Experiences with seasonal forecasts in sub-Saharan Africa relevant for the development and application of extended lead time seasonal climate forecasts and multi-year climate forecasts; examples from Sudan

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1. Introduction and scope

Seasonal forecast products for areas of Africa have been available for several decades, and whilst many studies and reports have highlighted their potential to improve natural resources management various challenges have limited their widespread use among smallholder farmers (Hansen et al, 2011) and more widely (e.g. water resources, Ziervogel et al., 2010). Seasonal forecasts provide information over the next month up to typically 6-months into the future, generally as a probabilistic assessment of temperature or rainfall conditions. Their aim is to inform and improve decision-making to enhance operational activities, management practices, planning and profitability (Soares and Dessai, 2016). The constraints to uptake are well covered in the literature and include legitimacy, salience, access, understanding, capacity to respond and data scarcity (see Hansen et al., 2011). Momentum in seasonal forecast interest and support has waxed and waned over time across different regions in sub-Saharan Africa (SSA), partly associated with funding availability but also the experiences associated with major El Niño events like 1997/98. New initiatives such as the Global Framework for Climate Services and the recent major El Niño in 2015/16 are re-invigorating interest in this area.

Recent scientific progress in skilful prediction of Sahel summer rainfall on inter-annual and multi-year timescales (Sheen et al., 2017) has the potential to substantially increase the lead time for climate forecast information products. This review draws from experiences with seasonal forecasts in SSA to assess the potential for the design of new longer lead time products and their application, with a focus on UK DFID operational considerations. Seasonal forecasting provides a good place to start with an assessment of multi-year forecast application potential because it has received a lot of attention in SSA, has been at the forefront of work on climate services and as multi-year forecast information is in many ways a development to the use of information on seasonal timescales.

This report uses several recent key reviews of seasonal forecast use in SSA (Hansen et al., 2011; and Vaughan et al. in press). The review is structured as follows; Section 2 briefly considers the range of applications of forecast products and Section 3 profiles issues for the design and application of new forecast products. Section 4 provides perspectives on key considerations relevant for the development and application of forecasts based on consultation with stakeholder organisations (representing Agriculture, Water and Social Safety Net sectors) in Sudan during October 2018. Section 5 presents examples for the development and application of

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new longer lead time forecast products and makes recommendations on next steps (An Annex presents relevant findings from a recent report on ‘Supporting the Use of Sub-seasonal and Seasonal forecasts in DFID’).

2. Applications of seasonal forecast products across sectors

Agriculture – There is limited research concerning the *actual use* of forecasts (see for example Soares and Dessai, 2015 in Europe; Patt et al, 2005 in Zimbabwe). However, there is significantly more evidence for the *potential use* of seasonal forecasts. Such potential uses are often context-specific and relate to the specific concerns of different users. To date the agriculture sector has received by far the most attention for seasonal forecasts. Seasonal forecasts can be important for farmers as they provide an overview of what can be expected. This is important for broad level planning, especially at the beginning of the season – for example in determining what crop to plant, or how many animals to keep. Whilst farmers may not be able to make fundamental shifts once the rainy season is underway, there are still useful modifications that can ensure optimal production; for example considering the option to plant an additional crop if the rains are expected later in the season, or shifting livestock to another location (Vincent et al., 2016).

Vaughan et al (in review) identified and reviewed 59 evaluation studies of climate information use for agriculture in SSA across 22 African countries during the last 40 years. They found considerable variations in the number of studies across Africa; West (26), East (21), and southern (17). These studies identified differing levels of use and a range of uses by farmers for decisions involving the choice of fields, crops/crop varieties; timing of agricultural activities; negotiation of annual loans and application of inputs (ibid). Use by farmers was much more common than by pastoralists. They found no evidence that farmers use climate information to make large investments such as for infrastructure associated with irrigation or agroforestry. In many cases actors affected by climate variability tend to complement seasonal forecasts with shorter-term (up to 10 day) weather forecasts as the season unfolds.

Only 16 of the documents reviewed by Vaughan et al (in review) estimated the impact (as opposed to access and use) of weather/climate information with respect to yields and/or income, using a variety of methods. The estimates were wide ranging, from losses to 66% marginal gains. Impact was shown to be contingent on various characteristics of the service, the user, and their operational context.

They argue that an overall lack of objective evidence restricts the seasonal forecasting community from developing a thorough understanding of the role that climate information/services play, actual and potential, in African agricultural development (Vaughan et al, in review). They also note substantive challenges to evaluation including: the non-exclusionary nature of forecasts (which makes it difficult to track cause and effect); the highly variable nature of the climate, forecast use and impact; and the use of information is also influenced by a range of other agricultural measures and by famers' varying skills, aims and challenges.

Water resources - At present, there are very few operational examples of seasonal forecast use in the water management sector in developing countries, and few even in developed countries (Yuan et al, 2015). In the USA, whilst in principle there is good potential for seasonal climate forecasts to be employed, managers may be sensitive to revealing exact decision processes, making assessment of extent of current use difficult. However, recent advances linking climate forecasts with better data assimilations (e.g. from satellites) with improvements in land surface hydrologic models (especially higher resolution) and greater appreciation for the need for added value through climate services are driving substantial progress in the development of linked climate model seasonal-hydrological forecasts (Yuan et al, 2015). Currently all applications are focused around the 6-month and less timescale, aided by lags in river basin systems due to snowmelt (not relevant in SSA), soil moisture storage (which can affect skill out to six months) and groundwater which is particularly important during low flow periods and in regions with strong rainfall seasonality such as the Sahel (Yuan et al., 2015).

For South Africa, despite more than a decade of research on hydrological applications of seasonal forecasts, there was limited evidence of their operational use in the water sector in a review conducted in 2010 (Ziervogel et al., 2010). One African example cited is use of seasonal catchment forecasts to model seasonal commitments for power generation and agriculture for the Manantali Dam in West Africa and to inform actual dam operations (Axel and Céron 2007). We are unsure whether this practice is still operational and it comes from a very obscure citation.

Health - On seasonal (or longer) timescales forecasts can provide outlooks for climate-sensitive diseases such as vector-borne diseases like malaria and dengue fever, or diseases that increase in severity with the onset of dust in the dry season (e.g. meningococcal meningitis). This could provide opportunities to plan interventions, like mobilizing community health workers and to increase the readiness of the health care system to respond to outbreaks (Rogers et al., 2010). Evidence of operational use is limited; whilst models of malaria incidence which include climate (observed or forecast) can be used to provide early warnings in semi-arid areas (Thomson et al., 2008; e.g. Rift Vally Fever in Senegal and malaria in Botswana) several technical and operational challenges remain to be overcome before such models become routine in malaria-control strategies (Cox et al. 2007).

It is clear from the literature that seasonal climate forecasts need to be integrated within early warning and monitoring systems with good understanding of lead times, skill and response options (Thomson et al., 2008). Improved surveillance requires investment in climate and weather observing systems (often lacking in large parts of SSA) although these can be augmented with quality-controlled products from satellites that include a range of variables (Nissan et al, 2017). Nissan et al (2017) identify other opportunities for using climate information to improve malaria control and eradication: capacity building and partnerships between policy-makers and practitioners, and between climate and health communities; identify specific case studies to generate evidence for malaria eradication; and finally, to explore potential for accessing global climate adaptation funds.

Humanitarian/Insurance/Forecast Based Finance - Index-based triggers in social protection programmes are designed to incorporate secure timely policy response in the event of a shock (often drought). Whilst such triggers could utilise advance warning of dry years, there are few operational examples of this in practice. Risk-based insurance mechanisms (where using international risk-pooling, e.g. the African Risk Capacity initiative, ARC) could benefit from advance warning of co-variate shock across multiple countries involved in schemes. Important factors that facilitate timely index-based trigger activation include: relevant, good quality data and clarity in the regulation of the trigger process (Bastagli and Hardman, 2015).

How forecast products integrate with trigger and response decisions is critical. This process can be complex, for example, Ethiopia’s Risk Finance Mechanism (RFM), an index-based mechanism within the Productive Safety Net Programme is a dedicated fund that can be drawn upon in the case of drought. The RFM was established to address drought and involves a wide range of actors and information sources, including government at many levels, development partners and satellite data from several sources (including the Central Statistical Agency, National Meteorological

Agency, Ministry of Agriculture and Rural Development, Early Warning Response Directorate, Livelihoods Integration Unit, World Food Programme, EU Joint Research Centre and Famine Early Warning Systems Network (Bastagli and Hardman, 2015)).

The RFM may be triggered either on the basis of a given increase in the number of households requiring assistance following severe drought or by accumulated requests from sub-federal government (Bastagli and Hardman, 2015). The actual decisions may be subject to discussion and various influences such that they may not be based on clear explicit thresholds, but rather indicators are “monitored and referenced against thresholds ‘assigned on the basis of long-term averages’ with expert consultation then used to interpret the results” (Bastagli and Hardman, 2015; page 19).

It is important to note that impacts associated with specific triggers (event characteristics) may vary widely depending upon other environmental or socio-economic conditions (successive shocks, etc.). Therefore, some flexibility in the response to triggers is required.

In recognition of the need to integrate Disaster Risk Reduction and emergency relief activities the Red Cross Red Crescent Climate Centre is developing a novel framework for Forecast-based Action, called Forecast-based Financing (FbF). The principles are similar to index-based triggers in social protection shock response. Early warning of hydrometeorological variables are translated into a probability of impact that provides the information necessary for deciding what actions to take; an FbF system has been initiated in Pilot Studies for flood risk in Uganda and Togo (Coughlan de Perez et al, 2015). Box 1 summarises findings from a recent review of 25 examples of such schemes.

Box 1: Forecast-based Action

Summarised from Wilkinson, E., Weingärtner, L., Choularton, R., Bailey, M., Todd, M., Kniveton, D. and Cabot-Venton, C. (2018) Forecasting disasters, averting hazards; implementing forecast-based early action at scale. Overseas Development Institute, London.

Wilkinson et al (2018) review the main features of over 25 Forecast-based Action (FbA) schemes that involve a range of climate and weather (or other) forecasts, indicators and decision-making mechanisms to trigger funding and action before a shock or acute impacts are experienced. The ultimate aim being to reduce impacts on vulnerable people and their livelihoods, improve emergency preparedness, response and recovery efforts, and hence reduce the humanitarian burden. Timescales may range from several days (e.g. cyclone) to a year (in advance of a drought).

Wilkinson et al. (2018; p. 7) argue that by 'integrating forecast-based decision-making in existing national and international organisations and NGO delivery systems and in international humanitarian financing mechanisms, forecasts could play a more significant role in humanitarian practice and disaster risk management.'

Examples of FbA use a variety of financing tools, including dedicated funds, specially allocated funds in emergency response funds, insurance and direct links to regular resource allocation processes. FbA programmes have been deployed through various delivery mechanisms, including social protection systems.

In terms of forecast methods roughly half the examples reviewed use probabilistic forecasts (including all the Red Cross pilot systems, the World Food Programme (WFP)'s FoodSECuRE programme and the Inter-Agency Standing Committee (IASC) El Niño Standard Operating Procedures). Some examples use real-time monitoring data (not forecasts), including social protection systems like the Hunger Safety Net Programme (HSNP). Others use insurance-based systems (African Risk Capacity (ARC) and the Extreme El Niño Insurance for Climate Change Prevention and Adaptation in Peru (EENIP)). They note that for slowly evolving hazards like drought, real-time monitoring of impact precursors is preferential to forecast information.

In terms of assessing potential impacts four major approaches are being used, based on vulnerability and exposure information integrated with hazard forecasts: the threshold method, the qualitative combination method, the impact modelling method and the climate sensitivity method.

As with seasonal forecasts they find limited evidence on the costs and benefits of FbA, with most studies reliant on modelling and estimations. Nevertheless the review finds that early action is rapidly advancing with proponents identifying similar experiences and modifying their approaches to deal with emerging challenges; 'Although limitations persist in the forecasting skill and capacities needed to generate and interpret data, establish triggers and target vulnerable populations, the evidence seems clear that early action can reduce disaster losses and has the potential to reduce the humanitarian burden.' Wilkinson et al. (2018; p. 29).

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Summary - The range of challenges identified in the literature (mainly from the agriculture sector, but with broader relevance) include trust and confidence in the forecasts, the utility of the information, and the spatial resolution of forecasts. These have been broadly categorized as credibility (perceived technical quality of information), legitimacy (belief that the information seeks to serve the users' interests) and salience (relevance to users' needs) (see Hansen et al, 2011, also Zebiak et al, 2015; Patt et al, 2007). Another categorization uses fit, interplay and interaction (Soares and Dessai, 2016). Fit includes users' perceptions of how climate information fits with the organizational context; interplay considers how well information can integrate with pre-existing knowledge or information in the organization; and interaction deals with the relationship between the information producers and the users (Soares and Dessai, 2017). Many studies find that **a process of co-production between users, boundary agents and scientists would likely improve the effective use of seasonal forecasts**. Section 3 considers these types of challenges in relation to the design and uptake of the new longer lead time products.

3. Considerations for the development and application of new forecast products

Credibility (Risk of a 'wrong' forecast) – there are considerable institutional and political barriers to using uncertain forecast information. **Risk perception is a key factor to consider in the design of applications**. For a perfectly reliable forecast, a 10% chance of an event equates to action "in vain" 90% of the time. Accessible skill scores are required that can give decision-makers an understanding of the consequences of acting in vain (e.g. the False Alarm Ratio which indicates the likelihood of acting in vain given a specific forecast probability). Calculating the probability on which to take action requires understanding the costs of not acting and acting in vain, but these costs are difficult to quantify given that the effect of false alarms on future behaviour is not well known (Stephens et al, 2015).

Salience – there is often a major gap between seasonal forecast information and user's requirements for decision-making. For example, in agriculture for use at the farm-scale, forecasts need to be downscaled and interpreted locally; include information about growing season weather beyond the seasonal average (e.g. risk of dry spells); expresses accuracy in transparent, probabilistic terms; and interpreted in terms of agricultural impacts and management implications (Hansen et al, 2011). **Users are generally most interested in the scale and likelihood of specific impacts and these need to be derived from the forecast** – see below.

Legitimacy – **all the evidence points towards the importance of joint involvement in the design of information, dissemination and guidance on use, between producers and users (especially at the initial uptake phase)**. This requires consultation right from the outset of all the actors involved in the forecast and application process.

Access – effective, equitable and timely information delivery is required. Radio, cell phones and internet offer increasing potential (e.g. WhatsApp groups, Facebook ages). Studies show that access can vary considerably. Dissemination delivery mechanisms need careful design and thorough consultation.

Understanding – understanding of probabilistic information is a major challenge. There are examples where such probabilistic information can be used by smallholder farmers but this requires education and technical guidance to help with initial experiences. Group exercises with carefully tailored examples, decision games and use of indigenous climate indicators and culturally relevant examples can facilitate understanding. Translation into local languages is important.

Capacity to respond – what is the ability of intended users to actually act on information? Resource limitations can be critical barriers to action. Research may be needed into the conditions required to establish an enabling environment (including guidelines and sharing best practices) for at-risk people to take action based on forecasts.

Fit, interplay and interaction - fit includes users' perceptions of how climate information fits with the organizational context; interplay considers how well information can integrate with pre-existing knowledge or information in the organization; and interaction deals with the relationship between the information producers and the users (Soares and Dessai, 2017).

Linking seasonal forecast to impacts and consequences - **Joint efforts between forecast producers and information users are critical**. Results suggest that existing seasonal forecasts do not focus enough on users' needs. For water resources, in order to increase uptake, seasonal forecasts need to include information on the likely impact of rainfall fluctuations on runoff and water availability (Ziervogel et al., 2010). For health, seasonal forecasts need to be part of an integrated early warning and surveillance system with the lead times and opportunities available for control options to be explicit (Thomson et al, 2008). Regional and national level forecasting systems for drought and flood are becoming increasingly detailed and high-enough resolution for operational decision-making (Sheffield et al 2014; Jury, 2017). Such models represent good potential to translate seasonal and multi-year forecasts into impact risk assessments (and could include longer-term issues associated with groundwater recharge and reservoir storage).

Box 2 highlights the policy implications of a review of index-based trigger in social protection programmes (potentially a strong candidate for adopting the longer seasonal or multi-year forecasts).

Box 2: Design considerations identified from a review of the effectiveness of index-based triggers in ten social protection programmes with shock response mechanisms
(Paraphrased from Bastagli and Hardman, 2015):

- The number of indicators and data sources/requirements underlying the trigger mechanism influences policy response timeliness. A higher number of indicators and higher data requirements may lengthen the time of response.
- The degree of automation with which data are collected for a specific indicator also contributes to timeliness.
- Indicators that by design allow for an ex ante (predictive) response to shocks rather than those that can only allow for an ex post response.
- The type of indicator also has implications for basis risk. Indicators that capture directly observable outcomes (e.g. actual rainfall, fodder availability, crop yields) may offer lower basis risk than those that rely on proxies (e.g. estimated rainfall based on cloud coverage, estimated vegetation coverage as a proxy for fodder availability). The reliance on proxies adds scope for error to the reliance on index-based mechanisms (i.e. increases the risk of incorrectly specifying the intended target event).
- In practice, the reliance on independently observable indicators and data to activate and expand social protection has helped to ensure timely and effective social protection response.
- The timeliness of policy response once a trigger is met also hinges critically on the agreement of clear and detailed plans outlining the planned policy response.
- Once a trigger is met and/or activation is agreed on, one of the key determinants of adequate policy response is policy coverage and associated social protection targeting mechanisms.
- Contingency financing plans in the case of social assistance and reinsurance in social insurance have proved to be essential to permitting social protection index-based trigger mechanisms to function as intended. Adequate infrastructure and administrative capacity are also key requirements.

4. Consultation with stakeholders in Sudan regarding application of seasonal and multi-year rainfall forecasts

A one-day workshop – Exploring applications of multi-year predictability of Sahel rainfall – was held in Khartoum, October 15th. Introductions were made by the UNEP Office, WISER consultants, UK DFID and the Sudan Meteorological Authority (SMA). A range of government, multi-laterals and academic participants attended (see organization list in Table 1). Presentations covered the latest science on: climate predictability, timescales, variables and skill; and lessons from seasonal forecast use for multi-year applications. Thematic break-out groups were organized around (i) Agriculture, (ii) Water and (iii) Social Safety Nets, to discuss examples of potential applications of two new forecast products and their challenges and opportunities.

A longer lead time for seasonal forecast. Rather than current 2-4 months there is forecast skill for the rainy season from the preceding November (8 months lead time)

A multi-year forecast encompassing years 2 – 5 after the forecast. The forecast would be an average for the 4 years and would indicate the likelihood of rainfall being above, near, or below average across all 4 years combined (i.e. individual years could be quite different, but the average should be similar to the forecast). Forecasts could also be produced for temperature.

The discussion in the workshop was quite wide-ranging and there was considerable interest in the potential of the new forecast information. Some key points recurred as follows.

- In addition to forecasts for the rainy season characteristics, there was also substantial interest in forecasts of high temperatures during the dry season due to a range of impacts including on livestock, irrigation, crop production and human health.
- Major concern about forecast skill – SMA needs high levels of trust and reliability, whilst 2-5 years could be useful it would only be so with high confidence in forecast reliability – communities need to be convinced about effectiveness.
- Questions about skill reductions with longer lead times (and skill changes with averaging periods e.g. forecasts for the average rainfall over years 2-5 is relatively high), and questions about what are the main influencing processes of relevance to Sudan climate that are represented in the model.

- Some concerns that a 2-5 year average would not give users what they need – there is more interest in information about individual years.
- There are still challenges with dissemination and use of seasonal forecasts, how would a multi-year forecast be communicated and received given these issues?
- Incorporating more information/downscaling forecasts to local areas (something that users desire) requires considerable capacity and resources.

Key points from the three groups included;

Water: the discussion frequently came back to a range of issues relating to SMA and forecast skill and dissemination (which communication channels are most effective) and target audiences (debate about aiming for higher level technical users or extensive rural communities where there is a need for intermediaries such as extension service). This also featured and emphasized challenges that need to be considered: reliability and trust, communication to users, awareness of users, rainfall characteristics important (forecasts need to specify the onset and cessation of the season, and daily characteristics, and have clear explanation of spatial and temporal resolution). The four year average result was considered a constraint because the interannual variability is critical.

Agriculture: general issues highlighted by the agriculture discussion group included: interest in winter-time seasonal forecasts, including temperature (max/min) and wind speed, including for irrigated agriculture and nutrition / health impacts extending into the pre-monsoon hot season (spring); emphasis on the value of remotely sensed data, including for forecasting; interest in estimates of the risk of an extreme year within a 4-year mean forecast; interest in longer-lead forecasts, such as a forecast in March for the summer monsoon rains; interest in information about mean anomalies of recent periods (5-year, 10-year, 30-year), to help appreciate areas already under climate stress, and therefore help interpret the implications of the multi-year forecast.

There was recognition that a sequence of severe dry years has not been experienced since the 1980s, and while there is some evidence of greater drought resilience after learning from the 1980s experience, it is unclear what the impact now would be of a series (multi-year tendency) of relatively dry years. This led to discussion on the importance of understanding the causes of the recent shifts in climatic zones, with implicit attribution of the drivers of Sudan's climate.

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SMA is experimenting with working with agricultural extension in several areas, providing a package of products from weather to seasonal forecasts. The general feeling in the discussion was that multi-year forecasts were for now better targeted at higher level users, not for agriculture extension / farmer uptake at this stage. The Strategic Reserve was thought to be administered by the agriculture bank. Indeed, banks (and insurance companies) in general were considered likely to have the capacity to assimilate the probability multi-year forecast into their risk management strategies related to agriculture. Large agriculture companies might also have the capacity and flexibility to benefit from multi-year forecasts (such as planning for herbicides, seed strategies); one specific commercial crop / company mentioned was the Gum Arabic company, since the Gum Arabic tree takes 4-5 years to mature, while sesame was another important commercial crop sensitive to climate.

A further angle discussed was that research institutions were also potential users of the new science, developing and applying in national context the new findings presented at the workshop.

Social safety nets: key issue is precision and reliability of the climate information. The seasonal forecast must be one of many tools, so that not everything hinges on it.

Insurance companies are potential users as they need to plan to change premium rates, then make payouts later in the season. Season conditions affect the types of crops (e.g. sesame in low-rain, or sorghum in higher rain) – farmers can ask for early maturing varieties if the rainy season is short. Heavy rain will affect sesame and early maturing varieties if the rain falls when the crops are close to harvest – e.g. degrading crop and high moisture content which affects storage. Temperature for winter crops is also important – high temperature initializes flowering of plants.

The African Risk Capacity Initiative country level insurance requires premiums. 2-5 years forecasts could support greater confidence in benefiting from the insurance opportunity. This type of forecasting can be helpful. Seasonal forecasting has good potential for contingency planning.

For each group some examples of applications of the potential new forecast products were discussed (Section 5).

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Organisation	
Swedish Embassy/Swedish International Development Cooperation Agency	Ministry of Water Resources, Irrigation and Electricity - MOWRIE
Sudan Meteorological Authority	World Food Programme
Tufts University	UNDP - Climate Risk Finance
University of Medical Science and Technology	Catholic Relief Services
UN Habitat	Dams Directorate
UNDP	DFID
UNEP	FAO
UNHCR	UNRCO
UNICEF	IOM
University of Khartoum - Institute of Environmental Studies	Ground Water & Wadi Directorate- Wadis Department (within MOWRIE)
MOWRIE- Dams Implementation Unit	WHO

Table 1. Organisations with members present at the workshop.

5. Examples for the development and application of new longer lead time (seasonal) and multi-year forecast products – from Sudan

5.1. Introduction

This section reviews aspects of the discussions that delivered ideas for taking the new science forward into applications across a range of sectors. No specific discussions were conducted with partners on practicalities (sectoral risk management, climate products), in part to ensure expectations were managed at this stage, and that the discussions remained free-flowing. Therefore, to move forward, a first step would be to discuss further with the potential partners and stakeholders. Nonetheless, the impression at the workshop, and through initial post-workshop feedback, is that there is much interest amongst the sectoral groups to explore further, and that SMA were also interested on the technical climate product development side.

In the notes, some examples emerge of actions that could be undertaken relatively quickly and which could potentially serve as initial pilot activities to learn from. In addition, other examples emerge that clearly would require a substantial effort to fully elaborate, with sustained engagement across institutions in order to deliver on potential advances.

5.2. Ideas emerging in each discussion group

5.2.1 Agriculture Group

Potential in-Sudan partners: WFP, SMA.

During the discussion, participants emphasized two aspects of agriculture in Sudan that could benefit from tailored enhanced seasonal forecasts: (i) For agriculture focused on the June-September rainy season, it was felt that increasing lead time, at least to have a first indication available in March, would add great value, including to WFP activities. Therefore, it may be considered whether the Sheen et al. model runs (or other) may be available for SMA to evaluate this potential over Sudan. Sheen et al. runs are initialized in November and so are for even longer-lead than requested: these could be analyzed, or perhaps others are available. (ii) For agriculture activity during the winter half of the year, strong demand was expressed for forecast information including temperature, and if possible, wind speed. Therefore, analysis may consider the predictability of seasonal temperature (including min and max temperature as well as wind speed) for the winter cropping season. The period of interest would be Oct-Feb/Mar. Therefore, ideally hindcasts initialized in Aug/Sep would be of most interest. But the Sheen et al. results (initialized in Nov) may be analyzed as a starting point: one aspect of particular interest was risk of excessive heat in Feb-Mar which can lead to crop failure. Such a follow-up activity with WFP may also make some targeted verifications of the Sheen et al. multi-year predictions in Sudan, to focus thinking about the potential of using the multi-year forecast as a contribution to WFP strategic planning on those timescales, as a contribution to planning the most effective development interventions.

5.2.2 Water Group

Potential in-Sudan partners: SMA, Ministry of Water Resources, Irrigation and Electricity (MOWRIE).

Main area discussed: Reservoir management for hydropower and irrigation **–** most potential for use in the Nile system because of the large size of reservoirs (particularly Merowe and Roseries) and larger irrigation schemes. This is a good entry point for both products because there are already established some early warning measures that could be built upon. Electricity from hydropower – interest in forecasting deficits in electricity generation as they are facing problems in the flood season (too much water) and dry season (too little). Longer lead time forecasts of rainfall could help with reservoir management decisions. This could become more critical with the Grand Ethiopian Renaissance Dam (GERD) as dry years could lead to problems in Sudan particularly during the filling stage.

Rainfall estimates are used to provide roughly three days early warning from monitoring rainfall over Ethiopia. For the Nile system hydrology the ministry has various models (from the Nile Basin Initiative) including for flood warning, river flows, and crop modelling. These are high resolution models and seasonal forecasts would require some kind of downscaling (spatial and possibly temporal).

A flood early warning system for the Blue Nile uses combined data sources for input derived from meteorological stations, hydromet stations and satellite data (includes critical river levels as trigger points for action). There are data issues associated with low reporting/operation of observation stations. The Ministry of Water Resources, Irrigation and Electricity (MOWRIE) receives daily, dekadal and monthly reports about rainfall and temperature all through the year from SMA (a recent move of SMA into MOWIE could help with coordination). MOWRIE control river gauges. Some agromet stations are controlled by the Ministry of Agriculture and Animal Resources, but they are separate at the moment, and there is limited coordination.

Key organisation at national level is MOWRIE - many lower level departments with a range of responsibilities would also be relevant (e.g. Dam Implementation Unit). The Ministry of Agriculture and Forestry, and the Minstry of Animals Wealth and Fishery lead on planting decisions and irrigation water management.

Two other opportunities were discussed in brief:

1. Beyond areas served by the Nile there is extensive reliance on rainwater harvesting (RWH) particularly in drier areas (RWH is situated within MOWRIE with a regional research centre for RWH). People reliant on alluvial aquifers in some eastern areas and if there is low rainfall then groundwater levels decline. Early warning would be helpful, but information on rainfall intensity and distribution and evaporation would be most useful.
2. Pastoralists migration - in Darfur for example pastoralists are using movement corridors from north to south, following rains/grazing. There is potential to support interventions using forecasts to delay movement of animals going south, to take full advantage of grazing resources, where good rainfall is expected. But reliability of forecasts also critical – example given of Darfur during 2015/16 El Niño when northern areas had reasonable rainfall but southern areas were dry – however, there is no evidence presented in the Sheen et al analyses of information at this spatial scale (nor is there science out there to suggest it should), so this situation is probably not a high priority aspect to explore for now.

5.2.3 Safety Nets Group

(Group included WFP, FAO (academic/consultant), IES, UNHCR, SMA, RC office and UNEP)

Potential in-Sudan partners: Not discussed but WFP with SMA were a strong candidate partnership.

Main Area 1: Micro-finance and risk using weather index insurance. With an indexing approach if the rainfall is below average, the insurance company doesn't have to go to the farm to see losses, they are indexed against an estimated relationship between rainfall and harvest. There is an on-going weather finance and micro-insurance project run by the HCENR as part of the NAPA. The funding is from the LDC fund. SMA operates a 1-3 days weather forecast and plans to issue a 10-day weather forecast after recently holding a product development workshop. To add an element of early warning would require SMA to provide the forecast and probably also a reliable weather station nearby to derive a more robust index relationship. SMA has recently begun installing raingauges in various localities to expand the rainfall monitoring network to support the Climate Risk Finance project. The weather index itself is a challenge – it is very site specific, especially in Sudan where rainfall variability is high. This is a problem faced in the current project – it has been difficult to identify a clear relationship between the crop yield and rainfall. More analysis and more observations are required (rainfall and crop yields). If a robust index is found there is potential to expand to the livestock sector, possibly using remotely sensed vegetation. However, whilst SMA has developed staff capacity to model sorghum, the phenology and soil data are scarce and not available in a suitable format. Hence, collaboration with research institutes would be crucial to ensure the implementation of crop modelling and uptake of results.

Main Area 2: Productive safety nets – WFP programme. Prioritizing areas of low food security and coordinating with the MOWSS Productive safety net in North Kordofan. The programme is using their Zakat list for cash transfers, working to strengthen the proxy they currently use. There is potential to explore how reactive this system could be if it had a longer term forecast and whether it would be able to incorporate that predictability for fundraising. At the moment, cash is calculated based on the minimum or accepted wage for unskilled labor. If paid earlier, they may not lose their assets. WFP would need strong donor buy-in to develop such a scheme, e.g. high probability (and confidence) of drought, would be necessary to set up a project to reach beneficiaries before shortfalls occur. The need to integrate seasonal forecasts with socio-economic factors was stressed.

Forecasting agricultural seasons and reducing post-harvest losses was also a key interest. To be able to go out 8-months in advance with drought and overlay that with socioeconomic factors, would allow earlier preparation for projects.

Further area: Fire Management. One other opportunity was discussed in brief: FAO project on fire monitoring, the amount of biomass depends on the rainy season, and frequency of fires in Sudan. There is ongoing work to monitor biomass each year using information from the SMA. Interested in trying seasonal forecast to assess potential application to early warning.

5.3. Recommendations for next steps

SUMMARY OF GENERIC CLIMATE PRODUCTS

Potential for Action Now – Products 1 - 2

1) Development of the current seasonal and multi-year forecast. Building on the Sheen et al. analysis and drawing on UKMO model output, a tercile rainfall product for indices of the Sahel, West Sahel and East Sahel could likely be operationalized with a modest amount of additional applied-oriented research and development . The product could be for year-1 (extension of seasonal forecast) and years 2-5 (a multi-year forecast). A target could be to have information available ahead of the 2019 rainy season.

2) Risk of extreme years within the 2-5 year period. A small amount of additional diagnostic work could provide supporting diagnostic information on the risk of very dry / very wet years within a 2-5 year period, based on the predicted 2-5 year tercile. This information would address concern over what the 2-5 year forecast means in terms of within-period variability.

Potential for Action Medium Term – Products 3 - 5

3) Multi-model forecasts. Building on the Sheen et al. analysis, and the role of UKMO as WMO lead center coordinating with forecasts from other centers, a pathway to a multi-model product may be envisioned with a possible timeline of 1-2 years. Considerable discussion, and methodological development would be needed along the way.

4) Expression of forecast as simple Drought risk indices. A fast-track option would be to generate diagnostics relating tercile rainfall forecasts to drought risk indices such as SPI, WRSI or other.
[A further project opportunity exists to couple climate forecasts with biophysical modelling across the Sahel. This has high likelihood of success (literature has already established the basis) but the work would require a multi-year project with appropriate modelling expertise).]

5) **Recent Multi-year rainfall anomalies / trends for context.** Contextualizing information on recent multi-year trends / anomalies. Products 4 and 5 would add value to the multi-year forecast for users, and require relatively modest inputs of time for development.

Item with Longer-term Potential – Product 6

6) Regional forecasts through regional collaboration. Moving to a regional multi-year product with a regional partner (such as ICPAC) may be considered as 1-2+ year target, initially extending the boreal summer work of Sheen et al (therefore only applicable to the northern part of the ICPAC domain), and ultimately, assuming new evaluations justify, to other seasons / regions as well.

SUMMARY OF SUDAN APPLICATIONS (All requiring coordination with and/or some inputs from SMA)

Potential for Action now - Products 7 - 9

7) Safety nets. The workshop identified a demand for multi-year rainfall / drought forecast information to help inform actions associated with safety nets under a WFP programme. Combined with more general interest in using the multi-year information to help inform investments, this appears to create a framework for a quick-start collaboration to explore details of predictability and undertake experimental product development in the context of a clear demand for the information.

8) Longer-lead seasonal rainfall forecast for agriculture planning. Demand for the extended lead seasonal forecast was expressed by WFP. In some respects, this may be considered to have lower priority than Product 7 above, given the relatively lower skill of the product and less innovative application, but this would represent opportunity to develop further existing seasonal forecast capacity (SMA) and also, explore skill assessment with denser network of observations. It may be a valuable complement to Product 7 above.

9) Other quick start applications of forecast products, but requiring some scoping.

i) Winter temperature (and wind speed) focus, choose one or two targets from those discussed at workshop, to drive some exploration of this under-explored aspect of climate risk in the Sahel. May have lower priority than Product 7, and may be more considered medium term for starting given some further discussions needed to choose target applications, but represents a clear outcome of the workshop to explore opportunity for both seasonal and multi-year forecasts, which at least for temperature, can be expected to have good levels of skill that would allow relatively confident interventions. (If undertaken, it may be natural to consider also building a winter temperature product for the Sahel region as a whole, as well as for the targeted application in Sudan, thereby also triggering a complement to the generic products 1-6).

ii) Water availability, water harvesting. Further scoping is needed, although clear expression of demand was made for seasonal and multi-year information.

iii) Fire management. Further scoping is needed, but represents a focused target of opportunity, an area that has been addressed in other fire risk areas.

Items with Longer-term Potential - Products 10 - 12

10) Reservoir management. Perhaps the most substantial opportunity for further development. Integrating information from seasonal to multi-year in reservoir operations represents the potential for substantial improvements including in flood management, power generation, and irrigation efficiency.

11) Index Insurance. Initiatives in Sudan are clearly sensitive to climate, but the ways in which the forecasts may be effectively used remains challenging. There may be potential to connect to other initiatives addressing the forecast question explicitly.

12) Extension into Regional application. There is good potential to explore link-up with opportunities from Sudan workshop with other regional application initiatives, e.g. food security.

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Annex: Relevant recommendations taken from 'Supporting the Use of Sub-seasonal and Seasonal forecasts in DFID (SUSSD) Final Project Report' UK Met Office/DFID, 2018

University of Reading and the Met Office produce a monthly Climate Note for DFID. The Note reviews recent climate conditions and summarises the latest sub-seasonal and seasonal forecasts (1-6 months ahead) of temperature and precipitation. Information is presented at country scale. SUSSD is a six-month research project to improve the Notes by investigating (a) the performance of seasonal forecasts in East Africa; (b) user perceptions of the existing Notes; (c) improvements to the information design and graphic presentation of the Notes.

Survey results show that users have a favourable perception of the Notes, particularly the text-based summaries and the map-based "current status" and forecast information.

Users have a wide remit and so find regional-scale information most useful.

Most respondents indicated that they scanned the Note quickly, to find potential "red flags" for the need for humanitarian response.

Users requested sub-national information, map-based rather than tabular presentation of data and further information on the risk of extremes leading to humanitarian impacts (e.g., drought, famine, flooding, heatwaves).

We recommend further research into methods for extracting accurate sub-national information from forecasts and developing a web-based platform to allow users to filter information for their countries of interest.

Design workshops held at DFID and expert opinions from information designers have culminated in a proposed revised PowerPoint deck that creates more space for text-based commentary, eases scanning and access to country- and region-specific information and reduces the file size for easier distribution via email.

Further information-design recommendations include introducing a controlled vocabulary in the text-based sections to avoid misperceptions among users, producing brief training videos to aid users in interpreting the Notes, and exploring

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new and revised methods for presenting map-based information, including at sub-national scale.

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