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# Sensing weather: scientific and experiential modes of knowledge production for small-scale farming in western Kenya

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**Abstract.** Agriculture depends in large part on relations with weather phenomena, such as rain and temperature. Anticipatory knowledge about the atmosphere therefore is vital in agricultural livelihoods. Based on an ethnographic case study of weather forecasting for small-scale farming in western Kenya, in this paper I discuss different ways in which knowledge about the future weather is produced. While development organizations promote expert forecasts that draw on meteorological sensing technologies as a solution to dealing with climate change, I show how knowing the weather is an entangled affair in a sensory assemblage that simultaneously draws on scientific instruments and on other entities such as animals, plants, clouds and embodied sensoria associated with experiential knowledge. Building on concepts related to science and technology studies that address the relations between humans and nonhumans, I suggest to treat scientific and experiential devices symmetrically by looking at their more-than-human sensoria, proxies and imaginations to understand how farmers attune to the weather. In practice, then, navigating the uncertainties of the weather is not enabled by scientific meteorology alone, but by combining different sensory devices and practices of interpretation that together mediate the weather as something to be known and acted upon.

## 1 Introduction

"A good farmer has to know the weather. If someone is not interested in the weather, that person is not a farmer" (field notes, 29 November 2017). As this statement shows, an understanding of the weather is considered crucial both for the success of farming and farmers' identities. However, impacts of climate change such as increased frequency of extreme occurrences and of overall climate variability seem to make anticipating the weather more difficult for farmers (Ouma et al., 2013). To meet the resulting challenges both for Kenya's food security and for its economy, to which rain-fed agriculture is a major contributor, suggestions have been made to improve the distribution of climate information to farmers (Government of Kenya, 2010). One particular channel to circulate such information that has been identified as promising for its potentially wide reach and low cost is the dissemination through mobile phones (e.g., Caine et al., 2018).

In this paper, I discuss the relations of different ways of producing environmental knowledge pertaining to "climate information" for farmers. I particularly draw on the case of a project that, following the above argumentation, aims to spread weather forecasts through SMSs to small-scale farmers in western Kenya, a major production region of Kenya's main staple crop, maize. While rural populations in this region have a rich tradition of experiential forecasting (Ouma et al., 2013; Gumo, 2017), this project assumed that experiential knowledge of the weather was stable and unable to navigate change and that responses to this demand scientific knowledge.

This view of scientific and experience-based approaches has been a common feature of development interventions, which often embrace technologies and repertoires of knowledge that are perceived as more modern. Interventions that concern natural environments commonly have been studied through the lens of political ecology. Traditionally employing a historical-materialist perspective, it critically engages with access to resources and related question of power and control (Goldman and Turner, 2011). While this perspective has merit for addressing uneven distributions of natural resources and the power-laden relations of social actors, recent literature informed by science and technology studies (STS) has pointed to some shortcomings and necessary additions.

Two of these are important here. First, Bauriedl (2016) not only calls for a stronger focus on postcolonial perspectives but also for decentering the human as knowing actor – an argument that follows concepts of agency as coproduced in hybrid networks, which have been prominent in STS especially through the works of Latour (2014, 2007). Second, knowledge and expertise should not be treated as "blackboxes" that can be used and transferred equivalent to a resource. Instead, STS suggests to explore how knowledge is produced and contested in specific contexts involving humans and nonhumans (Whatmore, 2014; Goldman and Turner, 2011). Discussing multiple ways of knowing, both assumptions about the dominance of science and uncritical beliefs in technocratic solutions can be avoided (Watts and Scales, 2015).

Instead, this understanding allows us to explore how science and technology are mobilized in the name of development and how accepted (or contested) knowledge about reality comes to be in and through social, technical and material relations. Focusing on how weather is sensed and made sense of, this paper attends to the "plurality of sensing practices, together with the expanded environmental collectives that are involved in sensing" (Gabrys, 2019: 725). It specifically asks how knowledge about the weather is produced in multiple forecasting practices informing smallholder agriculture in western Kenya. Subquestions are how these forms of knowledge can be understood more symmetrically and how they relate in farmers' activities.

To answer these questions, I will proceed as follows. In Sect. 2 I will explain the different modes and stakes of knowing the weather in the case of an information service for small-scale farmers in western Kenya and outline my methodology researching it. In Sect. 3, I will develop the conceptual grounds to move beyond essentialist separations between scientific and non-scientific knowledge. In Sect. 4 I will present some insights from my fieldwork to show symmetries among scientific and expert ways of sensing weather, particularly paying attention to their more-than-human sensoria, proxies, as well as the images and imaginations they make use of. On that basis, in Sect. 5, I show how experiential and scientific modes of knowing the weather are connected in various and distinct ways. In Sect. 6 I finally offer some concluding remarks on how people inhabit their environments through multiple ways of knowing and the implications for development interventions.

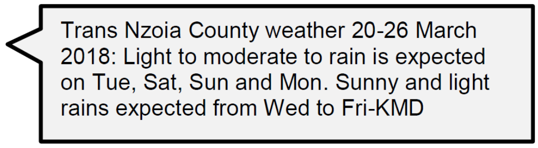


**Figure 1.** Example of weather forecast message.

## 2 Farming and modes of anticipating the weather

Recognizing the general importance of the weather for agriculture is not new, and there have been well-documented historical connections between farming and weather forecasts, both through applications of folk knowledge (e.g., Taylor, 2013 [1812]) and as an early driver in the development of scientific meteorology (c.f. Harper, 2008). This importance of weather knowledge is also evident in small-scale agriculture in Kenya. Here it is exacerbated by climate change leading to higher variability, increased occurrences of weather extremes and, overall, a reduced reliability of weather patterns (Ouma et al., 2013). This presents major challenges for the mostly rain-fed farming in western Kenya, which is a main agricultural production area in the country. According to FAO's (2021) crop calendars, in the (sub)humid mid-elevation areas of western Kenya the main staple crop maize can be planted from early to mid-March and harvested from August through September with a subsequent second planting from August/September. However, conversations with farmers and experts in agricultural organizations suggest that these periods can no longer be fully relied upon. For example, during October 2017 farmers in Trans Nzoia were waiting for unusually lasting rains to cease in order to harvest.

To address these challenges, one project that I focus on in this paper was initiated in 2016 to develop a system in which farmers in nine counties in western Kenya receive weekly weather forecasts as SMS messages. To implement this, the Kenya Meteorological Department (KMD) collaborated with international and local NGOs that already had an established outreach to farmers. KMD's meteorologists in the involved counties produced seasonal, monthly and weekly forecasts for the agroclimatic zones in their area and sent them to those organizations. They sent them as text messages (Fig. 1) to key individuals such as farmer group leaders and extension workers who passed on the information to farmers they worked with.

Asking one of these meteorologists about how the forecasts that inform such messages are produced, he asserted, "this is purely scientific, you have to be a meteorologist" (interview, 24 October 2017). On another occasion, one of his colleagues explained that "weather forecasting involves the collection of data, past and present data, and then you use assumptions of physical processes in the atmosphere to determine, really determine the future, the future weather" (interview, 14 November 2017). The meteorologists further explained that the products they use as a basis for their forecasts are numerical weather prediction products. Based on physics and mathematical modeling, these have been the main technique of weather forecasting since the 1950s and are closely linked to the wider rise of computer-based modeling in the sciences (Harper, 2008). Equipped with the authority of science and particularly calculative techniques, the meteorologists cited above therefore are certain to provide farmers with determinate information on the future weather.

This, however, is not the only kind of information farmers targeted by the climate information project are exposed to. Indeed, alternative forecasting practices are common among rural communities in Kenya. For example, in late 2017 a farmer called Richard who lives near Kakamega told me this:

> When the climate changes, I just use my own information. You can detect the climate on your own. ... For example, when the dry season is coming, insects [butterflies] migrate to places where the sun does not hit. They will move from dry land to the forest, because they assume that the forest is not dry. When it gets cold, when the rainy season is coming, they move out.

Intrigued by this method of detection, which he called cultural, I tried to put his knowledge to the test and asked him what the weather would be like in the days to come. He replied:

> "we might have showers for two to three days from now on to the 12th. Before the 12th, we'll have some minimal rain, maybe not continuous". I asked him what told him and he said, "the owl. Usually, when it expects continuous rain it comes out of the forest, and when it expects heavy downpours, or heavy rain, it goes to the edge of the forest and out of the forest". And this time, he said, the owl had appeared and then vanished back inside the forest. Therefore, he expected just showers and minimal rain. He also noted that "it's hard to see the owl. You have to be patient. You can't really see it, but you can hear it". (excerpts from field notes, 7 December 2017)

Here, knowing the weather involves a different set of entities to be observed and other interpretative techniques in order to determine future states of the atmosphere. Calls to conceptualize weather knowledge from the perspective of its users and to recognize non-scientific knowledge have especially been voiced with regards to often marginalized rural communities in the Global South, including Ethiopian pastoralists (Balehegn et al., 2019; Iticha and Husen, 2019), as well as farmers in northern Ghana (Nyadzi et al., 2021), southern Uganda (Orlove et al., 2010) and various communities in Kenya (Ouma et al., 2013; Vervoort et al., 2016). Although not challenging scientific knowledge per se, Rice et al. (2015) more explicitly critique the hegemonic knowledge politics of those sciences that marginalize other ways of knowing.

While developing a critical perspective on the dominance of science and recognizing other forms of knowing are important, it is also necessary to understand how different knowledges of the weather are produced in specific practices, how they may be understood more symmetrically and what their relations are in people's lives. The conceptual approach that informs these questions and the methodology used to answer them draws on insights from STS, which has pointed to the hybridity of actors and mutual constitution of humans and nonhuman beings (Whatmore, 2006; Latour, 1993). Crucially, it has also highlighted the ways in which (scientific) knowledge is not a mirror image of reality but is constructed in hybrid networks of researchers, instruments, interpretative techniques and academic institutions (e.g., Latour, 1987).

Especially applying Latour's (2007) take on actor network theory to the production of both scientific and experiential knowledge provides a useful mode of researching by tracing the associations that make up those networks and through which knowledge is produced and disseminated. Thus following actors and knowledge through their networks, this research took the form of a multi-site ethnography (Hannerz, 2003). Focusing on two of the counties targeted by the weather forecast project introduced above, Trans Nzoia and Kakamega, these sites included small-scale farms, agricultural training sites, weather stations, and the offices of NGOs working for agrarian and rural development. Applying an ethnographic approach to the use of information technologies in the production and use of environmental knowledge can be understood as "technography" (Kien, 2008; Jansen and Vellema, 2011). Research included recurrent periods of participant observations with farmers and field officers employed by NGOs between October 2017 and April 2018. During this time and during a later period in March and April 2019, I conducted a total of 43 qualitative interviews. These comprised 24 interviews with farmers, 8 with meteorologists, 8 with staff of NGOs and 3 with voluntary rainfall observers. In addition, I conducted 7 group discussions with farmers and farmer group leaders. For the purposes of this paper, all individual names of research participants were anonymized.

Before presenting empirical insights from this research, in the next section I will outline in more detail the conceptual basis on which I problematize essentialist and dichotomical understandings of scientific and non-scientific forms of environmental knowledge and argue for an alternative conceptualization.

## 3 From epistemological binaries to attuned sensing

While acknowledging the plurality of knowledge practices and the value of non-scientific knowledge is important, it is in itself insufficient to overcome essentialist conceptualizations. Despite having relied on their own experience with the weather, such thinking is not uncommon even among some farmers:

> As one woman in a western Kenyan village said, "we looked at the clouds and we would try to imagine that there will be rain". … Her husband explained, "in Kiswahili-speaking countries we have a saying, which is 'dalili ya mvua ni mawingu', the sign for rain is clouds. For a long time, we used this, but scientifically clouds do not necessarily mean rain; the assumption has been overtaken by knowledge and events". (excerpt from field notes, 28 November 2017)

Evident here is a thinking that upholds a categorical distinction between scientific and non-scientific knowledge to an extent that only science is considered knowledge at all, while observations and experience are assigned a status of mere assumptions. Such claims of essential difference often are made along substantive, epistemological and contextual lines (Agrawal, 1995). Along these lines, scientific knowledge is based on abstract philosophies, is presumed to be neutral, produced in an analytical, systematic and objective way and makes universalist claims about reality. On the other hand, so-called indigenous knowledge is based on an intimate connection with livelihoods, is based on common sense, is non-systematic, non-objective and closely linked to its context of application.

While this hierarchical understanding of scientific and non-scientific knowledge seems persistent, work in STS warrants a move beyond such a conceptualization, asking how and under which conditions environmental knowledge is produced, circulated and used (Goldman and Turner, 2011). This starts with a general perspective on scientific knowledge as the outcome of a set of practices that hinge on large networks of institutions and instruments (Latour, 1987). While not implying a criticism of scientific knowledge as such, this is indeed a critique of powerful, authoritative claims of science (Latour, 2013). Similarly, studies on environmental sensing have pointed to the power of (scientific) data in environmental management and related decision-making processes (Adams, 2020; Gabrys, 2016b). Selectively privileging certain objects of study and possibilities of interpretation, environmental data practices not only beg epistemological but also normative questions (Gabrys, 2016a).

This epistemological power contrasts with a plurality of non-academic ways of knowing the world that inform people's lives as much and that may involve affect, embodiment, situatedness and performativity (Law, 2016). In addition, Coté (2010) challenges hierarchical relations between *episteme* (abstract knowledge) and *techné* (practical knowledge) by arguing that not only scientific knowledge but also embodied experience and the human sensorium are always already mediated. In turn, Ballestero (2019) traces how embodied senses are turned into conceptual resources in scientific practices, arguing for an attention to sensorial combinations. In other words, presumably abstract science also has embodiment, and ostensibly direct, embodied experiential sensing also accesses the world in a mediated way.

Deconstructing categorical distinctions between scientific and indigenous knowledge, Agrawal (1995) makes two points. First, indigenous knowledge and scientific knowledge are in themselves heterogeneous and may share elements among each other. Second, both indigenous and scientific knowledge are dynamic and have been in contact with each other for centuries, often rendering it impossible to clearly separate them. One attempt to relate traditional weather forecasting with science is made by Kenyan climate scientists, who try to "harmonize" their predictions with those of Nganyi indigenous forecasters and develop an agreement among the two groups (Ouma et al., 2013). However, by "demystifying" indigenous knowledge, they stay within the scientific perspective, implicitly setting it as the norm of knowing. As a consequence, explaining indicators used by indigenous forecasters through science would ultimately make considerations of indigenous forecasting obsolete, because it presumably could be fully explained by science. Similarly, Iticha and Husen (2019) have attempted to integrate scientific and indigenous forecasting among Borana pastoralists in Ethiopia, and Nyadzi et al. (2021) have tried to compare indigenous forecasting with scientific meteorology in a quantitative assessment of their respective success in actually predicting the weather.

While these comparative approaches can be useful in recognizing the value of non-scientific forecasting methods, they lack an engagement with how different knowledge practices relate in ordinary people's everyday activities. This has been addressed by Balehegn et al. (2019) who show that Afar pastoralists do not use a single indicator to predict weather but draw information from a wide variety of sources, both traditional and scientific. Similarly, Vervoort et al. (2016) demonstrate how farmers in Kenyan communities use weather information flexibly, drawing on several local and external sources in agricultural decision-making. As Orlove et al. (2010) point out in their study of indigenous climate knowledge among farmers in southern Uganda, farmers are not only consumers of weather information but also share their experiential knowledge to actively engage as producers in programs that draw on climate science for climate change adaptation. These examples show the importance of both scientific and experiential knowledge. Adding to this, I argue that it is important to develop a better conceptual understanding of the ways in which they are produced in practice, how they can be understood more symmetrically and in which ways they become entangled in what Vervoort et al. (2016) call farmers' "working knowledge".

To think of sensing and making sense of the weather in non-essentialist ways, I seek to understand how scientific and experiential forms of knowledge are produced and how they relate by considering how people attune to the weather. Generally, attunement refers to practices and processes through which people form relations with the environments they care about and/or that are vital for them. While the term has originally been used to conceptualize humans' relations with animals (Despret, 2004), more recently it has been employed to think through people's engagement and the knowledges related to the atmosphere, e.g., controversies concerning air quality (Calvillo, 2018) and ways of knowing climate change (Howe, 2019). Considering the production of knowledge, thinking in terms of attunement rejects the possibility of universal and distanced knowledge and instead points to situated practices of noticing described by Tsing (2015, 2017). In this vein, it assumes a fundamental impossibility of unmediated and complete knowledge and instead enables – always incomplete – knowledge in "a living, dynamic relation" (Morton, 2018: 89). With regards to farming in western Kenya, the concept therefore raises questions about how farmers relate to the weather, an environmental factor that vitally and intimately concerns them, by drawing on various imperfect knowledges and applying them in their everyday contexts.

In the following section, I will discuss three aspects through which farmers attune to weather, both with scientifically produced and experiential knowledge. First, sensoria will be discussed. These are the more-than-human devices and capacities through which phenomena are registered, including technological devices, but also embodied senses of humans, animals and plants. The second aspect is what I call proxies. Here, I use the term in the sense of Rice et al. (2015) when they speak of the way in which climate change is detected through observations of landscape change and personal memories. In this understanding, proxies are the mediators that stand in for weather processes, e.g., indicators, measurements and data, as well as the behavior of animals, trees, plants, clouds, etc. The third aspect consists of images and imaginations, or in other words "models", through which weather is made sense of. This includes cultural beliefs, as well as theoretical assumptions, through which meaning is given to what sensoria "tell" by providing observable proxies for future weather.

## 4 Symmetries: imagining weather through more-than-human proxies and sensoria

In order to develop a fuller understanding of how weather comes to be known, in this section I will discuss how scientific and experiential practices can be understood symmetrically by exploring the sensoria, proxies and models that together make weather knowledge. This means to not assume foundational differences between their respective sensing devices and practices, the environmental indicators they observe, and their models of the world. As will become clear, they all use proxies and none has direct access to the world they seek to know. Also, all their sensoria can be understood as more-than-human and all use models, imaginations and images.

### 4.1 Experiential proxies and sensoria

Reconsidering the example of experiential knowledge I quoted above, Richard observed butterflies that migrate in and out of the forest when it is hot and cold, respectively. In addition, he observed the behavior of an owl also in relation to the forest. In the course of our conversation, he further recounted how he also observes snakes to know the advent of cooler rainy weather and hotter dry spells (field notes, 7 December 2017).

I received similar accounts from various farmers and groups of farmers throughout the time I spent in western Kenya. For example, in early 2018 I accompanied a field officer of an agricultural NGO to a meeting with a group of farmers in Trans Nzoia, where I also had a conversation with the farmers about how they use and produce knowledge about the weather. These farmers get expert forecasts from meteorologists but experiential methods of knowing the weather, which they report having acquired from their ancestors, are still relevant to them. Similar to Richard, these farmers observe birds: when a specific kind of black and white bird is seen flocking in groups, they said that was a sign for coming rain. Other indications of rain are observations of clouds and lightning, heat at night, frogs croaking at night, and the wind blowing from east to west. In addition, the onset of seasonal rains is expected when a type of ant, called the safari ant, enters the house at a particular time of the year, when butterflies can be seen in groups flying from east to west, when morning dew is observed when it is cold in the morning and when the leaves start regenerating in some family of trees that shed their leaves in the dry season (field notes, 8 February 2018).

This list shows the multiple relations that people engage in to know the weather. These are relations with living and non-living entities, which I understand as proxies, because people use them as entities that tell something about the weather. These are in part multispecies proxies: to know the weather, people enact relations with multiple living beings such as birds, butterflies, trees and forests. However, experiential knowledge is not limited to multispecies proxies and multispecies relations. Since people do not only observe living organisms but also other phenomena such as lightning, clouds and physical indications of wind direction, they truly engage multiple entities that can be understood as more-than-human proxies, including other beings that "stand in" for the weather.

As a consequence, not only the proxies but also the sensoria of experiential knowledge are more-than-human. To clarify the difference, proxies in the sense of Rice et al. (2015) can be understood as standing in for the weather, like indicators and measurements, but also the behavior of animals, plants and trees. In contrast, I understand sensoria as the devices and capacities through which phenomena are sensed and registered. Briefly then, the more-than-human sensoria are the entities themselves, while proxies are what they show in their behavior. That said, experiential knowledge draws on embodied sensoria in multiple ways. On the one hand these are human embodied senses when people feel heat, cold or humidity, when they see clouds, wind direction, the visibility of the sky and other environmental indications, and when they hear, see and feel what animals and plants do. But those sensoria are not only human precisely because they in part draw on what animals and plants themselves sense and how they react to environmental processes and dynamics. For example, in some tree species flowering or the shedding of leaves can indicate changes in humidity before humans might be able to sense them, and some ant species are known to leave their nests before rain sets in to protect themselves from drowning (Ouma et al., 2013). Engaging in such multispecies relations therefore makes experiential sensing a more-than-human affair.

Observing, feeling and hearing all those entities and accessing them with a full human sensorium then means to use them similar to sensing devices. In a certain way, people "read" ants, trees, butterflies, birds and all the other entities that they observe in a composite way. Only by taking all those "readings" together, can people draw conclusions about what to anticipate. In a similar way, scientific meteorology also uses proxies to register phenomena that say something about the weather, which can be understood as more-than-human sensoria as well.

### 4.2 Scientific sensoria and proxies

While the immediate purpose of data produced by meteorologists in Kenya is not to produce locally tailored weather forecasts for farmers, they still play a role in those predictions, however in a more indirect and mediated way. Generally, data produced in Kenyan weather stations are fed into national and international databases and inform weather prediction products on various spatial scales and in various institutional settings. Such prediction products are important for a general consideration of how scientific meteorology produces its knowledge about future states of the atmosphere. Since Kenyan meteorologists widely use them, they are also relevant to understand how localized forecasts are produced.

Here, I draw on some accounts that I experienced during my research in Kenya. Not having discussed remote sensing technologies, this is not a comprehensive account of all sensing practices used in meteorology. Nonetheless, it provides insights specifically into the sensing practices of Kenyan meteorologists that also form a part of the production of global weather data. During a visit to the weather station in Kitale, the lead meteorologist based there showed me around the plot with weather data collection devices. These included automatic and semi-automatic rain gauges, thermometers, hygrometers to measure humidity, and anemometers for wind speed and direction, which are in different ways susceptible to registering atmospheric phenomena. For example, the meteorologist demonstrated to me the functioning of a rain gauge. On opening it, he revealed a mechanism with two buckets that are balanced on a tipping point (similar to a scale) and explained that the two buckets of equal size can hold the same amounts of water. Rain water is channeled into one of the buckets until it contains a defined amount of water. It then tips over and water fills the other bucket until that contains the same amount of water, and the process repeats. At each time the buckets tip over, the rain gauge takes a reading, and the amounts of rainfall can be determined by counting how many times they have tipped over a certain period (field notes, 30 October 2017). In a simpler way, the meteorologists in Kitale also engaged voluntary rainfall observers whom they provided with simple rain gauges. Here, water collects in a bottle, which on a daily basis is emptied into a measuring cup, and the collected rainfall amount is documented on paper in a tabular form (interviews, 22–23 March 2019).

As is the case with experiential sensoria, these scientific instruments can be understood as more-than-human. While they do not consist of living beings or environmental phenomena, scientific sensing equally has no direct access to the weather but uses an extended array of entities to register atmospheric phenomena. This does not imply that they are the same and there remain noteworthy differences. Importantly, on the one hand, technical devices are designed for a specific purpose. On the other hand, the entities drawn on in experiential knowledge practices are not designed to know the weather. However, it is not only important to note the ways in which they are made and the purposes they are made for (if they can be said to be "made" at all, which usually does not apply to living beings like animals and plants) but also to understand the purposes they are assigned and the ways they are related to by people in order to know the weather.

This more-than-human character not only applies to the sensorial devices through which weather is detected but also to the data and indicators that they express about rainfall amounts, humidity, temperature, wind, air pressure and others. For example, voluntary rainfall observers note their readings on a standardized sheet documenting the amounts of rainfall they have collected in millimeters for each day of the month. These sheets eventually are collected by the meteorologists and sent to a national repository. Of course, data are also collected in meteorological weather stations. Here, some devices work automatically, feeding their readings into a digital database in an automated way. Other readings have to be taken periodically by hand, or they have to be copied into digital form. For example, some rain gauges mark readings on a rotating slip of paper and trained staff have to copy their readings into a digital form for further processing (field notes, 30 October 2017). As meteorologists indicated, such data are then sent to databases and computing centers at the national headquarters in Nairobi and further to the World Meteorological Organization (WMO) where they are fed into and inform national and global weather prediction products.

Here, too, knowledge about the weather is derived from skillful readings of sensory devices. This is in line with longstanding insights from STS that have pointed to the role played by technical instruments and observational choices through which scientific knowledge is constructed (Latour, 1987). As is seen here, nonhuman sensoria and related proxies are crucial to make statements about the future weather both in meteorology and experiential knowledge practices.

### 4.3 Imagining weather

Sensing and knowing the weather does not only entail sensoria and proxies. Both modes of knowledge additionally hinge on imaginations and models of the world. For example, when I interviewed Mary and Isaac, a married couple of farmers living near Kakamega, Isaac remarked that before they got the weather forecasts, they "just used imagination". Mary continued, "we used the *kienyeji* [Swahili for traditional, indigenous, local] one, the natural one. It's a belief from the ancestors. We see the clouds this side or that side in the morning or the evening and the wind direction. But the present one is a bit correct. When it says it doesn't rain, it doesn't rain. Like this week, if you use this cloud, there were clouds but no rain". So the natural one, as she called it, is not accurate: "you plant crops, you plant and the crops will disappear. It's wrong most of the time" (interview, 29 November 2017).

In this account it is noteworthy that the couple describes the traditional and experiential ways of knowing the weather in terms of imagination and beliefs, which in their view is opposed to knowledge. They particularly talk of imagination in a sense that denounces the validity of statements derived from it, arguing that scientific forecasts are more accurate. This implies that to use experiential ways of forecasting, one has to believe in them. In addition, when Isaac talks about imagination, he implies that this is something fictitious, not based in reality. However, the notion of "imagination" may be adequate to understand both experiential and scientific ways of knowing if we consider it being rooted in images, not only referring to visual depictions but also more generally to a "bigger picture". Reinterpreted in this way, speaking of imagination alludes to the models of the world and the techniques through which observations become meaningful in reference to existing rules in already established systems of knowledge that, in the case of experiential knowledge, have conventionally been understood as "cultural" (Gumo, 2017; Ouma et al., 2013).

Talking about different modes of the weather symmetrically then means to ask in turn what are the imaginations, images and models that are used by scientific meteorology, too? Notably, when the meteorologist quoted in Sect. 2 explained that weather forecasting hinges on "assumptions of physical processes in the atmosphere" (interview, 14 November 2017), it becomes clear that scientific knowledge, too, is shaped by prefigured concepts about how the atmosphere behaves. Another meteorologist talked about how it is necessary to tune models: when he tries to make predictions about the weather in his area he uses models that relate to larger spatial scales. He further explained that, in order to give correct predictions for his smaller geographical area, he has to do what he called "tuning": "you have to filter and remove model errors … and there is a way of doing it. For example, I know where Lake Victoria is, and with time you realize if you have an easterly or westerly wind; in this particular month the model is underestimating or overestimating the rain. So you tune it" (interview, 24 October 2017, paraphrased).

This need to "tune" models based on his experience and data series of the local climate shows that, despite universal claims, scientific knowledge does not provide immediate descriptions of reality but hinges on context-dependent interpretative practices (Agrawal, 1995). As Morton (2018) argues, reality can never be known directly and completely. Hence, there is always a gap between the world and the models through which it is known. Similarly, just as imaginations and beliefs are said to make (up) the world, Edwards (2001) understands atmospheric modeling as a practice of world-making rather than one that precisely describes present and future realities. Looking at the outputs of such models, which often are visual depictions in the form of maps (Fig. 2), it can be argued that they have imaginary qualities: like the models of the world that inform experiential knowledge, they enable their users to imagine future states of the atmosphere and to act on this basis.

## 5 Entanglements of scientific and experiential knowledge in practice

Scientific meteorology and experiential weather forecasting cannot only be understood symmetrically. In farmers' practices, they are indeed entangled. This means that distinctions between science and experiential knowledge are challenged not only by conceptualizing attunements to weather through sensoria, proxies and the imaginative qualities of models but also by what farmers do in their everyday activities. Here, I identify three kinds of entanglement between those two ways of knowing the weather.

The first one is reflected in the ways in which the actual weather intrudes on the senses, even when preference is given to scientific forecasts. I experienced this myself when I was on a day trip with a field officer from a local NGO at the beginning of the rainy season in 2018. After visiting farmers, we were on a motorbike going back to a small market town on the main highway where we would end the day. The morning had been clear and sunny, but over the course of the day some clouds had been building up. By then it was mid-afternoon, and we were going back on a dirt road. The field officer looked back over his shoulder and pointed to the clouds that had become larger and larger on the slopes of Mount Elgon. He urged the driver to go faster so that we would reach our destination before the rain started. Eventu-

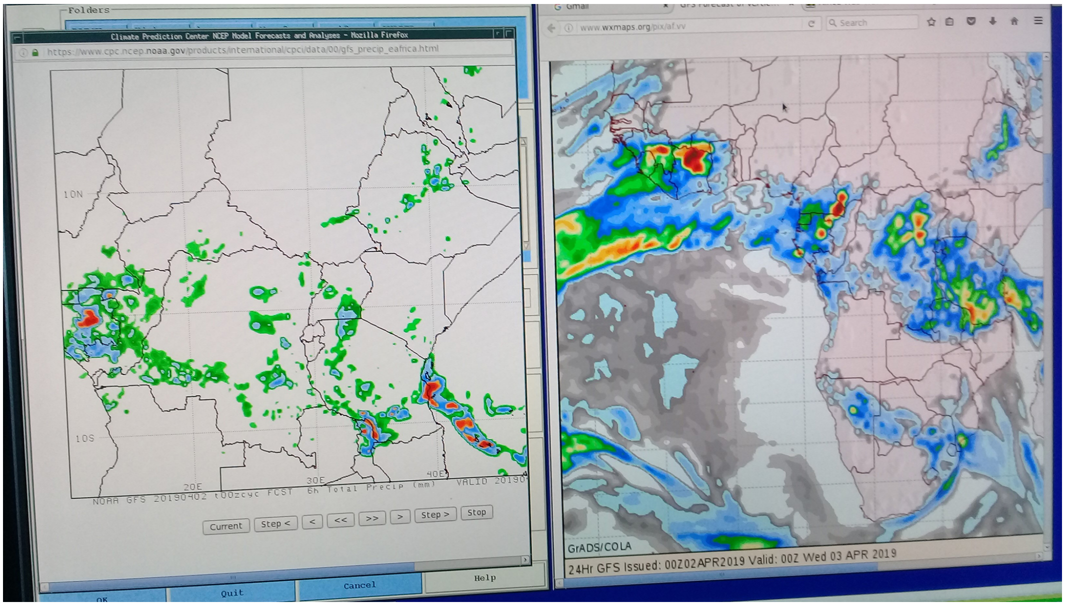


**Figure 2.** Examples of visual forecast products used by Kenyan meteorologists (photo taken by the author, 2 April 2019).

ally, however, he asked the driver to take a different route and to go to a place where we could seek shelter. As the downpour started we arrived on a large-scale farm where the officer knew one of the workers. There, we spent the next 2 h in a grain storage, waiting for the rain to subside (field notes, 16 March 2018).

This experience shows that, even if one follows scientific forecasts as we did, sometimes weather can come as a surprise. The state of the sky can change quickly on timescales shorter than a forecast depicts. Similarly, walking to a meeting with other farmers with Mary, she looked up at the sky and said "today there'll be no rain". I asked her how she knew and she replied "because it's so hot" (field notes, 27 November 2017). Here, Mary clearly used her own observations, despite receiving and using scientific forecasts, which she had described earlier as a lot more accurate, denouncing experiential knowledge as mere belief.

A couple of days later, I sat in front of the house with her husband Isaac. When I casually remarked that it is a windy day, he started explaining that easterly winds are a sign of coming drought, that westerly winds from the direction of Congo rather indicated rain, and that northerly and southerly winds are a quite strong indication of rain. Only having said that, he added that at least this was the imagination that people followed in earlier times (field notes, 30 November 2017). While here he reaffirmed his doubt stated earlier, it is clear that he still holds this knowledge. And the sincerity with which he explained it, not having been specifically asked about it, left an impression that it is still relevant to him.

At a meeting with another farmer group in Trans Nzoia, one of the farmers stated that he preferably uses expert forecasts. However, he then remarked that the safari ants, which are said to be a traditional indication of coming rain, bite regardless (field notes, 5 February 2018). This is an interesting statement, because it shows that experiential proxies are constantly present and make themselves recognized. In this case, they may even bite. Therefore, while farmers may use expert predictions, they still cannot ignore other proxies that stand in for the weather.

As a second type of connection, farmers actively compare scientific forecasts with their observations. This is the case when the farmer Joseph told me that the current forecast predicts some rain. He added that he had seen clouds, too, but that there had not been any rain yet. He later explained that before he started to receive expert weather forecasts, he had used what he called his own knowledge (field notes, 9 December 2017) and apparently he still does: while he receives scientific forecasts, he also looks for the predicted rain by observing clouds. Here, he compares what he sees with information he gets from meteorologists. Another farmer, Malcolm, said that "you can see the weather and that the weather tells you when to plant". Nonetheless, the weather forecasts Mary forwards to him "help because I can compare them with my own observations" (field notes, 8 December 2017). This farmer, as well, uses his own observation and double-checks with expert forecasts.

Such comparisons were not only made by farmers around Kakamega but also common in Trans Nzoia. In a group discussion farmers explained their observations of plants and animals in this way: "it is a kind of indigenous knowledge. It supplements the weather forecast. What we see is that the weather forecast says this, and the observation says the same. So it is another indicator" (field notes, 7 November 2017).

Here, experiential knowledge becomes yet another indication of rain in addition to the scientific weather forecasts farmers receive. During a different time of the year, the beginning of the of the rainy season (and hence the planting season), I met Grace, a group leader who receives weather forecasts on her phone, and her son Theodore. When I asked them how important the so-called natural knowledge is compared to the weather forecasts during that season, Grace replied that both are helpful. Theodore, in turn, added that the forecasts are more accurate and explained that his mother had received the forecasts, and that they have experienced what they said. He stated, "with the leaves you cannot know what amount of rain will come or how long" (interview, 17 March 2018). While this seems to be favoring scientific forecasts, Theodore does not trust them blindly and still considers observational signs for a comparison with expert forecasts. In other words, even in judging the two ways of knowing weather and stating that the scientific forecast is more useful, Theodore is acutely aware of the weather through what he experiences and observes himself.

Such comparative practices are not the same for each and every farmer. While some emphasize scientific knowledge, others put more faith in their personal experience and observations. On the one hand, Theodore puts a lot of trust in scientific forecasts. The same applies to most members of one farmer group who characterize the forecasts as accurate and useful since, "with climate change, we are comparing it to indigenous knowledge but weather becomes less predictable" (field notes, 7 November 2017), making experiential observations more difficult to use.

On the other hand, the farmers from Kakamega cited above stress their own knowledge. Malcolm seems to predominantly use his own observations to determine the time of planting and verifies them with scientific forecasts. Joseph, too, receives weather forecasts but seems to wait until he can see clear signs of rain before he acts on the information he gets both through expert predictions and his observations. What is important for me here is not to determine which one is actually more accurate and more trustworthy. The point instead is that, in practice, farmers combine and compare several ways of knowing the weather as a basis for making decisions. In farmers' practices, then, no fundamental distinction is drawn between scientific and experiential knowledge and both are important.

A third type of entanglement can be identified when scientific and experiential knowledge are combined differentially, i.e., by using different kinds of information they provide. On the one hand, experiential knowledge is predominantly used to determine points in time of the start and cessation of rainfall events. In particular, it is used to estimate the beginning and end of rainy seasons in order to know when to plant and to harvest, respectively. On the other hand, the example of Grace and her son shows that scientific forecasts provide additional information on the amounts and the spatial distribution of rainfall. Farmers thus get a more fine-grained image and make more detailed decisions on agricultural activities. Here, it is not only crucial to know if and when rain is expected to fall but also whether it is likely to be sufficient for planting.

Of course, both modes of anticipating weather have a temporal dimension, which means that they make statements about when things will happen and at what time actions should be taken. As the examples of Mary and Joseph show, however, farmers combine information from scientific forecasts and experiential knowledge that pertains to differing temporal scales. Joseph stated that he receives weekly weather forecasts from Mary, but in continuously comparing this forecast with what he actually observes, he combines the two sources of information in a way that he continuously checks on what is happening in his environment. Here, he draws on weekly weather forecasts, but in order to keep "up to date" with the weather throughout the week Joseph uses his experiential skills of weather observation. A similar observation can be made on a larger timescale, namely for the beginnings and the ends of agricultural seasons. For example, approaching the planting season, Mary stated, "We have to see the rain to plant. When we get the forecast, it says it rains in A, B, C, but we might not get it here. But you can prepare" (phone call, 8 March 2018). Farmers get scientific forecasts well ahead of time and use these to prepare their fields. Being aware of scientific forecasts' inherent uncertainties, when the expected time of planting draws closer, they use their own observations to make a decision to act.

Farmers' use of both scientific and experiential knowledge generally reflects earlier insights that rural populations draw on multiple sources of and often mix indigenous and external information (Balehegn et al., 2019; Vervoort et al., 2016). Adding to this, farmers' practices studied here show how knowledges are combined in complex ways: on the one hand, with regards to their temporal dimensions, scientific knowledge seems to be used more for a general picture of what is going to happen, while experiential knowledge then is used to determine specific points of time for actions to be taken. On the other hand, when it comes to what kind of information they provide the picture is reversed. Here, experiential knowledge tends to be used predominantly to determine points of time, such as the beginning and cessation of rainfalls. In turn, scientific knowledge, although coming with uncertainties, too provides a wider array of additional information, including the amounts and distributions of rain, which is also relevant information for farmers and their decision-making.

## 6 Conclusions

Knowing the weather is vital for small-scale farmers in Kenya, especially under changing conditions which make farming more difficult. Against this background, this paper set out with a critical engagement with conventional approaches to development that seek to solve those problems by focusing on scientific knowledge and making it accessible to farmers through the use of modern communication technologies. Instead, employing a perspective informed by STS, I tackled problems of knowing the weather by recognizing the multiplicity of knowledges at play among farmers in western Kenya and by asking how knowledge about the weather is produced in scientific and experiential practices, how these two forms can be understood more symmetrically, and how they relate in farmers' everyday activities.

Thinking forms of anticipating the weather particularly in terms of their sensoria, proxies and imaginations allowed me to discuss the ways in which they work symmetrically, which means to apply the same vocabulary to describe their methods of observation and interpretation. While some parallels between scientific and experiential knowledge have been identified e.g., by Agrawal (1995), in the case explored here some aspects additionally stand out: while the indirect and mediated character of scientific measurement has been recognized, this is also the case in experiential knowledge. Often assumed to rely on direct encounters with its objects of knowledge, it partially depends on observing nonhuman sensoria and using them as a proxy. In addition, the notion of "imagining" adequately describes the context-dependent interpretative practices of both scientific and experiential ways of weather forecasting. Considering how these forms of knowledge relate in farmers' activities it became clear that these are not separated but connected forms of knowing through which they attune to their environment. While not necessarily in harmony with each other and some farmers upheld essentialist distinctions with an explicit preference for expert forecasts, in practice experiential and scientific knowledge appeared far from opposed and were combined with regards to their respective contents and temporal frames.

This symmetry and hybridization of knowledge practices has important implications for development projects that promote the dissemination and application of scientific knowledge. Recognizing that all knowledge is relational upsets universalist claims and means the "collapse of [science's] distant gaze" (Ziebritzki, 2020: 263). Scientific knowledge that projects that distant and global gaze then is not a solitary solution to problems of change and uncertainty but one among many knowledge practices. Here, certainty is not guaranteed by receiving and following scientific knowledge alone, but it is derived from and honed through practices that combine various ways of knowing environments. This profoundly challenges modernist beliefs in technical fixes not uncommon in many development projects adopting information technologies (Díaz Andrade and Urquhart, 2012) by providing an example of how new knowledge does not take over but rather folds into an existing context in unforeseen ways.

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