-related disasters has also prompted disaster relief organizations and national-level decision-makers to demand information they can use to help reduce disaster-related risk (Hellmuth et al. 2011; Braman et al. 2013; van den Hurk et al. 2016; Street et al. 2019).

In the decade since WCC 3, climate scientists have engaged with a range of users to produce and tailor information to specific decision-making contexts. Scientists around the world are now working to produce climate information on timescales from seasons to decades and to contextualize this information for sectors as diverse as agriculture, health, transportation, water management, urban and coastal planning, and disaster risk reduction (Lourenco et al. 2016). To date, climate services focus primarily on forecasting forthcoming seasons to inform decision-making; projecting long-term trends to guide policy making and strategic planning; and monitoring and predicting climate-related hazards for disaster risk management (Goddard et al. 2010; Vaughan et al 2018). The development and use of information at seasonal-to-sub-seasonal and seasonal-to-decadal scales are the focus of a growing body of research (Lowe, García-Díez, et al. 2016; Vitart and Robertson 2018; White, Franks, and McEvoy 2015).

Unfortunately, the process of developing climate services has not been easy (Agrawala, Broad, and Guston 2001; Cash, Borck, and Patt 2006; Cash and Buizer 2005; Coelho and Costa 2010; Rayner, Lach, and Ingram 2005). In many cases, the connections between climate information users and providers are weak or non-existent (Changnon 2004; Mahon et al. 2019; Gerlak et al. 2018). Even in cases in which these connections do exist, climate information providers often do not fully understand the contexts in which decisions are being made (McNie 2007; Carr et al. 2019). As a result, information is provided in a format that prospective users find difficult to understand and/or incorporate into decision-making (Orlove, Broad, and Petty 2004; Power, Plummer, and Alford 2007; Meinke et al. 2006;

Podesta et al. 2002; Hansen et al. 2019). While the impact of this may be neutral across socioeconomic groups in some situations, in other cases the inappropriate use of climate information can increase users' risk exposure and lead to bad decisions (Ekström et al. 2016; Meinke et al. 2006). Climate services have also been shown to privilege certain actors over others, potentially exacerbating existing inequities (Carr and Onzere 2017).

These challenges have convinced both scientists and decision makers to focus on holistic solutions derived from cross-disciplinary and participatory user-oriented research (Brasseur and Gallardo 2016; National Research Council 2001). In this way, climate scientists now strive to work closely with sectoral experts, practitioners, and policy makers in a process of joint problem solving. In theory at least, the "co-production" of climate services leads to services that are more effective, more usable, and more suited to users' needs (Lemos, Kirchhoff, and Ramprasad 2012; Dilling and Lemos 2011; Lövbrand 2011; Hegger et al 2012; Bremer et al. 2019; Vincent et al. 2018). Despite a strong interest in co-production, deciding when and how it is best carried out remains an active research area marked by some contention (Lemos et al. 2018).

The Global Framework for Climate Services, implemented in 2012 after a period of consultation (WMO 2012), engages with this context. In this sense, the GFCS is both a product of 30 years of effort on the part of the WMO and many others, and a direct response to on-going developments in science and society. It attempts to create a framework to coordinate and promote activities including:

- reducing the vulnerability of society to climate-related hazards through the better provision of climate information
- advancing key global development goals through better provision of climate information
- mainstreaming the use of climate information in decision-making
- strengthening the engagement of providers and users of climate services
- maximizing the utility of existing climate service infrastructure

A guiding framework that helps organize and guide a set of national, regional, and international arrangements to develop climate services, the GFCS has focused efforts on developing countries and five priority areas (agriculture and food security, disaster risk reduction, health, energy, and water resources), though it is expected to expand to other countries and sectors over time. The GFCS currently draws funds from the WMO and several voluntary contributions, though additional investment will be required if the GFCS is to build infrastructure and capacity and address existing funding gaps (Hewitt, Mason, and Walland 2012).

Growing interest in climate services has brought a growing sophistication with respect to what constitutes good practice in the development, delivery, and use of such services; it has also expanded the use of climate services as tools for adaptation and other societal aims (e.g., Cortekar et al. 2016; Lourenco et al. 2016; Romsdahl 2010). Nevertheless, the field remains marked by a sense of unfulfilled potential, with a general recognition that the vast majority of climate-sensitive actors are underserved by climate information even while large quantities of potentially useful information goes unused (Ernst et al. 2019; Vaughan, Dessai, and Hewitt 2018).

The reasons for this shortfall are many and, in some cases, relatively well documented. Indeed, research identifying barriers to the success of climate services currently spans a range of disciplines, exploring issues both social and scientific (e.g., Bruno Soares and Dessai 2016; Dilling and Lemos 2011; Flagg and Kirchhoff 2018; Rayner, Lach, and Ingram 2005). Bureaucratic concerns such as the institutional arrangements that support funding and governance of climate services have received limited attention, despite being recognized as important to the production and use of climate information (Vaughan and Dessai 2014).

Addressing this gap has become more pressing as the field develops. How can we foster arrangements that attract investment and lead to sustainable services that are of benefit to society? To what extent do these arrangements determine the quality of the service? If we know more about what constitutes good practice, and more about how to prevent bad practice, why do climate service activities continue to fall short of expectations? As with other fields, institutional and governance arrangements are important to the planning, implementation, management, and use of climate information services. Refining these arrangements is critical to ensuring that our evolving sense of good practice translates to improved societal outcomes.

1.2 Definitions

While the diversity of actors engaged in climate service provision increases the coverage and hopefully the quality of climate services, it also challenges our ability to talk about and distinguish between different kinds of 'services'.

In current parlance, for instance, the German Climate Service Center—a free-standing organization that engages in a range of different activities—is described as a 'climate service' in just the same way that the provision of forecast information to the Red Cross through an online mapping tool is. Similarly, Ethiopia's Climate and Health Working Group—which meets to discuss issues related to climate impacts on health—is described as a 'service' in the same way that climate information bulletins or decision-support tools are (Vaughan and Dessai 2014).

Given this situation, the range of actors, entities, and activities that fall under this term can sometimes be confusing. For the purposes of this thesis, we will use the following terms:

- **Climate services** involve the direct provision of knowledge and information to specific decision makers. They generally involve tools, products, websites, or bulletins.
- **Climate service users** employ climate information and knowledge for decision making; they may or may not participate in developing the service itself. In some cases, climate information users may also pass information along to others, making them both users and providers.
- **Climate service providers** supply climate information and knowledge. Climate service providers may operate on international, national, regional, or local levels and in a range of different sectors; they may be public or private, or some mixture of both.

- **Climate service coordinating bodies**, including the Global Framework for Climate Services, work to increase connections between climate information users and providers and to support the development of climate services in particular contexts.
- **Climate impact monitoring groups** meet to monitor and discuss evolving climate impacts and implications of forecasts for decision making in particular contexts, especially with regard to health (e.g., Climate and Health Working Groups that monitor the incidence of climate-sensitive diseases) and food security. They generally include decision makers, sectoral experts, and representatives from practitioner communities (Vaughan and Dessai 2014).

It is important to clarify as well the difference between weather and climate services, both of which provide information for decision making, but at different timescales (Vaughan et al. 2019). **Weather services** provide weather forecasts and warnings about hazardous conditions that may occur in the coming hours up to two weeks. Such services may include storm warnings, daily, three-day, and 10-day (dekadal) forecasts, etc (Troccoli 2018). **Climate services**, on the other hand, involve the use of information at timescales greater than two weeks. They may include seasonal outlooks, drought forecasts, agro-climatic bulletins, etc (Hewitt et al. 2020; Lemos et al. 2017).

Finally, it is important to define several of concepts used to describe the processes by which climate services may be created and governed. For instance, this thesis defines the concept of **co**-**production** as an “iterative and interactive” process between climate service providers and users that is intended to create products that are improved, as a result, with respect to usefulness and usability (Bremer et al. 2019). While a full discussion of the various lenses of co-production, visible at different stages through the climate service process, is found in Bremer et al (2017, 2019), the thesis uses the term more generically, allowing the different lenses to appear in various contexts as appropriate.

The thesis defines climate service **governance** as related to a range of activities involved with the steering and/or regulating of social behavior (Biesbroek et al. 2009; Fukuyama 2016). It is concerned with the processes of interaction and decision making – including rules and norms, as well as the way these rules and norms are structured and sustained – that help to shape the development, delivery and impact of climate services. This specifically includes strategic tasks such as setting goals, direction, limitations, and accountability.

2. Aim and objectives

The thesis advances our understanding of what it means to create climate services for society. As such, the thesis is structured around three interrelated research objectives:

(1) characterizing the current state of climate service practice;
(2) diagnosing institutional arrangements that support investment in climate services; and
(3) analysing key features of climate service governance

3. Research strategy

3.1 Research philosophy

The motivation for this research was to explore what it means to create climate services for society; underpinning this question was a drive to aid in the creation of more, and more effective, services that help society to meet the pressing challenges associated with climate variability and change. Given this orientation, the thesis was developed iteratively in response to real-world conditions and with a pragmatic approach.

While some researchers employ a positivist (generally quantitative) or interpretivist (generally qualitative) approach, pragmatic researchers are more focused on the outcomes of the research. To pragmatists, instead of a focus on methods, the important aspect of the research is the problem being studied and the questions asked about this problem (Creswell 2007). To address these questions, pragmatists identify methods that seem best suited to specific problems. While there are many versions of pragmatism, pragmatic researchers grant themselves the freedom to use different methods, techniques, and procedures as appropriate. They frequently combine both qualitative and quantitative methods, recognising that every method has its limitations and that the different approaches can be complementary (Pistrang and Barker 2011).

Developing the thesis with a pragmatic orientation has allowed the author to choose research methods based on the specific questions, which combined a broad analysis of the climate services field with an in-depth case study of a single service, using both framework analysis and grounded theory.

3.2 Research design

The thesis employs both broad sampling techniques and in-depth case study analysis. To characterize the current state of climate service practice, the study uses quantitative and qualitative methods to analyse a unique dataset of more than 100 climate service activities, submitted to the World Meteorological Organization and the Climate Services Partnership in 2012. In addition to characterizing the state of the field, this analysis provides perspective on several common challenges faced by climate service providers; it also helps define what might be considered a "typical" climate service at the time the analysis was conducted.

The conclusions of this study were used to inform the selection of a case study, which looked broadly at issues of users' engagement within the context of a typical climate services – in this case a national-level agricultural climate service in Uruguay. To underpin these studies, 61 semi-structured interviews were carried out over the course of a four-year project to develop Uruguay's National Agricultural Information System. A small number of people were interviewed multiple times. This is explained in table 1, below.

Year	Number of interviews	Number of repeat interviewees	Number of new interviewees
2013	33	--	33
2015	10	3	7
2017	18	8	10
TOTAL	61	11	50

Table 1: Number of interviews by year

The results of these interviews were analysed to answer two broad questions about the institutional and governance arrangements that support the SNIA.

Specifically, a grounded theory approach is used to identify the institutional arrangements that led to the decision to invest in the SNIA. Grounded theory is particularly useful when reasearchers seek to document people's understanding of the world; to develop typologies of relevant phenomena; and to identify patterns in complex systems (Morse et al. 2016). Indeed, the result of this analysis is a typology of factors that, while grounded in the Uruguayan contexts, may be useful in understanding and in fomenting investment in climate services in a variety of contexts.

A second analysis, employing framework analysis, was conducted to explore the concept of climate service governance. As Srivastava and Thomson (2009) explain, framework analysis is well suited to research that has specific strategic questions and a limtied time frame. In this scheme, interview data was sorted based on a conceptual framework, grounded in the project governance literature, that was used to guide and facilitate the process of sensemaking (Srivastava and Thomson 2009). The conceptual framework helps illuminate the arrangements that have been useful in facilitating the development of the SNIA, as well as those that may be lacking.

The research design is illustrated in Figure 1, which articulates a visual representation of the research design.

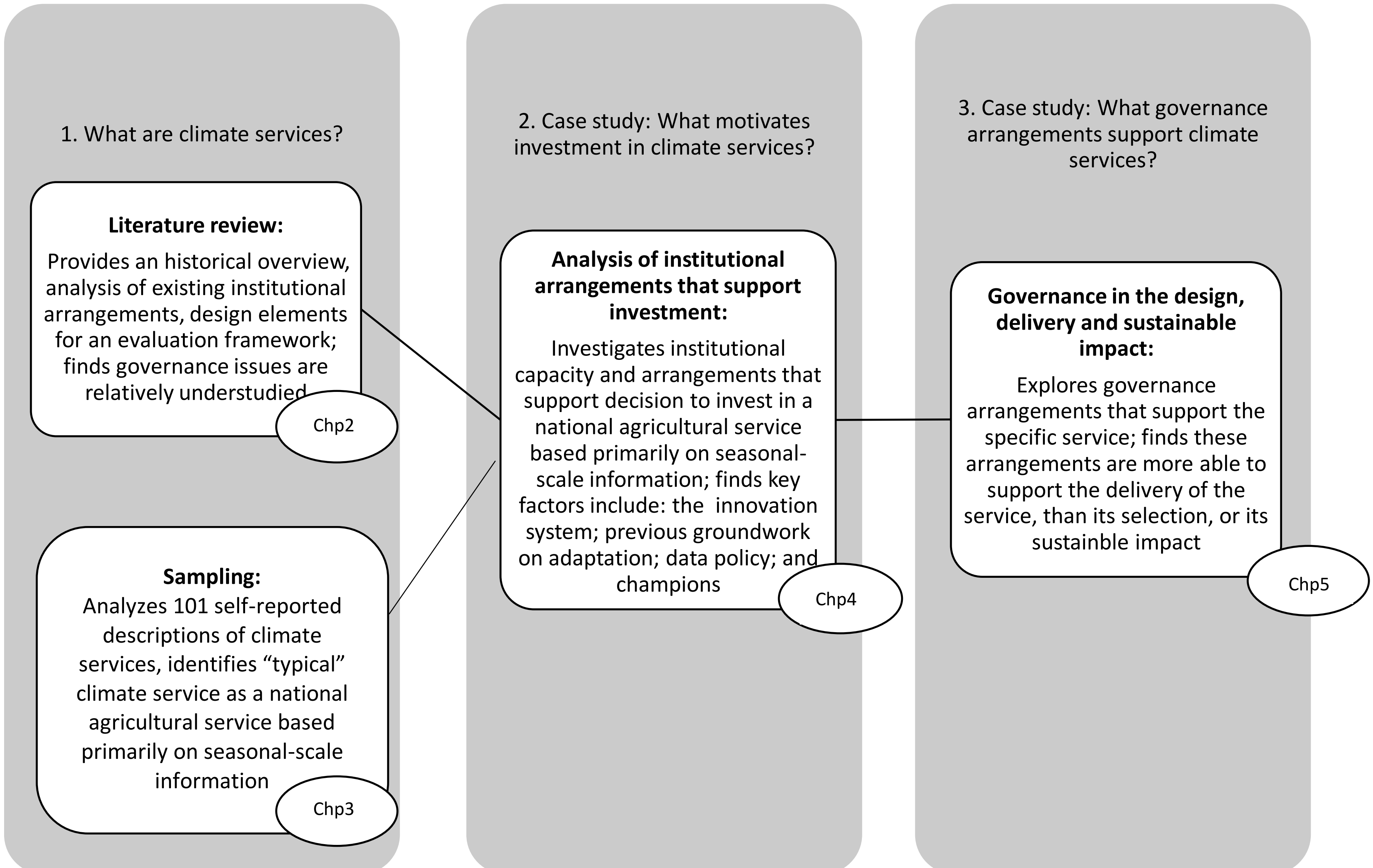


Figure 1: Visual representation of research design

3.2.1 Sampling

As described above, the third chapter of this thesis is based on a broad sampling of climate services. This effort was based on the analysis of written descriptions of more than 100 climate services collected independently, though in a coordinated fashion, by the Climate Services Partnership (CSP) and the World Meteorological Organization (WMO) in 2012. Given the broad reach of the WMO and the CSP, this dataset represents the most comprehensive detailing of climate service activities to date. It is nevertheless a "sample of opportunity" rather than one specifically designed for the purposes of this analysis. This brings with it several caveats. There is, for instance, no way to determine whether or not this sample is representative, nor is there a way to independently verify the information included in these self-reported descriptions. These caveats are described in further detail in Chapter 3.

3.2.2 Case study

To explore themes identified as important through the sampling activity and literature review, the thesis conducts a detailed study of Uruguay's National Agricultural Information System. An in-depth look at a single national agricultural climate service relying primarily on seasonal-scale information, the case study meets Hay's definition of a case study as an investigation that involves "the study of a single instance or small number of instances of a phenomenon in order to explore in-depth nuances of a phenomenon and the contextual influences on and explanations of that phenomenon" (Hay 2010). The selection of this case study follows a purposive sampling approach (Johnson and Onwuegbuzie 2004), informed by the previously described sampling activity.

3.2.2.1 Uruguay's National Agricultural Information System

Given the importance of agriculture to Uruguay's national economy, an information system to support agricultural decision making was first proposed by Uruguay's Ministry of Agriculture, Livestock, and Fisheries in 2011; the concept was further developed by actors in and outside of the country and ultimately funded, in 2013, under the auspices of a World Bank project entitled Development and Adaptation to Climate Change.

The National Agricultural Information System (or, SNIA for its Spanish-language acronym) brings a range of data produced by the Ministry together with information developed by other national-level actors; this includes information on soils, vegetation, and land use and on water, weather, and climate. Agricultural census data, including that regarding production and sales, are also included (Baethgen et al 2016). Chapters 4 and 5 analyse the SNIA as a national-level climate service with the goal of translating and disseminating contextualized information about climate variability and change. The SNIA is found online at http://snia.gub.uy/.

3.2.2.2 Case study research

Following Denzin and Lincoln (2008), qualitative methods were used to explore factors that enabled investment and the governance of the SNIA. This involved collecting empirical evidence through semi-structured interviews and the analysis of key policy documents.

***Interviews*.** A total of 33 interviews were conducted in March of 2013, roughly 6 months after work on the SNIA began**.** In December 2015, six months after the SNIA launch, an additional 10 interviews were conducted to develop a more precise understanding of the issues pertaining to each theme; three people interviewed in this round had also been interviewed in 2013. In May of 2017 another 18 interviews were conducted. In total, this thesis is based on 61 interviews with 50 people over a span of five years.

Policy documents. In addition, relevant policy documents were identified in conversation with the SNIA office, the interviewees, and via an online search, including through Uruguayan government records.

3.2.2.3 Generalizability of findings

Defining the generalizability of case study results is a challenge since case studies are, by definition, “detailed examinations of a single example” (Ford et al. 2010). Indeed, while the notion that one could use a single case study to uncover predictive theories or universals in the realm of climate services is attractive, it is unlikely to be true in most cases. Rather knowledge about the functionality of climate services, like much of that about human affairs, is context dependent, and may not be generalizable. On the other hand, in-depth case studies can help to illuminate important factors in different contexts, helping us to understand which variables may be transferable, and which may not (Flyvberg 2006).

Nevertheless, the decision to focus on a service that met the definition of a “typical” climate service as defined by the first sampling activity was intended to ensure that the results were as applicable to other service as possible. At the same time, it is clear that several factors specific to Uruguay make the context particularly unique. For instance, Uruguay is a very small country, in which only a few steps separate most actors, including those at the highest level of government (Rivoir and Landinelli 2017). It is also one of the more affluent countries in South America; it rates high for most development indicators and is known for its secularism, liberal social laws, open government, and well-developed social security, health, and educational systems (Oyhantcabal 2018; Suárez and Köster 2016; UNDP 2019). Agriculture contributes roughly 6% to its GDP, but accounts for 13% of the workforce and more than 70% of exports (CIA World Factbook 2017).

3.3 Positionality

Positionality describes the researcher’s perspective with respect to the research participants. It may be shaped by the researcher’s “unique mix of race, class, gender, nationality, sexuality and/or other identifiers” (Mullings 1999). One particular issue is whether the researcher is perceived as an insider or outsider, and how that might influence the way that research participants engage with the researcher and the research questions. With respect to the Uruguay case study, I was likely perceived as both an insider and outsider in different ways.

One important factor had to do with my employment status. That is, while I made it clear to research participants that I was completing this research as part of my doctoral studies with the

University of Leeds, my affiliation with the International Research Institute for Climate and Society (IRI) was generally known; if it was not, I disclosed it. Since the IRI was a member of the team developing the SNIA, I believe I was seen as a part of the team, someone to whom the participants could be honest about the state of the process, whether their perception was positive or negative. I formed this impression based on the level of candour I experienced in the discussions.

It is also possible that people's perception of me as a familiar entity was increased by my intermittent presence in Uruguay over several years; in addition to the research work, this also included a two-week climate and health training course organized with the meteorological service in 2011; a week-long visit around the time of the World Climate Research Programme conference in 2013; and six weeks leading up to the fourth International Conference on Climate Services, which I co-organized in Montevideo in December of 2015 on behalf of the Climate Services Partnership and in conjunction with local hosts, the Ministry of Livestock, Agriculture, and Fisheries (MGAP); the National System of Response to Climate Change (SNRCC); the University of the Republic (UdelaR); and the National Meteorological Institute (INUMET).

On the other hand, I am clearly not from Uruguay, a small country with tight social networks and a unique culture. While I was able to conduct most of my interviews in Spanish, a language in which I am highly proficient, I am not a native speaker, which may have also influenced the extent to which I was perceived as an outsider by those I engaged. Similiarly, it is possible that my role at IRI limited people's willingness to speak freely about their perceptions of the SNIA. While IRI was not a funder of the project, interview subjects may have been concerned about sharing opinions with a representative of an external partner organization. It is also likely that my history and experience at IRI colored the kinds of questions that I asked and the ways in which I interpreted responses. In some cases, this familiarity and perspective may have been an asset, and in others, a limitation.

3.4 Research ethics

Because the case study work required the involvement of human participants, relevant risk assessments were completed, and ethical approval was sought from both the University of Leeds Ethics Review Committee and Columbia University's Institutional Review Board. The key concerns covered in the ethical review for this research were focused on obtaining participant consent and ensuring confidentiality (Berg and Lune 2011). Interviews were solicited by email, though in some cases names were suggested by others (including on one occasion a supervisor) while I was on the premises at the Ministry of Agriculture, Livestock and Fisheries. Research participants were provided with informed consent forms in advance of each interview.

4. Novelty and contribution of the thesis

The thesis offers several empirical contributions to the field of climate services. The analysis of GFCS / CSP survey provides a snapshot of the field of climate service at the time. Meanwhile, the Uruguayan case study is the only in-depth study that looks at institutional arrangements that support investment, and the first one that specifically looks at governance, though these issues have been covered more tangentially in other works. In addition, this work is the first major analysis of Uruguay's National Agricultural Information System, or of climate services in Uruguay in general. It generates important insight regarding the structuring of national climate services which may be useful to other countries and/or the Global Framework for Climate Services. Since the project that funded the SNIA (DACC) marks the first time the World Bank funded a climate change adaptation project that did not include the use of long-term climate projections, this analysis may help inform the shape of adaptation work in years to come.

More broadly, while there has been very little research on governance and institutional arrangements to date, work in this area can help address questions including:

(a) how different organizations can work together to develop and deliver climate services;

(b) how and whether those organizations can develop and draw on different institutional resources to build the services; and

(c) how organizations / networks can prepare to use climate services to effectively respond to climate variability and change.

5. Outline and structure of the thesis

The thesis is divided into six chapters. Having outlined the overarching research context and strategy in this chapter, Chapter 2 presents a broad literature review, with more targeted reviews found in each of the following chapters. Chapter 3 presents the results of the global sampling of climate services; Chapter 4 and 5 present the case study results; and Chapter 6 presents the discussion and concluding remarks. More information is below:

Chapter 2 surveys the literature to answer the question “what are climate services?” It specifically considers existing delivery structures; key success factors; and critical research gaps.

This chapter is complemented by **Chapter 3**, which presents the analysis of climate service descriptions collected by the Climate Services Partnership and the Global Framework for Climate Services. It highlights the nature of a typical climate service, which involves seasonal information tailored to the agricultural community and offered at a national level.

The results of the case study, which looks at the mechanisms to understand and address climate information needs for a national-level agricultural climate service focused on seasonal information in Uruguay, are presented in chapters 5 and 6. **Chapter 4** presents the results regarding the institutional arrangements that supported the decision to invest in Uruguay’s National Agricultural Information System, while **Chapter 5** presents results regarding the governance structures that guided the development and delivery of the SNIA.

The thesis concludes in **Chapter 6** which consolidates the work of chapters 2-5, presenting overarching observations about the state of the climate service field and several key factors needed to advance national-level climate services.

CHAPTER 2: CURRENT SERVICES and DELIVERY MODELS

The Global Framework for Climate Services (described in chapter 1) may be the world's most visible climate service activity at the moment, but it is just one of a range of on-going efforts which now engage both the public and private sectors at global, national, regional and local scales. Climate services and climate service providers contextualize scientific knowledge, enabling climate information to be created and tailored to specific decision contexts (Von Storch et al. 2011). In this way, climate services operate at the boundary between climate science, policy, and practice (Guston 2001; Jasanoff 1986). Across scales, the institutions that support climate services seek to create a structure in which credible sources of information can be explored and defined by climate scientists and decision makers alike (Brasseur and Gallardo 2016; Shafer 2008). A brief review of literature that describes efforts at these various scales is included below.

1. International service delivery

In addition to the WMO, the Copernicus Climate Change Service (C3S) is the world's largest international climate service. Provided by the European Commission and implemented by the European Centre for Medium-Range Weather Forecasts (ECMWF), C3S became operational in 2018. It seeks to provide information about the current and past state of the climate, forecasts on a seasonal time scale, and projections for the coming decades (Copernicus Climate Change Service 2018).

A number of organizations with global reach have begun to incorporate climate services into their repertoire. Together with the International Federation of Red Cross and Red Crescent Societies, the Netherlands Red Cross established the Red Cross Climate Centre in 2002 in order to better connect the scientific and humanitarian communities and improve the application of scientific knowledge about climate change to the early warning of disasters, health programmes, and awareness raising (Red Cross Red Crescent Climate Centre 2007). While the Climate Centre is based in the Netherlands, it provides climate services to Red Cross Red

Crescent Societies around the world. International agencies and non-governmental organizations including the Food and Agricultural Organisation, World Food Programme, Oxfam, CARE, and the World Health Organisation have also engaged in the production and delivery of relevant climate information to constituents (Harvey et al. 2019; Meybeck et al. 2012; Perez et al. 2012; Smyth 2009; Samimi, Fink, and Paeth 2012; Urich, Quirog, and Granert 2009).

2. National climate service providers

At national scales, many state meteorological agencies provide climate services, particularly to the water and agriculture sectors (Bellow et al. 2007; Hunt 2012). National meteorological departments also collect and manage climatological data and many produce seasonal climate outlooks (World Meteorological Organization 2012). In recent years, a number of countries have consolidated these capacities into national climate service centres.

According to Miles et al (Miles et al. 2006), national climate service centres meet national needs for climate information, providing an overarching and coordinated approach to managing climate observation systems and producing and disseminating information on climate and its impacts to stakeholders at federal and local levels. Centrally funded organizations in Australia (Australia National Climate Centre 2014), Austria (Climate Change Centre Austria 2014), China (Chinese National Climate Centre 2014), Finland (FMI Climate Services Centre 2014), Germany (German Climate Service Center 2014), Italy (Euro-Mediterrean Center for Climate Change 2014), the Netherlands (KNMI Climate Services 2014), and the UK (UK Met Office Climate Service 2014) currently strive to meet these needs, producing timely, actionable, decision-relevant information on climate variability and change and the associated environmental, economic, and societal impacts of these phenomena; the United States' Climate Prediction Centre performs similar tasks (National Climate Prediction Center 2014). Some authors have suggested that similar organizations are needed to support development in Africa (Dinku 2010; Rogers et al. 2007).

While national climate centres are increasingly seen as useful (Kwok 2009; Visbeck 2008), institutional arrangements that support existing organizations vary widely. While some exist as part of their national meteorological agencies, others (e.g., the German Climate Service Centre) are more independent. Some employ top-down approaches to climate information provision, while others start with bottom-up methods, including vulnerability and risk assessments; these organizations also employ different business models. Mahon et al (2019) has also explored the challenges that national meteorological services in the Caribbean face in expanding more traditional aviation and hydro-meteorological portfolios to include climate services. Because these organizations have historically focused on meteorology, they face knowledge and expertise gaps related to the translating, transferring, and fostering the use of climate information (Mahon et al. 2019).

2.1 Regional climate services

Regional climate service activities currently exist at both sub- and supra-national scales. A prime example of the sub-national climate services comes from the United States, where a system of Regional Climate Centres (RCCs) dates to the creation of the National Climate Program Act of 1978 (De Gaetano et al. 2010). Conceived as flexible and innovative institutions, RCCs respond to the fact that needs and uses for climate information occur in specific locations and settings (Horsfall et al. 2004; Redmond 2002). By operating within these specific locations, climate information providers improve connections with potential users and their understanding of local impacts (Changnon, Lamb, and Hubbard 1990; Bellow et al. 2007).

Because RCCs are located in different physical, economic and climatic regions, their functions vary according to regional needs. In general, however, these organizations concentrate on acquiring and managing relevant data for the region and conducting applied climate studies, including the monitoring of anomalous conditions, the fostering and promoting of regional research, the creation of specialized products and decision support tools. While oversight and funding is provided by NOAA's National Climatic Data Centre, each RCC is also supported by the academic institution from which it operates, and from each state that agrees to be a participating member (Regional Climate Centers 2014). Several RCCs enhance their funding by grants and contracts for services, data, and research projects from government and private-sector sources (De Gaetano et al. 2010).

In the US, RCCs also interact with the Regional Integrated Science and Assessment (RISAs) programme, which was implemented to facilitate a greater depth of understanding of the use and decision-making environment in selected sectors (Parris et al. 2016). So while RISAs were primarily designed as research entities, exploring user needs and the decision environment, RCCs tend to emphasize on-going delivery of climate services as a quasi-operational activity. In this way, RCCs serve a wide range of users in federal, state, and private institutions (Hill, Pulwarty, and Nierenberg 2004).

Sub-national climate services exist in other counties as well. The Northern German Climate Office, established in 2006 at the Helmholtz Centre's Institute for Coastal Research, provides climate information for the general public (Von Storch et al. 2011). As with RCCs in the US, the Northern Germany Climate Office produces technical information about the regional climate and localizes this knowledge in the social and cultural setting where people live (Krauss and von Storch 2012). In somewhat similar fashion, the Pacific Climate Impacts Consortium, a federally registered not-for-profit organization, has produced practical information on the physical impacts of climate variability and change in the Pacific and Yukon Region of Canada since 2005 (Pacific Climate Impacts Consortium 2014).

Regional climate services have also crossed state lines. In some cases, this involves regional organizations such as the African Centre for Meteorological Applications for Development (ACMAD), the AGHYRMET Regional Centre, the Catalan Institute for Climate Sciences, the Caribbean Institute for Meteorology and Hydrology (CIMH), the International Centre for Research on the El Niño Phenomena (CIIFEN), the IGAD (Intergovernmental Authority on Development) Climate Prediction and Applications Centre (ICPAC) and the Latin American Observatory of Extraordinary Events (OLE). A few of these regional climate providers have published on their experience (Martínez Guingla and Mascarenhas 2009; Muñoz et al. 2012; Ogallo 2010).

In other cases, groups of scientists from diverse organizations collaborate to provide regional climate assessments, including for instance, the BALTEX assessment of climate change for the Baltic Sea (Reckermann et al. 2011) and the North Sea climate change assessment (NOSCCA) (North Sea Regional Climate Change Assessment 2014). A significant body of research looks at how to improve these assessments, including in the United States (Jacobs, Moser, and Buizer 2016). Since the late 1990s, Regional Climate Outlook Forums have also brought international, national, and regional experts together to produce consensus seasonal forecasts for particular areas with similar climatic conditions. As part of this process, sectoral scientists, extension agencies, and policy makers assess the implications of the outlooks on society and communication regarding appropriate actions (Berri, Antico, and Goddard 2005; Daly and Dessai 2018; Gerlak et al. 2018; Ogallo and Oludhe 2009; Patt, Ogallo, and Hellmuth 2007).

2.2 Research institutes and the not-for-profit sector

Academic and research organizations play a critical role in climate services, focusing primarily on data compilation, analysis, and product development, and engaging either on their own or with public- or private-sector partners. While the universities engaged in climate research and service development are too many to mention, a few examples are included here:

- The University of Cape Town's Climate Systems and Analysis Group (CSAG) has developed a Climate Information Portal which provides a wide range of users with climate information (CSAG Climate Information Portal 2014).
- The Ethiopia Meteorological Department teamed up with colleagues at the University of Reading, University of East Anglia, and Columbia University to produce an online climate service based on 30 years of rainfall and temperature data (Dinku et al. 2011).
- Researchers at the University of Southern Queensland and James Cook University worked to develop seasonal forecasts useful to Australia's Queensland Sugar Limited,

the third-largest sugar supplier in the world (Everingham et al. 2012; Everingham et al. 2002).

- The Climate Impacts Group (CIG) of the University of Washington provides tools and planning advice that take into account the impacts of natural climate variability and global climate change (Climate Impacts Group 2015).
- The University of Arizona has worked together with the Caribbean Institute for Meteorology and Hydrology explore social science research questions related to the provision and use of climate services (Gerlak et al. 2018; Mahon et al. 2019).

The European Union has also funded a large number of climate services research programs, focusing specifically on creating and providing climate information and on engaging specific European user groups. These project include EUPORIAS, SPECS, NACLIM, ClimateEurope, ERA4CS, CRESCENDO, PRIMAVERA, EUCP, AXIS, RESCCUE, EU-MACS, MARCO, EU-CIRCLE, IMPREX, CLARA, CLARITY, PROSNOA, BLUE-ACTION, and others (Pietrosanti and Witschke 2017). In the developing world, a number of collaborations help build and provide climate service capacity; one such example is the Climate Change Agriculture and Food Security (CCAFS) project, a collaboration of among CGIAR Center and Research Programs with a theme focused specifically on climate services and safety nets. CCAFS divides its nearly 20 projects into four research themes focused on improving the delivery of climate services in Africa, Asia and Latin America (CCAFS 2014).

2.3 Private sector services

In increasing numbers, private sector actors have begun providing climate services (Agrawala et al. 2011; Paull 2002). To inform long-term planning, private companies in the energy and insurance fields have created their own climate risk management teams and/or hired consultants to help them prepare for climate-related risks. A major energy player, the EDF group is now modelling climate change impacts on long-term energy demand and supply in different regions around the world (García-Morales and Dubus 2007; Giger, Vailhen, and

Arrondel 2007). The Swiss firm e-dric.ch produces forecasts of river discharge that are used for flood management and the development of sanitation systems (E-dric.ch 2014).

A number of private companies, such as Climate Risk Analysis (Climate Risk Analysis Group 2014), Predictia (Predicitia 2014), Climpact (Climpact 2014), and Prescient Weather (Prescient Weather 2014), have also sprung up to develop tools that help business and public sector actors to more effectively manage climate-related risk. Jupiter helps asset owners, planners, developers, investors and government agencies incorporate climate impact data into risk modelling for specific assets (Jupiter 2018). Acclimatise focuses on using climate information for adaptation and risk management (Acclimatise 2019). In many ways, these companies are similar to private weather service providers – using government-collected data to develop new tools and products that they then sell to individual users and, in certain cases, collecting their own proprietary data as well.

Several research activities have focused on needs and opportunities for business development within the private sector. This includes research on the potential for climate services to spur economic activities in particular sectors and how the government may be able to facilitate this. While this research is most developed in Europe (Cavelier et al. 2017; Damm et al. 2019; EU MACS 2014; MARCO 2014), some work has focused on the United States (National Research Council of the National Academies 2003) and in the developing world (Usher et al. 2018) as well. The Global Framework for Climate Services has also developed 17 goals for public-private partnerships (WMO 2014).

Webber and Donner have warned that commercializing climate services may limit the development and delivery of climate services that meet the needs of vulnerable actors in developing countries (Webber and Donner 2016). Related work has explored the business models (Keele 2019) and the legal and policy environments that support private-sector services (Usher et al. 2018; Perrels et al. 2018), though there is not yet a consensus on how these different factors limit or enable climate services in different contexts, nor on how national governments may make decisions about the kinds of services that rightly belong in the public domain and which should be developed by private-sector actors for a fee.

2.4 Need for further research on service delivery models

While the above literature review of service delivery structures helps generate an understanding of the field, it is not able to describe the relative frequency, nor the specific characteristics, of different service delivery models. Neither is this review able to contribute in an empirical way to the comparison of different methods, nor the development of strategies to design, diagnose, and evaluate climate services. Indeed, a great deal about the effective implementation of climate services remains unknown. This gap in knowledge regarding the state of current practice limits learning and impedes larger efforts to advocate for climate service development around the world; as such, a more detailed analysis of the field of climate services (i.e., Chapter 3) is required.

3. Key determinants of the benefits of climate services

Understanding the value and relative contribution of climate services is a critical step in improving our ability to adapt to climate variability and change. By improving capacity to recognize and articulate which initiatives are successful, why, and to what extent, the evaluation of climate services can help inform adaptation decisions and guide future investments. Unfortunately, this evaluation is complicated by the fact that the benefits of such services can take many forms – and by the multiple, interacting attributes that contribute to creating these benefits when they do occur.

A review of the literature describing the use of seasonal forecasts and long-term scenarios identifies various factors that influence the benefits and relative success of climate services (Vaughan and Dessai 2014). In broad terms, these can be described as follows:

- Problem identification and the decision-making context
- Characteristics, tailoring and dissemination of the climate information

- Governance, process and structure of the service
- Economic value of the service

3.1 Problem identification and the decision-making context

Climate services are developed to improve decision making in specific contexts, and naturally involve certain assumptions about those contexts. An agricultural climate service may assume, for instance, that climate variability is a constraint on production, and that low production is a constraint on farmers' livelihoods. To address this, the service supplies information at appropriate times, assuming that farmers who make better decisions – employing conservative strategies in good years, and investing when the likelihood of favourable conditions are high – will increase production and with it their ability to earn a profit. In many cases, this premise may be a valid one; in other cases, however, other factors (e.g., access to markets, trade agreements, etc.) may mean that the increase in production facilitated by the climate service does not lead to an improvement in the farmers' livelihood.

Indeed, in many cases there has been an implicit assumption in many circles that as the technical constraints – including the characteristics and communication of the climate forecast – are removed, forecasts will allow various end users to improve planning and better manage the risks associate with climate variability (Millner and Washington 2011; Broad and Agrawala 2000). The truth is that in many contexts, the strongest impediments to forecast adoption are contextual or institutional (Vogel and O'Brien 2006). Conversely, certain situations make climate services more impactful than others. Though they have not been well studied, the factors that contribute to the relative impact of climate information include the variability of the climate; the exposure to climate variability; capacity to incorporate climate information into decisions; and the cultural and individual context (Peterson et al. 2010).

In this regard, it is important to remember that climate services are not neutral. Climate information can be used to help specific users, potentially at the expense of others. Several case studies suggest that some users have greater access to forecasts than others, and that politics, ethnicity, and gender influence this (Archer 2003; Gumucio et al. 2019). This is particularly true in cases in which asymmetric information and one-sided uncertainty about resources privilege certain members of society (Broad, Pfaff, and Glantz 2002). Carr and Onzere (2017), for instance, have shown that the Mali Agrometeorological Advisory Program was explicitly designed to empower the rich and powerful farmers at the expense of others – and that this trade-off was forgotten when the project was uncritically converted to a development program that was assumed to have broad-based benefits.

Access, comprehension, and adoption rates are all important determinants of the distributional impacts of climate services (Lemos and Dilling 2007). Identifying methods to assess the extent to which climate services address tractable problems, and do so in a way in which benefits targeted users, is something that has not yet been well addressed in the literature (Carr et al. 2019).

3.2 Characteristics, tailoring, and communication of the climate information

The success of a climate service naturally depends on the quality of the climate information that underpins it. But while advances in climate science have allowed climate information providers to extend the limits of predictability beyond the traditional limits of weather forecasting, climate predictions are still far from perfect. Limitations in climate models and uncertainties in the observations that are used to drive them – along with intrinsic unpredictability in the climate system – mean that climate predictions are inherently probabilistic (Slingo and Palmer 2011). The extent to which these efforts have been successful depends on the extent to which the information that underpins it matches users' needs in terms of skill, scale, and lead-time (Stockdale et al. 2010). Efforts to assess the skill of forecasts are found throughout the literature (Duerden 2004; Furman et al. 2011; National Research Council 2006), as are efforts to improve the temporal and spatial scale of forecasts and projections (Hansen et al. 2011; Troccoli 2010; Goddard et al. 2012; Giorgi, Jones, and Asrar 2009). Scientists have also worked hard to improve the lead-time of seasonal forecasts (Livezey and Timofeyeva 2008) though the extent to which a mismatch between lead-time and the decision-making context is assessed is much less documented (Corringham, Westerling, and Morehouse 2008).

The characteristics of the climate information involved are critically important, but not sufficient, to make climate services effective. Indeed, the technical and probabilistic nature of climate information makes it very difficult for non-experts to interpret (Harrison and Williams 2007). As a result, climate information is most effective when tailored to meet recipients' needs in terms of coping strategies, cultural traits, and specific situations (National Research Council 2006). If the information is not appropriately tailored to specific decision contexts, it will not be useful to or usable by decision makers. As a result, it will not be used.

In that regard, assessing the extent to which information is appropriately tailored is important to understanding the efficacy of climate services. Three important aspects of this tailoring process are: the relevance, and perceived relevance of the information; the accessibility of the information (Duerden 2004; Furman et al. 2011); and the distributional impact of various groups, including those who may be more or less well off (Broad, Pfaff, and Glantz 2002).

In the face of climate change, Bettencourt (2011) has also suggested that national planners need to consider what is likely to happen in the future; how these changes will impact key sectors; how much these impacts will cost; and how to prioritize adaptations. While descriptions of future climate certainly play an important part in answering these questions, a host of different kinds of information are also needed. Providing decisions makers with this information will frequently require climate scientists to collaborate with sectoral experts. The extent to which climate services are able to provide information is an important attribute of their effectiveness.

Other aspects that limit effective communication have also been explored. Much of this research draws on social and decision science, particularly where challenges posed by the communication of climate science are typical of challenges faced in other fields with technical content (Brulle, Carmichael, and Jenkins 2012; Kahneman 2013; Pidgeon and Fischhoff 2011). This work has resulted in the identification of several lessons regarding the way that mental models and social processing affect risk perception and the evaluation of response options, particularly with respect to long-term climate change (Marx et al. 2007; Morton et al. 2011; Wong-Parodi, Fischhoff, and Strauss 2014).

Related research has explored models for the communication of uncertainties – both those associated with climate science, and those associated with adaptation and/or other response options (Moser 2010; Patt and Dessai 2005; Patt and Weber 2014; Taylor et al. 2015). This includes the exploration of best practice in the tailoring of climate information for specific audiences (Adams et al. 2015; Jones et al. 2015), particularly with respect to appropriate use of language (Fløttum and Dahl 2012; Nerlich, Koteyko, and Brown 2010), narrative (Lowe et al. 2006; Paschen and Ison 2014), websites (Hewitson and Waagsaether 2016) and visualizations (Daron et al. 2015; Davis, Lowe, and Steffen 2015; Lorenz et al. 2015).

3.3 Governance, process and institutional arrangements

The range of actors involved, and the range of issues that must be addressed, in the development of climate services requires the development of structures that can facilitate interactions between dispersed institutional and administrative mechanisms, projects, and financial resources (World Meteorological Organization 2010). In this context, the structure and governance of a climate service are important determinants of the effectiveness of the service itself (Kruczkiewicz et al. 2018). But despite a few tentative efforts to explore this area, more attention is required to understand the factors that contribute to effective governance of climate services (i.e., Chapter 5).

For instance, while a service built on sustained dialogue between users and providers is generally considered more effective than one that does not include this dialog – there is no guidance on how organizations can work together to create a context for that dialogue (Klenk et al. 2015). Likewise, while it is clear that the perceived objectivity of the process by which the information is shared determines the extent to which users will engage with information (Cash and Buizer 2005), very limited work has considered how to foster that sense of objectivity.

Effective climate service governance may require some measure of intellectual, economic and political independence of the groups generating knowledge. In some cases, it may also require sustained public support. While the range of funding mechanisms underwriting the climate service operations described above is diverse, many rely either on public funds; others rely on project funding and have no permanent source of support. This more precarious situation is seen to limit their effectiveness over time (Bettencourt 2011). Thus, understanding the factors that promote investment in climate services (i.e., Chapter 4) is of critical importance.

The extent to which climate services engage with research is also important (Vaughan et al. 2016; Street 2016). The quality of climate service products is directly dependent on advances made by the fundamental and applied science. As a result, strong ties between climate services and research institutions are essential. This is true both of climate service centres and of climate service activities targeted to specific locations. Financial arrangements – including how to attract and sustain investment in climate services – are also critically important. While there has been very little research on governance and institutional arrangements to date, further work in this area is critical in advancing the utility that climate service provide, and in helping a variety of organizations work efficiently to create and use them.

3.4 Socio-economic value of the climate service

Assessing the effectiveness of a climate service should involve some assessment of its socio-economic value. Building off similar studies with weather information (Katz and Murphy 1997), a significant body of literature has been devoted to economic valuation, particularly with respect to seasonal climate forecasts (Clements, Ray, and Anderson 2013a; Rogers and Tsirkunov 2010; Perrels et al. 2013; Roudier et al. 2016; Hansen et al. 2011; Simelton, Gammelgaard, and Le 2018). Unfortunately, while the notion that climate information is economically valuable has been established, questions of when this information is more or less valuable have been proven harder to resolve (Anderson et al. 2015). Part of the difficulty associated with this is related to challenges of methodology. Determining just how to assess the value of a service is complicated, involving a range of different methodologies for assessing perceived local-level and aggregated impacts (Millner and Washington 2011; Tall, Coulibaly, and Diop 2018). User surveys, case studies, contingent valuation methods, and empirical modelling have been used to assess the economic value of different forecast types, different inputs and decision systems, and environmental and policy contexts (Vaughan et al. 2019).

In addition to the challenge of modelling a complex and unwieldy interaction with many moving parts, scholars who attempt to estimate the value of climate information are challenged by oversimplification (e.g., lack of attention to outcomes that are not easily measured, lack of explicit attention to the distribution of damages and benefits, especially the impacts of catastrophically large negative events on highly vulnerable activities or groups). There are also challenges in incorporating realistic estimates of the imperfect nature of forecast information and the extent to which they are skilful for specific geographic regions, time horizons, and climate parameters. Among other things, to accurately characterize the economic value of climate services, researchers will need to improve present indicators of the concept of skill (Pfaff, Broad, and Glantz 1999). In some cases, scholars side-step the issue of economics and focus on social outcomes (Lowe, García-Díez, et al. 2016; Schwab and von Storch 2017; Braman et al. 2013).

4. Key research priorities

While the general categories of factors that determine the success of climate services are relatively clear, understanding how specific arrangements lead to more or less positive outcomes in different contexts still requires a great deal of research. A recent survey of climate service professionals reveals that among other things, the climate services community has an overarching interest in advancing research that can better connect climate information to users (Vaughan et al. 2016).

To date, research on this connection has focused on barriers to the success of climate services. While this work spans a range of disciplines – exploring a number of issues both social and scientific (Bruno Soares and Dessai 2016; Dilling and Lemos 2011; Flagg and Kirchhoff 2018; Rayner, Lach, and Ingram 2005) – bureaucratic concerns, such as the institutional arrangements and governance of climate services have received limited attention, despite being recognized as important to the production and use of climate information (Vaughan and Dessai 2014). What research does exist in this field remains fragmented, spread throughout disparate case studies and without a coherent framework to organize existing knowledge or to guide future work.

Building the volume and sophistication of this research will require better engaging social science. This includes the development of methodologies that can link climate-related information to particular capacity and vulnerability contexts (Thornton et al. 2006, 2014). The development of such methodologies requires the analysis of a range of social, economic, institutional, technological, ethical, organizational, ecological, and cultural issues related to how societies function, including how they access and use information in decision making. Governance and institutional arrangements are of particular concern, as they structure the way that climate services are conceived, funded, developed, delivered, used, and sustained.

Taking into account the fact that these arrangements naturally look different in different contexts, this thesis pursues three interrelated research activities:

(1) characterizing the current state of climate service practice (Chapter 3);
(2) diagnosing institutional arrangements that support investment in climate services (Chapter 4); and
(3) analysing key features of climate service governance (Chapter 5)

CHAPTER 3: SURVEYING CLIMATE SERVICES

1. Introduction

While Chapter 2 illustrates a growing interest in climate services, there is nevertheless an active debate on what climate services are, where they are most effective, and how they should be designed to best deliver societal benefits. Questions regarding the kinds of information on which climate services should be based, the sorts of problems they can most effectively address, and the institutional arrangements needed to support them continue to consume planning efforts, as the users and providers of climate services engage in a simultaneous and loosely coordinated process of learning by doing.

Some aspects have been more studied than others. Indeed, relatively more attention has been paid toward assessing particular attributes of the climate information itself – including, for instance, the quality of the data that underlies specific services (Bhowmik and Costa 2014; Brunet and Jones 2011; Girvetz et al. 2013; Overpeck et al. 2012) and the verification of climate predictions (Goddard et al. 2012; Hyvärinen et al. 2015; Mason and Chidzambwa 2008), among other things. In the social science realm, efforts have focused on defining the parameters of "usable" science (see for instance, Dilling and Lemos, 2011; Tang and Dessai, 2012); identifying factors that improve the communication of climate information (for example: Lorenz, Dessai, Paavola, and Forster, 2013; Marx et al., 2007; Taylor, Dessai, and Bruine de Bruin, 2015); and in assessing the impact of specific services (see for instance Clements, Ray, and Anderson 2013b; Mills et al. 2016; Thornton 2007).

To date, however, a broad-based review of the existing practice of operational climate services has not yet been attempted (for an overview of commercial investment, see Georgeson, Maslin, and Poessinouw, 2017). The current chapter fills this gap by analysing a unique dataset of more than 100 self-reported descriptions of climate service activities, which were submitted to the Global Framework for Climate Services and the Climate Services Partnership in 2012 (detailed descriptions of the Data and Methods are found in Section 2). In doing so, the chapter creates a snapshot of the state of the field shortly after the implementation of the GFCS

(Results appear in Section 3), allowing for a point of comparison in this evolving field. The chapter also offers observations on what can – and cannot – be learned from this kind of broad sampling activity (this Discussion occurs in Section 4), ending with some Conclusions regarding how best to design future sampling efforts in order to more effectively advance learning (Section 5).

2. Methods

2.1 Data

The chapter draws on the written descriptions of 101 climate services collected independently, though in a coordinated fashion, by the Climate Services Partnership (CSP) and the World Meteorological Organization (WMO) in 2012. Both entities used the same template (see Appendix 1) to solicit self-reported descriptions of climate service activities from within their networks. Both organizations called these "case studies," though the methodology used was an open-ended survey, rather than a social science case study per se. Both described the goal of this activity as identifying good practice.

To faciliate data collection, both entities sent the template to their respective networks. The WMO reached out to all the national meteorological and hydrological services that make up its membership, but also collected case studies from universities, private companies, and other public-sector entities. The CSP – which had itself just launched at the first International Conference on Climate Services (October, 2011) – reached out to its own smaller and more informal network.

When made aware that the same person and/or organization had been contacted by both organizations, the leadership of the GFCS and CSP coordinated regarding the overlap; in some cases, the leadership was not aware of the overlap, resulting in several duplicates between both collections.

There were several differences in the way that the studies were edited for publication. For instance, the CSP case studies are in general longer than the GFCS ones, which reflects the fact that the GFCS documents were collected into a hard-cover publication, while the CSP documents were published online. The structure of the documents is also slightly different, as the CSP editors pressed authors to complete the entire template, while GFCS editors accepted documents that followed the template more loosely.

The WMO categorized its case studies as: agriculture; water; health; disaster risk reduction; energy; ecosystems; transport & infrastructure; urban issues; communities; and capacity development. The CSP categorized its case studies as: agriculture; decision support; disaster risk reduction; ecosystems; education; energy; financial services; food security; health; tourism; urban issues; and water.

These results of this joint activity were published in conjunction with the second International Conference on Climate Services (September 2012) and an extraordinary session of the World Meteorological Congress focused on the implementation of the Global Framework for Climate Services (October 2012), respectively. Though the WMO represents the official coordinating body of the world's governmentally mandated meteorological and hydrological services, both CSP and WMO collections include submissions from public, private and third-sector sources – perhaps reflecting the extent of collaboration between these different kinds of organizations.

While the authors of both CSP and WMO studies responded to the same template to design their responses, some differences in the way the studies were collected, edited for publication, and categorized by the different organizations complicated the combining of data sets. For instance, the responses ranged in length and quality across both collections, with the longest piece nearly 9000 words long and the shortest closer to 1000.

In addition, four climate services are described in both collections. As the goal of our analysis is not to contrast CSP and WMO documents but to use both collections to learn about the practice of climate service design and implementation, we analysed these duplicates together, using information from both texts to create a more comprehensive view of the service in question. As a result, eight CSP/WMO documents were consolidated into four combined studies in our analysis.

Another complication stemmed from the fact that three responses challenged our understanding of "climate services" as defined earlier in this chapter. These were removed entirely from the study, though a more thorough treatment of these cases appears in the Discussion section.

Finally, four studies collected by the WMO provide a general overview of the activities of a project of climate service provider without delving into the details of a particular service. These documents describe broad concepts and goals but do not provide enough detail to answer many of the questions we used in our analysis; as such, these too-broad responses were included in overarching analyses, but left off analyses that addressed more specific questions. A full listing of the 101 climate services included in the analysis is found in Appendix 2.

2.2 Theoretical framing

Our method of analysis follows the climate-service evaluation framework proposed by Vaughan and Dessai (2014). Designed to help guide future work on climate service evaluation, this framework identifies four factors drawn from the literature on the use of seasonal and long-term climate information that influence the benefits and relative success of climate services. These factors are described in the original article and summarized in brief below.

Problem identification and the decision-making context: The contexts in which climate services are provided naturally condition their success. Indeed, in some cases the strongest impediments to the adoption of climate information are contextual or institutional, rather than technical. Conversely, certain situations create opportunities for climate services to be more impactful than others. [For more on this, see for instance (Kenneth Broad and Agrawala 2000;

Millner and Washington 2011)]. Our analysis of the responses explored questions including where and in what sectors climate services are provided and whether or not such services are designed with specific users in mind.

Characteristics, tailoring and dissemination of the climate information: The success of a climate service depends on the quality of the climate information that underpins it; it also depends on the extent that information is appropriately tailored to meet users need and the ability of users to access information in a timely fashion. [See for instance (Furman et al. 2011; Harrison and Williams 2007)]. We analysed studies to identify the timescale of the climate information provided, whether or not the services report information describing the “quality” of the information (i.e., data quality control, forecast verification, etc.), and any contextual information included in the service.

Governance, process and structure of the service: Climate services require the development of structures that can facilitate interactions between dispersed institutional and administrative mechanisms, projects, and financial resources. In this context, the structure and governance of a climate service are important determinants of the effectiveness of the service itself. [For more on this see (Broad, Pfaff, and Glantz, 2002; Lemos, Kirchhoff, and Ramprasad, 2012)]. Our analysis explored the scale on which services are provided, the kinds of actors involved in service provision, the mechanisms by which the service connects to users, and how the services are funded.

Socioeconomic value of the service: Assessing the effectiveness of a climate service should involve some assessment of its economic value and the value it has to individuals or to society writ large. Indeed, benefits from climate services may take many forms and may accrue to the individual, the collective or the natural environment. [For more on this, please see (Clements, Ray, and Anderson 2013a)]. Though none of the documents in the current study identify the economic impact of their services, our analysis reports on those that discuss efforts to evaluate the services in question.

Our analysis used this framework to develop a series of questions (see Table 1) to guide our research regarding the topics addressed by the template (see Appendix 1).

Studies were coded to facilitate the identification and aggregation of information specific to each question. While all documents responded to the same template, the fact that they were self-reported means that there was some variation in both the topics and the level of detail. In some cases, information relevant to our research questions appeared at different places in the document. In other cases, requested information was not explicit in the material; in these cases, we report how many studies reported relevant information before describing the responses themselves.

2.3 Caveats

While the CSP/WMO case study collection represents the most comprehensive detailing of climate service activities to date, it is important to remember that it is a "sample of opportunity" rather than one specifically designed for the purposes of this analysis. This brings with it several caveats, including:

- We cannot assume that the breath of the case study collection reflects a representative sample; since we have no way of knowing how many climate services currently exist, we are not capable of stating whether or not this sample is representative of that larger group.

Table 2: Factors and key questions address by the study

Factors that define the success of climate services	Key questions addressed by the studies
Problem identification, decision-making context	* Where are climate services provided? * What sectors do climate services engage? * What kinds of services are implemented where? * Do climate services engage specific users? * What user organizations do services engage?
Characteristics, tailoring and dissemination of the climate information	* What is the timescale of information provided? * Do climate services measure/report the quality of information? * Do climate services solicit user input on the design of services? * How is information communicated to users?
Governance, process and structure of the service	* On what scale is the service provided? * Who's involved in the service provision? * How do climate services connect to users? * How are climate services funded?
Socioeconomic value of the service	• What evaluation methods are used? * Do studies provide a metric of the economic impact of the service in question?

- We are not able to control for the role that selection bias may play on the case study collection. CSP case studies were collected primarily from CSP members, while the WMO solicited studies from its own network – including, but not limited to its 191 member states – which is likely to have affected the number of case studies received from national meteorological or hydrological services (see, for instance, the discussion on African climate services under "Results).

- We cannot independently verify information included in the studies. Since nearly all documents were reported by people involved in providing the service in question, some may (or may not) exaggerate accomplishments or selectively omit challenges. All documents are likely to highlight the topics the authors found most important, perhaps sacrificing topics of interest to our analysis.

While these caveats are important to consider, they do not impede our ability to draw meaningful insights from the collection as a whole – which, while imperfect, represents a sample of 101 climate service activities in 106 countries and involving 133 different organizations and is the most comprehensive source of information on climate services in the world to date.

3. Results

Our analysis of the 101 responses engages specific questions around the four factors that influence the relative success of climate services.

3.1 Problem identification and decision making context

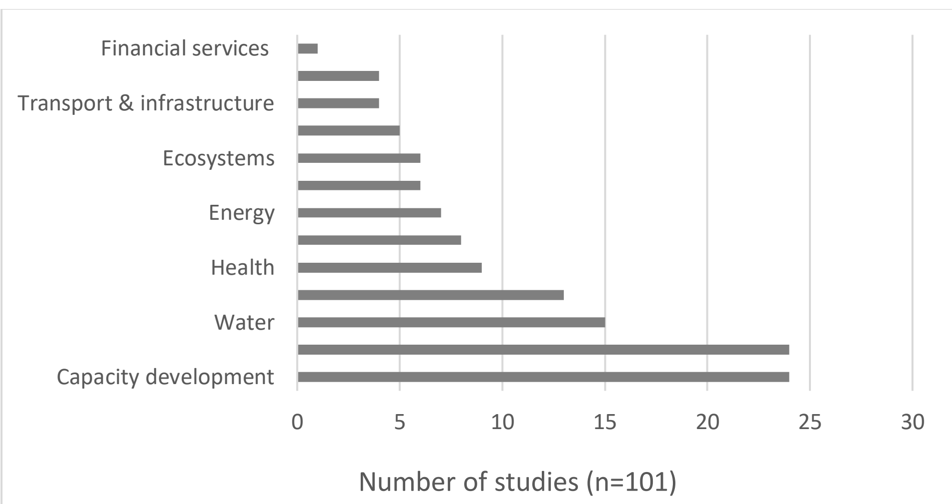
Where are climate services provided? The regional foci of responses are included in Table 3. It is important to note, however, the role that sampling methods may play in these numbers. For instance, the WMO solicited responses from each of its member states, so while there are 26 responses focused on Africa, this must be considered in light of the fact that 53 member states in Africa were asked to submit an example of their work. Conversely, 28 case studies were submitted from the area that constitutes WMO Region II (Asia), which comprises 35 member states. In some cases, international organizations submitted studies that cover more than one country or region; as a result, the sum of the number of regions studied exceeds the total number of studies themselves. Nine climate services are considered to be global in scope.

Table 3: Regional focus of studies (n=101)

WMO Region	Number of Studies	Number of WMO Member States	Relative representation
Africa (I)	26	53	49%
Asia (II)	28	35	80%
South America (III)	8	12	67%
North America, Central America, Caribbean (IV)	11	20	55%
South-West Pacific (V)	7	19	37%
Europe (VI)	20	49	41%
Global	9	-	-

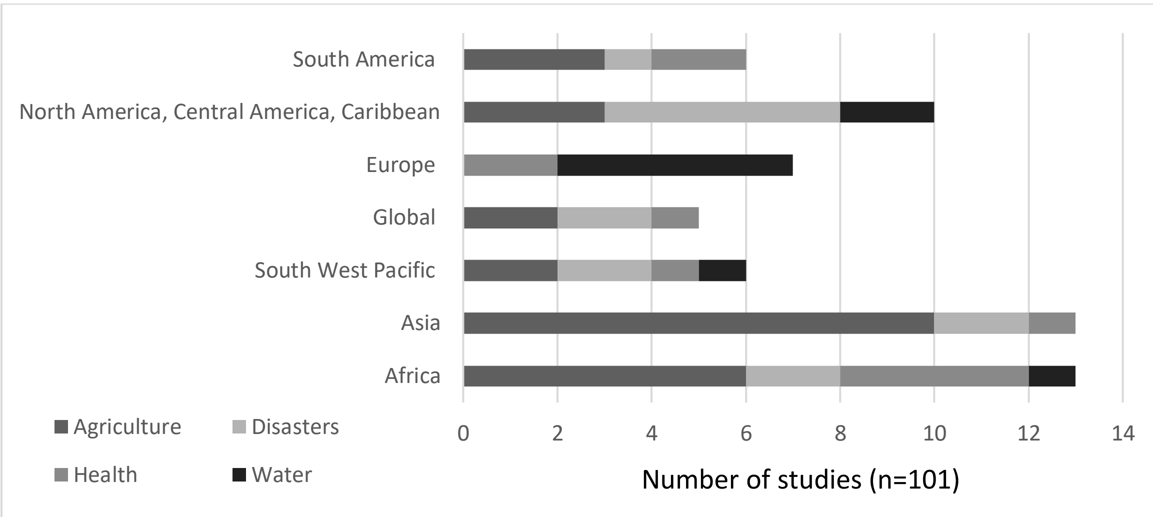
What sectors do climate services engage? As illustrated in Figure 2, the most commonly engaged sectors include agriculture (24), water (15), disasters (13), and health (9). A description of the 24 studies that are classified as pertaining to "capacity development" is included in the Discussion session. Roughly one-third of the case studies were assigned to more than one category – engaging, for instance, water and capacity building, or agriculture and ecosystems.

Figure 2: Thematic focus of survey studies



What kinds of services are implemented where? To get a sense of whether some sectors are more actively engaged in certain locations, we compared regions and sectors, revealing that the responses that engaged with agriculture were more common in Africa and Asia than in Australia, Europe or North America. Water-related case studies were most commonly drawn from Europe, including, for instance, analyses of the impact of climate change on the Nieman and Danube rivers (ICPDR 2012; Korneev 2012). More details are found in Figure 3, below.

Figure 4: Regional vs. thematic focus of survey studies



We also looked to see if services were more likely to be provided at certain scales in certain regions. The region including North America shows more sub-national services than national services – perhaps reflecting services that cater to regions within the relatively large countries of the US and Canada – while Europe has more national and regional services and only one sub-national service (Table 4).

Do climate services engage specific users? To help explicate the extent to which existing climate services were targeted to specific problems and/or how these problems were understood, we analysed the number of responses that mentioned specific users. We considered studies as targeted to users whether these groups included specific organizations or broad groups (for instance, “farmers,” “disaster risk managers,” etc.). We found that 50 of the 101 cases mentioned users in this way. Of this group, 48 discussed involving users in the development of the service in any capacity. Users include both individuals (e.g., specific farmers, humanitarian workers, disaster managers, extension agents) and organizations (planning ministries, railway companies); seven case studies also appeal to the general public (e.g., the Health Heat Warning System).

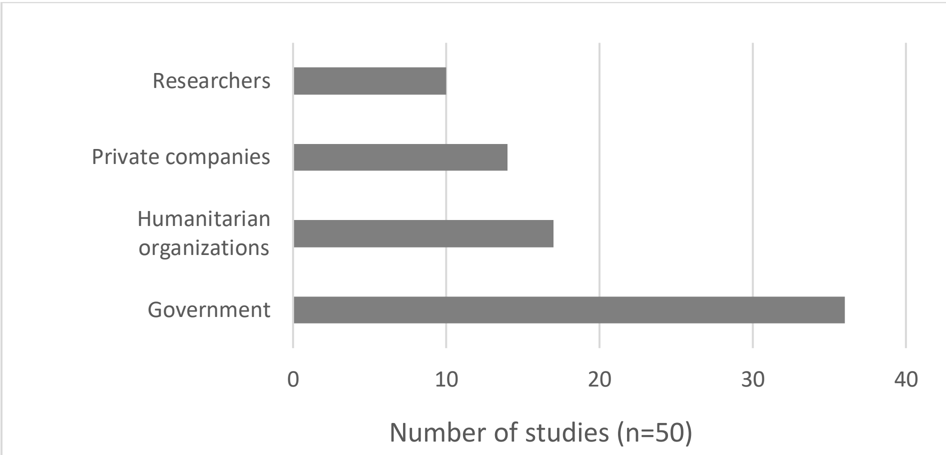
Table 4: Scale of service by region (n=72)

WMO Region	Regional	National	Sub-National
Africa (I)	9	11	3
Asia (II)	6	5	5
South America (III)	1	6	3
North America, Central America, Caribbean (IV)	1	4	6
South-West Pacific (V)	1	6	0
Europe (VI)	5	7	1
	23 (23)	39 (39)	18 (18)

When possible, we also considered the decisions that the service was intended to inform. These range considerably, but include those related to farm management (e.g., planting, seed selection, harvest, etc.); disaster risk reduction (including preparedness and prevention); and transport (planning and infrastructure investment). Cases that directly mention users are roughly five times as likely to operate at sub-national than at global scales. Twelve cases report operating at more than one scale.

What kinds of user organizations do services engage? The data allows us to describe the specific user organizations mentioned in the studies, the majority of which include government offices (36), humanitarian organizations (17), private companies (14), and researchers (10), among others. More information on user types is found in Figure 4, below.

Figure 4: User organizations of survey studies



3.2 Characteristics, tailoring, and communication of climate information

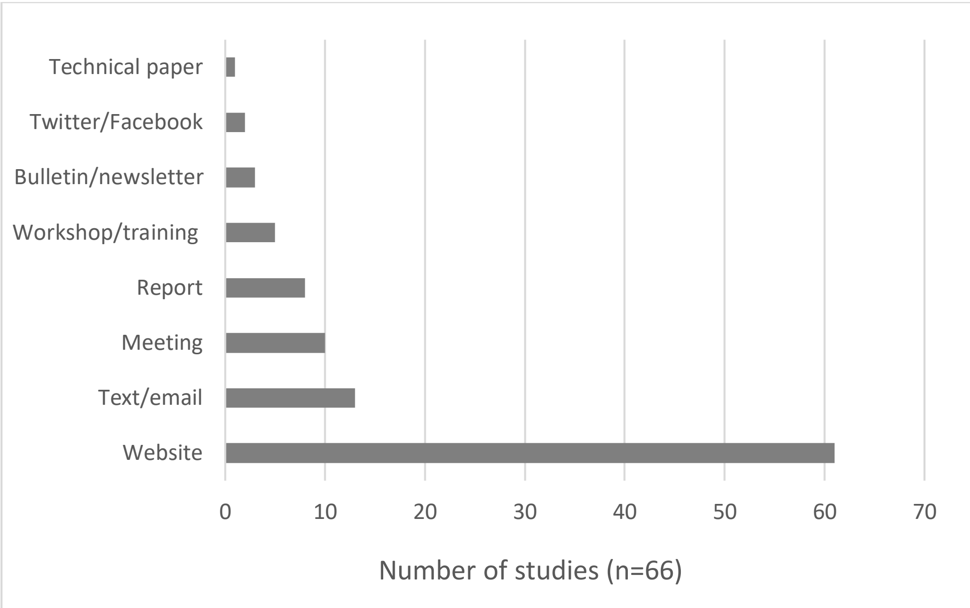
What is the timescale of information provided? For those studies that included this type of information (83/101), seasonal information was by far the most prevalent, though weather and long-term information was also used by nearly 30% of studies as well. More details are found in Table 5, below.

Table 5: Timescale of climate information (n=83)

Timescale	Definition	# of studies
Seasonal	three to six months	56
Weather	one day to two weeks in the future	25
Long-term	several decades to centuries in the future	23
Historical	past observations	10
Monitoring	current conditions	7
Decadal	one year to several decades in the future	5

Do climate services measure/report the quality of their information? While the quality of information was not explicitly addressed by the case study template, we have attempted to characterize the extent to which case studies discussed the quality of information in several ways. For instance, 10 case studies in the collection mention the verification of their forecasts. Another 22 mention the quality control of data that goes into their analysis.

Figure 5: Provision method used by survey studies



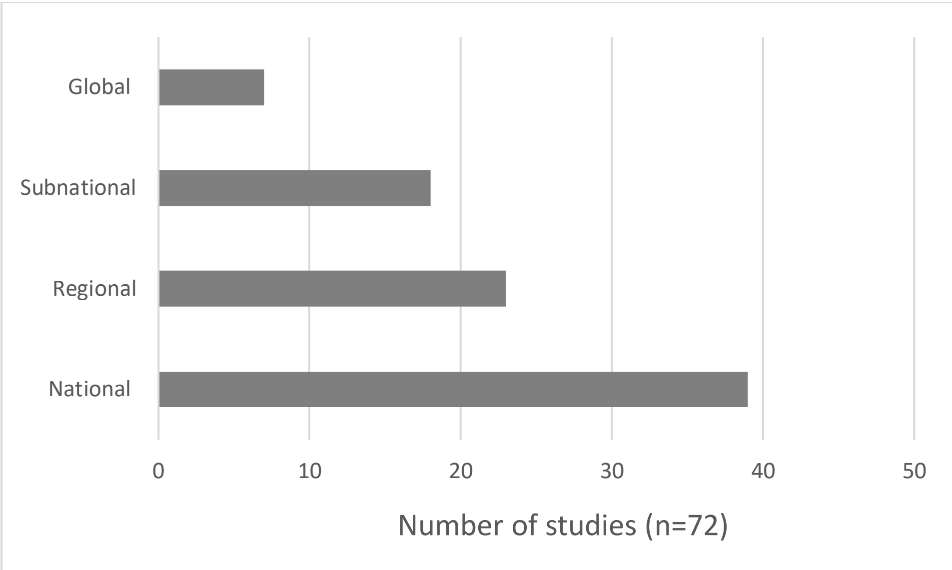
Do climate services solicit user input to design the services? It was not possible to develop quantitative measures of information tailoring; we did, however, count 48 case studies that specifically discussed user engagement in the development of the service, soliciting input through workshops, consultation, or surveys.

How is information communicated to potential users? For those that provided this information (66/101), websites were far and away the most prominent mode of information provision. More information is found in Figure 5.

3.3 Governance, process and structure of the service

On what scale is the service provided? As illustrated in Figure 6, more services operate on national scales (39) than on regional (23) or subnational (18) scales. Seven of the documents mention services that provide information on a global scale.

Figure 6: Geographic scale of surveyed service



Who is involved in the service provision? We used the organizational affiliation of the authors of the submitted documents as a proxy for those organizations involved in the service provision. For the most part, this includes research institutes (52 out of 132 named organizations) and meteorological agencies (34 out of 132). Universities (20/132) and humanitarian organizations (11/132) also have a sizeable presence in the list of organizations that contributed to the collection.

How do climate services connect to users? The connection between climate service users and providers is described in an earlier section on problem identification. Of course, this is also a governance issue, as climate services must create a context for sustained interaction between users and providers; as mentioned above, only 50 of the 101 studies mention specific connection with users. We are also able to characterize the extent to which the studies describe the processes by which providers stay in contact with users even after the service has launched. For instance, 14 case studies suggest they solicit ad hoc feedback from users, while another 10 mention consultation workshops that help the providers to understand how information is used.

How are climate services funded? The case study collection provides a general sense of the funding models that currently support climate services. For instance, of the 42 case studies that describe the funding schemes that support the services in question, 25 are funded by the national government receiving the service; another 23 are donor funded on a project basis. Only 11 of the services in question describe their funding as “sustainable”; eight are able to operate on little or no funding, primarily by piecing together budgets associated with existing activities that benefit from climate services.

3.4 Socioeconomic value of the service

What evaluation methods are used? The case study template specifically asked authors to describe mechanisms for evaluation. Of the 37 that do so, 10 describe forecast verification, a method of evaluating the quality of the forecast itself; another 10 describe consultation workshops by which climate service providers receive user feedback. Fourteen case studies say the climate service providers receive this feedback in an informal ad hoc fashion; another nine use surveys. Two case studies describe independent evaluators contracted to assess the extent to which the service contributed to project goals; several studies mention website statistics as a valuable source of information regarding how many people are using the service.

No studies mention efforts to economically value the climate service, though it seems likely that authors would have reported information on this type of evaluation were it available.

4. Discussion

Analysis of this unique dataset has allowed us to make several observations about the state of climate service implementation in 2012, including the extent to which certain practices were common to services around the world.

The dataset confirms, for instance, that climate services were provided in all regions and in a range of different sectors – though there were relatively more services that engaged sectors including agriculture, water, disasters, and health than other sectors (e.g., energy, transport, etc.). Services based on seasonal climate information were more common than those based on other types of information. Nearly half the climate services in question are targeted to government offices, though services were also targeted to the private (18%) and third sectors (22%) in roughly equal numbers. The majority of climate services are provided on websites.

The dataset also allows us to make several overarching observations about the state of the field – identifying the faint outline of what could be called a typical climate service (4.1), while also revealing the relatively inchoate nature of the field (4.2). Ways to improve this overview, and our analysis of it, are also considered (4.3). This includes topics that were not included in the original studies but merit attention in future such surveys.

4.1 A typical climate service

Based on the frequency with which certain characteristics appear in the dataset, we surmise that in 2012, a "typical" climate service was provided by a national meteorological service – frequently in conjunction with a research institute – and that it operated on a national scale to provide seasonal climate information (paired, perhaps, with weather forecasts and/or long-term climate information) to agricultural decision makers online.

It is possible that our sample – and thus our characterization of a typical climate service – was influenced by the entities that requested the studies: For instance, given the direct communication with the World Meteorological Organization, national-level climate service providers may be somewhat overrepresented in our study. On the other hand, the fact that much of the world's climate data is in the hands of national meteorological agencies ensures these actors will be heavily involved in the production, dissemination and distribution of climate services for years to come (Daly and Dessai 2018; Gerlak and Greene 2019; Mahon et al. 2019; Overpeck et al. 2011).

Other aspects of this characterization of a "typical service" are consistent with the literature – including the relative focus on seasonal forecasting (Bruno Soares, Daly, and Dessai 2018; Bruno

Soares and Dessai 2016; Clements, Ray, and Anderson 2013b; Dilling and Lemos 2011; Vaughan et al. 2019). The field of seasonal climate prediction is more advanced than that of decadal or long-term forecasting (though not more advanced than monitoring or observations) and there is also a relatively extensive literature on the use of seasonal forecasts for decision making. In some cases, this literature has been used as an analogue to understand information uptake, indicating the extent to which scholars and service providers have focused on the use of information at this scale, particularly following the 1997/1998 El Niño (Adger et al 2003; Lemos et al 2003).

The focus on agriculture also seems borne out by other types of information. Indeed, 63% of respondents to a recent survey on research priorities for climate services identified climate services for agriculture as most developed, when compared to other sectors including water, health, financial services, and disaster risk management (Vaughan et al. 2016). It is likely this is due in part to the directness of the connection between climate variability and the impacts of human welfare: Whereas health-related climate impacts are frequently moderated by disease vectors (for instance, mosquitos), the impacts of climate on agriculture track basic climatological factors, including rainfall and temperature. This direct connection made it easier for people to observe, understand, and respond to climate fluctuations over centuries, leading to a more developed understanding of how climate information can link to decision making.

In this context, the relatively well-developed field of agro-meteorology also means that there is a trained cadre of professionals and extension officers able to interpret and employ climate information in agricultural decision-making (Sivakumar, Gommes, and Baier 2000); while hydro-meteorologists perform the same function in the water sector, there is no corollary for health or disaster managers. These experts bolster the capacity of the sector to absorb and act on climate information.

It is important to note that our perspective regarding a "typical" climate service is based on a tabulation of the most common characteristics across a number of different categories. In this sense, it does not mean that a majority of the cases in the collection describe national-level agricultural climate services that provide users with seasonal information over the web. On the other hand, it is not difficult to identify cases within the collection whose services match this archetype exactly.

In Ethiopia, for instance, the National Meteorological Agency uses the Enhancing National Climate Services (ENACTS) initiative to integrate local observations and global monitoring data, and provides information to agricultural and other users, through online map rooms (Figure 6) (Dinku and Sharoff, 2012). Another example is found in Chile's Agroclimate Outlook (Figure 7), a monthly bulletin produced by the Dirreción Meteorológica de Chile (DMC) and made freely available in the organization's website. It contains information about the predicted seasonal climate conditions that are most likely to prevail during the next three months (Quintana, Piuzzi and Carrasco, 2012). Both of these cases represent the model of a "typical" service as identified by this study.

4.2 An emerging field

While the studies in question more frequently target agricultural than users in other sectors, our analysis makes it clear that as of 2012, the field was still emerging – marked by contested definitions, an emphasis on capacity development, uneven progress toward co-production, uncertain funding streams, and a lack of evaluation activities.

Contested definitions. One indication of the emergent nature of the field in 2012 is the fact that the World Meteorological Organization used a rather broad scope for incorporating studies in their own collection, even to the point of including several studies that do not meet most traditional definitions of climate services. Indeed, two of these studies describe new methods to collect information about the climate system, rather than efforts to tailor that information to specific decisions. A third describes a low-carbon growth service that helps businesses understand how they may reduce their greenhouse gas emissions.

The services in these studies are not just very different from each other; they are also clearly at odds with the WMO definition of climate services, expressed on the website in this way: "Climate services provide climate information in a way that assists decision making by individuals and organizations"(www.gfcs-climate.org). That these services were included in the WMO case study collection seems to reflect the contested nature of a term whose meaning was still being debated; as the field has developed, it seems unlikely such services would be included if this kind of activity were conducted today.

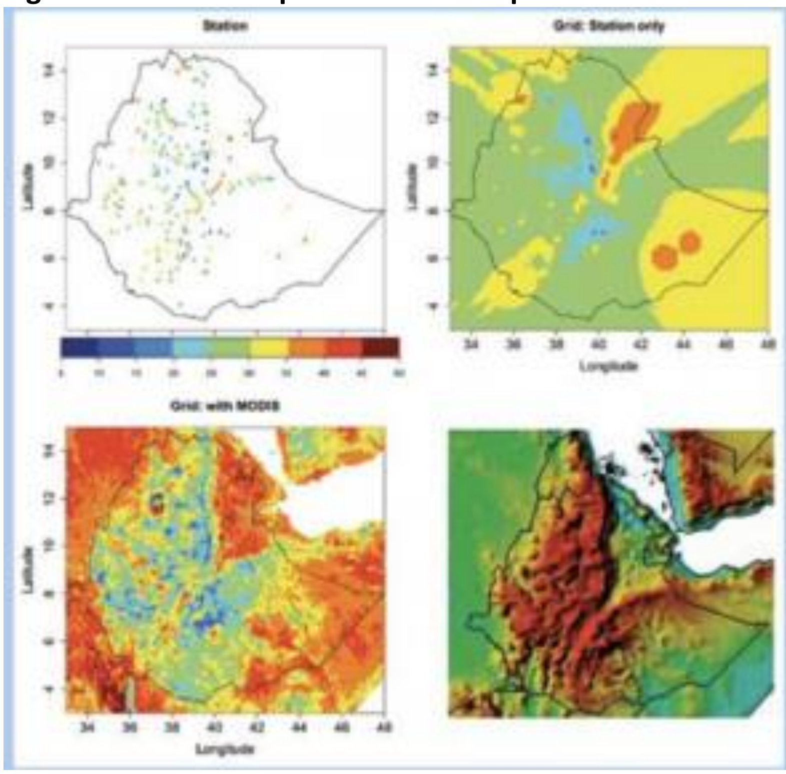
It is curious as well to note the inclusion of 25 services that are based, at least in part, on weather information. As information at this timescale is not traditionally considered to be part of a "climate" service, it may reflect the extent of the studies collected from operational weather service providers who were engaged, more or less, in business-as-usual activities. Conversely, this prevalence of services based on weather information may reflect the beginning of an evolution toward seamless services, providing information at timescales from days to decades.

Though a number of organizations now offer official definitions of the term "climate services" (e.g., European Comission 2015) it is likely that our general sense of what counts as a climate service, and what does not, will continue to remain fluid for some time (Hulme 2009).

Emphasis on capacity development. Another indication of the emerging nature of climate services in 2012 is the relative emphasis on capacity development within the dataset.

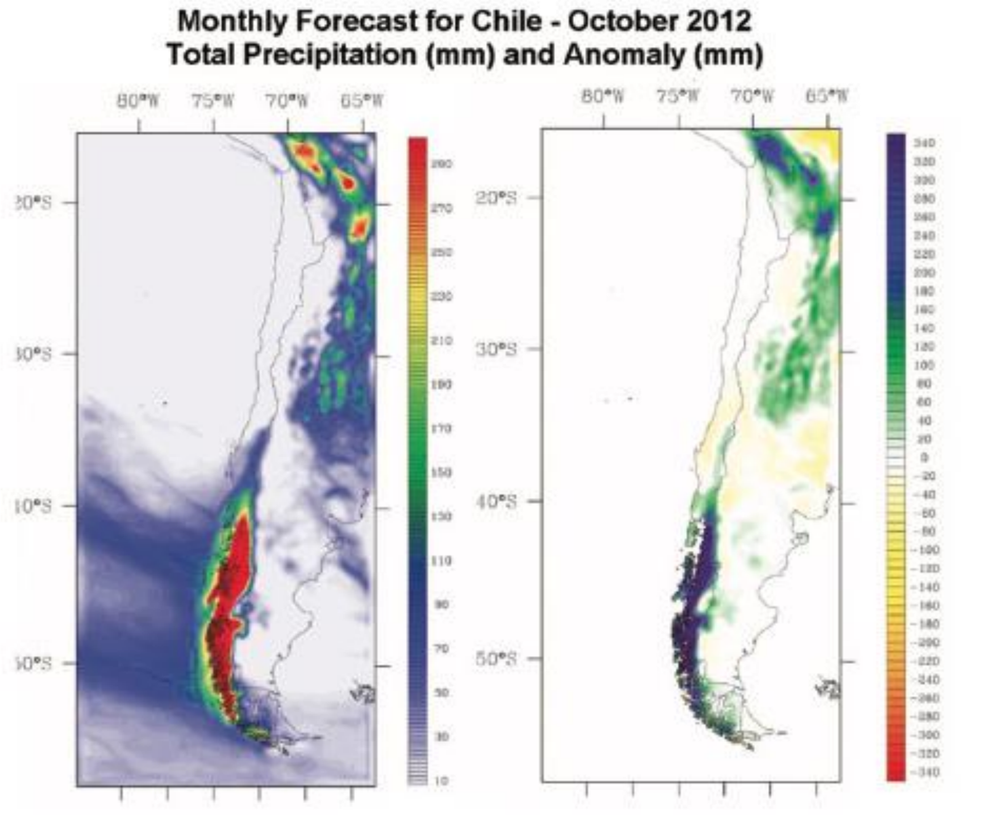
This focus squares well with the priorities of the Global Framework for Climate Services, which explicitly includes capacity development as one of the "five pillars" of the framework. As articulated in the Capacity Development Annex to the GFCS Implementation Plan, the GFCS specifically seeks to develop the human resources needed to advance the other four pillars of the framework, which include: observations and monitoring; research, modelling, and prediction; climate services information system; and the user interface platform (WMO 2014).

Figure 7: ENACTS map rooms for Ethiopia



Graphic is taken from a CSP case study which describes the ENACTS information product for Ethiopia. Graphics show maximum temperature for the second 10-day period in April 2000. The top-left panel is station data, while the top-right panel is interpolated station data. The bottom-left panel is station data combined with 10-day period averages of MODIS LST and elevation. The bottom-right panel has included topography for reference (Dinku and Sharoff 2012).

Figure 8: Agroclimatic Outlook in Chile



A GFCS case study describes the Agroclimatic Outlook for Chile. The graphic shows a climate forecast for precipitation accumulation for October 2012, using Climate Mesoscale Model (version 5) (Quintana, Piuzzi, and Carrasco 2012)

The GFCS also strives to bolster the basic requirements (including national policies/legislation, institutions, infrastructure and personnel) needed to enable GFCS-related activities to occur.

In this context, it is interesting to note that the 24 documents in this dataset that deal with capacity development fall roughly into three categories, including those that seek to build capacity by training individuals, mostly with respect to the analysis or use of climate information; those that make climate data and/or information available to researchers and decision makers; and those that seek to build and/or strengthen the institutions that produce or use climate services. These do not necessarily map well to the five pillars of the GFCS, meaning that some GFCS-priority topics (e.g., observations and monitoring, and some aspects of the user interface platform) were not being addressed. Reviewing the extent to which capacity building activities have and continue to evolve since 2012 will help to gauge the extent these efforts have fallen in line with GFCS priorities.

Uneven progress toward co-production. As noted above, a growing literature has sprung up around climate services, particularly involving the use of seasonal forecasting. The literature seems to converge around the need to engage users in the "co-production" of climate services in order to ensure that products are useful, useable, and used (Lemos, Kirchhoff, and Ramprasad 2012; McNie 2007; Roncoli et al. 2009; Ziervogel and Downing 2004). While the importance of "co-production" is certainly reflected in the collected documents, the interpretation of this term is relatively irregular.

There are, for instance, several case studies that detail extensive efforts to communicate with users regarding climate information needs. One such case study describes the efforts of the Australian Bureau of Meteorology to solicit and incorporate user feedback into the presentation and dissemination of their seasonal climate outlook. This process – which included targeted interviews, a survey, focus groups, and user testing – provided the BoM with a better understanding of how their users understand and employ seasonal climate information; it also afforded users the opportunity to advance their understanding of and confidence in the seasonal climate outlook itself (Boulton, Watkins, and Perry 2012).

While this example seems to reflect good practice as reflected by the literature on user engagement (e.g., Lemos and Morehouse, 2005; Steynor et al 2016), more than half the case studies in the collection did not mention specific users, nor the process by which those users were incorporated into the development of the service. This seems to reflect rather uneven progress toward the co-production of climate services, with some services exemplifying the demand-driven principles and many others retaining the “loading dock” approach (Cash, Borck, and Patt 2006).

Uncertain funding streams. Another observation can be made regarding the funding streams on which climate services depend. While the documents describe funding to support climate services as coming primarily from national governments (25) and donor organizations (23), only 11 of the case studies describe the funding that supports the service as sustainable. Other services relied on project funding and have sometimes had to scramble for funding to support continued operations.

This was true of even relatively long-running services, including the West African Regional Climate Outlook Forum (PRESAO), which began in 1998 but had not yet been institutionalized with funding from regional budgets. The PRESAO case study in particular makes clear that financial sustainability will rely heavily on the development of documents that illustrate the economic value of this sort of climate services and to policymakers and donors (Kadi 2012). This was echoed by those who saw sustainable funding as one of the main challenges to the Regional Climate Outlook Forum process (Ogallo et al. 2008).

Dearth of evaluation activities. No case studies explored the economic value of their service or mention attempts to do so, reflecting logistical and theoretical challenges to economic valuation that have been discussed elsewhere (Anderson et al. 2015; Clements, Ray, and Anderson 2013b; Lazo et al. 2009). Those studies that have engaged in evaluation relied mostly on the ad hoc feedback of users' groups with whom they are in regular contact and/or slightly more formal processes, including surveys and user workshops. These processes provide the climate service provider with a better understanding of the users' needs and capability, in the interest of co-production, but do not advance the work of assessing priorities or informing investment decisions; this lack of evaluation represents a major gap in practice at the time the case studies were collected.

4.3 Improving upon our bird's eye view

We used the collected documents to provide a birds-eye view of the state of the field of climate services in 2012. But while the analysis offers a reasonable snapshot of climate services in 2012, it is important to note how difficult it is to use these cases to identify "good practice" in the way that those who solicited the studies may have liked. Indeed, because these studies are self-reported, primarily from the point of view of the climate service provider, it is relatively hard to get a sense of which services were more or less successful, or why; authors were not incentivized to be forthcoming regarding challenges or failures and there is little objective evaluation to refer to. Furthermore, it is difficult to use the studies to understand the users' experience of the services, or the extent to which individual climate services and/or climate services in general are able to improve social and economic well-being.

This is unfortunate given that the documents were dubbed "case studies" by the coordinating organizations – and case study research is uniquely suited to addressing these kinds of detailed questions. Indeed, the case study approach can be particularly useful in documenting specific practice and experiences; in identifying causal links between interventions and outcomes; and in enlightening situations in which an intervention has no clear, or clearly defined, set of outcomes (Yin 2014). Case studies are also valuable in developing and elaborating theory, which creates opportunities for the sort of analytic generalization that could shed empirical light on current hunches regarding what constitutes good practice in climate services development and delivery (Ford et al. 2010).

That the 2012 collection does not lend itself to this kind of analytic generalization calls attention to the need to shift focus regarding the development of such case studies moving forward. In setting priorities for further efforts, two items that deserve particular attention include: (1) a focus on analysis in addition to sampling; and (2) a focus on efforts to evaluate the relative contribution of specific climate services. More on each of these items are described below.

Sampling versus analysis. A primary goal of the 2012 data collection activity was to capture the breadth and depth of climate services that were being offered at the time. Since the effort coincided roughly with the launch of the Climate Services Partnership and the implementation of the Global Framework for Climate Services, this kind of sampling activity was interesting to the sponsoring organizations, both of whom were motivated to document and learn about contemporary practice to support larger efforts to advocate for climate service development around the world.

Capturing the breadth of activity in this field is still a worthy goal, of course, though it does not necessarily have to be carried out through case studies. Indeed, the GFCS Compendium of Projects, which lists GFCS projects that meet certain basic criteria, makes a good start in sampling current efforts. To the extent that it is able to facilitate easy monitoring of key indicators (e.g., target sector, timescale of information, provision method, user groups, etc.), this kind of sample could allow researchers, practitioners, and the donor community to maintain a general overview of the climate services community as it evolves over time.[1] Similar efforts are organized by the European Joint Programming Initiative "Connecting Climate

1 While the compendium is an important contribution, we must also note that it currently falls short in describing both the breadth and depth of climate services. Indeed, the compendium describes just the scope, objectives, activities, benefits, and deliverables of just 40 GFCS projects, with another 10 “contributing” that projects not funded through the GFCS included on the website. This results in a partial picture of a small-subset of activities. Bolstering this activity (by including for instance, information on quality control measures, modes of communication, the scale of services provided, and the sustainability of services, etc.) should be an important priority moving forward.

Knowledge for Europe" (Monfray and Bley 2016) where the mapping of climate service providers has been undertaken for a few European countries (e.g., Manez, Zolch, and Cortekar (2014) for Germany; and Goransson and Rummukainen (2014) for the Netherlands and Sweden).

This sort of overview can also fuel the development of hypotheses that can be investigated through the production of case studies that are exploratory and/or explanatory in nature – using such studies to develop and hone hypotheses for further inquiry, and to explain the causal links between specific interventions and the ultimate outcomes. Building off existing work (Hellmuth et al. 2009, 2011; Hellmuth, Moorhead, and Williams 2007), this sort of effort would employ multiple-case research methods that could advance the identification and refinement of principles, improving our understanding of the forces and factors that limit the applicability of such principles in certain situations.

To this end, case study researchers will need to greatly expand the range of topics they explore – moving beyond efforts to document climate services in specific regions or sectors, to engage with thornier issues (e.g., ethics, institutional arrangements, sustainability, etc.). Case study authors will also need to pay careful attention to concerns of validity and reliability in order to avoid common criticisms of case studies as anecdotes from which it is impossible to generalize (Bennett and Elman 2006; Flyvbjerg 2006). Case study authors may also make efforts to perform analyses that are similar with regards to the questions explored and the methodologies used by other authors; in this sense, the field will begin to develop a host of case studies that can undergo specific meta-analyses allowing us to learn more about the implementation of climate services in different contexts.

The development of a priority list of these hypotheses and methodologies is something that climate services coordinating bodies may like to take up. At the very least, the current analysis suggests that topics regarding capacity development, co-production, funding, and evaluation should be included.

Case studies and climate service evaluation. The case study collection highlights several challenges related to evaluation. First, the fact that the case studies were all self-reported makes it very difficult to use them to impartially assess the services in question. At the same time, the content of the case studies underscores just how few climate services are engaged in any kind of formal evaluation – relying, at best, on informal communication with users to gather feedback on information needs as well as on current and planned activities.

Of course, this reflects a challenge of resources as evaluative activities require dedicated efforts. It is clear, however, that the climate services community will need to prioritize the development of formal monitoring and evaluation protocols, and the involvement of independent evaluators. Without a strong push to improve evaluation, the community will struggle to justify its own efforts to improve service development and delivery; it will be challenged as well in attracting and sustaining funding from public and private sector actors interested to get the most out of their investment (Anderson et al. 2015; Bruno Soares, Daly, and Dessai 2018; Lazo et al. 2009; Vaughan et al. 2019).

This is especially true with regards to economic valuation, which can describe the return on investment from climate services in different contexts, and regarding the extent of uptake and use of climate services (Clements, Ray, and Anderson 2013b; Meza, Hansen, and Osgood 2008; Vogel et al. 2014). At the same time, answering questions regarding good practice will involve assessing the extent to which services are operating effectively along all aspects of the value chain (Tall, Coulibaly, and Diop 2018b; Vaughan, Muth, and Brown 2019). Tying the evaluation of information use and/or economic outcomes to long-term monitoring and evaluation activities can help to illustrate the relative contribution of certain practices.

Indeed, while climate service evaluators should avail themselves of the full suite of evaluation methodologies, the role of case studies in evaluation bears special mention in this chapter. In contrast to survey or quasi-experimental methods, case studies are able to capture the complexity of services, and of the contexts in which they operate, making them particularly well suited to identify strengths and weaknesses, or to explain previously identified causal links, in this emerging field (Rogers 2000). Case studies are also useful in providing initial feedback in cases in which climate services take years to develop or in which the impacts of information use are expected to develop over long periods of time.

5 Summary and conclusion

This chapter analyses a unique dataset comprising the self-reported descriptions of 101 climate service activities, collected separately but in a coordinated fashion by the Climate Services Partnership and the World Meteorological Organization, in 2012.

The dataset provides a birds-eye view of the emerging field of climate services as it was in 2012, confirming that climate services were provided in all regions and in a range of different sectors – and that services that engaged agriculture, water, disasters, and health were relatively more common than those that engaged other sectors (e.g., energy, transport, etc.). Services based on seasonal climate information were found to be significantly more common than those based on other types of information, although a range of other timescales (historical, monitoring, weather, decadal, long-term) were also included in the study. While nearly half the climate services in question were targeted to government offices, services were also targeted to the private (18%) and third sectors (22%) in relatively equal numbers.

The dataset reflects a diversity of climate services – but it also allows for the identification of certain attributes that were more common than others. For instance, the most common type of service reported involved seasonal climate information provided by national meteorological services, in conjunction with research institutes, to agricultural actors over the Internet. A large number of case studies also dealt with capacity building, either through individual education, the development of information portals, and the bolstering of institutions involved in the production and or use of climate services.

The prevalence of case studies focused on capacity building illustrates the extent to which climate services were still an emerging field in 2012; other factors that seem to confirm this characterization include the fact that several case studies did not match the definitions of climate services provided by the World Meteorological Organization, and the fact that many case studies did not discuss specific users (Lourenco et al 2016) but rather focused on the supply-driven provision of climate information. In addition, very few climate services maintained sustainable funding streams; even fewer evaluated their progress.

While a number of caveats limit the utility of the 2012 dataset, it remains the most comprehensive source of information on climate services in the world to date and is thus useful in providing a snapshot of the state of the field at the time the GFCS was implemented. It will be important to continue to survey the field of climate services with respect to these factors in order to develop a picture of how the field is changing – particularly as new methods, new information, and new investments change the way that climate services are designed, developed, and delivered. Other topics, including methods to diagnose climate information needs and prioritize service development, should also be monitored as the field develops.

Importantly, while the caveats mentioned above do not impede our ability to draw meaningful conclusions from the case study collection as a whole, but they do highlight the challenge inherent to efforts to keep an account of progress in this rapidly changing field. Efforts to sample climate services, such as the GFCS Compendium of Projects, will need to be expanded, and kept up to date, if researchers are to be able track changes to the climate service community as a whole and keep tabs on the extent to which such services contribute to society's efforts to adapt to climate variability and change. Other perspectives – including, for instance, Harjanne (2017)'s analysis of the institutional logics of climate services as derived from articles published in the Bulletin of the World Meteorological Organization – can offer additional perspective on the changing field.

It is important to note as well that while the current dataset is useful in providing a historical overview of the field in 2012, it is less useful in providing a sense of good practice. To advance this discussion, case studies will need to move past a simple accounting of practice to explore and explain current strengths and weaknesses of climate services from a more theoretical perspective. To this end, case studies should develop hypotheses for future inquiry, and explain causal links between particular interventions and ultimate outcomes. Case studies also have a key role to play in climate service evaluation, complementing experimental and quasi-experimental methods, and supplementing them in cases in which such methods may be inappropriate or premature.

CHAPTER 4: AN ENABLING ENVIRONMENT FOR INVESTMENT IN CLIMATE SERVICES

1. Introduction

While society has always struggled to manage climate-related risk, increased vulnerability and the spectre of climate change have stimulated recent investment in climate services (Hewitt, Mason, and Walland 2012). Often provided in the form of tools, websites, and/or bulletins, climate services involve the timely production, translation, transfer and use of climate information for societal decision-making; they are increasingly seen as critical to improving the capacity of individuals, businesses, and governments to adapt to climate change and variability (Vaughan and Dessai 2014).

Investment in climate service development varies widely across the globe; some countries have well-developed climate services while others have very few or even none (Hewitt, Mason, and Walland 2012; Brasseur and Gallardo 2016). A number of factors are thought to contribute to this – including the economic development of the country, its relative climate exposure, and the predictability of the climate system in that area (Stern and Easterling 1999). While it is clear that these factors are important, it is equally clear that these are not the only determinants of investment, and that a host of other considerations help to shape climate service investment decisions as well.

One factor that appears to have stymied investment in climate services is the relative dearth of information regarding the economic impact of climate services; without estimates of the value of climate information in particular contexts, governments and the private sector have found it difficult to invest beyond the pilot level (Anderson et al. 2015; Clements, Ray, and Anderson 2013b). To remedy this, a growing cadre of researchers has dedicated considerable effort to understanding the value of climate services in socio-economic terms, albeit with somewhat mixed results (Anderson et al. 2015; von Gruenigen, Willems, and Frei 2014; Lazo, Raucher, and Weiher 2008; Perrels, Nurmi, and Nurmi 2012; Solís and Letson 2013).

While this field continues to grow, less attention has focused on the institutional and policy factors that shape investments in climate services. This stands in contrast to a relatively robust literature on the role that such factors have played in influencing climate change adaptation more broadly (Biesbroek et al. 2009; Eisenack et al. 2014; Ioris, Irigaray, and Girard 2014; Moser and Ekstrom 2010). In many cases, this work has involved explicating the notion of "adaptive capacity," in such a way as to characterize the barriers and enabling factors that affect adaptation action (Ford, Knight, and Pearce 2013; Grothmann et al. 2013; Williamson, Hesseln, and Johnston 2012).

While this work has been useful in helping to identify the contexts in which investments in adaptation are likely to take place, it does little to illuminate the factors that lead countries to invest in climate services per se. Distinguishing the factors that enable investments of this nature is an important step in advancing our understanding of adaptation readiness (Ford and King 2015); it is even more critical in advancing the field of climate services, where such knowledge can inform the planning and investment strategies of local, national, and international actors.

This chapter addresses this gap by assessing the drivers of investment in climate services within a nation. Semi-structured interviews were used to identify several factors that contributed to the decision to invest in and develop a national-level climate service for the agricultural sector in Uruguay. The climate service itself, Uruguay's National Agricultural Information System (Sistema Nacional de Información Agropecuaria, known as the SNIA for its Spanish-language acronym), as well as the context in which it was developed, are described in section 2. Section 3 provides an overview of our study methods, before results and analysis are presented in section 4. A discussion of the potential implications for the study of other contexts in which climate services may be developed is included in section 5. Conclusions are found in section 6.

1.1. Uruguay's National Agricultural Information System

The SNIA was officially launched in June 2016. Representing a significant investment on the part of the Uruguayan government in climate change adaptation, this national-level climate service is relatively unique with regards to the breadth of the endeavour and the extent to which it characterizes the adaptation challenge primarily as one of near-term (e.g., seasonal) climate risk management, rather than focusing on climate scenarios to 2050 and beyond. As such, it makes an interesting case from which to explore the role that social and institutional factors have played in enabling investment in climate services.

1.2 Climate and agriculture in Uruguay

Agriculture contributes roughly 6% to Uruguay's GDP, but accounts for 13% of the workforce and more than 70% of exports (CIA World Factbook 2017). Taking into account associated activities, Uruguay's Ministry of Livestock, Agriculture and Fisheries (MGAP) estimates that the total contribution of Uruguay's agricultural sector reaches nearly 25% of GDP (OPYPA 2014).

In this context, the Uruguayan government has viewed agricultural production as an important piece in Uruguay's development– increasing efforts to support sustainable intensification and focusing on high-value, well differentiated products that can be marketed at a premium in Europe and the US. Many Uruguayan farmers have embraced this strategy, actively looking for ways to increase the efficiency of their production (Equipos Mori 2012).

Climate risk management has captured particular attention as the country has experienced a series of damaging climate shocks in recent years. The government has estimated, for instance, that economic losses associated with the 2008-2009 drought neared $1 billion USD (Paolino et al. 2010). The 2015-2016 El Niño event also contributed to the worst floods experienced in Uruguay in more than 50 years, with more than 12,000 people made temporarily homeless and economic losses in a range of productive sectors (Uruguay Antes y Después de las Inundaciones 2016).

While total precipitation is expected to increase, long-term climate projections suggest that the country will face an increase in the frequency and intensity of extreme weather phenomena, including rainstorms and drought (Magrin et al. 2014; W. Oyhantcabal, Sancho, and Galván 2013). In this context, roughly 15% of Uruguayan farmers report climate fluctuations as a significant challenge (Equipos Mori 2012).

1.3 National Agricultural Information System

Given the importance of agriculture to Uruguay's national economy, an information system to support decision making was first proposed by the MGAP in 2011; the concept was further developed by actors in and outside of the country and ultimately funded, in 2013, under the auspices of a World Bank project entitled Development and Adaptation to Climate Change (DACC).

The SNIA brings a range of data produced by the MGAP together with information developed by other national-level actors; this includes information on soils, vegetation, and land use and on water, weather, and climate. Agricultural census data, including that regarding production and sales, are also included.

The varied inputs to the SNIA make it easy for the tool to be seen differently by different actors. For instance, the SNIA can well be characterized as a data delivery tool, providing citizens and government actors with one-stop access to a host of different data sets; given the SNIA's focus on facilitating interoperability and visualization, it is also rightly described as an analysis tool, allowing MGAP to combine dissimilar data collected from different agencies and across different spatial scales to answer pressing policy questions.

This chapter analyses the SNIA as a national-level climate service, with the goal of translating and disseminating contextualized information about climate variability and change.

1.4 Partners

The SNIA effort is led by the MGAP, in conjunction with the International Research Institute for Climate and Society (IRI) at Columbia University, which has supported the SNIA by providing MGAP with its own version of IRI's Data Library – an online data management and analysis tool – and by collaborating with Uruguayan actors to develop several information products, including crop forecasts and an online decision support tool for crop production.

The SNIA was developed as a collaboration between more than 30 Uruguayan organizations. Significant contributions have come from the National Institute for Agricultural Research (INIA), particularly their Agro-Climate and Information Systems (GRAS), which has provided Uruguay's agricultural community with tools to characterize, contextualize, and track climate variability since the late 1990s. The Uruguayan Institute for Meteorology (INUMET) supports the SNIA by providing and analysing data from the country's meteorological stations; the SNIA is also built around a number of climate-related products developed by the Engineering Department at the University of the Republic (UdelaR). The SNIA is found online at http://snia.gub.uy/.

2. Methods

Following Denzin and Lincoln (2008), qualitative methods were used to explore factors that enabled investment in the SNIA. This involved collecting empirical evidence through semi-structured interviews and the analysis of key policy documents.

An initial list of key stakeholders was developed in conjunction with the SNIA office, though a snowball approach was used to add additional stakeholders when appropriate. Stakeholders were contacted via email and interviews were conducted in person, in Spanish, with the exception of three stakeholders who preferred to speak English and two interviews that were conducted by Skype to accommodate schedule conflicts.

A total of 33 interviews were conducted in March of 2013, roughly 6 months after work on the SNIA began. The results were analysed using a grounded theory approach (Glaser and Strauss 2017), whereby an open coding process allowed for the identification of categories drawn from within the transcripts themselves. As the coding process evolved, categories were consolidated into seven themes presented in the results section below. Grounded theory is appropriate to this kind of analysis as it helps in forming typologies of relevant phenomena and identifying patterns in complex systems (Morse et al. 2016). In December 2015, six months after the SNIA launch, an additional 10 interviews were conducted to develop a more precise understanding of the issues pertaining to each theme; three people interviewed in this round had also been interviewed in 2013.

Interviews were in-depth (Marshall and Rossman 2011), with the goal of revealing stakeholders' perception of the process, and lasted roughly an hour. All interviews were recorded and the first 33 were transcribed. An interview protocol is included in Appendix 3. In all, a total of 43 interviews were conducted with 40 people representing 12 organizations, 10 directorates of MGAP, and three departments within the University of the Republic. A list of interviewee affiliations is included in Appendix 4. A full list of interviews is found in Appendix 5.

Relevant policy documents were identified in conversation with the SNIA office, the interviewees, and via an online search, including through Uruguayan government records. A list is included in the Appendix 6.

3. Results and analysis

Interviews revealed six factors that enabled investment in the SNIA, shaping the way it was conceived, designed, and implemented. These factors are presented and analysed below.

3.1 Institutional support for sustainable agriculture

Most people reported that the focus on sustainable intensification and the production of high-value crops helped develop both the vision and the technical capacity needed to invest in the SNIA. Though this was generally accepted, two activities stand out as particularly meaningful in shaping the context in which the decision to invest in the SNIA took place.

The first of these followed a 2009 policy to reduce soil erosion by requiring producers to submit certified land-use plans to MGAP's office of Renewable Natural Resources (RENARE); this policy was ratcheted up over time, and in 2016 RENARE accepted nearly 15,000 plans covering more than 1.5 (of 1.7) million hectares of cropland (DGRN 2016). This activity generated a great deal of information and know-how, both of which are seen to have contributed to the decision to invest in the SNIA.

> "We know the land use of each paddock, what the producers are planning to do in terms of land use, so … there's a great wealth of information in the Ministry – and not just in the Ministry but across the agricultural institutes – so with the SNIA we are in a position to begin to share and overlay that information and generate mechanisms of interoperability to allow the authorities to make decisions, either to implement policies or if they want to establish insurance." (MGAP employee; interview #31)

A second activity involved the development of Uruguay's National Livestock Information System (SNIG); first proposed after a 2001 foot-and-mouth outbreak and ultimately launched in 2011, the SNIG ensures that all cattle are fully traceable, maintaining a database of more than 11.5 million animals and cataloguing more than 350,000 transactions annually (SNIG 2017).

> "With the National System of Livestock Information – the SNIG, the system that supports traceability – we began to create a database … Uruguay had a lot of information, so I think the reason that Uruguay took this step [i.e., to invest in the SNIA] is because it was already in the process for many years. And we just said "Let's create an

> interoperable information system, with all the databases that exist." I think it was a great bet on the part of the current government, but actually the logic was there and it was working." (MGAP employee; interview #20)

In that sense, the work of SNIG and RENARE – neither of which engaged climate-related issues – shaped the environment in which the MGAP operates. This includes advancing the organization's vision and capacity (for instance, regarding database management necessary to manage and geo-locate thousands of land-use plans) as well as that of Uruguay's farmers, who now submit livestock and land-use information electronically. These efforts also allowed MGAP to build the knowledge and partnerships – and thus the innovative capacity – of Uruguay's agriculture sector. All of this is seen to have helped pave the way for cross-agency discussions about climate-risk management, which ultimately led to a plan to invest in the SNIA.

3.2 Previous work on climate change adaptation

While MGAP's focus on sustainable agricultural intensification set the context in which the SNIA was developed, three activities that were focused on climate change adaptation laid the foundation for a larger investment in climate risk management.

The first of these activities was the National System of Response to Climate Change (SNRCC). Immediately following the 2008-2009 drought, Uruguay's then-president Tabaré Vazquez put the issue of climate change on the national political agenda, inviting the heads of various government departments to work together to mount a collective effort to confront the issue. This resulted in the creation of the SNRCC, formed by official decree that year and soon followed by the National Plan for Response to Climate Change (PNRCC). A multi-agency, multi-disciplinary group coordinated by the Ministry of Housing and Environment, the SNRCC met on a monthly basis to discuss climate-related issues and was responsible for national communications, reports, and meetings (SNRCC 2017).

> "[The creation of the SNRCC] was a great step, to sit around a table with different ministries, to establish consultation mechanisms to diagnose problems and make strategic change, with the support of the University of the Republic, with institutes of science and technology. This participatory process has been strengthened over time … and in that context there is a much richer and more integrated vision of information and public policies and in the [MGAP]." (MGAP employee; interview #46)

Shortly after the creation of the SNRCCC, MGAP set out to understand current and future climate-related impacts to the agricultural sector, and to prioritize options for adaptation (Aguerre 2014; Duran Fernández 2010). In a second activity, the task of identifying, evaluating, and proposing policies related to adaptation fell to the newly created "Agricultural Climate Change Unit" of the Office for Agricultural Planning and Policy (OPYPA). The unit ultimately defined a transversal approach to adaptation, which included expanding services offered by existing agricultural organizations. While the work of this office is ongoing, the task of priority-setting raised interest in climate risk within the Ministry (Paolino 2008).

At roughly the same time, an interdisciplinary group including government and non-government actors developed a proposal to the Food and Agriculture Organization, requesting funds to conduct a study on climate vulnerability in the agricultural sector. Launched in 2011, the project was coordinated out of OPYPA with the goal of characterizing agricultural vulnerability. The finished work, a seven-part series called *Clima de Cambios (Climate of Change)*, offered a range of suggestions for climate risk management in the agricultural sector (W. Oyhantcabal, Sancho, and Galván 2013). This effort strengthened capacities within each agency in terms of understanding climate variability and change and advanced the collaboration of several groups that had not previously interacted with MGAP.

> "[The *Clima de Cambios* project] began the whole process of exploring who should be involved in this kind of work … and more importantly, what do we want? What kind of information? What products? What content do we need? This was an opportunity to

start doing this exercise, the effort of working to integrate policy with academia and understanding how the process worked." (UdelaR researcher; interview #15)

It's important to note that neither this kind of groundwork, nor the institutional support for sustainable agricultural activities mentioned above, made the SNIA a foregone conclusion. Indeed, members of the SNIA team report struggling to advance their work when they leaned too hard on the connections and momentum developed through existing activities to form Working Groups to help "co-produce" some information products.

Indeed, while many actors found these groups useful in fostering discussion and in keeping people abreast of SNIA-related developments, they were not generally successful at generating products – primarily because they were voluntary, requiring people to take time out of already-busy schedules to contribute, and because they were not well enough supported by the SNIA team to ensure that work plans were completed. Though the SNIA team eventually became aware that institutional fixes would need to be found to support these groups, the connections and momentum that were developed through the three institutional activities mentioned above were key in creating an environment conducive to investment in the SNIA itself.

3.3 Modernization of the meteorological institute

Begun in 2008, a process to modernize the Uruguayan meteorological institute also shaped the decision to invest in and build the SNIA. Founded in 1920, the Meteorological Institute of Uruguay was originally part of the Faculty of Humanities and Sciences at the UdelaR; it was eventually moved to the Ministry of National Defense when it was incorporated as a government office. As the National Meteorological Department (DNM), the organization continued as part of the defence ministry through two external reviews conducted in 2008 and 2013, respectively.

Both of these reviews found a series of challenges that prevented the DNM from providing the country with adequate weather and climate information in useful forms (Programa de

Cooperacíon Iberoamerica 2009; Riosalido Alonso 2013). Both reports offered a number of recommendations regarding how to improve performance – and though neither was implemented in its entirety, each led to important actions that contributed to the modernization of the meteorological service.

After the 2008 report, for instance, the DNM undertook a large-scale effort to modernize the national meteorological database, structuring and organizing its own weather and climate data along with that collected by the national energy company (UTE) and the national agricultural research institute (INIA). The rollout of this database was fundamental to the decision to invest in the SNIA, since it allowed meteorological data to be shared and analysed in a way that was previously impossible.

Though initial efforts at modernization focused on data, later efforts were more geared toward organizational reform – and in 2013, an Inter-Ministerial Commission issued a series of guidelines for transforming the DNM into a separate institute outside of the Ministry of Defense. The process of restructuring the DNM into what is now the Uruguayan Institute of Meteorology (INUMET) began that same year, resulting in a number of changes designed to make the organization more flexible, more relevant, and more outward facing, focused on developing demand-driven information products.

The first of these changes was to create a new institutional home for the organization. When it was located in the Ministry of Defense, the DNM was entirely beholden to defence-oriented colleagues for budgetary requests and institutional programming; it was frequently not at the top of the list of funding priorities.

> "There's been modernization and strengthening of meteorological services that until recently was known as National Direction of Meteorology – but by a law that was passed last year became the Uruguayan Meteorological Institute, INUMET. The quality of the services, the staff, the equipment, the number of meteorological stations – these

> had all fallen quite a bit, but now I think we are in a process of strengthening meteorological services because we're more aware of how important they are." (MGAP employee; interview #46).

Outside the Defense Ministry, the new INUMET is more independent, with more flexibility to develop its own work plan and to request an increase in funding to support that work plan. INUMET does submit budgets to Parliament through the Ministry of Housing and Environment, but the goals of this ministry are more aligned with a "modern" meteorological institute, able to develop products and services to supply the SNIA.

> "In this new format, [INUMET] can partner with companies, public services, can establish and manage projects, which in the old arrangement [i.e., DNM] was impossible. I think [the new arrangement] gives more flexibility." (INUMET employee; interview #34)

Decentralizing the agency has allowed INUMET to set its own course regarding the kinds of skills and services it would like to develop. In addition, this restructuring has allowed INUMET to shift from an extremely horizontal organizational structure into one that includes more high-level experts that can perform higher quality climate analyses. This is intended to include the hiring of graduates of the UdelaR's bachelor program in meteorology, created in 2007, and represents an important shift in interest toward the development and use of climate-related information in the country (Meteorólogos con formación terciaria 2007). The result is an organization better skilled to produce climate data and information useful to the SNIA.

While some aspects of this modernization process happened at the same time as the decision to invest in the SNIA as a national-level climate service for the agricultural sector, it was clearly a critical step; without the national database or the restructuring effort, the meteorological service would not have been able to contribute the data, products and/or the understanding needed to support the development of this information tool.

3.4 Open data

Within this institutional context, a key policy measure was also critical to the decision to invest in the SNIA: Uruguay's policy on open data. Indeed, unlike many countries in Latin America, Uruguay is legally obligated to make all data freely available, as enshrined in Law 18.381, the Right of Access to Public Information (Ley de Acceso a la Información Pública N° 18.381 2008).

Open data policies are intended to ensure the long-term transparency of government information and are seen to increase the participation, interaction, and empowerment of data users and providers – stimulating innovation and economic growth and enlisting the citizenry in analysing large quantities of data (Zuiderwijk and Janssen 2014). While this openness is lauded in certain circles, open data remains a particularly controversial topic within the international climate community; many countries reserve data collected by national meteorological agencies for sale, with far fewer making data widely available to the public sector for free (Overpeck et al. 2011).

It is clear Uruguay's open data policy has had both a push and a pull effect on the decision to invest in the SNIA. For instance, the fact that MGAP was already required to make data public increased the attractiveness of a public data platform; it also helped to foster interest in finding ways to sync disparate agricultural datasets to provide for a holistic analysis of current and emerging conditions.

> "What you're seeing from the SNIA – presenting the data with the goal of meeting needs across sectors, making data available so that it can benefit everyone – these days the Ministry is trying to move forward on this and the SNIA is spearheading that."
> (MGAP employee; interview #26)

On the other hand, the SNIA is obviously greatly facilitated by Uruguay's data policy. Indeed, the current version of the tool would not be possible without open data – and other possible versions, potentially based on derived information products that did not allow for users to directly download data (e.g., Dinku et al., 2014), would have been much more complicated to develop and to maintain.

> "Before this, things were more conservative – they had the idea that the data from the Ministry should not be shared. Well, we started to work through the SNIA because there were already needs for the data, and in that sense [the SNIA] has helped to create this different dimension at the Ministry." (MGAP employee; interview #8)

But while open data requires a certain relinquishing of control on the part of the public sector, which must trade its role as gatekeeper for a new role as information provider, public agencies are not always ready for this shift either logistically or conceptually (Zuiderwijk, Janssen, Choenni, Meijer, and Alibaks 2012). In the case of Uruguay, some aspects of the open data law are still being implemented, including the formal designation of which information should be made public and which should not, based on citizen's privacy concerns (Government of Uruguay 2008).

At the same time, the SNIA has forced the government to confront a number of data-related challenges, including around the interoperability of data sets and the provision of metadata. There are also issues related to collaboration, as some of the groups responsible for contributing data and products to the SNIA have expressed a desire to contribute to the development of products, a need for their own contributions to be clearly recognized, and an interest in making it clear to users who they could contact with specific questions regarding the data. As such, the SNIA portal currently lists 37 collaborating organizations and clearly indicates the organizational provenance of specific datasets.

3.5 Focus on the near term

SNIA's policy of focusing on near-term climate variability, as opposed to providing information on longer timescales (e.g., 2050 or 2100), also played a part in motivating the investment. Indeed, while the project that funded the SNIA focused on climate change adaptation, it was the first World Bank climate change project not to involve long-term climate projections.

In focusing on the near-term, the SNIA is able to respond to the immediate needs of the government and its constituents – a focus on the agricultural sector in a place where inter-annual variability accounts for more than 80% of the observed climatic variance in Uruguay in the last 100 years, while decadal variability accounts for just ~10% and the contribution of the climate change signal is extremely limited (Baethgen 2010; Baethgen and Goddard 2013).

> "We are more concerned with variability than with long-term trends, especially because in Uruguay the long-term trends – particularly in relation to water – are to increase water availability.… So the soils have more water, the problem is that the distribution of water is very irregular within a year or between years, and if that variability increases, the averages are not necessarily a good indicator that everything is fine. So we worry more than anything about what will happen with the extreme events … and right now, the first step is to begin to close the gap between adaptation to the present variability. Are we well adapted? No, well then we go to first step to adapt to the current variability." (MGAP employee; interview #10)

By focusing on the near term, the SNIA also responds to a need to show tangible benefits during short political cycles – a factor that has been shown to complicate investments in adaptation in other places (L. Dilling et al. 2014). In this sense, investing in climate service tools that make near-term rather than/as well as long-term information available are sometimes more attractive to politicians and to those they serve (Baethgen 2010; Thomalla et al. 2006), though in other cases the need to respond to international processes or address the "newest thing" may make orienting climate services toward long-term trends more viable.

3.6 Key individuals

As is frequently the case with major policy and institutional developments, key individuals – and the relationships of trust that developed between them – played a role in conceiving and shaping the SNIA. This jibes well with previous work on climate services that has documented the important role of "champions" in advocating for the development of such tools and capacities (Nisbet and Kotcher 2009; Solera-Garcia 2012); in this case, two characters were seen to have played a key role in motivating investment in the SNIA.

The first is the minister of MGAP, who first proposed the idea of developing a national information system that could help to manage climate-related risk both in the near- and long-term. A landowner and producer himself, he had previously served as the president of a national association of rice producers (2006-2009), where he gained knowledge in the use and dissemination of seasonal forecasts for decision making. Upon taking up his position in the government in 2010, the minister sought to translate this to a wider scale.

> "We have a minister who is very technical, who understands the subject well – that gave him a lot of momentum in saying 'This is an issue that is very important for Uruguayans.'" (MGAP employee; interview #9)

Another important figure was a Uruguayan agricultural scientist (and co-author of the paper based on the chapter) based at the International Research Institute for Climate and Society, who helped facilitate discussion regarding how such a tool might be developed and the sorts of climate and weather information that might be helpful in improving decision making within Uruguay's agricultural sector. In Uruguay, a country of just 3 million people, this scientist had collaborated with the minister before he took up his government position, which made it easy to re-initiate the connection after 2010. At least one SNIA collaborator described the connection and the trust between this scientist and the minister was described as "fundamental" to the development of the SNIA (UdelaR researcher #25).

4. Discussion

Analysis reveals six factors that helped create an enabling environment for investment in Uruguay's National Agricultural Information System, a national-level climate service for the agriculture sector. These factors offer important lessons for future efforts to identify and create contexts in which investments in climate service can occur and flourish. Indeed, while the context in which these factors emerged is uniquely Uruguayan, it seems likely that many of the factors identified here are broadly generalizable to other countries. Though only further case studies can confirm this, the potential relevance of four main themes, and the research needed to explore them, is discussed below.

4.1. Innovation systems

Analysis revealed that support for sustainable agricultural intensification helped create the context in which investment in the SNIA took place. These factors also helped define the scope and capacity of specific actors, networks, institutions and approaches within Uruguay. To the extent to which these items, taken together, can be seen as contributing to the innovation of the SNIA, they can be thought of as an "innovation system."

The concept of an "innovation system" was first developed in the 1980s as a response to the neo-classical economic approach to studying innovation, in which the main impediment to innovation was seen to be high wages (Sharif 2006). In contrast to an economics-focused analysis, the innovation system literature conceptualizes innovation as the result of a number of interdependent processes (e.g., the existence of appropriate organizations, formation of social, political and learning networks, the alignment of institutions and the accumulation of knowledge) which interact to create contexts conducive to innovation (Bergek et al. 2008; Francis et al. 2016; Jacobsson and Bergek 2011; Pamuk, Bulte, and Adekunle 2014; Williamson, Hesseln, and Johnston 2012). To date, the main contribution of this type of analysis has been to help create frameworks to diagnose failures or weaknesses that can be addressed with specific policies (Jacobsson and Bergek 2011).

Such a framework has not yet been used to understand the development, or lack thereof, of climate services in particular contexts – though analysis of "agricultural innovation systems" has been useful in identifying ways for governments to take action to foment innovation in the agriculture sector (see for instance, Hall, Rasheed Sulaiman, Clark, and Yoganand, 2003; Hermans, Stuiver, Beers, and Kok, 2013; Klerkx, Aarts, and Leeuwis, 2010). Further developing the concept in the climate service sphere by looking specifically at the infrastructural, institutional, interaction, and capacity failures that limit climate services investments is likely to help develop our understanding of how to build contexts conducive to the development of climate services.

4.2 Groundwork

Given the important role that the SNRCC, the priority setting activity at MGAP, and the *Clima de Cambios* book played in informing the decision to invest in the SNIA, these activities can be seen to fall under the rubric of "groundwork" for climate change adaptation, as defined by Lesnikowski et al. (2011). In that analysis, roughly 2,000 adaptation initiatives mentioned in the Fifth National Communication of Annex 1 Parties to the UNFCCC are grouped into three categories: recognition, groundwork, and action.

This three-prong scheme is loosely echoed by Biagini et al. (2014), whose analysis of 158 adaptation activities (funded by the Least Developed Country Fund, the Special Climate Change Fund, the Adaptation Fund, and the Global Facility Trust Fund) identified 10 categories of adaptation action, including: capacity building; management and planning; practice and behaviour; policy; information; physical infrastructure; warning or observing systems; green infrastructure; financing; and technology.

Biagini et al. (2014) find that the first three of these categories (capacity building, management and planning, practice and behaviour) are much more common than the others, hypothesizing that these low-cost actions are necessary antecedents that must precede and help direct high-value investments (e.g., technology, infrastructure) that may come later. Biagini et al (2014) also suggest that the especially high number of references to capacity building – more than twice as frequent as references to management and planning activities, more than 20 times as frequent as references to investments in technology – may reflect an early stage societal adaptation, and/or the prevalence of barriers that must first be grappled with before adaptation can be actualized (Biagini et al. 2014).

While the notion that activity to address adaptation to climate change and variability progresses in a relatively ordered manner – beginning with basic recognition, proceeding to groundwork, and moving on to more high-level investments in technology or infrastructure – makes sense intuitively, no detailed case studies have explored whether and how such an evolution might play out with respect to individual adaptation investments.

Analysis of the SNIA seems to confirm this progression, however, suggesting that further study of what constitutes effective groundwork; the timeframes on which these kinds of activities take place; and the extent to which they may be cyclical and/or additive are important areas of research needed to inform our understanding the context in which climate services develop. In this sense, institutional analyses of climate services in other contexts may help shed light on the sorts of near- and medium-term actions that can help to mainstream the development of climate services over time.

4.3 Data providers and data policy

The "modernization" of Uruguay's meteorological institute and the country's open data policy were found to have played critical roles in creating the context in which the SNIA was conceived and developed. Finding ways to analyse and diagnose these systems will clearly be important in identifying contexts conducive to climate service investment.

As mentioned earlier, two external reviews were conducted to help inform this modernization process of INUMET (Programa de Cooperacíon Iberoamerica 2009; Riosalido Alonso 2013); it is likely that many other meteorological services have undergone similar processes, though the results are generally not made public (for exceptions, see Fread et al. 1995; Friday 1994; National Research Council 2012). Several authors have, however, looked broadly at how to structure meteorological services to best deliver weather, water, and climate services (Freebairn and Zillman 2002; Hallegatte, Henriet, and Corfee-Morlot 2010). The World Bank in particular has developed several principles to guide the modernization of national meteorological services so as to create robust professional agencies capable of delivering the right information to the right people at the right time; they have also looked at organization and funding models (Rogers and Tsirkunov, 2013).

Comparative work – and that focused on specific services (e.g., Rogers and Tsirkunov, 2010; WMO, 2010) – has been helpful in laying out the principle issues involved in understanding how the structure of meteorological institutes contributes to the development and delivery of climate services. However, further study in this regard, including the analysis of a range of services in context, is needed to understand how the structure and institutional home of a meteorological institute contributes to the relative success of climate services.

It is also important to consider the role that the MGAP played in conceiving the SNIA and in motivating investment for it. Comparing investment in (and the outcomes associated with) climate services developed by sectoral agencies versus those developed by meteorological services is also an important area of research, and one that should inform further discussion within the Global Framework for Climate Services.

Related to the modernization of the meteorological institute is the topic of data policy. Several of the aforementioned studies (Rogers and Tsirkunov 2013) have considered the role that data policy plays in informing services, though more work is clearly needed – including comparative analyses of the value to an economy of selling versus making data freely available. While making data available to the public is increasingly seen as an unalloyed good, there are a number of reasons that doing so can be legally and logistically challenging; identifying ways to characterize and measure the existence of infrastructure in place to manage these challenges is thus a critical precondition to climate service development.

The relative benefit of experiences in data sharing (e.g., between European meteorological services, or through international partnerships such as the Latin American Observatory on Extreme Events) should also be explored.

4.4 Champions

Consistent with other literature regarding the uptake of scientific information (Mumford and Harvey 2014; Solera-Garcia 2012; Warner and Pomeroy 2012), this analysis shows the role that key individuals played in helping to create and actualize a vision for the SNIA. Indeed, the role of climate service "champions" seems relatively well recognized, though research on the skills and knowledge that support such champions lags. Further work to identify commonalities across climate service champions could inform efforts to train and develop more people with the skills to motivate climate service investment.

Importantly, while the champions identified in this analysis had their own motivations for participating in the SNIA, this work also reveals that the actors involved in SNIA Working Groups were often not properly incentivized to contribute new products to the SNIA. Though the performance of the Working Groups did not affect the decision to invest in the SNIA *per se*, it did affect the outcome, with no public products developed as a result of the Working Groups.

In that sense, investments in climate services are more likely to take place when incentives to participation are clearly identified. While the greater good is a noble motivator, personal motivations – including specific salaried time for key employees or support staff to collaborate with other offices and to follow up on their suggestions – proved essential for developing appropriate products. This jibes well with previous literature on "co-production" of climate services, which indicates that this sort of bridging activity is time and resource intensive and frequently under-resourced (Steynor et al. 2016).

5 Summary and conclusions

This chapter investigates the context in which Uruguay's Ministry of Livestock, Agriculture and Fisheries invested and developed the National Agricultural Information System, a national-level climate service for the agricultural sector.

Six drivers were found to have shaped the context in which this investment was made. This includes a number of actions that developed an "innovation system" around sustainable intensification in agriculture; previous "groundwork" on climate change adaptation; and the modernization of the national meteorological service. Policy measures, such as Uruguay's requirement that all public data be made available, and the SNIA's policy of focusing on near-term climate variability rather than long-term climate change, enabled the investment. Key individuals, and the relationships of trust between them, were also found to be critically important.

While the context in which the SNIA was conceived was, of course, uniquely Uruguayan, it is likely that many of the factors identified here are broadly generalizable to other countries. The role of innovation, groundwork, data providers, and champions merit further attention, particularly as the first two of these items have not yet been explored in the climate service literature.

Indeed, analysis of national and/or regional innovation systems may help climate service funders to identify where best to invest without focusing narrowly on the climate service "value chain." Likewise, the notion that "groundwork" activities may precede successful investment in climate service has not been recognized; identifying what sort of activities are more impactful in creating conditions conducive to investment, and how to measure the effectiveness of those activities, should be a key priority as the field continues to grow.

Further developing these themes, and the relative importance of them, through additional empirical and theoretical work will help to illuminate the contexts in which the development of climate services is likely to be successful, and the sorts of measures that can enable them. It will also help inform our understanding of adaptive readiness, distinguishing between factors that enable adaptation efforts broadly and those that influence investments in climate services specifically and informing a host of planning activities at local, national, and regional scales.

CHAPTER 5: GOVERNANCE OF and THROUGH CLIMATE SERVICES

1. Introduction

While the research and observational programs that shape our understanding of the climate system date back more than a century, work focused on the use of this information for societal decision-making has accelerated in recent years. This growth is evidenced by an increase in the number of peer-reviewed papers that focus on the development and use climate services and by the growing number of public-sector investments that seek to foster the production and use of climate information (e.g., the Global Framework for Climate Services, the Copernicus Climate Change Service, etc.) for societal outcomes. It takes place in the context of a wider conversation on adaptation to climate change.

Growing interest in climate services takes place in the context of a wider conversation on adaptation to climate change; it is both a response to, and a driver of, recent improvements in the quality of climate information. T This growing interest has brought a growing sophistication with respect to what constitutes good practice in the development, delivery, and use of such services (e.g., Cortekar et al. 2016; Lourenco et al. 2016; Romsdahl 2010). Nevertheless, the field remains marked by a sense of unfulfilled potential, with a general recognition that the vast majority of climate-sensitive actors are underserved by climate services even while large quantities of potentially useful information goes unused (Ernst et al. 2019; Vaughan, Dessai, and Hewitt 2018).

The reasons for this shortfall are many and, in some cases, relatively well documented. Indeed, research identifying barriers to the success of climate services currently spans a range of disciplines, exploring a number of issues both social and scientific (e.g., Bruno Soares and Dessai 2016; Dilling and Lemos 2011; Flagg and Kirchhoff 2018; Rayner, Lach, and Ingram 2005). Bureaucratic concerns such as the governance of climate services have received limited attention, despite being recognized as important to the production and use of climate information (Vaughan and Dessai 2014). What research does exist in this field remains patchy, comprised primarily of glancing observations spread throughout disparate case studies and without a coherent framework either to organize existing knowledge or to guide future work.

Addressing the issue of governance has become more pressing as the field of climate services develops. If we know more about what constitutes good practice, and more about how to prevent bad practice, why do climate service activities continue to fall short of expectations? As with other fields, governance components (including rules and norms, as well as the ways in which these rules and norms are structured, sustained, and regulated) are important to the planning, implementation, management, and use of climate services. Refining these arrangements is thus critical to ensuring that our evolving sense of good practice translates to improved societal outcomes – and yet, improving our ability to refine these arrangements requires:

(1) defining the key goals and components of climate service governance; and

(2) developing recommendations for how these can be improved, both in the case study context and more broadly.

This chapter uses a single case study to explore these issues.

The chapter begins by developing a conceptual framework to explicate the goals and components of climate service governance. Grounded in the project governance literature, this framework is used to analyze the development of a national-level agricultural climate service in Uruguay, paying particular attention to the extent to which existing arrangements have helped or hindered this service in pursuit of three broadly stated governance goals (**#1**). In detailing the nature and consequences of climate service governance in Uruguay, the paper creates a lens through which to consider the state of climate service governance more generally. It also proposes a number of research questions that can advance our understanding of what constitutes "good" governance in the realm of public-sector climate services (**#2**).

The chapter is organized as follows. A selective review of relevant topics in the governance literature is presented in **section 2**. In **section 3**, these topics are developed into a conceptual framework that is used to engage and organize insights from the burgeoning literature on the development and use of climate services. Research methods, including the case study context, are described in **section 4**. Results are presented in **section 5**, followed by a discussion (**section 6**) that locates these results in the wider conversation on public sector climate services. Conclusions, including recommendations for further research, are found in **section 7**.

2. Background

A first task for this chapter is to distinguish between governance and management. While "management" involves the oversight of day-to-day operations and the allocation of resources, "governance" is concerned with the strategic tasks of setting goals, direction, limitations, and accountability. As such, the term governance is applied to a range of activities involved with the steering and/or regulating of social behavior (Fukuyama 2016). This paper uses the term governance to describe the processes of interaction and decision making – including rules and norms, as well as the way these rules and norms are structured and sustained – that help to shape the development, delivery and impact of climate services.

Political scientists generally recognize three "modes" of governance, framing differences between them with respect to the formality of institutions involved. Hierarchical governance, for instance, is characterized by centralized mechanisms and strictly enforced contracts – while market governance describes the informal rules that shape the behavior of non-state economic actors. Network governance, which comprises the patterns of coordination that occur within organic social systems, is the most informal governance mode; it is also considered the most conducive to learning, as it allows for multiple sources of knowledge generation and exchange (Howlett 2009).

Within each mode, governance "models" articulate and respond to normative theories about how governance should operate in particular contexts. Research into "participatory science governance," for instance, explores the models of interaction that foster public participation in science (Burgess 2014; Newig and Fritsch 2009). Likewise, "knowledge governance" explicitly recognizes the important role that knowledge plays in shaping society – including the possibility that the purposeful generation and dissemination of knowledge can, in some cases, offer the coordinative power of governance itself (Gerritsen, Stuiver, and Termeer 2013).

Applied and theoretical work has explored the implementation and relative success of different governance modes and models in different contexts. Among other things, this includes research into hierarchical, market, and network governance for a variety of resources that underpin climate services, including data (e.g., Weber, Otto, and Osterle 2009) and projects (Too and Weaver 2014), among others. But while a large number of concepts explored in the governance literature may be relevant to the climate services sphere – and many deserve exploration in different contexts – this chapter mines work on project governance (e.g., Steyn and Bekker 2009; Winch 2014) as a means to help capture and frame the specific experience of the case study.

2.1 Project governance

A growing awareness that our institutional frameworks must include governance arrangements for adaptation has informed the Earth system governance literature (Biermann et al. 2012; Smith et al. 2011). While a number of concepts explored in this literature are relevant to the climate services sphere this chapter mines the work on project governance (e.g., Steyn and Bekker 2009; Winch 2014) to develop a framework to explicate goals of climate service governance. The focus on projects seems appropriate given that many climate services are developed with project-based funding (Vaughan, Dessai, and Hewitt 2018). In addition, the cross-agency nature of many public-sector climate services may require those responsible for developing and managing them to operate outside the routine structures of their individual bureaucracies in a way that is very similar to projects, even after the service is up and running (van Donk and Molloy 2008).

Within the literature on project governance, a range of authors explore the notion of "good" governance in different project contexts. This includes an investigation into the various structures that have been designed to help in defining project goals; in setting boundaries for project management; and in establishing a distinction between the ownership and control of tasks (Ahola et al. 2014; Crawford and Helm 2009; Garland 2009). Literature also details pitfalls of poor project governance – including, for example, the festering of conflicts that arise between various means of achieving project goals and the difficulty of resolving inconsistencies between intended processes and available resources (e.g., Muller 2017).

In this context, research on "governance frameworks" documents the roles and regulations that are associated with particular projects; while these frameworks have been shown to be critically important to project outcomes, they vary considerably in order to accommodate specific situations, defying any universal prescription for success (Joslin and Muller 2016). In an effort to synthesize commonalities, Steyn and Bekker (2009) have found that most project governance frameworks include provisions that pertain to the:

(1) composition and responsibilities of the project team;
(2) project quality;
(3) financial reporting and control; and
(4) remuneration, ethics, and conflicts of interest.

In the context of public-sector projects, the four elements articulated above provide the means through which project stakeholders pursue broadly stated goals of project governance, which are described in the literature (Ahola et al. 2014; Klakegg et al. 2008) as:

(1) choosing the right projects;
(2) efficiently delivering the chosen projects; and
(3) ensuring the sustainable impact of those projects

3. Conceptual framing

To guide its analysis, this chapter relies on a framework based on the elements and goals of project governance. This framework highlights the potential for different kinds of governance interventions to help or hinder projects in pursuit of these different governance goals. Though governance has received scant attention in the climate service literature to date, related themes are reviewed to inform the conceptual framework below (see Table 6).

	Selecting climate services	**Delivering climate services**	**Ensuring sustainable impact**
Composition & responsibilities of team	Who is involved in decisions regarding the prioritization of climate services? How do individuals, and the interests they represent, work together to align climate service investments with public policy?	Who is involved in the co-production of climate services? How do those individuals, and the interests they represent, work together to produce services that are useful, useable, and used?	Who is involved in ensuring that tailored climate services are provided at scale? Who is responsible for ensuring that the service is sustainable, or for measuring / estimating impact over the life of the service?
Rules & norms that ensure quality	What measures exist to provide oversight of climate service investments?	What procedures help to determine when climate services are adequate or fit for purpose? How is feedback gathered, analysed, and incorporated?	Are there targets with regards to the kinds of impacts the service is expected to create? How are these assessed?
Rules & norms regarding funding and financial management	What measures exist to provide oversight of climate service investments?	What procedures help ensure that funding supports the team over the life of the co-production process?	Will funding be available to support the services into the future?
Rules & norms regarding ethics and conflict of interest	What measures exist to help balance the concerns of different stakeholders in the selection process?	What measures exist to help balance the concerns of different stakeholders in the co-production process?	What measures exist to help balance the concerns of different stakeholders as the service is implemented, and into the future?

Table 6: Conceptual framing of the goals and components of climate services projects

3.1 Selecting public-sector climate services

Public-sector projects use public resources to pursue the economic, institutional, and/or social development goals of the societies in which they are embedded; since projects are important policy-implementation tools, the selection of appropriate projects is a critical part of ensuring that investments align with stated priorities (Shiferaw and Klakegg 2012). Within the realm of climate services, consideration of the factors that should inform project selection have progressed from a strict focus on climate information to one more centred on the notion of "usable knowledge" – including the factors that help ensure that scientific information is both usable and used (Dilling and Lemos 2011).

This literature on usability has focused on the role of contextual (e.g., organizational, cultural and decision contexts, reward structures, etc.) and intrinsic factors (e.g., quality of information, spatial and temporal scales; trust, accessibility, etc.) in fostering use of knowledge. It has identified a number of possible arrangements that can better connect scientific knowledge to users (Lemos et al. 2014; Mase and Prokopy 2013; Meadow et al. 2015; Morss, Demuth, and Lazo 2008); it also highlights the flexibility of research agendas as important to the process of selecting projects that lead to knowledge use (Dilling and Lemos 2011). Though improving, our sense of the governance measures that can inform the selection of projects where information is likely to be useful is still relatively undeveloped (Eden 2011; McNie et al. 2016; National Research Council 2006; Owen et al 2019). Key questions include:

- Who is involved in decisions regarding the prioritization of climate services? Where should those decisions reside? How do individuals, and the interests they represent, work together to align climate service investments with public policy?
- What measures help balance the concerns of different stakeholders in the selection process?
- What measures can help guide and/or provide oversight of climate service investments?

3.2 Delivering public-sector climate services

All public-sector projects involve some level of complexity; this is especially true for climate services, which experience both internal (i.e., that related to analysis, technology, and the interfacing with existing systems) and external complexities (e.g., stakeholder relationships) which may overlap with each other (Linehan and Kavangh 2006). As in many other fields, the climate service community has increasingly relied on the concept of "co-production" to help diverse stakeholders negotiate these complexities to build information products that are useful and used (Bremer et al. 2019).

Despite a burgeoning literature on the co-production of climate services, practitioners may still struggle to identify concrete guidance on the governance of co-production; even focusing on just one of the eight different lenses (Bremer and Meisch 2017) that scholars identify for the term, the bounds of what constitutes "co-production" remains unclear (Jagannathan et al. 2019). While certain principles of successful co-production seem settled, their interpretation in different contexts remains an important topic of research (Lemos et al. 2018). Key questions in the developing governance structures to guide the delivery of climate services thus include:

- Who is involved in the co-production of climate services? How do those individuals, and the interests they represent, work together to produce services that are useful, useable, and used?
- What procedures help to determine when climate services are adequate or fit for purpose? How is feedback gathered, analysed, and incorporated?
- What procedures help ensure that funding supports the entire team over the life of the co-production process?
- What measures exist to help balance the concerns of different stakeholders in the co-production process?

3.3 Facilitating the sustainable impact of public-sector climate services

Klakegg et al. (2008) has identified several challenges to the sustainability of public projects, including a lack of commitment to the project from key stakeholders; conflicts over objectives and/or strategies; low benefits compared to investment and/or operational costs; and a change in external conditions affecting the project's relevance or value. While these challenges may be faced by many types of projects, others may be more unique to the realm of climate services – including the scaling of locally specific pilot-scale climate services to national and/or regional levels and the monitoring and evaluation of both use and impact.

Indeed, a number of challenges make it difficult to evaluate the extent to which climate services deliver benefit to intended users (Bruno Soares, Daly, and Dessai 2018; Vaughan et al. 2019). In some cases, service providers have no way to document who uses the service, or to what end – and without a relatively robust sense of the return on investment, they may struggle to mobilize the kind of ongoing financial support necessary to provide and update it (Skelton et al. 2019). These challenges are amplified when services are provided at large spatial scales – making it more difficult to tailor the service to specific users and to gather information about use and impact (Hansen et al. 2019; Kalafatis et al. 2019).

Creating governance structures to overcome these challenges requires answering questions including:

- Who is involved ensuring that tailored climate services are provided at appropriate scale? Who is responsible for ensuring that the service is sustainable, or for measuring / estimating impact over the life of the service?
- Are there targets regarding the kind of impacts the service is expected to create? How are these assessed?
- Will funding be available to support the services into the future?
- What measures exist to help balance the concerns of different stakeholders as the service is implemented, and into the future?

4. Methods

To understand climate service governance in context, the chapter examines the governance structures that have shaped the development of Uruguay's National Agricultural Information System (SNIA), a national-level agricultural climate service developed by the Uruguayan government as part of a four-year project supported by the World Bank. The case study uses a framework analysis based on the above conceptual framework to explore how and to what extent SNIA governance structures have supported each of the governance goals described above. As explained by Srivastava and Thomson (2009), framework analysis is grounded, dynamic and based on accounts of participants. It allows for an analysis to explore both those governance arrangements that do exist and those that may be lacking.

4.1 Case study context

Given the importance of agriculture to Uruguay's national economy – and the recent success of the country's National Livestock Information System (Abraham, Dassatti, and Cal 2014) – Uruguay's Ministry of Agriculture, Livestock and Fisheries (MGAP) proposed a system to support climate-informed agricultural decision making in 2010. The idea for this kind of decision support system was further developed by actors in and outside the country and ultimately funded as part of a six-year World Bank project entitled Development and Adaptation to Climate Change (DACC) beginning in 2012.

Officially launched in June 2016, the SNIA is intended to inform a range of agricultural decisions. It brings together information resources from all departments of MGAP and from more than 37 national and international partners. This includes Uruguay's National Institute for Agricultural Research (INIA); the Uruguayan Institute for Meteorology (INUMET); the Engineering Department at the University of the Republic (UdelaR); and the International Research Institute for Climate and Society (IRI) at Columbia University in the United States. The SNIA currently hosts more than 40 climate-related decision support tools, as well as a number of maps and downloadable data related to soils, land use, production, environmental safety, and sales (Baethgen, Berterretche, and Gimenez 2016; Cruz et al. 2018).

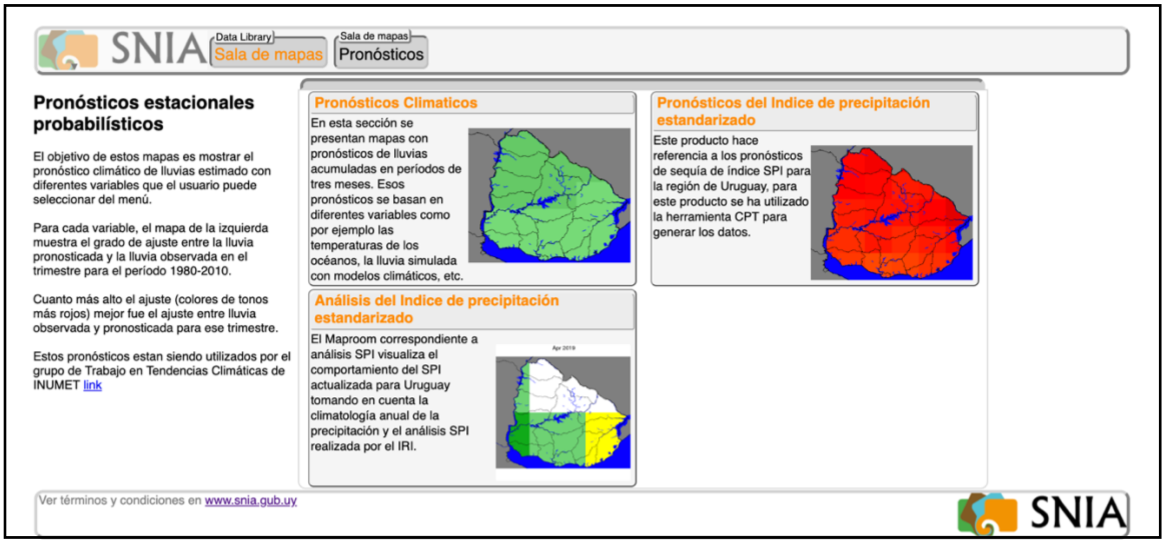


Figure 9: Screenshot of the SNIA, made available through Uruguay's Ministry of Agriculture, Livestock, and Fisheries

More information regarding the evolution of the SNIA is found in Vaughan et al. (2017)**.** The SNIA is available online at http://snia.gub.uy/.

4.2 Research methodology

Research regarding the development of the SNIA began in 2013, roughly 6 months after the SNIA project was initiated, and continued through the middle of 2018. This research included a series of interviews on a variety of topics, including the factors that motivated investment in the SNIA (Vaughan et al. 2017). The topic of governance was addressed in the first round of in-person interviews, as 33 interviewees from a wide range of organizations responded to questions regarding the actors/organizations involved in developing the SNIA, their motivations, and their modes of interaction, among other things. Governance was addressed in a more direct fashion during in-person interviews with 18 MGAP employees conducted in May of 2017, in several follow-up conversations conducted by Skype after the project official wound down in March and April 2018.

Interviews were transcribed and analysed using framework techniques (Spencer, Ritchie, and O'Connor 2003), with responses organized based on their relevance to each of the goals and components articulated in the conceptual framing above. Content was indexed in nVivo, and ultimately summarized in matrices that applied the four governance components to each of the three project goals (see tables 3, 4 and 5) following the framework articulated above.

5. Results

Results are organized with respect to the specific governance components that were relevant to (1) the selection of the SNIA; (2) the delivery of the SNIA; and (3) ensuring the sustainable impact of the SNIA.

5.1 Selecting the SNIA

In describing the governance components that supported the selection of the SNIA, respondents described two processes: the first identified the SNIA as an activity worth investing in, while the second guided the selection and prioritization of the individual information products that compose the SNIA. Both are described below.

5.1.1 A national-level agricultural climate service

While a number of contextual factors influenced the decision to invest in the SNIA (Vaughan et al. 2017), the formal process of developing and approving the idea took place within two relatively well-established governance systems defined by the Uruguayan government and the World Bank, respectively.

Within Uruguay, the idea was developed as part of a larger loan application put forth by MGAP and ultimately approved by the Ministry of Economy and Finance. Both organizations had established committees to help develop and review the proposal – including with respect to the project budget, measures for financial management, and the potential for the SNIA to contribute to existing priorities in the development of Uruguay's important agricultural sector. The review process at the World Bank very roughly mirrored the one conducted in Uruguay –

assessing the extent to which the project aligned with previously expressed priorities for the country and the likelihood that Uruguay would be able to repay the loan.

Within the country, the approval process for the grant that underwrote the SNIA was similar to that which underwrote the National System for Livestock Information (SNIG), which was also funded by a World Bank loan.

> "The minister had a set of advisors specializing in the different areas – soil, water, crop, livestock, economics, of course – a small group of advisors that was very close to them, and he discussed all of his ideas and he converted that into a policy, and at the end those ideas were vetted by the World Bank. Of course, every loan in the country has to be vetted by the Ministry of Finance." Interviewee #17, April 2014

One thing to note is that while both processes involved a broad-brush cost-benefit analysis to gauge the extent to which the project was likely to pay off, neither the World Bank nor the government of Uruguay required this analysis to make explicit assumptions about who the SNIA would target nor the kind or magnitude of benefits it was expected to deliver to those users.

Rather, the SNIA was seen as just one part (~10%) of a larger adaptation project judged in rather broad strokes. Based on an estimate of the cost of the most recent drought (~$340 million USD), WB documents suggest that the DACC project could be considered a success if it made just 10% of farmers more climate resilient – resulting in an estimated $30 million in avoided losses for each subsequent drought year (World Bank Sustainable Development Department 2011).

The broad scope of this cost-benefit analysis may also reflect a general perception that the impacts of improved information would be self-evident, if unpredictable and hard to measure. In fact, while the framers of the SNIA always had the idea that it would be useful to individual farmers, they originally focused mainly on ministry-level decision making, since the demands associated with these kinds of decisions were more immediately available.

> "We figured it was more important to get started with the work before nailing down exactly who it would be useful to. We had the idea that if we focused on information that we knew was useful to the ministry, we would ultimately show value no matter what." Interviewee #37, April 2015

5.1.2 Specific information products

The decision to invest in the SNIA as a whole was followed by a number of decisions about how to prioritize specific information products the SNIA would comprise. Three separate but related processes governed these decisions.

i. An **initial** list of information products was developed by MGAP in consultation with partners at the IRI, INIA, INUMET, and UdelaR. This was based on expert consultation intended to gather perspectives regarding (a) existing information gaps; (b) priority information needs for key agricultural actors; and (c) human, data, and technical capacities. While this process was based on informal consultation, it culminated in firm contracts that covered work to develop priority products.

ii. A **second** process took shape after the project began. This process involved the creation of a series of cross-agency working groups, each focused on "co-producing" information products to address specific agricultural challenges (e.g., availability of grazing, etc.). These groups engaged a large number of actors – but they were not specifically resourced by MGAP. As a result, these groups – which met regularly and generated a number of ideas – were not by and large successful in contributing products to the SNIA.

iii. A **third** process involved the minister making urgent requests for information to help addresses emerging social or political challenges. These requests were relatively diverse

> (related, for instance, the declaration of a drought-related state of emergency in 2015; the monitoring of effluents in the Santa Lucia River; and the application of pesticides) and prioritized for a variety of reasons. In prioritizing the development of these products, the SNIA team sometimes de-prioritized products selected in other ways.

The overlapping structures that governed the selection of the information products that comprised the SNIA allowed a large number of actors to participate in formulating ideas for the kinds of information that might be useful. It also allowed the SNIA team to respond to evolving conditions – for instance, by de-prioritizing products that faced data-quality limitations and/or by developing new products to address emerging issues. While these overlapping processes were generally discussed in a positive light by those involved in the SNIA, they were also seen to have created a somewhat chaotic atmosphere in which many products were started, progress on those projects was intermittent, and many were left unfinished. This was reflected both by SNIA staff and by those hoping to work with SNIA to develop products.

Of course, the contracts established a number of products that were developed by IRI, INIA and UdelaR, and the development of these products was supported by MGAP – but the fact that the original project documents did not prioritize MGAP's tasks may have also led to this environment of competing priorities.

> "There should have been a clearer protocol for selecting products, or it could be that the SNIA is in service of the minister, but at some point, a lot of demands came together and it would have been good to have clear priorities." Interviewee #30, May 2017

5.2 Delivering the service

The process of delivering the SNIA involved developing an interoperable database and data visualization system, as well as a large number of data information products.

The team responsible for this ultimately evolved to include an office of roughly 10 "technical" and "functional" analysts located at MGAP; a loose group of collaborators at other department within MGAP (e.g., DGRN, SNIG); two contracted partners (IRI, UdelaR); key government allies (INUMET, INIA); a diffuse network of 30+ organizations that voluntarily contributed data and/or expertise to the SNIA; and an interagency steering committee. Across this diverse web of actors, both data and analysis posed particular challenges for the delivery of the SNIA. The governance arrangements that pertained to these themes are analysed below.

		Selecting the SNIA		**Selecting information products**
Composition and responsibilities of team	●	WB, GoU both had existing teams with clear responsibilities designed to facilitate the development and review of projects of this nature	◑	Three overlapping processes to select products; no uniform rules regarding who got to participate in what context.
Rules and norms that ensure quality	●	WB, GoU both had existing procedures and metrics for proposal review, though they didn't require a high level of detail w/r/t outputs, outcomes & impacts of the SNIA	◑	Three overlapping processes to select products; no uniform rules or procedures to assess quality of data or information products.
Rules and norms regarding funding and financial management	●	WB, GoU both had existing procedures to govern funding and management of proposal develop activities	◑	Products developed by partners supported by contracts; WGs not supported; products deemed a priority by the minister drew SNIA resources from ongoing activities
Rules and norms regarding ethics and conflict of interest	●	WB, GoU both had existing procedures to avoid conflicts of interest w/r/t to proposal development and support	○	No rules or norms regarding ethics, conflicts of interest, etc.; political priorities influence product selection

Table 7: Simplified representation of governance components that supported the selection of the SNIA as a project, and the selection of individual information products within the SNIA. Full circle indicate a perception that these rules and norms were fully developed; a half-circle indicates a perception that the rules and norms were partially addressed; empty circles indicate a perception that rules and norms on this issue were not developed.

5.2.1 Governance of data resources

As described elsewhere, the Uruguayan government is legally obligated to make all of its data freely available, except where doing so would conflict with existing privacy laws (Vaughan et al 2017; Asamblea General de Uruguay 2008a, 2008b). To ensure the SNIA complied with these regulations, a small committee reviewed each dataset before it was included in the system, taking into account privacy concerns and password-protecting, aggregating, or anonymizing data as appropriate.

While this committee oversaw the incorporation of 60 datasets from across MGAP and more than 30 other organizations, no formal mechanisms compelled any of these entities to share their data through the SNIA. Likewise, no formal arrangements ensured the quality of data in cases in which the SNIA staff was not sufficiently familiar with the data (or decision context) to judge quality. This led to several challenges, particularly regarding data quality and metadata.

Regarding data quality, for instance, a member of the SNIA staff reported:

> "The issue of data quality, we play by hand – that is, we have to go by the decision of each unit. Obviously, to make a [data base] system there are basic [standards], but I know, for example, we give [units] development support for data they want to include; if they want to include that data without control, that is a decision for [the unit]." Interviewee #25, May 2017

Still, the issues of data quality was very important to the SNIA staff. In discussing the need to provide only good quality information, one MGAP employee said:

> "You can see clearly that there are many applications in the market that are of use for producers, but that the information and the basic data they handle are of low quality, so what we have to do is … have very tight information, so we don't give "fried potatoes." We have to give the real thing." Interviewee #19, May 2017

The question of added value was also important:

> "When can I say this is a product of the SNIA … when soil information has something layered on top of it? Because if not, the soil information is the same here, there, if it's red, green, yellow. We say it's a product of the SNIA because we are all the SNIA, when in reality it's just the Ministry's soil data …. For this to work, the technicians need to feel that SNIA is a way to improve their work by adding new information that is going to add a lot of value." Interviewee #32, May 2017

To address these challenges, the steering committee developed a branding strategy that would allow SNIA users to clearly and easily identify the organization(s) responsible for developing and maintaining each specific dataset within the SNIA. This arrangement removed potential conflicts of interest associated with contributing data to this larger effort, and allowed the original data provider to continue to take credit (lowering some barriers to collaboration) and responsibility (reducing the need for SNIA staff to be responsible for quality-control) for their data. While the arrangement did not abrogate the need for standardized metadata, it did allow users to default to metadata produced by the originating organizations.

5.2.2 Governance of human resources

Building the information products that comprise the SNIA required technical expertise in a range of fields; it also required significant levels of collaboration between a large number of different actors. In many cases, an informal system of collaboration between technical staff worked well, allowing SNIA staff to co-produce information tools with those that would ultimately use or promote them. In other cases, disagreements regarding the quality of the information caused friction.

> "In terms of assessing the quality of the data, in some cases it is not good – and so we started a process of improving the quality of the data, a process that we had to create, because inside the Ministry there was no process for quality control at all. We are not producers of the data, we get it from others, but we have to convince them to improve the quality, and it is not easy." Interviewee #37, May 2017

While these kinds of disagreements are to be expected, the governance structure of the SNIA project created a situation in which actors involved in co-producing the tools negotiated around these disagreements from different positions. While MGAP was able to use World Bank funds to directly support the technical contributions of the SNIA office and a small number of contracted partners, other MGAP units – and many other governmental and non-governmental organizations – contributed to the SNIA without direct compensation.

In some cases, these organizations saw their contributions to the SNIA as part and parcel of their own work. One example is the Fruit and Horticulture department, which reported both using and supplying the SNIA with information. A member of that department described their collaboration with SNIA thusly:

> "Actually in the dynamic with the SNIA, the idea is give and take – the SNIA serves the information that we provide, adding layers and information to each area." Interviewee #13, May 2017

		Delivering the SNIA
Composition and responsibilities of team	●	SNIA team included an office of ~10 of "technical" and "functional" analysts; contracted partners (e.g., IRI, INIA, and UdelaR); a larger SNIA network (30+ organizations that voluntarily contributed data and/or expertise); and an interagency steering committee.
Rules and norms that ensure quality	◑	SNIA team and various partners informally negotiated regarding the quality of data, analysis, visualizations, etc. with no clear norms, standards, or procedures.
Rules and norms regarding funding and financial management	◑	The contributions of some partners (outside of MGAP) were resourced through contracts; others were asked to contribute to voluntarily. Working groups were not resourced.
Rules and norms regarding ethics and conflict of interest	◑	A branding strategy attempted to limit conflicts of interest associated with sharing data through the SNIA; conflicts regarding which tools should be prioritized / which groups should be served were not addressed.

Table 8: Simplified representation of governance components that supported the delivery of the SNIA. Full circle indicate a perception that these rules and norms were fully developed; a half-circle indicates a perception that the rules and norms were partially addressed; empty circles indicate a perception that rules and norms on this issue were not developed.

The Ministry's statistics office also reported finding it easy and fruitful to work with the SNIA.

> "In reality, two things happen – we do our own analysis and … after that, our information is used by the Ministry and the SNIA to make their own products. Because of the profile of the technicians, they have a good training in development, in georeferencing – we don't have that – then we use that information for analysis as well. Both sides benefit. " Interviewee #27, May 2017

Other actors were more conflicted about contributing time and expertise to co-produce the SNIA. This was particularly true for departments and organizations where existing tools and/or capacities seemed to adequately serve immediate information needs. This conflict of interest may have limited, at first, collaboration and ultimately the number and range of tools that were developed through the SNIA.

> "People don't say, but sometimes the SNIA is sometimes seen more as a threat than as an opportunity … the human being is like that for new things in general, the first thing you do is get scared, think that you want to be the owner of what's yours." Interviewee #32, 2017

The SNIA also reported challenges aligning incentives and priorities.

> "Sometimes it is difficult to achieve a connection with the different actors, with other organizations or with other departments. Sometimes it is difficult to achieve that, not for technical reasons, but rather because of people, as they say … 'this is mine," and not sharing information, that is sometimes seen. I think that is the problem, and then also bureaucracy. Everywhere there is bureaucracy and … that can make things difficult or slow things down." Interviewee #17, November 2015

5.3 Ensuring sustainable impact

In March 2018, the World Bank's formal support for the SNIA ended with the end of the first phase of the DACC project; the SNIA office was closed, with some technicians rolled into a new office at MGAP focused on "e-government."

5.3.1 Providing and measuring impact at scale

To date, the SNIA team has focused on building data interoperability and on rolling out new information products, without conducting either outreach or evaluation regarding the use of those products. No one, for instance, was tasked with promoting the SNIA either in or outside of MGAP; similarly, no one has undertaken to assess the relative impact of the SNIA in particular contexts. Neither the SNIA office nor the steering committee has included anyone with a particular expertise in these topics.

This inattention to outreach and evaluation cannot be considered an oversight per se, as nearly all of the actors who were interviewed as part of this effort expressed an interest in connecting the SNIA to a diverse group of users and in measuring its contribution in different decision contexts. Rather, challenges to understanding and ensuring the impact of the SNIA seem more structural in nature. Since no provisions for user engagement or evaluation were included in the original proposal, the SNIA was not staffed or resourced for these activities – nor was it evaluated by MGAP or the World Bank in these terms. Also, because the SNIA proposal did not mention specific user groups outside of the ministry, it was never clear whose information needs were tantamount, nor how the ability of the SNIA to meet those needs would be assessed. As a result, different people within MGAP had different visions of who the end users should be.

As a result, the evaluation metrics that were defined between MGAP and the World Bank were oriented to the information providers – counting the number of products developed and the number of page views, rather than the number of people who report using the information, how they use it, and the value they associate with its use (World Bank Agriculture Global Practice 2017).

> "At present, evaluation is related to the number of visitors to the webpage, the number of people in the government trained on the use of the webpage; we should revise the indicators, but we're not sure what those indicators should be." Interviewee #37, May 2017

In fact, MGAP did not actively promote SNIA's information products outside the Ministry in the first years after the SNIA was launched.

> "Yes, this is another pillar, the topic of diffusion, marketing. Because [the SNIA has] a lot of products and tools that are interesting for the agricultural sector, and when you show it to people [they say] "This is good, it's useful for me," but they didn't know. So the part about diffusion, it depends a bit on the technician." Interviewee #40, May 2017

5.3.2 Sustainability of the SNIA

In its initial review of the project concept, the World Bank saw no threats to sustainability of the SNIA – citing MGAP's track record in maintaining the National Livestock Information System as evidence that the SNIA would also be supported ((World Bank Sustainable Development Department 2011). At the time that the World Bank project officially ended, however, the future of the SNIA was unclear.

> "We depend on the World Bank to fund the project, but we should open ourselves to other offers; other available money is out there, so we are analysing those options to see what we can do. The World Bank has so many rules, and you need them, but you need to plan with a lot of time in advance what you are going to do, whereas there are some situations that appear, that are going to appear, where you need the flexibility to

take these opportunities. The private sector is one possibility." Interviewee #37, May 2017

Some of this ambiguity was likely tied to the fact that the minister responsible for conceiving the SNIA project ended his term in January 2018 after almost eight years in office, the longest term any minister of agriculture has served in Uruguay's history. The SNIA was seen as part of the legacy of this individual, and it wasn't originally clear that his successor would devote the resources necessary to maintain the SNIA into the future. Another change which altered the flavour of the project came when the SNIA manager was replaced in 2018 by someone who was very skilled in information management, but somewhat less connected to the agricultural sector.

		Ensuring the value of the SNIA		**Ensuring the sustainability of the SNIA**
Composition and responsibilities of team	○	No one involved in the SNIA team has specific expertise in outreach or communication; no one was specifically tasked with these activities	○	There is no clarity regarding who will be involved in developing and managing the SNIA moving forward
Rules and norms that ensure quality	○	No measures were taken to specify what would constitute quality w/r/t the outcomes or impacts of the SNIA, nor the methods that would be appropriate to evaluate them	○	There are no measures to identify the quality of products and/or prioritize which parts should to be continued into the future
Rules and norms regarding funding and financial management	○	No measures were taken to fund outreach or evaluation activities, nor to develop capacity in these areas	○	No clear funding was designated to support the SNIA at MGAP moving forward, though it was rolled into a larger effort on e-governance
Rules and norms regarding ethics, and conflict of interest	○	No measures were taken to identify possible ethical issues or conflict of interest associated with SNIA's value	○	No measures were taken to identify or mitigate any ethical issues associated with the sustainability of the SNIA

Table 9: Simplified representation of governance components that supported the sustainable impact of the SNIA. Full circle indicate a perception that these rules and norms were fully developed; a half-circle indicates a perception that the rules and norms were partially addressed; empty circles indicate a perception that rules and norms on this issue were not developed.

A separate and likely larger threat to the sustainability of the SNIA may be tied to the fact that it has not developed clear evidence of its impacts for specific user groups. Without this evidence, the SNIA may struggle to garner the political commitment needed to support it into the future. As described above, this shortcoming can be seen to be at least partially related to the fact that no one involved in the SNIA was specifically tasked with generating this kind of information – and while the SNIA office was tasked to develop a sustainability plan, it came quite late and left a number of questions unaddressed.

6. Discussion

6.1 Goals and components of climate service governance

The conceptual framework developed as part of this analysis defines the key goals of climate service governance as:

(1) Selecting climate services
(2) Delivering climate services
(3) Facilitating the sustainable impact of climate services

The analysis shows that the framework was relatively useful in capturing the experience of the SNIA. Indeed, the framework was able to help illuminate the extent to which the SNIA team rather easily developed solutions to the governance challenges associated with delivering the SNIA, while struggling somewhat to address those challenges associated with selecting appropriate information products and with ensuring the sustainable impact of those products. The framework was also helpful in articulating the extent to which these goals are intertwined (i.e., the decision not to define specific users as part of the selection process made it difficult to measure the impact or foster sustainability of the SNIA later on).

The framework identified the key components of climate service governance, which include rules, norms, and guidelines to define the:

(1) composition and responsibilities of the project team;
(2) quality of the climate service;
(3) financial control and reporting;

(4) remuneration, ethics, and conflicts of interest.

The analysis indicates that the SNIA team was relatively inclusive with respect to who was involved in discussions regarding who to design and deliver the SNIA. As illustrated by the experience of some SNIA working groups, however, this inclusive attitude was not always supported financially. Likewise, the SNIA team sometimes struggled to agree on definitions of quality, regardless of whether disputes over quality were primarily focused on data or regarding whom the information products were intended to serve – and in many cases, these two issues may be intertwined. This observation serves to support a spate of recent articles that stress the need to develop metrics and standards by which to evaluate climate services.

6.2 Priorities in improving climate service governance

While the Uruguayan experience is unique, this analysis may indicate that the climate service community has focused more attention on governance challenges associated with the delivery of climate services, rather than those associated with selecting and ensuring the sustainable impact of such services. An important distinction between these functions is made in the project governance literature, where the three governance goals have been organized under two headings that distinguish between "governance of projects" and "governance through projects" (see Table 10 below and also Klakegg et al. 2008).

In this characterization, the *governance of projects* is defined as a method of "controlling the project and ensuring its success by defining, documenting, and communicating reliable and repeatable, project practices**"** (Project Management Institute 2013). Enacted at the interface of the project with its various stakeholders, this kind of governance can also be thought of as the governance of project management (Muller 2017).

Governance through projects, on the other hand, involves the collective governance of all the projects within a program or organization (Klakegg et al. 2008). In this context, a project is not an objective itself but a means of bringing about strategic change or benefit for the organization, community, or world at large. In this wider realm, governance involves: (1) choosing projects that serve the strategic objectives of the organization; and (2) ensuring that chosen projects provide sustainable value (Muller 2017). Particularly when the project involves the development of knowledge products, this value may be tied to the selection, contextualization, communication, and/or targeting of specific information – though it may be tied as well to a host of other factors that influence the impact of information use (Foss 2007).

While these issues have been addressed in various ways in the climate service literature, this distinction highlights the need for the climate service community to reckon not just with the development – or even the "co-production" – of information and knowledge, but also with the way those tools do and are intended to have an impact on the world. Several issues that may help to advance these discussions are elaborated below.

6.2.1 Governance of climate services

The experience of the SNIA draws attention to challenges of governing the data and human resources required to deliver effective climate services. While specific governance measures will necessarily take shape differently in different contexts, documenting common challenges, and creating templates for the successful resolution of those challenges, may save the web of actors involved in "co-producing" climate services time and effort as they attempt to meet a growing array of climate information needs. Describing challenges in these terms can also call attention to the need for climate information providers to draw on existing resources to help address challenges that may not be unique to the climate service sphere.

The literature around **network governance**, for instance, offers a number of models to describe how diverse entities can govern their interactions as they move toward common goals. This literature seems particularly relevant to the human-resource challenges faced by the SNIA, and to climate services in general (Provan and Kenis 2008). Also, while the SNIA was able to develop governance structures to address questions of privacy, quality, credit, and transparency, a range of other models for addressing similar concerns are found in the **data governance** literature – which seems particularly relevant to large-scale information systems that house and distribute a mix of publicly available and private data, such as the SNIA (see for instance, Chander 2016; Donker and Loenen 2017).

6.2.2 Governance through climate services

While arrangements that support the governance *of* climate services are focused on the factors that help or hinder climate service stakeholders to develop useful information products, arrangements that support governance *through* climate services have a wider scope, engaging issues of power and representation, among others. A number of authors have explored these topics in the context of climate change adaptation, sustainability and even climate services (Broad, Pfaff, and Glantz 2002; Furman et al. 2014; Lemos and Dilling 2007; McNie 2013; Orlove and Tosteson 1999; Tall et al. 2014; Vogel and O'Brien 2006). Translating these insights into practical advice regarding the governance of national-level climate services remains a challenge on which the SNIA case study may help shed light. Four areas of particular importance are discussed below.

Governance of climate services	**Governing the development of the service: Controlling the process of building the service by defining, documenting, and communicating reliable and repeatable practices**
Relevant governance questions	Who is involved in the co-production of climate services? How do those individuals, and the interests they represent, work together to produce services that are useful, useable, and used?
	What procedures help to determine when climate services are adequate or fit for purpose? How is feedback gathered, analyzed, and incorporated?
	What procedures help ensure that funding supports the entire team over the life of the co-production process?
	What measures exist to help balance the concerns of different stakeholders in the co-production process?
Governance through climate services	**Collective governance of all the services within a program, organization, or country: Choosing appropriate services and ensuring their effectiveness and sustainable impact**
Relevant governance questions	Who is involved in decisions regarding the prioritization of climate services over other services, or over other interventions with similar development goals? Where should those decisions reside? How do individuals, and the interests they represent, work together to align climate service investments with public policy?
	How are the needs of some groups prioritized over others? What measures help balance the concerns of different stakeholders in the selection process?
	What measures can help guide and/or provide oversight of climate service investments?

	Who is involved ensuring that tailored climate services are provided at appropriate scale? Who is responsible for ensuring that the service is sustainable, or for measuring / estimating impact over the life of the service?
	Are there targets regarding the kind of impacts the service is expected to create? How are these assessed?
	Will funding be available to support the services into the future?
	What measures exist to help balance the concerns of different stakeholders as the service is implemented, and into the future?

Table 10: Questions and topics that illustrate the difference between the governance of and the governance through climate services

6.2.2.1 Prioritizing climate service investments

The SNIA case study found that the high-level processes used to make the decision to invest in the SNIA did not require the project designers to be specific about who would use the information, nor to what benefit. Though this kind of open-endedness may have been intended to allow the SNIA to develop organically, it left space for an element of ambiguity that was reproduced later in the project, including in the evolution of multiple processes for product selection without clear guidelines for how to prioritize among the specific information tools that composed the SNIA.

A lack of structure to support this kind of prioritization is not unique to the SNIA. Indeed, many factors influence the success of climate services – including the decision context, the characteristics, tailoring and communication of the climate information, and the process by which that service is created and delivered. Nevertheless, how these factors combine to determine which services are likely to successfully deliver impact remains opaque. Even the guidelines that govern the inclusive stakeholder-driven processes fostered by the United Nations' Global Framework on Climate Change do not articulate processes by which priorities should be set, but rather who might be involved in those discussions (WMO 2018).

While there is an urgent need to distil our current understanding of the relative success of climate services into theories that can guide prioritization, research into the governance structures that facilitate prioritization should explore a host of related questions, including:

- Who should be involved in decisions regarding the prioritization of public-sector climate service investments at the national level?
- What metrics can be used to ensure that national frameworks prioritize those services that are most likely to deliver on national development and adaptation goals?
- What arrangements can ensure that the financial arrangements that underpin these decisions are managed ethically and transparently?

6.2.2.2. Balancing needs at national and local scale

Another challenge highlighted by the SNIA is the need for governance structures that can facilitate climate services that strike a balance between the provision of national-level information and the tailoring of that information to context-specific needs (e.g., Hansen et al. 2019). Indeed, the case of the SNIA highlights how certain governance arrangements – even those intended to be inclusive – may limit the uses of a product, even in a country as small as Uruguay. Research into governance arrangements that can help to facilitate the balance between national-level and context-specific needs would require answering questions such as:

- How can we evaluate the extent to which services strike an appropriate balance between scales?
- How should the appropriateness of this balance be defined?
- What arrangements can ensure that the financial arrangements that underpin climate services ensure that the needs of local and national-level actors are adequately met?

6.2.2.3 Supporting climate service evaluation

While the climate service literature has recently expanded to include a number of papers focused on evaluation (Bruno Soares, Daly, and Dessai 2018; Clements, Ray, and Anderson 2013; Gerlak et al. 2018; Vogel et al. 2014), discussion of the practical aspects of how to fund and foster improved evaluation remain quite rudimentary (Vaughan, Muth, and Brown 2019). In the case of the SNIA, for instance, the discussion around evaluation remained at a relatively high level, recording the number of products developed and the number of page views each received without consideration of how those products may have been used, nor the impact to which they may have contributed. This is not surprising since the SNIA team did not include an expert in climate service evaluation, no funds were allotted for the evaluation of the SNIA, and (outside of the original agreement with the World Bank) no guidelines described the metrics by which the SNIA should be judged. While there is no doubt more to learn, the SNIA case study highlights a few key points about how governance can support evaluation:

- The team responsible for developing climate services should engage an expert in evaluation
- Teams should set the terms by which the service should be evaluated, developing specific theories of change and metrics to understand access, use and impact
- Project teams should make provisions to support evaluation efforts over the life of the project, and beyond, where possible
- Evaluators should declare any conflicts of interest

6.2.2.4 Fostering sustainable impacts

In some cases, investments in climate services may be intended as one-offs, where long-term climate projections are analysed to understand the implications of long-term investments, for instance regarding evolving tidal risk (e.g., Thames Estuary 2100). In most other cases, however – and particularly where services depend on seasonal-scale information – the investments generally only make sense if the information products are accessible and used over a period of years. To facilitate this, however, services may need to be updated as new information or analysis techniques become available, or as the needs of users change (Adams et al. 2015). Developing teams that can be responsible for these services is challenging for climate services supported by project funding; to assist in this, projects should develop guidelines for how often information will be updated, who will be responsible for doing so and based on what input, and how those efforts will be funded. In many cases, project funding may be inadequate for climate services that are intended to be sustained; climate service teams should develop services with careful consideration for the future.

7. Summary and conclusions

A framework based in the project governance literature was used to analyse the governance structures that supported the development of Uruguay's National Agricultural Information System, a national-level climate services for Uruguay's agricultural sector. It defined the goals of project governance as:

(1) Selecting climate services
(2) Delivering climate services
(3) Facilitating the sustainable impact of climate services

It established the components, or means of achieve these goals, as the rules, norms, and guidelines to define the:

(1) composition and responsibilities of the project team;
(2) quality of the climate service;
(3) financial control and reporting;
(4) remuneration, ethics, and conflicts of interest.

The analysis found this framework was useful in capturing the experience of the SNIA. It also found that while the team responsible for the SNIA was relatively successful at developing ad hoc solutions to governance challenges associated with delivering the SNIA, it struggled somewhat to address the governance challenges associated with selecting the information products that composed the SNIA and ensuring their sustainable impact.

This analysis is consistent with the notion that the climate service community is somewhat more advanced with respect to the governance of climate services, and rather less advanced with respect to governance through climate services – which pertains to the strategic use of climate services to pursue adaptation and/or development goals. Improving our ability to use climate services to advance these goals involves developing governance structures to

(1) assist in the prioritization of climate service investments;

(2) identify and, if appropriate, balance trade-offs between national-level information provision and context specific needs;

(3) support climate service evaluation; and

(4) foster sustainable impact past the traditional project lifecycle.

While not all climate services will be developed as projects, all can likely benefit from considering the goals and components listed above. Assessing the extent to which current governance arrangements facilitate these goals is a promising area for future research as well as an important step in improving the use of climate services as a means to achieve resilience to both climate variability and change. It also contributes to a broader conversation on the need to develop governance arrangements that support adaptation, facilitating society's ability to cope not just with current climate variability but also with long-term climate change.

CHAPTER 6: DISCUSSION and CONCLUSIONS

This thesis has advanced our understanding of what it means to create climate services for society. It began with a broad analysis of the emerging field of climate services, which was used, among other things, to define a "typical" climate service and the key research priorities needed to advance its development. Uruguay's National Agricultural Information System, a national agricultural climate service that matches the archetype, was the focus on an in-depth case study of both the governance and institutional arrangements that support it. A summary of the research results is found below.

1. Overview of research results

A literature review that set the stage for the research identified a range of service delivery structures: international, national, regional, research institutes, and private sector actors. It also defined the categories of factors that determine the success of climate services; these include the decision context; the characteristics of the climate information; the governance and structure of the services; and the socio-economic value of the service. Likewise, the literature review identified key research gaps needed to advance climate services; among other things, these include connecting information to users, both by better understanding climate information needs (e.g., Carr et al. 2019) and by better understanding the range of structures that inform the design, development, delivery and use of such services (e.g., Hansen et al. 2019).

In this context, this research addresses three research objectives: (1) characterize the current state of climate service practice, using the archetype of a "typical" climate service to define a case study; (2) diagnose institutional arrangements that support investment in climate services and; (3) analyse key features of climate service governance. A review of the results of the thesis is presented below.

1.1. Characterizing the current state of climate service practice

An analysis of a unique dataset of more than 100 climate services informed several conclusions regarding the state of climate service implementation in 2012, including the extent to which certain practices were common to services around the world. This analysis confirmed that, as of 2012, climate services were provided in all regions and in a range of different sectors including agriculture, water, disasters, and health were relatively more common than those that engaged other sectors (e.g., energy, transport, etc.).

Services based on seasonal climate information were found to be more common than those based on other types of information, though a range of other timescales (historical, monitoring, weather, decadal, long-term) were also included in the study. While nearly half the climate services in question were targeted to government offices, services were also targeted to the private and third sectors in relatively equal numbers (18% and 20%, respectively). In this sense, while the dataset reflected the diversity of climate services, it also allowed for the identification of certain attributes that were more common than others: the most common type of service involved seasonal climate information provided by national meteorological services, in conjunction with research institutes, to agricultural actors over the Internet.

While the dataset was useful in providing a historical overview of the field in 2012, it was less useful in providing a sense of good practice. To advance this discussion, the analysis found that case studies are needed to move past a simple accounting of practice to explore and explain current strengths and weaknesses of climate services from a more theoretical perspective. To this end, case studies should explore under researched issues, explaining causal links between particular interventions and ultimate outcomes. Case studies may also play a role in climate service evaluation, complementing experimental and quasi-experimental methods, and supplementing them in cases in which such methods may be inappropriate or premature.

1.2 Institutional arrangements that support investment

Building on this initial analysis, the thesis develops a case study that follows this archetypical model, looking at the institutional arrangements that support investment in a national-level agricultural climate service based on seasonal-scale information and provided to the Uruguayan agricultural sector over the Internet. The research reveals six factors that created an enabling environment for investment in Uruguay's National Agricultural Information System. These are: institutional support for sustainable agriculture; groundwork on climate change adaptation; the modernization of the meteorological service; an open data policy; a focus on the near-term; and the role of key individuals.

In particular, the results reveal the role that "innovation systems," "groundwork," and the modernization of the meteorological service play in fostering an enabling environment for investment in climate services – suggesting avenues by which national governments can advance toward investment in climate services, even when these investments may seem remote. Policy measures, such as Uruguay's requirement that all public data be made available, and the SNIA's policy of focusing on near-term climate variability rather than long-term climate change, were also critically important. Key individuals, and the relationships of trust between them, were also found to be central to the decision to investment in the SNIA.

1.3 Key features of climate service governance

A second thread of the case study analysis looked specifically at governance arrangements that supported the development and use of SNIA. This analysis found that the team responsible for the SNIA was relatively successful at developing ad hoc solutions to governance challenges associated delivering the SNIA. At the same time, the team was relatively less successful at addressing the governance challenges associated with defining the SNIA, including by selecting the information products that composed it and ensuring the sustainable impact of the tool.

As one of the first studies focused specifically on climate service governance, this analysis finds some utility in the application of themes from project governance to the climate service sphere.

Extending these concepts, it suggests that those concerned with the governance of national climate services should be particularly concerned with issues related to (1) prioritization of one climate service opportunity over another, or between different types of services (i.e., social protection, etc.) designed to achieve similar ends ; (2) balancing needs and opportunities at local and national scales; (3) supporting evaluation; and (4) fostering sustainable impact.

2. Implications for theory and practice

This work addresses several overarching questions regarding the provision and development of national-scale climate services – and while the Uruguayan context is unique, it provides a useful context in which to study the development of climate services.

In particular, Uruguay is a small developed country with a thriving agricultural sector. While farmers in other countries may struggle to acccess basic inputs needed to improve agricultural outcomes, or be protected from climate fluctuations by subsides, there is reason to believe that investments in climate information can lead to improvements in Uruguay's agricultural sector. It is also true that Uruguay's government is relatively stable and corruption free (CIA World Factbook 2017), making it a more effective context to study governance and institutional arrangements than a country in which governments struggle to provide basic services, or where a plurality of different actors increase the likelihood that climate service efforts get sidetracked by unrelated political forces.

In this context, the experience of the SNIA provides lessons regarding (1) a new model for national-level climate services, as well as the (2) resources and (3) considerations necessary to foster those services. These issues are explored below.

2.1 A new model for national services

The literature presents a range of models for climate service provision, which is detailed in Chapter 2 and in the analysis of climate service descriptions found in Chapter 3. While the SNIA follows the archetypal model of national-scale climate services in many regards, it differs from this model in one important way. Specifically, the SNIA is provided not by INUMET but directly by the Ministry of Agriculture, Livestock, and Fisheries.

Of course, the SNIA relies heavily on INUMET, and on its modernization, which helped create an organization that was better able to contribute the data, products and/or the understanding needed to support the development of this information tool. But while some donors have focused strongly on the modernization of meteorological services as a means to advance climate resilience (Rogers and Tsirkunov 2013), the development of the SNIA was ultimately controlled by MGAP. This arrangement brought with it several advantages – specifically, because MGAP is a powerful ministry, it was better able to secure the financial and political support needed to develop a project at this scale. Indeed, it is highly unlikely that the project would have been able to garner this kind of support with INUMET as the lead agency. Meanwhile, locating MGAP at the centre of the SNIA project put the user organization in control of designing and developing the climate information products, bringing experts from the national meteorological service in as partners to what was essentially a user-driven activity.

Locating such a large-scale climate service at the Ministry of Agriculture also challenges the notion that climate service expertise should be consolidated in a single agency (e.g., a national meteorological service or a national climate service centre), a notion that currently underpins a range of climate service arrangements, including those advocated through the Global Framework for Climate Services. Indeed, while the GFCS focuses on the development of "national frameworks" informed by an inter-ministerial committee, it sees the national meteorological services as leading the climate service design process (WMO 2018). Other unconnected activities have focused on the development of national climate service centres – whether these are specifically tied to meteorological services or to research institutes (Medri, Banos de Guisasola, and Gualdi 2012; Miles et al. 2006).

In contrast, the SNIA model seemed to align more closely with the concept of demand-driven climate services, a notion that has gained increasing support since Cash et al (2006) highlighted a need to counter the “loading dock approach.” In the last decade, a range of authors have documented the extent to which linking the supply of climate information with users’ demands is a complex, highly contextual social process that requires ample resources and time management (McNie 2013). Several have presented models for institutional arrangements that can facilitate this kind of process, with a recent focus on collaboration and “boundary chains” as a way to move information from research institutes to potential user organizations (Kirchhoff, Lemos, and Kalafatis 2015; Lemos et al. 2014).

Locating the service directly at the user organization, and inviting operational and research experts to participate at the users request, presents a new model for climate service development. While this models brings with it its own challenges – including the fact that the SNIA was seen as a leading achievement of the minister who built it, thus making it somewhat of a liability when the next minister was installed – this kind of arrangement is relatively novel and merits continued study in different contexts.

2.2 Key resources in fostering national climate services

The research also highlights three inputs critical to the development of national climate services. While some of these issues (e.g., data) have previously been identified as important by the climate services community, others are entering the climate services literature for the first time. Further research into these themes may influence the way that climate service bottlenecks are diagnosed and understood, and the way that national governments and donor organizations invest in various activities designed to use climate information to improve adaptation and resilience. These themes are considered in brief below.

2.2.1 Innovation systems

The analysis revealed the extent to which Uruguay’s agricultural innovation system contributed to the environment in which the decision to fund the SNIA took place. As detailed above, innovation is the result of a number of interdependent processes (e.g., the existence of appropriate organizations, formation of social, political and learning networks, the alignment of institutions and the accumulation of knowledge) which interact to create contexts conducive to innovation (Bergek et al. 2008; Francis et al. 2016; Jacobsson and Bergek 2011; Pamuk, Bulte, and Adekunle 2014; Williamson, Hesseln, and Johnston 2012). In the wider literature, the main contribution of this kind of analysis has been to help create frameworks to diagnose failures or weaknesses that can be addressed with specific policies. Further developing this concept in the climate service sphere would involve looking specifically at the infrastructural, institutional, interaction, and capacity failures that limit climate services investments. It would require thinking about climate services holistically, and as something that occur in a wider context; it would require considering bottlenecks to climate services beyond what is traditionally considered within the climate service value chain (e.g., Frisch 2019).

2.2.2 Groundwork

The Uruguayan case study also seems to confirm the notion that activities to address adaptation to climate change progress in a relatively ordered manner – beginning with basic recognition, proceeding to groundwork, and moving on to more high-level investments in technology or infrastructure. This seems to indicate that further study on what constitutes effective groundwork is an important aspect of building climate service capacity. Focusing on this kind of groundwork may involve considering the timeframes on which underpinning activities take place and the extent to which they may be cyclical and/or additive. It also opens a relatively broad research agenda which overlaps with, but is not fully addressed by, earlier work that focuses on the need to build trust and foster mutual understanding between different actors that may be involved in developing climate services (Lacey et al. 2018). This research may also overlap with a number of other related concepts, including co-production (Bremer et al. 2019; Vincent et al. 2018) and boundary spanning (McNie 2007; Bednarek et al. 2016) both of which are seen as important components of groundwork. A final issue here has to do with the SNIA's focus on near-term variability as a mode of adapting to long-term climate change. While a number of papers have considered (a) the extent to extreme events make it more likely that people will take action to adapt to climate change (Carlton et al. 2016; Patt and

Schröter 2008); and (b) when and whether adapting to current variability improves capacity to adapt to long-term change (Dilling et al. 2014), a focus on groundwork may help to integrate these currently separate discussions, providing guidance on how national organizations may use experiences of current variability to build adaptive capacity.

2.2.3 Data

Data, and the policies that govern it, are widely recognized as critical to climate services. While the development of the SNIA development shows the power of open data, it also illustrates some of the challenges that come with it – and while several studies have considered the role that data policy plays in helping meteorological services to meet climate information needs, more work is clearly needed (Rogers and Tsirkunov 2013; Overpeck et al. 2011). Indeed, though making public data available publicaly available is increasingly seen as an unalloyed good, there are a number of reasons that doing so can be legally and logistically challenging (Borgman, Wallis, and Mayernik 2012; Jahnke and Asher 2012). Identifying ways to characterize and measure the existence of infrastructure in place to manage these challenges is thus a critical precondition to climate service development. Other work, including analyses of existing data sharing arrangements [i.e., between European meteorological services (Haymaker et al. 2018) or through the Latin American Observatory on Extreme Events (Muñoz et al. 2012)] and comparative analyses of the potential value to an economy of selling data versus making it freely available.

2.3 Key considerations in developing national-level climate services

The Uruguay case study also highlights several considerations for those interested in researching and/or developing national-level climate services. Further research on these issues in the Uruguayan agricultural context, and in other country and sectoral contexts, can help the international community to develop a sense of good practice in how to address these challenges in a range of climate services. Indeed, while these issues created challenges for the team developing the SNIA, strategies to address these issues are likely to make national-level climate services more effective and efficient.

2.2.4 Priorities

The first major issue for national governments is that of priority setting. While the Uruguayan government has not engaged in this process, one system for prioritization has been developed by the Global Framework for Climate Services, which articulates a step-by-step process to convene stakeholders and ultimately develop a National Framework for Climate Services (WMO 2018). This process locates decisions about climate services development – including which services get made and whose needs get met – within national governments, relying on the legitimacy of existing political systems to facilitate democratic decision making processes. Though this has not yet taken place, countries may decide to more explicitly connect climate service planning to National Adaptation Planning processes (Mullan et al. 2015). Documenting the relative success of these activities will be an important research activity moving forward. Another key issue will be understanding the information needs of potential users; a recent paper articulates a research agenda that may be helpful in guiding advancement in this regard (Carr et al. 2019).

2.2.5 Scale

Developing effective agricultural climate services at a national scale requires managing trade-offs between the goals of meeting the context-specific needs of farmers and providing cost-effective services at scale (Hansen et al. 2019). While national meteorological services provide climate information at a national scale, much of the research and effort toward the delivery and use of climate services has remained at a pilot scale. The resulting body of experience offers a great deal of insight into the challenges that farmers face in accessing, using, and benefiting from climate information – but it does not directly address the need to provide climate change adaptation at scale. Identifying services that can balance these trade-offs is a key research priority for those interested in national climate services.

2.2.6 Funding and sustainability

The question of how to fund climate services has been explored from a variety of angles, including in terms of cost-benefit analysis (Levi and Hautala 2009; Strong and Shi 2008) and with respect to the potential role of public-private partnerships (Gordon 2008; Haigh et al. 2018; WMO 2019). Within this thesis, the analysis conducted in Chapter 3 confirms that many climate services are supported through project funding, while Chapter 5 identifies some challenges associated with relying on that kind of funding, at least in the Uruguayan context. In the case of the SNIA, a fundamental challenge to the sustainability of SNIA derived from the political context in which it was developed: While the political clout of the agricultural ministry, and the minister himself, allowed the SNIA to attract funding, its visibility also created a liability for the next minister, who saw it as a signature achievement of the previous administration. Ultimately, the SNIA was transferred to INIA, allowing it to access a sustained funding stream and taking it out of the political context.

Another challenge to sustainability involves the need to continually update the climate and other information that underpins each climate service (Adams et al. 2015). Indeed, scientific understanding is always evolving, which means that climate services can potentially go out of date. In some cases, climate service providers may also make mistakes that ultimately result in subpar or even harmful decisions. It is important that climate service users and providers discuss these possibilities and develop shared expectations regarding the life of the product, the ways in which it may be refreshed or revised over time, and how the provider will address mistakes or errors that come to light. Climate service products must document and clearly distinguish different versions of the same product. Though the SNIA has not yet developed protocols to manage this, the case study highlights these issues as critical for consideration.

2.2.7 Evaluation

Issues of priorities, scale, funding and sustainability are ultimately related to evaluation, which creates a structured process by which climate service stakeholders can explore and document progress toward goals. To date, the bulk of work on climate services evaluation has focused on questions of access, use, and impact (Vaughan et al. 2019)– though several efforts have also focused more on process-oriented metrics as well (e.g., Gerlak et al. 2018). Indeed, while the literature on climate service evaluation has expanded significantly in recent years, the Uruguay case study makes it clear that climate services should articulate the measures by which they should be evaluated upfront, even those that are likely to change over time. Even these more process-orientated evaluations have failed to consider issues of prioritization, scale or funding, all of which require more attention in the future. This protocol should also provide the justification for adjustments to fit changing socioeconomic needs and a changing understanding of climate science.

3. Reflections on the research approach

The pragmatic approach employed in this thesis balanced a broad survey of climate service activities with detailed analysis of a single case study. This approach allowed the researcher to focus on the outcomes of the research as opposed to commiting to a single methodological frame. This approach also allowed the researcher to develop a range of research skills, including confronting the challenge of generating insight through a process grounded in soliciting insight from others. Importantly, the research approach also highlights the complementary nature of survey and case study approaches, with the initial survey work helping to narrow in on an appropriate case study context, and the case study generating a number of questions that may be useful to explore through additional survey activities.

One notable aspect of the research approach involves focusing on a climate service in Uruguay, a small developed country with a thriving agricultural sector. While some limitations to the generalizability of the case are considered below, there are several reasons to believe that conducting the research in this context has allowed for the generation of insight that might be more difficult to generate elsewhere, because of confounding economic or political issues of which Uruguay is relatively free.

3.1. Limitations of current research

The survey approach was marked by a number of limitations. While the CSP/WMO dataset represents the most comprehensive detailing of climate service activities to date, there is no way of knowing how many climate services currently exist, nor of knowing whether or not this sample is representative of that larger group. There is also no way to control for the role that selection bias may play on the case study collection, nor to independently verify the information included in the studies. Despite these limitations, the dataset has allowed for a rich empirical analysis, including the emergence of a number of interesting and novel insights.

The case study approach also has limitations. For instance, while the case study provides a rich description of the experience in Uruguay, the Uruguayan experience may not be generalizable to other climate services in other countries. Indeed, Uruguay is a very small and relatively affluent country with good data resources and a strong interest in agricultural innovation. As such, this situation may have been uniquely conducive to the development of a national level agricultural climate service. At the same time, it is reasonable to assume that all climate services are context-specific. In-depth case studies can help to illuminate important factors in different contexts, helping us to understand which variables are transferable and which are not.

3.2. Avenues for future research

A number of avenues for future research have been identified in section 2. Among other things, this includes a more detailed consideration of **user-led models for national-level climate services**. The Global Framework for Climate Services, championed by the world's national meteorological and hydrological services through the World Meteorological Organization, has largely focused on climate services developed by those who specialize in the production of climate information.

More broadly, the thesis identifies the extent to which similar research in different contexts stand to reveal new and important insights into the institutional arrangements and governance that can create useful climate services. Indeed, the current case study was focused on a national-level climate service led not by the national meteorological service, but by the Ministry of Agriculture, Livestock and Fisheries. As such, the factors that fostered an enabling environment for investment in the SNIA, and the key governance features that defined it, may be very different for the SNIA than for other national-level services. Conducting similar case studies in climate services led by national meteorological services, or those developed under the auspices of a National Framework, will be an important contribution to the literature.

For instance, operating through user-organizations (e.g., the Ministry of Agriculture or other sectorally focused institutions) would address the call for demand-driven climate services, while also creating opportunities for those interested in using the climate services to consider issues of priority setting, funding, and evaluation. Further research might consider how different types of institutional arrangements lead to different solutions to these challenges in different contexts, improving the abiltiy of countries to navigate the development of effective climate services and/or improve the National Frameworks developed in conjunction with the WMO.

Another key area for research is the role that **ground work and innovation systems** play in the development and use of climate services. While the climate services community has considered the role that specific types of climate information can play in improving sectoral decision making, they have focused less on how improvements to the wider community, including the existence of appropriate organizations; the richness of social, political and learning networks; the alignment of institutions; and the accumulation of knowledge contribute to the success of climate services. To the extent that the climate services community has engaged these ideas, it has focused on the concept of boundary chains (e.g., Lemos et al. 2014); the current research indicates that there is a great deal left to be learned.

4. Conclusions

The thesis advances our understanding of what it means to create climate services for society. Grounded in a broad analysis of the emerging field of climate services, the thesis begins with an analysis of a global survey of more than 100 services, which it uses to draw general conclusions about the current state of practice and the persistence of a number of common challenges across a range of different services. This sampling activity was used to define a pattern of attributes that define a "typical" climate service. A national agricultural climate service that matches this archetype was selected for further study, allowing for an in-depth case study of both the governance and institutional arrangements that support it.

The case study revealed six factors that created an enabling environment for investment in Uruguay's National Agricultural Information System. These are: institutional support for sustainable agriculture; groundwork on climate change adaptation; the modernization of the meteorological service; an open data policy; a focus on the near-term; and the role of key individuals. It used a framework approach grounded in the project governance literature to explore the governance of the SNIA. This analysis found that the team responsible for the SNIA was relatively successful at developing ad hoc solutions to governance challenges associated delivering the SNIA; it found the SNIA was relatively less successful at addressing the governance challenges associated with defining the SNIA was, including by selecting the information products that composed it, and ensuring the sustainable impact of the tool.

The work contributes to a larger discussion on the governance and institutional factors that contribute to the success of climate services; and to a growing understanding of what determines "good practice" in the field of climate services more broadly. The thesis also consolidates a range of social science literature that has expanded in the climate service field over the past decade.

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APPENDICES

Appendix 1: Case study template (Chapter 3)

Global Framework for Climate Services and Climate Services Partnership
Case Study Solicitation
January 2012

Introduction

The **Climate Services Partnership** (CSP) was formed at the first International Conference on Climate Services (ICCS) to advance climate services around the world. In doing so, the CSP supports the **Global Framework for Climate Services** (GFCS), a formal international system that facilitates the coordinated support of climate services worldwide.

In an effort to advance common goals, the GFCS and the CSP are soliciting case studies that document experiences in the provision, development and application of climate services. Case studies should detail the perspective of users of climate information as well as that of providers of such information. They should highlight successful strategies, detail challenges, and share lessons learned.

Case studies will form an integral part of the GFCS implementation plan. The plan, currently being drafted by over 100 experts worldwide, will be presented before an Extraordinary Congress of the World Meteorological Organization (WMO) in October 2012; it will guide the activities of the GFCS in the years ahead. Case studies provided by WMO Members will be collected into a single document and distributed at the October 2012 Extraordinary Congress as well.

The Climate Services Partnership will distribute case studies through an online knowledge capture portal. In making case studies available to the broader community, the CSP hopes to offer perspective on approaches that can be adopted or adapted by other interested parties.

Though each case study will of course be unique, authors should attempt to answer as many of the question posed by the case study guidelines as possible. Questions, comments, or suggestions should be directed to:

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Global Framework for Climate Services
WMO
flucio@wmo.int

Catherine Vaughan
Climate Services Partnership
cvaughan@iri.columbia.edu

GFCS/CSP Case Study Guidelines

Please describe your climate service activity in the following terms.

a. **WHAT?**
   i. Briefly describe the service being provided. What socioeconomic issue/problem does your project/service address? What audience does it target?
   ii. Briefly describe the climate and contextual information that is incorporated into service.
      - What kinds of climate information are used? What are the sources of this information (National Meteorological Service/other)? How is information accessed (including, for instance, format, cost)?
      - Is information regarding socioeconomic factors a part of the service? If so, what is the source of this information and how is it accessed?
      - Is the information tailored to specific users? Who is responsible for tailoring information (user/provider/ joint team)?
      - How is climate information used in decision making?

b. **HOW?**
   i. Processes & mechanisms

      1. ***Stakeholder identification***: Who are the stakeholders involved in the process and how were they identified? How did the group decide to focus on this issue? Who was involved in making this decision?
      2. ***Stakeholder involvement***: Please describe the full chain or network associated with your activity and any mechanisms to facilitate the dissemination of information. Who do you give information or advice to? Who gives information or advice to you? Describe the channels used to access climate information products and services.
      3. ***Funding mechanisms***: Briefly describe the program's business model. Is the program supported by donor, government, or private sector funding, or by some combination thereof? Are their challenges to financial sustainability? Is it possible to upscale this project? What investments have been made in infrastructure?
      4. ***Implementation***: Does the service involve one or more institutions? If more than one institution is involved, what are their roles in the management of the project? How are decisions made?
      5. ***Evaluation***: Is there a process by which the project/service is evaluated? Are there mechanisms to understand the value of the decisions informed by the service? Are there processes for soliciting user feedback and adjusting the service in response? Are their concrete examples of this activity facilitating adaptation to climate change?

ii. Capacities

1. ***Present***: What human, infrastructural, institutional and procedural capacities were necessary to build your service? Please describe the level of climate expertise in user organizations and the extent to which these organizations rely on external support for interpretation of information.
2. ***Lacking***: What capacities were lacking and how were they overcome (for instance, joint projects, interchange of personnel, etc.)?
   i. Describe a challenge you faced in matching information products or services available to needs.
   ii. Describe any innovations that were put in place to meet needs.

c. WHAT NEXT?

i. What are goals for the future of the project/service?
ii. Could your program be scaled up? Could lessons learned be transferred to other sectors and/or locations? What did and did not work?
iii. What are the main challenges moving forward?

d. PRINCIPLES of the GFCS:

Authors are also encouraged to indicate which, if any, of the Principles of the Global Framework on Climate Services (listed below) are reflected in their service and how they have been included. More on the background, history and ongoing activities of the GFCS can be found under www.wmo.int/gfcs.

Principle 1: All countries will benefit, but priority shall go to building the capacity of climate-vulnerable developing countries.
Principle 2: The primary goal of the Framework will be to ensure greater availability of, access to, and use of climate services for all countries.
Principle 3: Framework activities will address three geographic domains; global, regional and national
Principle 4: Operational climate services will be the core element of the Framework.
Principle 5: Climate information is primarily an international public good provided by governments, which will have a central role in its management through the Framework.
Principle 6: The Framework will promote the free and open exchange of climate-relevant observational data while respecting national and international data policies.
Principle 7: The role of the Framework will be to facilitate and strengthen, not to duplicate.
Principle 8: The Framework will be built through user – provider partnerships that include all stakeholders.

Appendix 2: Complete list of case studies included in the analysis (Chapter 3)

Title	First author	Organization	Collection
Climate services and agriculture in the Caribbean	Adrian Trotman	Caribbean Institute for Meteorology and Hydrology	GFCS
Reducing crop loss through Climate Field School -- the Indonesia Experience	AE Sakya	Indonesian Agency for Meteorology, Climatology, and Geophysics	GFCS
Provision of climate services in Tanzania	Agnes Kijazi	Tanzania Meteorological Agency	GFCS
Climate change adaptation: when there is a will, there is a rail way!	Alexander Vetich	International Union of Railways	GFCS
When worlds collide: urbanization, climate change, and disasters	Allen L Clark	Pacific Disaster Centre, USA	GFCS
New Zealand's climate change and urban impacts toolbox	Andrew Tait	National Institute of Water and Atmospheric Research	GFCS
Engaging users in the production and delivery of information in Africa	Anna Steynor	University of Cape Town	CSP
Climate information for disaster management and decision making: the IRI-IFRC partnership	Ashley Curtis	International Research Institute for Climate and Society	CSP
Extreme precipitation event: the Weather Public Alert System of the Chilean Weather Service	Benjamin Caceres	Chilean Meteorological Department	GFCS

Early warning systems for food security in Eastern Africa: Linking the Food Security Outlook with the Climate Outlook Forum	Carlo Scaramella	World Food Programme	CSP
Building the capacity of smallholder rice farmers under a changing climate in Nigeria	Catherine Nnamani	Research Group for Climate Change Adaptation in Nigeria	CSP
Building the seasonal streamflow forecasting service	Claire Hawksworth	Australian Bureau of Meteorology	GFCS
Climate education for the public health sector	Cynthia Thomson	International Research Institute for Climate & Society; Mailman School of Public Health, Columbia University	CSP
Communicating climate variability: La Nina Drought Tracker	Daniel Ferguson	University of Arizona	CSP
The Climate Change Mitigation and Adaptation International Training Programme	Daniel Homestedt	Swedish Meteorological and Hydrological Institute	GFCS
Climate services and disaster risk reduction in the Caribbean	David Farrell	Caribbean Institute for Meteorology and Hydrology	GFCS
Indigenous stories and climate services	David Griggs	Monash Sustainability Institute; Yorta Yorta Nation	GFCS
Low Carbon Growth Plan for Australia: providing climate services to businesses	David Griggs	Climate Works Australia	GFCS
User-centred design approach to the seasonal climate outlook	Elizabeth Boulton	Climate Information Services, Australian Bureau of Meteorology	GFCS

Making climate science useful: cross-regional learning from Kenya and Senegal	Emma Visman	King's College London	GFCS
Understanding climatic processes on Earth: the invaluable contribution of satellites	European Space Agency	European Space Agency	GFCS
Devils Lake Decision Support System: Using climate information to manage flood risk	Fiona Horsfall	National Oceanic and Atmospheric Administration	GFCS/CSP
Climate services for agricultural production in Guinea Bissau	Francisco Gomes	National Institute of Meteorology, Guinea Bissau	GFCS
MOSAICC: an inter-disciplinary system of models to evaluate the impact of climate change on agriculture	Francois Delobel	Food and Agricultural Organization	GFCS
Data sharing and collaboration: Regional and National Climate Outlook Forums in South America	Gabriella della Croce	International Centre for Research on the El Niño Phenomenon	CSP
Climate information for public health: Filling knowledge gaps and building connections	Gilma Mantilla	International Research Institute for Climate and Society	CSP
Adaptation to climate change in the mountain forest ecosystems of Armenia	Government of Republic of Armenia	Government of the Republic of Armenia	GFCS
Climate information applications in famine early warning and decision making systems	Greg Husak	Climate Hazards Group, University of Santa Barbara	CSP

Applying science to society: the Climate Service Centre	Guy Brasseur	Climate Service Centre, Germany	CSP
An integrated climate service for the river basin and coastal management of Germany:KLIWAS	H Moser	Federal Institute of Hydrology, Germany	GFCS
Climate services in Hong Kong: accomplished through partnership and outreach	Hilda Lam	Hong Kong Observatory	GFCS
Climate Services Across Borders	ICA&D Team	Royal Netherlands Meteorological Institute	CSP
The Danube River Basin climate adaptation strategy	ICPDR	International Commission for the Protection of the Danube River	GFCS
Short-term weather forecasting for disaster preparedness in Venezuela	Ingrid Garcia	Centre for Scientific Modelling	CSP
The use of seasonal climate forecasts to inform decision making and management in the renewable energy sector of Samoa	JA Smith	Australian Bureau of Meteorology, Samoa Met service, Electric Power Company, AusAID	GFCS
Developing the capacity of Central Asian national planning agencies to model climate impact scenarios and develop adaptation strategies	Jaako Nuottokari	Finnish Meteorological Institute	GFCS
Climate change impacts on Indonesian fisheries	Jason Lumban Goal	Bogor University, Institute of Fisheries and Marine Affairs for Research and development, National Institute of Aeronautics and Space	GFCS

Building resilience to future climate change in ports: Terminal Maritimo Muelles el Bosque in Colombia	Jean Cristophe Amado	Acclimatise	GFCS
ENACTS Ethiopia: partnerships for improving climate data availability, accessibility, and utility	Jessica Sharoff	Ethiopia Met Department; University of Reading; University of East Anglia	CSP
R4 Rural Resilience Initiative in Ethiopia	Jessica Sharoff	International Research Institute for Climate and Society	CSP
Multinational efforts to produce regional climate prediction for informed decision-making	Jin Ho Yoo	Asia-Pacific Economic Cooperation Climate Centre	GFCS
The use of a seasonal fire early warning tool for managing peat fires in Indonesia	Joyce Wong	International Research Institute for Climate and Society	CSP
Seasonal climate prediction in Chile: the Agroclimate Outlook	Juan Quintana	Chilean Meteorological Department	GFCS
Making climate change information available online	Juha Karhu	Climate Service Centre, Finnish Meteorological Institute; Finnish Environmental Institute; Aalto University	GFCS
Desert Locust Information Service	Keith Cressman	Food and Agricultural Organization	CSP
IBTrACS: collaborative effort to consolidate tropical cyclone best track data worldwide	Kenneth Knapp	World Data Centre for Meteorology	CSP
Climate variability & change: perceptions, experiences, & realities	KPC Rao	International Crops Research Institute for Semi-Arid Tropics	GFCS
Identifying climate impact on the	Laurence Cibrelus	World Health Organization	

incidence of meningitis epidemics			CSP
Developing climate services: the role of the energy sector	Laurent Dubus	EDF Energy	GFCS
Development of climate services in Sweden to support climate change adaptation	Lena Lindstrom	Swedish Meteorological and Hydrological Institute	GFCS
Health Risk Management in a Changing Climate: Using climate information to help manage malaria and diarrheal disease in TZ	Lindsay Bouton	Tanzania Red Cross Society	CSP
Atmospheric Climate Information for Urban Planning: Beijing Municipal Climate Centre	Linwei Liu	Beijing Climate Centre, China Meteorological Administration	CSP
Strengthening hydromet services in Mozambique	Louise Cronenberg	World Bank	GFCS/CSP
Delivering advisory services by mobile phone	LS Rathore	Indian Meteorological Department	GFCS
Reaching farming communities in India through the Farmer Awareness Programmes	LS Rathore	Indian Meteorological Department	GFCS
Identifying local climate impacts on weather and water: LCAT	Marina Timofeyeva	National Oceanic and Atmospheric Administration	GFCS

Insurance against drought and destabilization of energy costs in Uruguay	Mario Bidegain	National Meteorological Department, Uruguay	GFCS
Seasonal to decadal climate forecasts for renewable energy: connecting to users through the ARECS initiative	Melanie Davis	Catalan Institute for Climate Sciences	CSP
Global Drought Monitoring Portal	Michael Brewer	National Oceanic and Atmospheric Administration	GFCS/CSP
Enhancing cooperation in climate services through the sub-regional virtual climate change centre	Milan Dacic	Republic Hydrometeorological Service of Serbia	GFCS
Forecasting for disaster: Climate help desk for humanitarian action and decision making in Africa	Mohammed Kadi	African Centre of Meteorological Applications for Development	CSP
Climate information and development: regional climate outlook forums in Africa	Mohammed Kadi	African Centre of Meteorological Applications for Development	CSP
Climate Information in support of the health sector: Madagascar	Nirivololona Raholijao	Madagascar Directorate General of Meteorology	GFCS
Building a scientific basis for climate change adaptation -- the research program on climate change adaptation	Nobuo Mimura	Ibaraki University, University of Tsukuba, Waseda University, Remote Sensing Technology Centre of Japan	GFCS
Climate information services for herder families in Mongolia	NWHS, Mongolia	National Weather and Hydrological Service, Mongolia	GFCS

The development of climate scenario fact sheets for engineers or infrastructure relevant climate indicators	Ouranos	Ouranos	CSP
Creating an atlas of climate scenarios for forest management in Quebec	Ouranos	Ouranos	CSP
Climate local information in the Mediterranean region: responding to users' needs	Paolo Ruti	Italian National Agency for New Technologies, Energy and Sustainable Economic Development (ENEA); Energy, Environment and Water Research Centre; National Centre for Meteorological Research (France); International Centre for Theoretical Physics; Catalan Institute of Climate Sciences National Observatory of Athens (NOA); Centro Euro-Mediterraneo; TEC Services Consulting; Plan Blue; Potsdam Institute for Climate Impact Research; University of East Anglia; GREVACHOT; Joint Research Centre; Meteorological and Hydrological Service of Croatia; University System of Maryland; University of California	CSP
Climate outlooks for food security in Central America	Patricia Ramirez	Regional Committee for Hydraulic Resources, Central America	GFCS/CSP
Mainstreaming climate information for agricultural activities in Kenya	Peter Ambenje	Kenya Meteorological Department	GFCS
Seasonal forecasting for Africa: water, health management, and capacity building	Philipe Dandin	Météo-France	GFCS

Partnerships on water resources management in France	Phillipe Dandin	Météo-France	GFCS
Drias, the futures of climate: a service for the benefits of adaptation	Phillipe Dandin	Météo-France, Centre of Basic and Applied Research Specialized in Modelling and Numerical Simulation, National Centre for Scientific Research (France)	GFCS
Data rescue: a necessary look at climate	Phillipe Dandin	Météo-France	GFCS
Building resilience to climate-related hazards	PPCR	Ministry of Environment, Science, and Technology's department of Hydrology and Meteorology (Nepal); Civil Aviation Meteorology Authority, Yemen Meteorological Service (CAMA/YMS)	GFCS
Climate information services for food and agriculture	Ramaswamy Selvaraju	Food and Agricultural Organization	GFCS
Preparing for ENSO events in the Pacific	Rebecca McNaught	International Federation of the Red Cross and Red Crescent Societies	CSP
Teaching journalists to understand climate change	Reija Ruuhela	Finnish Meteorological Institute	CSP
North American Drought Monitor	Richard Heim	National Oceanic and Atmospheric Administration	CSP
Supporting decision making in the sugar industry with integrated seasonal climate forecasting	Roger C. Stone	University of Southern Queensland	GFCS
Governing drought information systems	Roger Pulwarty	National Oceanic and Atmospheric Administration	GFCS
The Heat Health Warning Systems as an Example of Climate Services at the Deutscher Wetterdienst	S. Rosner	Deutscher Wetterdienst	GFCS

Drought & precipitation monitoring in the Caribbean	Sari Blakely	Caribbean Institute for Meteorology and Hydrology	CSP
Innovative approaches to engaging communities in participatory dialogues that enhance community disaster preparedness	Selina Maenzanise	American Red Cross	CSP
Climate science and services to support decision making	Seok Joon Cho	Korean Meteorological Administration	GFCS
The Chilean Ultraviolet Radiation Network: Monitoring and forecasting the UV index for health protection	Solangela Sánchez Cuevas	Dirección Meteorológica de Chile	GFCS
Climate services for large engineering projects in China	Song Lianchun	China Meteorological Agency	GFCS
Improved livelihoods and building resilience in the semi-arid tropics: science-led, knowledge-based watershed management	Suhas P Wani	International Crops Research Institute for Semi-Arid Tropics	GFCS
ENACTS Ethiopia: Partnerships for improving climate data availability, accessibility, and Utility	Tufa Dinku	International Research Institute for Climate and Society	CSP
How the Met Office (UK) is building capacity and supporting adaptation in some of the world's	UK Met Office	Hadley Centre; The Energy and Resources Institute	

most vulnerable regions			GFCS
Climate Science Research Partnership	UK Met Office	UK Met Office	GFCS
Adapting to climate change in the Nieman River Basin	Vladimir Korneev	Central Research Institute for Complex Use of Water Resources, Belarus	GFCS
Helping the world's poorest farmers to adapt to a changing climate	Warren Page	Australian Centre for International Agricultural Research	GFCS
Exploiting the Changing Global climate	WeatherNews	WeatherNews	GFCS
Informing decision-making in health using seasonal climate outlooks	Yahya Abawi	Solomon Islands Meteorological Service	GFCS
Early warning information on extreme events	Yoshiji Yokoe	Japan Meteorological Agency	GFCS
Developing an early warning system to mitigate temperature stress on rice production	Yoshiji Yokoe	Japan Meteorological Agency	GFCS
Toward climate risk resilient cities: spatially explicit land-use scenarios	Yoshiki Yamagata	Centre for Global Environmental Research, National Institute for Environmental Studies	GFCS
Climate change adaptation methodologies in the Bay of Bengal fishing communities	Yugraj Singh Yadava	Bay of Bengal Programme Inter-Governmental Organization	GFCS

Appendix 3: Interview Protocol (Chapter 4)

Socio-demographic questions

Age?
Sex?
What is your educational background?
Where do you work? What is your title?
What is your specific role in this organization?
How long do you have in this role? In the field?

General context questions

Do you know the term climate services?
Can you tell me what is meant by climate services?
Are there climate services in Uruguay?
Do you think climate variability and change are of concern to most people in Uruguay?
Are there specific people who are more concerned about this?
Do you think the government in general, or specific government offices, are concerned with climate variability and change?
Can you remember any recent climate impacts?
Are you aware of any cases in which climate information was used for decision making?
What sorts of decisions can people make if they have access to climate information?

SNIA-related questions

Do you know about the SNIA project?
What is the goal of the SNIA?
How did the project come about?
What motivated this investment?
Who was the driving force behind the project?
What organizations are involved in the development of the project to-date?
Have any particular people or organizations taken the lead?
To what extent will climate information be a part of the SNIA?
Do you believe the SNIA will be worthwhile project?
To whom will the SNIA be most useful? What sorts of decisions will it inform?

Appendix 4: Number of interviews in each organization / department (Chapters 4 and 5)

Acronym	Organization	Number of Interviewees
AEGSIC-IDE	Agencia de Gobierno Electrónico y Sociedad de la Información -- Infraestructura de Datos Espaciales	1
FAO	UN Food & Agricultural Organization	1
FUCREA	Federación Uruguaya de Grupos CREA	1
INALE	Instituto Nacional de la Leche	2
INIA - GRAS	Instituto Nacional de Investigación Agropecuaria -- Unidad de Agro-clima y Sistemas de información	3
INUMET	Instituto Uruguayo de Meteorología	4
IPA	Instituto Plan Agropecuario	1
MGAP	Ministerio de Ganadería, Agricultura y Pesca	
MGAP OPYPA	MGAP Oficina de Programación y Política Agropecuario	3
MGAP UAI	MGAP Unidad de Asunto Internacionales	1
MGAP-DACC	MGAP Desarrollo y Adaptación al Cambio Climático	1
MGAP-DGDR	MGAP Dirección General de Desarrollo Rural	2
MGAP-DGSA	MGAP Dirección General de Servicios Agrícolas	2
MGAP-DIEA	MGAP Estadísticas Agropecuarias	1
MGAP-RENARE	MGAP Dirección General de Recursos Naturales Renovables	3
MGAP-SNIA	MGAP Sistema Nacional de Información Agropecuario	8
MGAP-SNIG	MGAP Sistema Nacional de Información Ganadera	3
MGAP-UCC	MGAP Unidad de Cambio Climático	2
MVOTMA	Ministerio de Vivienda, Ordenamiento Territorial y Medio Ambiente	
MVOTMA -- DINAGUA	MVOTMA Dirección Nacional de Aguas	2
MVOTMA -- DINAMA	MVOTMA Dirección Nacional de Medio Ambiente	2
SINAE	Sistema Nacional de Emergencias	1
SNRCC	Sistema Nacional de Respuesta al Cambio Climático	1
UdelaR	Universidad de la Republica	1
UdelaR EI	UdelaR Espacio Interdisciplinario	1
UdelaR Facultad de Ciencias	UdelaR Facultad de Ciencias	1
UdelaR FAGRO	UdelaR Facultad de Agronomía	1
UdelaR FING	UdelaR Facultad de Ingeniería	1

Appendix 5: Full list of interviews

Organization	Role / expertise	Interviewee number
MGAP-RENARE	Land use planning and management	1
INIA	Research into family farms	2
MGAP - AI	International programs	3
INUMET	Climate scientist	4
INIA	Agro-meteorology	5
self-employed	Farmer	6
INUMET	Coordinator	7
MGAP - AI	Legal expert	8
IPA	Extension services	9
MGAP-UCC-OPYPA	Policy expert	10
MGAP - SNIA	Data analyst	11
IPA	Extension services	12
MGAP - DIGEGRA	Registration of fruit resources	13
MGAP - DIGEGRA	Management of pests	14
UdelaR	Climate scientist	15
INALE	Outreach to dairy producers	16
MGAP - SNIA	Data analyst	17
MGAP-OPYPA	Policy expert	18
MGAP DACC	Project management	19
MVOTMA	Policy expert	20
self-employed	Farmer	21
MGAP - OPYPA	Economist	22
self-employed	farmer	23
MGAP - SNIA	Communications expert	24
MGAP - SNIA	Agronomist	25
MGAP - OPYPA	Legal expert	26
MGAP - OPYPA - DIEA	Statistician	27
MGAP -DINARA	Water resources expert	28
Office of the president	Coordinator of data resources	29
MGAP - OPYPA	Expert in agricultural insurance	30
MGAP-SNIG	Expert in animal traceability	31
MGAP - RENARE	Soil expert	32

MGAP - SNIA	Programmer	33
INUMET	Climate scientist	34
MGAP-RENARE	Soil expert	35
MGAP - SNIG	Data coordinator	36
MGAP - SNIA	Data analyst	37
INUMET	Data coordinator	38
MGAP - SNIA	Data analyst	39
MGAP - SNIA	Data analyst	40
INUMET	Data analyst	41
MGAP-DIEA	Data analyst	42
MGAP-RENARE	Land use planning	43
MGAP - OPYPA	Data analyst	44
Emergencia	Emergency response coordinator	45
UdelaR	Climate scientist	46
FAO	Coordinator of international programs	47
AGESIC	Data coordinator	48
MGAP - DIGEGRA	Engagement with horticulturalist	49
Office of the president	Project management	50

Appendix 6: Key policy documents (Chapters 4 and 5)

Organization	Acronym	Title	Year
Oficina de la Presidencia		Ley No 18.381: Derecho de acceso a la información pública	2008
República Oriental de Uruguay, Poder Legislativo		Ley Nº 18.564: conservación, uso y manejo adecuado de los suelos y de las aguas	2009
Ministerio de Ganadería, Agricultura y Pesca	MGAP	Lineamientos Políticos del MGAP y la Institucionalidad Pública Agropecuaria 2010-2015	2010
United Nations	UN	Marco de Asistencia de las Naciones Unidas para el Desarrollo en Uruguay 2011-2015	2010
Ministerio de Ganadería, Agricultura y Pesca	MGAP	Metas Ejercicios 2012: En base a los “Lineamientos Políticos del MGAP y la Institucionalidad Pública Agropecuaria 2010-2015”	2012
Ministerio de Desarrollo Social	MIDES	Vulnerabilidad y exclusión: aportes para las políticas sociales	2012
Alianza para el Gobierno Abierto	OGP	2do. Plan de Acción Uruguay 2014-2016	2013
United Nations Water	UN Agua	Desarrollo de Capacidades en apoyo a las Políticas Nacionales de Gestión de Sequías	2013
Ministerio de Ganadería, Agricultura y Pesca - Oficina de Programación y Políticas Agropecuarias	MGAP - OPYPA	Las condiciones de sequía y estrategias de gestión en Uruguay	2013
Ministerio de Ganadería, Agricultura y Pesca - Oficina de Programación y Políticas Agropecuarias	MGAP - OPYPA	Nuevas políticas para la adaptación del sector agropecuario al cambio climático	2013

Ministerio de Vivienda, Ordenamiento Territorial y Medio Ambiente	MVOTMA	Comisión Nacional de Meteorología Orden del Día	2014
Ministerio de Ganadería, Agricultura y Pesca - Instituto Uruguayo de Meteorología	MGAP - INUMET	Convenio Marco -- Ministerio de Ganadería, Agricultura y Pesca - INUMET	2014
Ministerio de Vivienda, Ordenamiento Territorial y Medio Ambiente	MVOTMA	Comisión Nacional de Meteorología Orden del Día	2014
Agencia de Gobierno Electrónico y Sociedad de la Información y del Conocimiento	AEGSIC	Digital agenda Uruguay: 15 Objectives for 2015	2015
Instituto Uruguayo de Meteorología	INUMET	Iniciativa presupuestaria 2016-2021	2015
International Monetary Fund	IMF	Uruguay: Selected Issues	2015
Ministerio de Ganadería, Agricultura y Pesca	MGAP	Sistema Nacional de Información Ganadera	2017