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The land management tool: Developing a climate service in Southwest UK

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ABSTRACT

Seasonal climate forecasts (SCFs) have significant potential to support shorter-term agricultural decisions and longer-term climate adaptation plans, but uptake in Europe has to date been low. Under the European Union funded project, European Provision Of Regional Impacts Assessments on Seasonal and Decadal Timescales (EUPORIAS) we have developed the Land Management Tool (LMTool), a prototype seasonal climate service for land managers, working closely in collaboration with two stakeholder organizations, Clinton Devon Estates (CDE) and the National Farmers Union (NFU). LMTool was one of several prototype climate services selected for development within EUPORIAS, including those for the UK transport network, food security in Ethiopia, renewable energy production, hydroelectric energy production in Sweden, and river management in two French basins. The LMTool provides SCFs (1–3 months ahead) to farmers in the Southwest UK, alongside 14-day site specific weather forecasts during the winter months when the skill of seasonal forecasts is greatest.

We describe the processes through which the LMTool was co-designed and developed with the farmers, its technical development and key features; critically examine the lessons learned and their implications for providing future climate services for land managers; and finally assess the feasibility of delivering an operational winter seasonal climate service for UK land managers.

A number of key learning points from developing the prototype may benefit future work in climate services for the land management and agriculture sector; many of these points are also valid for climate services in other sectors. Prototype development strongly benefitted from; working with intermediaries to identify representative, engaged land managers; an iterative and flexible process of co-design with the farmer group; and from an interdisciplinary project team. Further work is needed to develop a better understanding of the role of forecast skill in land management decision making, the potential benefits of downscaling and how seasonal forecasts can help support land managers decision-making processes. The prototype would require considerable work to implement a robust operational forecast system, and a longer period to demonstrate the value of the services provided. Finally, the potential for such services to be applied more widely in Europe is not well understood and would require further stakeholder engagement and forecast development.

Practical implications

As part of the EU project EUPORIAS (Buontempo and Hewitt, 2017), the UK Met Office, University of Leeds, Predictia and KNMI—in close collaboration with Clinton Devon Estates (CDE) and the National Farmers Union (NFU)—have developed the Land Management Tool (LMTool), a prototype

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climate service providing seasonal climate forecasts (1–3 months ahead) to support land management-related decision making for Southwest UK. This service focuses on the winter months since recent advances in the prediction of the North Atlantic Oscillation (NAO) allows for better seasonal forecasts of the Northern Europe winter climate (see Scaife et al., 2014, for further details). The choice to focus on winter seasonal forecasts was a deliberate, a priori decision of the development team, given that forecast skill was a requirement during the EUPORIAS prototype selection process (Buontempo et al. 2017).

The LMTool was iteratively developed between January 2014 and May 2016, building strongly on a range of stakeholder engagement activities (workshops, interviews, surveys and feedback gathering) carried out with land managers. During the first winter (2014/2015), the project worked closely with a small, representative subset of farmers to blueprint the prototype service, providing 3-month outlooks of temperature and precipitation for the county of Devon in hardcopy and email. Insights gained from the several stakeholder engagement activities during the first winter were then taken forward, alongside engaging a wider farmer group, in developing forecast products for the following winter (2015/2016): 3-month outlooks of temperature and rainfall for the whole UK (delivered at the end of each month from September to February), and also 14-day forecasts of rain, temperature and winds for a set of weather stations across South West UK (updated every 6-h). This time, these products were delivered via an interactive password-protected website (which forms part of a more general micro site describing the whole prototype: http://lmtool.euporias.eu/) and a mobile app. These user-friendly e-platforms have been found to be very useful to carry the prototype to the public.

A number of key learning points from developing the prototype may benefit future work in climate services, particularly those in the land management and agriculture sectors. Working closely with stakeholders is an important element of climate service development including developing the initial research proposal, and we found significant value in involving intermediaries (CDE and NFU) to both set initial scope, and help identify engaged, representative farmers to work with throughout the project. For instance, working initially with a small, representative user group allowed us to rapidly test and develop products which could then be rolled out to a larger group in the following steps. Prototype development strongly benefitted from an iterative process of co-design with the farmer group, and from an interdisciplinary project team (e.g. weather/climate science, social science, technology).

Remaining flexible about project scope also helped us to deliver a prototype that was more relevant to, and usable by the farmers. For example, although the initial scope was around seasonal forecasts for cover-crop decisions, the farmers found additional value in the provision of shorter-term (14-day) weather information and the outlooks were relevant to a much wider range of land management decisions (e.g. forestry, grassland and livestock management). The farmers asked for seasonal forecast information to be made available to them in a tiered approach, starting with headline messages and gradually increasing in depth and complexity to reveal full background information depending on their level of interest.

Driven by farmer feedback, clear and simplified presentation of probabilistic forecasts increased their uptake and comprehension. The users noted that even relatively complex probabilistic forecast information that was new to them could be understood given time to become familiar with it. Finally, although it was often difficult to identify a particular decision or action which directly depended on a forecast provided by the prototype, making it challenging to attach a monetary value, farmer feedback suggested a much broader definition of value (e.g. increased knowledge of climatology, forecast uncertainty, useful background information alongside shorter-term forecasts, etc.).

There are several areas for further development of our prototype. Firstly, especially given the low skill of current seasonal forecast systems in Europe outside the winter period, further work is needed to understand the role of forecast skill in land management decision making, and the potential benefits of techniques such as downscaling to provide more locally-relevant forecasts. Secondly, our prototype was developed as a research tool, and considerable work would be required to implement a robust operational forecast system. Although we gained considerable insights from the two seasons of prototype development, a much longer period would be required to demonstrate the value of the services provided given the seasonal nature of decision making, and the skill levels of the underlying forecast systems. Finally, the potential for such services to be applied more widely (e.g. across the UK or Europe) is not well understood and would require more stakeholder engagement work and forecast development. This requires not only gathering and coordination of appropriate impact data (Buontempo et al. 2017) but also the development of new methods for understanding the value of climate services in land management decision making (Bruno Soares, 2017). It is also recommended to focus on areas where the forecast models have considerable skill. In particular, provision of seasonal forecasts for key world crop growing regions could be of benefit to farmers in anticipating changes in grain prices and market changes, whilst acting as an entry point to more local application of similar climate services in the longer-term.

1. Introduction

Climate variability and extreme weather events can have wide-ranging impacts on agriculture including, but not limited to, crop stress due to high temperatures, impacts on crops due to high rainfall (lodging, water logging), and reduced water availability due to drought (Falloon and Betts, 2010; GFS, 2014; Falloon et al., 2015). For example, the summer of 2012 was a remarkably wet season which impacted wheat yields in the UK with an overall yield reduction of 14% (Defra, 2012). In contrast, the 2003 heat wave in Europe was one of the hottest summers on record, reducing maize yields in France and Italy by 30–35% as a result of the increased heat and drought stress (Ciais et al., 2005). In this context, availability and access to climate information such as seasonal climate forecasts (SCFs) which provide probabilistic outlooks for a month to a year ahead, can have a significant potential to support and inform both shorter-term agricultural decisions as well as longer-term climate adaptation plans (Van der Linden and Mitchell, 2009).

SCFs have been applied in agriculture and land management contexts in some regions of the world, notably Africa, Brazil, the US and Australia (Dessai and Bruno Soares, 2013; Hansen et al., 2011). For example, the Brazilian state of Ceará adopted SCFs in 1989 to manage drought conditions. In 1992, the government used forecasts to warn local farmers of an imminent El Niño and provide them with drought-tolerant seeds, substantially increasing farmers' yields compared to what was expected. Since then, the Ceará's weather forecasting agency (FUNCEME, http://www.funceme.br/) has been continuously developing SCFs to inform government sectors involved in agricultural policy-making and drought relief for subsistence farmers (Lemos et al., 2002). Another example is AgroClimate (http://agroclimate.org/) which provides a range of outlooks relevant to local producers in the southeast US, such as SCFs of temperature and rainfall, alongside short-term rainfall forecasts, a drought outlook, hurricane forecasts, and a range of agriculture-focused tools including a planting date planner and disease advisories. The European Joint Research Centre also provides monitoring bulletins and crop yield forecasts for Europe (http://mars.jrc.ec.europa.eu/mars/About-us/AGRI4CAST/MARS-Bulletins-for-Europe). These include an agro meteorological overview looking back at the weather over the past month, and a forecast for the next ten days. The content varies according to the time of year e.g. frost kill analysis for winter crops, and more detailed observed information such as heat wave/rainfall forecasts around ripening time. The main purpose of these bulletins is for policy decisions as they contribute to the evaluation of global crop production estimates which feed into the management of the Common Agricultural Policy.

However, these examples do not reflect the norm and overall there has been relatively little uptake of SCFs for decision-making in Europe, including in the agricultural sector (Bruno Soares and Dessai, 2015, 2016). Seasonal forecasts are also not currently targeted at the European land management community (Calanca et al., 2011), and most current land management decisions rely on short-term weather forecasts (mainly 1–5 days). The limited uptake is partly driven by the relatively low accuracy of SCFs in Europe (Meinke et al., 2006; Davey and Brookshaw, 2011; Demeritt et al., 2013) as well as other non-technical factors such as the lack of relevance of the information to the user, the lack of awareness and/or accessibility to the forecasts, and capacity to understand and use SCFs (Bruno Soares and Dessai, 2016; Lemos et al., 2012), all of which may limit their direct use in operational applications (Coelho and Costa, 2010). For example, SCFs are commonly uncertain and presented as probabilities, which brings additional challenges in communicating forecast information to end-users (Falloon et al., 2013). Therefore, to be useful, climate information must be tailored to meet the needs of users, and improvements in the dissemination of actionable seasonal climate information are also needed. To meet these needs, climate services bridge the gap between forecast producers and users by aiming to provide timely, useful and understandable information to a wide range of sectors, and the public.

European Union funded projects such as European Provision Of Regional Impacts Assessments on Seasonal and Decadal Timescales (EUPORIAS; Hewitt et al., 2013; Buontempo and Hewitt, 2017, www.euporias.eu) and Seasonal-to-decadal climate Prediction for the improvement of European Climate Services (SPECS: http://www.specs-fp7.eu/) have contributed to the development of climate services in Europe. Within EUPORIAS, a number of climate services prototypes have been developed focusing on a range of sectors and European countries, including agriculture and transport (see http://www.euporias.eu/cuip). The selection of prototypes (Buontempo et al., 2017) in EUPORIAS consisted of two phases. Firstly, general criteria that contribute to the success of a climate service were agreed upon by all project participants including the presence of a well identified user with a clearly defined question to be informed, and evidence of sufficient skill in the prediction of the relevant climate parameters. Each project partner was then invited to submit one or multiple proposals for their evaluation as prototypes. Finally, the management board of the project appointed an external panel to rank the proposals using the selected criteria.

One of the selected prototypes was developed between project partners in close collaboration with two stakeholder organizations, Clinton Devon Estates (CDE) and the National Farmers Union (NFU). This working climate service prototype entitled the Land Management Tool (LMTool) provides SCFs (1–3 months ahead) to farmers in the Southwest UK, alongside 14-day site specific weather forecasts.

While the predictive skill of seasonal forecasts is limited during much of the year in Northern Europe, recent advances in seasonal forecasting mean it is now possible to provide advance notice of a colder and drier, or warmer and wetter winter than average conditions (see Scaife et al., 2014; Dunstone et al., 2016 for further details), so the LMTool only provides forecasts during the winter months, in line with the EUPORIAS prototype selection criteria noted above (Buontempo et al., 2017).

The aims of this paper are threefold. Firstly, to describe the processes through which the LMTool was co-designed and developed with the farmers involved, focusing on the technical development of the tool and its key features. Secondly, to critically examine the lessons learned through the development of the LMTool and the implications for providing and improving potential future climate services in the UK and Europe in general. Thirdly, to assess the feasibility of delivering an operational winter seasonal climate service for UK land managers. The scope was deliberately limited to UK farmers given the wide range of potential land management activities across Europe and limited resources for stakeholder engagement activities.

Section 2 describes the methods applied in the development of the LMTool, both in terms of stakeholders' engagement and the technical aspects of the forecasts provided. It also describes the principles of climate services development which served as a guiding framework when developing the LMTool. Section 3 describes the two main stages of developing the tool focusing on the winter periods of 2014/2015 and 2015/2016. Section 4 reviews the development of the prototype with respect to the ECOMS climate service principles and assesses the potential value and limitations of the LMTool for farmers within and beyond the Southwest UK.

2. Stakeholder engagement methods and weather/climate data sources

The LMTool was iteratively developed between January 2014 and May 2016, using agile project management practices as a co-developed service with farmers and land managers through a range of engagement activities (workshops, interviews, surveys and feedback forms) to inform the technical aspects of the tool.

A mixed methods approach was used in the development of the LMTool in order to allow the collection of complementary data with regard to the information needs of the farmers involved as well as the refinement of the technical aspects of the tool. As a result, both qualitative and quantitative data were gathered using different types of data collection including surveys, interviews and workshops (Gray, 2009). The outcomes of these stakeholder engagement activities and their impact on prototype development are more fully described in Section 3.

Another critical and underpinning framework used in the development of the LMTool was the principles of climate services development (Table 1). These principles, developed under the auspices of the ECOMS[1] initiative served as a guiding framing both in the development of the LMTool and as a reference when reflecting on the success of developing and implementing the tool.

As previously mentioned, the LMTool provided two types of forecast products: 3-month outlooks and 14-day forecasts. The former were based on the Met Office's UK contingency planners forecasts (CPFs), which provide 3 month outlooks for temperature and precipitation for the UK as a whole each month. These outlooks were provided during the winter months (September-May) building on the recent improvements found for the predictability of the winter North Atlantic Oscillation (NAO) in the Glosea5 seasonal forecast system (Scaife et al., 2014). Glosea5 underpins the CPFs, leading to more skillful seasonal winter climate predictions over Northern Europe.

As a general indication of skill, the correlation between Glosea5 ensemble hindcasts and the observed winter NAO (December-February)

[1] ECOMS stands for European Coordination of Climate Services Activities. For more information see: http://www.eu-ecoms.eu.

Table 1
Application of ECOMS climate service development principles (http://www.euporias.eu/sites/default/files/event/files/ECOMS_principles_web.pdf) in the LMTool prototype.

Principle	Elements	Application in LMTool
1) Be mindful of the edges	Who are the users and possible users of the climate service? What is the proposed approach? What are the motivations of each participant to take part to the project?	Users: initially land managers and farmers in Southwest UK, potential for broader application to the land sector and other regions. Proposed approach: develop user-friendly ways to present seasonal forecasts to support winter land management decisions. Motivations: use longer-term weather/climate information to inform more robust decision making and support resilience in land management activities.
2) It takes (at least) two to "service"	Have all the relevant people been involved in the discussion? Does the project initiator have a good understanding of the end-users' needs? Do the providers have all the skills needed to deliver the service on time and in full? What expertise will the users contribute to the climate service development?	Broad initial discussions with CDE began with high level representatives of key areas, helping to define the initial focus on agriculture, and provided contact with a small group of "on the ground" farmers to work with more closely. User group expanded in second year, via wider involvement from CDE farmers, and involvement of NFU representatives. Project partners involved in provision were changed in response to evolving demands. Users defined service development via user engagement activities (interviews, workshops, feedback gathering, surveys)
3) Listen to understand	It is essential that the scope is clearly defined at the beginning of the project and to ensure there is a common understanding how the scope is evolving throughout the project. It is also important to maintain a clear understanding of what is not within the scope of the project	Scope clearly defined in initial project workshops involving all project partners, and redefined as necessary during the project in response to findings of user engagement activities. Activities out of scope kept in a log for future service development
4) Be open to be believed	Be honest about what is and it is not achievable within the project. Be open about new ideas that can alter your perception of what is and is not possible. Spell out all the possible issues, (scientific, technical, legal, political or commercial) which could limit the service	As noted above, scope, as well as the strengths and weaknesses of the forecasts were clearly defined and communicated to the stakeholders from inception. A critical aspect of this is that it would not be a fully-functioning operational service, but was a prototype. The close working relationship between project partners and stakeholders facilitated transparent discussions about achievable outcomes
5) Take the journey together	The service (should) provide value to users but it is also important to identify value (not necessarily monetary) to the provider. Make clear what each actor involved is expecting to get out of the service, meaning the journey can be more easily taken together	Detailed interviews were held with stakeholders early on in the project, helping to define the value to users. Value to users was further assessed through questionnaires, surveys, a workshop and regular feedback gathering. The prototype nature of the project defined value to the providers - learning about the process of developing a climate service for land managers, and lessons for future work
6) Be flexible!	Expect changes in the scope as this is part of human nature. Maintaining a highly interactive and flexible work – programme you will be able to account for some of those changes. Make clear what this means in terms of scope and what are the boundaries of flexibility	The project changed scope considerably during the project, in some cases by design. For instance, the user engagement activities were specifically designed to inform development of the service provided to users. This was an iterative and continual process. Changes in scope and service provision were communicated back to users regularly, also identifying suggested changes that had not been made, and why
7) Scope – deliver – evaluate: iterate	If possible divide the service in small components that can be delivered separately. Scope each of these, deliver to and evaluate them with the users and then, if necessary, re-scope. Some project management practices (e.g. agile) are intrinsically designed for this sort of applications	Agile project management was applied. The project was split into product development, stakeholder engagement and external communications activities. These were split into subtasks as appropriate. As noted above, this approach made dealing with changes in scope much easier

between 1993 and 2012 is 0.62, and significant at the 99% level (Scaife et al., 2014). Since the NAO governs many aspects of European and North American winter weather, predictability of the NAO in Glosea5 leads to similarly skillful predictions of surface winter climate – for example, similar levels of correlation between observed and simulated temperature are seen over the UK to those for the NAO. For the South West UK, observed precipitation shows positive correlations (up to 0.6) to the observed winter NAO over North Devon, Cornwall and South Wales, with a stronger correlation (in places up to 0.7) between observed precipitation and Glosea5-simulated winter NAO. The broad implication of these skill levels is that Glosea5 predictions could be expected, on average, to be "correct" for approximately six years out of ten in indicating a warmer and wetter, or cooler and drier than average winter.

During winter 2014/2015, forecasts were only provided as three-month outlooks for a small, representative subset of farmers in the county of Devon, which allowed for early and rapid testing and development of the prototype. The outlooks were provided with an information sheet covering background on seasonal forecasts and their skill levels, notes to aid interpretation, and a feedback form. Since the CPFs are provided for the whole UK, a simple downscaling method was used to scale the UK forecasts to Devon. In particular, downscaling was performed by regressing annual values of temperature and precipitation, for each three-month period at UK scale, against those for Devon, using data from the Met Office's National Climate Information Centre. These relationships were then applied to the UK tercile probabilities. During winter 2015–2016, the 3-month outlooks were provided directly from the UK-scale CPFs, but supplemented with observed county-scale climatological information across the larger region of Southwest UK.

The 14 day site-specific forecasts were provided during winter 2015–2016, based on data from the Met Office BestData system, which blends recent weather observations and ensemble forecasts to provide an optimal probabilistic forecast. These forecasts were provided for a set of seven sites broadly covering the farm locations (see Fig. 1), and updated every six hours.

3. Developing the LMTool

The development of the LMTool was pursued from winter of 2014 to the spring of 2016. The sections below describe the main activities undertaken, both in terms of the technical development of the tool and the engagement with the farmers involved. Fig. 2 provides a timeline of the key activities.

3.1. First stage: Winter of 2014/2015

The starting point for developing the LMTool was marked by an initial workshop in July 2014 with 8 representatives of key areas of land management business from the CDE management board. The aims of this scoping workshop were 1) to identify a subset of CDE farmers' representative of the main farming types in the region and who could act as the main user group during the first winter of the project (2014/

Fig. 1. Location map: the black/white dots represent the farmer locations (for winter 2015–2016), whereas the blue icons represent the seven weather stations across SW England considered.

2015) and 2) to identify key potential beneficiaries, critical land management decisions, and priorities for the prototype. In addition, given the higher predictive skill of seasonal outlooks for the region during winter months (Scaife et al., 2014) it was agreed to focus on land management decisions occurring during winter months. The workshop also resulted in an agreement to generally focus on farming with cover crop planting as a specific example. More informed decisions on cover crop planting could help to justify the additional expenditure involved (seed, fuel, labor) and help to reduce soil loss, and thus contribute to preventing potential negative impacts on the environment and communities from nutrient leaching and soil on roads, when these crops are present.

Following from the scoping workshop, interviews were then held with this representative sub-group (n = 4) of the CDE farming community to help us to better understand the key characteristics of their farming businesses, their vulnerability to weather and climate, and their needs for seasonal forecasts to support decision making. These farmers each represented a particular farming enterprise in the CDE (e.g. vegetables, organic beef and crops; mixed farming; dairy cattle and arable), covering the two main areas of North and East Devon, and included different farm business types (tenant farmer, large contract share farmer, smaller traditional share farmer, manager of CDE's home farm).

The interviews were audio recorded, fully transcribed and analyzed using NVivo qualitative data analysis software (QSR International Pty Ltd., 2014). While all of the land managers interviewed used a range of different sources of short-term weather information out to 14 day lead times (Table 2), none of them had been exposed to SCFs or similar climate services. There were some common aspects to their requirements from SCFs – for example most had a strong interest in forecasts outside of the winter season; on the other hand, their specific needs for winter SCFs diverged depending on the nature of their businesses. For example, autumn crop planting and harvesting decisions were specific requirements of arable systems, while those with livestock noted animal management activities (e.g. feed planning, housing, grazing order, lambing) as priorities (Table 2).

The subset of four CDE farmers were then provided with forecast sheets (which were sent out via email and post) describing the likelihood of experiencing below, normal and above normal temperature and precipitation for the next three months, on a rolling monthly basis (i.e. at the end of the month from September to February). These forecasts were based on the CPF and downscaled as described in Section

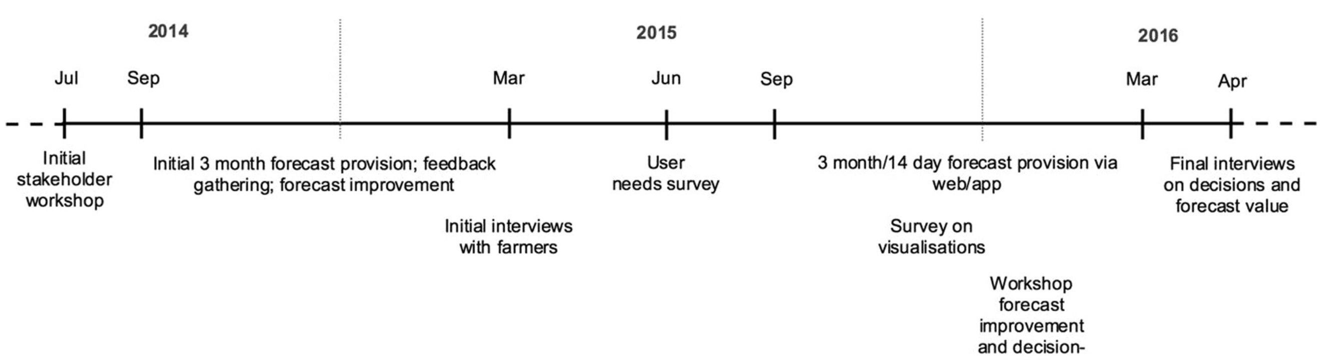

Fig. 2. Timeline of key activities during the development of the LMTool.

Table 2
Key findings from the 1st year interviews with land managers.

	Farm Type			
	Organic dairy and cereals	Mixed beef and arable	Integrated farming system: extensive cattle, goats and vegetables	Mixed beef, arable and sheep
Current experience with weather and climate services	Daily use of forecasts from web sources, Met Office rainfall radar, Local interpretation	Daily use of Accuweather app for 1 week forecasts, Met Office website for 5–14 day forecasts	Daily use of Metcheck, BBC websites, up to 5 sources used, Forecasts out to 14 days, Grass growth software	Daily use of Yourweather for forecasts out to 14 days
Potential uses for winter seasonal forecasts	Autumn crop planting, Cover crop planting and choice, Livestock feed/straw	Autumn crop planting	Crop harvesting, Grazing order decisions, Cover crop planting and choice	Slurry management, Cattle management – housing and feed, Sheep and lambing decisions

2. The forecast sheets were provided with detailed explanation of the information provided including background on SCFs and their skill levels, and with a feedback form that was completed by the farmers and collected via email and post. A summary of the results from the feedback forms, and their outcomes on the forecasts is given below.

During the first winter period, the successive forecasts were refined by taking into consideration the feedback provided by the farmers involved. In situations where these refinements required longer development timescales or were unrealistic, this was conveyed back to the farmers. In summary, the feedback forms collected during this period showed that the land managers found the forecasts provided generally useful with potential applications mentioned including livestock management (e.g. overwintering cattle), predicting grass growth and land condition, spring cereal planting, and fertilizer application planning. However, it was often difficult to pinpoint how they specifically impacted a particular decision and they were considered too general to make decisions upon. Some of the key points which emerged from feedback gathered were a) the forecast sheet was too complex and made extracting key messages challenging; b) graphics provided were too small; c) interpretation of five (quintile) categories was found difficult since the “most likely” forecast category was not clear as presented, and d) historic weather information would be better presented separately from the main forecast. In addition, provision via email was preferred and additional variables (e.g. wind) were suggested.

As a result of this feedback loop, the following key improvements to the 3-month outlooks were implemented:

- The forecast sheet was simplified in order to emphasize the main message; the graphics were made larger; and all the supporting information was put on the reverse side.
- For easier interpretation the forecasts were presented in terms of three (terciles) instead of five (quintiles) categories. This involved plotting a different bar for each category – the furthest bar from the “average/climatology” corresponding to the most likely to occur category. An example of the two kinds of plot are shown in Fig. 3.
- Information on the underlying climatology and last year’s weather were added as text (rather than included in the graphics).

As discussed previously, sufficient forecast skill was one of the required criteria for prototype selection during EUPORIAS, as described by Buontempo et al. (2017). The land managers involved were made aware of the broad skill levels expected from Glosea5 discussed in Section 2 during the initial workshop, in the subsequent interviews and via information sheets provided with the forecasts; interestingly discussions with them (both in the workshop and interviews) found that skill levels of approximately 60–70% forecast accuracy would be required for them to be “actionable”. This is broadly in line with findings across a wide base of users and sectors, including those for agriculture, across Europe (Bruno Soares et al. 2017).

3.2. Second stage: Winter of 2015/2016

During the summer of 2015, the farmer group was widened to include a broader set of stakeholders beyond the representative group of four from CDE. These included other farmers from the CDE (n = 26), and from the NFU (n = 12) across the South West UK making a total of 38 farmers potentially involved in the development of the prototype.

Building on the engagement activities pursued during the first stage of development we sent an online and postal survey (about their farming activities, use of weather information, and potential uses and requirements for SCFs, as well as forecast comprehension) to this wider group. A total of 20 new farmers replied to the survey (62% response rate). However, of these 20 new farmers only 15 wished to continue being involved in the development of the prototype. In the end, a total of 19 farmers (both from the CDE and NFU) based in Cornwall, Devon, Dorset and Somerset counties in South West England were involved in

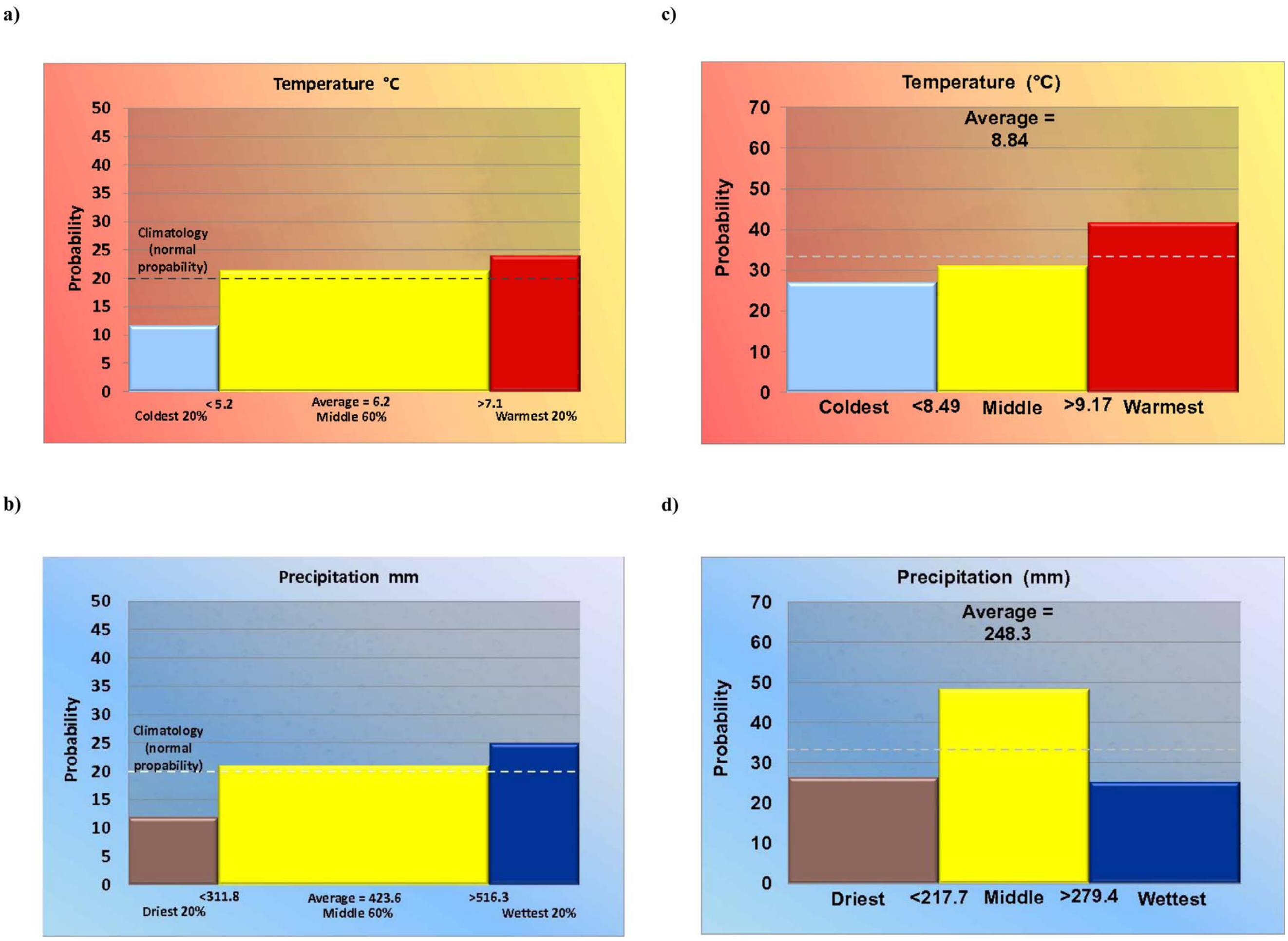

Fig. 3. Three month outlook for UK-mean temperature (a, c) and precipitation (b, d) for November-December-January (NDJ) 2014 (a, b) and March-April-May (MAM) 2015 (c, d). The horizontal dashed lines represent the climatological (1981–2010) probability of each category occurring. The values on the x-axes between bars indicate bounding values for the categories. The forecast for NDJ 2014 is based on quintile categories (with the central three lumped) while that for MAM 2015 is based on terciles.

the second stage of development of the tool.

The survey found that the farmer group were dominated by arable and beef farming, with smaller numbers from dairy, sheep, chicken and pig farming (Table 3). The main sources of weather information were weather forecasts and rainfall radar data from a variety of sources, but predominantly television, Met Office website and other websites (Table 3). Almost all farmers said that SCFs would be useful to them, especially during Spring, Summer and Autumn, and to a lesser extent during Winter, with precipitation and temperature being priority variables (Table 3). In terms of forecast lead times and provision, the majority of land managers were interested in receiving three-month outlooks provided one month in advance, and delivered via a website or mobile phone application, with supporting information provided online. Based on both the survey results and the feedback gathered during provision of 3 month outlooks to the farmers involved for the winter of 2015/2016 we found that farmers:

Table 3
Key findings from the survey of CDE and NFU farmers (n = 20).

Question	Summary of responses, ordered by popularity (number of responses in brackets)
Main farming activities	Arable (12), Beef (11), Other (8), Dairy (5), Sheep (4), Chickens (2), Pigs (1)
Weather information used	Weather forecasts (19), Radar data (5), Historic data (3), Other (2), Weather station data (1)
Sources of weather information	Television (16), Met Office website (15), Other websites (14), Radio (7), Other (6), Friends (1), Newspaper (1), Industry partners (1)
Would it be useful to have seasonal forecasts to help you make land management decisions?	Yes (19), No (1)
What seasons of the year would be most useful to have seasonal forecasts?	Spring (18), Summer (16), Autumn (15), Winter (11), Other (1)
What type of seasonal forecast would it be most useful to have?	Rainfall (19), Temperature (18), Flooding (8), Ice (8), Snowfall (4), Other (3), Humidity (1)
What would be the ideal length of the seasonal forecast?*	Up to 3 months (45), Up to 1 month (15), Less than 1 month (14), Up to 6 months (3), Over 6 months (1)
How well in advance would you like to receive the seasonal forecasts?*	1 month (26), 3 months (11), 2 months (8), 6 months (4), 4 months (3), 5 months (3), Up to 1 year (2), > 6 months (0), > 1 year (0)
How would you like to receive the seasonal forecasts?	Website (17), Mobile application (11), Text message (6), Other (3), Telephone call (1)
Besides receiving the seasonal forecast, would you like to have further information or support available to you?	Online information (17), Video information (5), Online expert support (4), Expert support via telephone (3)

* Received responses summed across weather variables.

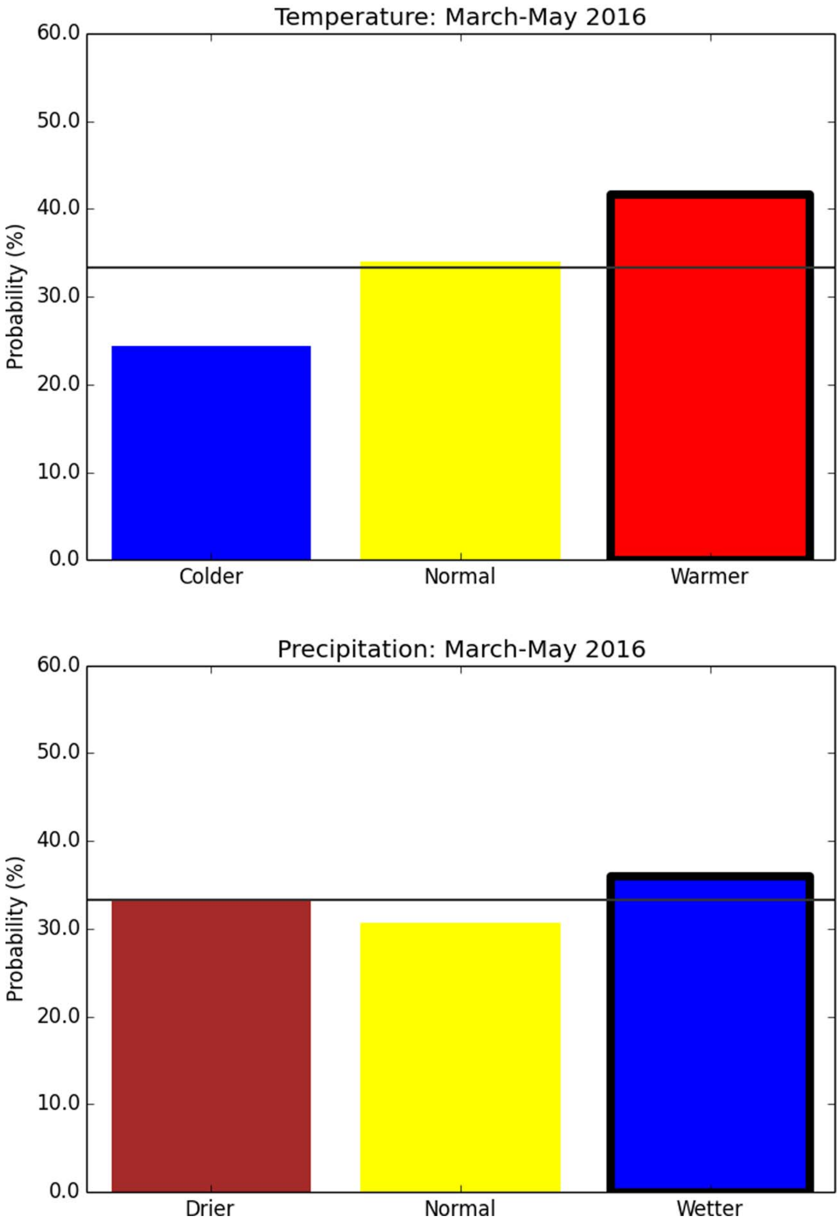

Fig. 4. Three month outlook for UK-mean temperature and precipitation for March-April-May 2016, as delivered at the end of February 2016. The horizontal line represents the climatological (1981–2010) probability of each category occurring, while the bold outlined bar shows the most likely category according to the ensemble of predictions.

- Were interested in additional weather variables (e.g. wind speed and direction);
- Were interested in more local, shorter-term forecasts alongside the 3-month outlooks;
- Requested the delivery of the forecasts via a website, and/or a mobile app.

Building on these findings, UK-scale 3-month outlooks of UK-mean precipitation and temperature were provided to the farmers for the winter of 2015/2016 and updated at the end of each month from September to February. The forecasts were provided at UK level, rather than county-scale following an assessment of forecast skill, which showed little additional value for precipitation in downscaled forecasts. These outlooks were provided as bar charts indicating the forecast probability for each tercile category—below normal, normal, above normal—(see Fig. 4 for an illustrative example).

For each outlook, background information regarding the observed climatology at county-scale was also provided (Fig. 5) to give context to the probabilistic forecasts (e.g. illustrating the absolute values of the tercile categories and presenting recent years in terms of the tercile categories). There is little direct evidence of the reaction of the farmers to these new graphics (since little feedback was received online or via the app as noted below) but the format and content of these graphics were positively received during an additional discussion with one of the farmer group, and more broadly, as noted earlier, forecast content and presentation was iteratively developed working with the farmer group.

Alongside this longer-term product, 14-day site specific forecasts of precipitation, temperature and wind (updated every 6 h) for a set of seven weather stations across South West UK were also provided to give more detailed short-range information (see Fig. 6 for an example at Exeter). Both the 14-day forecasts and the 3-month outlooks were delivered via a password-protected website (http://lmtool.euporias.eu/en/content/euporias-lmtool-14-day-forecasts-south-west-england and http://lmtool.predictia.es/en/content/euporias-lmtool-forecasts-south-west-england), with the first draft forecasts being made available in early November 2015. Note that these websites form part of a more general micro site which has been created to carry the prototype to both the general public and relevant decision-makers (http://lmtool.euporias.eu/en). Feedback on both the 3-month outlooks and 14 day forecasts was collected online, through this micro site, making use of

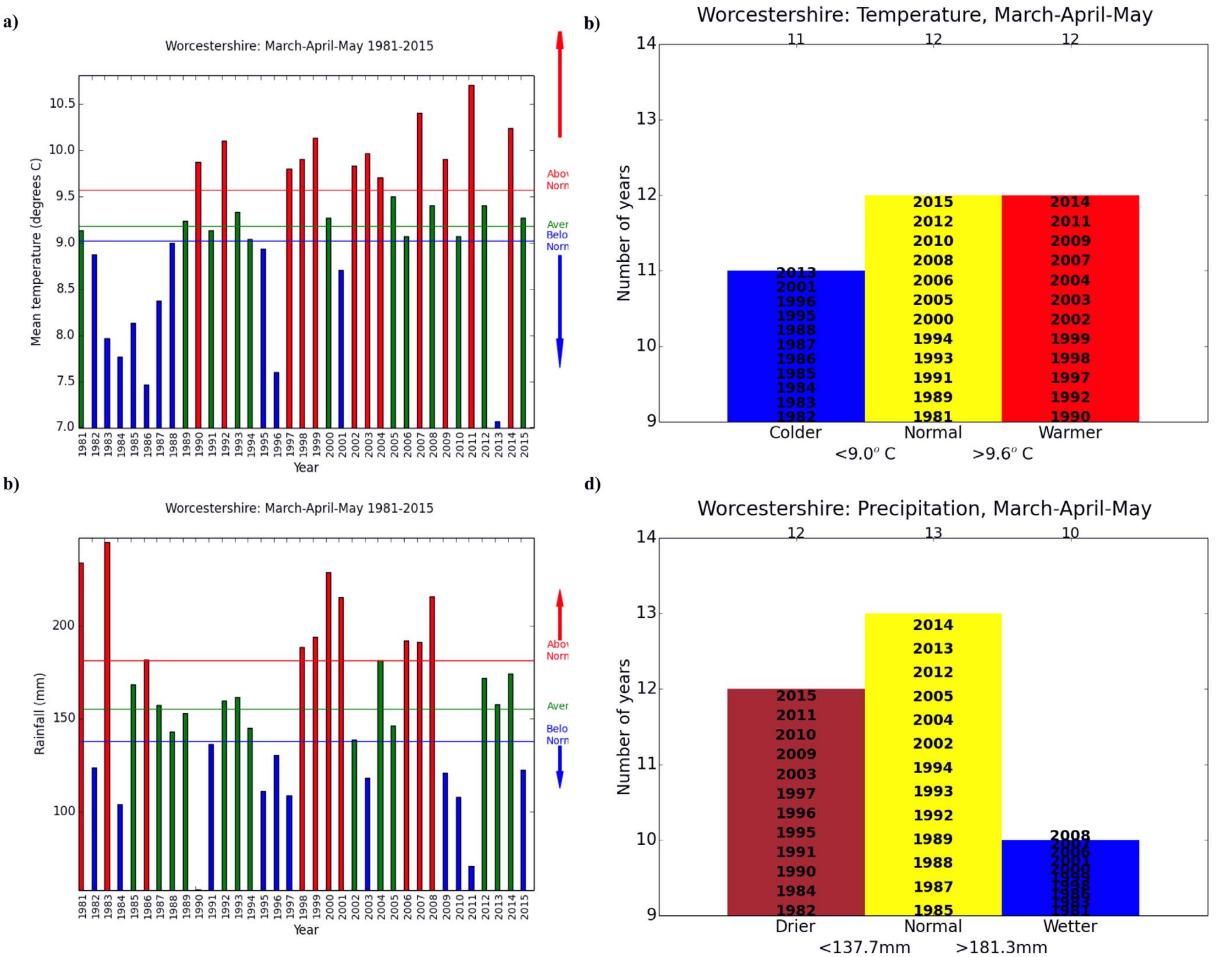

Fig. 5. Climatological information for temperature (a, c) and precipitation (b, d) for March-April-May 2016, for Worcestershire as delivered at the end of February 2016. Coloured bars/lines in a and b represent below-normal (red), average (green) and above-normal (blue) categories and their boundaries. Climatological information was presented both as timeseries (a, b) and "catalogues" (c, d). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

the EUSurvey service to this aim (https://ec.europa.eu/eusurvey). However, very little feedback was obtained through the website (or indeed the app discussed below), possibly because concerns and requirements had largely been met through the survey, earlier feedback forms and interviews which led to the iterative co-design of the forecasts.

A survey on forecast visualizations was then developed and implemented in December 2015 to help us define how the forecasts could be better represented and the level of understanding of the farmers in relation to the visualizations provided. The survey covered visualizations for both the 3-month outlooks and the 14 day forecasts and was sent to all 19 farmers involved. In general, the main message of all the visualizations used to represent the 14 day forecasts was well understood. However, "spaghetti" plots (with separate lines representing individual ensemble forecasts plus an average line) were easier to understand for temperature (in part due to the trend line used). For precipitation, box and whisker plots (where the box represents the range between the 25th and the 75th percentiles and the "whisker" lines represent range of the rest of the forecasts) were perceived as easier to understand the message. In relation to the 3 month outlooks, the farmers preferred simple graphics and text as the main forms for representing the information. In addition, farmers requested the information to be disclosed to them gradually (from the very simple headline message to the more technical and complex information) depending on the interest to know more or less regarding the forecasts provided.

Findings from the survey were used to further improve the forecast products. In particular, a workshop was held in January 2016 with 8 representative farmers across the user group to discuss key findings from the visualization survey and feedback forms in greater depth, regarding both types of forecasts provided. For 14 day forecasts, the farmers found them useful as provided but suggested that for precipitation, the contrast between colours could be stronger, and an ensemble average would be useful; for temperature, minimum and maximum temperatures were requested. While the main messages of the 3-month outlooks were broadly understood by the land managers, they were also generally perceived as being more challenging to understand than the 14 day forecasts. This was partly due to the small differences in probabilities between categories. The 3-month outlooks were considered potentially useful for decision-making if the content was improved. In particular, monthly forecasts were suggested as an addition. The forecasts were therefore improved based on these findings resulting in the format shown in Figs. 4–6. For the 14 day forecasts this included a stronger colour contrasts and ensemble average line added for precipitation, minimum and maximum temperature and wind information added. Whilst for the 3-month outlooks a tiered provision of forecast message was included with headline message as the entry point through to a detailed explanation if required.

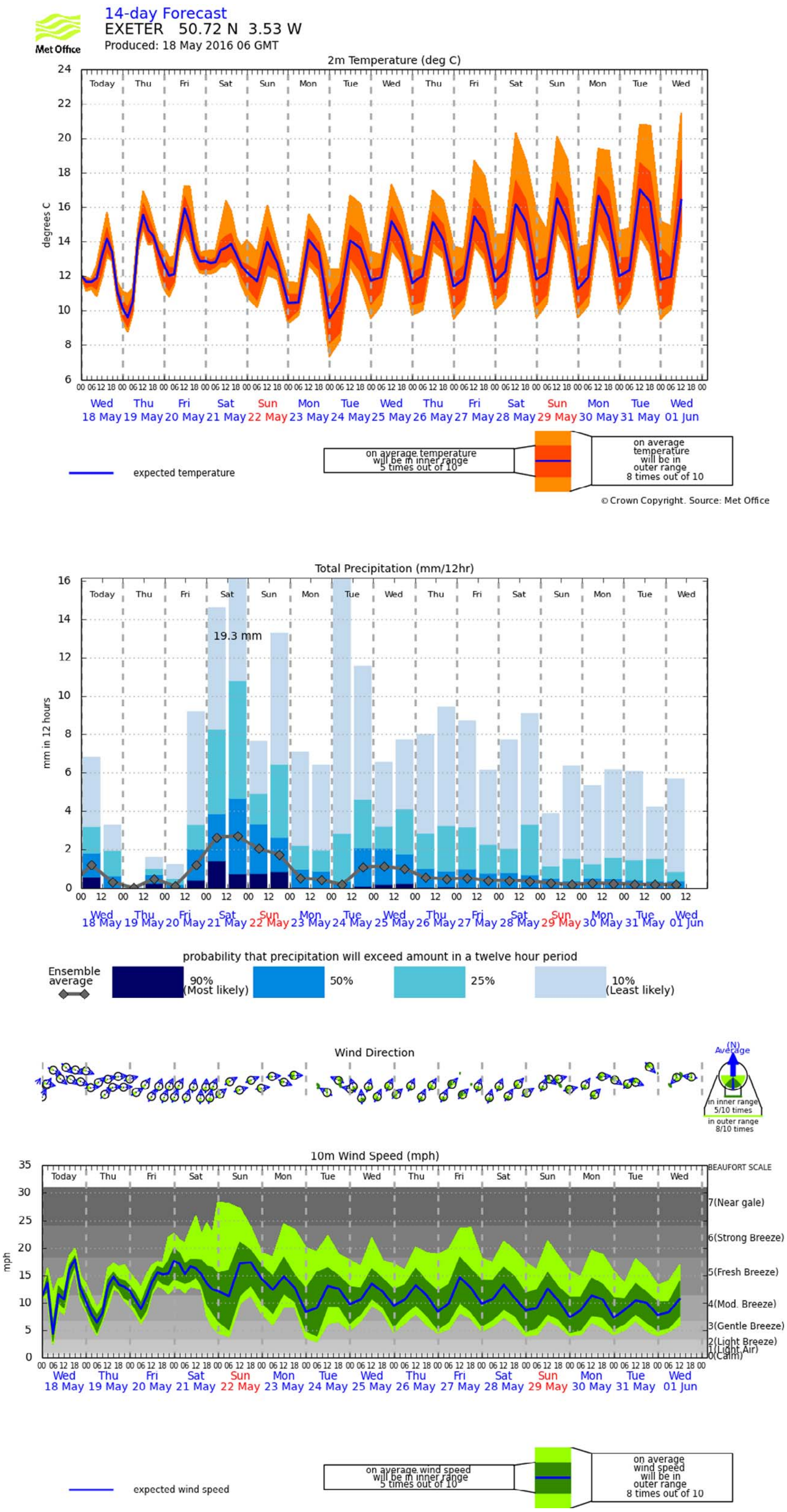

Fig. 6. Fourteen-day forecasts of temperature, precipitation and wind (top, middle and bottom panel, respectively) for Exeter, issued on 18 May 2016 at 06.00 GMT.

The workshop also aimed to set the scene for exploring the value of the 3-month outlooks in farmers' decision making (for more information see Bruno Soares et al., 2016). The idea was to identify the different entry points in the farmers' decision process in which SCFs could be of use and the conditions that needed to be in place to allow them to use it in their decision-making processes (cf. Bert et al., 2006; Jones et al., 1998). This was achieved by asking farmers to identify the key farming decisions they would have to pursue in the following months (between Feb-Apr) and ask them to reflect on these decisions based on the 3-month outlooks provided. Follow up interviews were then conducted with six farmers in April to help us understand the (potential) value and benefit of the forecasts for those farmers decisions (see Section 4.2 and Table 4). In this respect, the workshop and follow-up interviews found that it was difficult to gather concrete information

Table 4
Key findings from the 2nd year interviews with land managers.

	Farm type				
	Arable	Vegetable/arable	Integrated farming system: extensive cattle, goats and vegetables	Dairy cattle	Mixed arable, cattle and goats
Current experience with weather services	Daily use of forecasts from Met Office, Metcheck, BBC, and Met Office rainfall radar	Daily use of Will It Rain Today, local interpretation and also BBC website and Metcheck	Daily use of BBC weather website	Unspecified mobile app	Daily use of Weatherpro app for 10 day forecasts
Feedback on 3-month outlooks	Climatological observations would be useful	Not generally useful due to: market/contract driven decisions; contractors used; short-term planning focus; irrigation.	Historical average observations would be useful Need more time to over-ride "gut feelings" Limited by importance of antecedent conditions	Limited use – accuracy and trust required Short-term decisions dominate	Useful for winter decision making
Potential uses for 3-month winter outlooks	Spraying windows Autumn crop planting International forecasts may be useful for understanding markets and price changes.	International forecasts may be useful for understanding markets and price changes	Long windows for cattle grazing, feed, silage and grass growth Planning content of vegetable boxes/harvesting	Cattle management – housing, silage, feed.	Cattle housing and management Goat management. Contracting fieldwork and use of heavy machinery. International forecasts may be useful for grain prices
Feedback on 14-day forecasts	Wind information would be useful	Confidence levels well understood. Wind information would be useful.	Liked display, easy to interpret Wind information would be useful for spraying	Trust depends on experience of use Wind information would be useful.	–
Potential uses for 14-day forecasts	Shorter-term planning when used alongside 3-month outlooks	–	Planning yields to inform buyers Harvest timing Organising labour	Spraying decisions Water and slurry management Cattle movement/ management	–

Fig. 7. The mobile app developed for the LMTool prototype, showing a) the location map, and examples of 14-day forecasts for Exeter for b) temperature, c) precipitation and d) wind speed/direction. The app is freely available for both Android and Apple iOS, while the data is not freely available and requires a pass-code. Legends for b-d are as in Fig. 6.

relating how farmers made land management decisions in response to weather and climate, pointing to the need to develop new methods to understand the value of SCF in agricultural decision-making (Bruno Soares, 2017). Section 4.2 discusses key findings from the interviews and workshop, regarding the land managers' experiences with SCFs.

A mobile application for both types of forecasts was also developed during this period (see Fig. 7) and made available for Android via the Google Play Store (https://play.google.com/store/apps/details?id=es.predictia.lmtool), and for iPhone via the App Store (https://itunes.apple.com/us/app/lmtool/id1118042668?mt=8).

The information shown by the aforementioned e-platforms was served by the Application Programming Interface (API) created in EUPORIAS. The EUPORIAS API is a service to ease the management of the outcomes delivered by the different project prototypes, providing a common framework for security and data storage aspects.

4. Discussion

4.1. Applying the principles of climate services development to the LMTool

Table 1 summarizes how the ECOMS climate services principles were applied during the development of the LMTool. Here, we discuss some of the key learning points related to these principles. First, we found considerable benefit in engaging stakeholders via intermediaries (in this case the CDE and NFU) from the beginning of, and throughout the project, as they helped to identify proactive and motivated farmers for the project team to work with from a cross-section of representative farming businesses and also provided a trusted initial point of contact. The user's positive capacity to engage and interact with the development team is a major asset in climate service development, with key aspects being understanding the issue, commitment to the project and time to invest in it (Buontempo et al., 2017). In addition, the early discussions with high-level contacts at CDE (and later NFU) helped to ensure that we included the relevant people in developing our prototype. As noted by Buontempo et al. (2017), having a strong and structurally relevant interaction between end-user and provider from project outset and throughout it can result in a change in the dynamic between them and deliver effective, user-focused services.

Second, working with a smaller group during the first winter forecasting period allowed us to test initial concepts rapidly, and apply the lessons learned during the second winter to a broader group. Nevertheless, it is worth noting that farmers may often have little time available for lengthy discussions and research, and operational business needs may also affect availability at short notice.

Third, although the initial scope of the project was intended to focus on cover crops, it became clear from an early stage that a broader approach was required as not all of the farmers used cover crops, or decisions related to cover crops were predominantly driven by other factors (e.g. land management policies). The strong relationship established with our stakeholders made being open about scope, and managing expectations much easier. As noted in Table 1, effective and regular communication on changes in scope and the application of agile project management techniques made delivering the co-designed service relatively straightforward.

4.2. Potential value of the LMTool

The potential value of using the 3-month outlooks was assessed via in-depth interviews conducted with six of the farmers that attended the workshop in January 2016. Table 4 provides a summary of the findings from the interviews including current experiences with weather services, and feedback and potential uses of the 3-month outlooks and 14 day forecasts. As found in the interviews conducted during the first year (Table 2, Section 3.1), potential uses for the SCFs provided varied across farming activities. For example, arable and livestock farming had specific applications for the forecasts similar to the differences identified in Section 3.1. An interesting potential application mentioned by three of the interviewees was the possibility of using SCFs for other world regions to understand grain prices and market changes. This may be a promising way to encourage more farmers to engage with SCFs given that forecast skill is higher in some regions (and seasons) outside Europe, although further research would be required to assess how "hotspots" of skill overlap with key cropping regions and seasons (e.g. Iizumi et al. 2013).

Of the six farmers only two had actively used the 3 month outlooks to help them plan their activities and which ended up changing their normal course of action, rather than identifying potential uses. In one case, the farmer's decision was about when to spray fungicides, which requires having a dry spell of at least a few days. Based on the 3-month outlook of wetter but milder months the farmer decided to spray as soon as he got a window of dry spell (the farmer also used the 14-day forecasts provided by the LMTool as well as radar information and weather forecasts that he normally uses) rather than waiting for drier conditions at a later stage. In this sense, evidence suggests that the 3-month outlooks provided useful background information on longer-term trends that, when combined with other information e.g. shorter term forecasts, provided usable information for their decision making (Table 4).

In the other case, the farmer's decision was related to the timing to contract people to work in her fields which normally has to happen 2 or 3 months beforehand. However, as her fields were already wet and the outlook for February and March 2016 indicated a higher probability of wetter conditions she decided not to contract people until the end of April (as opposed to mid-March as she usually does). This change in her decision process avoided having people going into the fields and ruining the grass as well as incurring unnecessary costs.

Although both farmers agreed on the benefits of having use the 3-month outlooks to inform their decision-making processes (in the form of avoided/incurring unnecessary costs) it was not possible to determine the economic value of having used the forecasts as opposed to not using them. Future development of this service could therefore benefit from collection, storage and maintenance of impact data (Buontempo et al., 2017) that relate weather/climate changes to land management decisions, since this would support a better understanding of the potential value and application of the forecasts provided. Bruno Soares (2017) further suggests that a deeper understanding of forecast usability and value requires the development of new research methods capable of addressing the complex nature of the decision-making process in the farming sector.

It is important to note that the reasons why the other farmers did not use the 3-month outlooks (Table 4) were, in most cases, not related to the information provided (i.e. the skill, content or format of the forecast) but due to other conditions such as the type of enterprise pursued (e.g. renting the land to other users), the fact that their farming activities were not susceptible to weather conditions or the conditions of the ground in their farm at the time that limited the usability of the forecast (Bruno Soares et al. 2016; Bruno Soares, 2017).

Another key finding from our analysis with regard to the potential value and benefit of using 3-month outlooks to help inform land-management decisions was the need for the farmers to have more time to build trust in the outlooks (Table 4; Bruno Soares, 2017), a similar finding to studies in other regions of the world (e.g. Lemos et al., 2012). The novelty of this type of forecast and the content of the information provided (i.e. average conditions over 3-month period) meant that most of the farmers involved mentioned the need for more time to gain confidence and trust in the information provided as exemplified in this statement by one of the farmers: *"The problem I've got with it [SCF] at the moment is I've not got enough confidence in it because it's not been running long enough to actually overrule my gut feeling."* Having more time to test, translate and fine tune the information provided in the 3-month outlooks with the changes and impacts on their land would allow farmers to have a better understanding of how these forecasts could be used to inform their planning and decision-making (Bruno Soares et al. 2016; Bruno Soares, 2017). As noted in Section 3.1, the skill of current forecast systems (Section 2) broadly matches farmers requirements for SCF skill and confidence but does not exceed it – so clearly uptake and use would be improved given greater skill, since this could also improve their confidence in these services, as further discussed in Section 4.3.

The LMTool was designed as a time-limited research prototype project and considerable further work (and funding) would be required to continue the service and develop an operational system. However, we hope that the lessons learned here are of wider value to potential developers of future climate services for land management.

In a broader context, the forecasts provided by the LMTool showed potential for a much wider range of land management decisions not only in agriculture but also in forestry. For example, CDE themselves used an early version of the 3-month outlook during autumn 2014 to delay forestry operations on an area with heavy clay soils. This stresses the fact that the strong relationship established with our stakeholders allowed changes in scope and application of the service provided to be better managed. Discussions with CDE highlighted that the prototype presented here could have relevance to a much wider set of land management decisions, for instance those related to livestock management, placement of renewable energy farms, biodiversity management, or infrastructure decisions. In addition, many of the lessons learned here could be applied to other regions of the world beyond the UK, particularly where sufficient skill in SCFs exists.

4.3. Limitations of the LMTool

Despite the potential usefulness of seasonal weather information for land management in the UK, the land managers stated that an extended trial period (more than the two seasons of trialling the LMTool) would be needed to fully demonstrate benefits to them, and for them to routinely make changes based on the forecasts. This is particularly the case given the current skill levels of the seasonal forecasts (Section 2; as discussed below); and secondly feedback from the farmers suggested more experience with new forecast products would increase confidence in their application (Section 4.2, Table 4). Indeed, more broadly Buontempo et al. (2017) note that developing an environment of mutual trust between users and service providers is one of the most critical elements of climate service development. In the case of LMTool, the need to gain experience and confidence does not appear to be related to the land managers experience with available climate services, which was broadly similar across users, and they had no previous experience of using SCFs. However, as noted earlier, different farming groups did have different potential uses for the SCFs. The findings of the interviews conducted in year two (Section 4.2, Table 4) and of the other user-engagement activities suggests that lack of experience with the forecasts was one of the main factor limiting uptake and a better assessment of value, given that their requests for improved presentation, format and content were largely met through the process of iterative co-development. As discussed earlier, trust in, and experience with the forecasts also appear to be dominant factors in uptake (cf. Bruno Soares and Dessai, 2016) compared to economics, or the impact of making a "wrong" decision.

As noted in the introduction, in a general sense SCFs are virtually un-used for agricultural decision-making in Europe (Bruno Soares and Dessai, 2015, 2016). There are a number of potential reasons for this, some of which have been tackled by LMTool while others remain future challenges. For example, via strong stakeholder engagement and involvement within the development of LMTool we have attempted to target forecasts for the intended audience (Calanca et al., 2011), improve user-relevance of forecasts, raise awareness, accessibility, and capacity to understand the information provided (Bruno Soares and Dessai, 2016; Lemos et al., 2012), with the aim of improving their usability (Coelho and Costa, 2010).

However, a key remaining limitation of the LMTool may be related to the limited skill that is found for seasonal forecasts outside the tropics (Manzanas et al., 2014), and particularly for Europe (Meinke et al., 2006; Davey and Brookshaw 2011; Demeritt et al., 2013). As noted in Section 2, Glosea5 forecasts can generally be expected to produce "correct" outcomes for warmer, wetter or colder, drier winters than average approximately six times out of ten, which roughly matched the minimum skill levels required for them to be "actionable" in our user group. This is broadly in line with findings across a wide base of users, including those for agriculture, across Europe (Bruno Soares et al., 2017). This indicates that even during the winter period, the seasonal outlooks on their own might still be of somewhat marginal value in directly influencing land management decisions.

However, as indicated in Section 4.2, when used in combination with shorter-range weather forecasts, they may provide helpful background information in decision-making. Outside of the winter period, there was also significant interest in three-month weather outlooks for land-management decision making, should sufficient skill exist. It is therefore clear that while further skill improvements in seasonal winter weather forecasts would improve their uptake and use, there is likely to be even greater potential in skillful outlooks for spring-autumn, should they be available. Since improving forecast skill in seasonal outlooks is a long-term research activity, ways to improve usability in the near-term are required. For example, recent work carried out within EUPORIAS (Fernández et al., 2016) indicates that statistical downscaling might serve to bias correct seasonal forecasts whilst preserving its ability to simulate the interannual variations of climate, thus providing suitable local-scale seasonal forecasts. Further research in this field is still required. As noted in Section 4.2, international applications of SCFs to help understand grain price and market changes may provide a potential entry route for familiarizing land managers with such climate services.

In summary, improving the usability and uptake of seasonal forecasts for land management in Europe requires a combination of (a) appropriate targeting to regions and seasons with adequate skill level, (b) improving user awareness of, and experience in using, the products, (c) investigation into means of improving usability of current SCFs despite limited skill (e.g. post-processing, bias-correction, downscaling), (d) new research methods for better understanding the value of SCFs for land management decision making (Bruno Soares, 2017), (e) coordinated gathering of relevant impact datasets (Buontempo et al., 2017), and (f) the longer-term aim of improving forecast skill throughout the year.

5. Conclusions

We found significant value in involving intermediaries (CDE and NFU) to both set initial scope, and help identify engaged, representative farmers to work with. Working initially with a small, representative user group allowed us to rapidly test and develop products which could then be rolled out to a larger group during the second stage of development. Prototype development strongly benefitted from an iterative process of co-design with the farmer group, and from an inter-disciplinary project team. Remaining flexible about project scope also helped us deliver a prototype that was more relevant to, and usable by the farmers. The farmers asked for seasonal forecast information to be made available to them in a tiered approach, starting with headline messages and gradually increasing in complexity, depending on their level of interest. Clear and simplified presentation of probabilistic forecasts increased their uptake and comprehension, and even relatively complex, unfamiliar probabilistic forecast information was understood given time. Farmer feedback suggested a much broader definition of value beyond purely monetary, in the services provided. Overall, the ECOMS climate service principles proved a valuable framework for developing the prototype.

Further work is needed to better understand the role of forecast skill in land management decision making, investigate the potential benefits of techniques to improve usability of current forecast systems (e.g. forecast downscaling), and to implement a robust operational forecast system. In the longer-term, improvements in seasonal forecast skill, especially outside the winter period, could have great potential for application in land-management decision making. Given the limited use of long-range forecasts for land management in Europe, the potential for such services to be applied more widely is not well understood and would therefore require more stakeholder engagement work and forecast development. However, there may be opportunities to familiarize farmers with SCFs through investigating the potential for the application of global-scale SCFs to understand changes in grain prices and markets. As noted by Buontempo et al. (2017), prototype development represents a trade-off between the two opposite pushes to deliver very deep and narrow services addressing the need of a specific user on the one hand, and the desire to develop services to address a range of users that may have broader uptake and use. While some of our findings generally apply to the development of future climate services for land managers beyond the South West UK, insight into the wider applicability of seasonal forecast services in Europe remains unclear because of our focus on a specific region of the UK.

On the other hand, many of the issues identified here are common barriers and enablers to the uptake of climate services across sectors in Europe (Bruno Soares et al., 2017) including the format and presentation of information provided; dealing with uncertainty in predictions; compatibility with existing information systems; familiarity and experience with new products; the perceived credibility and trust of information providers; and the need for centralized climate and impact data (Buontempo et al., 2017). As noted by Bruno Soares (2017), new research methods may also be required to better understand the value of SCFs in land management decision making. Lessons learned from the EUPORIAS project overall are provided by Buontempo and Hewitt (2017).

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