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Original research article

How can co-creation improve the engagement of farmers in weather and climate services (WCS) in India☆

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Practical Implications.

This paper compares how the governance of four agro-met services operating in the same basic area of Maharashtra, India condition the engagement between the users and the providers of the services. The four cases reveal diverse institutional designs and engagement mechanisms for involvement of end-users and intermediary users and partners.

The four services studied included a mix between public and private providers; the Agro-met Advisory Services of the Indian Metrological Department (IMD-AAS); IFFCO Kisan agro-met services hosted by the Indian Farmers Fertilisers Cooperative Limited (IFFCO) with funding from the government; Reuters Market Light (RML AgTech), a private firm; and, the Agricultural Meteorological Program of Watershed Organisation Trust's (WOTR), a civil society organization.

A governance approach was developed and utilized to document and compare the institutional structure and operations of the four case studies. Documentation of actors involved and institutional mapping was complemented with key informant interviews with management and staff of these service providers at state, district and local levels. These semi-structured interviews were combined with individual farmer and focus-group interviews in three villages in two districts of the state (Pune and Ahmednagar). A survey among 86 farmers subscribing to the services was also undertaken to better understand the uptake and use of the services.

The levels of engagement varied across the four services, depending on the mechanisms employed for furthering participation and feedback within the services. Four broad categories of user engagement were identified to illustrate a 'ladder of engagement'. The various rungs or levels of this ladder represent how different web-based tools and institutional mechanisms were differently combined to condition various forms of engagement and interaction among partners. These engagement categories ranged from passive to active and from involvement of few to multiple kinds of actors and scales in the services. Moving up the ladder indicates increase in the resources and attention paid to engage farmers and extension agents in the services.

- *Level 1.* Information provision - one-way transfer of information through websites/web-based tools;
- *Level 2.* Dialogue based service - two-way information systems that enhance dialogue through e.g. call centres/web-sites;
- *Level 3.* Co-production of service - two-way or multi-way communication of knowledge and co-design of the service
- *Level 4.* Co-creation of the service - regular multi-way communication and intense interaction among multiple actors (workshops) and co-implementation, including also interface with social media for inclusion of practice-based knowledge and social learning at local level.

In assessing the performance of the four services in terms of the forms of engagement that took place, one service provider RML AgTech., was considered to perform at Level 1; IMD-AAS and IFFCO-Kisan at Level 2; while WOTR was the only provider to have reached Level 3. None performed at Level 4.

Our findings suggest that success in the governance and operations of the agro-met advisories to support farmers' adaptation and risk decision-making is likely to be highest when farmers' are engaged, the provider make use of multi-modal and multi-way communication systems; and user involvement is combined with on-site extension support and multi-actor partnerships. This is in line with recent findings in the WCS literature (Singh et al., 2017; Lobo et al., 2017; Vaughan et al., 2017; Hewitt et al., 2017).

However, we insist that improved mechanisms for greater participation of farmers alone, while being a necessary requirement to enhance performance, is not a sufficient condition for taking the WCS agenda forward. The incentives for farmers to become really active partners will only come if the knowledge provided is better targeted and tailored to specific local circumstances than what is observed today. Each of the services were hampered by the same limitations in the format, accuracy, tailordness and relevance of the knowledge provided, and similar complaints by local farmers to this end. Improvements on these basic aspects will require continuous advancements in weather models and data input and investments in more localized and

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dynamic crop- and farm-advisories adjusted to changing local weather forecasts and climate.

It was found that progressive farmers were the most responsive to the services and most appreciative of agro-met advice and forecasts. Uptake among them seemed highest linked to specific and locally tailored early warnings about the risks of extreme events, such as hailstorms and extreme rainfall, and information about specific pests and how to address such. These farmers frequently possessed smart phones and access to internet. However, there were several indications that subscribers, especially if required to pay for the services, tended to lose interest in the services over time. A large majority of farmers in the villages were not subscribing or not aware that agro-met services were available for free in the villages (Nesheim et al., 2017). Less progressive farmers, female farmers and land-less were, on the other hand, relatively absent among the subscribers.

There are several strategies required for improving the governance and engagement mechanisms towards more co-created agro-met services:

i) First, there is the need for *conscious institutional design at two levels* – related to a) the design of engagement mechanisms, and b) to the overall institutional structure. The aim of the institutional design would be two-fold: a) to improve multi-way communication, multiple interfaces for user engagement, and a more co-produced and co-created service (to produce more useful knowledge and build awareness and trust in the knowledge products provided); and, b) to build appropriate structure and relationship between relevant partners and scales (multi-partner service for multiple interfaces).
ii) Second, an approach to enhance consciousness among decision-makers about the appropriate institutional co-design of the services should start by building awareness and capacity among key decision-makers about the importance of such design for improving governance and operations. This may also clarify roles of and relationships and responsibilities across public and private agencies, sectors and levels.
iii) Third, the use of web-based tools for engagement should be combined with state- and district level *user-focused workshops* – preferably hosted by user organisations, such as farmer unions or local civil society organisations, to include the national meteorological organization (IMD), agricultural colleges/agro-met experts, local research & training (KVKs), and extension service agents to set the stage for ongoing interaction and co-creation of the services through partnerships (in line with Hewitt et al., 2017:616). This should build on the principles and ideals of how knowledge networks and information services should be designed and operate.
iv) Fourth, there is a need to develop continuous and multiple ways of eliciting feedback from end-users and intermediary users of the services and utilize this information to continuously improve institutional design and co-creation processes. Such feedback should be encouraged through multiple interfaces including direct face-to-face interaction on-farm, local workshops, village laboratories (VillageLabs), surveys/ evaluations and interviews. Such methods can both strengthen engagement and local, social learning and enhance high quality, locally relevant and practice-based knowledge.

In particular, there would be added benefit of designing and ensuring a more deliberate role for social media platforms, such as WhatsApp groups, to interface with agro-met services. Local crop-based WhatsApp groups are observed in Maharashtra (and across India) to be initiated by both the farmers themselves and by local extension staff, and have started to become integrated with larger public and private agro-met programs. To this end, the farmer-initiated WhatsApp groups represent ingenious examples of bottom-up institutional innovation to inform adaptation decision-making at farm- and community levels. This development – if further nurtured - may open up innovative ways forward for WCS in this evolving field.

1. Introduction

Increased vulnerability to a rapidly changing climate have resulted in a growing interest in India and elsewhere to engage in the provision of Weather and Climate Services (WCS) as a means to enhance climate adaptation and reduce risks in the agricultural sector (Adger et al., 2009; Vaughan and Dessai, 2014). WCS are being developed worldwide for policymakers and decision-makers within the agricultural sector to enable rural society, especially the most vulnerable, to better manage risks and opportunities arising from changing climate and weather. This paper reviews a sample of four public and private agro-met service providers in the state of Maharashtra, India, which represent the landscape of such WCS providers in the state for the agricultural sector. The paper aims to contribute to a better understanding of the conditions for effective governance of such agro-met services, especially regarding how to design more effective mechanisms of engagement between the users and the providers of relevant information and knowledge that can enhance co-production and co-development within this emerging field.

Agriculture is still the main source of livelihood in rural Maharashtra, including for many of the poorest people. The agriculture in Maharashtra is mostly rain fed and thus vulnerable to weather and climate variations e.g. shifts in monsoon rains. Increased climate variability has led to more irregular weather, and thus a more acute need among farmers for advance warning about extremes weather events and advice on how to adapt to climate change in the medium to long-term (e.g. regarding cloudbursts, hailstorms, spread of pests, monsoon forecasts).

The papers compares the governance arrangements of four services operating in the same basic geographical area of Maharashtra focusing on the institutional designs and engagement mechanisms between the users and the providers of the services. Users involve both farmers as end-users and local extension agents as intermediary users. As an interrelated concern, we reveal how and to what extent useful knowledge is co-created, transferred, received and integrated across participants in the services in collaborative manners and contributes to (collective) learning (in relevant, tailored, and appropriate format as perceived by the farmers and end-users).

WCS is here defined to involve the timely production, translation, transfer and use of weather and climate information and knowledge intended to support local decisions on adaptation and disaster risk reduction (https://www.wmo.int/gfcs/). Weather forecast – as it is bundled with agronomic knowledge - is thus part and parcel of such WCS as defined in this paper.

Agro-met services, when appropriately designed and provided, have been found to provide farmers with relevant and useful agro-meteorological advice in support of risk coping and adaptation (Rathore, 2013; Buontempo and Hewitt, 2018; Singh et al., 2017; Lobo et al., 2017). However, recent research argues that WCS need to address a variety of gaps or 'disconnects' between the service providers and the users to improve management and operational efficiency and outreach (Vaughan and Dessai, 2014; Street 2016; Brasseur and Gallardo, 2016; Vaughan et al., 2018). The interface between the users and providers is by many observers perceived to be the least-developed aspect of such services (Hewitt et al., 2017). A number of challenges and deficiencies have been identified suggesting that the services often remain largely supply-driven (including in the literature on Indian agro-met services), such as,

i) *Inadequate governance and business models in terms of engaging users* (Vaughan et al., 2018; Hewitt et al., 2017; Christel et al., 2017; Golding et al., 2017a,b; Lobo et al., 2017; Singh et al., 2016, Singh

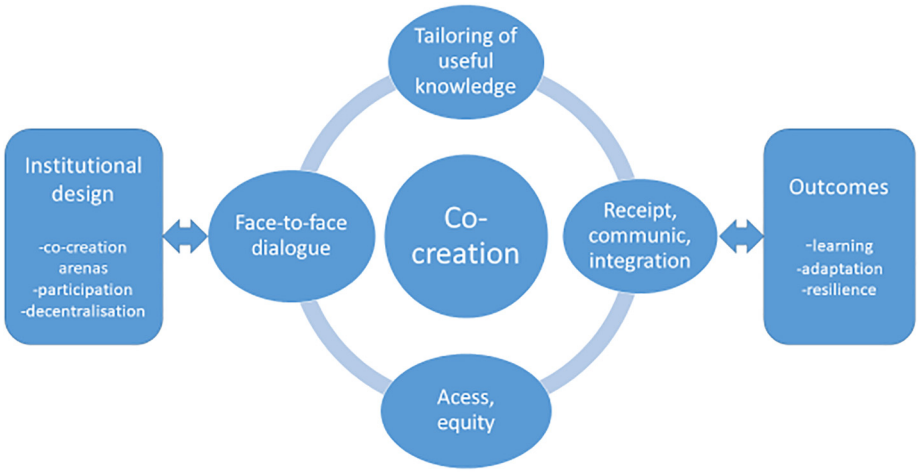

Fig. 1. Co-creation of agro-met services: knowledge networks as a cyclical & iterative process.

et al., 2017).

ii) *Lack of relevant knowledge format and products* (Dinku et al., 2014; Vaughan et al., 2016; Singh et al., 2017; Kundzewicz et al., 2017; Harjanne, 2017);

iii) *Lack of tailored and reliable knowledge due to deficiencies in accuracy/reliability and accessibility* (Vaughan and Dessai, 2014; Vogel et al. 2017);

iv) *Issues of access, uptake, equity and distributional consequences, particularly in cases from developing countries* e.g. *regarding female and low-income farmers* (Singh et al., 2017; Carr and Onzere, 2018; Vogel et al., 2017)

Internationally, there is an increasing body of reviews and case studies of WCS that investigates institutional issues and performance (Vaughan and Dessai, 2014; Dinku et al., 2014; Brasseur and Gallardo, 2016; Street 2016; Singh et al., 2016; Buontempo and Hewitt, 2018; Harjanne, 2017; Christel et al., 2017; Golding et al., 2017a,b; Vaughan et al., 2018). In India, there is also a growing literature on the subject that discusses projects and pilots implemented by state and private/civil society actors (Rathore, 2013; Rathore and Chattopadhyay, 2016; Venkatasubramanian et al., 2014; Manjula and Rengalakshmi, 2015; Singh et al., 2016; Singh et al., 2017; Thakur et al., 2017; Lobo et al., 2017). However, very few *comparative* studies with a governance perspective have been undertaken of WCS in India or elsewhere (Vaughan et al., 2018 is one exception). Comparative case studies of this kind also represent an under-researched area within governance network theory (Weber and Khademian, 2008; Ansell and Gash, 2007; Hofstad and Torfing, 2015; Meadow et al., 2017; Torfing et al., 2016). To this end, the paper builds upon these two strains of literature; both the network governance literature and the more empirically-based literature on WCS and agro-met services.

The paper proceeds as follows. First, the analytical and methodological approach is provided, emphasizing the comparative case study design. Second, the empirical findings of the four Indian cases are presented. Third, the similarities (and differences) between the services systems in structures and operations of engagement mechanisms are identified and compared. Finally, conclusions are presented and the implications of the empirical findings for policy and governance are outlined (summarized under Practical implications).

2. Analytical framework: Institutional design, governance and co-creation

The analytical approach starts from the central role of institutional design in the management of a knowledge network and an information service (Weber and Khademian, 2008). WCS in this regard rely on a range of institutions and sciences (weather, climate, agronomy, and social) and application across many actors and sectors (Vaughan et al., 2016; 2017). The governance challenge at hand is thus to effectively coordinate and integrate multiple partners and actors that operate across sciences, sectors, institutions, and scales for some commonly agreed purpose (from local to global). *Governance* is defined as the process of steering such services through collective action among the partners involved in accordance with common goals (inspired by Ansell and Torfing, 2016). Collective action in this context occurs when more than one actor/partner is required to contribute to an effort in order to achieve desired outcomes. *Networks* are understood in broad terms to be defined by 'the enduring exchange relations established between organizations, individuals, and groups' (Weber and Khademian, 2008:334). *Co-creation* is a 'process through which two or more public and private agencies attempt to solve a shared problem, challenge or task through a constructive exchange of different kinds of knowledge, resources, competences and ideas that enhance the production of public value in terms of visions, plans, policies, … or services' (Torfing et al., 2016:8). Co-creation relates to concepts such as collaborative governance (Ansell and Gash, 2007), co-production (Vargo and Lusch, 2006), co-design/co-implementation, public participation and engagement. But 'co-creation' goes beyond the concept of participation, which may also involve 'passive' involvement. Moreover, 'co-creation' differs from 'co-production' if the latter is defined in its strict sense, as the joint production and delivery of a particular service between end-users and providers (Vargo and Lusch, 2006). Co-creation focuses on collaboration between multiple actors, complex problem solving, innovation, and the creation of public value (Torfing et al., 2016). Fig. 1 provides a visual overview of the analytical model and four key 'co-creation process' elements guiding the analysis and the comparison of the four agro-met services. The framework has two key dimensions or variables; i) the *institutional design;* and ii) the *co-creation process variables* (conditioned by the institutional design and vice versa).

The analytical framework calls attention to the fact that communication between all partners is essential for making the services effective in design and operations (Vaughan et al., 2016, 2018). A large body of evidence suggests that WCS are most useful when they are developed as part of an iterative process of co-design, co-creation, co-development, and co-evaluation, involving both the providers, intermediaries and the users of the knowledge communicated (Brasseur and Gallardo, 2016; Vaughan et al., 2016).

Institutional design defines the structure of the services systems and sets the basic ground rules under which collaboration and interaction takes place. It focuses on the kinds of actors involved and the structure of relationships between them. The institutional design variables consist of the following more fine grained variables; first, the design of

arenas of interaction and collaboration across dispersed institutional actors and boundaries; second, the mechanisms by which the service connect to and engage (end-) users (participation mechanisms), and; third, the degree to which the services are decentralized and engage in on-site agricultural extension support for farming communities, and thus involve extension agents as partners.

The *co-creation process* and variables in the figure relates to ways and means of overcoming the fundamental challenge to effectively manage a knowledge network and achieve key network attributes within the overall agro-met services (Ansell and Gash 2007; Weber and Khademian, 2008). Hence, the figure addresses the implications of the structure and governance on the behaviour of service actors, and performance of the service itself in relation to the four basic institutional process elements defining the 'co-creation process variables', each requiring attention in institutional design;

i) Face-to-face dialogue and communication between partners;
ii) Tailoring and production of useful knowledge;[1]
iii) Receipt, communication and integration of knowledge across all partners; and,
iv) Access and use by users to agro-advisories and distributional issues

This knowledge production and communication process would ideally follow a virtuous circle between the initial convening of participants through institutional design and through the 'co-creation process' itself. Outcomes of these processes would be considered in terms of uptake and use of knowledge in farm-level decision making to enhance resilience, risk reduction, adaptation and learning as perceived by end-users at farm level. The outcomes in our cases are assessed according to the observed *perceptions among farmers* about the usefulness and relevance of the knowledge accessed in relation to uptake and use. This allow us to comment on the perceived quality of the knowledge communicated among partners without entering into any in-depth assessment of the quality of the knowledge and information from a scientific point of view.

3. Methodology and comparative research design

The methodological approach involves a comparative case study research design of four agro-met services; all with major operations in the state of Maharashtra. These agro-met services operated in parallel ways within the same basic geographic locations with similar farming systems, climate conditions, and broader socio-politico-institutional conditions. They were selected on the basis of representing the key agro-met service providers in this area of the state (with key informants of the government).

Maharashtra is the second largest state in India and one of the most important from an agricultural point of view. Reflecting its specific weather and climate risks, situated in the monsoon shadow belt, the state has a long tradition for developing agro-met services and related disaster risk management systems. The state hosts the Agricultural Meteorological Division of IMD, and the state has long been provided with public agro-met services. The state was among the first in India in which international private telecom-businesses initiated operations of agro-met services, first by NOKIA (2007), second by RML Ltd. (2008). Maharashtra thus constitutes an interesting context for studying WCS as an emerging field (Lobo et al., 2017). The four agro-met cases studied were deliberately selected to represent a mix of public, public-private, private and civic organisations as the key agency operating the services. They were studied through their operations in the same basic socio-geographic and eco-climatic area, but with diverse institutional designs and approaches to provider-user interaction. The four service providers included;

i) The Agro-met Advisory Services of the Indian Metrological Department (IMD-AAS) - the longest existing and most important large-scale public agro-met service provider in the state (and in India);
ii) Reuters Market Light (RML AgTech) - one of the first private service providers to establish itself in the state (and with operations across many states);
iii) IFFCO Kisan agro-met services - a large-scale public–private provider hosted by the Indian Farmers Fertilisers Cooperative Limited (IFFCO); and
iv) Watershed Organisation Trust's (WOTR) Agricultural Meteorological Program – the main civil society agro-met service provider in the state engaged in an innovative, yet small-scale pilot program in collaboration with IMD (Lobo et al., 2017; https://www.wotr.org/about).

Combined, the four services represented the landscape of the most important agro-met service providers in the districts chosen; each exploiting the rapid penetration of mobile internet and smart phones across the state. Field-work and surveys among farmers subscribing to each of these four service providers was undertaken in three villages in two districts of the state (Pune and Ahmednagar). Each of these villages were selected on the basis of being well serviced by agro-met services (selected in consultation with staff of these services).[2]

Our key hypothesis was that if we found similar governance challenges in the comparison of four rather diverse institutional designs and business model, it would enhance the robustness of the observations and the potential for generalizations from the findings.

The research methodology combined qualitative and quantitative approaches. The data involved about 57 interviews with program officials, experts, relevant stakeholders and farmers at different scales and representing different institutions, through semi-structured interviews of 1–2 h duration. Field-work and interviews were carried out in Maharashtra in 2015/2016 and a few follow-up interviews were undertaken in New Delhi in 2017/2018 with headquarter staff. The key informants were mainly engaged by (or had personal knowledge of) one or several of the four WCS providers. We interviewed the national and/or state top-level officials for each of the four services providers (14 interviews), several mid-level officials (8 interviews), and a few field-level officials that had hands-on experience in interacting with farmers in the field (5 interviews). We also interviewed experts who were associated with the WCS program in their individual capacities, not necessarily employed, to obtain more independent observations of the structure and performance of the services.

The semi-structured interviews were combined with in-depth interviews of farmers/local stakeholders, both men and women, subscribers and non-subscribers, to the agromet services (30 interviews). We furthermore conducted 9 focus group interviews among farmers and field observations through four visits. The field approach included a survey among 86 farmers that subscribed to one or several of these agro-met services in three villages. We also consulted national and international literature, policy and grey literature, websites/portals/APPs, and mapped institutional structures and histories. Two local and one national-level workshops with national experts were utilized to verify the research approach and findings and enhance co-learning.[3]

[1] We distinguish between science-based external knowledge and local practice-based knowledge, and the need to integrate the two in knowledge production and actual operations, accepting that traditional or local knowledge often dominates in farm-level decision-making (linked to learning from neighbours and peers) (Singh et al., 2017; Nesheim et al., 2017).

[2] The details of the farmers' survey are reported in Nesheim et al., 2017.

[3] The main findings were presented at World Sustainable Development Summit (WSDS) in Feb., 2018.

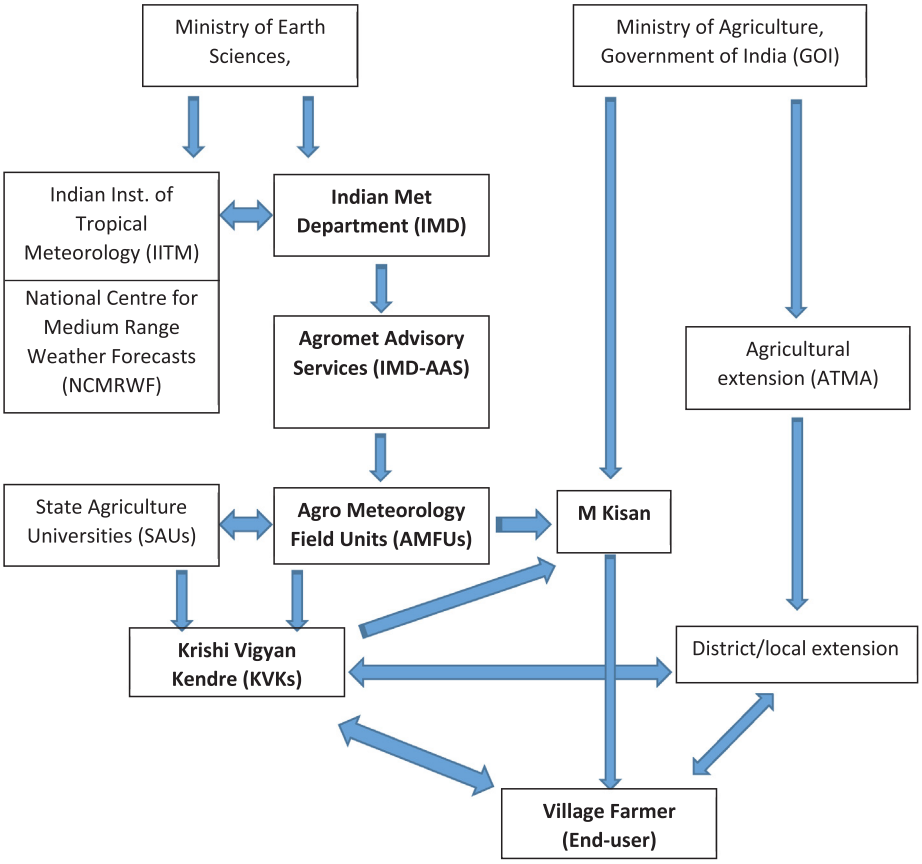

Fig. 2. IMD-AAS agro-met scheme (in bold) within the broader public services system.

4. The landscape of agro-met service providers in Maharashtra, India: An overview

The landscape of weather and climate service providers in Maharashtra was in most respects highly advanced and complex, with several operational service providers of agro-met services, both from the public, private, and civil society sectors (Rathore, 2013; Lobo et al., 2017; Singh et al., 2017; Thakur et al., 2017). In the villages we surveyed, typically 2–3 service providers operated side-by-side, and several of the interviewed farmers used the services of one or more of the providers (Nesheim et al., 2017). Below we present the typical structure of the agro-met services represented by the IMD-AAS scheme, which involves a national meteorological service operating from national/state scale to provide weather (and climate) information to agricultural decision makers and end end-users/farmers online. Fig. 2 provides an illustration of the institutional actors and relationships of the IMD-AAS scheme. Except for RML Agtech, the two other service providers draw invariably upon the services of IMD and elements of the IMD-AAS system. Hence, their structures contain many of the same organisational structures as the IMD-AAS scheme.

4.1. IMD-Agro-met advisory services (IMD-AAS): Institutional design and co-creation of services

The Integrated Agro-meteorological Advisory Services (AAS) is India's largest agro-met program, and a main case for our comparative study (http://www.imdagrimet.gov.in/ddkview). The program aims to serve farmers and research/extension across India with a host of agro-met services.[4] It is a nationwide program, which according to a top-level manager of the agro-met services reached close to 25 million rural farmers with SMS in 2018 across India. He added; "the next 2–3 years we will reach about 95 million farmers" (Personal communication, February 2018). The AAS program is hosted and run by the by the Agricultural Meteorological Division of IMD (set up in 1932) in the city of Pune, Maharashtra. AAS is arguably the largest agro-met service system in the world in terms of outreach - and one of the longest existing (in simpler forms since 1971; IMD was established in 1875) (Rathore and Chattopadhyay 2016; Rathore 2013). The launching of a District-level Agro-meteorological Advisory Services (DAAS) in 2008 resulted in an ambitious, more decentralized and locally relevant service, spurred by competition from the emerging private sector. IMD-AAS is mainly a public program, involving many public agencies directly as partners or indirectly, but it engages also with NGOs and private business in various manners through various public-private partnerships or informal networks and arenas of interaction (Government of India, 2017).

AAS is part of the national and state government structure and involves a complex four-tier organizational structure with an array of partners (Rathore, 2013; Rathore and Chattopadhyay 2016):

- A top-level coordinating planning body in Delhi, which includes a multi-purpose services portal (mKisan or 'Farmer'; started in 2013) (http://mkisan.gov.in/) managed by the Ministry of Agriculture (MoA)
- Execution body by the Division of Agricultural Meteorology, IMD (in the city of Pune, Maharashtra (http://www.imdagrimet.gov.in). Input by IMD' weather forecasting units for national/district-wise weather forecasts, includes 'now cast' (a few hours), short term (up to 3 days) and medium term (3–10 days) forecasts and an open access website. Medium range forecasts e.g. seasonal forecast of monsoon weather is provided by the National Centre for Medium

[4] AAS is now known in India as the Gramin Krishi Mausam Seva project (GKMS) – Rural agricultural information services project.

Range Weather Forecasts (NCMRWF) to be communicated by IMD
- Coordination, knowledge creation, communication and monitoring by assigned Agro-met Centres and six field units with agronomists and meteorologists hired from state agricultural universities (AMFUs); each covering an identified ecosystem and 4–6 districts across the state (36 districts in Maharashtra) (across India there are 130 AMFU's for each agro-climatic zone)
- District level research and training centres (KVKs) for coordinated support and input management of the advisory service – with links to the agricultural extension (even if the extension system is not a formal partner in the IMD run program at local level)

The IMD-AAS scheme represents a mix between a one-way information service (SMS), and multi-way dialogue through various web-based tools and multiple interfaces, including the mKisan portal and some interaction with KVK staff in local farmer training. The mKisan portal (in Delhi) provides a broad set of information. The KVKs engage farmers in training events, and in surveys and studies to learn from local practice. Knowledge is co-produced among agricultural and meteorological scientists in bulletin form and communicated through a diversity of products and channels of communication, combining the use of mass media, group awareness campaigns and direct messages to individual farmers (e.g. a daily district level AAS bulletin on e.g. land preparation and pests), SMS, video messages/response systems, websites with bi-weekly advisories, and call centres for two-ways communication).

Based on recent top-level encouragement from the Chief Minister of the state, the agro-met services of Maharashtra in 2016 reached 5 million farmers with SMS (twice weekly). State level bulletins and agro-met advisory bulletins are issued weekly for key decision makers. Weather forecasting and agro-met service have been downscaled to the district level – bundled with crop-specific agro-met advisories (to 36 districts in Maharashtra state). AAS also provides weather alerts, warnings, and drought monitoring. Regarding knowledge creation, the bundled agro-met advisories are prepared by staff of the state agricultural units in special ecosystem-based field unit (AMFUs), which aim to provide locally relevant knowledge on crops and farm operations, based on twice-weekly weather forecasts sent by IMD. About half of the staff of these units are meteorologists, the other half agronomists.

Meetings are held between staff of AAS and the state agricultural departments and bulletins produced with agro-met advice and submitted to KVKs and the extension system.

4.2. IFFCO Kisan: Institutional design and co-creation of services

IFFCO Kisan (Sanchar Limited) is a program for communicating agro-met advisories to rural communities hosted by the Indian Farmers Fertiliser Cooperative Limited (IFFCO), the largest organization in India responsible for distribution of fertilizers for farmers through 40 000 cooperative societies (http://www.iffcokisan.com/). The agro-met program rallies mainly around the Kisan call centres and an APP for engagement of farmers. IFFCO was selected by the Ministry of Agriculture, GOI (in 2007) to manage these call centres. The Kisan program involves a joint venture with Bharti Airtel for the communication services (the largest mobile service provider company in India with more than 265 million subscribers) and Star Global Resources Ltd, which is an international non-banking finance company involved in promoting innovative business in telecom services. It provides venture capital to the enterprise. IFFCO Kisan provides farmers with an Airtel 'green' SIM card which connects the farmers to the agro-met services (for access to call centres, video messages, SMS, mKisan portal, and an APP) (cf. also Darabian, 2016). IFFCO Kisan is part of IFFCO's overall business program as a private company, meaning it is not a Social Corporate Responsibility program. The voice messaging is monitored and analyzed (e.g. what kind of messages are listened to and for how long).

IFFCO Kisan operates in half the districts of Maharashtra (and in 18 states in India covering 10 languages). The services in Maharashtra include a mobile APP service (which is free of cost) with a set of products and channels of communication and a call centre that links up to about 35 000 active farmers in the state (2016). The APP is targeted at progressive farmers, and there are about 37 000 users in Maharashtra (whose farmers constitute an important user base). India-wide there are about 170 000 users across India (in 2016). Reasons why uptake of the APP is relatively high in the state are likely to be a relatively good internet connectivity, large proportion of progressive farmers, and IFFCO field-staff being trained in the APP (Darabian, 2016). However, only about 10–20% were estimated to be active users. The mobile APP also provides access to telecom products from Airtel (since 2015). According to a top-level official in IFFCO, the program has close to 4 million subscribers of voice messages India wide, and about 1,7 million regular listeners to helpline phoning programs (Personal Communication, Feb., 2018, cf. also Darabian, 2016). IFCCO Kisan relies on the field units with agricultural experts from the state university colleges of Maharashtra under the IMD program to bundle thematic and geographic relevant agro-met advice. The program draws upon weather information from IMD, and IFFCO subscribers have access to the mKisan portal run by MoA in Delhi.

4.3. Reuters Market Light (RML AgTech): Institutional design and co-creation of services

RML (RML AgTech. Ltd) formerly known as "Reuters Market Light" is a private service provider delivering market information, weather forecast (7 days), and agro-met services to farmers (http://rmlagtech.com/web/). It is mainly a SMS-based information service (one-way flow) that aims to provide farmers with personalized market and agro-met information in the local language. Information is also provided on health and education. The firm was established by Thomas Reuters in 2007 in Maharashtra. Thomson Reuters further teamed up with the venture capital company IvyCap to support the continued development of RML (McNally, 2014; Shoham, 2016). RML however became an independent entity from 2013 (with several hundred employees).

RML works with FORECA (https://corporate.foreca.com/en/weather-data); a private Finnish weather forecasting company focusing on providing weather services for international business (the largest of its kind in the Nordic countries; established in 1996). In the first few years of operations, RML worked with IMD (and later with Skymet; a private weather services provider), until it shifted to FORECO. RML partners with a small number of mobile network operators; not one large company.

According to RML management, the number of users in Maharashtra is about 1 million – 50% receiving SMS and 50% utilizing the APP (2016). In 2015, RML had 1.5 million registered users across India (according to staff estimations). The services India-wide covers over 450 crops and crop varieties, and more than 1300 markets and 6200 weather locations across 50,000 villages and 18 states. The service is also provided to large agribusiness enterprises that interact with farmers (McNally 2014). RML's business model is private for-profit.

4.4. WOTR's agricultural meteorological program

Watershed Organisation Trust (WOTR) started to pilot their agro-meteorology program in 2012 in some regions of western and central Maharashtra with external donor funding (http://www.wotr.org/agro-meteorology). A weather based crop advisories program in local languages was developed in collaboration with IMD, the Central Research Institute for Dryland Agriculture (CRIDA) and the Maharashtra State Agricultural University. WOTR is a non-profit organization established in India in 1993. The program received initial funding support from the Swiss donor agency (SDC).

The overall goal of the program is to improve agriculture

Table 1
Comparison of institutional design of four agro-met services, source: survey data 2015–17.

Institutional structure and design features	IMD-AAS	IFFCO Kisan	RML Agtech	Watershed Organisation Trust (WOTR)
Institutional home	Scheme hosted by IMD; complex four-tier administrative system within the agricultural research & training sector	Programme with IFFCO fertilizer cooperative company; involves local agencies at block/ village level. Relies on IMD and agro-met experts	RML Agtech in collaboration with international private company FORECO and local market agents.	WOTR in partnership with IMD, agro-met experts and farmers for management of automated weather stations
Public or private agency	Public authorities in limited partnerships with private and civic	Private business in partnership with public authorities	Private business partners	Civil society in partnership with public authorities (IMD)
Institutional history	Old program; reinforced from 2007	Initiated in 2007; reinforced from 2014	Initiated in 2007; restructured in 2016	Initiated in 2012 with external funding
Basic mode of governance and funding stream	Bureaucratic mode/ partnerships of public agencies - dialogue at different levels	Quasi marked – private business contracted and funded by public authorities – dialogue based	Market-based - one-way information provision to farmers for improving efficiency	Community based, multi-modal, multi-way communication, dimensions of co-production in partnerships
Costs of subscription (except sim card which is charged by all)	Open access information; all services free of costs	Open access information; free SMS, APP in-bound calling	Fees to farmers for SMS; free access to APP	Fees to farmers for SMS; other services for free
Main knowledge focus	Mainly agro-met knowledge; but also other types of information	Agro-met; some market information	Mainly market information; some agro-met information	Mainly agro-met; some market information
Number of users – scale and outreach in the state	Large scale; reaches 5 million farmers with agro-met SMS	Medium-scale; reaches 35 000 farmers through call centres; many more with APP and SMS	Large-scale; reaches 1 million farmers–50% through SMS 50% through APP	Small-scale; reaches around 12,600 farmers with SMS advisories.

productivity. WOTR reaches around to 12,600 farmers with specific SMS advisories in the local language at least twice a week based on the local weather data and the particular crop growth stage to about 61 villages. The installation of 77 automated weather stations (AWS) in selected village locations with involvement of local farmers in their management has enhanced the engagement of farmer communities and the knowledge content of the services (Lobo et al., 2017). The program includes on-site support and capacity building and engagement with farmers and local institutions.

5. Comparison of institutional design and engagement mechanisms

In this section, we first provide a comparative overview of key institutional design features and business models of each of the services (Table 1); second, we compare the mechanisms employed by each of the services for engaging farmers and extension agents. Based on these observations we analyse the engagement mechanisms in relation to how and to what extent useful knowledge is co-created and communicated across which partners in the services. For the purpose of this paper, it is important that the opportunities for engagement of users and extension agents in the services depended on both the institutional design features and what mechanisms for engagement of users the service providers actually employed.

5.1. Analysis of institutional design and structure of the service providers

The four cases represent a variety of institutional designs, type of actors, business models, financial sources, knowledge products, and mechanisms for engagement and communication among partners. The knowledge products themselves cut across different time scales (short, medium, seasonal), spatial scales and have different outreach (geographic and number of subscribers/users). There are several important similarities in institutional structure and operations – and some critical differences. First, three of the services are organized through a program approach that is integrated within a structure of national meteorological and agricultural research and training institutions (IMD-AAS, IFFCO Kisan; WOTR). In this regard, RML Agtech is the exception, since it is basically a private company that partner with other private companies, and does not solely draw upon the forecasts and weather information provided by IMD. It also uses the services from the private Finnish weather forecasting company; FORECA.

Second, each of agro-met services are multi-tier institutional systems that combine public and private agencies in the creation and communication of agro-met knowledge with various business aims. Only RML Agtech, as a private business actor, provides non-open access information to subscribers and has a business and profit motive with their services. The three other services depends on public agencies and support and/or external funding for their agro-met scheme.

Third, regarding strength and weaknesses of the services, the main strength of the IMD-AAS's institutional structure lies in its vast institutional capacity and capability and long history as a public funded program within IMD and the government services systems. It enjoys a relative secure financing and receives high political support and backing from the state and national levels. It is an open access services (e.g. the web-portal mKisan) with vast outreach. It involves a rich multi-modal communication system with multiple interfaces for user engagement and information/knowledge production (see below). Institutionally, the weak part lies in the complex four- or five-tier organizational structure and its bureaucratic mode of operation and weal links to on-site extension system. Moreover, the bundling of crop- and farm-level advisories with local weather forecasts is not well tailored or targeted and spatially adjusted to local conditions and changing circumstances. It should of course be accepted that this is also technically very hard to produce (Lobo et al., 2017). There are also limitations to the accuracy and timely delivery of agro-met advisories, although

uptake and use of targeted early warnings about extreme events, are according to our field interviews, highly appreciated by farmers and acted upon. There are weak links between the IMD-AAS production and communication of knowledge and the agricultural assistants at local level to provide village-level support to farmers. It is mostly progressive farmers that register and utilize the mKisan portal according to management (Personal Communication, Feb. 2018). The links to the disaster risk management system and early warnings are also weak (Vedeld et al., 2014).

The IFCCO Kisan agro-met program is funded by the Ministry of Agriculture within a public-private partnership. The program is not a core business, IFCCO being mainly a fertilizer company, but according to management, IFCCO perceives the program as part of their business activities that they want to pursue (Personal communication, 2018). The strength of the IFCCO Kisan institutional design lies in its large presence across the state and relatively large outreach. The biggest challenge is the low user retention of the APP; nearly 80% of users churn out after only two months from downloading. No reminder notifications are sent out, which could be a low-cost way of increasing engagement of users (Darabian, 2016). The weak element lies in the lack of on-site extension support, due to limited capability and mandate of the local IFFCO marketing associates at district/block levels to provide such input. The program also relies on government funding and support. Moreover, the agro-met advisories communicated are basically produced by the same public agencies as for IMD-AAS and thus suffers from the same basic weaknesses regarding accuracy and tailordness.

The strength of the RML Agtech institutional structure lies in its market information and provision of agro-market information to farmers. The market information is to some degree localized through input by local market agents hired by the program. The weak part of RML Agtech programs is the perceived high cost of the information services by the farmers, and reluctance among subscribers to renew subscription. Hence, the private business models has proved to have limited sustainability. In its latest business model from 2016, RML Agtech focuses even more on reaching wealthy/progressive farmers and agro-businesses that can afford to pay for the information services.

The relative strength of WOTR's institutional approach, WOTR being a non-governmental and not-for-profit organization, lies in its pilot and experimental character. Their agro-met program involves an integrated multi-model and multi-way communication approach, and a relatively higher presence of on-site extension support and face-to-face interaction with farmers than the three other programs. WOTR has also made some efforts to customize advice better to local conditions based on input from village-based automatic weather stations as an innovative element, and on utilizing own agro-met experts. WOTR has been able to break across public private divides and enhance co-creation in program development through its active collaboration established with IMD. However, even this program is confronted by the generic challenges that the agro-met sector faces in Maharasthra; the weather-based agro-advisories are not (yet) sufficiently local and crop- and farm specific to meet local needs and demands (Lobo et al., 2017). Moreover, WOTR pilot agro-met program is faced with uncertain funding streams as it depends on external donor support and/or government finance and support (from IMD).

5.2. Comparing the mechanisms for engagement between users and providers

The forms and levels of engagement varied across the four services depending to a large degree on the specific mechanisms employed for engagement between the service providers and the end-users. Each of the services involved multimodal delivery systems in governance approaches. However, it varied between the four providers the extent to which they relied on web-based tools and websites for one-way information provision (mobile phones/SMS messages, voice messages, APPs and web portals) versus two-way or multi-way communication and interface with multiple actors.

Websites and web-based tools (APPs, SMS) are relatively passive channels and serve mostly one-way information transfer, although two-way dialogue can also be achieved through such tools. For more active involvement of users and feedback that resemble co-production of the services, mechanisms that enhance face-to-face interaction and multi-way interaction through multiple interfaces are required. For this to occur some level of on-site extension support and regular follow-up on the ground is required. Such engagement mechanisms may include workshops, on-farm training or community laboratories for social learning and various forms of input through evaluations and surveys with active involvement of users (Hewitt et al. 2017). There are, however, opportunities for making mobile-technology platforms more interactive and accessible to broader groups and with opportunities for feedback, for example through emphasis on voice messages and call centres, such as with IFCCO Kisan, or through interfaces with WhatsApp groups (see below). Such channels can both enhance feedback and reach also illiterate users and thus less progressive farmers and women (provided they have access to mobile phones).

Four broad categories of user engagement were identified in an attempt to illustrate a 'ladder of engagement'. These engagement categories range from passive to active and from involvement of few to multiple kinds of actors and scales in the services cf. Fig. 3. The various rungs or levels of engagement in this ladder represent how different web-based tools and institutional mechanisms were differently combined to condition various forms of engagement and interaction and

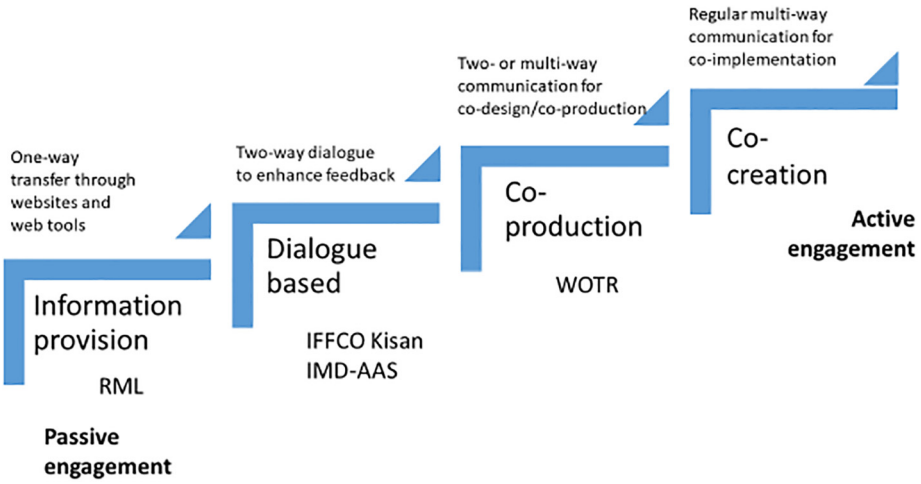

Fig. 3. Fig. The 'Ladder of engagement' in agro-met services, source: survey data 2015–17.

collaboration among partners. Moving up the ladder indicates increase in the time, resources and attention for both end-users and providers in providing mutual feedback and learning or in co-producing service. In this regard, it matters for both users and providers what benefits they perceive when deciding to shift from a more passive form of engaging to a more active and face-to-face interaction.

Based on the case studies and assessment of the types of mechanisms that dominated governance approaches of each of the services, we suggest a categorization of four levels in a 'ladder of engagement' of the agro-met services as follows;

i) Information provision - one-way transfer of information through mainly websites/web-based tools, such as SMS, APPs, and portals;
ii) Dialogue based service - two-way information systems that combine web-based tools with various mechanisms for enhancement of dialogue e.g. call centres/web-sites, feed-back surveys, training;
iii) Co-production of service - multi-way communication of knowledge and co-design of the service, combining a broader set of tools and channels of communication to enhance input by farmers into the design of knowledge products, including with the input of local extension and training agents;
iv) Co-creation of the service - regular multi-way communication and intense interaction among multiple actors (workshops) and co-implementation of the services, including also interface with social media (WhatsApp crop-specific groups) for inclusion of practice-based knowledge and social learning at local level.

Applying this analytical framework to the four service providers, the following picture emerges in terms of variation in mechanisms for engaging farmers. The overall engagement levels and the degrees and forms of integration of extension in the services and on-site support are outlined in Table 2.

We argue that RML Agtech is basically an information service – with one-way information provision to progressive farmers related to regional and local market information on crops (input/output) and with limited feedback systems. IMD-AAS and IFFCO Kisan both provide a agro-met service, with some degree of two-way communication, although the outreach is largest with one-way SMS and APPs. IMD-AAS provides a wide array of knowledge products and channels of communication (multi-modal) which are free of costs to the farmers. WOTR is the only service with some degree of co-production and partnership in the institutional design related to how the agro-met service involves farmers (rally around AWSs), local extension workers and IMD and agricultural experts for agro-met advisories. WOTRs pilots a multi-modal and multi-way communication system with semi-regular on-site extension support. But it does not provide access to an APP or an agro-advisory portal, beyond its web-sites with training material.

6. Analysis of engagement of farmers: The co-creation process

Related to the analytical framework (Fig. 1) and the 'co-creation process', the knowledge exchange relationships between the service providers and end-users did not follow any staged or structured process, but involved more fuzzy interactions in time and scale through various 'stages' of the knowledge production and communication processes. An assessment of how each of the services performed along each of these co-creation variables and how users engaged at various stages of the process have been compiled and presented in the Table 3 below.

6.1. Engagement in the creation and tailoring of useful knowledge

The farmers – and local extension agents – were to limited degree involved in creating and tailoring the knowledge provided in each of the services, WOTR's agro-met program being the exception. However, all the services encompassed a variety of more passive participation and feedback mechanisms, such as the call centres and feedback through voice messages in the IFFCO Kisan program or through web portals and APPs and SMS within IMD-AAS and IFFCO Kisan. Feedback from farmers were also collected through surveys and evaluations (IMD-AAS, IFFCO Kisan, WOTR) and invariably through local extension and training centres (IMD-AAS and WOTR). However, while for example the strength of IFFCO Kisan's program was in the call centres and voice messaging (reaches also illiterate farmers), officials in charge of the program claimed that 'not too many farmers utilize the call back service' (Personal information, 2016, 2018). The IMD-AAS mKisan portal/platform was to limited degree utilized by farmers for feedback. Hence, despite the opportunity for active feedback being available to farmers, in reality they rarely provided such. Feedback was mostly provided in passive ways by program staff collecting information through surveys and evaluations or some sporadic local training (e.g. at KVK farmer's training centres).

Hence, the agro-met advisories created by bundling weather forecasts with agro-met advisories (for short and medium term forecasts) was done by local scientific experts employed within ecosystem level field-units (AMFUs) with no or limited farmers' input. This knowledge was developed through similar scientific methods and approaches by the four service providers. Customization to local crop and farm specific conditions was not really done and crop calendars/advisories were not really adjusted well to the crop cycle, changing soil and water conditions, risk of pests, and the changing local weather forecasts at the time of formulating the advisory. It should be added that such local customization is also not technically feasible at present level of technology and institutional capacity (Lobo et al., 2017). The agro-met information is at present only provided with a crude district level precision or relevance. It is not really crop or farm specific. WOTR also faced problems

Table 2
Comparison of farmer and extension engagement mechanisms, source: survey data 2015–17.

Service provider/ engagement mechanisms	Farmer engagement mechanisms	Extension support at local level (on-site)	Engagement level of farmers/end users
WOTR	Multiple channels and knowledge products. Partnerships with IMD and villages. Co-produced service with farmers through local AWS, pilot farmers, local meetings and consultations.	Local presence of extension and semi-regular on-site extension support	Co-production and partnership – multi-way communication and relatively more tailored
IFFCO Kisan	Multiple channels and knowledge products. Mutual dialogue through call centres and mKisan portal. Help line. Voice messages. SMS. APP. Evaluations of calls.	Ad hoc meetings at local level; some interactions with IFFCO agents at market depots	Dialogue based service
IMD-AAS	Multiple channels and knowledge products. Feedback through mKisan portal. SMS. APP. Surveys and evaluations.	Ad hoc extension advice by agricultural assistants. Irregular local training and extension (through KVKs)	Dialogue based service
RML	Web tools; web based (SMS, APP)	Ad hoc interactions with market agents, limited impact	Information provision

Table 3
Overview of 'co-creation process variables' of four agro-met services.

Co-creation process variables	IMD-AAS	IFFCO Kisan	RML Agtech	(WOTR)
Engagement of farmers in tailoring of useful knowledge	No real involvement of farmers in knowledge production. Limited tailoring of crop- and farm level advisories.Weather forecast with spatial limitations.	No farmers' involvement in knowledge production. Limited tailoring of crop- and farm level advisories. Agro-met knowledge drawn upon from IMD's weather forecasts.	Engagement of local market agents for input on market information; no farmer input. Market info fairly local and utilized. Weather forecast not tailored to local conditions.	Farmers involved in managing AWS for data input into IMD's weather forecast. Specific crop calendars produced for local crops, some limited farmers' input.
Receipt, communication and integration of information	Despite great outreach through SMS and portals, our village observations suggest limited engagement and actual use/uptake among farmers (Nesheim et al., 2017).	Large outreach of voice messaging/ helpline phoning programs, but actual feedback and response to the programs is limited.	Good outreach of market information, but farmers engaging or to limited degree renewing subscription - unwilling to pay fees for SMS service.	Some engagement of farmers through AWS. Multimodal system of communicating agro-met advisories through SMS and blackboards combined with local extension support.
Access, equity, social learning	Access and uptake mostly among progressive farmers. Some local interaction and social learning.	Access and uptake mostly among progressive farmers. Some local interaction and social learning.	Access and uptake mostly among progressive farmers.	Access and uptake mostly among progressive farmers. On-site extension facilitate uptake local/ social learning.
Face-to-face dialogue with farmers	Limited on-site support by extension agents and farmers.	No or limited on-site dialogue; some dialogue through call centres.	No on-site interaction with farmers	On-site support and some face-to-face interaction with farmers.

in basing its advice on dynamic crop calendars and changing local conditions.

Farmers themselves also expressed mixed perceptions about the tailoring and usefulness of both agro-met information and market information (cf. Nesheim et al., 2017).

Regarding weather predictions, each of the services made use of state-of-the-art numerical weather prediction methods and models for near-term weather predictions (up to five days) and provision of medium-term monsoon forecasts. In this regard, the probabilistic nature and limited accuracy of the weather forecast and the lack of local specificity of the agro-met advisories remain critical issues (raised by both farmers and program officials in our interviews). It remains a fact that weather predictions lose all skill beyond a lead-time of approximately two weeks.[5] Only in the case of WOTR were farmers indirectly involved in providing data for weather predictions through managing local automated weather stations and input of local weather data into IMD's models.

6.2. Transfer, receipt, access and integration

We have shown that each of the four services all included a variety of knowledge products and channels for communicating knowledge to users in order to ensure receipt, access and integration of knowledge among partners. There were various critical access issues faced by farmers related to availability of internet and agro-met services as well as their own access to phones/smart phones, form of farming system (e.g. progressive/non-progressive farmer) and levels of literacy. We found among the interviewed subscribers, about 63% possessed smartphones and 37% had ordinary mobiles (Nesheim et al., 2017, see also Darabian, 2016). Women were not among subscribers, and to much lesser degree than men had their own mobile phones. They very rarely possessed smart phones. Female farmers relied mostly on phones owned by men, occasionally observed to consult with men on agro-met advice (cf. Nesheim et al., 2017).

However, in surveying local farmers, we found that even if the agro-met advisories were available as open access and free of costs to the villages, the majority of farmers did not actively access or utilize the services in any substantive ways. Moreover, many of the local farmers were actually not aware of these agro-met services (beyond the weather forecasts) despite them being accessible in the villages (Nesheim et al., 2017). Several staff members of providers suggested in interviews that 'farmers want block and village specific messages' and that present messages are 'only moderately useful' (Personal communication, 2016). The greatest uptake and use among farmers was for specific information or warnings about extreme weather (heavy rainfall, hailstorms), spread of specific plant diseases, and forms of local market information (cf. also Nesheim et al., 2017). Moreover, the services were utilized mostly by the more wealthy and progressive farmers; not by female farmers and to very limited degree by the small-scale farmers and landless (cf. also Venkatasubramanian et al., 2014; Lobo et al., 2017).

In this regard, our field observations underscore a widely acknowledge observation within agriculture that farmers rely mostly on their own experiences and knowledge of neighbors and friends and traditional farm practices in taking farm decision making; more so on external agro-met advisories or advice from the local extension system (cf. also Lobo et al., 2017; Vedeld et al., 2014; Pant et al., 2012). The

[5] None of the agro-met services provides much long-term climate knowledge, except that medium-term monsoon forecasts are provided by IMD with input from the National Centre for Medium Range Weather Forecasts (NCMRWF) and the Indian Institute of Tropical Meteorology (IITM). A National Climate Centre (NCC), IMD, Pune can potentially bring in further climate information and learning from its work as a WMO Regional Climate Centre (RCC), but also new issues about comprehending its probabilistic nature (Manjula and Rengalakshmi, 2015).

agro-met advisories come only as 'an additional source of information' to the farmers in relation to his complex on-farm decision-making situation (Personal communication, 2016). Farmers' knowledge in on-farm decisions is largely localized, embedded and invested in practice and their local culture. Such hard-won practice-based knowledge is not easily shared and transmitted across participants in a network (Weber and Khademian 2008; Singh et al., 2017; Harjanne, 2017).

6.3. Face to face communication and involvement of on-site extension agents

Across the four service providers, face-to-face dialogue, focused relationships and local interactive group activities were limited, beyond some occasional discussion of agro-met advisories at the temple square among local farmers (Nesheim et al., 2017). WOTR was to some extent the exception. Within IMD-AAS, the agro-met service is mandated to the research and training wing of the government i.e. the KVKs (not the extension wing/ADMA); which each covered vast areas and lacked mandate for undertaking local extension at the village and farm levels.

Interestingly, to this end, we found in each of the three villages that farmers in Maharashtra, at their end, were taking own spontaneous initiatives for sharing agro-met knowledge. They were doing this through establishing local crop-specific WhatsApp groups, which enhances the scope for contextualizing information provided and social learning within farm communities (Nesheim et al., 2017). These groups open for inclusion of broader sets of information and integration of more practice-based knowledge and local learning in the services. Among the 86 subscribing farmers interviewed, 35% were members of one or more WhatsApp groups. A few women also reported to be member of WhatsApp Groups. These groups pass on agro-met information from service providers. IMD as well as local government departments have also extended support in this regard. Government officials have joined farmers' WhatsApp groups, and officials of AMFUs indicated that they have initiated WhatsApp groups. This is a recent development observed in several parts of India, and the groups are being monitored (Thakur et al., 2017). According to a manager of IMD-AAS "nearly all farmers are connected to WhatsApp and receive crop specific information" (Personal communication, Feb., 2018). An advantage with such decentralized, self-organized knowledge exchange systems is that the rate of information sharing is fast, and it allows users to share images of their crops or pest attacks to the group (Thakur et al. 2017).

7. Conclusions

The four cases analysed show differing engagement mechanisms and levels between service providers and end-users and diverse involvement of intermediary users and partners of the overall agro-met system. The institutional design of WOTR's agro-met program came closest to the ideal of a co-produced or co-created service. In conclusion, we suggest that success in the governance and operations of agro-met advisories to support farmers' adaptation and risk decision-making is likely to be highest when farmers' are engaged, the provider make use of multi-modal and multi-way communication systems; and user involvement is combined with on-site extension support and multi-actor partnerships. This is in line with recent findings in the WCS literature and is the way forward to include also less progressive and female farmers (Singh et al., 2017; Lobo et al., 2017; Vaughan et al., 2017; Hewitt et al., 2017). In particular, we suggest more deliberate and novel ways of integrating social media platforms more profoundly into the services to enhance the scope for co-creation, such as crop-specific WhatsApp groups.

However, we insist that improved mechanisms for greater participation of farmers alone, while being a necessary requirement to enhance WCS performance, is not a sufficient condition for taking the WCS agenda forward. The incentives for farmers to become really active partners will only come if the knowledge provided is better targeted and tailored to specific local circumstances than what is observed today.

This is not to argue that all agro-met services need to be highly targeted or tailored. The level of engagement should be based on the users' needs and considerations of how engagement can improve the services. Service providers may thus choose to have at their disposal multiple tools for multiple interfaces and shift between different mechanisms, in an iterative manner. This may provide opportunity for improving web-based services based on more interactive and face-to-face engagement and learning (Hewitt et al., 2017). This raises the need for more conscious institutional design of the services including an appropriate mix of multiple mechanism for user engagement in co-design and co-creating the services (cf. Practical implications).

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