




# Managing expectations: articulating expertise in climate services for agriculture in Belize

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## Abstract

A range of institutions and individuals are engaging in the provision, translation, and application of scientific climate information, with the aim of supporting agricultural decision-making in the context of climate variability and change. This article contributes to understanding political and ethical dimensions of climate services by focusing on how expertise is articulated by those who deliver anticipatory information to potential users. The article draws on interviews and observations with forecasters, advisors, and decision-makers in Belize—a low-lying, coastal country recognised to be particularly vulnerable to the impacts of climate change. I show how emerging debates over who and what is left out of climate services are not only about the use and usability of climate knowledge, but about how individuals and institutions are positioned in relation to each other and to uncertain futures in Belize and elsewhere.

## 1 Introduction

The domain of climate services, conceived as providing decision-makers with timely and targeted climate information derived from scientific research, has been developed to enable more effective adaptation by bridging a gap between science and policy. In the USA, explicit efforts in this direction included the promotion of public-private co-operation under the 1978 National Climate Program Act (Hecht 1984), the resulting regional climate centres (Changnon et al. 1990), and debates about the establishment of a national climate service (Miles et al. 2006).<sup>1</sup> Long-standing concerns with societal impacts of climate have gained international

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<sup>1</sup>Associated efforts included the International Research Institute for Climate and Society (IRI) at Columbia University, and Regional Integrated Sciences and Assessments (RISA) program.

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policy momentum through IPCC assessments and the Global Framework for Climate Services, implemented in 2012 (Hewitt et al. 2012; Vaughan and Dessai 2014). The identification of a need for user input to help balance credibility, salience, and legitimacy (Cash et al. 2006), and facilitate social accountability (Meehan et al. 2018) has motivated the “coproduction of climate science knowledge” (Meadow et al. 2015), sometimes within “boundary organisations” that mediate science and policy (Agrawala et al. 2001; Guido et al. 2016). Tools, portals, maps, and workshops have proliferated under this rubric. A growing body of work has examined farmers’ responses to climate forecasts (Broad and Agrawala 2000; Crane et al. 2010; Hansen 2002; Letson et al. 2001; Patt and Gwata 2002; Roncoli 2006) and the role of public and private sector intermediaries (Haigh et al. 2015; Lemos et al. 2014). Less well understood are the associated epistemological, political, and ethical implications (Carr and Owusu-Daaku 2016; Goldman et al. 2018), and the perceptions, needs, and choices of those acting as intermediaries/advisors (Mase and Prokopy 2014).<sup>2</sup> This article contributes to understanding these dimensions of climate services by examining what they mean and entail for those working “on the ground” to deliver them in the Belizean agriculture sector.

As a low-lying, coastal country, dependent on climate-sensitive industries including agriculture, fisheries, and tourism, Belize has been recognised in international and regional risk assessments as vulnerable to weather and climatic variability: from day-to-day weather events to seasonal/interannual variability in precipitation and temperature, and longer-term changes in temperature, precipitation, and storm intensity (CaribSave 2012). Precipitation is an important limiting factor for Belizean agriculture (rain-fed cultivation is common). Excessive rainfall can cause waterlogging and disease; drought conditions limit water availability for crops. Much of the Caribbean, including Belize, has an annual dry season (Nov/Dec–May/June), and a wet/hurricane season (May/June–Nov/Dec). The El Niño Southern Oscillation (ENSO) is an important driver of interannual rainfall variability (WMO 2016).

Increasing understanding of ENSO and other drivers has contributed to production of seasonal consensus predictions of rainfall including by the Caribbean Climate Outlook Forum (CARICOF) and Central American Climate Outlook Forum (CACOF)—two of 20 regional forums supported by the World Meteorological Organisation (WMO 2017). Belize attends both. The regional forums constitute deliberate attempts to engage “users” of climate information, though they go about this in different ways, from linear information transfer to more collaborative efforts (Daly and Dessai 2018). Daly and Dessai (2018) found that the CARICOF and CACOF are among the forums that have developed collaborative strategies to co-produce sector-specific products. In Belize, efforts to deliver climate services for agriculture at the national level have primarily involved monthly to seasonal rainfall outlooks, published by the Belize National Meteorological Service (NMS).<sup>3</sup> Belize is thus a productive site to study if/how purposeful efforts at user engagement play out, in a context where climate variability and change are recognised as potential threats to livelihoods, businesses, and food security.

This article examines how people working between climate research and forecast application engage with agricultural decision-makers, in a context where climate services are promoted by global, regional, and national organisations as ways to mitigate weather- and climate-based risks. It is informed by anthropological and science studies approaches that foreground how expertise is enacted in practice, and recognise the mutual implication of knowledge production

<sup>2</sup> For a recent study addressing this issue in the USA, see Haigh et al. (2018).

<sup>3</sup> These timescales are the focus of this article, although my interlocutors’ perceptions and experiences of weather and climate variability did not always fit these frames.

and world-making. Many accounts of climate services focus on technical and institutional barriers to uptake and co-production of knowledge (Dilling and Lemos 2011; Guido et al. 2016; Vogel et al. 2017). In line with this special issue, I focus rather on contextualising how knowledge is articulated and contended in everyday interactions, to help understand how climate hazards and services relate to wider practical, political, and ethical challenges. This is a way to critically analyse established utilitarian modes of accountability, which cater to those in a position to represent “society” and make claims on the scientific community, for example, funders and governments (van der Hel 2016; Meehan et al. 2018). As Strathern argues: “Only certain social practices take a form which will convince, one which will persuade those to whom accountability is to be rendered – whether it is ‘the government’ or the taxpayer/public – that accountability has indeed been rendered” (2000:1–2). How might environmental knowledge be more answerable to perceptions and realities of broader constituencies? Vaughn has described interdisciplinary climate adaptation collaborations as responses to an “unruly world” that “forces one expert group to seek help from others, building a new ecology of expertise to adapt to a changing climate” (2017:262). The uncertain world is one of environmental, political, and social dynamics that often overspill established categories of technical resolution and practical governance.

The article proceeds by explaining the research methodology and outlining concepts of expertise and co-production in relation to climate services. I then describe the institutional landscape of climate services provision in Belize, setting out the key organisations, products, and perceived challenges. The main empirical section focuses on accounts of how advisors work to “manage expectations”—that is, how they tackle the interconnected challenges of anticipating uncertain environmental futures, negotiating their own roles as “experts”, and engaging potential “users”. I close with a discussion of how attention to ground-level articulations of expertise and participation sheds light on understandings of responsibility that come into view as climate services are situated in broader political and ethical contexts.

## 2 Methods

This article is based on 3 months of qualitative anthropological fieldwork in 2014 in Belize—a small country of fewer than 400,000 people yet much diversity in ethnicity, ecology, class, and education—where I have conducted anthropological research since 2006.<sup>4</sup> The 2014 study was part of a wider research programme investigating social and technical dimensions of forecasting for resource stewardship across international cases, reflecting a range of governance styles, environmental contexts, technical capacities, and cultural settings. The Belizean case was an opportunity to study the role of forecasting in a country where weather and climate sensitivities are recognised, national capacity for forecast modelling is limited, and international institutions play key roles relating to the production and circulation of weather/climate information.

Research in Belize included interviews with 60 participants with professional interest in weather/climate forecasts for resource and hazard management. I identified potential interviewees in an institutional mapping process that started with core relevant organisations (e.g. Caribbean Community Climate Change Centre (CCCCC), NMS, Ministry for Natural Resources and Agriculture) and proceeded via key informant networking, attendance at relevant events, and documentary research. Participants ultimately represented a wide range of sectors

<sup>4</sup> Detailed examination of demography/ethnicity is beyond the scope of this article; for more, see Bolland (1988); Medina (1997).

(agriculture, development, education, emergency, environment, forecasting, municipal, water) and public, private, and non-governmental organisations. In line with the study's aims to better understand the perceptions, needs and choices of forecasters, advisors, and other decision-makers, the interview method enabled participants to articulate priorities and experiences in their own words. To accommodate their interests while ensuring consistency (Bernard 2006:212), I used a semi-structured protocol covering: organisational priorities; decision-making processes; weather/climate sensitivities; availability of forecasts; and future planning.<sup>5</sup> Where possible, interviews were ethnographic (Heyl 2001): informed by ongoing interactions which aided mutual understanding and encouraged participants to develop narratives beyond organisational mission statements. To trace how knowledge is developed, communicated and debated among actors and organisations, and to understand practice and narrative in relation to one another, I supplemented interviews with participant observations (Bernard 2006:342). These included three operational shifts at the NMS, a hydrological modelling workshop, a coastal planning seminar, and a university climate change conference.

I categorised the cohort of 60 interviewees according to primary and, where relevant, secondary sector.<sup>6</sup> Of the total, 27 were involved in agriculture, development and/or forecasting (primary or secondary sector). These interviews form the main empirical basis for this article. They include weather forecasters, meteorologists, and climate scientists; agriculture ministry liaison staff and extension officers; sugar industry researchers and buyers; other agricultural researchers; representatives of cacao, citrus, and grain growers' associations; environmental NGO staff; and adaptation practitioners. The majority of interviews were recorded and transcribed. I undertook a qualitative thematic analysis, using iterative reading and memos to identify and cross-check material that related to respondents' perceptions and experiences of delivering and accessing climate services.

### 3 Expertise and co-production in climate services

Core rationales underpinning climate services identify information supply and demand as key problems, and user-orientation as an important potential remedy (Harjanne 2017). Climate services involve transnational frameworks, resource-intensive technologies, expert networks, and user engagement. As such, they are a productive domain for studying how information and ideas travel (or do not) across global and local contexts (Weisser et al. 2014). Climate services are promoted on the grounds of their societal benefit; however, social science studies of climate knowledge provision have shown there can be ethical and social justice implications of imposing particular visions of the future or models of decision-making under uncertainty (Broad et al. 2002; Lemos and Dilling 2007; Furman et al. 2014; Webber and Donner 2017). Taddei's ethnographic work in Brazil highlights the "performativity" of climate forecasts; he argues that their technocratic use entails "flattening the imagination of future realities" (2013:258), as they necessarily simplify the world, incorporating often implicit decisions about what "counts" and can be acted upon. These studies call attention to what is and is not recognised as legitimate expertise in climate services, and to the practical and political implications of who participates (or does not) in the co-production of knowledge (and society).

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<sup>5</sup> See [supplementary material](#).

<sup>6</sup> See [supplementary material](#).

The notion of “expertise” is well-embedded in climate services discourse: “scientifically credible information and expertise” is fundamental (Hewitt et al. 2012); institutional providers are centres of climatological expertise (Changnon et al. 1990). In apparent tension with the user-orientation of climate services discourses that typically argue for highly collaborative activities (Harjanne 2017), this emphasis on scientific expertise as the defining feature of centres of production arguably shores up a linear model of science. In this model, expert knowledge is delivered to relatively passive users (McNie 2012); the scientific category of climate becomes the determinant of regional futures (Hulme 2011; Krauss and von Storch 2012). Turning to the agricultural context, this recalls Scott’s (1998) account of scientific agriculture as an authoritarian intervention that renders nature and production “legible” and therefore manageable. Scott argues that such attempts usually fail, precisely because they neglect situated knowledges that do not fit their paradigm. An alternative approach emphasises expertise as enacted and contended by a range of actors (Carr 2010), and experts as “desiring, relating, doubting, anxious, contentious, affective... human-subjects” (Boyer 2008:38). Paying attention to the experiences of advisors who deliver climate services is a way to explore multiple and embodied tensions of expertise and collaboration.

The term “co-production” has gained traction in debates about climate knowledge in general and climate services in particular (Jasanoff and Wynne 1998; Dilling and Lemos 2011; Meadow et al. 2015; Bremer and Meisch 2017). However, its interpretation has been ambiguous. *Normative* uses of the term, which foreground the instrumental goal of co-producing knowledge by bringing together a range of different stakeholders, arguably risk overshadowing fundamental questions of politics and ethics (Goldman et al. 2018). *Descriptive* formulations (Jasanoff 2004) interpret co-production not as an instrumental practice or normative ideal, but as an analytical idiom that describes the inevitable mutual constitution of science and society. Lövbrand’s study of a European climate research programme investigated tensions between interpretations: “there may be a trade-off between research co-produced to be accountable to the knowledge needs of societal decision-makers, and co-produced research that seeks to challenge and transform existing ways of thinking” (2011:231).

If we take seriously both the proposition of involving different actors in knowledge production, and the inseparability of knowledge-making and world-making (Goldman et al. 2011), choices about how knowledge is produced and whose knowledge counts are also questions of who gets to shape the future. The crux shifts beyond delivering robust and/or fair outcomes for specific problems, to broader questions: who decides what constitute legitimate concerns, appropriate evidence, acceptable solutions, and possible futures? This calls for reflexivity about often well-intentioned efforts to include diverse voices. As critical scholars of development have shown—including for projects involving weather/climate information—utilitarian and normative ideals of participation do not always lead to effective or equitable outcomes (Cooke and Kothari 2001; Peterson et al. 2010; Taddei 2011). Failure to address power dynamics of participation in practice can introduce or reinforce inequalities that resonate beyond specific projects. The challenge is arguably magnified in contexts involving long timescales and uncertain outcomes—such as climate adaptation (Few et al. 2007).

#### 4 Institutional landscapes of Belize climate services

Prior to my 2014 visit, consultations under the Global Framework for Climate Services had been initiated in Belize by a group of national, regional, and global organisations including the

NMS, the CCCCC, the Caribbean Institute for Meteorology and Hydrology (CIMH), and the WMO. Their activities included a 2013 stakeholder meeting on agriculture and food production (WMO 2014) and the first national climate outlook forum in 2014. Perhaps unsurprisingly, given Belize's low population count, the cohort of people involved in climate services at national level constitutes quite a small world. The national work was led by the NMS: an organisation with fewer than 10 meteorologists, forecasters, and climatologists, and a focus on operational weather forecasting. At the time of research, there was no national capacity to run sophisticated computer simulations of future weather and climate. As such, international networks were influential in supporting climate services and related efforts.<sup>7</sup> With its distinctive history as a former British colony on the Caribbean coast of Central America, Belize straddles geopolitical regions and attends both the Caribbean and Central American Climate Outlook Forums, in which countries prepare national seasonal forecasts using a standardised methodology<sup>8</sup> and discuss results face-to-face or by teleconference to agree a probabilistic regional outlook.<sup>9</sup> Following regional forums, the NMS publishes the consensus seasonal forecasts on its website, alongside monthly forecasts of expected rainfall ranges tuned to each of its 12 weather stations.

Senior NMS staff reported feeling isolated from feedback about the forecasts from potential users (exceptions included the National Emergency Management Organisation and an agriculture department contact). With other meteorologists and climate scientists, they often framed the problem of uptake as one of public education (Callon 1999), highlighting boundaries between research and application, scientists and (non-scientist) stakeholders (Gieryn 1983). CCCCC staff described tensions between dual organisational goals of effective adaptation and innovative science, for example attributing the difficulty of explaining a new weather scenario product to potential users to the fact that it was “the front line of research”. One staff member distinguished different stakeholder mindsets, and distanced them from meteorologists and climate scientists: “the water people think differently than the agriculture people, and they all think differently than the weather people and the scientists.” A former government meteorologist called for a “socialisation of the forecast”. For him, this meant facilitating a linear chain of information from forecasters to extension officers to “progressive” farmers who could educate others. He and others identified resource issues (a small, weather-focused NMS team) and public perceptions (that the NMS was only relevant during emergencies<sup>10</sup>) as key obstacles.

Research participants discussed different solutions to these challenges. Mobile telephone messaging was much-discussed; however, obstacles included expense and poor rural coverage. While radio could help overcome these issues, some agricultural researchers felt that personal interactions were needed, albeit these were often described as one-directional: technical advisors would “tell [growers] what they need to do” (as recommended by a sugar researcher). Following a more participatory, “co-production”-oriented model of user engagement, the NMS

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<sup>7</sup> As well as monthly/seasonal forecasts from NMS and regional forums, the government sources climate expertise from CCCCC projects and from consultants hired to draft policies/environmental impact assessments using long-term projections.

<sup>8</sup> The IRI Climate Predictability Tool.

<sup>9</sup> CACOF was convened in 2000 following the 1997/8 El Niño; it issues three outlooks per year. CARICOF was relaunched in 2012 (following a 1998 attempt); it issues monthly 3-month outlooks (WMO 2016; Guido et al. 2016).

<sup>10</sup> One forecaster attributed this to the service being moved under the National Emergency Management Organisation.

(supported by regional bodies such as CIMH) had promoted “farmer forums” to bring agricultural stakeholders face-to-face with scientists who could communicate forecast content and uncertainties, while eliciting user needs. However, a government scientist noted that because the NMS usually just puts its agro-meteorological forecasts online and many farmers do not have internet access, more quotidian forecast communication often falls to the agricultural extension service. In the rest of this article, I examine how extension agents and others in similar roles articulate expertise in relation with other agents of climate knowledge and agricultural decision-making.

## 5 Articulating climate services for agriculture

Agriculture is a mainstay of commercial and subsistence economies in Belize, with sugar, bananas, and citrus juices leading crop exports. Sugar dominates in the north<sup>11</sup>; citrus and banana are focused in southern districts. Sugar and citrus juice production involves small- to large-scale growers, represented by associations, who sell to processing plants in Belize. The banana industry consists of mainly large-scale growers (also with an association) who sell to an international brand. Other common crops include grains (maize/rice), beans, cacao, and other fruits and vegetables. Outside major export industries, much large-scale production is undertaken by Mennonite communities that have adopted mechanised cultivation.<sup>12</sup>

Weather sensitivities vary with crop and scale. In export industries, concerns about precipitation were closely tied to their impact on crop-specific pests and diseases (sugarcane froghopper *Aeneolamia postica jugata*; citrus disease *huanglongbing*, spread by the psyllid *Diaphorina citri*; sigatoka, a disease of bananas caused by *Mycosphaerella fijiensis*). Interview participants expressed different orientations to risk and success: buyers and researchers prioritised productivity and scientific management; small-scale farmers were anxious to avoid serious losses; mechanised farmers considered how they could combine weather knowledge with machinery and pest control. A grain growers’ representative described risk management as dependent on an art of “leaning” rather than calculating; a metaphor that conjures a situational attentiveness in navigating uncertainties and information sources: “The most successful person is ... not the person who hits it exactly right all the time; it’s the one who manages the risk.” He was discussing mechanised farming, which can include irrigation: this can delink growing cycles from weather patterns, but requires large investments, inaccessible to many growers. Reliable seasonal forecasts could be useful for those able to obtain irrigation equipment in advance of a dry spell, a citrus researcher noted, but not all farmers had the capacity to respond: “if you don’t have the means you have to suffer the losses.”

A range of actors commented that increasingly unstable climatic conditions had reduced their confidence in seasonal expectations based on historical patterns, prompting a search for more reliable and relevant information, in line with the stated aims of climate services:

It becomes very difficult to look at your past data and have some reliability... That used to be a way of forecasting, but it’s difficult now (Farmer liaison, sugar factory)

<sup>11</sup> Since 2014, planting and processing has started in western Belize.

<sup>12</sup> Mennonites have arrived in Belize from the USA and Canada since the 1950s, many via Mexico and El Salvador. Some eschew mechanised farming; others have embraced it.

We don't believe any more in [historical data] because of climate change. In the past it was a good thing to use historical data to predict, but now it's very complicated (NGO agriculture officer)

You can't rely anymore on saying we have rainy season, hot months... I think it's becoming worse every year... [the farmers] come to you now for information (Government extension co-ordinator)

The Met Office ... need to better understand what kind of decisions farmers are making, and therefore would be better able to answer questions that the farmers have. (Farmers' association leader)

The first two quotations identify problems with established sources of information (i.e. expectations based on historical trends); the third is an observation about farmers' demand for information from extension officers; the fourth argues for user engagement to help forecasters give more salient advice, suggesting an instrumental role for "co-production". The following sub-sections focus on key predicaments that meteorologists, researchers, and farmers' advisors raised during interviews: the risks of providing as well as following expert advice under uncertainty; and the power dynamics of legitimate knowledge and legible practice.

### 5.1 Advice under uncertainty

Situated between research and operational science, meteorologists occupy a liminal position, enacting expertise in relation to atmospheric uncertainty and the vagaries of public communication (Daipha 2015; Fine 2007). Some NMS forecasters expressed resignation about failures of linear communication ("if they don't heed [the forecast], we cannot do anything"). Agricultural extension services also act as mediators, arguably representing archetypal "boundary organisations" (Cash 2001), bound into debates about participatory agricultural research and development (Scoones and Thompson 2009) and tasked with translating science and technology into usable advice that—unlike most meteorologists—they deliver directly to farmers (Hansen 2002). Government-supported extension in Belize operates mainly through the ministry responsible for agriculture (the statutory sugar research institute also has an extension department); services are also provided by NGOs (notably in the south where government provision is less developed) and growers' associations.

Faced with farmers' demand for weather/climate information (as per the third quotation above), government agriculture officers reported feeling ill-prepared. They noted that salient information is often unavailable or inconsistent; its flow impeded by limited data and staff time. Within the ministry responsible for agriculture, an officer had been appointed as a climate change "focal point" specialist to sit on the National Climate Change Committee endorsed by Cabinet in 2010. The person holding this role in 2014 had taken it on in 2011 in addition to existing duties. At the time, he was the only officer specialising in climate change and agriculture. Resource pressures made it hard to process information from the wide range of sources and communicate with policymakers, farmers, and scientists. Upstream delays were another challenge: having developed confidence in seasonal outlooks through interactions with senior NMS staff, he had taken it upon himself to convert NMS monthly agro-meteorological forecasts into maps for distribution to extension officers, NGOs, and others. However, he had



recently stopped because of delays in obtaining the forecasts. I was told that some of the government extension officers delivered printed NMS agro-meteorological forecasts to farmers, but were not monitoring their use or tracking a dialogue. An extension co-ordinator described the work that would be needed to properly equip the advisors, noting that they were starting from a point where “the farmers look at us and we look at them, and we are not too sure what to say.”

Other ministry representatives compared seasonal forecast content and farmers’ expectations: the forecasts predict averages over time and do not account well for timing of precipitation—this is problematic because much rain comes in tropical waves. A grain farmers’ representative explained that rainfall onset and duration was more critical than average amount, owing to the threat of waterlogging. A senior agricultural researcher in a regional institute noted a mismatch between forecasters’ and users’ perspectives on success. He observed that a probabilistic forecast showing 33% likelihood for each tercile (above-normal/normal/below-normal rainfall) may satisfy its producers, who assess the reliability of the forecasting system over time. However, information in this form “is not anything to us [farmers]”. A statistical measure of forecast system performance may not seem helpful if a decision-maker’s livelihood depends on a one-off binary choice. To illustrate, the researcher explained how his confidence had been dented after a recent seasonal forecast (of elevated chance of above-normal rainfall) had informed his own decision to plant soybeans rather than cowpeas—a decision that resulted in a perceived loss when retrospectively compared with the decision he stated he would have made without the forecast.

While these problems of resource constraints and forecast format/performance provide insights into possible barriers to information uptake, of particular relevance to this article are the personal narratives through which advisors reflected on the challenges of climate service provision. Extension service staff expressed apprehension about giving advice in the context of incomplete knowledge and high decision stakes:

[Extension officers] might not feel confident enough to be able to tell someone to plant or not to plant. Because we know the cost of that investment, so you might have to find a way to let them decide somehow... some officers might not want to take that chance ... We’re not really trained, we’re not too sure how to make these decisions and how to advise properly. Because just as they don’t understand, we’re trying to keep up – even the definition of what climate change is and what it means for us. (Government extension co-ordinator)

The co-ordinator’s resolution that farmers “make that decision ... take that risk on their own” acknowledges the probabilistic character of the forecasts and the economic and reputational stakes of climate services provision. It moves to position the farmer as the responsible subject (Phillips and Ilcan 2007). Although the co-ordinator explained that their worst-case scenario would be to fail to pass on advice and thus be deemed useless, this danger exists in tension with a reluctance to offer firm guidance, given possible unfavourable outcomes. Another agriculture officer noted the problem of being perceived (or perceiving oneself) to have “cried wolf”: “If we prepare for something and it doesn’t happen, then we’ll get discouraged the next year when maybe it will hit for real”. Even when adverse weather did eventuate, some extension officers were uneasy about potential dependency entailed by associated government decisions, such as providing seed and fertiliser following excessive rains. In this case, the extension service invited the department’s climate change specialist to give a scientific presentation (including graphs and historical data) as a strategy to enact expertise beyond the “casual, general conversation” that characterised extension officers’ usual interactions. The

objective was to explain uncertainties and—they hoped—encourage farmers to take the issues seriously and be proactive. Yet, as the senior researcher’s comments showed, communicating uncertainty may not guarantee “success”.

As well as acknowledging resource-related factors (time, funding, data, training), these narratives highlight different understandings of success given uncertainty, and raise questions about the roles and responsibilities of experts and the meaning of climate change. The confidence and capacity of extension workers to support decisions—and their perceptions of what is at stake and who takes the blame for adverse outcomes—affect their delivery of climate services. As Desai (2006) has described for Rajasthan, extension agents negotiate shifting and conflicting identities and modes of authority in their work at the interface of science, government, and rural life. Their articulations of apprehension, and the tensions in the narratives of those who are both researchers and farmers, resonate with Boyer’s (2008) description of experts’ human-subjectivity. They reflect situated understanding of the diverse goals and priorities of different actors, and anxiety about how they might be called to account for the outcomes of decisions that do not sit comfortably in a narrow domain linking knowledge and action. As such, they recognise that as well as the challenge of co-producing knowledge in an instrumental sense (e.g. aligning the timescales of forecasts with farmers’ decision processes), there is a deeper sense in which these services can performatively “co-produce” forms of accountability and behaviour change. Interactions between advisors and advisees involve delicate negotiations of responsibility—for example through disclaimers about accuracy, reliability, and dependency—that shape relationships among farmers (citizens), the state, and other collectivities.

## 5.2 Negotiating legitimate knowledge and legible practice

Faced with variable climatic conditions, imperfect forecasts, and lack of confidence in official sources, farmers continued to make decisions based on a range of indicators, experience, and advice. Many listened to NMS weather bulletins on the radio (focusing on the next 24 h, with an outlook to 4 days), supplementing with other available resources: online sources or their own instruments (larger-scale farmers) and/or tried-and-tested local knowledge, risk-spreading strategies like multi-cropping, and moral economies (smaller-scale and subsistence farmers<sup>13</sup>). Extension workers acknowledged these other sources of information:

The farmers consider [the NMS forecast] to be more general. So, they don't count on it. They go by experience, or they have their own way of going on a hill top and looking at such an angle. They have their own cultural - their own little ideas of how they determine. They work a lot with the moon and that kind of thing. So, they make their decisions on their own (Government extension worker)

The planning of agricultural activities according to lunar phases is widespread among many Mestizo, Creole, and Maya farmers. A Mennonite farmer and growers’ representative also reported use of environmental indicators (fog and dew characteristics), noting that “some people make fun of it”—an observation suggestive of many scientists’ and technicians’ views of “planting by the moon”. One government forecaster who had facilitated a “farmer forum” discussion session described how participating farmers had persistently asked for information about moon phases, demanding recognition of their practices. The forecaster recalled that on reporting this in plenary, the convenors preferred not to discuss it: they were there to discuss “farming scientifically”. It struck me

<sup>13</sup> Wilk (1997) and Zarger (2009) present examples from Maya communities.

that the forecaster’s summary of the impasse—“so that is what we are faced with: people who have a mindset about certain practices that work”—could arguably refer to both parties: the farmers interested in lunar phases to the exclusion of curiosity about scientific forecasts, and the convenors reluctant to discuss practices that were illegible in the framework of the scientific workshop.<sup>14</sup> The accounts of scientists and extension workers perform “boundary work” (Gieryn 1983) when they seek to distinguish certain situated practices (especially those of smaller-scale farmers) from scientific knowledge. The discursive separation and hierarchization of “scientific” and “cultural” knowledge would appear to limit the scope of user engagement in these interactions to a linear model of knowledge transfer and public education (Callon 1999). The extension worker’s comment bolsters the assertion of farmers’ responsibility by noting that farmers are drawing on knowledge outside legitimised technical frameworks of extension and climate services.

Technical staff at the research arm of the citrus growers’ association reflected on the reluctance of their members to heed their technical advice. They framed this as a problem of their legitimacy as “local experts”, embedded in the farming communities that constitute the users of their technical advice. They described in Biblical terms their perception of a culture among farmers that undermined their organisation’s credibility: “you cannot be a prophet in your own land” (Luke 4:24). For advice to be heeded, they felt it would have to be enforced by a more distant authority—probably government. This perspective presents a challenge to prevailing social science ideas about the effectiveness of interpersonal communication at community level (e.g. Kunreuther et al. 1985), and suggests a need to think carefully about the contexts of participatory expertise and authority, noting how trust relations and hierarchies operate within “community” settings as well as between “communities” and other entities such as governments.

Meanwhile, in the banana industry—dominated by a few large growers—the latest project to involve weather/climate information was led by an NGO which was purposefully not working through government, on the grounds of inertia and bureaucracy. The NGO’s interest in using precipitation modelling to reduce unnecessary fungicide application had an environmental basis; however, they argued their case to growers using an economic rationale. The ongoing conversation relied on the NGO as an intermediary identifying the growers’ economic priority and framing the information in terms that the growers perceived as legitimate. Climate services advisors (whether government extension agents, growers’ association researchers, or NGO staff) were pushed to consider and perform alternative cultural, political, and economic framings. These debates about legitimacy highlight diverse priorities and relations of trust that depend on the needs and capacities of potential “users” and also their social relations with those who provide and communicate forecast information.

A brief consideration of proposed scientific management for the sugar sector further illustrates how questions of environmental knowledge are embedded in relations among citizens, the state, and other entities. The language of yield maximisation is prevalent across commercial agriculture; however, sugar productivity was framed as particularly urgent as the industry braced for a price drop in 2017.<sup>15</sup> Sugar is sensitive to rain at harvest (waterlogged fields are hard to reap; excess water dilutes cane) and the froghopper pest’s lifecycle and control are rain-dependent. Although not explicitly framed as a “climate services” project, the management system’s developers at the industry’s statutory research institute (SIRDI)

<sup>14</sup> For a contrasting example from Kenya, where traditional and scientific forecasts were purposefully brought into conversation (though not without political/epistemic challenges), see Haines et al. (2017).

<sup>15</sup> The EU was lifting quotas that had protected African, Caribbean and Pacific cane sugar industries.

explained the aim to incorporate weather and climate data and forecasts (e.g. from their own weather stations, NMS, and NOAA, and via models developed by international institutes/NGOs) alongside other variables. The objective was for the system to help the buyer (privately owned processing factory) and other industry actors set harvest dates, schedule factory stops, adjust quotas (used to manage the factory's purchase of farmers' cane), mobilise pest treatments, and predict crop quality.

These motivations underpinned the development of a GIS database: a bird's-eye view that aimed to make production legible to those with access to the maps. A SIRD I technician stressed the anticipatory promise of a management system that would be "one step ahead", enabling SIRD I to advise farmers when to harvest. Factory and institute representatives hoped for insight into farmer behaviour, aiming to encourage farmers to work harder during good weather, mitigate perverse incentives (whereby a farmer may hold onto degrading cane to meet quotas), reward "progressive" farmers (those increasing yields/quality), and change behaviour of growers characterised as planning-averse. They saw potential for anticipatory quality control: the model would "know" when cane from each field should be ready and could reject deliveries outside the expected window. For the researchers, it seemed, the system promised more legitimate decision-making than that of the farmers.

While much data could be obtained from satellites, it also had to be "ground-truthed". This required the participation of individual farmers; at the time of research, this was proving difficult. Factory and SIRD I staff noted that the farmers' association had provided some soil data, but personal details and field access were less forthcoming. Trust between farmers and factory—long subject to antagonism—was foundering amid a dispute about by-product pricing and tensions about precarious markets.<sup>16</sup> In this situation, some farmers were apparently resisting attempts to make their practices digitally legible. While researchers within the industry asserted that weather was the greatest threat to the sector, factory representatives indicated that key decisions were more sensitive to investments, markets and industrial disputes. Considering how climate forecasts might fit into such a management system thus demands reflection: on accountability for decisions influenced by probabilistic predictions; on flexibility to include or exclude alternative grounds for decision-making; and on how existing power dynamics work implicitly through new technologies.

The system's anticipatory ambition brings to mind Scott's (1998) characterisation of scientific agriculture as a process of taming nature and disciplining growers from a position of remote oversight. However, it does not neatly fit Scott's characterisation of such schemes as the domain of an authoritarian state. While sympathetic to Scott's argument, Li (2005) raises critiques that are pertinent here: questioning the possibility of an all-seeing state; noting the roles of non-state actors and welfare approaches; and challenging the separation of situated knowledge from power structures. Indeed, this example involves multiple non-state authorities (private companies, development partners), and the system's proponents did not aim to fully eliminate local knowledge, instead seeking insights into farmers' knowledge, behaviour, and decision-making, and promising transparency and fairness as well as productivity. Thus, the system could be seen to represent a utilitarian effort to co-produce knowledge, combining different data sources to create information with proposed benefits to a range of stakeholders. This instrumental ideal was nonetheless disrupted by tensions that suggested what was really at stake were industrial relations and farmer autonomy.

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<sup>16</sup> I was unable to meet with the association (which has since split into three), ostensibly owing to these circumstances.

## 6 Discussion

In this article, I have examined how people positioned as mediators of climate services articulate expertise in their work. I have argued that attention to their perceptions and choices can help identify the inclusions, exclusions, and contentions that lie behind utilitarian goals of climate services and normative discourses of participation. Different advisory relationships (e.g. involving government extension workers, growers' associations, or NGOs) present a range of challenges for negotiating what is (or is not) legitimate knowledge, and thus for shaping as well as being shaped by the political and ethical landscape of agriculture and society.

Meteorologists noted that evaluation of climate services would be meaningless without understanding their use: “we might be in here congratulating each other on an excellent product that is useless out there”. This illustrates the concern of forecast producers to engage with users in the design and delivery of climate services. However, a focus on the utilitarian accountability of climate services as scientific products that reflect “knowledge needs of societal decision-makers” (Lövbrand 2011:231) cements a boundary between science and society that is likely to reinforce established policy agendas and modes of decision-making. Scientists' and advisers' narratives of interactions with certain groups (particularly small-scale farmers) often side-lined non-scientific practices, and framed projects as ways to maximise productivity. This arguably favours prevailing approaches of larger-scale farmers and buyers, many of whom who have better access to additional information sources (weather stations, websites), and risk-mitigating technologies. As such, ostensibly participatory processes risk reinscribing inequities. Recognising this calls attention to differential abilities to act on information, to the modes and constituents of engagement, and to the values embedded in forecasts that have a particular orientation to the future—that see climate impacts as amenable to foresight and management (Broad et al. 2002; Peterson et al. 2010; Taddei 2013). Debates about climate services thus provoke consideration of what transnational expert frameworks mean for the resilience of situated expertise and practices through which communities address political-economic and environmental changes (Vaughn 2017).

The extension workers, ministry liaisons, and industry researchers tasked with delivering information are pushed by eclectic predicaments of climate and agriculture to be “jacks-of-all-trades”, convening and navigating diverse bodies of knowledge, and negotiating blame/credit in relationships shaped by contested power dynamics and multi-dimensional uncertainties. It is perhaps unsurprising that these experts appear as complex human-subjects (Boyer 2008), rather than abstracted agents of a separated realm of modernity or the state. Extension workers' frequent emphasis on farmer responsibility exists in tension with normative ideals of co-production that would arguably implicate shared responsibility, and with the proposed sugar system that would overrule certain farmer decisions. The examples reveal factors other than climate variability that may be decisive for agricultural decisions and relationships, but are not explicitly accounted for in available climate forecast products: the politics of agricultural production (historically configured relationships between sugar producers and buyers; government support for small-scale farmers); institutional versus individual responsibility for decisions (anxious expertise of extension workers; contested legitimacy of non-scientific knowledge); and different (moral) economies (small-scale farmers' wishes to avoid serious losses in tension with commercial pressures to increase production). The case of the sugar management system highlights how contexts such as industrial relations are not “external” barriers that limit the uptake of information: the rationales underpinning the proposed system were not only the challenges of environmental conditions, but the perceived behaviours of

farmers with respect to their relations with the factory owners. These historical and political relations are thus at the core of the production and promotion of scientific management of agricultural decisions, not only a limiting factor to be confronted with reference to knowledge uptake. Such recognition is aligned with the descriptive idiom of co-production as the mutual constitution of knowledge practices and social order (e.g. Jasanoff 2004).

New ecologies of knowledge are being assembled in contestations of farmer autonomy, the (de)valuation of different types of expertise, and the vagaries of global economies (Vaughn 2017; Taylor 2018). These points of contention—often considered as background contexts or external barriers for climate services—are central to how knowledge and action are (dis)connected through social and political processes. They call for approaches to climate services that do not focus merely on the use and usability of a product, but on the performance of agricultural livelihoods (Roncoli 2006) and on relations among citizens, the state, NGOs, and the private sector. This demands that we question the discursive boundaries between producers and users, and calls attention to how responsibility might be shared in contexts where participatory approaches are promoted. The Belize case highlights specific issues relating to historic colonial and postcolonial agricultural-industrial relations, land tenure, and the reliance on international networks and donors in the development, promotion, and delivery of user-oriented climate services. Many of these are also relevant in other geographical locations. The diversity of approaches and challenges within the sector considered here indicates a need to attend to the singularity of relationships as well as their broader dimensions. By paying attention to the different ways that advisors work to manage expectations—both of uncertain environmental futures and of their own expertise and responsibility—we can better understand emerging models of environmental governance that influence how individuals and institutions are positioned in relation to each other and to uncertain futures.

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## Compliance with ethical standards

Research involving human participants followed principles of informed consent, approved by the University of Oxford Central University Research Ethics Committee and the Belize Institute for Social and Cultural Research.

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