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Creating an enabling environment for investment in climate services: The case of Uruguay's National Agricultural Information System

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ABSTRACT

Increasingly challenged by climate variability and change, many of the world's governments have turned to climate services as a means to improve decision making and mitigate climate-related risk. While there have been some efforts to evaluate the economic impact of climate services, little is known about the contexts in which investments in climate services have taken place. An understanding of the factors that enable climate service investment is important for the development of climate services at local, national and international levels. This paper addresses this gap by investigating the context in which Uruguay's Ministry of Livestock, Agriculture and Fisheries invested in and developed its National System of Agriculture Information (SNIA), a national-level climate service for the agriculture sector. Using qualitative research methods, the paper uses key documents and 43 interviews to identify six factors that have shaped the decision to invest in the SNIA: (1) Uruguay's focus on sustainable agricultural intensification; (2) previous work on climate change adaptation; (3) the modernization of the meteorological service; (4) the country's open data policy; (5) the government's decision to focus the SNIA on near-term (e.g., seasonal) rather than long-term climate risk; and (6) the participation of key individuals. While the context in which these enablers emerged is unique to Uruguay, it is likely that some factors are generalizable to other countries. Social science research needed to confirm the wider applicability of innovation systems, groundwork, data access and champion is discussed.

Practical Implications

This paper, which identifies and describes six factors that contributed to the decision to invest in a national-level agricultural climate service in Uruguay, is intended to inform both research and practical applications regarding the development of climate services around the world.

As the paper makes clear, investment in climate services varies widely across the globe. While some factors thought to condition this variation have been identified (e.g., the economic development of the country, its climate exposure, and/or the predictability of the climate system in that area), a host of other considerations seem likely to shape climate service investment decisions as well. Our paper is one of the first to investigate these factors in context, identifying the circumstances that led Uruguay's Ministry of Livestock, Agriculture, and Fisheries to make a sizable investment in the development, delivery and use of climate-related information for national- and local-level decision making.

As such, our paper informs future research activities intended to explore similar questions regarding the factors that help shape design in developed and developing countries alike. The paper is also relevant for government organizations and international donors who may like to identify and/or help to create contexts conducive to climate service investment and can use the factors identified here as guideposts. The role of groundwork and of agricultural innovation systems should be particularly useful in this regard.

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1. Introduction

While society has always struggled to manage climate-related risk, increased vulnerability and the specter of climate change have stimulated recent investment in climate services (Hewitt et al., 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 (Brasseur and Gallardo, 2016; Hewitt et al., 2012). 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 (Clements et al., 2013; WMO et al., 2015). 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 (Lazo et al., 2008; Perrels et al., 2012; Solís and Letson, 2013; von Gruenigen et al., 2014).

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 et al., 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 et al., 2013; Grothmann et al., 2013; Williamson et al., 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 paper 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), 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.

2. 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 endeavor 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.

2.1. Climate & agriculture in Uruguay

Uruguay is 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, and well-developed social security, health, and educational systems. Agriculture contributes roughly 6% to its 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 (El Observador, 2016).

Uruguay's humid subtropical climate is marked by strong inter-annual variability. Mean annual temperatures ranges from 16° to 19 °C and mean annual precipitation from 1100 to 1600 mm (INUMET, 2017). While total precipitation is expected to increase over the course of the coming century, long-term climate projections suggest that the country will face an increase inter-annual variability and in the frequency and intensity of extreme weather phenomena, including rainstorms and drought (Cabré et al., 2016; Magrin et al., 2014; Oyhantcabal et al., 2013). In this context, roughly 15% of Uruguayan farmers report climate fluctuations as a significant challenge (Equipos Mori, 2012).

2.2. 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 (Baethgen et al., 2016).

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 paper analyzes 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/.

2.3. 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 & 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 analyzing data from the country's meteorological stations; the SNIA is also built around a number of climate-related products developed by the Engineering School at the University of the Republic (UdelaR).

3. Research 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 stakeholders – including people and organizations who had a role in conceiving and/or developing the SNIA, or who were seen as potential suppliers and/or users of SNIA information – 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. A framework analytical approach (Srivastava and Thomson, 2009) was used to analyze data gathered through these interviews; as such, transcripts were coded using NVivo into categories that allowed for the creation of a new structure for the data, a framework that was developed dialectically while reading through the transcripts. 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 1. In all, a total of 43 interviews were conducted with 40 people representing 12 organizations, 10 directorates of MGAP, and three schools within the University of the Republic. A list of interviewee affiliations is included in Appendix 2.

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 3.

4. Results & 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 analyzed below.

4.1. 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 #13

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 cataloging 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 #24

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.

4.2. Previous work on climate change adaptation

While MGAP's focus on sustainable agricultural intensification set the context in which the SNIA was developed, interviews revealed three activities focused on climate change adaptation that 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 & Environment, the SNRCC met on a monthly basis to discuss climate-related issues and was responsible for national communications, reports, and meetings (SNRCC, 2014).

> "[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 #35

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, university, and non-government actors developed a proposal to the Food & 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 Changes)*, offered a range of suggestions for climate risk management in the agricultural sector (Oyhantcabal et al., 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 #6

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, though many interviewees 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.

4.3. 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 defense ministry through two external reviews published in 2009 and 2013, respectively (WMO and AEMET, 2009; Riosalido Alonso, 2013).

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 (WMO and AEMET, 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 2009 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). Interviewees describe the rollout of this database as fundamental to the decision to invest in the SNIA, since it allowed meteorological data to be shared and analyzed 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 (Asamblea General de Uruguay, 2013)).

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 defense-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 #35

Outside the Defense Ministry, interviewees describe the new INUMET as 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 #3

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 (Universiaria Uruguay, 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.

4.4. Open data

Within this institutional context, interviewees describe a policy measure 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 (Asamblea General de Uruguay, 2008a).

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 analyzing 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 #39

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 #40

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 et al., 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 (Asamblea General de Uruguay, 2008b).

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 interviews reveal that some of the groups responsible for contributing data and products to the SNIA have expressed a need their own contributions to be clearly recognized as well as 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.

4.5. Focus on the near term

Interviews suggest that SNIA's policy of focusing on near-term climate variability, as opposed to providing information on longer timescales (e.g., 2050 or 2100), has 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 #25

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 (Dilling et al., 2015). 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.

4.6. Key individuals

As is frequently the case with major policy and institutional developments, interviews make it clear that 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 #27

Another important figure was a Uruguayan agricultural scientist (and co-author of this paper) 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).

5. 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. While these factors developed in a context that is uniquely Uruguayan – one marked by relatively high levels of political stability, economic growth, and social capital – they offer important lessons for future efforts to identify and create contexts in which investments in climate service can occur and flourish. Even accounting for Uruguay's unique history, it seems likely that many of the factors identified here are broadly generalizable to other countries. While only further case studies, and the comparative analysis between them, can confirm this, the potential relevance of four main themes, and the research needed to explore them, is discussed below.

5.1. 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 et al., 2014; Williamson et al., 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 et al., 2003; Hermans et al., 2013; Klerkx et al., 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.

5.2. 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 2000 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 & planning; practice & behavior; 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 & planning, practice & behavior) 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.

5.3. 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 analyze 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 (WMO and AEMET, 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 et al., 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.

5.4. 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 (including, for instance, a problem-oriented focus, as well as commitment to interdisciplinary work) 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).

6. Summary and conclusions

This paper 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.

As with all countries, Uruguay is unique. As such, the broader Uruguayan context – including its relative affluence, political stability, high educational standards, and high levels of social capital – also played a role in shaping the decision to invest in climate services. Nevertheless, it is likely that many if not all of the factors identified as part of this study 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.

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Appendix 1. Interview Protocol

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 2. Organizational affiliations of interviewees

Acronym	Organization	Number of Interviews
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	1
MGAP-DGSA	MGAP Dirección General de Servicios Agrícolas	1
MGAP-DIEA	MGAP Estadísticas Agropecuarias	1
MGAP-RENARE	MGAP Dirección General de Recursos Naturales Renovables	3

MGAP-SNIA	MGAP Sistema Nacional de Información Agropecuario	5
MGAP-SNIG	MGAP Sistema Nacional de Información Ganadera	3
MGAP-UCC	MGAP Unidad de Cambio Climático	1
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 3. Key documents

Organization	Acronym	Title	Year
Ministerio de Ganadería, Agricultura y Pesca	MGAP	Lineamientos Políticos del MGAP y la Institucionalidad Pública Agropecuaria 2010–2015	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
Agencia de Gobierno Electrónico y Sociedad de la Información y del Conocimiento	AEGSIC	Digital agenda Uruguay: 15 Objectives for 2015	2015
Oficina de la Presidencia	Presidencia	Ley No 18.381: Derecho de acceso a la información pública	2008
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 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
Instituto Uruguayo de Meteorología	INUMET	Iniciativa presupuestaria 2016–2021	2015
Ministerio de Desarrollo Social	MIDES	Vulnerabilidad y exclusión: aportes para las políticas sociales	2012
Ministerio de Vivienda, Ordenamiento Territorial y Medio Ambiente	MVOTMA	Comisión Nacional de Meteorología Orden del Día	2014
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 Ganadería, Agricultura y Pesca	MGAP	Sistema Nacional de Información Ganadera	2017
International Monetary Fund	IMF	Uruguay: Selected Issues	2015
United Nations	UN	Marco de Asistencia de las Naciones Unidas para el Desarrollo en Uruguay 2011–2015	2010
República Oriental de Uruguay, Poder Legislativo		Ley N° 18.564: conservación, uso y manejo adecuado de los suelos y de las aguas	2009

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