Environmental Science and Policy 104 (2020) 208–216

Contents lists available at ScienceDirect

Environmental Science and Policy

journal homepage: www.elsevier.com/locate/envsci

Reaching out? Governing weather and climate services (WCS) for farmers

Trond Vedeld[a,*], Hege Hofstad[a], Mihir Mathur[b,e], Patrick Büker[c,1], Frode Stordal[d]

[a] Norwegian Institute for Urban and Regional Research (NIBR), Oslo Metropolitan University, Postbox 4, St. Olavs plass, 0130, Oslo, Norway
[b] The Energy and Resource Institute (TERI), India Habitat Centre, Lodhi Road, New Delhi-110 003, India
[c] Stockholm Environment Institute, York Centre, Department of Environment and Geography, University of York, York YO10 5DD, UK
[d] University of Oslo, Section for Meteorology and Oceanography, Gaustadalléen 210349 OSLO, Forskningsparken, Postboks 1022 Blindern, 0315, Oslo, Norway
[e] DESTA Research LLP, Okhla, New Delhi, India

ARTICLE INFO

Keywords:
Weather and climate services
Governance
Agro-meteorological services
Climate adaptation
Co-creation
Participation

ABSTRACT

High-quality weather and climate services (WCS) can be critical for communicating knowledge about current and future weather and climate risks for adaptation and disaster risk management in the agricultural sector. This paper investigates the structure and performance of weather and climate services for farmers from a governance perspective. Empirically the paper compares the institutional design and operations of agro-meteorological services in Maharashtra/India and Norway through a 'most different case study' approach. The two cases were selected to represent great diversity in location, scale and institutional design. A governance approach based on semi-direct interviews and policy and institutional analysis was combined with local survey data of farmers' perceptions and use of the services. Despite the fact that the context for the two agromet advisory services was very different from a climate-weather, eco-agriculture and socio-institutional angle, the analysis reveals great similarities in the services structures and critical governance challenges. In both countries the agromet services communicated knowledge that was largely perceived not to be well tailored to farmers' needs for decisions in specific crops- and farm operations, spatially too coarse to address local issues, and, often unreliable or inaccurate in terms of the quality of data. Farmers did, however, respond positively to specific and locally relevant information on e.g., warnings about high rainfall and spread of pests. Observing such similarities across very diverse contexts enhances the generalization potential, precisely because they evolved under very different circumstances. Similar observations find support in the wider WCS literature. Based on the empirical findings, we propose a more deliberate approach to institutional design of WCS in order to enhance governance performance and co-creation of the services at local, district and national scales. It is suggested that greater participation of farmers and agricultural extension agents in the co-creation of these services is a necessary means of improving the services, supported by the WCS literature. However, we insist that greater participation is only likely to materialize if the deficiencies in institutional design and knowledge quality and relevance are addressed to greater extent than done today. The comparison between the two services shows that Norway can learn from India that a more ambitious scope and multiple forms of communication, including the use of social media/WhatsApp groups, can facilitate greater awareness and interest among farmers in multi-purpose agromet services for multi-way communication. India can learn from Norway that a more integrated and decentralized institutional design can strengthen the network attributes of the services, foster co-creation, and improve participation of both poor and large-scale farmers and extension agents.

1. Introduction

While society has always been confronted with climate and weather related risks and uncertainty, increased vulnerability to a rapidly changing climate have resulted in a growing interest among most governments in the world to improve weather and climate services (WCS) as a means to enhance climate adaptation and mitigation (Adger et al., 2009; Vaughan and Dessai, 2014; Singh et al., 2016; Lobo et al., 2017; Vedeld et al., 2019). Farmers and rural communities are in this regard particularly exposed to weather dynamics and adverse effects of climate change, and

* Corresponding author.
E-mail addresses: trondv@oslomet.no (T. Vedeld), hegeh@oslomet.no (H. Hofstad), mihir09mathur@gmail.com (M. Mathur), patrick.bueker@giz.de (P. Büker), frode.stordal@geo.uio.no (F. Stordal).

[1] www.giz.de.

https://doi.org/10.1016/j.envsci.2019.11.010
Received 27 September 2018; Received in revised form 8 October 2019; Accepted 24 November 2019
1462-9011/

require advanced warnings about emergent weather conditions from WCS or agro-meteorological services (agromet services) in order to make informed farm-level decisions. Typically provided in the form of short message service (SMS), websites, Apps, and bulletins, WCS involve the timely production, translation, transfer and use of weather and climate information and knowledge intended to support local decisions on adaptation and mitigation (https://www.wmo.int/gfcs/). Weather forecast as they are bundled with agronomic knowledge in agromet services - are thus part of such WCS as defined here.

By comparing the institutional structure and operations of agromet services in India/Maharashtra and Norway, this paper aims to contribute to a better understanding of the conditions for effectively governing WCS and engaging farmers as end-users in the co-creation of the services. The paper compares two WCS of very different scales and complexity - situated in two highly diverse eco-climatic and socio-political contexts, based on a *most different case study design* methodology (George and Bennett, 2005).[2] Few comparative assessments of the governance structure and performance of WCS have been undertaken to throw light on why these services may not (yet) fully live up to their promise (Vaughan and Dessai, 2014; Brasseur and Gallardo, 2016; Harjanne, 2017; Vaughan et al., 2017; Vedeld et al., 2019).

The paper focuses on critical similarities (and differences) in the governance structure and approaches. In this regard, the paper builds upon two key strains of literature; first, the network governance & co-creation literature (Weber and Khademian, 2008; Ansell and Gash, 2007; Meadow et al., 2015; Ansell and Torfing, 2016; Torfing et al., 2017; Hofstad and Torfing, 2015); and, second, the more empirically based literature on WCS and climate adaptation (Adger et al., 2009; Pelling, 2011; Vaughan and Dessai, 2014; Venkatasubramanian et al., 2014; Brasseur and Gallardo, 2016; Vaughan et al., 2017).

The two services studied include the Agro-met Advisory Services of the Indian Meteorological Department (IMD-AAS) and the AgroMeteorology Norway (AMN) hosted by the Norwegian Institute of Bioeconomy Research (NIBIO) and supported by Met Norway. Farmers in both countries are highly exposed and vulnerable to weather and climate risks, and efforts have long been pursued in both contexts to develop advanced agromet services for the farmers.

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 Indian and Norwegian cases are presented. Third, the similarities (and differences) between the two services systems are identified. Finally, the implications of the empirical findings for governance theory and policy are outlined.

2. Analytical framework: Co-creation in networks and engagement of users

Agromet services, when appropriately designed and provided as one type of WCS, have been found to provide farmers with relevant and useful agrometeorological advice in support of coping, disaster risk reduction and adaptation (Buontempo and Hewitt, 2017; Singh et al., 2017; Lobo et al., 2017; Rathore, 2014). However, recent research argues that WCS need to address a variety of gaps or ‘disconnects’ between the service providers and the users when it comes to relevance, tailordness/reliability, accessibility of the knowledge produced; the distributional consequences of the services provided; and the inadequacy of the governance models and capability to engage and integrate end-users and intermediaries (Lemos et al., 2012; Dinku et al., 2014; Street, 2015; Vaughan et al., 2016; Brasseur and Gallardo, 2016; Carr and Onzere, 2017; Christel et al., 2017; Golding et al., 2017a,b; Hewitt et al., 2017; Kundzewicz et al., 2017; Harjanne, 2017; Lobo et al., 2017; Singh et al., 2017; Vogel et al., 2017; Vaughan et al., 2018; Vedeld et al., 2019).

The governance challenge at hand is thus to effectively coordinate and integrate a range of institutional partners across sciences (weather, climate, agronomy, social), sectors and scales in order to achieve the positive attributes of a network or co-creation processes (Weber and Khademian, 2008; Torfing et al., 2017; Vaughan et al., 2016 and 2017). *Co-creation* is defined as 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., 2017:8). ‘Co-creation’ thus relates to concepts such as collaborative governance, co-production and participation. Co-creation focuses on *active* collaboration and interaction been multiple, often interdependent, actors engaged in joint problem solving of wicked and unruly challenges by seeking innovation, institutional change/reforms and the creation of public value (Torfing et al., 2017; Hofstad and Torfing, 2017). Co-creation does not involve ‘passive’ collaboration or participation among actors. In particular, the concept’s focus on institutional and social innovation and change makes it useful for analysis of the institutional reform requirements for governing a changing climate. Hence, co-creation potentially covers both the politico-institutional and practical spheres required for developing pathways towards climate transformation (O’Brien, 2018). Co-creation differs from and goes beyond ‘co-production’ if the latter is defined strictly as the ‘joint production and delivery of a particular service between end-users and providers’ (Vargo and Lusch, 2006; Dilling and Lemos, 2011). Network governance relates closely to the literature on ‘boundary organisations’ and ‘boundary work’, which concerns the translation of science into policy- or practice-relevant advice, dealing with the separation or not between science and nonscience (Hoppe et al., 2013; Guston, 2001). Regarding governance of climate change, the nature and success of boundary organizations and the way they work, is related to the degree to which relevant players are tolerant of a blurring of the science-policy boundaries, and, hence, a two-way, co-productive relationship between the science/knowledge produced, and relevant policy and decision-making (Hoppe et al., 2013).

Our theoretical framework is specified in Fig. 1. The figure outlines the implications of the institutional design and structure on the behaviour of the service actors and calls attention to the fact that communication between all partners is essential for making the services effective, captured by the four basic co-creation process variables. Each of these needs attention in institutional design and management.

Institutional design defines the structure of the services and sets the basic ground rules under which collaboration and interaction takes place. The institutional design variables consist of the following more fine-grained variables; first, the *design of arenas of co-creation* across dispersed institutional actors and boundaries; second, the *mechanisms by which the services connect and engage* end-users (participation mechanisms), and; third, the degree to which the services are *decentralized* and engage on-site extension support for farming communities, and thus involve extension agents as partners.

Regarding governance and engagement of farmers, the actual mechanisms in use for participation are critical. To this end, websites and web-based tools tend to be relatively passive channels for engagement and serve mostly one-way information transfer. More active involvement of users and feedback that resemble a co-production or co-creation of the services, require mechanisms that enhance face-to-face interaction and multi-way interaction through multiple interfaces e.g. on-site extension, on-farm training or community laboratories (Vedeld et al., 2019; Hewitt et al., 2017). In order to compare the institutional structures and the level of engagement of various partners, including farmers as end-users, we developed four broad categories of user engagement as a ‘ladder of engagement’ dependent on various mechanisms employed by the service providers to enhance participation and feedback within the services (inspired by Hewitt et al., 2017 and Vedeld et al., 2019). The various rungs or levels of this ladder represent how different web-based tools and institutional mechanisms were differently

[2] Due to the vast differences in scale between India and Norway we chose to pursue the analysis of the Indian WSC in one state only, Maharashtra, see methodology for further explanation of the choice of areas and cases.

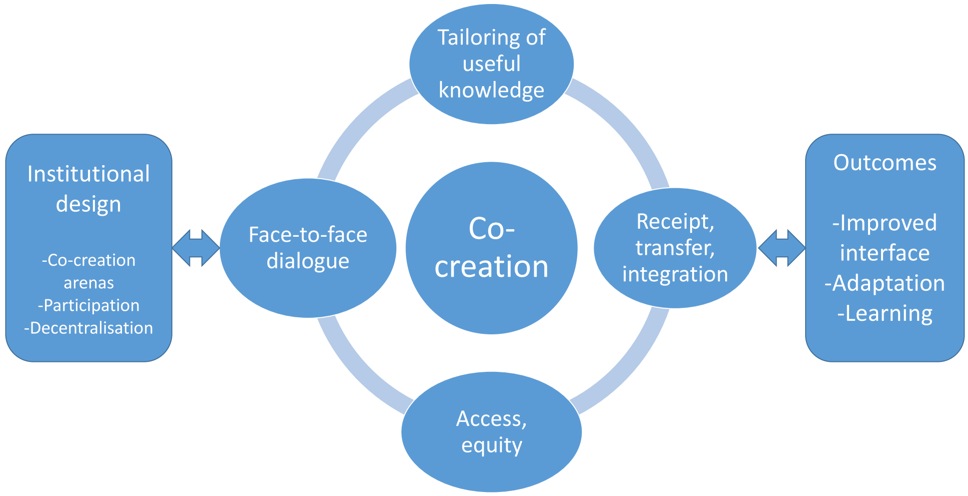

Fig. 1. Co-creation of agromet services: knowledge networks as a cyclical & iterative process.

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 and some co-production of knowledge
- ***Level 4.*** Co-creation of the service - regular multi-way communication and intense interaction among multiple actors (workshops) in producing and communicating knowledge and co-implementation, including also interface with social media for inclusion of practice-based knowledge and social learning at local level with on-site extension support.

The *co-creation process variables* relate to ways and means of effectively managing a knowledge network and achieve key *network attributes* within the overall agromet services (Ansell and Gash, 2007; Weber and Khademian, 2008).

The knowledge production and communication processes within an agromet services system would ideally follow a virtuous circle between the initial convening of participants through institutional design, co-creation process, outcomes and feedback. In reality, co-creation between partners do not follow a staged process but involve fuzzy and iterative interactions in time and scale.

i) *Tailoring of useful, bundled (agromet) knowledge* requires a focus on the co-production and bundling of useful knowledge tailored to specific purposes or usages (Brasseur and Gallardo, 2016). Tailoring involves bridging the gap between the content of the knowledge, scale, format and the lead-time that farmers need and the information otherwise routinely available as practice-based knowledge at local level in order to make the knowledge usable and actionable. [3]

ii) *Receipt, communication/transfer and integration of knowledge* raise issues of availability, understanding of what is appropriate actionable or usable knowledge for adaptation - and willingness to actually take the knowledge into use.

iii) *Access* to knowledge and services relates to the availability of the service as well as skills and capabilities to actually receive, access and utilize the services. Access raises issues of *equity* within and between diverse groups, for example regarding access for women and marginal farmers in India (Lobo et al., 2017);

iv) *Face-to-face dialogue and communication and engagement of end-users and intermediaries are* considered to be at the heart of building a co-creation process and bringing out the core attributes of a knowledge network. These relationships build trust, shared understanding and commitment and enhance (social) learning (Ansell and Gash, 2007; Vaughan and Dessai, 2014; Torfing et al., 2017). In turn, they foster legitimacy, relevance and usability of the services and collective adaptive capacity (Adger et al., 2009; Pelling, 2011).

Outcomes of these processes would be compared in terms of improved interface between service providers and users (farmers) and the observed *perceptions among farmers* about the usefulness and relevance of the knowledge and information provided and accessed. The actual quality of the knowledge and information produced and communicated is not assessed or compared from a scientific view.

2.1. Methodology and comparative research design

The methodological approach involved a comparative research design of two contrasting cases of agromet services embedded in very different contexts; one case located in India in the global south, and the other in Norway in the global north. The comparison thus followed a *most different case study design* (George and Bennett, 2005). We deliberately chose to compare two highly diverse case studies. The contexts are very different in terms of the history and scale of the institutions involved in agromet services, climate/weather issues, geography/environment, socio-economic context and local inequalities as well as in the level of outreach and number and types of farmers involved in the services. Norway, for example, is a country with only 5,2 million inhabitants and 30 000 relatively well-endowed farmers on an area of 324 sq. km (mainland); while the Indian state of Maharashtra encompasses 116 million inhabitants and 62 million people in rural areas and about 10–20 million highly diverse farmers in terms of wealth and capabilities within an area of 308 sq. km. However, in terms of the institutional structure, knowledge creation and communication, there are also many similarities. Our hypothesis was that if we found similar governance challenges in each of the two agromet services, it would enhance the robustness of the observations and the potential for generalizations from the findings.

Maharashtra was purposely chosen as the site for the Indian case due to

[3] We distinguish between science-based external knowledge and local practice-based knowledge, and the need to integrate the two in actual operations.

the state having a long-standing history and tradition in developing and providing both public and private agromet services (Lobo et al., 2017; Vedeld et al., 2019). The state hosts the Agricultural Meteorological Division of Indian Meteorological Department (IMD), which is located in the city of Pune, close to our chosen field-site. The state is well covered by agromet services (Vedeld et al., 2019; Venkatasubramanian et al., 2014). Maharastra is confronted with specific weather and climate risks, situated in the monsoon shadow belt, and thus the agromet service would be expected to be in high demand among diverse groups of farmers (Lobo et al., 2017). Fieldwork was carried out in the District of Pune and the neighbouring District of Ahmadnagar; two of the well-served districts with regard to agromet services in the state. In Norway, the case involved a whole-country-approach, reflecting the fact that only one major public-private agromet service is found in the country. It covers the whole country, although focused mainly on specific and relevant crop zones. The Norwegian service is highly limited in size and outreach compared to the Indian case. Both countries are known to host relatively well-operated WCS and agromet services supported by competent national meteorological institutions; the agromet services of Maharashtra are considered to be among the better performing in India (Venkatasubramanian et al., 2014; Lobo et al., 2017).

The research methodology consisted mainly of a governance approach and qualitative methodologies for data collection. Key informant interviews (semi-structured) were combined with relevant policy document reviews and institutional and web-site/portal/App analysis. The methodology was inspired by conventional governance network analysis (Weber and Khademian, 2008) and more recent approaches to the analysis of governance & co-creation (Ansell and Gash, 2007; Torfing et al., 2017). In India, the data gathered comprised 25 interviews with program officials and experts and relevant stakeholders at different scales and in different agromet institutions (mainly in Maharashtra; with some follow-up interviews in New Delhi). Six top level officials and seven medium/lower level officials within the IMD-AAS service were interviewed. Interviews were also done with thirteen officials of private agromet service providers in the state; some of which worked for NGOs or private service providers operating in parallel with IMD-AAS in the same basic districts (to obtain an outsiders view of the IMD-AAS service). The key informant interviews were combined with ten focus groups among farmers and field-visits in three villages (four visits over a three-years period from 2015 to 2017) in order to understand how diverse groups of farmers were involved and perceived the added value of the agromet services (details from the farmers' survey are reported in Nesheim et al., 2017 and in Vedeld et al., 2019). One local and one national-level workshop with national experts were utilized to verify the findings. The qualitative governance approach was combined with a village survey among 86 farmers in three villages that subscribed to agromet services.[4] The three villages were purposely selected in consultation with key officials of the agromet service providers as communities within which agromet services were considered to be among the best covered and possibly best functioning in the Districts (and thus in the state), and perceived to reach out to farmers better than in an 'average' village in the chosen Districts. The farmers surveyed were all subscribers of the AAS service (or another private agromet service). Hence, they were not necessarily representative of all farmers in each of the villages. They were likely to be slightly better-off farmers, and more frequently own a mobile phone/smart phones and have access to internet than the average farmer in the area (Nesheim et al., 2017). The methodology in India was inspired in part by previous studies of Indian agromet services, such as CGIAR's research program on Climate Change, Agriculture and Food Security, CCAFS (ref. Venkatasubramanian et al., 2014). In Norway, we interviewed fewer number of key informants, altogether 8 experts (program officials, researchers, planners, extension agents and farmers). We also consulted secondary studies and Norwegian literature on the subject and analysed relevant web-sites (Skaugen, 2014; Kundzewicz et al., 2017). Information on farmers' involvement with the services in Norway was based on secondary sources, including an internal survey carried out by AMN/VIPS staff (Personal communication, 2016). For both countries, we reviewed relevant national and international literature, relevant policy literature, and mapped institutional structures and histories.

3. Indian and Norwegian agromet services: an overview

The landscape of weather and climate service providers in India and Norway are in most respects highly advanced and complex, with several operational service providers of agromet services systems, both from the public, private, and civil society sectors (Rathore, 2012; Lobo et al., 2017; Singh et al., 2017; Thakur et al., 2017; Kundzewicz et al., 2017; Skaugen, 2014). However, the landscape was much richer in India and the scale of operations much higher (Vedeld et al., 2019). The institutional structures and basic features for each of the two services are presented below in Figs. 2 and 3. In the figures, dimensions of two-way/multi-way interaction is illustrated by a double-headed arrow; one-way information provision by a single-headed arrow (e.g. through SMS). The thicker arrow represents more substantive or important information flow.

3.1. Introduction to institutional design and co-creation arenas in India

The Integrated Agro-meteorological Advisory Services (IMD-AAS) is India's largest agromet program by far. It is hosted and run by the Agricultural Meteorological Division (set up in 1932) of IMD to serve farmers and research/extension across India at district level (reinforced in its present form in 2008). The service includes a host of agromet services (http://www.imdagrimet.gov.in/ddkview).[5] IMD-AAS is arguably the largest agromet 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 service reached about 25 million farmers with SMS agro-messages in 2018, according to a top-level official of IMD-AAS, and keeps rapidly expanding (Personal communication, February 2018). In the villages we surveyed, IMD-AAS existed side-by-side with three additional agromet providers (private and civic), and many farmers used the services of more than one provider (Nesheim et al., 2017; Vedeld et al., 2019).

The IMD-AAS is part of the national and state government structure and involves a complex four-tier organizational structure that includs the national meteorological service operating from state (and national) level to provide weather information to agricultural decision makers and farmers online (Rathore, 2013; Rathore and Chattopadhyay, 2016) (cf. Fig. 2):

- A top-level coordinating planning body in Delhi, which includes a multi-purpose services portal (mKisan) (http://mkisan.gov.in/) managed by the Ministry of Agriculture
- Execution body by the Division of Agricultural Meteorology, IMD, (http://www.imdagrimet.gov.in/). Input by IMD's weather forecasting units for national/district-wise weather forecasts, includes 'nowcast' (a few hours), short term (up to 3 days), medium term (3–10 days), and medium range forecasts e.g. seasonal monsoon forecast provided by the National Centre for Medium Range Weather Forecasts (NCMRWF), and an open access website with multiple information products
- Assigned Agromet Centres and six field units hired from state agricultural universities; each covering an identified ecosystem and 4–6 districts

[4] Fieldwork among farmers at local level was only undertaken in India/Maharashtra. The details of the farmers' survey are reported in Nesheim et al. (2017) and in Vedeld et al. (2019). Information on farmers' involvement with the services in Norway was based on secondary sources, including an internal survey carried out by AMN/VIPPS (Personal communication, 2016).

[5] AAS is now known in India as the Gramin Krishi Mausam Seva project (GKMS).

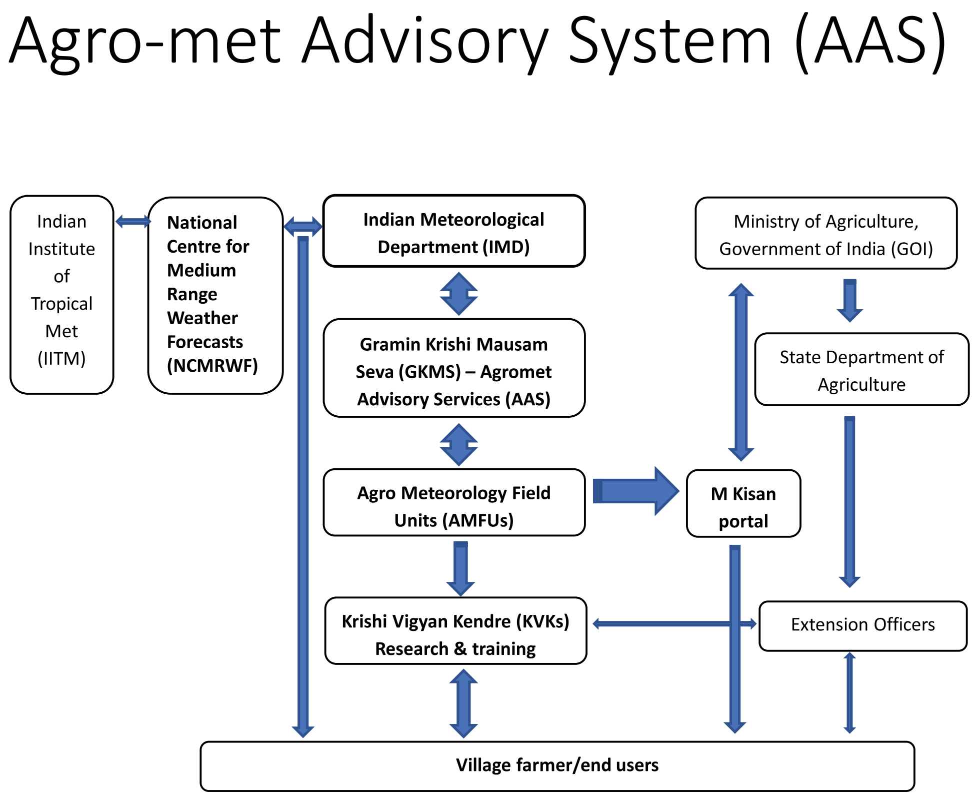

Fig. 2. India's agromet advisory system (AAS) & linkages to Indian Institute of Tropical Meteorology (IITM) and Ministry of Agriculture (MoA).

across the state (36 districts in Maharashtra) to enhance local/district-level coordination, knowledge creation, communication and monitoring

- District level research and training centres (KVKs) for coordinated support and input management of the advisory service – with links to the agricultural extension

The IMD-AAS program represents a mix between a one-way information service (SMS-, media-, and bulletin-based) and two-way (call centres) or multi-ways dialogue through various web-based tools and multiple interfaces, including the mKisan portal and some interaction between KVK staff and local farmers at district and local levels. Knowledge is co-produced among agricultural and meteorological scientists in bulleting form by staff of the state agricultural universities in special ecosystem-based field units, as bundled agromet advisories, and communicated through a diversity of products and channels of communication online (to 36 districts in Maharashtra state). Agromet advisories are fed into the national

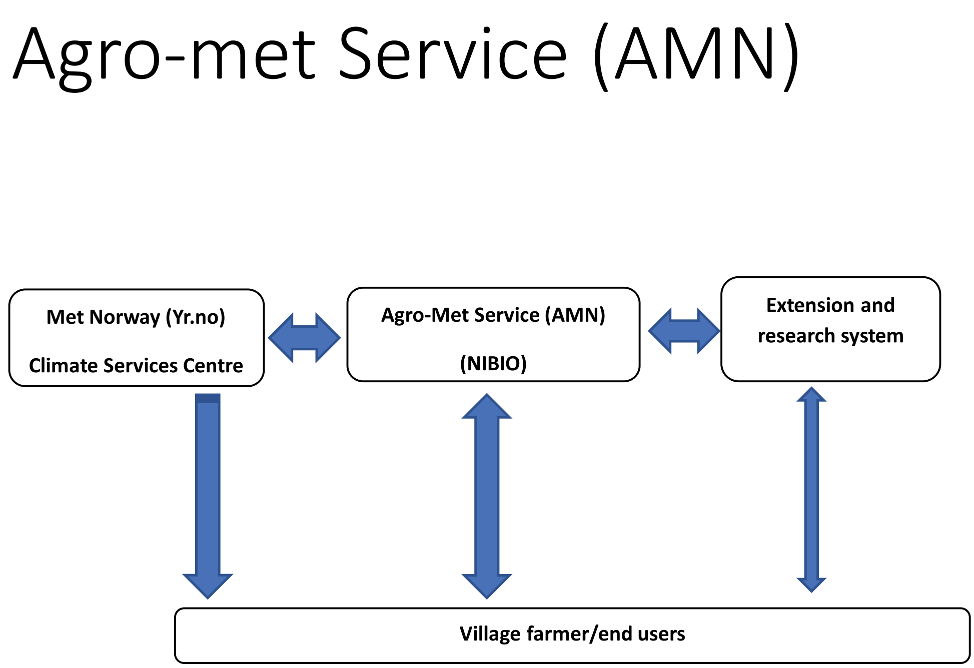

Fig. 3. Agromet service system in Norway (AMN).

level mKisan web-portal, which can be accessed by an App. SMS are also sent via the portal. There is no App developed for the weather services by IMD (at the time of our field-work in 2015/2017). AAS also provided weather alerts and warnings and drought monitoring.

Based on recent top-level encouragement from the Chief Minister of the state, the agromet services of Maharashtra in 2016 reached 5 million farmers with SMS (twice weekly) to warn about e.g. rainfall and drought risks (Personal communication, 2016).

The engagement of farmers in two- or multi-ways communication, as well as the integration of their practice-based knowledge, are recognized as two areas that are still underdeveloped in the AAS system (Pant et al., 2012; Venkatasubramanian et al., 2014; Lobo et al., 2017; Nesheim et al., 2017). Our observations in three villages selected for their relatively high exposure to agro met services, suggest that even if the service is available for most farmers and farmers are becoming increasingly interested and aware of the services, actual use and uptake is limited and concrete feedback to service providers happens rarely (Nesheim et al., 2017; Vedeld et al., 2019). Many of the farmers had been inscribed by local extension workers on a group basis, and their phone numbers were registered, without the farmers actually being aware of them becoming subscribers, according to information we received both by services staff and farmers themselves (Personal communication, 2016). That being said, the website of AAS encouraged user feedback to each of the field units, and some feedback was occasionally provided through call centres and the mKisan portal and through SMS. Some passive feedback from farmers is increasingly collected from other sources such as surveys and training sessions (Pant et al., 2012; Venkatasubramanian et al., 2014; Rathore and Chattopadhyay, 2016; Lobo et al., 2017).

3.2. Introduction to institutional design and co-creation arenas in Norway

Norway's agromet services was established in the late 1980s as AgroMeteorology Norway (AMN). AMN is a program hosted by the Norwegian Institute of Bioeconomy Research (NIBIO) as the operational entity; located at the University of Life Sciences campus. AMN draws upon the weather services of Met Norway (established in 1866), especially Yr.no, and the relatively newly established Norwegian Climate Services Centre (NCSC) for climate change data, which includes a free access portal (eKlima) (https://klimaservicesenter.no/). A variety of climate knowledge data for the agricultural sector is presented here. Yr.no is the multimodal weather forecasting App and a website of Met Norway (established in 2007), which provides open source weather data free of cost and information on extreme weather, medium range weather and some climate change knowledge (www.om.yr.no), including for an international audience. Yr.no is co-managed between Met Norway (provides the weather information) and the Norwegian Broadcasting Cooperation (handles the communication to users). Within the agromet services system, the weather forecast provided is perceived by the staff of the services to be relatively accurate and tailored to the local needs of the farmers, although there is recognition of certain limitations in the accuracy for example during summer and winter seasons (Personal communication, 2016). The WCS sector in Norway has not been extensively studied (Kundzewicz et al., 2017; Skaugen, 2014).

The most important sub-scheme of the agromet services of AMN is VIPS. This is an automatic forecasting system for agricultural pests and diseases (established 2001; modernized with improved user-interface from 2016). This scheme has been developed between NIBIO and the Norwegian agricultural extension service – as two collaborative partners. The data system is designed to be both a decision help system for the producer and a tool for bringing information between the consumer, the farmer, the extension service and the agromet researcher. The combined risk warning program – AMN plus VIPS – combines district level weather forecasts, continuously updated with local weather data from NIBIO's own weather stations, with pest warnings to specific crop farmers, as well as to research and other agricultural organisations. The services operate through a combination of one-way, two-way and multiway communication; through SMS, email services and an open internet portal (https://www.vips-landbruk.no/). The latest version of VIPS is an open source technology platform aimed at international collaboration and local adaptations. The portal is available to most farmers, since they generally have access to internet and G4/smartphones. There exists an App on local agro-weather forecasts to the users (served by automated local weather stations owned by NIBIO), which can be configured to personal preferences (location, crop and pest). Feedback and input about spread of local pests is provided by extension agents and can be provided also by farmers. The farmers own interest organisations are involved in the agromet services and runs a climate smart agriculture program, supported by NCSC; which provides climate advisories with the aim to reduce the greenhouse gas emissions from agriculture (https://klimasmartlandbruk.no/100-losninger/).

The AMN/VIPPS program has basically three tiers:

- Met Norway at national level provides weather and climate information, based on continuously adjusted weather forecasts and online weather stations and radars, (including weather forecasts ranging from 90 min., three days up to ten days (posted in yr.no), plus medium range weather and climate projections (in collaboration with three national partners)
- Coordination by AMN and VIPS at NIBIO, which communicate knowledge directly to the agricultural extension system and farmers
- Integration with the national and local extension system, which is a partner of the services, and involvement of farmers' interest organisations (in particular through the climate smart agriculture program)

In this regard, it is important to note that the Norwegian extension system is organized and funded mainly by the farmers themselves around farmer-groups (in ten regions; 24 000 members). The local extension agent is normally in daily or weekly contact with farmers, and thus receives farmers' feedback into the preparation of local advisories. At national level, a Facebook service has been established that communicate extension advice, news and events (www.nlr.no). While extension agents do provide direct feedback into the system, farmers rarely do, except indirectly through their local extension agent, even if the opportunity for feedback is available and accessible. Moreover, the percentage of farm-members in local extension groups that would actually utilize the VIPS-service is relatively low; only about 20 % according to a local survey (Personal communication, 2016).

4. Comparison of institutional design and co-creation processes in India (Maharashtra) and Norway

When comparing the agromet services of India (as they operate in Maharashtra) and Norway with such diversity in ecology and socio-politico-institutional contexts, the basic elements of the institutional structures defining the services come to the fore. Table 1 below compares the institutional design and co-creation processes of the two services systems with reference back to the factors provided in the analytical model (Fig. 1).

In summary, we find that the large and diverse organizational structure and scale of the IMD-AAS services provide specific challenges in terms of decentralization, co-creation arenas and integration among partners, and engagement of farmers. In comparison, the Norwegian AMN/VIPS services involve fewer bureaucratic layers, strong integration among institutional partners, a decentralized service, and some involvement of farmers through an active extension system.

4.1. Analysis of similarities in governance and co-creation

Despite the observed differences in design and performance alluded to above, there are certain key similarities that come to the fore of greater significance for understanding key challenges confronting the governance of agromet services. In both the services, which relied on similar types of meteorological models and bundling of agromet advisories, we found that both farmers and service staff suggested that the knowledge created and communicated was largely not appropriately tailored towards farmers'

Table 1
Comparison of institutional design and co-creation processes in two agromet services.

Institutional design and co-creation of agro-met knowledge	India (Maharashtra)	Norway
Institutional design		
Design/structure and institutional home	Complex four-tier public administrative/governance system of the agricultural research & training sector – with weak links to agricultural extension.	Small-scale three-tier organizational structure within the research & training sector - in partnership with the agricultural extension.
	Reaches about 5 million farmers with agromet SMS in the state.	Reaches about 8–10 000 farmers with agromet SMS.
Co-creation arenas for producing weather, agro-met and climate knowledge	Knowledge bundled/produced centrally with limited involvement of agricultural assistants at local level.	Knowledge is bundled/produced centrally with continuous input/update from local weather stations and some extension input. Extension system is partner and linkages to farmers' organizations established.
	IMD lacks mandate to communicate climate information, which is a responsibility exclusively of IITM and NCMRWF; none of which are fully integrated partners of the agromet services.	Met Norway is mandated to deal with relevant weather *and* climate information, a role reinforced by the establishment of NCSC.
Participation / engagement mechanisms	Mainly one- and two-way communication. Multiple channels and knowledge products (multimodal), such as media, bulletin, SMS, App, but no extensive interface with farmers. Some feedback through mKisan portal.	Mechanisms for two-way and multi-way communication and feedback to portal and email (multi-modal and multi-way). Some indirect farmers' feedback via local extension agents and farmers' organisations.
Decentralized – on-site support	Limited decentralization of the agromet services. Local field units and extension & training units with limited capacity to reach farmers.	Strongly decentralized agromet services integrated with decentralised agricultural extension system.
Co-creation processes		
Face-to-face dialogue with farmers	Limited on-site support and face-to-face dialogue between extension agents and farmers.	On-site support and regular involvement by extension agents raise trust and some involvement of farmers.
Co-tailoring of useful knowledge	No real involvement of farmers, despite multimodal channels of communication.	Some indirect input by farmers through multi-way communication although few products and less channels of communication and interfaces.
	Weather forecast; limited accuracy - related to 12 × 12 km resolution. Accuracy of weather forecasts an issue during monsoon. Agromet advisories not well tailored, nor continuously updated.	Weather forecast – limited accuracy; 3 × 3 km resolution. Accuracy of weather forecasts an issue e.g. in summer season. Agromet advice regularly updated and geared towards prioritized types of crops, farming systems, locations.
Receipt, communication and integration of information	Despite great outreach of SMS, limited local awareness and use of the services among farmers - less than 5 % of the local farmers found to use the agromet services. Extension agents not well integrated for on-site support.	Some limits to local awareness of the services. Only about 20 % of farmers utilize agromet services according to one AMN/VIPS survey. Agricultural extension agents receive information and engage in on-site support to farmers.
Access, equity, social learning	Access and use mostly among progressive farmers; not female or poor farmers, due to lack of mobile phones / capabilities and limited awareness. Weather forecasts regularly consulted by local farmers. Local social learning at temple sites or in village with peers.	Most/all farmers have smart-phones and internet access; yet actual use of the services is at low rate, except for weather forecast (Yr.no). Local learning in farmers' groups and in meetings with extension agents and district farmers' organisations at community- and farm-level.

needs for specific crops- and farm operations, spatially too coarse to address issues at specific locations, and, often unreliable in terms of quality of data (inaccurate) and timely delivery (Nesheim et al., 2017; Vedeld et al., 2019). The probabilistic nature and limited accuracy of the weather forecast and the lack of local specificity of the agromet advisories remained critical issues. Our interviews confirmed that participants in the services have different meanings and perceive different potential uses and values of the knowledge transferred and shared. For example, the meteorologists of the national meteorological departments would be preoccupied with the installation of local weather stations mostly to improve weather and climate models and forecasts, while farmers were more concerned about risk to on-farm decisions, not fully comprehending how additional weather observations could help them target these goals.

Knowledge can in this perspective not be separated from the application, use and development of the knowledge of the different participants. Farming knowledge is localized, embedded and vested in practice and local cultures, and thus internalized in the roles of and relationships between partners in the services. The 'knowledge' to be created by external experts and transferred to farmers needs to be viewed pragmatically and become an integrated part of practice-based knowledge. This raises two issues. First, it suggests that the challenges confronting the services and the network managers become particularly acute and difficult in terms of bringing actors together to co-produce relevant and timely knowledge (Weber and Khademian, 2008). Second, it needs to be acknowledged that hard-won practice-based knowledge is not easily shared and integrated across network participants (Weber and Khademian, 2008; Singh et al., 2017; Harjanne, 2017). Interestingly, we found that farmers in villages of Maharashtra, at their end, are taking own initiatives for sharing agromet knowledge through establishing local crop-specific WhatsApp groups, which enhances direct local interaction, information exchange and social learning (Nesheim et al., 2017). This is an ingenious example of a bottom-up process of institutional innovation and development, and fast sharing of local information e.g. of images of crops or pest attacks (Thakur et al., 2017). Local government departments have also extended support in this regard, and have joined farmers' WhatsApp groups or initiated their own groups. In Norway, the Facebook site of the national extension system serves to some extent similar forms of interactional learning, although it is run from the national level and not by the farmers themselves.

4.2. Similarities in transfer, receipt and integration: co-created and reaching out?

Regarding communication across partners in relation to the co-creation process variables, we find that both services involve multi-modal delivery systems in the governing approaches. However, it varies to which extent each of the services relies on web-based tools and websites for mostly one-way information provision (mobile phones/SMS messages, Apps and web portals) versus two-way or multi-way

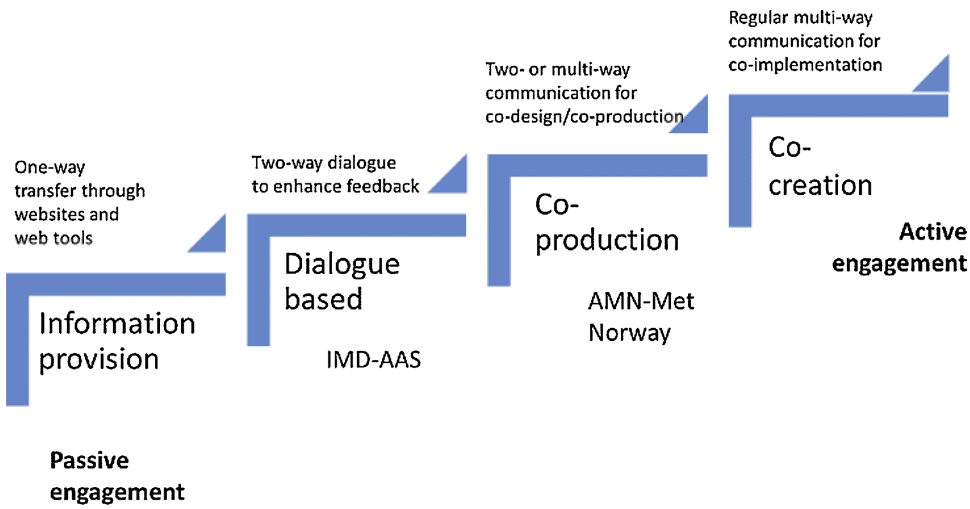

Fig. 4. Co-creation and 'ladder of engagement' in agromet services: IMD-AAS & AMN-Met Norway, source: survey data 2015-2017.

communication and interaction among multiple actors.

If we make a comparative assessment of the performance of the two services regarding the forms of interaction and engagement that took place (cf. analytical framework on the rungs in the *'engagement ladder'* and Fig. 4 below), IMD-AAS can be considered to perform at ***Level 2*** (mainly one- and two-way communication); while AMN/Met Norway on certain accounts reached ***Level 3*** (co-production). None of the two performed at *Level 4* (co-creation). One may argue, however, that such a comparison is not fair, given the huge difference in the scale and complexity between the two services and differences in socio-institutional contexts.

Despite continuous efforts within both services to improve the communication modes, we found that even when the agromet advisories were available as open access and free of costs at local level, most farmers, whether in India or in Norway, did not actively access and utilize the services in substantive ways. Hence, potentially useful weather/climate information communicated often go unused (cf. Lemos et al., 2012; Vaughan et al., 2016). Moreover, the field-work in India suggests that many of the local farmers were not really aware of these agromet services (beyond the weather forecasts), despite their rapid expansion and proliferation. This is also the case in Norway, according to AMN-Met Norway staff.

Our survey at village level in Maharashtra revealed that the farmers subscribing to the various services complained about the agromet information often not being specific enough and useable for farm level decisions. Farmers considered 'personal competence' and 'interaction with others' as the two most important factors influencing their farm-decisions; while the input from agromet services was ranked third after these two (Nesheim et al., 2017:10; Vedeld et al., 2019). Hence, farmers relied mainly on their own experiences and traditional farm practices in farm decision making, more so than on external advisories (cf. also Vedeld et al., 2014). Among active subscribers, the agromet information received was, utilized only as one source among many for taking farm decisions. Moreover, the services were utilized mostly by the more wealthy and progressive farmers who possessed mobile or smart phones; not by women and to lesser degree by the small-scale farmers. The majority of poor and marginalized farmers were in reality structurally excluded from much of the information. This may be less of a reason why Norwegian farmers did not actively use these services, since most farmers have access to internet and smart phones.

5. Conclusions

Based on our comparative analytical approach, we found great similarities in key governance challenges related to limitations in the format, relevance, accuracy and tailoring of knowledge communicated. Observing such similarities across very diverse contexts, enhances the potentials for making general hypotheses beyond the two cases studies, precisely because they evolved under very different circumstances.

We therefore suggest that these agromet services do not (yet) supply useful enough knowledge to meet requirements of farm operations, except for certain types of knowledge for specific purposes and operations, such as warnings about extreme weather (heavy rainfall, hailstorms) and spread of specific plant diseases. Hence, only if these services are geared towards specific decision-making situations of the farmers, do they have potentials to become more fully useable (Rathore, 2013; Rathore and Chattopadhyay, 2016; Lobo et al., 2017).

Many case studies of WCS across all regions have similarly found that such services continue to be largely supply-driven and are not well-informed by specific or changing user needs and demands due to changing weather or climatic or specific local environment conditions (Brasseur and Gallardo, 2016; Lobo et al., 2017; Singh et al., 2017; Golding et al., 2017a, b, Street, 2016).

Based on our findings, we propose, first of all, that a more deliberate approach to *institutional design* of WCS would be required to facilitate a stronger integration and interconnectedness of all partners in the services through arenas of co-creation at local, district and national levels. A lesson from both India and Norway is that a decentralized system that resembles a network of actors that challenges conventional administrative sector silos and professional boundaries may best mobilize the attributes assigned to knowledge networks. Moreover, success in the governance of the services is likely to be highest when farmers' and intermediaries are engaged, and the provider makes use of multi-modal and multi-way communication systems. User involvement should be combined with on-site extension support and multi-actor partnerships for co-design and co-creation of the services (between providers, intermediaries, users). This is in line with the recent WCS literature (Lobo et al., 2017; Vaughan et al., 2016, 2017; Hewitt et al., 2017), and finds support in the literature on boundary organizations (Hoppe et al., 2013). This literature suggests that the deliberate blurring of boundaries between science and policy and practice (e.g. farm decision-making), rather than advocating an intentional separation between science and nonscience (policy & practice), is likely to lead to more productive policy making (Guston, 2001; Hoppe et al., 2013).

Second, in both countries, there are *fundamental scientific challenges in terms of continuously improving the co-creation of useful and relevant knowledge* that need to be addressed, if the aim is to enhance outreach of the services and participation (Golding et al., 2017a,b; Christel et al., 2017). On the one hand, this relates to the probabilistic nature and limited accuracy of the weather forecast and agromet advisories; a critical issue raised by all types of stakeholders (Lobo et al., 2017). On the other hand, it points to the problems of how to ensure better integration of the external/scientific knowledge with the farmers' practice-based knoweldge into the services; recognizing that farmers' dispersed practice-based knowledge cannot readily be created and codified and transferred through the system in meaningful manners (Weber and Khademian, 2008; Ansell and Gash, 2007).

In conclusion, greater participation of farmers alone, while being a necessary requirement to enhance WCS performance, is not a sufficient condition; even if this is often suggested in the WCS literature (Vaughan and Dessai, 2014). Greater incentives among farmers to become active partners in WCS will only come if the relevance, accuracy and format of knowledge are improved.

Regarding specific lessons from the comparison of the two services, we suggest that Norway can learn from India that a more ambitious scope with a richer variety of knowledge products and multi-modal channels of communication can facilitate greater awareness and interest among a wider group of farmers. Norway can also learn from India about the potentials of integrating social media more profoundly into the services, such as local WhatsApp groups, building on their own experiences with a national Facebook group.

India can learn from Norway that a more integrated institutional design, including bringing the national extension system and farmers' own organizations on board as stronger partners, can help improve the practice-based content, co-creation and co-governance of the services.

Reflecting that combined weather, climate and agro-advisory services is an emerging field or sector, continuous efforts are observed both in India and Norway to improve the institutional design and co-governance of the services along the lines suggested here. These policy actions are likely – over time - to produce more useable knowledge and enhance the relevance of these services for all kinds of farmers – small and large - which continue to rely heavily on practice-based knowledge.

Funding

Funded by the Research Council of Norway (RCN) under the project GovClimServices (2015–2018) no. 240018.

References

Adger, N.W., Lorenzoni, I., O'Brien, K., 2009. Adaptation to Climate Change. Cambridge University Press.

Ansell, A., Gash, A., 2007. Collaborative governance in theory and practice. JPART 18, 543–571. https://doi.org/10.1093/jopart/mum032.

Ansell, A., Torfing, J. (Eds.), 2016. Hanbook on Theories of Governance. Edward Elgar, Cheltenham.

Buontempo, C., Hewitt, C., 2017. EUPORIAS and the development of climate services. Clim. Serv. 2017. https://doi.org/10.1016/j.cliser.2017.06.011.

Brasseur, G.P., Gallardo, L., 2016. Weather and climate information services: lessons learned and future prospects. Earths Future 4, 79–89. https://doi.org/10.1002/2015EF000338.

Carr, E.R., Onzere, S.N., 2017. Really effective (for 15% of the men): lessons in understanding and addressing user needs in climate services from Mali. Clim. Risk Manag (in press, open access 2017).

Christel, I., Hemment, D., Bojovic, D., Cucchietti, F., Calvo, L., Stefaner, M., Buontempo, C., 2017. Introducing design in the development of effective climate services. Clim. Serv. 2017. https://doi.org/10.1016/j.cliser.2017.06.002.

Dilling, L., Lemos, M.C., 2011. Creating usable science: opportunities and constraints for climate knowledge use and their implications for science policy. Glob. Environ. Change 21 (2), 680–689.

Dinku, T., Block, P., Sharoff, J., Hailermariam, K., Osgood, D., del Corral, J., Cousin, R., Thomson, M.C., 2014. Bridging critical gaps in weather and climate information services and application in Africa. Earth Perspect. 2014 (1), 15 http;//www.earth-persepectives.com/content/1/1/15.

George, A.L., Bennett, A., 2005. Case Studies and Theory Development in the Social Sciences. Belfer Center Studies in International Security. The MIT Press, Boston.

Golding, N., et al., 2017a. Improving user engagement and uptake of climate services in China. Clim. Serv. 5 (2017), 39–45 https://doi.org/10.1016.

Golding, N., Hewitt, C., Zhang, C., 2017b. Effective engagement for climate services: methods in practice in China. Clim. Serv. 8 (2017), 72–76. https://doi.org/10.1016/j.cliser.2017.03.004.

Guston, D.H., 2001. Boundary organizations in environmental policy and science: an Introduction. Sci. Technol. Human Values 26 (4), 399–408 Autumn 2001.

Harjanne, A., 2017. Servitizing climate science – institutional analysis of climate services discourse and its implications. Glob. Environ. Change 46 (2017), 1–16. https://doi.org/10.1016/j.glonvcha.2017.06.008.

Hewitt, C., Stone, R., Tait, A., 2017. Improving the use of climate information in decision-making. Nat. Clim. Change 7 (9), 614–616 https://doi.org/10.1038.

Hoppe, R., Wesselink, A., Cairns, R., 2013. Lost in the problem: the role of boundary organisations in the governance of climate change. WIREs Clim. Change 2013 (4), 283–300. https://doi.org/10.1002/wcc.225.

Hofstad, H., Torfing, J., 2015. Collaborative innovation as a tool for environmental, economic and social sustainability in regional governance. Scand. J. Public Admin. 19 (4).

Kundzewicz, Z.W., Førland, E.J., Piniewski, M., 2017. Challenges for developing national climate services – poland and Norway. Clim. Serv. 8 (2017), 17–25. https://doi.org/10.1016/j.cliser.2017.10.004.

Lemos, M.C., Kirchhoff, C., Ramprasad, V., 2012. Narrowing the climate information usability gap. Nat. Clim. Chang. 2, 789–794.

Lobo, C., Chattopadhyay, N., Rao, K.V., 2017. Making smallholder farming climate-smart. Integrated agro-meteorological services. Econ. Polit. 7 (Jane 1), 2017 vol LII No.

Meadow, A., Ferguson, D.B., Guido, Z., Horangic, A., Owen, G., 2015. Moving towards the deliberate coproduction of climate science knowledge. Am. Meteorol. Soc. (April), 2015. https://doi.org/10.1175/WCAS-D-14-00050.1.

Nesheim, I., Barkved, L., Bharti, N., 2017. What is the role of agro-met information services in farmer decision-making? Uptake and decision-making context among farmers within three case study villages in Maharashtra, India. Agriculture 7 (8), 70. https://doi.org/10.3390/agriculture7080070. 2017.

O'Brien, K., 2018. Is the 1.5 _C target possible? Exploring the three spheres of transformation. Curr. Opin. Environ. Sustain. 2018 (31), 153–160.

Pelling, M., 2011. Adaptation to Climate Change: From Resilience to Transformation. Routledge, London.

Pant, B., Rathi, A., Rathi, A., 2012. Effectiveness of crop advisory services in Aurangabad District of Maharashtra in India. Int. J. Agric. Man Dev (IJAMAD) ISSN:2159-5860.

Rathore, L.S., 2013. Weather information for sustainable agriculture in India. J. Agric. Phys. 13 (2), 89–105. (2013) ISSN 0973-032X. http://www.agrophysics.in.

Rathore, L.S., Chattopadhyay, N., 2016. Weather and weather and climate information services for farmers in India. Weather Bull. 65, 2016.

Singh, C., Daron, J., Bazaz, A., Ziervogel, G., Spear, D., Krishnashwamy, J., Zaroug, M., Kituyi, E., 2017. The utility of weather and climate information for adaptation decision-making: current uses and future prospects in Africa and India. Clim. Dev. https://doi.org/10.1080/17565529.2017.1318744.

Skaugen, T.E., 2014. Mapping Climate Services Providers in Norway, JPI Report. The Research Council of Norway.

Street, R.B., 2015. Towards a leading role on weather and climate information services in Europe: a research and innovation roadmap. Weather Clim. Inf. Serv. 1 (2016), 2–5.

Thakur, D., Chander, M., Sinha, S., 2017. WhatsApp for farmers: enhancing the scope and coverage of traditional agricultural extension. Int. J. Sci. Environ. Technol. 6 (4), 2190–2201 ISSN 2278-3687(0).

Torfing, J., Sørensen, E., Røiseland, A., 2017. Transforming the public sector into an arena for co-creation: barriers, drivers, benefits and ways forward. Adm. Soc (forthcoming 2017).

Vargo, S.I., Lusch, R.F., 2006. Service-dominant logic: what it is. what it is not, what it might be. In: Lush, R.F., Vargo, S.I. (Eds.), The Service-Dominant Logic of Marketing: Dialog, Debate, and Directions. M. E. Shape, New York, pp. 43–56.

Vaughan, C., Dessai, S., 2014. Climate services for society: origins, institutional arrangements, and design elements for an evaluation framework. WIREs Clim. Change 2014 (5), 587–603. https://doi.org/10.1002/wcc.290.

Vaughan, C., Buja, L., Kruczkiewicz, A., Goddard, L., 2016. Identifying research priorities to advance climate services. Clim. Serv. 4 (2016), 65–74. https://doi.org/10.1016/j.cliser.2016.11.004.

Vaughan, C., Dessai, S., Hewitt, C., Baethgen, W., Terra, R., Berterretche, M., 2017. Creating an enabling environment for investment in climate services: the case of Uruguay's National Agricultural Information System. Clim. Serv. 8 (2017), 62–71. https://doi.org/10.1016/j.cliser.2017.11.0041.

Vaughan, C., Dessai, S., Hewitt, C., 2018. Surveying climate services: what can we learn from a bird's eye view? Water, Weather Clim. Soc. 10, 373–395. https://doi.org/10.1175/WCAS-D-170030.1.

Vedeld, T., Aandahl, G., Barkved, L., Kelkar, U., de Bruin, K., Lanjekar, P., 2014. Drought in Jalna. Community-based Adaptation to Extreme Climate Events in Maharashtra. TERI Press, New Delhi.

Vedeld, T., Mathur, M., Bharti, N., 2019. How can co-creation improve the engagement of farmers in weather and climate services (WCS) in India. Clim. Serv. Add: Clim. Serv. 15, 100103. https://doi.org/10.1016/j.cliser.2019.100103.

Venkatasubramanian, K., Tall, A., Hansen, J., Aggarwal, P., 2014. Assessment of India's integrated agro-meteorological advisory services from a farmer perspective. CCFAFS Working Paper no. 54. CCAFS, Copenhagen, Denmark.

Vogel, J., Letson, D., Herrick, C., 2017. A framework for climate services evaluation and its application to the Caribbean Agrometeorologcial Initiative. Clim. Serv. 6 (2017), 65–76. https://doi.org/10.1016/j.cliser.2017.003.

Weber, E.P., Khademian, A.M., 2008. Wicked Problems, Knowledge Challenges, and Collaborative Capacity Builders in Network Settings. Public Administration Review March/April 2008.