Gaining user insights into the research-to-operational elements of Impact-based Forecasting (IbF) from within the SHEAR programme

Summary of Findings

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1 Introduction

Impact based Forecasting (IbF) is an expanding and evolving area of research within National Meteorological and Hydrological Services (NMHSs) and the humanitarian sector, with a broad aim to enhance communication and timely action to reduce losses associated with natural hazards. Although the principles of IbF may seem new to some disciplines, they leverage knowledge built over several years within the risk and emergency management communities (Smith, 2013) and therefore although its application may be newer to some disciplines, many of the principles and practices are based on existing risk theory concepts. However, a key advance of IbF is the pull-through of these concepts into implementable prototypes, tools and services and in order to do this, a growth in interdisciplinary working.

The World Meteorological Organisation (WMO), as well as global Non-Governmental Organisations (e.g. Red Cross Red Crescent) strongly advocate for a shift towards IbF and have developed supporting guidelines (WMO, 2015a; Red Cross Climate Centre, 2020; WMO, 2021) to enhance implementation of such techniques across the globe. In doing this the WMO have distinguished two main types of IbF, subjective and objective. A subjective IbF relies on expert interpretation to provide the impact-based elements to a forecast or warning, whilst an objective IbF utilises vulnerability and exposure datasets, together with hazard information to calculate the risk and/or impacts. It is noted however, that risk assessments almost always utilise a combination of both subjective and objective methods. There are a wide range of dependencies on how an IbF system might evolve, and it is these dependencies which have introduced variety into the approaches and methods used to generate impact-based forecasts and warnings. This variability is also driven by different interpretations of what IbF should provide. Some stakeholders desire to have information on the number of assets or people that might be affected; however, most IbF warnings systems currently provide categorical risk forecasts (i.e. very low, low, medium and high) with supporting generalised impact information. Although the difference between these styles of output may appear subtle it can have significant implications for the development of forecasting and warning applications and the upstream modelling requirements.

IbF has rapidly become an umbrella term under which a plethora of methods are being tried and different disciplines engaged. This broad scope is beneficial for research as it enables blue-sky thinking, transdisciplinary research opportunities and ideally, sustained cooperation and collaboration between a wide range of groups (e.g. stakeholders, researchers, technologists, practitioners, decision-makers). However, these same benefits can pose challenges when moving towards operational implementation, particularly for NMHSs with reduced institutional capacities. It should also be noted that the term IbF is linked to a range of other activities and terminologies, including forecast-based action and forecast-based financing (FbF). The lens through which IbF is viewed therefore influences its role and the value it might provide in meeting the objective 'to enhance usability by making forecasts and warnings more actionable'.

Given the growing scope of IbF and the potential challenges this may have for implementation, this research aims to answer the following questions: (1) Is there a shared understanding of what IbF is across individuals involved in its development? (2) Is there a shared perception of the challenges, barriers and opportunities associated with implementing IbF operationally? To accomplish this aim, practitioners, forecasters and researchers, working within the NERC Science for Humanitarian Emergencies and Resilience (SHEAR) Programme, were invited to provide their perspectives on a range of IbF related topics through a set of semi-structured interviews. This report provides a synthesis of the interviewee transcripts from key informant interviews. In section 2 the methodology is described, while section 3 provides a review of the key findings from the complete set of interviews. The final section (section 4) provides recommendations and concluding remarks.

2 Methodology

Semi-structured interviews were conducted with a range of key informants from across SHEAR. The key informants were selected by the project team, including SHEAR knowledge brokerage, based on their experience and expertise regarding impact-based forecasting. The team endeavoured to interview a range of perspectives from researchers through to practitioners. A total of 11 interviews were held with stakeholders from the UK, South Africa, Uganda, Kenya, India, and Nepal, representing a range of international institutions and NGOs, research institutes and hydro-meteorological agencies.

A semi-structured interview template was developed by the project team. This provided an outline of the types of questions that would be asked of each interviewee. Despite the template, it was expected that interviews would be organic in nature, enabling each participant to speak freely on topics most pertinent to them. Potential interviewees were invited to participate at a time and date convenient to them, with interview lengths expected to last no more than one hour. An information pack was provided to each interviewee once they accepted the invitation to participate. This document (Appendix 1) described the background to the research project, the purpose of the interview and provided a list of questions around which the interview would be based. All interviews were conducted remotely, in English, and recorded for transcription purposes.

Responses were anonymised and compiled for qualitative analysis using NVivo software. The analysis was based on pre-defined categorisation of key informants as researchers, forecasters, and practitioners, and identified points of convergence and divergence against a thematic framework. A two-stage approach was used, whereby transcripts were first reviewed against pre-identified themes, and secondly against themes originating from the complete set of interviewee responses, as follows:

Pre-identified themes:

- Understanding of IbF
- Roles and skills needed for IbF
- Data needed for IbF
- Stakeholders in IbF
- Gaps and barriers to implementing IbF
- Value-add of IbF

Themes originating from interviewee responses:

- Inequality of impacts
- Governance of IbF
- IbF and anticipatory action

In total 11 interviews were completed and analysed. Of these, four interviewees were identified to represent practitioner perspectives. Another five were identified as forecasters, or of having forecaster experience, and two interviewees were identified to represent researcher perspectives. Although this represents a small sample, particularly when considering group representation, it provides a sufficient preliminary indication to likely differences and similarities which can provide a valuable baseline for future expansion.

3 Synthesis of findings

3.1 Is there a shared understanding of what IbF is?

The interviewees expressed a shared high-level understanding of what IbF is. For example, almost all referred to IbF as the transition from communicating what the weather will be, to communicating what the weather will do. There was also unanimous agreement that IbF aims to give more useful relevant information to decision makers, addressing the questions that they want answers to. Similarly, all referred to IbF forecasts needing to be actionable. There was, however, some disparity regarding the role of IbF. This was subtle, but it was evident from the responses that some saw IbF outputs as an end point (e.g. the provision of an impact-based warning), while others saw them as requirements to achieve other objectives (e.g. activities related to FbF and risk financing). This appears to be related to the lens through which IbF is being considered and was raised by one of the interviewees who observed that, for example, "the UK Met or WMO, have their own way of defining IbF and implementing those, and if you talk to the Red Cross movement and different practitioners who are also working in IbF, we have our own way of doing things" – KII7. This is perhaps not surprising given that NMHSs and humanitarian sector (I)NGOs have different remits and, traditionally, different roles within the Disaster Management Cycle.

Typically, NMHSs are focussed on providing timely warnings, that enable disaster management authorities and sector-specific stakeholders to take appropriate actions with the aim of reducing losses associated with hazardous hydrometeorological events. The humanitarian sector has traditionally had the role of responding to hazardous events once they have occurred, to ensure that those affected and in need receive support and relief quickly. However, this has changed over recent years as there is a growing desire across the sector to take earlier action in response to forecasts of adverse hydrometeorological conditions, with the aim of improving response effectiveness (i.e. reducing losses and therefore the overall response requirement) as well as response efficiency. NMHSs are not expected to take actions on the ground, while disaster management authorities and the humanitarian sector play a significant role in the logistics of needs assessment. Across the interviewees, some had experiences of IbF from the NMHS perspective (5), while the remaining interviewees (6) tended to express views based on experiences linked to the humanitarian sector. The responses highlight that despite consistency in their over-arching understanding of IbF there is variability in terms of opinions of IbF's purpose, which appears to be linked to different interpretations of what IbF should provide.

The interview responses exposed different opinions of what IbF should provide and this translated into different methodologies being implemented (Figure 1). Some interviewees focussed on the development of Early Action Protocols (EAPs) and to facilitate this described the need to identify hydrometeorological triggers and/or thresholds that inform action. This typically involves historical analysis of past events and stakeholder discussion e.g. as described in Box 1 regarding the FATHUM project. Interestingly, several forecasters spoke of their move away from singular hydrometeorological thresholds to a more fluid assessment of risk that accounted for the context within which information was being disseminated (e.g. environmental and social antecedent conditions). Within this framework, methodologies included consultation with responders to inform the operating procedure for warning issuance, the development of generalised impact tables relevant to the responder capacity and sustained engagement to encourage dialogue so that the appropriate warning levels (impact severity) can be issued (Box 2). Furthermore, the interviewee responses appear to suggest a growing scale of complexity in IbF methodology development. For example, one forecaster highlighted that their initial impact-based forecasts included no vulnerability assessment. Others refer to "static" IbF methods which are considered a steppingstone towards "dynamic" IbF systems and include the integration of appropriate dynamic vulnerability and exposure information. Although, automated impact models and tools were only explicitly mentioned by a couple of interviewees, there appears to be a general shared understanding that there are different levels of IbF (Figure 1), which relate to increases in scientific and technical complexity as well as capacity and governance needs (discussed in Section 3.2).

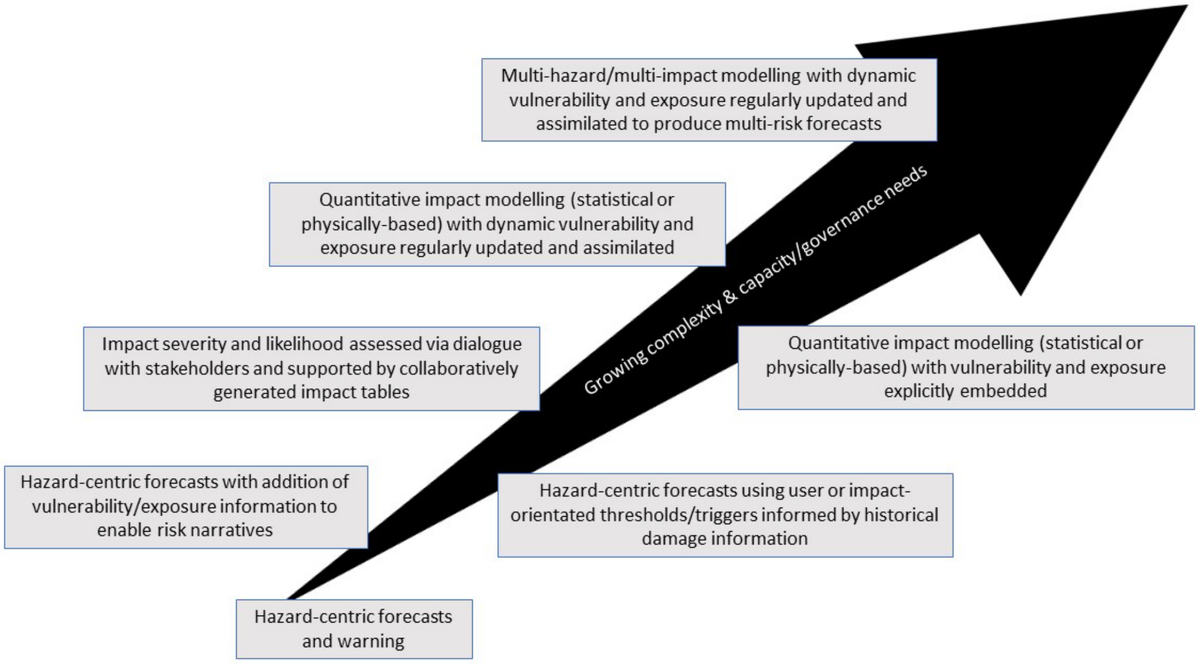

Figure 1: Simplified diagram of different IbF methodologies discussed by interviewees and identified within the literature. Note - interviewees were not directly asked to describe their IbF methodologies and therefore the above has been synthesised from their responses as a means of illustrating the variability and differing complexities. Further details and examples of IbF methodologies are provided in WMO, 2021 and Golding et al., 2022.

It was noted that there has been a lot of focus on IbF at the national scale. However, several interviewees, particularly practitioners, talked about sub-national scale outputs and being able to know exactly how many homes might be destroyed. There was also reference to a holistic assessment of impact which accounted for impacts across sectors and assets (e.g. infrastructure, livelihoods, agriculture), which requires more data and processing. In both cases, interviewees discussed the development of indicators (for vulnerability and exposure) that could be used to facilitate the integration of this information with hydrometeorological forecast information. This led to discussion about whether a single or uniform indicator of vulnerability was appropriate for IbF or whether indicators need to be more bespoke and specific to the hazard-impact combination. One forecaster shared that a one size fits all approach can work, as illustrated by some national-scale warning systems, but that perhaps "more can be gained through a degree of tailoring, whether that splits it up into two or three different methodologies" – KII4. Other interviewees recognised that in some cases subjective approaches were being used, while in others there were attempts to develop quantitative impact models. The latter were frequently linked to the concept of automation, although inclusion of quantitative and/or automated approaches didn't necessarily mean an absence of subjectivity within the full forecast value chain. It should be noted that it was almost universally recognised across the interviewees that subjective approaches were considered appropriate for IbF in the context of collaboration and deriving information and expertise from different areas. Another interviewee described how IbF methods were being developed for specific use cases and this raised questions for scalability, sustainability and uptake. For some interviewees, the disparity in methodologies was challenging, and there was a desire to harmonise approaches. However, it was recognised that these differences were largely the product of varying institutional capacities and the differing ambitions of countries and regions to support the transition to IbF.

Box 1: Experience of IbF within SHEAR - FATHUM Project

The Forecast for Anticipatory Humanitarian Action (FATHUM) project conducted research in Uganda and Mozambique to improve humanitarian response to flooding by increasing how far in advance floods can be forecast and linking forecasts to making financing available before a flood occurs. The project encompassed two key underpinning components of IbF: the linking of forecasts to actions, and collaboration between different stakeholders.

Researchers have been linking work on forecast predictability and skill, drivers of risk, and the financing of effective, appropriate, and impactful action before a disaster. This has included the development of Early Action Protocols (EAPs), which outline actions to be undertaken once forecast triggers and thresholds are reached. For example, in Mozambique, the team worked to link tropical cyclone magnitude to associated impacts and identify early actions which are appropriate and effective for the specific hazard impacts.

The project was also based on extensive collaboration between researchers and practitioners. The multi-stakeholder approach included an examination of the different parameters of success for different stakeholders, facilitating the identification of the varying perspectives, needs, and priorities of the range of actors involved. In Uganda, the Ugandan Red Cross and Ministry of Water were closely involved in the development of EAPs, including identifying and assessing suitable forecast triggers, guiding the development of a system which enables them to take effective early action.

Box 2: Experience of IbF within SHEAR - ForPAc Project

In Kenya, the Forecast-based Preparedness Action (ForPAc) project improved forecasts for flooding and drought to provide information about the impact of weather and climate conditions as well as their likelihood for decision-makers. This inclusion of impact in the forecasts supports action in anticipation of disasters, rather than in response to them.

The project delivered new operational forecasts of drought impact, co-produced by Kenya Meteorological Department (KMD), the IGAD Climate Prediction and Applications Centre (ICPAC), and the Regional Centre for Mapping of Resources for Development (RCMRD), using Vegetation Cover Index (VCI) and Standard Precipitation Index (SPI) thresholds for normal, alarm, emergency conditions established by the National Drought Management Authority (NDMA). The thresholds are based on a comparison of quantitative early warning data with baseline historical reference data as well as qualitative information from key informants and field reports.

These forecasts are used nationally by the NDMA and the Kenya Red Cross Society, who incorporate the impact information into early warning bulletins and EAPs respectively. At a regional level, the East African Regional Food Security and Nutrition Steering Group issued their first food security warning in September 2020 based on this new robust forecast method.

3.2 Is there a shared perception of the challenges, barriers and opportunities associated with implementing IbF operationally?

This section explores some of the key challenges, barriers and opportunities associated with IbF which were raised by interviewees. Specific themes have been identified and used to capture points raised.

3.2.1 Challenges and barriers

Focusing first on the challenges and barriers to IbF implementation, responses can be grouped into three broad themes: (1) Institutional capacity and governance, (2) technical expertise and knowledge and (3) transformation and sustainability.

3.2.1.1 *Institutional capacity and governance*

There is acceptance across the interviewees that the transition to IbF is a significant commitment, particularly as the shift towards more collaborative ways of working is identified as critical for IbF implementation. This has implications for resourcing, which was raised as an important challenge by all the interviewees. One researcher highlighted the need for sufficient human resource to enable organisations to engage in all the various aspects of IbF implementation. They identified this as essential when looking to scale-up approaches. Practitioners noted the need for capacity within institutions to engage with a wide range of stakeholders, and that this required a significant time commitment. One interviewee indicated that this could cause some institutions to drop away from conversations and suggested that in some cases institutions may need incentives to remain engaged. The scope of engagement can also prove challenging (e.g. bridging gaps between national and local level), particularly where there are a wide range of potential impacts, and therefore actions, associated with the hazard(s) being addressed. This is compounded where institutions have previously worked in silos and had limited, or previously negative experiences of working together.

Although there is consensus across the interviewees that successful IbF requires collaboration and engagement with a wide range of stakeholders, many also recognised that this brought additional challenges. One interviewee remarked that collaborations should be entered into cautiously, making sure that the right people are brought together and that stakeholders need to be of value, providing information and reliability, which can give confidence to the co-production process. With this, another interviewee recognised that there was potential for confusion around the roles and responsibilities of organisations involved in IbF. This was supported by another interviewee that felt that the traditional roles and responsibilities of institutions involved in the Disaster Management Cycle needed to be revised because IbF encourages a less distinct categorisation of 'users' and 'producers'. This was also raised by forecasters who highlighted that a lack of clarity around how different stakeholders are contributing to an IbF system can be a barrier (e.g. if there is concern about overlapping or replacing roles), and that there has been a need to allay the fears of some organisations who were concerned their roles might be supplanted. The challenge of evolving roles and responsibilities led several interviewees to express a need for better coordination, through a coordinating body, to manage these growing collaborations, to steer the process and coordinate the effort, as well as to ensure regular two-way communication. One of the practitioners described the importance of understanding mandates (i.e. who is responsible for leadership and coordination of IbF) and identified this as key to managing the numerous institutions involved and in developing effective and efficient IbF which can be delivered at scale. Interestingly, interviewees appeared somewhat split as to who should own or oversee IbF development with some seeing this role sitting with the response community (e.g. disaster management authorities) and others with NMHSs, although one forecaster highlighted that legislative issues can prevent some institutions from being able to implement IbF and issue impact-based warnings.

The human resource and time commitment challenges led many interviewees to highlight the need for improved governance and enhanced funding. One practitioner noted that there continues to be challenges around institutional structures and regulatory frameworks, while another emphasised the importance of a governance structure that enables effective and efficient data and knowledge sharing, as well as ensuring the ethics of integrating data that is collected, held, and used by different agencies, and that methods meet the objective – to inform action. Of course, building institutional capacity and governance structures also requires appropriate funding. Several interviewees have experience of IbF through pilot activities funded through grants. These experiences led to two financial challenges being raised. The first was on available funds to undertake the work itself. One practitioner indicated that it costs money to undertake the work needed to develop IbF science (e.g. collecting data), while there was also a need to invest financially to upskill individuals in new methods as well as to maintain and update information. The individual indicated that this was leading them to seek out funders that wanted to provide funds over longer-term programmes. They also suggested that funders who were prepared to be more agile in their thinking and be willing to iterate the activities within a programme would be beneficial for IbF development. The need for continuous funding was also raised by another interviewee, particularly when considering scaling-up and sustaining IbF beyond pilot activities. This issue is further discussed in Section 3.2.1.3.

The second financial challenge raised is related to the link between IbF and its desire to inform actions. One practitioner asked, "where's the money to implement these different actions" – KII1, recognising that there is a potential gap between early warning and early action. Similarly, another noted that funds tended to be ring-fenced for response and were not available to be integrated into forecasts, hindering preparedness activities ahead of anticipated impacts. A further interviewee raised a concern that there was a risk of losing sight of the financing element (i.e. the link between IbF and FbF) and that it was important that conversations around IbF engaged with finance systems at different levels.

3.2.1.2 Scientific and technical expertise and knowledge

The capacity and governance challenges expressed in the previous section have direct implications on what can be achieved under the umbrella of IbF. As highlighted by one interviewee, there is rarely "the capacity or resource to target everywhere at once" – KII4. This has implications for the development of tailored IbF products, as well as the potential risk that generic IbF products and services may not provide the desired benefits. The successful implementation of IbF, and the extension to FbF, requires sustained research activity across the entire forecast value chain (Figure 2 and Figure 3). The interviewee responses highlight that in addition to the people, time and monetary resource challenges, there are also technical capacity gaps.

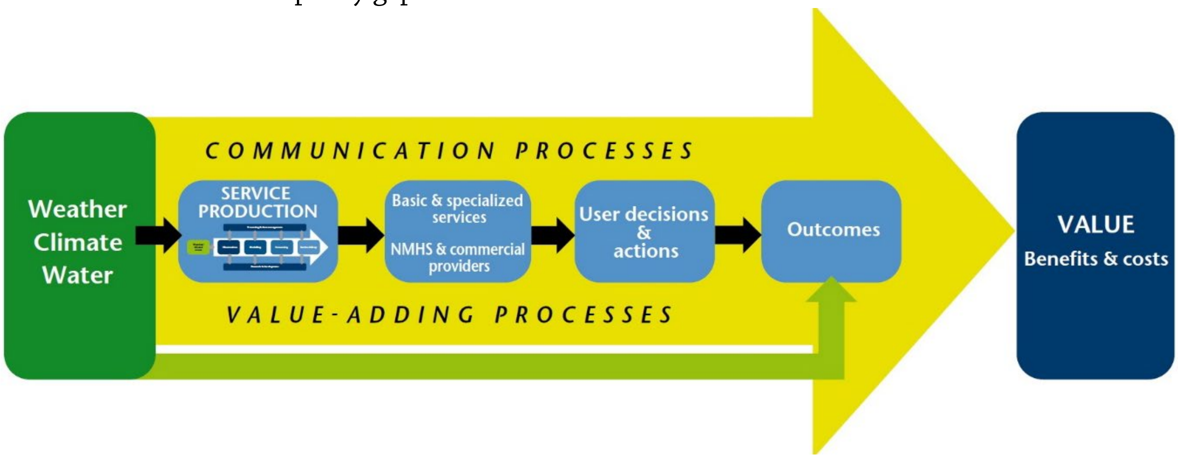

Figure 2: A simplified schematic of a meteorological/hydrological service information value chain (from WMO, 2015b).

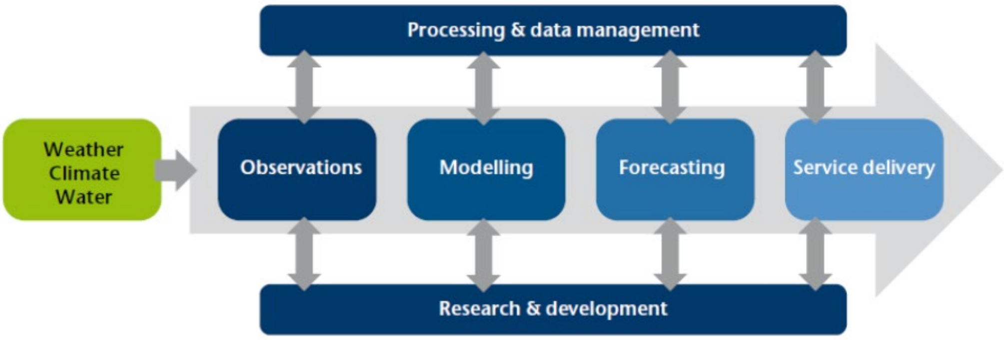

Figure 3: Components of the service production and delivery system of NMHSs (from WMO, 2015b).

A critical component of IbF is the forecast and in many cases the dynamic hazard element is defined using some form of meteorological or hydrometeorological forecast information. There is consensus across the interviewees around the need to build modelling capacity. In some cases, this was to address the lack of modelling capabilities (e.g. a lack of flood models), while in others it was to address the lack of appropriate hazard metrics (e.g. metrics relevant to the decision maker). A forecaster and practitioner both raised the issue that global models were being used in the absence of higher resolution forecasts, which resulted in the spatial distribution of the hazard being poorly represented. Both acknowledged that this had implications for impact assessments as the accuracy of the location, timing, and impact severity assessment at a locally actionable level is limited. Another forecaster stated the importance of forecast accuracy to IbF and the need for tools and technology that enable the confidence level of the forecast to be assessed. The importance of understanding the skill of forecasts was re-iterated by forecasters, researchers and practitioners alike, and was raised as a specific gap by two of the interviewees. One practitioner stated, "No one tells you how many times in the past two years this forecast is right" - KII2, while a forecaster highlighted that even where this information is known, it is rarely provided to those that might find it useful for decision making. This led many of the interviewees to express a need for improved modelling and data analysis skills (e.g. the interpretation and synthesis of data) and technical capacity across institutions. One practitioner highlighted the importance of building internal capacities by tapping into the expertise of knowledge producing centres (e.g. academic institutions) to provide scientific and technical support when undertaking skill assessment for different models.

Another significant challenge raised by the interviewees was uncertainty. One forecaster suggested a need to go down a fully probabilistic forecasting route when looking to implement IbF. This has a modelling and visualisation commitment from a resource perspective but also introduces challenges in communication. Another forecaster reflected that probabilistic forecasts are not easy for stakeholders to grasp and that it's a challenge to explain uncertainty in a way that forecasters inherently understand. Yet another suggested that communication would be easier if stakeholders understood the science of forecasting and uncertainty, and therefore additional capacity building to understand predictions and the uncertainties associated with them, as well as increased connectivity between stakeholders and service providers, was required. Across the interviewees the uncertainty discussion was predominantly focussed on the meteorological and hydrometeorological forecasts, which may be linked to their experiences of specific IbF methodologies (Figure 1). However, the complexity of linking forecasts to potential impacts was also highlighted as a source of uncertainty and errors and this raises questions as to weather forecasters can fully appreciate the uncertainties associated with dynamic exposure, vulnerability and response/behaviours. In turn, this speaks to the potential benefit of wide-ranging expertise and collaboration.

The interviewee responses indicate that there remains a challenge in identifying where and when impacts are going to occur. To make information actionable, a key aim of IbF, several interviewees talked about community, household and even individual-level impacts and the need to know the number of assets or people that might be affected by an event. This was particularly relevant to those viewing IbF through the humanitarian response lens. As one interviewee described, there remains a gap in being able to determine "this 100 households, this means I need to buy, say, 100 jerry cans. And that has hindered both decision making and also when we are writing appeals or requests for support" – KII1. This description suggests that the expectations of what IbF can achieve are much greater than where most operational and pilot IbF systems are at present, where warning systems tend to provide categorical risk forecasts (i.e. low, medium and high) with supporting, generalised impact information. This issue was further raised by one of the forecasters who highlighted that it is challenging to identify actions people should take based on broad risk forecasts, such as when a large area yellow warning, categorised as low probability and high impact, is issued (e.g. for thunderstorms). However, steps to move towards more detailed impact assessment are difficult because of the resolution of available data, particularly impact and vulnerability data.

Interviewees mentioned a range of vulnerability indicators to inform IbF, including socio-economic indicators such as poverty, literacy levels, population density and monetary resources (i.e. disposable household income), to understand coping capacities in crises. More than one interviewee expressed the need for quantitative vulnerability data, acknowledging that qualitative vulnerability information was insufficient for some purposes. Collectively responses suggest that quantitative vulnerability data challenges fall into two categories: (1) data availability and the fragmented nature of current data management structures and (2) the collection of information at a sufficient granularity. The former links to the need for governance structures, discussed in section 3.2.1.1, and is not unique to vulnerability data. One forecaster reflected that obtaining impact data was still challenging, which in turn makes understanding the interaction between hazard and vulnerability difficult. One interviewee discussed this in terms of clean water access, stating "why don't people have access to clean water when there's a flood? Maybe it's because the water sources are not well protected from other elements? It could be the sewage in cities, or in informal settlements, maybe the infrastructure for clean water is not available. Maybe the access, like the distance to access water is quite long. And when you start to look at that you start to figure out what is causing people to be vulnerable. And so, who is this person who's actually going to be vulnerable, who is this person who has to walk a long distance to access a clean water facility, who is this person who lives in a place where the infrastructure is not well set up such that this pollution of clean water, and why is that happening?" - KII3. Several interviewees highlighted that both vulnerability and impact information are often collected and stored by different organisations and that this fragmentation of information meant adjustments had to be made to tie things together for impact assessment. One suggested that more work was needed to make vulnerability data accessible (e.g. via a vulnerability database) and interactive, while another indicated that improved collection of risk information required common agreements and/or data policies on how data is reported, recorded and shared.

The issue of the granularity of impact and vulnerability data also emerged as a key theme. Gaps in the availability of vulnerability data at a useful, local scale, were highlighted. It was noted that the collection of digital, geospatial information was a time-consuming process, particularly in large and diverse countries. One practitioner indicated that there was a need to decentralise data collection and enable people in communities to collect and send information to disaster management agencies. The same interviewee also expressed a need for data collection approaches to embrace remote data collection, particularly with regard to quantifying livelihoods information. Interestingly, there appeared to be inconsistencies across the interviewees about whether a centralised or decentralised approach would be preferable to enhance risk information availability. It is likely that the solution is somewhat dependent on the hazard(s) and impact(s) being focussed on, as well as the geographic scale of the implementation. For example, one interviewee highlighted the difference between developing IbF pilots for slow-onset and rapid-onset hazards in terms of the complexities around data requirements. This consideration is also relevant to another issue raised by the interviewees – the dynamic nature of vulnerability. This was a particular concern for forecasters, where it was felt that IbF methodologies needed to move away from a 'static' approach to a 'dynamic' representation of risk. It was recognised however, that to do this vulnerability data needed to not only reflect spatial variability but also temporal variability. One forecaster stated "vulnerability in itself is variable, it's dynamic, it is not static .... You'd also have to study the dynamics of vulnerability and the variability." – KII9. Interviewees involved in Disaster Risk Management (DRM) also reflected this, describing the complexity of vulnerability data and identifying issues around the dynamics of vulnerability due to changes over time or emerging factors such as the Covid-19 pandemic. Interestingly, even should such data be available, one forecaster pointed out that there is still the challenge of integrating this information with meteorological data, stating "it has to be parametrised, understood and assimilated in the models." – KII10. It was noted therefore, that outside the hydrometeorological agencies, there needed to be human resources and skills capacity within other organisations to support them in monitoring the indicators needed for IbF. All the observations raised about risk information have connotations for the sustainability of IbF implementation, which will be discussed in the following section (3.2.1.3)

Finally, interviewees recognised the valuable role of communication and the need for communication skills and expertise in IbF. Practitioners emphasised the importance of communicating forecast information in ways that are relevant to, and useful for, decision-makers at different levels, highlighting the need to be succinct, including only information that specific users need. For example, one interviewee claimed that "There's too much science behind [the communication], and what's mostly needed is just the critical one, or two, or three words, really: this village is going to flood, this is going to be the impact, on these days… So, you develop it from the science, but summarised and digitalised, if possible, to text, or something very, very specific and very precise. And different stakeholders will need different information, so the communication bit of it has to be really well packaged." – KII 1. A forecaster also reflected on this, intimating that attempts to get everyone to understand the risk matrix were probably not practical and that using it for communication purposes could result in messages losing their simplicity and clarity. This was further supported by another interviewee who suggested that IbF outputs needed to be made relevant to the individual receiving the information. It was also noted that individual forecasts related to IbF do not occur in isolation, and that it is important for the context of forecasts to be communicated, linking a forecast to preceding bulletins, announcements or warnings, to construct a consistent narrative that can be understood.

To support the above needs, interviewees highlighted the value of advocacy skills in relation to influencing policy to facilitate the development and implementation of IbF. The need to fully resource internal and external communications skills and functions was mentioned, with the capacity to visualise and tailor information to meet different needs and aid decision making for different users. Forecasters emphasised engagement with media, including social media, to engage and communicate effectively with the general public, and described the role of forecasters as intermediaries between the science and the various stakeholders who use the information. As well as social media, communication tools such as press releases and press conferences were mentioned. One forecaster explained the value of holding joint press conferences with representatives from both the meteorological agency and the disaster management agency, so that the public can connect the warning information with action being taken. Several interviewees also described the importance of being able to communicate effectively when forecasts or warnings were incorrect. As noted by one of the forecasters, it is a challenge to deal with false alarms and missed events, and this is even more challenging in the case of impact-based warnings which aim to be actionable. "IbF is an actionable forecast, people take actions therefore it involves money and resources and should not be wasted." – KII10. This can increase the pressure on those issuing warnings and speaks to the challenges of how institutions adapt to accommodate IbF.

3.2.1.3 Transformation and sustainability

Across the interviewees there were three prominent challenges that emerged related to transformation and sustainability. The first was predominantly identified by forecasters who frequently have the remit to produce and issue warnings as part of their national remit. As already alluded, the transition to IbF is frequently seen as a significant commitment, which has associated resource and scientific and technical challenges. However, for many forecasters the transition to IbF can be seen as an expansion of their role and this can represent a source of tension. For example, one forecaster highlighted that they undertook IbF pilots around the country to assess its practicality. However, to do this, they continued to issue traditional forecasts simultaneously, therefore increasing the workload of forecasters. Another highlighted that as NMHSs transition towards IbF there is a feeling that the scope and remit of a forecaster's role is always extending. Yet another referred to the fact that forecasters need to be "smart meteorologists now instead of the traditional meteorologist" and that this involves being smarter in "communicating actions, in communicating the uncertainty in the forecast and the uncertainty with the impacts expected." – KII10.

This could have implications for meteorologist training but could also mean an increased need for more risk/impact specialists. It was also noted that the move to IbF has introduced some fuzziness or subjectivity to decision making (i.e. when, where and what severity to issue a warning) which can be challenging for forecasters who have been trained to work in a specific way. One forecaster also noted that it wasn't always possible to define all the rules for implementation, which can be difficult for organisations and individuals alike. Similarly, IbF requires collaboration, and this means bridging organisational silos and overcoming existing organisational inertia. As highlighted in section 3.2.1.1, this requires new skills and organisational frameworks, and many look to NMHSs and/or disaster management authorities to take on coordinator roles which further extends the expectations on staff in those organisations.

The second crucial element for transformation and sustainability discussed by the interviewees was the need for an evidence base to confirm that IbF is the right approach and that it is achieving the desired goals. This was raised as important for the initiation of investment in IbF, providing a means to obtain funds and resource. One researcher highlighted that it was critical to be able to evaluate the potential of IbF outputs and able to demonstrate the value of IbF both internally (within collaborative networks) and externally (to users). One forecaster highlighted the importance of questioning "does it actually work" – KII4, and this was also echoed by researchers with one stating "people can come up with these beautiful products, but I have no idea if they're accurate." – KII8. A practitioner went further still, suggesting a need for quantitative cost-benefit analysis to enable organisations to say how much had been saved by the implementing of actions based on the IbF information. Cost-benefit analysis is only one of many different methods that could be employed to help understand the value of IbF and its various methodologies, however, what is recognised is that mechanisms to assess IbF and provide evidence to its efficacy are critical.

The final element was focussed more on sustainability. As mentioned previously, several interviewees have experience of IbF through pilot activities funded through grants. Practitioners in particular were concerned that, to date, there appeared to be limited thinking on ways to make IbF operational and sustainable. It was noted that this was closely linked with resourcing and organisational capacities, and therefore one interviewee suggested that IbF needed to be embedded within existing government structures to ensure both uptake and sustainability. Similarly, another interviewee highlighted the importance of building capacities at all levels, but particularly at local levels, and that encouraging and supporting people's own agency to act would be a valuable step in ensuring legacy and sustainability. This would also involve building trust and understanding across different administrative levels, with the long-term aim of building capacities at sub-national administrative levels which could then support the national agencies involved (e.g. supporting monitoring, data collection and ground truthing). To support this, interviewees recognised a need to enhance capacity at regional, national, district and local levels, which requires continuous training and engagement with stakeholders across administrative levels. One interviewee expressed the view that there continued to be an element of a traditional, top-down approach to IbF and that sustainability would be more likely achieved using a decision-centric framework in which decision-makers at all levels are empowered to make informed decisions about how to respond to a forecast.

3.2.2 Benefits and opportunities

All interviewees reflected that IbF encouraged interdisciplinary working, engagement with different and varied stakeholders and improved understanding of the needs of different stakeholders. Collaboration and partnership were therefore seen as a considerable benefit resulting from the transition to IbF. Interviewees involved in operational forecasting were particularly keen to emphasise the shift towards more collaborative ways of working. One interviewee explained that this collaboration is particularly important for subjective IbF approaches to ensure that the different risk appetites and opinions of stakeholders are considered and integrated within the IbF system. The complexities associated with IbF led interviewees to specify a need to work together with a wide range of technical and operational institutions, such as national government ministries (e.g. public health, urban planning), international institutions, (I)NGOs, water resources management, transport, and agriculture, to bring together the different data as well as experience and expertise. Most interviewees referenced the value of multidisciplinary research and collaboration between physical scientific disciplines, such as geological and geospatial agencies and observatories as well hydrological and meteorological departments. One interviewee highlighted the value of IbF in bringing different stakeholders together to collaborate in ways that are not otherwise facilitated and supporting stakeholders to work together outside of existing silos in a continuous, ongoing process. Technical Working Groups were highlighted as a mechanism to facilitate effective collaboration, which can also be used to agree and prioritise indicators, thresholds, triggers, and best practices for IbF systems.

Collaboration with local communities was also emphasised by one of the interviewees, who explained that including the local communities is critical to understand what kinds of early actions will be possible and beneficial, and to shape relevant early action protocols which can be undertaken to reduce the impacts of disasters. One practitioner spoke about the added benefits of IbF processes building trusting relationships between communities, forecasters, and disaster risk managers as this can enhance the integration of new risk information to continually improve the accuracy of the forecasts. Linked to this, another interviewee highlighted the role of district disaster managers and their detailed local knowledge about communities, the location of households, and households with particular vulnerabilities, as well as the data collection skills of livelihoods assessors, agronomists, and crop modellers, in order to better understand the impacts of disasters in more depth.

Several researchers referenced the changing roles of forecasters and the drive of NMHSs to use IbF to generate more understandable and actionable forecasts. This was considered particularly beneficial for improving public trust in forecasts and warnings. In addition, there was a general feeling across the interviewees that IbF provides added value by facilitating early action, shifting from a reactive to proactive response in the case of the humanitarian sector, enabling the impacts of disasters to be mitigated through focused, targeted, and impactful response. The value of integrating a process of analysis of who and what will be affected by a disaster into disaster risk management planning was also emphasised. Similarly, the improved timeliness and efficiency of early action and response was also highlighted as a benefit of IbF. The provision of reliable information about expected impacts enables appropriate pre-positioning and allocation of required resources, reducing the "back and forth" involved in traditional response to determine what is needed, how much, and where.

Operationally, the role of IbF in activating contingency plans and enabling DRM and humanitarian agencies to trigger funds to act before disasters occur was a key benefit identified, with IbF providing a level of information that is normally only available once a disaster has already taken place. At the policy level, interviewees pointed to the value of IbF in motivating early action by connecting forecasts to tangible impacts, influencing decision-makers to take actions in advance that they may otherwise be reluctant to take on the basis of an uncertain forecast. For example, one interviewee explained that, "For these districts to activate contingency funds to take action, they need something that activates them. And normally that has been a disaster. After disaster happens, they assess what has been the impact and then they tap into the contingency fund to take action… So that's a gap that IbF is addressing, because it offers a more concrete analysis, and information that you can depend on to activate contingency funds, and you take early actions." – KII1

One interviewee engaged in forecasting specified that IbF supports reduced expenditure on humanitarian response as a result of facilitating and informing DRM decision making and anticipatory and early actions. Enabling resources to be mobilised more cost-efficiently and effectively is of particular importance in contexts where such resources are limited and under increasing pressure from growing humanitarian needs. Similarly, interviewees discussed the systemic value of IbF, highlighting the importance of providing a system to incorporate new and emerging information and circumstances by building in processes for checking and updating contingency plans and resource allocations.

4 Discussion

There is a consensus across interviewees that IbF represents a move towards greater cohesion between the production of forecasts and their usefulness and application in DRM. Interviewees recognised the potential value of IbF for informing effective early action, and the value of the range of expertise and perspectives contributed by the different stakeholders involved. The interviewee responses do however identify a clear gap around quantifying and assessing the value of IbF (i.e. answering the question – "Are IbF forecasts more useful and usable than traditional forecasts?), even where interviewees also cited the value of IbF as a benefit. This gap may be particularly evident across this group of interviewees because several participants have views based on non-operational IbF systems. Many of the pilot IbF systems that these interviewees were involved in have only been active for a relatively short period. Given the nature of high-impact events it is essential that evaluation and value assessment is done over multiple years. It is widely acknowledged that evaluation needs to be an iterative process and factored into IbF system implementation from the design phase and throughout the construction and application stages. Although it might be assumed that this gap was only identified by those involved in non-operational IbF pilots, it was clear that understanding the value of IbF was also seen as important to forecasters who had experience of operational systems. In these discussions, the emphasis was not only on "do IbF forecasts add value over traditional forecasts", but the interviewees also raised questions about which IbF methods might be most appropriate. As far as these authors are aware, there hasn't been any comparisons between IbF methodologies either in terms of forecast/warning accuracy or user value (e.g. interpretability and actionability). Given the differing requirements and potential capacity and governance needs of different IbF approaches (Figure 1), it would seem important for these differing approaches to be reviewed to see whether different tangible benefits to decision-makers are identifiable.

It was also interesting to reflect on the primary forecast lead times that were of interest to the different interviewees. Forecasters generally referred to IbF in the context of issuing warnings. Given the uncertainties associated with high-impact weather and impact forecasting, most warnings are issued at the short-range (i.e. 1 to 5 days ahead) and this means that the majority of impact-based forecasts relate to short-term impacts (i.e. direct and tangible impacts). This can result in specific (and potentially bespoke) hazard-asset forecasts and communications (e.g. heat and health, flooding and infrastructure) as well as more generalised assessments. However, one interviewee referenced slow-onset hazards and more complex, long-chain impact cascades. Some also referred to seasonal forecasts and climate adaptation. This raises several questions including, for example, the seamless utility of IbF approaches across different forecast lead times, the scope of impact assessment when applied at different forecast lead times (i.e. how far down the impact cascade is necessary to meet decision-maker needs) and also the additional capacity needs to engage with a growing set of stakeholders. Uncertainty grows with forecast lead time, and therefore it is likely that different forecast metrics will need to be utilised to inform IbF outputs. Similarly different styles of communication will likely be needed as actions at these different forecast lead times are often very different. Different IbF methods may be more conducive to specific forecast time horizons, but this is yet to be fully assessed.

5 Conclusions

This report provides a synthesis of 11 semi-structured interview responses, which were analysed to understand whether there is a shared understanding of what IbF means. Based on this analysis it has been possible to collate key challenges and barriers to IbF implementation, as well as identify the key benefits and opportunities expressed by the participants. Although this represents a small sample, it provides a sufficient preliminary indication of differences and similarities in stakeholder opinions of IbF implementation which can provide a valuable baseline for future expansion. Below is a summary of the key findings:

- Interviewee responses show that there is a high-level, shared understanding of what IbF is, and consensus that IbF aims to make forecasts and warnings more useful and actionable.
- Despite this consensus, different methodologies are being used to develop IbF systems, driven in part by differing perceptions of what IbF should provide. This has implications for the implementation of IbF systems which are listed in the point below.
- The interviewees expressed a range of challenges and/or barriers to IbF implementation. These can be grouped under 3 themes: (1) institutional capacity and governance, (2) scientific and technical expertise and knowledge and (3) transformation and sustainability. Under these headings the main challenges/barriers identified by interviewees include:
    - Managing limited human resources, a lack of over-arching coordination for IbF strategy and engagement and managing limited/restricted financial resource.
    - Limited understanding of the forecast skill of different models when applied to IbF, lack of metrics to effectively communicate forecast uncertainty, restricted data availability at suitable resolution for impact assessment, and a need to invest in and enhance communication strategies (internally and externally).
    - Managing increasingly fluid roles and responsibilities of organisations involved in IbF and dealing with the challenges of up-scaling, transferability and sustainability.
- All interviewees agreed that a key benefit of IbF was the growth in interdisciplinary and collaborative working, as well as the shift in focus to move towards more actionable forecasts and warnings that relate directly to the questions decision-makers and users ask.
- A critical requirement for IbF is improved evaluation and assessment of the value of the different approaches being used, with a focus on determining value from the decision-maker

perspective. This remains a gap, which if addressed, could provide an evidence base to support longer-term advocacy to address the challenges raised across these interviewee responses.

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7 Figures and boxes

8 Appendix 1

Impact-Based Forecasting for Improved Disaster Risk Preparedness and Reduction

Key Informant Interviews: Key Informant Preparation Pack

Science for Humanitarian Emergencies and Resilience (SHEAR) is an interdisciplinary, international research programme jointly funded for five years by the UK's Foreign, Commonwealth and Development Office (FCDO) and the Natural Environmental Research Council (NERC).

It aims to support improved disaster resilience and humanitarian response by advancing monitoring, assessment and prediction of natural hazards and risks across sub-Saharan Africa and South Asia. SHEAR is working with stakeholders to co-produce demand-led, people-centred science and solutions.

Research Project Background

Thank you for agreeing to participate in this interview.

As part of the SHEAR programme, a small number of "Impact and Integration" projects are working to bring together the results and findings from individual SHEAR projects, developing more robust evidence and information for users of the new science, data and tools that the SHEAR programme is generating. These projects will directly improve risk assessment and support policy development in the management of natural hazards.

This Impact and Integration project is examining SHEAR learning about impact-based forecasting (IbF), with a focus on establishing a consensus on what IbF is and identifying effective practices for establishing and implementing IbF for improved disaster risk preparedness and reduction.

We want to speak with a range of people with different experiences of IbF to understand what IbF is perceived to be, and how it can add value to disaster risk management and response.

Defining impact-based forecasting

Impact-based forecasting refers to a forecast which describes what the weather/hazard will do, as distinct from a traditional forecast which describes what the weather/hazard will be.

Purpose and process of the interview

The interview will be semi-structured, and will last for no longer than one hour. We want to hear from you, about your experience; we will provide you with the questions (see below) in advance so that you have time to think about them, and identify any questions which are of more or less interest and relevance to you. The interview will be recorded and transcribed for the purpose of analysis; all responses will be anonymised and we will consult with you before including any direct quotes.

The discussions and findings of the interviews will inform a paper which will be made publicly available as a SHEAR research output. We will share a draft of the paper with you to ensure you approve our characterisation of your input, and we will consult with you regarding acknowledgement of your valuable contribution before publication.

Thank you again for sharing your time and knowledge with us.

The interview will be based around the following questions, however we want to hear about your experience, so we will prioritise the topics which are most relevant to you.

Interview questions: IbF producers and researchers

1. Can you tell us about your experience of IbF?
2. Can you tell us about who was involved in developing the IbF you have experience of?
3. Can you tell us about what inputs were needed?
4. In your experience, what value do you think IbF offers over traditional forecasts?
    a. To whom?
    b. In what circumstances?
5. Are there any changes that you think would make the IbF(s) you have experience of more effective?
6. Could you tell us about any challenges you perceived to establishing and implementing IbF?
7. Do you have any other reflections which haven't been covered?

Interview questions: Disaster resilience and response practitioners

1. What is your understanding of IbF?
2. Can you tell us about your experience of IbF?
3. Are there any ways in which you think IbF would add value to your work?
4. What are some key challenges you face that you think IbF could help address?
5. Do you think there are any barriers to developing IbF?
6. Who do you think would be needed for IbF to work for resilience/response?
7. Do you have any other reflections that haven't been covered?