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EUROPEAN PROVISION OF REGIONAL IMPACT ASSESSMENT ON A SEASONAL-TO-DECADAL TIMESCALE

D41.3 AND D41.4

EVALUATION OF THE VALUE AND IMPACTS OF USING SEASONAL CLIMATE FORECASTS IN DECISION-MAKING PROCESSES

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1. Executive Summary

Analyzing and assessing the role of seasonal climate forecasts (SCF) to help inform decision-making is a pre-condition to understanding the value and impact that climate services can bring to one (or more) specific sectors of human activity. Such an analysis can potentially be able to quantify in economic and/or non-economic terms the difference that SCF can have in making systems and processes more adaptive and resilient to climate variability, as well as influence and inform the development of a climate services market in Europe.

For the purpose of this report, which merges together both D43.3 and 43.4, onus of the analysis is on both the value and impact of the SCF on the decision-making processes, which are defined as:

- **Value:** the (potential) economic and/or non-economic benefit of using seasonal forecasts in that particular decision to the user; and
- **Impact:** the effect that the seasonal forecast has in the decision under analysis (i.e. has it changed the course of action to the user?).

Since addressing both value and impact of the SCF proved to be a challenging objective due to the intrinsic complexities of each prototype in either measuring economic value in the sector of analysis (e.g. benefits and costs associated to multiple water uses of a dam) or by providing an indication of the effect that SCF can have on highly political decision making processes, each prototype has focused its attention only on one of the two aspects – the value or impact of SCF in the DMP. However, recommendations for further research and follow up actions in order to address the aspect that was not analysed are provided in each case.

The table below provides an indication of the prototypes analysed, the primary aspects on which they focused on, as well as the methodology used by each of them. A short summary of the methodologies of the prototypes and the key results achieved is provided below.

Prototype	Focus of analysis	Methodology
Resilience	Economic Value	Weather Roulette
Land Management tool	Impact on DMP	Decision Maps
RIFF	Impact on DMP	Placebo concept
LEAP	Economic Value	Cost Benefit Analysis
Climaware	Impact on DMP	Avoided Cost Analysis
CMTool	Impact on DMP	Survey

RESILIENCE

RESILIENCE is a semi-operational prototype that aims to provide robust information on the future variability of wind power resources based on probabilistic climate predictions. It operates at seasonal time scales providing seasonal wind speed predictions for the energy sector.

The prototype used the Weather Roulette methodology in order to assess the economic value of the SCF. The methodology takes this name because it is defined as a bet between two opponents. In this case the selected climatology forecast is the opponent to be beaten by the RESILIENCE forecasts. Each of the forecasts bets on a possible outcome, which is then checked with the real one.

The results of this work indicate that the effective interest rate is linearly related to a standard skill score for the scientific community such as the RPSS. Skill scores require a longer training period for those users that are not familiar with probabilistic scores, instead, translating this scores to economic concepts widely used has a potential to improve the understanding of the value of seasonal predictions over climatology.

The main limitation to analyse the value of climate predictions in the energy decision-making context is the impossibility to use actual observed/generated benefits in particular locations. This information is highly sensitive as a wrong interpretation of it in the media can have a direct impact on the actual benefits of a company or can provide a strategic advantage to competitors. The weather roulette results in terms of Return on Investment can't be directly translated into actual ROIs, which can be seen as a drawback, however we expect it to be a tool to demonstrate and quantify the potential impact on decision-making that will lead to further interactions and questions from the energy stakeholders.

LMTOOL

The Land Management Tool (LMTool) is a semi-operational prototype that aims to provide relevant and usable climate information to land managers in the Devon region in the UK. The prototype was coordinated by the Met Office together with partners at the University of Leeds, The Netherlands Met Service, the University of Lisbon, Clinton Devon Estate and the National Farmers' Union. The prototype provided two types of forecasts: 14-day forecasts (for both temperature and rainfall; updated every 6 hours) for specific weather stations in the region; and 3 month outlooks (for both temperature and precipitation; updated monthly) for the whole region.

The methodology to assess the impacts on decision making of the SCF was a qualitative approach based on decision maps and interviews to understand the key farming decisions that need to be made in the coming months, the different management options available to the land managers, the different entry points in the decision process in which SCF could be of use and the conditions that need to be in place to allow the land managers to use it in their decision-making processes (cf. Bert et al., 2006; Jones et al., 1998). At a workshop, the farmers were asked to develop their decision-maps for the key decisions they would have to make for the following 3 months. In-depth interviews were then conducted 3 months after to discuss the decision-maps and assess the usability of the SCF in the key decisions identified by the farmers at the workshop.

The key finding from the interviews with the farmers was the difficulty in operationalizing the methodological approach adopted i.e. the decision maps. This was due to the complex and dynamic nature of the decision-making processes in farming which are very susceptible to change due to an array of factors e.g. weather, financial, etc. The focus then turned to the decisions pursued during those 3 months and reflect on the usability of the SCF during that period. Of the six farmers interviewed only two used the SCF to inform their DMP which changed their usual course of action. Both farmers agreed on the positive benefits of using the SCF in their DMP (by avoiding costs) although they were not able to quantify the value per se. A couple of the farmers had no interest in using SCF but due to the type of enterprises they pursued. Another key finding was the need to allow more time for farmers to build confidence and trust in the SCF i.e. learn how the SCF translates in their farms over time and fine tune the information provided to their needs. Finally, further research is required to develop methodologies capable of assessing the value and impact of using SCF in real and highly complex decision-making contexts such as the farming sector.

RIFF

The RIver flow Forecasts for water resource management in France (RIFF) prototype developed by Météo-France (MF), aims to provide useful information based on seasonal hydrological forecasts to improve dam management for water resources issues in France.

This prototype has focused on understanding the impacts of the introduction of SCF on the decision making processes by using the “placebo” methodology. A placebo is a widely used medical method to test new medical treatment which has been adapted to climate field. Its principle is to put the stakeholder in a context close to the real one, and to ask him to apply its decision making process with two inputs: the seasonal forecast, and the placebo one, without the forecast (the placebo). This experiment has been lead in collaboration with the stakeholders of the Seine-Grands Lacs region over a sample of past situations, in order to calculate a performance score (Viel et al, 2016).

The main interest of this analysis was to consider the value of Climate Information for its use onto a DMP with a metric defined by the stakeholder and by simulating different methods in close real conditions over a quite long period (29 years).

We have seen first that the impact of climate conditions on DMP was very changing from one year to another and often very low. A difference in the results according to the method used appears only around 1 year over 3. Results between SF and Placebo are very close limiting the robustness of the interpretation.

A second point to highlight is the workload to prepare the different simulations and to play them by the stakeholder (estimation of 2 days for 29 years).

LEAP

The Livelihoods, Early Assessment, and Protection System (LEAP) is a food security early warning system developed in Ethiopia that is designed to enable early response to drought-related food crises, using monitoring information to project anticipated beneficiary numbers. The economic value of the prototype has been quantified through the Cost Benefit Analysis (CBA) methodology.

CBA is an economic technique used to organize, appraise and present the costs and benefits, and inherent tradeoffs, of public investment projects (Kopp et al., 1997), and is widely used in government decision-making all over the world (Pearce et al., 2006; Zhuang et al., 2007). CBA is mainly concerned with the question of efficient allocation of resources; in the context of DRR and humanitarian decision making, it therefore seeks to assess the impact of a unit of aid spent on a given intervention (Mechler, 2008). Unlike financial appraisals, which only quantify monetary benefits, CBA seeks to capture a project’s overall benefits to society, and therefore usually involves quantifying non-monetary values (Cellini and Kee, 2007).

Based on the cost of food/cash alone, the LEAP forecasts result in a higher total cost over the eight years of analysis as compared with a late response based on needs assessments. This is because costs are allocated to the full number of beneficiaries when LEAP over-predicts the number in need (as compared with needs assessments) and is topped up to needs assessment figures whenever it under-predicts. Therefore, responding based on LEAP forecasts will always appear more expensive based on a cost analysis alone.

However, LEAP forecasts can be a critical component of raising funds in time to facilitate an early response. When this response is funded and triggered early, benefits arise as households avoid negative coping strategies, engage in greater investment, and avoid long term impacts to household growth, nutrition and educational outcomes.

As a result, when the benefits of early response are incorporated into the analysis, responding based on forecasts becomes the most cost effective option in this analysis.

The benefits modelled here arise from documented and quantified benefits in the literature from a greater use of cash (which is only possible through early response when food is still available in the markets and prices have not yet begun to escalate) and also through benefits from using early warning information to reduce losses as well as generate additional economic benefit.

Further, this analysis is limited by data availability on the benefits of early response, and therefore it is likely that the cost effectiveness of response to forecasts will only increase with better data availability.

S-CLIMAWARE

The objective of the case study S-CLIMWARE is to incorporate seasonal forecast in dam management and water system management in Spain. The case study area of the S-Climaware encompasses all the river basins supervised by the Spanish state.

Based on the work of Brown et al. (2010) a step by step methodology has been proposed and is currently applied with the stakeholders through regular meetings and workshops. The methodology consists of different exercises of increasing complexity allowing to define the best way(s) to integrate seasonal forecast into decision making process.

The case study of the S-Climaware brings information on the potential added-value of forecast, but also on the limitations and barriers in the update of decision making according to seasonal forecast. The methodology developed has been applied and the first three steps completed.

However, it has not been possible to complete the two last steps of the methodology, and in particular calculating the economic value of the benefits for a series of reasons:

1. The update of the decision making process would require more information than the one provided by the S-Climaware (e.g. forecast of all the drought indicators, forecast of water demand).
2. The update of the decision making process would require legal modification and approval at a higher level.
3. The simulation of potential impact of change in decision making process will require another modelling approach (e.g. flood modeling).

Based on these results, the stakeholders and the project partners involved in the S-Climaware have decided to apply the methodology developed in another case study more suitable (where both decision making process and physical processes can be simulated).

CMTool

The CMTool is a prototype case study of a climate-driven mortality model to provide probabilistic predictions of exceeding emergency mortality thresholds for heat-wave and cold spell scenarios. The predictions are based on temperature forecasts (1–3 months ahead) to support decision making for the preparedness of health services and protection of vulnerable communities ahead of future extreme temperature events.

In order to assess the impacts of the prototype on the decision making process a 20-question survey was developed to undertake the review of heat–health action plans (HHAPs) in the European Region. The participants were the representatives of organizations and Member States who were participants of the European Working Group on Health in Climate Change (HIC) meeting of the European Environment and Health Task Force (EHTF).

Participants who had a seasonal climate forecast on health-related mortality available during the preparatory phase of their heat–health action plans all considered a seasonal climate forecast to be influential on all sub-elements of preparation, and thus the SCF having a significant potential impact on decision-making. This was strongly the case for ‘particular care for vulnerable groups’, who are by definition more susceptible to temperature-related mortality and morbidity and who thereby place a greater burden on health systems, thus making a case for the value of a SCF. Another highly influential sub-element was ‘communication and dissemination of public health information’, which could potentially be the most effective measure to improve personal practice of prevention and induce behavioural changes that would further reduce the health impacts of heat-waves.

It is unsurprising that shorter lead time climate forecasts would be considered more favourable for the health sector and would have a greater effect on decision-making regarding preparation. This is largely due to the fact that currently no mechanisms exist to take longer lead time into consideration for long-term adaptation measures. This is also highlighted by the need to strengthen monitoring and evaluation as a core element of heat–health action plans, to feed into a multi-annual iterative review of HHAP performance, and thus present and opportunity for incorporating SCFs into preparation and planning for the health sector.

The main limitations of this investigation are small sample size and low response rate. Not all participants of the HIC Working Group contacted were able to participate in the survey due to various reasons. Moreover, there were fewer responses to questions related to existing HHAPs as some countries surveyed did not have them. Therefore, the results may be biased towards those who have, or are aware of, HHAPs.

These limitations call for further study to increase sample size by raising the interests that are more applicable to their countries or geo-climatic contexts. There is a need to tailor the survey more specifically to countries and regions with existing heat-health action plans. Furthermore, further validation of European heat–health action plans is necessary as very limited studies on the value of heat-health action plans exist.

2. Project Objectives

With this deliverable, the project has contributed to the achievement of the following objectives (DOW, Section B1.1):

No.	Objective	Yes	No
1	Develop and deliver reliable and trusted impact prediction systems for a number of carefully selected case studies. These will provide working examples of end to end climate-to-impacts-decision making services operation on S2D timescales.		x
2	Assess and document key knowledge gaps and vulnerabilities of important sectors (e.g., water, energy, health, transport, agriculture, tourism), along with the needs of specific users within these sectors, through close collaboration with project stakeholders.		x
3	Develop a set of standard tools tailored to the needs of stakeholders for calibrating, downscaling, and modelling sector-specific impacts on S2D timescales.		x
4	Develop techniques to map the meteorological variables from the prediction systems provided by the WMO GPCs (two of which (Met Office and MeteoFrance) are partners in the project) into variables which are directly relevant to the needs of specific stakeholders.		x

5	Develop a knowledge-sharing protocol necessary to promote the use of these technologies. This will include making uncertain information fit into the decision support systems used by stakeholders to take decisions on the S2D horizon. This objective will place Europe at the forefront of the implementation of the GFCS, through the GFCS's ambitions to develop climate services research, a climate services information system and a user interface platform.	x	
6	Assess and document the current marketability of climate services in Europe and demonstrate how climate services on S2D time horizons can be made useful to end users.		x

3. RATIONALE FOR THIS (MERGED) REPORT

The proposal to merge D41.3. and D41.4. was a consequence of changes that took place within WP41 over the past couple of years. The starting point for these changes was the recognition by partners that the scope and aim of those two deliverables would be very difficult to be addressed in the context of the developments made within the EUPORIAS project. In particular, the initial aim of assessing the value of a decision-making *per se* (i.e. within D41.3) was not possible to be pursued within the prototypes being developed under the auspices of the project. This was mainly due to the novelty of seasonal forecasts for those organisations involved in the prototypes which made very difficult for them to identify a specific decision-making to be evaluated (in the context of D41.3) particularly when, those same decisions were supposed to, at a later stage, be assessed again but in a context where seasonal forecasts would be made available to them (in the context of D41.4). As such, partners decided to develop D41.2. focusing on the development of methodologies for assessing the <u>value of using seasonal forecasts in decision-making</u> and subsequently, applying these methodologies to the EUPORIAS prototypes and case studies in the context of D41.3.

It was this change of scope of the D41.2. and D41.3. that led us to propose a merge between D41.3. (Report on the evaluation of the value of the decision-making process) and D41.4. (Report on the impacts of, and risk related to, climate forecasts in the decision-making process). This merge would allow us to use the findings from the implementation of the assessment methodologies (developed in D41.2) in the various EUPORIAS prototypes and case studies to deliver what is expected in both D41.3 and D41.4.

However, a critical aspect of this proposal is how to effectively distinguish between “value” and “impact” in the context of applying seasonal forecasts in the decision-making processes being studied. Following discussions within WP41 partners and the European Commission we have agreed that, in the context of this report, these concepts would be defined as:

- **Value:** the (potential) economic and/or non-economic benefit of using seasonal forecasts in that particular decision to the user; and
- **Impact:** the effect that the seasonal forecast has in the decision under analysis (i.e. has it changed the course of action to the user?).

4. INTRODUCTION

The value of using seasonal climate forecasts (SCF) to help inform decision-making is a critical aspect that needs to be understood particularly in the emerging context of climate services development. Such understanding of the current or potential value (either economic or non-economic) of using SCF to inform and support a decision can lead to different paths of action and thus improve the outcomes of such process which ultimately can benefit the user of such climate information. On a wider context, the uptake of SCF in decision-making can also lead to a more adaptable and resilient society as well as enhance the development of a climate services market which is emerging in Europe.

The conceptualisation of the word value can be associated to a multiplicity of meanings and understandings such as: a) as monetary worth and/or as something that is a fair return in money, services or goods; b) as something useful, estimable or important; and/or c) as a set of beliefs and concepts in individuals (Oxford English Dictionary, 1933). In a similar vein, the value of using SCF to inform and support a decision can also be defined and interpreted in different ways. For example, Stern and Easterling (1999) define the value of a SCF as the difference between the outcomes of a decision made with and without a climate forecast. In their conception, the value of SCF is therefore a function of different factors that influence its use and value including the users' activities, how sensitive they are to weather and climate conditions, the time horizon of the decision(s), their strategies and capacity to cope (Stern and Easterling, 1999).

According to Murphy, the value of SCF is acquired "through their ability to influence the decisions made by users of the forecasts [and] to guide their choices among alternative courses of action" (Murphy, 1993, p. 285/6). The value of SCF is described as the benefits that can be yield from using SCF and allow us to consider alternative metrics (e.g. non-economic value) in the assessment of SCF value (cf. Clements et al., 2013). Nicholls (1996) on the other hand identifies the range of benefits that can be yield from using climate information in decision-making which are regarded as the “marginal change in the outcome for a user” (p. 3). These measures of benefit can include qualitative improvements in the decision, environment, and outcomes as well as quantitative changes to the outcome either in economic value or non-economic value (Nicholls, 1996).

Assessing the value of SCF in decision-making can be pursued by applying a range of methods including Decision theory-based models (e.g. Rubas et al., 2006; Letson et al., 2005; Meza et al., 2008; Hill and Mjelde, 2002; Meza and Wilks, 2004), Contingent Valuation Method (e.g. Mitchell and Carson, 1989; Smith and Sach, 2010; Bateman et al., 2002; Clements et al., 2013; Anaman and Lellyet, 1996), Benefit Transfer (Bateman et al, 2002; Johnston and Rosenberger, 2010; Frei, 2010), and Participatory or qualitative studies (e.g. Changnon, 2002; Luseno et al., 2003). For more information on each of these method see our deliverable D41.2. which can be accessible here:

According to the Cambridge English Dictionary, impact is “a powerful effect that something, especially something new, has on a situation or person”. Consequently, “impact” relates to the effect that that specific novelty has on the situation under analysis. In a similar vein, the Intergovernmental Panel on Climate Change define impact as the “(…) effects on lives, livelihoods, health, ecosystems, economies, societies, cultures, services, and infrastructure due to the interaction of climate changes or hazardous climate events occurring within a specific time period (…) Impacts are also referred to as consequences and outcomes (…)” (Agard et al., 2014).

This definition of impact fits the scope of this deliverable as it is used to describe the effects of a novelty, such as the practical application of SCF on the decision making processes identified in the prototypes, which are problem-solving activities ultimately carried out by a set of persons. As a result, in this deliverable, we hold true to the seminal distinction between the definition of the economic/non-economic value of

SCF and the changes that such novelties have (or it is assumed to have) on the established historical decision-making processes (DMPs) in such sectors.

The previous report – D41.2, Preliminary guidance document on the evaluation of the decision making process value – presented the various methodologies proposed to assess the value of SCF in specific decision-making contexts. These methodologies have since been implemented by EUPORIAS partners in the context of specific EUPORIAS climate services prototypes[1] or other case studies also being developed within the project.

The sections below provide the main findings from six prototypes from the EUPORIAS consortium of partners, highlighting (where available) both the economic value and the impact of using SCF on the DMPs under analysis.

[1] For more information on the EUPORIAS prototypes see: http://www.euporias.eu/prototypes

5. Assessing the value and impacts of using seasonal climate forecasts in decision-making

5.1. The Weather Roulette methodology applied to the Resilience prototype

5.1.1. The weather roulette methodology

Nowadays, the field of climate services is increasingly facing the challenge of understanding the value of its products to companies and stakeholders. Many scientific diagnostic tools exist to assess such quality, including widely used forecast skill scores. However, such measures are not well known by people outside the scientific community, which poses a challenge. The need of intuitive diagnostic tools becomes evident, especially when dealing with customers which are not experts in this area.

Whereas one cannot expect decision makers to be familiar with the statistical techniques employed by the scientific community, and their results, economic and financial knowledge is widespread in the corporate world, and terms such as “profit”, “interest rate” or “returns” are commonplace, particularly in the field of energy trading. For this reason, conveying forecast quality in such terms is a very appealing communication tool for bridging the gap between the scientific world and private companies.

The weather roulette methodology (Hagedorn & Smith, 2009) is a diagnostic tool created to inform in a more intuitive and relevant way about the skill and usefulness of a forecast in the decision making process, by providing an economic and financially oriented assessment of the benefits of using a particular forecast system. It is called weather roulette because it is defined as a bet between two opponents. Each of the two opponents bets that their prediction system is better. The roulette slots are each of the possible categories the prediction system predicts, and each probability is the probability of the ball falling into each of the slots. In this case study we selected the climatology forecast as the opponent to be beaten by the RESILIENCE forecasts.

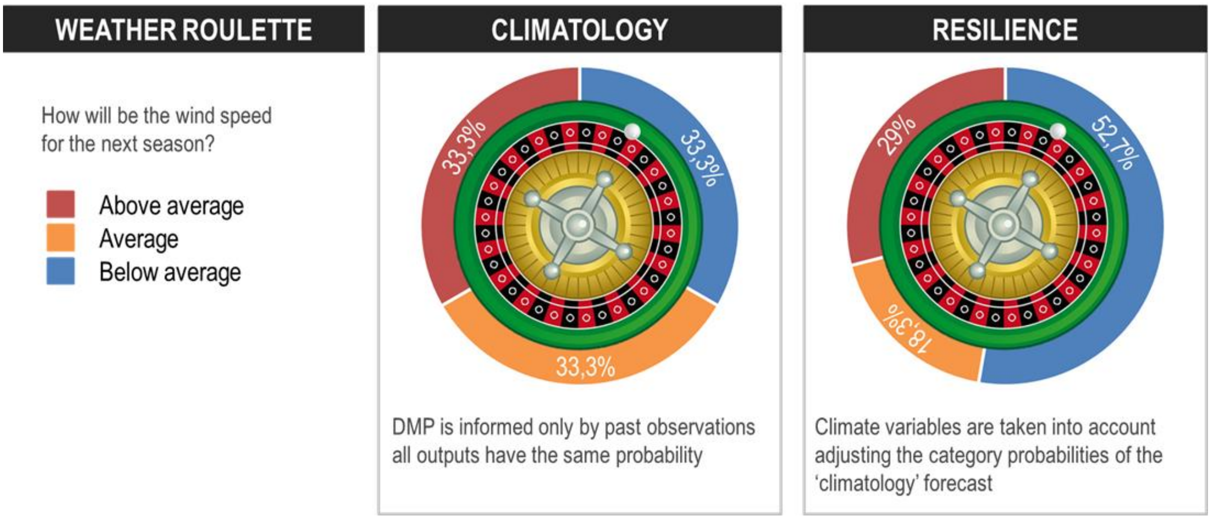

Figure 1 - Visual representation of the Weather roulette concept

(adapted from a slide courtesy of Tim Hewson).

Figure 1 shows that the outcome has a very clear element of chance, but it shows how adapting the probabilistic framework will influence the number of times a category is well predicted.

After the imaginary roulette for each prediction system has been defined, each of the players spreads their bets to the different categories ensuring that all categories have at least a small amount so they never go burst and the roulette is spun. The resulting slot is the slot where the real observations fell. At that moment, the players receive their payment according to their respective bets in the winning/observed category.

The weather roulette is then spun for a certain amount of rounds, and the results are expressed as three economic measures: **Return ratio (r)** for each round, an **Effective Interest Rate (IR)** for the full period played, and the **Return on Investment (ROI).** Return ratios larger than 1 indicate earnings (e.g. a value of 1.5 corresponding to a return of half the bet on top of the bet); a value of 1 indicates neutral return, i.e. no gain and no loss; and values smaller than 1 indicates losses. The Return on Investment indicates the net gains associated to a 1€ investment. By employing such attractive and simple measures, comparing two forecast systems becomes immediate, by just checking which of the two produced more gains after a certain amount of time.

Table 1 - Summary of terms, notation and calculation of the economic terms used in the weather roulette methodology

Return ratios of each round (r_t)

Average Return ratio (R) geometric average of r_t

Effective Interest Rate (IR) in percentage = (R - 1)x100

Initial Capital (c_0) arbitrary value set to 10€

Number of rounds (n) 33 years from 1981 to 2013

Final Capital (c_n) = $c_0 (R)^n$

Return on Investment (ROI) = $(c_n - c_0)/c_0$

5.1.2. The Resilience prototype

RESILIENCE is a semi-operational prototype that aims to provide robust information on the future variability of wind power resources based on probabilistic climate predictions. In order to reach this objective, the RESILIENCE prototype operates at seasonal time scales providing seasonal wind speed predictions for the energy sector. These predictions provide an estimate of wind speed, in terms of three categories: normal wind (an average level of wind speed for that region), below normal wind (low wind speed for what is usual in that region) and above normal wind (high wind speed for what is usual in that region). RESILIENCE provides the likelihood of wind speed falling inside of each of those three categories during the upcoming months. The predictions are accompanied by skill scores, which numerically illustrate how the performance of RESILIENCE's predictions in the past was and guide users about the performance of the future forecasts.

The decision context

Understanding and quantifying wind resource is a key element to multiple user profiles in the wind energy sector both in pre and post-construction. Operations and Maintenance (O&M) teams of onshore wind farms need to schedule operations during low wind periods to minimize the avoided gains while O&M teams of offshore wind farms need to schedule operations during the less windy periods in order to minimize the risk of storms and swell conditions. For grid operators, being aware in advance of the amount of renewable energy that will go into the grid can help schedule traditional power plant operations. For the financial teams running the wind farm business, having a budget of the energy they will produce in the coming months is of crucial importance to anticipate cash flow. In all of these cases the decision makers in each user profile use a retrospective climatology to have an estimation of the expected wind. Indeed, combining long-term reference datasets with on-site measurements by means of dynamical and statistical downscaling methodologies to forecast the future conditions has become quite standard in the wind industry (Landberg et al. 2003, Sanz Rodrigo 2010).

A common assumption in these methods is that future conditions will be similar to past conditions. This assumption entails two inherent shortcomings. The first one is that past conditions can be highly variable, which can make them of limited use when guessing the future. The second one is that climatology cannot predict events which have never been observed before or extreme events in the tails of the climatology distribution, which can be particularly harmful and whose prediction is of special interest for stakeholders. Our knowledge of climatology is based on a finite sample of past events. This sample is limited in time, and doesn't need to be fully representative of what can happen. Moreover, a climatological approach does not take into account changes in atmospheric dynamics, such as those caused by climate change. Climate change may render past conditions less useful for predicting future events, as they may no longer hold true.

The value of SCF in the decision-making

Despite being relevant to multiple roles in the wind energy sector, the primary user of RESILIENCE is the energy trading sector. Nowadays, many countries can not cover their energy needs from their own sources increasing the significance of energy trading not only for supplying energy but also for buffering the risks of supply shortages or price fluctuations. Supply and demand are the determining factors for the market and important decisions must be made in order to attain adequate load balancing between production and consumption. Production and its costs are variable and depend on many factors, such as wind speed for wind energy, fuel prices for thermal energy and rainfall for hydro power. This scenario is further complicated by the variability of demand itself. Energy traders must make their choices based upon which course of action will be the optimal in terms of expected production from renewable sources, fuel prices, water shortages, energy prices, etc.

One of the difficulties trading analysts face when dealing with probabilistic predictions is conciliating an array of probabilities with a yes/no decision (Cloke and Pappenberger 2009). To overcome this situation, several methods exist to translate probabilities into monetary risk, which is the expected value of losses or profits. Flood risk management, for instance, is a field where probabilistic forecasting is gradually being adopted. Risk-based approaches calculate the expected monetary values and adequate thresholds are fixed and thus a consistent decision-making policy can be defined (Dale et al, 2014). However, to promote the incorporation of probabilistic predictions in the decision-making process of climate analysts in energy trading firms the first step is to demonstrate the added value of these predictions compared to current practice.

The user's trust in the prediction system increases with the ratio of correct predictions for a given probability threshold (e.g. 70%) provided that the frequency of false alarms is low enough. Despite the ratio of correct predictions does not fully account for the probabilistic nature of climate predictions, it is an important aspect of SCF to bridge the gap between the definitions of value for scientists and users. A retrospective climatology assumes that the probability of future wind speeds being below-normal, normal, and above-normal is equal (one third each). By using RESILIENCE's probabilistic predictions the users are provided an improved characterisation of the probability of the wind speed falling into each of these three categories.

The goal of the RESILIENCE prototype within WP41 is to show to the potential users that - for the regions where the prediction system is skilful- the hit rate of RESILIENCE can be greater than mere climatology. This increases the perception of value for climate predictions promoting their inclusion in the decision making processes that require wind resource assessment.

The impact of SCF in the decision-making

Despite the high interest of some of the energy users engaged in the development of the energy prototype to provide SCFs for energy, the maturity of the sector is not ready yet to introduce in an operational basis the SCFs produced by RESILIENCE into their decision-making processes (DMPs).

The concept of impact, as defined in this report, is related to the actual influence of using seasonal forecasts in the decisions as well as the consequences in the DMPs at mid- and long-term. At this stage of user engagement, most of the users acknowledge the potential of SCFs but have indicated that incorporating them to their DMPs will require a long testing period, during which they will continue applying their current practice, followed by an internal evaluation and reporting of the performance of the new system compared to their current practice (the use of climatology). According to all users, an economic and operational impact assessment can only be performed by companies. The information related to costs, benefits and operational decisions is highly sensitive, and often companies are reticent to share it externally to avoid giving strategic advantage to other competitors.

Despite the difficulty to analyze the impact of SCFs in DMPs, the results of the user evaluation of the RESILIENCE seasonal wind predictions prototype (Makri, 2015) provide some insights on the potential impact of SCF in some areas of activity that will be further explained in the results section (5.1.5). Moreover, the interaction with stakeholders to assess the weather roulette methodology and outputs has also offered the opportunity to understand how such a methodology could have an impact in the understanding and adoption of SCFs in the DMPs.

5.1.3. Applying the methodology

We selected 37 locations around the world where wind farms have been installed (Figure 2) to assess the value of seasonal forecasts over climatology. We used DJF season for a period of 33 years from 1981 to 2013. To get the 2-m wind speed in each site we selected the nearest grid point for the ERA-Interim model (Dee et al. 2011), which was used as a proxy of the observed state for that location.

With the historical data for the winter season we calculate the terciles that define the thresholds of below normal, normal and above normal categories. According to climatology the three categories are equally probable for all of the games, with a probability of 1/3 each.

RESILIENCE's seasonal predictions are based on the calibrated forecasts from the ECMWF's System 4 seasonal prediction system. The predictions have 51 ensemble-members and they are calibrated with a variance inflation technique (Doblas-Reyes et al. 2005) to minimise the forecast errors that are linked to the inability of the prediction systems to perfectly reproduce all the relevant processes responsible of climate variability (Doblas-Reyes et al. ,2013).

The predictions are given in terms of probability. The probabilities are computed as the percentage of ensemble members under the lower tercile (below normal wind speed), the percentage of members between the upper and lower terciles (normal wind speed) and the percentage of members above the upper tercile (above normal wind speed). The lower and upper terciles are the ones computed based on the wind speed values from ERA-Interim in the past. For simplicity we just counted the number of members falling in each category, although kernel dressing methods would be beneficial in non-demonstrative applications.

Skill scores

In the climate predictions' community the performance of seasonal predictions is assessed with skill scores.

The **Ranked probability score (RPS)** is a measure of the squared distance between the forecast and observed cumulative probabilities (Wilks, 2011). It can be interpreted as a multicategorical generalization of the Brier Score (Brier, 1950). RPS is applicable to discrete probabilistic forecasts issued for categorical events (three in the case of the weather roulette) and it takes into account the ordering of categories by using cumulative probabilities (Jolliffe and Stephenson, 2012).

The **Ignorance score (or logarithmic score, IS)** is defined as an average of logarithms of the probabilities assigned to the observed outcome. From the point of view of information theory, the IS measures the average information deficit in bits of a user with a forecast but without the observed outcome yet. Note that lower values of IS mean less information deficit, thus a better forecast. This score is local, because it only uses information from the outcome category, i.e. it doesn't matters what probabilities have been assigned to the other categories. Also, it is a strictly proper score, which means that forecasts cannot be tweaked to fool the score.

For both scores we compute the skill over climatology (ISS, RPSS). Positive skill scores mean that the prediction system performance is better than climatology, whereas negative skill scores mean that it is not better than making a guess based on historical data.

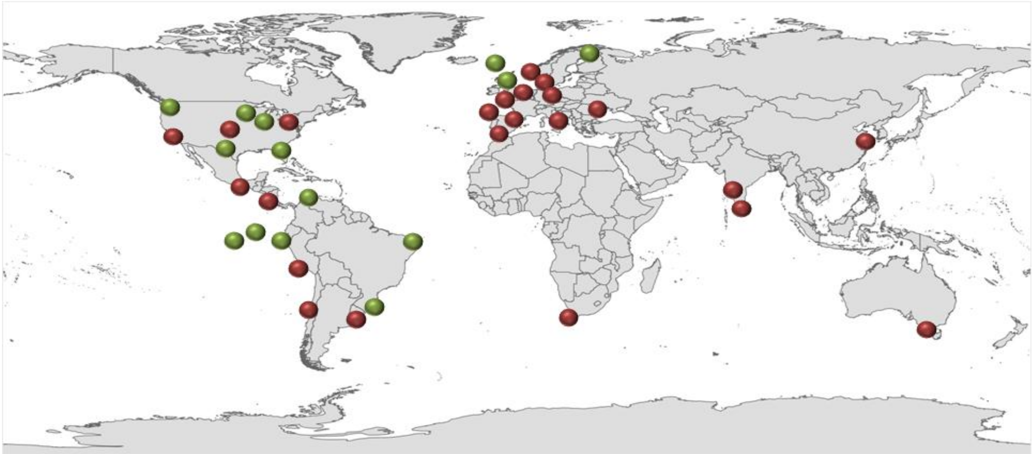

Figure 2 - Location of the 37 wind farms used in the analysis

Marked in red the wind farms in areas with negative RPSS values, in green the wind farms in areas with positive skill.

Fully variant of the weather roulette game

Following the paper of Hagedorn and Smith, this is the fully invested (and fully) variant of the game. The advantage of this version is that skill scores can be translated into effective interest rates. At the beginning an arbitrary initial capital of 10€ is set, and in each of the rounds all the capital is reinvested in the next round. In the game, the player bets proportionally to the probabilities estimated in the seasonal forecast for each category.

The wind speed value of the ERA-Interim is used as a proxy to real observation in the wind farm. The amount invested in the observed category is multiplied by 3 (i.e. the inverse of the climatology probability) and all the amount invested in the other two categories is lost (Figure 3)

Figure 3 - Example showing the betting dynamic in the Weather Roulette

With the performance of both models the Return ratio of each round (r) is calculated for the 33 years of the study period. In terms of model comparison, interest ratios above 1 indicate years where the forecast performed better than climatology and below 1 the prediction based on climatology performed better than the forecast.

The geometric average of all the Return ratios is calculated to have a global Return ratio (R) and then transformed into the Effective Interest Rate -expressed in percentage- for using climate predictions in a particular wind farm. The Return ratio can also be used to calculate the total capital earned after the game (c_0) and the Return on Investment (ROI) (see Box 1).

Weather roulette game in a portfolio of wind farms

Portfolio forecasts are commonplace in the wind industry. Companies that own several sites can sell their energy as a whole package instead of selling individually the energy of each site. Typically, forecasts for aggregated wind farms tend to be more accurate than individual forecasts themselves. This is very helpful, because deviations in the energy compromised in the daily market can have penalties depending on country regulations. This has been extensively shown and used for the day-ahead forecasts.

We were interested to check if using seasonal predictions in all the wind farms of a portfolio had an economic advantage over using them individually. We defined 10 random portfolios containing 6 windfarms with ISS larger than 0. For each portfolio an initial capital of 10€ was invested in each wind farm. The amount earned in each round was pooled and reinvested in equal parts in each wind farm. For each round, the aggregated individual results and the portfolio performance were computed in terms of Return ratios, Effective Interest Rate and the Return on Investment.

5.1.4. Stakeholders' engagement

The need for a methodology to demonstrate the value of SCFs emerged through the interaction with stakeholders throughout the EUPORIAS project. The comparison of the performance of climate predictions against their statistical methods has been a recurrent request. However, after presenting the results of D42.2 (Jiménez et al. 2015) to energy stakeholders, it emerged as a necessity. This deliverable aimed to select a number of user-defined key events in the past and assess the performance of the climate predictions provided by the prototype. Most of the users showed high interest in the reports created, but these reports led in turn to advanced questions about why some key events were well forecasted by the prototype while in other events the forecast failed. These questions were the reflection of a need for a better representation of probabilistic forecasts and their communication to users. This led to the development of the weather roulette approach applied to seasonal predictions.

Given the characteristics of the methodology (i.e. presented as a game), it is currently being implemented as a smartphone App by the EUPORIAS partner Predictia in liaison with WP43. The concept and the preliminary outputs of the methodology have been presented to stakeholders in face-to-face meetings. In the

EGU General assembly of 2016, a preliminary interactive game with the weather roulette was presented in the CL5.11 climate services session. This game was also presented in the poster sessions of the WindEurope summit in September 2016. This summit was a good opportunity to carry out face-to-face meetings and collect feedback of energy users regarding the game. Since the App was not operational users were presented the temporal demo together with additional information and figures.

Once the App will be operational, we aim to prepare a workshop with stakeholders presenting it, in which a number of tasks to be carried out by different groups will be suggested. The on-site feedback will be recorded and a follow-up analysis will be performed to evaluate if the game has improved user’s understanding of probabilistic forecasts and if that has had an influence in user’s perception of value of these predictions.

Regarding users’ involvement in the assessment of the impact of SCFs for DMPs, we have used the results of the user evaluation of the RESILIENCE seasonal wind predictions prototype (Makri, 2015). This evaluation was carried out in November 2015 with 5 potential users from the wind energy industry. During the evaluation, the users were asked to explore the prototype while thinking-aloud performing realistic tasks. Besides their feedback in the usability and design, they were also asked about usefulness and how likely they were to use the prototype in the future. This information provided some insights of the potential impact of SCFs in their jobs.

5.1.5. Results and discussion

From 37 wind farms, 14 locations had positive RPSS and ISS skill scores (up to RPSS=0.55; ISS=0.42), 5 had positive RPSS and negative ISS (0<RPSS<0.06) and 18 had negative skill (up to RPSS=-0.12; ISS=-0.14). See four examples in Figure 4.

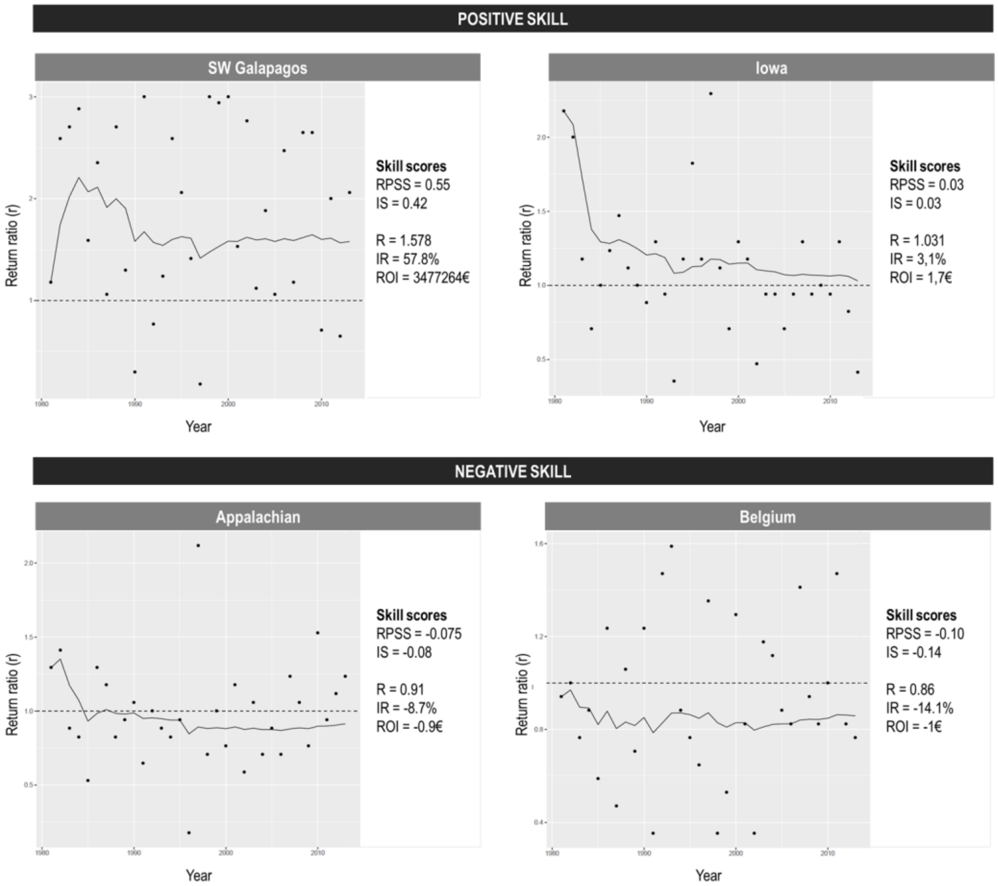

Figure 4 - Example of the results of the weather roulette played in four locations with different levels of skill

Dots are each year return ratio (r_t); over the dashed line, seasonal predictions outperform climatology; below the line, climatology is better. Solid line is the calculation of the geometric average of the Return ratios (R) that is used to calculate the Effective Interest Rate (IR) and the Return on Investment (ROI).

All wind farms with a positive ISS had global return ratios (R) over 1 and positive effective interest rates (IR) which means that over the years there is a net gain. This is because the Return ratio is a mathematical transformation of the Ignorance Score.

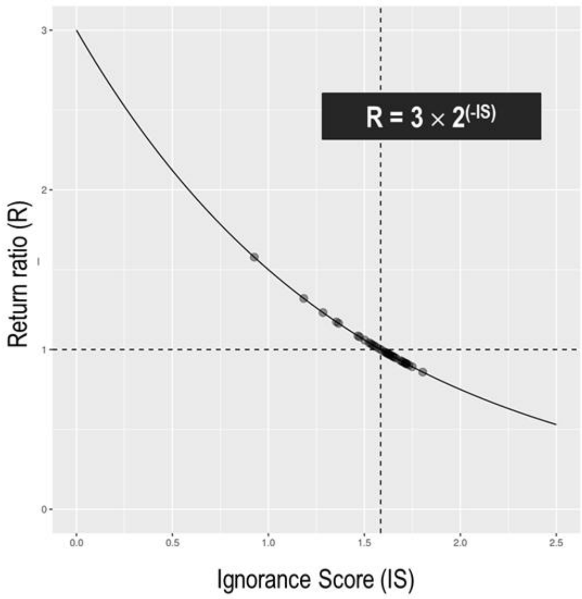

Figure 5 - Plot of the Return ratios calculated for the 37 wind farms

The Ignorance Score (IS) can be directly translated into Return ratios (R) with a mathematical transformation. The points over the horizontal dashed line indicate that RESILIENCE predictions were better than climatology. Wind farms in locations with IS values larger than 1.58 climatology will be better than RESILIENCE predictions (Return ration <1)

After a number of games, one will end up earning money in the roulette only when R>1. Using above equation, this is equivalent to ask for $IS<\log_2(3)$. Where $\log_2(3)=-\log_2(1/3)$ is in fact the Ignorance Score of climatology, hence one earns money only when Ignorance Skill Score (ISS) is positive (Roulston and Smith 2002). So, the ignorance score is the natural skill score to use when dealing with the weather roulette (Figure 5).

However, the Ranked probability score (RPS) is more widely used than IS (Jollife and Stephenson, 2012) because it is not a local score, and it uses the probabilities assigned to the three categories and the outcome category to compute the verification, i.e. it also takes into account how accurate the probabilities predicted for the non-observed categories were. Conversely, IS only takes into account the probabilities assigned to the observed or winning category. Although RPS and IS do not measure exactly the same things, they are highly correlated (0.978 in our site selection), i.e. forecasts with high RPSS will typically give high ISS and vice versa.

So we can expect also that high RPSS lead to gains in the weather roulette. In our particular site selection we had some locations where seasonal predictions had positive RPSS and negative ISS. In this cases the RPSS was bounded at 0.06. This means that in in terms of Return ratio and Effective Interest Rate for the weather roulette some forecasts are not better than climatology despite the positive RPSS value (Figure 6), therefore it is advisable to use ISS as skill score instead of RPSS in the game. A further analysis with a larger sample size would give a better sense of what the deviations between ISS and RPSS can be.

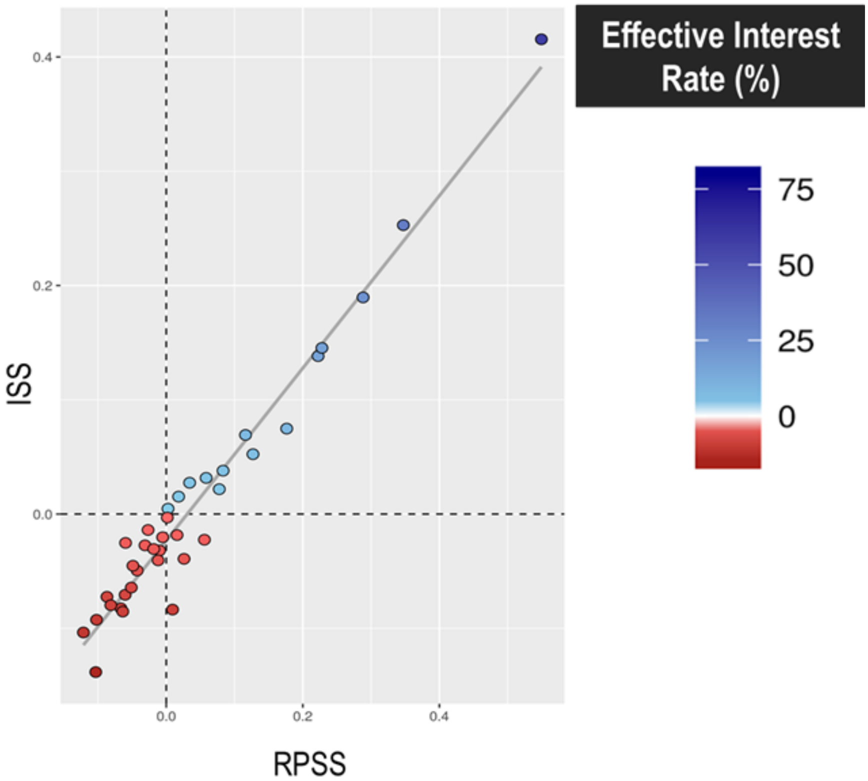

Figure 6 - Correlation between the Ranked Probability Skill Score(RPSS) and the Ignorance Skill Score (ISS)

The color scale indicates the Effective Interest Rate (IR)

The return on investment of the 14 wind farms in skillful areas (RPSS>0) is illustrated in Figure 7 that show how the return on investment for the full 33 years period increases exponentially with the skill.

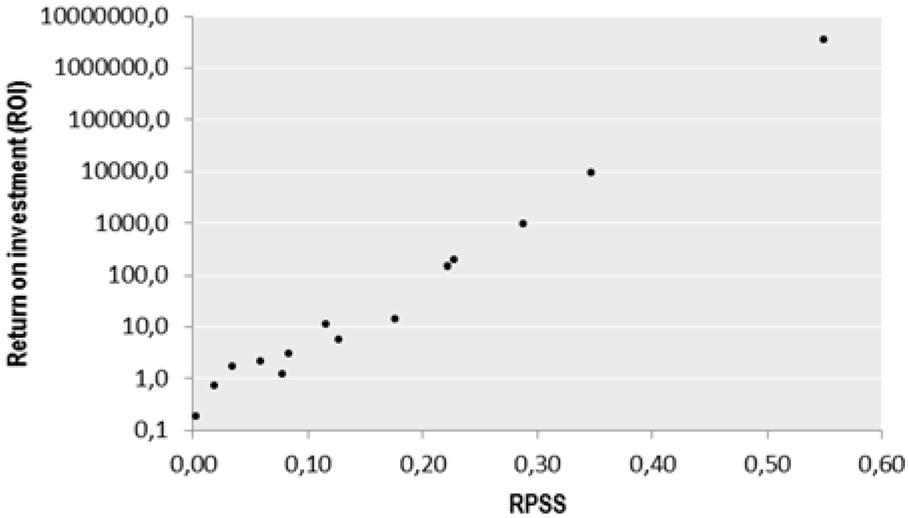

Figure 7 - Return on investment (ROI) in the wind farms located in skillful areas (positive RPSS)

The Wind farm portfolio effect is especially relevant when the locations of the portfolio have uncorrelated model errors that compensate each other on averaging. For the seasonal forecasts this has not yet been investigated. When applying the weather roulette to portfolios of wind farms redistributing the earnings and losses after each round, there was no clear advantage compared to playing the game in individual wind farms (see results in Table 2 and two examples in Figure 9).

Table 2 - Summary results of the Weather roulette played in wind farm portfolios compared to the aggregated result of the individual games

Portfolio ID	*Aggregated ROI*	*Portfolio ROI*	*Aggregated IR*	*Portfolio IR*	*Portfolio advantage*
2	*3.487.819 €*	*96.108 €*	*50%*	*34%*	
8	*3.486.989 €*	*53.420 €*	*50%*	*32%*	
5	*3.478.404 €*	*88.171 €*	*50%*	*34%*	

3	*3.477.487 €*	*33.119 €*	*49%*	*30%*	
9	*10.693 €*	*22.243 €*	*25%*	*28%*	*x*
4	*9.589 €*	*706 €*	*25%*	*16%*	
1	*1.183 €*	*3.827 €*	*17%*	*22%*	*x*
6	*1.004 €*	*2.040 €*	*17%*	*19%*	*x*
10	*367 €*	*2.254 €*	*13%*	*20%*	*x*
7	*169 €*	*490 €*	*11%*	*14%*	*x*

In half of the cases the portfolio performed better, but in the other half it did not. An initial hypothesis was that for portfolios of wind farms in areas affected by the same climatic phenomena (e.g. a strong el NIÑO), the seasonal predictions would have similar (correlated) errors. Conversely, in a portfolio of wind farms distributed across different areas affected by different climatic phenomena and hence non-correlated predictability, would lead to the compensation of errors between wind farms and thus a better performance of the portfolio. We analyzed the correlation between return ratios in each of the portfolios, but that didn’t give any insight into why some portfolio games work better than others. More work needs to be carried on this topic to achieve conclusions.

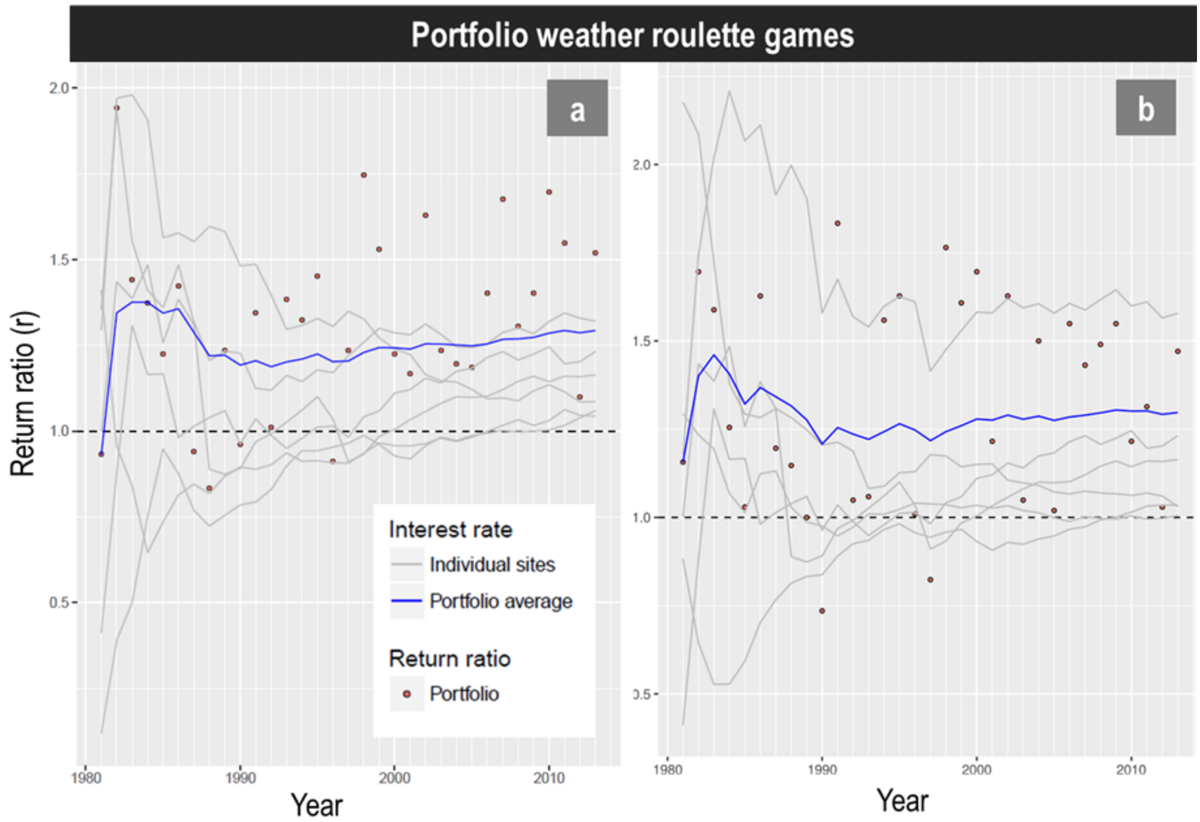

Figure 9 - Example of two portfolio games

a) Shows a portfolio that outperforms the sum of the individual games; b) shows a portfolio where the aggregated ROI of the individual games outperforms the portfolio.

Identifying the value/benefits for the users

Stakeholders have been informed about the weather roulette methodology and they have seen the preliminary results. However, having a platform to share the results of the methodology is also relevant for a correct understanding of the results. After having the possibility to liaise with WP43 and develop a smartphone App, the final systematic evaluation of the results will be carried out based on the user's interaction with the App. A workshop will be organised to make an assessment of user's understanding of the main results, and their views on how this can impact their perception of the value of seasonal predictions. In the meantime, a first round of face-to-face meetings was carried out to have preliminary feedbacks.

One of the comments raised by users was related to the time frame used to calculate the benefits. Although 30 years-time provides a long sample of events to compare SCFs with climatology, we were also asked for the opportunity to play the weather roulette for shorter periods (of 5 or maximum 10 years). The rationale behind this petition was that the wind farm developer usually needs 7 to 8 years to recover the initial inversion in the construction phase. During this period, it is critical to maximize the revenues of the wind farm to reduce the bank debt. This situation is regarded as a potential enabler for using seasonal predictions to improve the wind farm performance. Examples of decisions taken based on seasonal predictions include applying economic mitigation measures if low wind periods are expected, or signing in advance agreements for selling energy at a price set in the present if highly productive periods are expected in the future.

The game was run for individual wind farms as well as for portfolio assessments (which include various wind farms from the same energy trader). Although the portfolio game still requires more development, all users highlighted the importance of portfolio forecasts in the wind industry. Users expressed their willingness to see more results about the performance of the weather roulette using combinations of more realistic portfolios, that is, selecting portfolios more similar to the real ones either regionally(e.g. portfolios with wind farms from East, West and Central USA) or in the size of the portfolio in total MegaWatts.

The final most common remark was that they saw the weather roulette as an engaging tool to explain the concept of skill and how it works for probabilistic predictions, and they considered using the final App to explain climate predictions within their company. Despite the fact that effective Interest Rate (IR) is a direct measure of the performance of RESILIENCE compared to climatology, all users indicated that they would like to see a clearer reference to the climatology performance in the App to better highlight the value of using seasonal predictions.

Identifying the impact for the users

The wind power industry started in the 80's followed by a slow growth in the 90's. In the last 10 years, it has seen an exponential growth up to the point that the wind power industry installed more than any other form of power generation in 2015 (WindEurope, 2016). The wind energy sector is therefore still relatively young and, as such, there are a number of companies that might be expected to be early adopters of CSFs to gain a strategic advance towards other competitors (Reitg et al., 2016). Early adopters can help testing the service and improving it while accelerating the service broader adoption in the sector.

However, there is a gap between the technical analysts that foresee a future potential for seasonal predictions and the actual decision-makers in the energy companies. There are multiple types of energy companies such as O&M, wind farm operators, grid operators or energy trading companies. Moreover, within those companies, there are different user profiles ranging from climate analysts, technical engineers to financial teams. Even in those companies that have already stated an open interest in the RESILIENCE prototype (e.g. EnBW, EDPR or Iberdrola), all the contact points have remarked: i) the need for an internal process to adopt changes in decision-making, and ii) the need of operational predictions for a long period, so that they can make their internal benchmarking of the two methods and present the results to the actual decision-makers.

The users interviewed considered that CSFs would have an impact in the DMPs of three main activities of the wind energy sector: planning and development of wind farms, maintenance scheduling and investment decisions.

Planning and development:

- Assessing energy yield to prepare for negotiating loans with banks for new wind farm projects;
- Predicting wind farm performance and profitability;
- Identifying potential geographical regions for development;

- Decisions related to the time of wind farm construction (which demands a minimum condition of wind and rain);
- Making energy trading decisions.

Maintenance:

- Scheduling maintenance of wind farms;
- Pre-plan purchases of the necessary maintenance parts to mitigate typical wind farm breakdown issues (resulting from accidents caused by extreme wind conditions).

Investment decisions:

- Improving financial plans based on the findings about wind variability in a geographical area;
- Making cash flow predictions;
- Assessing financial risks (i.e. how much wind energy production, and therefore income and profitability, differ from financial plans);
- Indicating potential future income (these predictions are at the moment based on past averages rather than on predictions).

Final remarks from user's interactions

There was a general agreement in indicating the lack of predictability as the main reason for not using seasonal wind predictions so far (Makri, 2015) in line with the users' perception of lack of reliability of SCFs described by Bruno Soares and Dessai (2015).

In order to facilitate an understanding of the potential of seasonal predictions, user-engagement strategies need to be implemented. This should start with the more research-oriented staff, who is often more open to new developments and advances of the state-of-the-art research, and then address the final decision-makers who are more susceptible to risk aversion. By introducing the weather roulette to climate analysts and technical staff the aim is not only to present the potential of seasonal predictions to them but also to provide them with alternative tools and more intuitive skill assessments that they can use internally to report their evaluation of new methods such as seasonal predictions. This is a necessary step for a real impact of SCFs in the DMPs of the wind energy sector.

5.1.6. Lessons learned

The results of this work indicate that the effective interest rate is linearly related to a standard skill score for the scientific community such as the RPSS. Skill scores require a longer training period for those users that are not familiar with probabilistic scores, instead, translating this scores to economic concepts widely used has a potential to improve the understanding of the value of seasonal predictions over climatology.

The main limitation to analyse the value of climate predictions in the energy decision-making context is the impossibility to use actual observed/generated benefits in particular locations. This information is highly sensitive as a wrong interpretation of it in the media can have a direct impact on the actual benefits of a company or can provide a strategic advantage to competitors. The weather roulette results in terms of Return on Investment can't be directly translated into actual ROIs, which can be seen as a drawback, however we expect it to be a tool to demonstrate and quantify the potential impact on decision-making that will lead to further interactions and questions from the energy stakeholders.

Future work could take advantage of the weather roulette applied to seasonal predictions to show the effect of changes in different aspects of the prediction system, for example for comparing the results from two different locations or regions, a quintile categorisation of wind speed events or the effect of different lead times.

Although we can't provide yet the evaluation of user's feedback to the weather roulette methodology, our experience after presenting the interactive poster at EGU or commenting the development of the app to users is that having a multimedia tool such as an interactive online game or a smartphone app is a very engaging way to present scientific concepts to users.

5.2. Decision-maps applied to the Land Management Tool prototype

5.2.1. Decision-maps methodology

SCF are relatively new in Europe and little is known about its use (Bruno Soares and Dessai, 2015). In addition, the lack of reliability[2] of this type of forecasts across different regions in Europe can hinder its use (cf. Lemos et al., 2012). As a result, in order to understand the value and benefits of using SCF to help support farming decisions it is important to identify key management decisions where different management options can be made in order to take advantage of existing forecasts (Sonka et al., 1987). Those key decisions need to be identified through close interaction with the land managers given their in-depth knowledge of the practices and management decisions in place (Stone and Meinke, 2006). In addition, the first step to determine the relevance of SCF "(…) is to identify the existence of entry points for climate information into the decision-making process." (Bert et al., 2006).

Our methodology was based on a participative approach to understand the key farming decisions that need to be made in the coming months, the different management options available to the land managers, the different entry points in the decision process in which SCF could be of use and the conditions that need to be in place to allow the land managers to use it in their decision-making processes (cf. Bert et al., 2006; Jones et al., 1998). The first stage of the analysis i.e. the identification of the critical decisions in the coming months was achieved through the development of decision maps (cf. Bert et al., 2006) during a workshop held in January 2016 (see below). By identifying the critical decisions to be made by the farmers we were then able to assess, at a later stage, how those decisions had been

[2] The term Reliability is used here as a synonym of trustworthiness and, as a result, it can be mapped onto a number of other technical concepts such as skill, reliability, and sharpness.

(or not) informed by the SCF made available to the farmers and thus, understand the value and impact that this type of climate information had in the farmers' decision-making processes.

5.2.2. The Land Management Tool prototype

The Land Management Tool (LMTool) is a semi-operational prototype that aims to provide relevant and usable climate information to land managers in the Devon region in the UK. The prototype is being coordinated by the Met Office together with partners at the University of Leeds, KNMI, the University of Lisbon, Clinton Devon Estate and the National Farmers' Union.

The prototype provided two types of forecasts: 14-day forecasts (for both temperature and rainfall; updated every 6 hours) for specific weather stations in the region; and 3 month outlooks (for both temperature and precipitation; updated monthly) for the whole region. Both forecasts are provided to all land managers (n=20) involved in the prototype which can access the information via an online password protected micro-site (Figure 10) and an App developed for that purpose (Figure 11).

Figure 10 – The Land Management Tool micro-site

Figure 11 – The Land Management Tool Application

The development of this prototype started in the winter of 2014 and, although initially, only land managers working in the Clinton Devon Estate were involved. Other land managers from that region (linked to the National Farmers Union) were then also involved in order to increase the sample of the stakeholders involved.

A range of activities have been pursued since the start of the prototype, including:

- Initial interviews with a small pool of farmers (n=5) – to help us understand the type of land management activities and practices in place as well as current use of weather information and potential use of seasonal climate forecasts for their decision-making;
- Preparation of the first version of the seasonal climate forecasts for the winter of 2014/2015 (Figure 12);
- Feedback from land managers on the seasonal forecasts;
- Involvement of other land managers through the National Farmers Union (NFU);
- Survey on similar aspects from those explored in the initial interviews to larger farming community (both within Clinton Devon Estates and also other farmers from the NFU);

- Refine the seasonal climate forecasts (based on land managers' feedback) as well as preparation of 14-day forecasts as requested by the land managers (Figure 13);
- Preparation of online feedback regarding both types of forecasts. Feedback questions are embedded in the webpages for each of the forecasts making feedback easier and quicker for the land managers;
- Survey on visualisation techniques for both types of forecasts in order to improve their presentation to the land managers;
- Workshop with the land managers to improve both forecasts in terms of content, presentation as well as set out the foundations for exploring the value of seasonal climate forecasts in their decision-making processes.

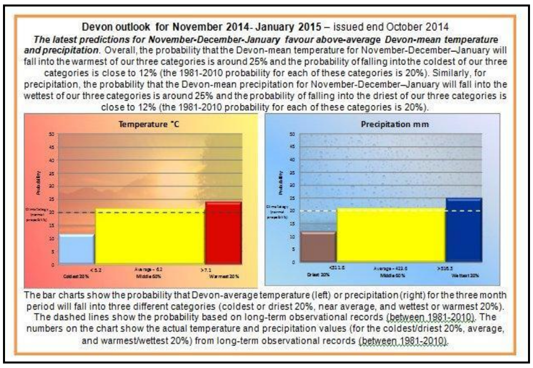

Figure 12 – Seasonal climate forecasts provided to the land managers in the winter months of 2014/2015

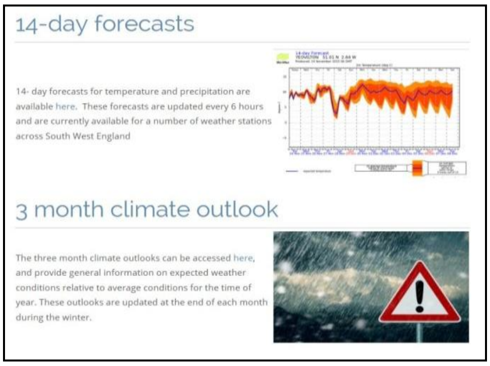

Figure 13 – Seasonal climate forecasts and 14-day forecasts provided to the land managers in the winter and spring months of 2015/2016.

Following from the workshop which took place in January 2016, the LMT team worked on improving both forecasts based on the outcomes and feedback received during the workshop. Both types of forecast were provided until May 2016.

The Decision-making context

The decision-making contexts within which the value of SCF was assessed are those of the land managers involved in the LMTool prototype. Their farming activities are varied (e.g. livestock, arable crops, dairy, mixed farming) and involved complex processes of decision-making. As a result, and as a way of narrowing down and selecting key decisions that were to be made by these land managers, we selected key decisions through an interactive session with the land managers at the workshop held in January 2016 (see below).

5.2.3. Applying the methodology

This methodology is participative in nature and the analysis of the value and impact of SCF to support decisions was based on qualitative methods i.e. workshop and in-depth interviews.

The workshop with a representative group of the farmers was held in January 2016. During the workshop, each of the six farmers were asked to (adapted from Bert et al., 2006, Jones et al., 1998):

- List the main decisions they will have to make in the next 3 months (Feb/Mar/Apr);
- Describe when these decisions are normally made (i.e. month(s), weeks, days);
- Choose the two most important decisions and briefly explain why they are important to them/their farm(s); and describe:
    - What are the weather events that influence this decision? Why and how do they affect the decision?
    - What other factors also affect this decision? Why and how do they affect the decision?

The information collected during the workshop was used to develop decision maps of those critical decisions which was then be used to further examine the potential value of the SCF being provided in the next few months against the decisions that need to be made. Table 3 shows an example of a critical decision identified by one of the farmers during the workshop.

Table 3 – Example of a critical decision identified by one of the land managers during the workshop

Critical decision	Planting wheat in spring
When to make decision	March
Weather/climate conditions influencing decision (6 months ahead; vary week by week)	Rainfall (i.e. not too wet)
Other factors influencing decision (6 months ahead)	Purchase seeds Greening agenda Market forecast (need to change from wheat to barley?)

Identifying these critical decisions would allow us to explore and understand the (potential) value and impact (e.g. planning actions, reduced wasted operational efforts; cf. Table 3) that the SCF provided to the land managers over the past few months had in the decisions identified at the workshop.

Following from the workshop the farmers were provided with 3 month outlooks for temperature and precipitation on a rolling basis and updated every month. Farmers were asked to reflect on the decisions they identified at the workshop and the forecasts provided (cf. figure 14). In April 2016, follow-up interviews were then conducted with the farmers to discuss both the usefulness of the SCF in their decision-making as well as the value and impact of having that information available.

Our aim was to identify the extent to which the SCF provided had influenced (or not) the decisions identified by the farmers in the workshop in January 2016. To achieve that, we used the decision maps developed during the workshop as well as the SCF provided to the land managers as a starting point for exploring key issues when considering or using SCF to inform those specific decisions. This included understanding to what extent the SCF has influenced (or not) their process of decision-making, analysing the factors enabling or constraining the use of SCF in that specific decision-making as well as further exploring the potential value of SCF with the land managers and what needs to be in place to allow that to happen.

Figure 14 illustrates the overall process of applying the methodology to the LMTool prototype.

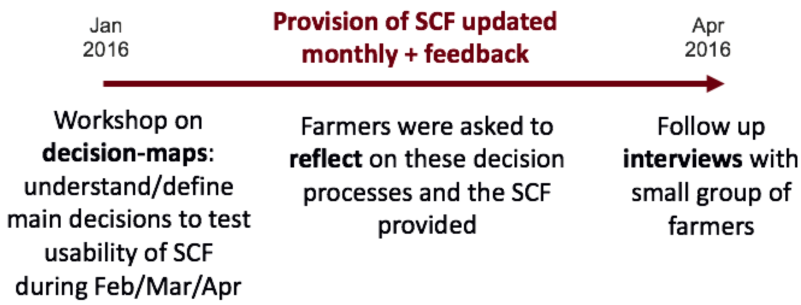

Figure 14 – Diagram of the main stages of the assessment of value and impact of seasonal forecasts in the decision-making of the farmers

5.2.4. Stakeholders' engagement

As described above, the assessment of the value and impact of the SCF in the farmers' DMP was pursued via an interactive workshop in January 2016 followed by in-depth interviews in April 2016. In addition, the farmers were also asked to continue providing us with online feedback of the SCF provided as a way of continuously improving the LMTool.

5.2.5. Results and discussion

In this context, the notion of value and impact was mainly related with the potential to use this type of forecasts to help support the processes of decision-making and associated benefits (e.g. potential increase in yield, income). Given the complexity and risk involved in the decisions being made by farmers as well as the low reliability of SCF in the Devon region, we explored the potential impact by examining the entry points within specific decision processes where SCF could be of use (or not) and the reasons why.

The first finding from the in-depth interviews conducted with the farmers was the difficulty in operationalizing the methodological approach adopted i.e. the decision maps. This was due to the complex and dynamic nature of the decision-making processes in farming which are very susceptible to change due to an array of factors e.g. weather, financial, etc. As such, we had to put aside the decision maps that had been developed during the workshop early in the year as the decisions identified then had since changed. Instead, we focused on the decisions that had been pursued by the farmers and reflect on the usability of the SCF during that period of reflection (cf. figure 14).

Different situations were identified with regard to how the farmers used (or not) the SCF provided:

- One farmer was not interested in SCF as he rents his land to other farmers and, as such, makes no use of weather or climate information. In addition, the farmers using his land all worked with contract with supermarket chains which required specific products at specific time of the year. As a result, those farmers were also bounded to the contract requirements which forced them to plant specific products at specific times of the year independently of the (weather/climate) conditions.
- Another farmer was interested in SCF but unfortunately was not able to use it to inform her decisions regarding the grazing of cows as the weather in previous weeks had already conditioned her options i.e. heavy rainfall had

saturated the soil and thus conditioned her decisions for the Spring months. As a result, she was not able to use SCF to help her inform her decisions as these were already constrained by current soil saturation.

- Another farmer mentioned the need for having more time to develop confidence and allow farmers to translate the SCF information into the specificities of their land: “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.”
- Only two of the farmers **used SCF** in their decisions:
    - “Before Christmas we had to do some (…) spraying later, and the prediction [from the SCF] was for a wetter but milder winter. It did focus us that (…) if we got a **window [for spraying] we needed to take it because there would be less dry spells.** (…) **So we did because the probability was that it was probably rain again**.”
    - “**I’ve not done any contracts** or invoicing for anybody to go on any of my fields **because the fields aren’t good enough, they’re too wet**, and I knew that they would be too wet because it was **going to be so wet in February and March**.”

Both farmers agreed on the benefits of having used SCF to inform their decisions in the form of avoided costs but they could not attribute an economic value for using the SCF (as opposed to not using the SCF and thus not changing their decision-making).

The value of SCF in the decision-making

Although it was not possible to determine an economic value in terms of the decisions taken based on the information provided by the SCF, both farmers claimed to have saved money as changing the decisions based on the SCF prevented them from spending unnecessary money. As such, determining the economic value of using SCF in those decisions would require farmers using this type of forecasts over a longer period of time in order to allow them to become more comfortable using this types of forecasts in their DMP and progressively gain more trust in dealing and using probabilistic forecasts.

The impact of SCF in the decision-making

The impact of using the SCF in those decisions was significant as the two farmers changed their normal course of action based on the SCF provided to them.

In one case the decision was if the farmer should invoice people to work in her fields which normally happens 2 or 3 months beforehand. However, as her fields were already wet and the SCF 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 the DMP avoided having people going into the fields and ruining the grass. For this farmer *"It's about expectations. Because if I'm planning on having income, let's say, coming in from the fields in April and then something goes wrong, I might worry and say, "Oh my God, why hasn't so and so...?" but I've got enough time to think, "Oh I know what's going to happen, it's going to be like this". And so, no, you take decisions on the day probably for various reasons; if the priorities are you've got to mend the fencing rather than turn the cattle out that's what you've got to do. But at least the (…) scenario is in place and so it gives you more comfort (…) in terms of planning and expectations".*

In the other case, the farmer's decision was about when to spray fungicides early in the year which requires having a dry spell of at least a few days. Based on the SCF prediction of wetter but milder months the farmer decided to spray as soon as he got a window of dry spell (the farmer also uses radar information, weather forecasts as well as the 14-days forecasts provided in the LMTool) rather than waiting for drier conditions at a later stage. Although the SCF was used in combination with other types of weather information the SCF helped to set and guide his decision for spraying. According to this farmer *"The benefits [of having SCF] are that you knew. Like certainly into the autumn and the winter, if it's showing it's going to be* *particularly wet. The benefit was planning, right we'll be as much as we can early, beforehand, sort of thing, knowing it was going to be wet, and as it turned out it was wet. And it's probably going to be another year to really trust it. Because the first three months certainly, you're taking it with a bit of pinch of salt, "Well is this going to work or not?", and then sometimes it absolutely chucks it down or it's randomly ridiculous hot for a week and you forget that this actually over, like you said, it's over three months [the SCF probability]."*

Both farmers agreed that if the SCF were available they would keep using it as an additional piece of information to their DMP: "Yeah, if it was available I think it would certainly be useful to use as a tool".

5.2.6. Lessons learned

This study has showed that there is potential to use SCF in farming-related activities and decisions. However, the complexity and volatility of farming activities and decisions to a wide range of factors made the assessment of value and impact difficult. Due to the novelty of the SCF to the farmers and the range of their decisions we opted to apply a qualitative approach – through the development of decision-maps - to examine the potential value and impact of these forecasts in their decision-making as this would allow us to engage more closely with the farmers and thus have a better understanding of the entry-point at which SCF could be used to support their activities and DMP. Although the focus of the SCF provided were for winter months due to the available skill during this season in the UK (see Scaife et al., 2014) farmers were more interested in the other three seasons as that is when they are most activities in terms of their operations. Nonetheless, the SCF for winter months were positively received and broad decisions were immediately identified by the farmers e.g. spreading of slurry, spraying of pesticides, grazing of cattle, etc.

The assessment of the value and impact of SCF in their DMP was pursued during the early months of 2016 (Feb/Mar/Apr) and of the six farmers interviewed only two actively used the SCF provided to inform and change their decisions (see above).

However, it is important to note that the reason why the other farmers did not use the SCF was, in some cases, not related to the information provided but due to other conditions such as the type of enterprise pursued, activities not susceptible to weather conditions or the conditions of the ground in their farm at the time that limited the usability of the SCF.

The two farmers that used the SCF did it to help them plan their activities and, in one of the cases, also to help manage their expectations with regard to their financial conditions.

Another critical finding from this study was the need to build trust in the SCF. The novelty of this type of forecasts and the content of the information provided (i.e. average conditions over 3-month period) meant that most of the farmers involved in this analysis mentioned that they needed more time to gain confidence and trust in the information provided as stated by a farmer: *"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 forecasts with the changes and impacts in their land would allow farmers to have a better understading of how SCF could be used in their DMP (similarly to their own experiences in using weatehr information).

"Yeah, well it would be interesting to see it. I say the more information you've got, and once you can build up a bit of trust in it, and that'll take…Probably need to do the whole year really to see it and then judge it. But yeah, the more information, it just helps you make decisions. I don't used to have to take it all on, but the more information you've got, I find you can make a better decision at the end of the day."

Another lesson learned from this study was the difficulty in understanding and assessing value and impact in the context of farming activities. The methodology chosen to pursue this analysis – decision-maps – was difficult to implement given the dynamic nature of the activities pursued by the farmers. As such, further research is required to develop adequate methodologies that allow us to fully understand the value and impact of using climate information, such as SCF, in real and highly complex decision-making contexts such as the farming sector.

5.3. The placebo concept and the RIFF prototype

5.3.1. The placebo methodology

The placebo concept, well known in medicine to test new medical treatment, has been adapted to climate field. Its principle is to put the stakeholder in a context close to real one, and to ask them to apply their DMP with two inputs: one is a seasonal forecast, the other is a false one (the placebo). This experiment has been lead in collaboration with our stakeholders EPTB Seine-Grands Lacs over a sample of past situations, in order to calculate a performance score (Viel et al, 2016).

To ensure a maximum objectivity, MF has compared decisions made with RIFF to decisions made with “classical” products operationally used by EPTB, in the same context (i.e. with the same external factors, potentially influencing the decision).

That is why we first have asked EPTB to redo some past decisions without any forecast information, instead of simply compared to real past decisions. For example, we know that the occurrence of a very critical dry event in previous years could strongly influence the decision, and in a way could bias the resulting emptying curve. This experiment is called NF (“No forecast”).

5.3.2. The RIFF prototype

The RIver flow Forecasts for water resource management in France (RIFF) prototype developed by Météo-France (MF), aims to provide useful information based on seasonal hydrological forecasts to improve dam management for water resources issues in France: see http://riff.euporias.eu/en.

Downscaled near surface temperature and precipitation data coming from a seasonal forecast system are used as input to a hydrological model, named Safran-Isba-Modcou (SIM), a refined SVAT model at an 8-km resolution coupled with a river flow routing module. This chain produces river flow probability forecasts for specific stations. The first investigations conducted by Météo France (Ceron et al. 2010, Singla et al. 2012) have demonstrated a significant predictability of the hydrological system in France, and moreover the added value of using seasonal forecast data instead of a random atmospheric forcing. The RIFF prototype intends to take advantage of this added value.

A crucial work has been done in close relation with stakeholders to tailor seasonal river flow forecasts, to fit to critical thresholds and key seasons for which decision making processes are established. The crucial decisional periods are typically May/beginning of June for the low flow period and the end of Winter/beginning of spring for the reservoir refilling periods. It should be noted that the same periods are also relevant to the energy suppliers.

In agreement with our stakeholder EPTB Seine-Grands Lacs (EPTB SGL), we have chosen to focus on the summer season for the prototype evaluation.

The decision-context

Water manager decisions are very sensitive to climate information. Many issues are at stake:

- Societal issues since they should anticipate devastating floods and severe droughts that could impact fresh water supply for a region as large as the Paris urban area;
- Institutional issues since they should fulfill well defined missions and meet corresponding objectives;
- Economic issues because a wrong anticipation of drought (or flooding risk) could lead to damage or agricultural losses.

To deal with this hazard, hydrological simulations based on general climate information are already used in decision making processes (Figure 15). Tailored seasonal forecasts integrating the current state of the river flows and others hydrological components as soil water content or mountain snow water equivalent constitute new information to assess all possible scenarios over the following season and plan the best reservoir draining plan.

The main objective of EPTB SGL for the summer season is to prevent river flow from falling under a pre-defined threshold, called "vigilance threshold". To meet this goal, it has to plan the slow emptying of its four lake-reservoirs, in order to sustain river-flow. To maximise the potential role of the dams against the flood risks in winter, all the reservoirs have to be empty at the end of the low flow period (November).

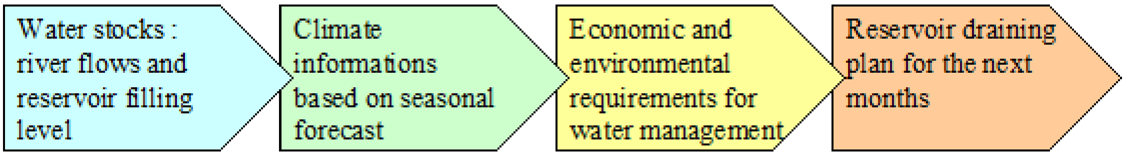

Figure 15 - Decision Making Process including Seasonal Forecast for dam management in Seine Basin

To make easier the evaluation, we have chosen with our stakeholder to focus on an only dam (among 4 reservoirs), the Marne reservoir:

See http://seinegrandslacs.fr/eptb-seine-grands-lacs/les-4-ouvrages/lac-reservoir-marne.

This is the largest reservoir of the basin, with 349 million m^3. It has been put into service in 1974, so we dispose of a long operation period. The downstream monitoring station is Gournay, a few kilometers from the confluence with the Seine (and from Paris). Each year, at the beginning of May, EPTB SGL has to build an emptying plan of its reservoirs for the dry season. The corresponding curve, validated in Consultative Committee with all water resources users of Seine Basin, is actually considered as the decision.

In practice, to draw this curve, ETPB SGL relies on the one hand on the last observed information concerning the reservoir filling status and the river flow (upstream and downstream); and on the other hand on tools simulating dry season scenarios based on historical hydrological and meteorological information. Note that this plan is rectified (if needed) in June, and could be readjusted every 15 days up to October and especially at the beginning of September to anticipate the end of the low flow period.

The value of SCF in the decision-making

It is difficult to measure the global value of a decision on water management issues which concerns both different economic sectors and societal stakes as drinking water supply and global water use for population, irrigation for agriculture, hydropower energy, navigation, tourism but also environment with requirements on good ecological state of the river. For example, a bad decision could lead to perturbations like restrictions on the water use for population (garden watering or car washing) or agriculture needs (irrigation).

Anyway, it emerged that if we were not able to quantify “good decisions”, it was easy to identify “bad decisions”. Indeed “good decisions” lead to normal conditions, where every users of the water resource could operate their activity without any perturbation or limitation. At the contrary “bad decisions” are periods of low flow downstream from the dam, where users (some of them, at least) have to change their nominal activity, so have to undergo disturbances.

So naturally we have decided with our stakeholder to define a metric relative to the occurrence of low flow situations. Concretely we have chosen the number of days when river flow is so low that it could lead to problems for sharing water resources with all users. The threshold we have used is called “vigilance threshold”, and the main objective of EPTB SGL is to avoid being too close to it.

Obviously this metric is not a measure of this economic value of decisions. Our stakeholder EPTB SGL does not evaluate this kind of impact. To carry out such an evaluation, we should have requested specific users (for instance farm operator or tourism company) able to detail the cost of such events. We decided to stick to the evaluation made by EPTB SGL, which is more qualitative but more universal in terms of impact. Furthermore, an exhaustive economic evaluation was clearly out of range of our competencies and of our project planning.

The impact of SCF in the decision-making

The results of the Placebo experiment have been presented and discussed with our stakeholder EPTB SGL. The different simulations made for each year and their impacts in terms of number of days below the vigilance threshold, have been analysed according to the occurancy period and their operational stakes.

The following ideas come from the experiment feedbacks.

First, the real impact on DMP of using SCF is difficult to establish because the climate forecasts remain a helpful decision tool which has to be combined with other information to an operational decision making.

However, the analysis of the 29 years redo allows to identify some weaknesses of the current DMP with a too late start of the reservoir emptying in July while the stocks are generally sufficient to cover the whole low flow season (until November).

The use of SF would have surely permitted for several years to take a better decision for the start of the emptying period in June or July.

EPTB SGL has also important expectations from SF during the low flow period to refine emptying strategy at the end of summer and to decide of the beginning of the refilling period.

5.3.3. Applying the methodology

MF has built two specific datasets for seasonal forecasts and placebo forecasts (figure 16). The seasonal forecasts (SF) are based on SIM (the hydrological model) forced by ARPEGE-System 3, in order to constitute a long hydrological hind-cast (1979-2006). The placebo forecasts (RAF for “Random Forecasts”) are obtained from random draw (with release) in a 1979-2006 meteorological observed dataset, which are used to force SIM, to deliver some “forecast-like” river flows.

Note that all those experiments are made “blind”. It means that EPTB don’t know which year it processes, it only knows the context (recent past and initial conditions) and of course the forecasts for SF and RAF experiments.

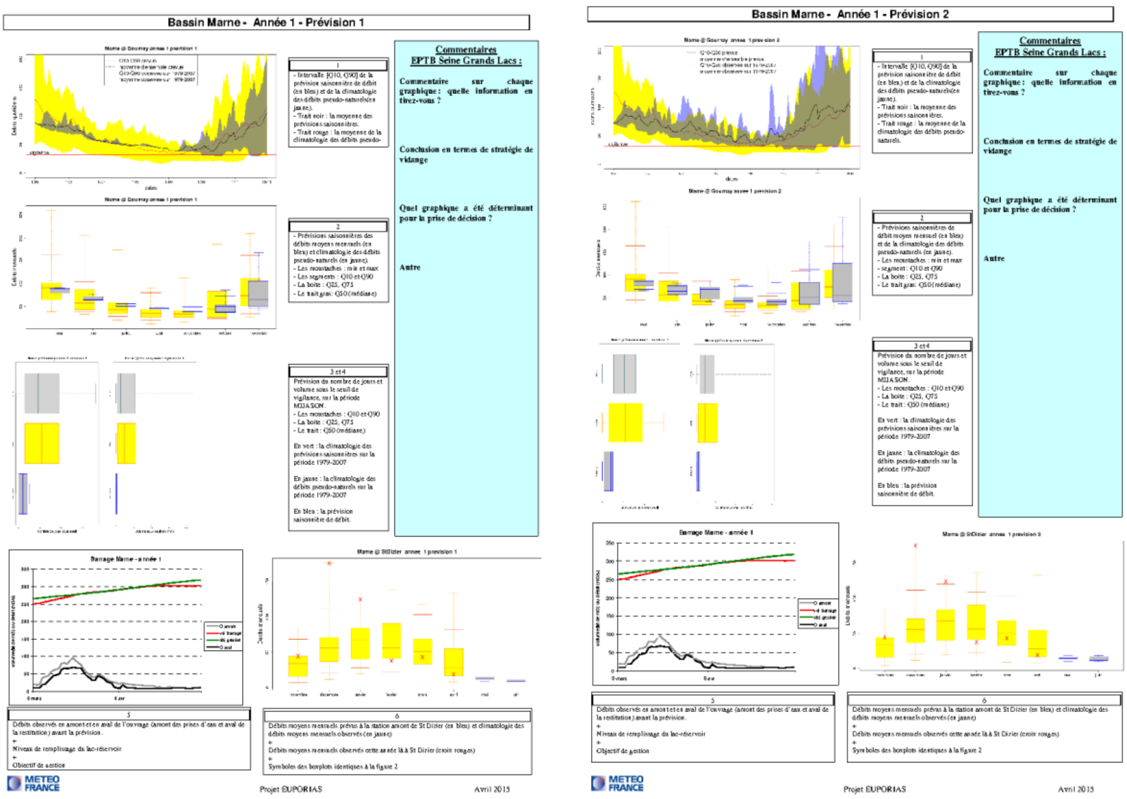

Figure 16 - Example of seasonal forecast and placebo (right and left, or vice versa…) for the same year

Concretely, the Placebo protocol has been tested on one dam, with May initial conditions. It means that EPTB SGL has replayed past decisions with SF and Placebo. Figure 17 illustrates for one specific year the result of the redo with the three different scenarios.

Beforehand the replay, MF has calculated and provided to EPTB SGL all the statistical scores about the performance of tailored product used to know confidence and uncertainties according to the forecast ranges.

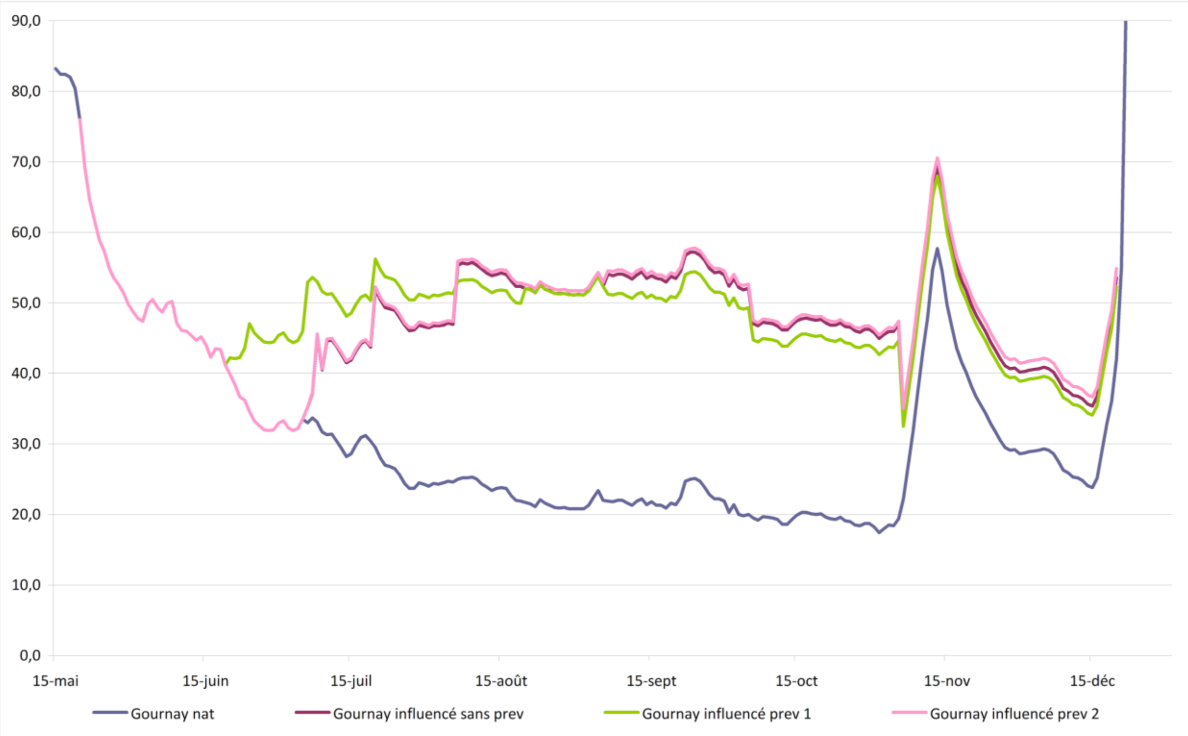

Figure 17 - Simulation of the river flows at the Gournay station for the year 1989 from the Placebo protocol

Reconstituted natural flows are in blue, simulated flows with SF input are in green, RAF in pink, NF in brown, vigilance threshold = 40 m3/s.

5.3.4. Stakeholders' engagement

EPTB SGL was very motivated by the project. Their long term decisions are mainly driven by the long experience and the strong expertise of a small team, who has developed some basic (but efficient) tools to program the dam summer releases. So during the first preparation meeting, they clearly expressed their interest in products that would be able to support their decision.

Over a one year and a half period, a series of 6 main meetings were being conducted in order to specify the experiment: period (summer or winter), choice of a basin and a dam, description of the DMP, products tailoring, definition of a metric to assess the value of a decision, writing of the experimental protocol, experimentation phase, analysis of the results. We don't count here the e-mails and phone calls.

An additional proof of involvement is the fact that EPTB SGL has invited us to present our project during its 2015 and 2016 coordination committees (named COTECO), that regroup the main institutional stakeholders of the Seine basin (representatives of the region, the State, National Defense, etc…) and some major water users (from energy industry, water supply, navigation etc…).

5.3.5. Results and discussion

The Placebo protocol was applied on May programming, for 29 situations corresponding to the 1979-2006 hindcast period of the seasonal forecast model. For each situation and for each set of forecast (without forecast, with seasonal forecast, and with Placebo), their decision consisted in drawing the most appropriate release curve considering the context (dam level and the last months' upstream river flow) and the forecast.

As a reminder, the metric of the quality of the decision was based on the number of days below the "vigilance" threshold. Thus, we obtain a 29 years dataset on the impact of Climate Information onto DMP (Seasonal Forecast and Placebo) measured as numbers of days below the vigilance threshold and compared with current decision (without Climate Information).

In figure 18a, we can see for each month:

- the added-value of Seasonal Forecast compared to Placebo is anything but obvious: looking carefully at the different situations, it appears that a little advantage of Seasonal Forecast especially for June (2nd month of forecast)
- However, No Forecast" experiment obtains the worst scores, except in September. It means that our hydrological system brings relevant information to the stakeholder, comparing to its current practice.

The Figure 18b shows the same information but integrated on several months. For the whole season, SF presents a very little advantage compared to Placebo (in mean, less than 0,5 day) but the improvement of current practice is clearer (1,5 days over 10 days in mean).

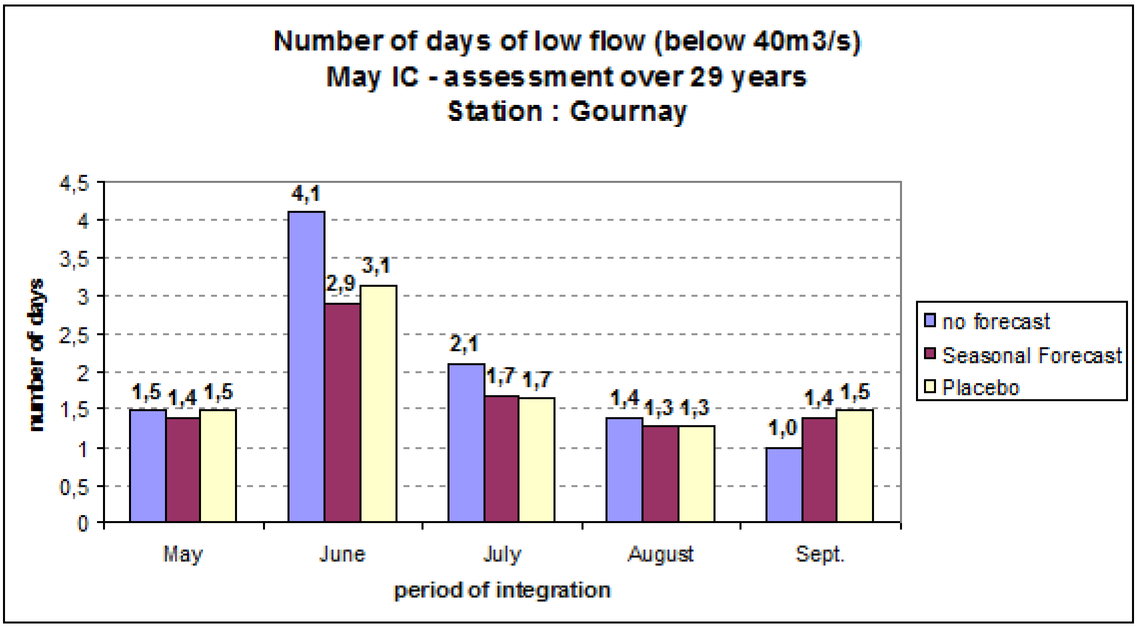

Figure 18a - Evaluation of the quality of the May initial conditions forecasts

The metric is applied for each month from May (1st month of forecast) to September (5th month of forecast). The best decisions would lead to "zero day below the threshold"

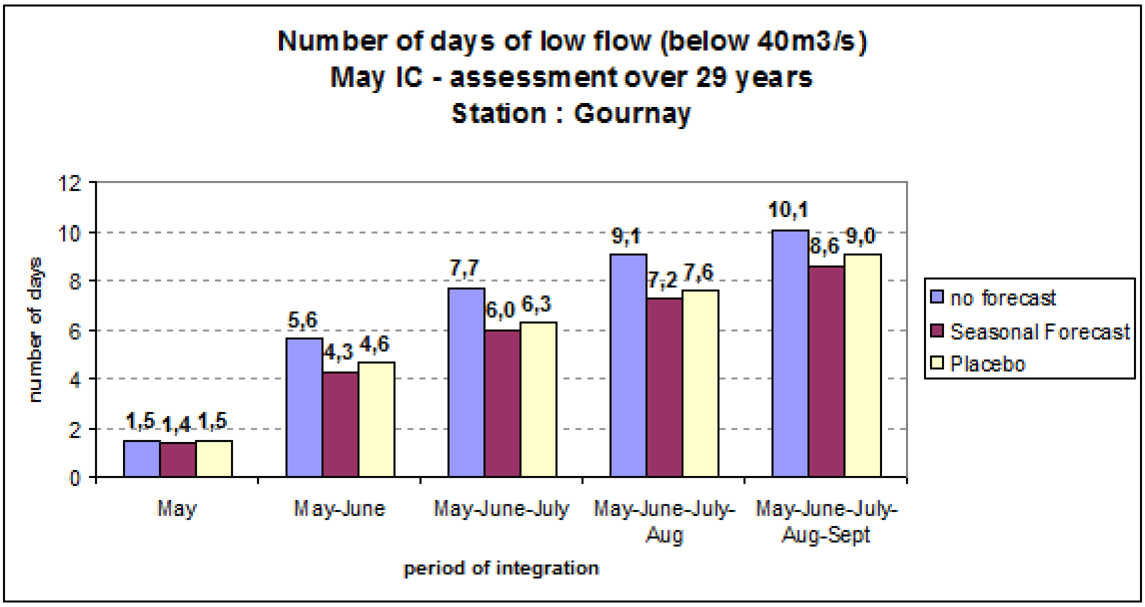

Figure 18b - Evaluation of the quality of the May initial conditions forecasts

The metric is applied for four periods of integration, from 1 month (May) to 5 months (May to September). The best decisions would lead to "zero day below the threshold"

To identify more in detail the value of using SCF, we can focus on the different simulated years reaching to potential damages (number of days below the threshold different from 0 with one of the three methods used). Table 1 presents 11 simulated years with impacting decisions.

Concerning the May initial conditions, the benefit of the hydrological suite (SF or Placebo, compared to EPTB SGL current practices) could be expressed as following:

- By using SF, we can take a better decision than NF, 7 times over 11 and a worse decision 2 times over 11
- By using RAF, we can take a better decision than NF, 6 times over 11 and a worse decision 2 times over 11
- By using SF, we can take a better decision than RAF, 3 times over 11 and a worse decision 2 times over 11

Table 4 - Number of days of low flows for the 11 simulated years (over a total of 29 years) with number different from 0 for at least one of the three methods used

No Forecast (NF), Seasonal Forecast (SF), Placebo (RAF)

Simulated year	Method	Number of days of low flows (whole period of integration)
2	NF	99
	SF	89
	RAF	99
4	NF	49
	SF	32
	RAF	40
5	NF	27
	SF	17
	RAF	17
6	NF	0
	SF	9
	RAF	9
9	NF	28
	SF	27
	RAF	27
11	NF	3
	SF	3

	RAF	3
	NF	1
13	SF	0
	RAF	0
	NF	18
14	SF	18
	RAF	0
	NF	3
20	SF	0
	RAF	0
	NF	27
24	SF	9
	RAF	27
	NF	37
29	SF	46
	RAF	40

Obviously, the interpretation of these results has to be prudent because they are not significantly different and should be confirmed for other initial periods and other stations.

These results were received very positively by EPTB SGL.

Having access to a long range modeling tool, able to use different input scenarios, is a need EPTB SGL has expressed from the very start of our collaboration. These input data could be seasonal forecasts, but also meteorological scenarios corresponding to past situations. They provide a wide range of possible futures, allowing EPTB SGL to better evaluate risks and to communicate them.

This experiment was also an opportunity for pour stakeholder to illustrate the real potentialities of seasonal forecast on their own area of interest. Because of the very small advantage of using seasonal forecast compared to past climate scenario, they became aware of the necessity to accompany SF by an expertise about predictability, to increase its efficiency. The notion of Climate Service takes on its full meaning.

5.3.6 Lessons learned

The main interest of this analysis was to consider the value of Climate Information for its use onto a DMP with a metric defined by the stakeholder and by simulating different methods in close real conditions over a quite long period (29 years).

We have seen first that the impact of climate conditions on DMP was very changing from one year to another and often very low. A difference in the results according to the method used appears only around 1 year over 3. Results between SF and Placebo are very close limiting the robustness of the interpretation.

A second point to highlight is the workload to prepare the different simulations and to play them by the stakeholder (estimation of 2 days for 29 years).

It was a very exciting experience to consider the value of CS from the user point of view. Results seem to us very encouraging but efforts needed to obtain them were very important and are a possible limitation for a systematic use of such approaches in implementation of other CS.

Another point concerns the interest of the redo of Decision Making for the stakeholder both to understand the real performance of the SF in the operational context and to identify the weaknesses and the improvement ways of the current practices.

5.4. Cost-benefit analysis and the LEAP prototype

5.4.1. Cost-benefit analysis methodology

Cost-benefit analysis is an economic technique used to organize, appraise and present the costs and benefits, and inherent tradeoffs, of public investment projects (Kopp et al., 1997), and is widely used in government decision-making all over the world (Pearce et al., 2006; Zhuang et al., 2007). CBA is mainly concerned with the question of efficient allocation of resources; in the context of DRR and humanitarian decision making, it therefore seeks to assess the impact of a unit of aid spent on a given intervention (Mechler, 2008). Unlike financial appraisals, which only quantify monetary benefits, CBA seeks to capture a project’s overall benefits to society, and therefore usually involves quantifying non-monetary values (Cellini and Kee, 2007).

CBA can be undertaken before an investment is made, to choose between project options (“forward-looking”), or after an activity has already been undertaken, to demonstrate the economic value of that activity (“backward-looking”).

A CBA typically looks at project costs and benefits over the project lifetime. Costs account for both up front capital costs as well as ongoing operations and maintenance. Benefits include any benefits, or in the case of humanitarian crises, avoided losses, that can occur as a result of the intervention. By comparing the scenario without the intervention, and with the intervention, an assessment of the net benefits over time can be made. The net benefit stream is typically discounted to account for the time value of money.

5.4.2. The LEAP prototype

In Ethiopia, as in many other countries subject to recurrent emergencies, the process of early warning, assessment, appeal and response typically takes around eight months, by which time significant livelihoods losses have already occurred.[3] This appeal-based process suffers from two main problems: it is slow, and the assistance is unpredictable and unreliable as it is based on voluntary contribution. Appealing governments around the globe therefore have limited knowledge about how much funding will be available, when it will be available, in what form and who will receive it, and are therefore unable to act upon early warnings in a timely manner.[4]

However, in the past decade, the Government of Ethiopia has made significant efforts to improve the timeliness of drought response, shifting from a purely relief-based approach to a risk management approach. The Livelihoods, Early Assessment, and Protection System (LEAP) is a food security early warning system developed in Ethiopia that is designed to enable early response to drought-related food crises, using monitoring information to project anticipated beneficiary numbers. It was developed in 2008 by the Ministry of Agriculture's Disaster Risk Management and Food Security Sector (DRMFSS) in partnership with the World Food Programme (WFP) and the World Bank. Modelled on weather index-insurance models, this mechanism seeks to increase the predictability and timeliness of response, by ensuring that funds are released automatically once an objective, pre-agreed drought level is reached.

Figure 19 shows how LEAP should, in theory, reduce the response time to severe droughts. Note that while the LEAP structure is in place, it has not yet been used to trigger an early response, which is why the proposed analysis presented here is based on idealized scenarios rather than on impact evaluations.

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[3] Hobson, M. and Campbell, L. (2012). "How Ethiopia's Productive Safety Net Programme (PSNP) is responding to the current humanitarian crisis in the Horn." *Humanitarian Exchange Magazine* 53 (March). London: Overseas Development Institute, Humanitarian Policy Group (ODI/ HPG).

[4] Haile, M. (2005). "Weather patterns, food security and humanitarian response in sub-Saharan Africa." *Philosophical Transactions of the Royal Society B: Biological Sciences* 360 (360):2169–2182.

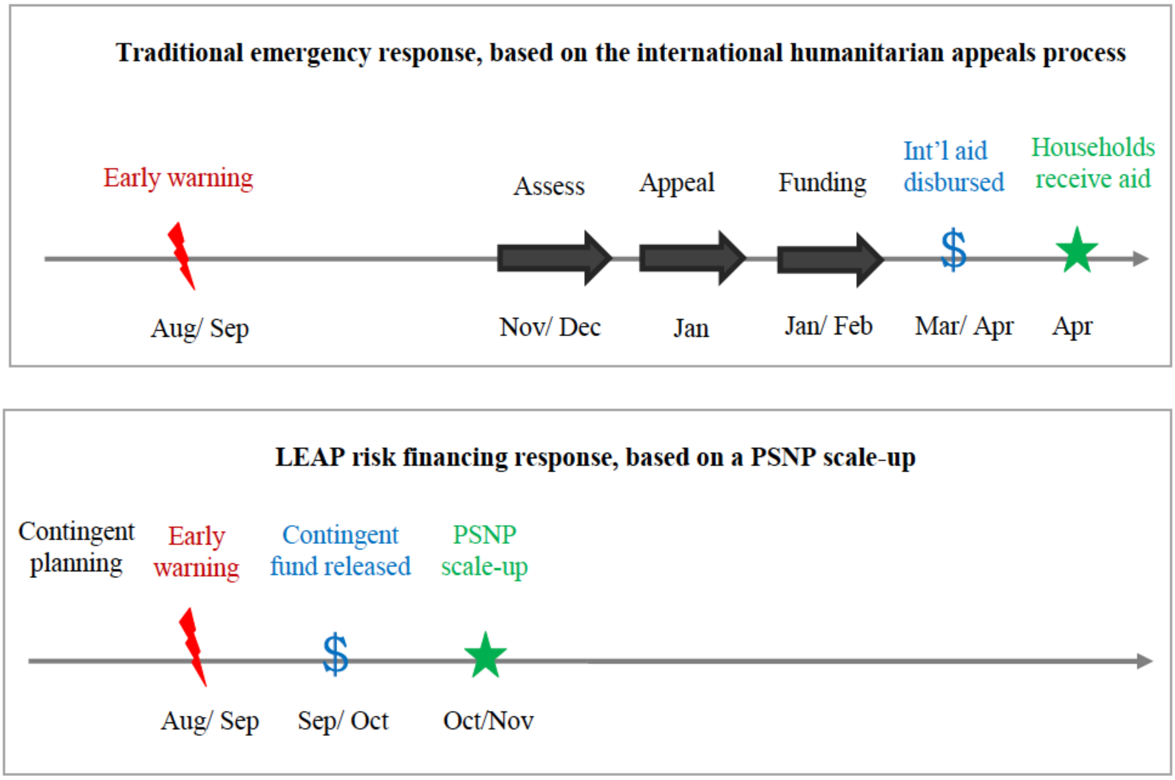

Figure 19 - Speed Benefits of a LEAP Triggered Response to a Meher Season Drought Compared to the Current Emergency System[5]

LEAP emerged as an attempt to address the failure of existing food security EWSs to translate warnings into action. It was therefore not designed as a standalone EWS, but as an integrated early warning-early action framework, based on three pillars: early warning, contingency planning and contingent financing. Figure 20 describes the LEAP mechanism.

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5 Law, A. (2012). "Evaluating the Cost-Effectiveness of Drought Early Warning-Early Response Systems for Food Security: A Cost-Benefit Analysis of Ethiopia's Livelihoods, Early Assessment, and Protection (LEAP) System." Masters Thesis, Oxford University.

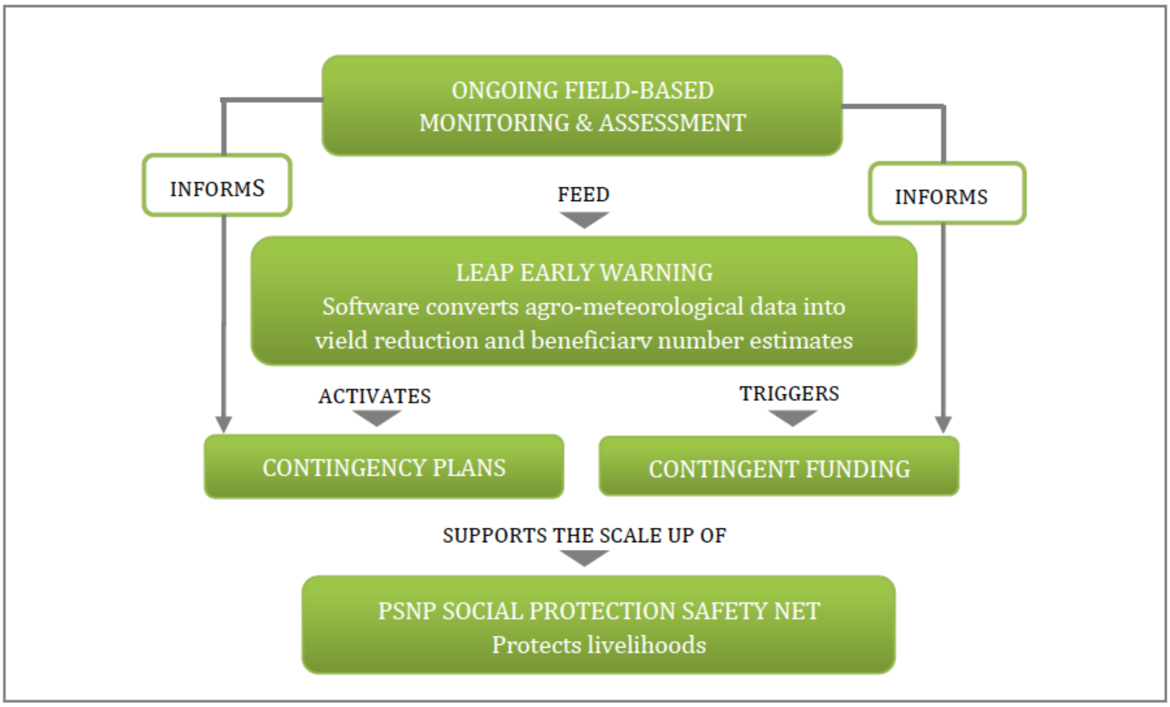

Figure 20 - The Key Components of the LEAP Early Warning-Early Action Framework

The early warning component is provided by the LEAP software, which combines crop, weather and climate data to estimate future yields, for all of Ethiopia's main crops. Knowing production levels well before harvest time should allow the government to plan and respond early to an impending crop failure. Weather station and satellite data are fed into the software every ten days throughout the growing season, enabling continuous monitoring. Yield estimates are considered highly reliable about one month before harvest.

Based on these yield projections, the software estimates the number of people in each *woreda* (district) in need of assistance. These preliminary estimates then trigger early (field-based) needs assessments. LEAP's clear outputs, which feed directly into the government's established risk management mechanism, seek to avoid the danger of warnings being either misinterpreted or ignored.

LEAP is unique among existing EWSs in that it is designed to trigger early response through the scale-up of a national social protection safety net, rather than through conventional food or cash hand-outs. The contingent funding component is part of the wider Ethiopia's Productive Safety Net Programme (PSNP) architecture. The PSNP was originally established in 2004 to support the country's 8 million chronically food insecure people in normal years. LEAP intends to use the PSNP's established food/ cash-for-work programs to assist the additional spikes in transiently food-insecure people who need assistance in case of drought. The contingency budget is designed to respond rapidly to low-level and unexpected transitory food insecurity among both PSNP and non-PSNP households by providing temporary additional employment/resources through the Public Works and Direct Support institutional structures. The contingency amounts to 20 percent of the PSNP's base program cost (15 percent is held at the regional level and five percent at the woreda level). The contingency budget, which should be critical to LEAP's effectiveness as an early response tool, seeks to bypass the inefficiency of the traditional international humanitarian financing process.

The decision context

This report presents the findings from a Cost Benefit Analysis (CBA) of using LEAP seasonal forecasts to compare the relative costs of humanitarian response. The CBA compares three scenarios, using data from 2003-2010:

1) Late humanitarian response via needs assessments, using historic data on the numbers in need.

2) LEAP Current: Early humanitarian response based on current LEAP predictions at the end of the crop season (August/September).

3) LEAP Forecast: Early humanitarian response based on LEAP Forecast, with numbers in need forecast four months before the first failed rains (February/March). It is assumed that a response based on forecasts will facilitate a greater use of cash transfers bringing multiplier effects and investment gains to beneficiaries. It is further

assumed that a response based on forecasts can facilitate greater investment in early action and resilience building measures.

The value of SCF in the decision-making

The concept of value of the LEAP SCF relates to both the reduced costs (through avoided losses) and the increased gains (through additional benefits achieved) that seasonal forecasting can bring, leading to beneficial impacts for Ethiopia's food insecure communities. The value of the SCF is thoroughly analyzed in the current research, which has managed to identify a precise monetary value added for the prototype (see Section 5.4.5.)

The impact of SCF in the decision-making

As defined in this report, the concept of impact is related to the consequences that the novelty of the SFC has had on the decision making processes (DMPs) for food security response of the involved stakeholders: Ethiopian Government, UN World Food Programme, and other international humanitarian and development actors. However, despite the encouraging results coming from the cost benefit analysis, showing benefits through the application of SCF to the LEAP prototype (see Section 5.4.5) it has not been possible to introduce SCF within the DMP, and consequently witness its effects. The impossibility of doing that comes out of context-specific conditions (see section 5.4.4 - Stakeholders' Engagement). As a result, only hypothesis could be made on the impacts on the DMPs.

5.4.3. Applying the methodology

The type of methodology used for LEAP is a Cost Benefit Analysis (CBA). In 2012, a Cost Benefit Analysis (CBA) was carried out by WFP to assess the economic benefits of the current LEAP system.[6] This initial CBA used a forward looking methodology (i.e. it assessed benefits over the next 20 years). In the context of the EUPORIAS project, through which WFP is testing the integration of seasonal forecasts into the LEAP system, WFP commissioned this modified CBA of LEAP. This new CBA aims to assess the economic case for using *seasonal forecasts* in LEAP to trigger early assistance.

This CBA aligns with WFP's wider efforts to provide evidence on the socio-economic benefits of using climate information in humanitarian financing mechanisms. This evidence will serve to support WFP's innovative work in the area of climate risk financing and loss and damage. Aside from the LEAP CBA, this work sits alongside WFP's work on documenting the value of climate information in humanitarian risk financing mechanisms, such as the CBA on the African Risk Capacity (ARC), and the planned CBA for FoodSECuRE.

Review of the 2012 CBA

The 2012 CBA compared three scenarios: a baseline "business as usual" humanitarian emergency response scenario, and two early response scenarios in which LEAP is used to trigger a PSNP scale-up. In this CBA, it was assumed that the LEAP software is able to issue a reliable early warning of production failure two months before harvest (though this is now estimated to be one month before harvest). The scenarios are based on the timing of response relative to this early warning.

- ***Baseline Emergency response:*** This scenario models a "typical" late emergency response to drought, 8 months after the early warning, or 6

[6] Law, A (2012). "Evaluating the Cost-Effectiveness of Drought Early Warning-Early Response Systems for Food Security: A Cost-Benefit Analysis of Ethiopia's Livelihoods, Early Assessment, and Protection (LEAP) System." Masters Thesis, Oxford University.

months after harvest failure. This late response leads to a humanitarian disaster, characterized by high relief costs and significant long-term livelihood losses. At this point, it is assumed that most households have started engaging in harmful coping strategies, in particular selling productive assets and reducing consumption.

- ***Ideal LEAP response****:* This models an idealized scenario in which LEAP successfully triggers the timely release of contingent financing for a PSNP scale-up, 2 months after the first early warnings, or at harvest time. Aid costs are calculated using the per capita cost of assistance under the normal PSNP. Almost all long-term livelihood losses are avoided, as intervention is assumed to be sufficiently early for households not to have started engaging in harmful coping strategies yet.
- ***Delayed LEAP response:*** This models a more realistic early response scenario, in which response occurs 5 months after the early warning, or 3 months after harvest failure. LEAP triggers a response earlier than in the emergency scenario, but not as early as in the “Ideal” scenario, due to delays between early warnings and disbursement of contingent funds, or between fund disbursement and delivery of assistance at the household level. The cost of aid is also calculated using the PSNP transfer costs, and is therefore assumed to be the same as in the “Ideal” scenario. However, livelihood losses are higher, as more households are assumed to have started engaging in negative coping strategies.

The analysis focused on agrarian regions, rather than pastoral ones, since LEAP currently only predicts crop yield reductions, not pasture productivity, and therefore cannot be applied to the predominantly pastoralist lowlands of Ethiopia.

The only additional cost of a LEAP-triggered early response, relative to a baseline emergency response, was assumed to be the cost of the LEAP system itself. The analysis was done both for a single drought, assumed to happen today, and over a 20-year time frame, assuming a severe drought every 5 years.

Rationale for an updated Cost Benefit Analysis

This report presents a revised CBA. Key additions and/or changes to the analysis have included the following:

- The revised CBA takes into account the Seasonal Forecasts to underpin the modelling (the seasonal forecast model is described in greater detail below).
- Unlike the initial LEAP CBA, which looked into the next 20 years, this CBA is retroactive, using hindcasts of seasonal forecasts, i.e. looking at historic events, and modelling the predicted impact if we had had the LEAP prototype to date.
- This analysis updates the data on the cost of response, importantly using the cost of a full food/cash response in all scenarios, as opposed to using PSNP costs which use a different size of package and therefore may have overstated the gains in the previous CBA.
- Further, this analysis updates the benefits of an early response, using the latest data available, and in particular with a stronger focus on a cash response as part of a forecast based mechanism.

5.4.4. Stakeholders' engagement

Continuous involvement of WFP staff at Country Office Level (Ethiopia) has been insured throughout the CBA exercise, through emails, teleconferences and in-country meetings. Senior Management staff (e.g. Deputy Country Director and Head of Programme) have been involved in the discussions alongside Disaster Risk Reduction (DRR) focal points.

A major issue for the successful completion of the CBA has been the lack of involvement of the Government of Ethiopia, which implements LEAP in conjunction with WFP. This lack of feedback from the Government has been a consequence of the food emergency situation in Ethiopia during the year 2015-2016, which has diverted the attention of Government officials from dealing with a longer term issues such as the introduction of seasonal forecasting within LEAP towards dealing with the immediate crisis.

However, the lack of involvement of the Government has not invalidated the results of the CBA itself: it has just posed a challenge in defining the key activities that could be implemented in order to better take advantage of seasonal forecasting. The value of the forecasts is not in doubt; it is more the actual impact that it can have that still has to be thoroughly defined.

5.4.5. Results and discussion

As described above, the analysis compares the following three scenarios – historic figures based on needs assessments, LEAP current, and LEAP Forecast.

- The “Historic analysis” uses the actual numbers of people in need according to needs assessments, and estimates the cost of providing a food aid package.
- The “LEAP Current analysis” uses the number of people in need predicted under LEAP Current, and estimates the cost of response. The analysis also includes a discussion of the potential magnitude of avoided losses through an early response that would be required to make LEAP Current more cost effective than a late response.
- The “LEAP Forecast analysis” uses the number of people in need predicted under LEAP Forecast, and estimates the cost of response based on an increased use of cash transfers as an early response mechanism. The

analysis also incorporates 1) the benefits of cash; 2) the benefits of investing in early warning/early action.

Historic Analysis

Number of beneficiaries

Historical data on the number of beneficiaries in need of humanitarian aid based on needs assessments is listed in Table 1.

Cost of response

The cost of response is estimated at $162 per person based on WFP's PRRO for 2015. Data on cost of response for each year of the analysis was not available. However, using the 2015 figure for all eight years of analysis ensures that each year is weighted equally, and does not affect the overall magnitude of difference in costs between scenarios.

The total cost of late response based on needs assessments over the eight years of analysis is estimated at $2,629m.

Table 5 - Historic Humanitarian Caseload and Estimated Cost of Food Aid, 2003-2010[7]

Year	Number Beneficiaries (Historic)	Cost (USD)
2003	5,369,700	$869,891,400
2004	1,238,917	$200,704,554
2005	719,100	$116,494,200
2006	357,358	$57,891,996
2007	782,719	$126,800,478
2008	3,043,130	$492,987,060
2009	3,209,218	$519,893,316
2010	1,510,902	$244,766,124
Total		**$2,629,429,128**
Average Annual Cost		$328,678,641

[7] Data on the number of beneficiaries is taken from the annual Humanitarian Requirements Documents.

LEAP Current

Number of beneficiaries

The number of beneficiaries using LEAP Current predictions is reported in Table 2.

Cost of response

The model assumes that the caseload predicted under LEAP current received a food aid package costed at $162 per person. This is equivalent to the cost of food aid under the late scenario, because the LEAP current is not early enough to secure cost savings on the cost of food.

Further to this, in two of the modelled years – 2003 and 2008 - the historic number of people in need is greater than the LEAP current predictions. It is assumed that the historic figures are based on needs assessments and therefore taken as the actual number of people in need. We therefore top up the costs for these two years to include the additional historic caseload above and beyond the LEAP prediction.

This analysis further accounts for the cost of LEAP, required to generate the forecasts. The original LEAP CBA outlined these costs as follows:

- Development Costs (software development, installation and project management): $500,000. These costs are only incurred in year 1.
- Annual maintenance costs, first two years: $45,050
- Annual maintenance costs, subsequent years: $22,740

While this cost is clearly substantial, it is very small in relation to the overall cost of response estimated.

Table 6 - Humanitarian Caseload and Estimated Cost of Food Aid, LEAP Current, 2003-2010

Year	**Number Beneficiaries LEAP Current**	**Cost (USD) of Response**
2003	3,582,295	$870,391,400
2004	4,775,072	$773,606,714
2005	1,652,106	$267,686,222
2006	730,844	$118,419,468
2007	983,115	$159,287,370
2008	2,673,380	$493,009,800
2009	6,682,336	$1,082,561,172
2010	404,709	$244,788,864
Total		**$4,009,751,010**
Average Annual Cost		$501,218,876

The total cost of an earlier response using LEAP Current estimates of those in need is estimated at $4,009m. These costs are significantly greater than responding to the needs assessment as a late response. However, they do not account for the avoided losses that can be generated through an earlier response.

Avoided Losses

Earlier response is very likely to result in immediate gains to households as early response can stop the downward spiral into asset depletion and negative coping strategies, which tends to happen under late response.

The original LEAP CBA estimated the potential avoided losses as a result of early response. The estimate was based on avoided stunting losses and avoided losses to household economic growth. Stunting losses due to drought were estimated based on the 1982 drought in Zimbabwe, at an average of $110 per capita. The CBA also estimates losses in lifetime earnings, based on the 1984 famine in Ethiopia, at an average of $216 per capita. This leads to a total estimated livelihood loss due to late response of $226 per capita. This estimate is based on extreme events and specific cases, which will not be relevant for the years included in this analysis, though clearly highlight the upper end of the magnitude of losses that can occur.

The 2012 CBA then goes on to estimate the potential for avoided losses under an early response. The study estimates that 90% of the losses can be avoided under a LEAP Forecast, and 70% of the losses can be avoided under a LEAP Current system. These estimates are not based on empirical evidence, and are likely ambitious levels of reductions in losses.

Along similar lines, the DFID study on the Economics of Early Response and Resilience in Ethiopia estimated livestock losses in Southern Ethiopia due to a high magnitude drought. The study found that livestock losses were on average $81 per person per year, but this effect persisted over 5 years, with a total economic loss of $403 per capita over 5 years. The study further found that commercial destocking as part of early response could reduce these losses by 68%, or $274 per person.

These estimates were focusing on the pastoral populations located in the lowlands of Ethiopia whereas LEAP is forecasting for an agro-pastoral population only at the moment[8]. As a result, the estimation of benefits and their impact on livelihoods will be different from the highlands to the lowlands, given the difference of livelihoods and income sources. However, the type of interventions mentioned above for the lowlands, such as de-stocking, can also be triggered by LEAP in the highlands, where the platform is available. The type of interventions LEAP can trigger can be vast, and livestock focused interventions such as de-stocking could be applied in case an early warning is issued. If yield reduction/agricultural deficit is seen as a proxy to food insecurity, then de-stocking could be applied, regardless of the fact that LEAP does not gauge pasture-deficit, but it focuses only on crop production deficits.

In the absence of more robust and applicable data, these estimates are not applied to the analysis presented here, but do help to demonstrate the significant losses that could be avoided through both the LEAP Current and Forecast models.

An alternative approach to the analysis is to look at the additional cost per person of responding early using LEAP Current, to give an indication of the magnitude of the loss that would have to be avoided in order to break even. The additional cost of LEAP Current is $1,380m above the cost of historic (taking the difference between the total cost of LEAP Current at $4,010m and Historic at $2,629m). For a caseload of 21.5m, this equates to LEAP Current costing an additional $64 per person affected as compared with responding to historic numbers.

We know, however, that the historic scenario, through late response, generates additional losses per person that could be avoided with LEAP Forecast. **If we are able to avoid losses of more than $64 per person through the use of LEAP, the net cost of responding to a LEAP current scenario is less than the cost of a late response.** Based on estimated losses of $226 per person in a high magnitude drought, this would suggest that avoidance of 28% of these losses would justify the investment in LEAP.

8

LEAP Forecast

Number of beneficiaries

The number of beneficiaries using LEAP Forecast predictions is reported in Table 3.

Cost of response

Under a forecast scenario, it is assumed that the humanitarian caseload is predicted early enough to allow for a greater response using a cash transfer. For the purposes of this analysis, it is assumed that 30% of the caseload can be replaced with a cash rather than a food response. On the one hand, not all of the population will be suitable for cash programming, due to market integration and other factors. On the other hand, the PSNP4 Business Case cites the World Bank estimates a planned move to cash for 70% of its clients, suggesting that this figure could be much higher[9], which would contribute to an overall decrease in the cost of the LEAP forecast scenario.

The cost of cash is estimated at $112 per person according to the WFP 2015 PRRO.

As with the LEAP current model, where historic numbers are greater than the LEAP forecast numbers, we top up the cost of response at $162 per person for the additional caseload. As with LEAP Current, the cost of the LEAP system is also included in the estimates.

Based on the LEAP Forecast estimates of numbers in need, and adjusting the cost of response for a 30% cash distribution, the cost of LEAP Forecast is estimated at $3,440m. This estimate is for the costs alone, and does not account for the benefits that can come about as a result of an early response using forecasts; these estimates are incorporated in the sections that follow.

[9] Ethiopia Productive Safety Net Programme Phase 4, DFID Business Case, page 24.

Avoided Losses

As with the LEAP Current model, early response through LEAP Forecast has the potential to result in significant levels of avoided losses. Data on the magnitude of those losses, however, is not available. Rather, we can estimate the amount of loss that would have to be avoided in order to justify using LEAP. The additional cost of LEAP Forecast is $810m above the cost of historic (taking the difference between the total cost of LEAP Forecast at $3,440m and Historic at $2,629m). For a caseload of 18.9m, this equates to LEAP Forecast costing an additional $43 per person affected as compared with responding to historic numbers.

We know however, that the historic scenario, through late response, generates additional losses per person that could be avoided with LEAP Forecast. **If we are able to avoid losses of more than $43 per person through the use of LEAP, the net cost of responding to a LEAP forecast scenario is less than the cost of responding late.** Based on estimated losses of $226 per person in a high magnitude drought, this would suggest that avoidance of just 16% of these losses would justify the investment in LEAP.

Benefits of cash

Under LEAP Forecast, a much greater use of cash response is envisaged. Early estimates of the number of people in need can facilitate a wider cash response because markets have not yet responded to a drought which can in turn affect the feasibility of cash. Cash transfers are documented to deliver additional benefits through multiplier effects and greater investment, which are incorporated into this analysis.

According to the business case for the PSNP4 in Ethiopia, using a local economy-wide impact evaluation (LEWIE) model, the study estimates that each birr transferred through the Social Cash Transfer Programme generated between 1.26 and 2.52 birr in local economy multipliers, depending on location and how local supply response is assumed to work. It should be noted that multipliers from regular and predictable transfers through safety nets are likely to be higher than multiplier effects from one-off transfers for spikes in need. To offset this, the lower end of the range of multiplier effects is used in the analysis, and it is assumed that for each dollar transferred to recipients, $0.26 of additional income is generated. Further, the total cost of cash of $112 per person is the fully delivered cost of cash. The actual transfer amount is 84% of the total figure, or $94. Therefore, each cash transfer of $94 should generate an additional $24 of additional income through multiplier effects.

For the total caseload that would receive a cash transfer, the multiplier effect would generate an additional $139m in multiplier benefits over the 8 years.

Further to this, the World Bank finds that cash transfers under the PSNP are typically used 75% for consumption purposes and 25% for investment purposes, including debt alleviation, accumulation of livestock, agriculture investments, and utilization on health and education services.[10] Global economic evidence indicates that investment in productive activities typically returns benefits of between $3 and $15 for every $1 spent, with a robust average return of $4 for every $1 spent.[11] Clearly, the nature and timing of the investment will greatly influence the returns and it is likely that these returns will vary. Further, these returns are documented for investment in disaster risk reduction activities, which often occur outside of disaster times, and it is not given that such activities in the face of an imminent disaster will yield the same gains. With these caveats in mind, and using a lower-bound estimate of 4:1 to estimate the returns from greater productive activities, cash as an early transfer mechanism would result in additional investment gains of $534m over the eight years of analysis.

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[10] World Bank (2014). "Project Appraisal Document for the Productive Safety Nets Project 4". P.111

[11] UN Office for Disaster Risk Reduction (2015). "Making Development Sustainable: The future of disaster risk management. Global Assessment Report on Disaster Risk Reduction". http://www.preventionweb.net/english/hyogo/gar/2015/en/gar-pdf/GAR2015_EN.pdf

When the benefits of cash are incorporated into the model, the total net cost of response under LEAP Forecast reduces to $2,767m, placing the cost on par with the cost of late response using needs assessments.

Investing in Early Warning/Early Action

Further to the benefits of early response, early warning can help to facilitate early action, particularly under a LEAP Forecast scenario where a significant amount of warning is given. Early action can cover a wide range of activities, from conservation agriculture practices to prevent loss of crops, to livestock initiatives that prevent animal death, as well as temporary water measures and preventative nutrition interventions, for example, that are initiated at the first signs of an impending drought.

LEAP is not currently structured to trigger early action measures as a result of forecasts; and yet this is part of the design of LEAP and likely to be the area of greatest benefit – benefits that will more than outweigh the additional costs of LEAP.

As a global benchmark, well-functioning, modern early warning systems in Europe reduce disaster-related asset damage by between 0.003% and 0.017% of GDP.[12] Ethiopia is considered a low-income country, and had a GDP of $62 billion in 2015.[13] The study goes on to assume that, in low income countries, 90% of these gains could be realized. This would result in an average value of avoided losses every year of between $1.7m and $9.5m. However, this estimate is also based on the assumption that 25% of global GDP is produced by weather-sensitive sectors, whereas in Ethiopia it is at least double this, with agriculture already contributing

[12] Hallegatte, S. (2012). *A Cost Effective Solution to Reduce Disaster Losses in Developing Countries: hydro-meteorological services, early warning, and evacuation*, Policy Research Working Paper 6058, World Bank. http://www-wds.worldbank.org/external/default/WDSContentServer/WDSP/IB/2012/05/04/000158349_20120504094326/Rendered/PDF/WPS6058.pdf

[13] http://data.worldbank.org/country/ethiopia, accessed July 25, 2016.

about 50% of GDP.[14] Therefore, these avoided losses are more likely to be on the order of $3.4m and $19.0m per year.

The same study then goes on to estimate the additional economic gains that can arise from having effective early warning, for example through using weather forecasts to improve productivity gains through improved planting decisions, as well as for maximizing efficiency across a range of sectors such as energy, transport and tourism. The additional economic gains are estimated to lead to added value of between 0.025% and 0.0025% of GDP. These are estimated to be very conservative estimates. As with the previous analysis, it is assumed that low income countries realize 90% of these gains. This would yield a further $1.4m to $14.0m in economic gains each year in Ethiopia.

The World Bank goes on to estimate that early warning and disaster risk management would result in benefits of $250m per year in Ethiopia. It is not clear how this figure is derived and therefore it could not be replicated here. However, it does suggest that the upper estimates of avoided losses of $19m per year, and economic gains of $14m per year in Ethiopia are very conservative estimates and therefore these are used below.

The investment in early action would bring the total cost of LEAP Forecast down to $2,504m over eight years, saving $125m over the cost of responding at the time of needs assessments.

Table 7 - Humanitarian Caseload and Estimated Cost of Response, LEAP Forecast, 2003-2010 (USD)

Year	Number Beneficiaries LEAP	Cost of Response	Cost Adjusted for Multiplier and Investment	Cost Adjusted for EWS Benefits

[14] World Bank (2014). "Project Appraisal Document for the Productive Safety Nets Project 4". P.111

	Forecast		Benefits	
2003	3,061,769	$824,464,865	$698,298,427	$682,659,501.00
2004	2,883,748	$423,956,006	$305,125,287	$288,481,467.52
2005	1,876,433	$275,880,701	$198,558,451	$176,228,540.31
2006	1,216,935	$178,912,185	$128,765,896	$102,713,250.47
2007	2,018,374	$296,723,718	$213,552,500	$192,023,817.40
2008	1,280,127	$473,807,895	$421,057,651	$395,361,711.40
2009	5,034,976	$740,164,212	$532,687,755	$528,187,187.09
2010	1,536,709	$225,918,963	$162,595,734	$138,348,148.73
Total		**$3,439,828,545**	**$2,767,379,624**	**$2,504,003,624**
Average Annual Cost		$429,978,568	$345,922,453	$313,000,453

Summary of Findings

Both LEAP current and LEAP forecast predict a higher number of beneficiaries overall than the historic data (clearly the historic data, based on needs assessments, has its own issues around over/under counting, but is the closest approximation to actual numbers in need that we have). Two of the eight years of analysis – 2003 and 2008 – are the exception with historic numbers proving to be (significantly) higher than the LEAP estimates.

The analysis is only able to account for the cost of food aid, and the cost is the same under both historic and LEAP current, as LEAP current does not provide predictions early enough to result in procurement cost savings. As a result, LEAP current is more expensive overall than the historic figures, and further inflated by the need to top up with significant additional caseloads in 2003 and 2008.

In the case of LEAP forecast, the cost of response is decreased by a greater use of cash programming which costs less. However, cash programming can only be used for a portion of the population (estimated at 30% - additional to those who would receive cash under a late response or LEAP current - for this analysis), and hence the cost savings are not realized for the whole population. These cost savings are offset by a higher caseload as well as the need for top up in the two years already mentioned.

Using only the cost of response, both LEAP current and LEAP Forecast are more expensive, because the forecasts tend to over-predict the number in need, and in the years where they underpredict, the model tops up the total cost to reflect the additional caseload at the time of the needs assessments.

However, when the benefits of early action specifically through a greater use of cash are incorporated into the LEAP forecast model (namely multiplier effects and the returns from greater investment spending), the cost of LEAP Forecast comes on par with the cost of responding to needs assessments. It is possible that some of these gains would also be realized in LEAP Current, though these are not modelled here.

Further to this, **when the benefits of EWS are added onto the cash benefits, the LEAP Forecast becomes the most cost efficient response.** It should further be noted that this analysis is very conservative, as the benefits from early response are likely to be much higher than those that could be modelled here.

Table 8 - Number of beneficiaries – Historic, LEAP Current, LEAP Forecast

Year	Number	Number	Number

	Beneficiaries Historical	Beneficiaries LEAP Current	Beneficiaries LEAP Forecast
2003	5,369,700	3,582,295	3,061,769
2004	1,238,917	4,775,072	2,883,748
2005	719,100	1,652,106	1,876,433
2006	357,358	730,844	1,216,935
2007	782,719	983,115	2,018,374
2008	3,043,130	2,673,380	1,280,127
2009	3,209,218	6,682,336	5,034,976
2010	1,510,902	404,709	1,536,709
Total	**16,231,044**	**21,483,857**	**18,909,071**

Table 9 - Summary of Cost of Food/Cash Aid

	Total Cost 2003-2010	Average Annual Cost
Historic	$2,629,429,128	$328,678,641
LEAP Current	$4,009,751,010	$501,218,876
LEAP Forecast – cost only	$3,439,828,545	$429,978,568

LEAP Forecast – with cash and EWS benefits	$2,504,003,624	$313,000,453

Impact on Decision Making Processes

Unfortunately, the CBA has still to be presented to the major stakeholders of the project: the Ethiopian Government. WFP will do its best to make sure that a workshop to present the current results will be organized, in view of better preparing to possible food security shocks. Within the organization itself, the results of the CBA have been welcomed, as they point out to the utmost value of seasonal forecasting in the context of humanitarian response.

As a result, WFP is optimist that the Ethiopian Government will take into consideration using seasonal forecasts to better prepare to food security crises.

Only hypotheses could be made on the potential impact of the SCF on the DMP, but these below should be the major outcomes:

1. The introduction of an additional layer of analysis to the LEAP early warning tool, which would need to rely on the work of experts at government level to identify SCF yearly for the rainy season.
2. The introduction of standard operating procedures (SOPs) at government level that would identify when actions needs to be triggered based on the SCF.
3. The inclusion of additional stakeholders in the DMP as a result of the introduction of specific early-response actions in the field of soil and water conservation, water access and hygiene, drought resistant crops… etc. These stakeholders would have not been part of the DMP previously as the humanitarian response would have only involved traditional food and cash based assistance.

5.4.6. Lessons learned

Based on the cost of food/cash alone, the LEAP forecasts result in a higher total cost over the eight years of analysis as compared with a late response based on needs assessments. This is because costs are allocated to the full number of beneficiaries when LEAP over-predicts the number in need (as compared with needs assessments) and is topped up to needs assessment figures whenever it under-predicts. Therefore, responding based on LEAP forecasts will always appear more expensive based on a cost analysis alone.

However, LEAP forecasts can be a critical component of raising funds in time to facilitate an early response. When this response is funded and triggered early, benefits arise as households avoid negative coping strategies, engage in greater investment, and avoid long term impacts to household growth, nutrition and educational outcomes.

As a result, when the benefits of early response are incorporated into the analysis, responding based on forecasts becomes the most cost effective option in this analysis.

The benefits modelled here arise from documented and quantified benefits in the literature from a greater use of cash (which is only possible through early response when food is still available in the markets and prices have not yet begun to escalate) and also through benefits from using early warning information to reduce losses as well as generate additional economic benefit.

Further, this analysis is limited by data availability on the benefits of early response, and therefore it is likely that the cost effectiveness of response to forecasts will only increase with better data availability.

To conclude, the analysis presented so far points out to the considerable quantifiable benefits of using LEAP seasonal forecasts, as well as additional benefits that we are currently only able to estimate. These result should persuade LEAP stakeholders, including the Ethiopian Government and international donors, to introduce seasonal forecasting to improve current early response initiative. Unfortunately, while it is part of LEAP's vision, LEAP is not currently established to trigger contingency planning and early action based on forecasts. And yet this is a significant component of the benefits that can be realized.

Therefore, it is recommended that key stakeholders for LEAP from the Ethiopian Government and other humanitarian and development organizations discuss and lay out a plan on how LEAP can most effectively be used to trigger early action, appropriate measures, and estimated costs and benefits, to incorporate into a revised version of this analysis.

5.5. The avoided cost methodology and the S-CLIMWARE case study

5.5.1. The avoided cost methodology

A step by step methodology has been specifically developed for the S-CLIMAWARE and is currently applied with the stakeholders through regular meeting and workshops. SCF bring new information to water operators but its integration into decision making process is also challenging on different aspects:

- The evaluation of future risks, currently based on historical records, should be replaced by probabilistic, uncertain and limited forecast;
- Decision making processes, well-structured and established between stakeholders, has to be modified to incorporate new inputs.

To answer these challenges and elaborate a complete methodology to insert – beneficially - seasonal forecast into decision making process, interactions with stakeholders are essential. Brown et al. (2010) developed a general climate risk management approach that could be adapted to the purpose of discussing and determining with stakeholders the best way to integrate seasonal forecast into decision making. The climate risk management approach consists of three steps: 1) Assess hydroclimatic risk, 2) Make probabilistic water supply projections incorporating climate information 3) Determine a portfolio of options to manage hydroclimatic risks.

Based on the work of Brown et al. (2010) a step by step methodology has been proposed and is currently applied with the stakeholders through regular meetings and workshops. The methodology consists of different exercises of increasing complexity allowing to define the best way(s) to integrate seasonal forecast into decision making process (Figure 21).

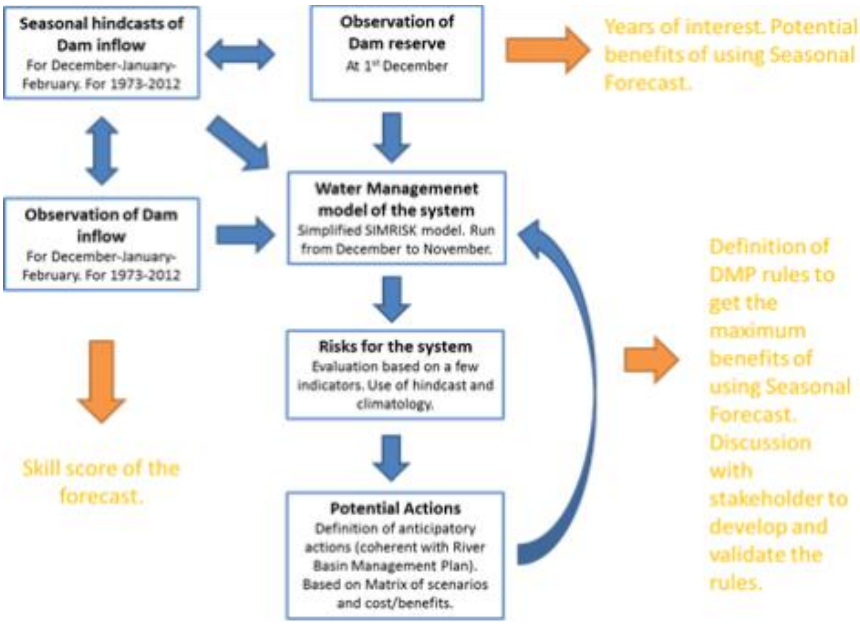

Figure 21 - General framework for the analysis of Decision Making Process Value for dam management in Spain

The methodology consists of five steps:

1. Potential added-value of the forecast: evaluation of the skill score: this consists in explaining to the stakeholder the seasonal forecasts produced and compared them with historical data. In this case study, this part is managed by the AEMET (presentation of ROC scores, etc.).

2. Potential benefits of using Seasonal Forecast: this consists in analyzing together the forecast with the situation of the water system at the beginning of the forecasted period. This allows having a first idea on the potential uses of the forecast (percentage of year where forecast could have been useful, etc.). This part is detailed below.

3. Simulations: comparison of risks using forecast and climatology. Simulations are done in hindcast mode using forecast and climatology, keeping the same baseline decision rules for both. This part is detailed below.

4. Simulations: update of DMP. This part consists in determining the precise DMP that could be upgraded and simulate the potential benefits that they could bring (in hindcast mode).

5. Calculation of the benefits. A method of evaluation is selected according to the context and applied to the case study.

5.5.2. The S-CLIMWARE case study

The objective of the case study S-CLIMWARE is to incorporate seasonal forecast in dam management and water system management in Spain. The case study area of the S-Climaware encompasses all the river basins supervised by the Spanish state. The most up-to-date tests have been performed for the Dam of "La Cuerda del Pozo" situated in the Douro River Basin.

The methodology for study, application and preliminary results has been previously described in Deliverable D41.2 "Preliminary Guidance Document on the evaluation of the value of DMP". Accordingly, this report summarises the evaluation methodology and presents updated results of S-CLIMAWARE.

La Cuerda del Pozo reservoir is located in the municipality of Vinuesa, in the province of Soria (Autonomous Community of Castilla y León), and regulates the Douro River in the headwaters. The reservoir has a height of 36 meters, a length of 425 meters and a storage capacity of 249 million cubic meters.

The reservoir has several uses:

- **Douro River regulation**.
- **Water supply**: the reservoir provides water supply to Soria and partially to Valladolid.
- **Irrigation**: it provides water to 26,000 hectares to its confluence with Pisuegra River.

- **Hydropower production**: it is managed by the concessionary company Iberdrola, with an installed capacity of 6,080 Kw and an average annual energy production of 8.5 GWh.

The reservoir allows practicing several activities: windsurf, sailing, fishing, camping, etc, which provide indirect benefits to the tourist industry.

Figure 22 - Map of La Cuerda del Pozo Reservoir
Source: www.foros.embalses.net

The decision context

In Spain, the operational management of a dam is done to benefit to the different uses (agriculture, urban, industrial, environment) from the beginning to the end of the hydrological year (October to September). This management is currently based on the state of the reserve for the month considered and, to some extent, scenarios of future inflows to the system in the next months. These scenarios are commonly based on historical information only (e.g. historical inflows) and physically based climate forecast are not considered.

One of the most important governance organism is the Reservoir Releases Commission (Comisión de Desembalse). It meets twice a year to define actions relative to reserve management, revision of ecological flows and ground water abstraction and definition of precautionary water allocation schemes. All these measures affect farmers, hydropower units, environment, urban users and others (Garrote 2007). The Commission meets in October to decide upon the proper filling level of the reservoirs during the wet season and at the beginning of spring to decide upon the allocation of reservoir releases during the dry season (Bhat 2004).

Accordingly, the decisions of interest in the S-CLIMAWARE are the ones of the Reservoir Releases Commission. The table below provides some examples of the decisions taken in October and March for some variables. In general, the management plan specified some basic values for these variables that could later be updated by the commission according to the context (but this is not always possible). In addition, all the decisions taken by the end-users could also be of interest (context specific).

Table 10 - Example of decisions from the Reservoir Releases Commission of La Cuerda del Pozo dam

	OCTOBER	MARCH
Minimum safeguards in December, January, February, March and April	since 2012: 53 hm3 for December, 11-22* for april (*if snow)	
Minimum discharge from October to April	2012: Reduce for drought since 2014: Use of the standard discharge specified in the Management Plan	
Maximum discharge from October to April (in normal state)	since 2014 : 60m3/s	

Minimum volume in dam by the end of September		2011: 70hm3 2012: 30hm3 (reduce since drought)
Irrigation period beyond September		2013: allowed in October due to the delay in seeding corn

The value of SCF in the decision-making

The current DMP are based on past events (basic rules defined from a risk-adverse perspective) and climatology (operational rules or adjustment of the basic rules according to the context). By using S-CLIMWARE 's probabilistic predictions the Reservoir Releases Commission can benefit from a better knowledge of the potential state of the system and the associated risks, and can therefore adapt better some operational rules. The end-users (domestic uses, agriculture, tourism…) would directly benefit from and improved management of the resources. Also, if they know the potential risk on the systems, the end-uses could participate in the realization of proactive measures (e.g. change the type of crops to be seeded in November according to the prediction on the winter period).

However, obtaining and quantifying (in a qualitative way or in monetary terms) the potential economic benefit of using SCF for the abovementioned end-users is a task very difficult to undertake for the following reasons:

- Difficulty to quantify how many end-users would be affected by improved management of resources. For example, it is hard to estimate how many hectares of land could benefit from economic benefits in terms of crop decisions (i.e. decisions like “when to sow”, “what type of seed to choose”, etc.).
- Difficult to know accurately in what way/ to what extent those end-users would be affected by improved management of resources. For example, in the case of a tourism operator which offers different activities in a reservoir (i.e. sailing,

fishing, camping, etc.) and hence its benefits are directly affected by water availability, it is possible that despite of having information about future water availability, it could have low margin of manoeuvre (perhaps due to legal or economic factors that cannot be known a priori).

The best solution would be interviewing each potential end-user about their expected economic benefits based on the possibility to take better decisions. However, this solution would be an extremely time and resource-consuming task.

An alternative solution could be gathering information about past climate impact costs (drought and flood) in terms of economic losses in agriculture, losses in hydropower production, decreases in number of customers in tourism activities, etc.). In other words, economic costs associated to “bad decisions” in the past. A research about this issue was undertaken, and is presented in sections “Calculation of the benefits” and “Climate impacts costs”. However, the little information found corresponds to river basin level, instead of Cuerda del Pozo reservoir level. Therefore, a strong hypothesis should be done, and estimate what amount of costs can be associated to the reservoir level.

The impact of SCF in the decision-making

As mentioned above, the Reservoir Releases Commission is one of the most important governance organisms. Some of the decisions it takes are summarised in Table 10, and they can be potentially impacted by seasonal forecasts as follows:

1. Minimum safeguards in December, January, February, March and April. The main influence that seasonal forecasts can have on this decision is that if the forecasts indicate a higher risk than normal to have flooding, these safeguards can be increased.
2. Minimum discharge from October to April. A relevant influence that seasonal forecasts can have is that if drought risk is forecasted, the minimum discharge

should be the drought minimum ecological flow (to preserve water for irrigation).

3. Maximum discharge from October to April (in normal state). An important impact of seasonal forecasts in this case is that if flood is forecasted, the maximum discharge could be increased preventively (and hence this could avoid emergency meeting to increase it).
4. Minimum volume in dam by the end of September (Decided in March). A relevant impact of seasonal forecasts on this decision is that if low precipitation is forecasted during summer, this target minimum volume can be adjusted. In the same way, if high or low precipitations are forecasted during autumn, this decision can also be adjusted.
5. Irrigation period beyond September. The impact of seasonal forecasts on this decision depends mostly on the condition before March (current planting) but it could be adjusted according to the impacts of future conditions on the plant growth and hydric needs.

It is worth mentioning that not all these decisions can be modified easily, as the decision making processes are complex and involve many actors beyond the Reservoir Releases Commission.

Additionally, more decision could be impacted besides the mentioned ones, i.e. users of water (irrigation, hydropower) – linked to the more general decisions of the Dam Commission (those users have votes in the Dam commission).

With the application of the methodology, and especially with the implementation of the 4th step “Simulations: update of DMP”, after having meetings with stakeholders, the particular decisions that can be upgraded are identified and the potential benefits that they could bring are assessed.

5.5.3. Applying the methodology

The implementation of the methodology followed the steps described above including:

1. Potential added-value of the forecast: evaluation of the skill score In this case study, this part is managed by the AEMET (presentation of ROC scores to end-users, etc.).

2. Potential benefits of using Seasonal Forecast

This step consists in analyzing past information, discuss with stakeholders about the usefulness of the forecast taking as reference some past events (e.g. If you have the information on future inflow for the period DJF, what decision seems more reasonable to be taken on the 1st of December?" Figure 23 below), evaluate the possible changes in decision making (e.g. "How can you update this particular decision according to the forecast?).

Year	Inflow Observed DJF Category	Dam reserve Observed 1st Dicember
1973	NN	32
1974	BN	43
1975	BN	49
1976*	AN	71
1977	AN	151
1978	AN	131
1979	NN	119
1980*	BN	105
1981	AN	105
1982	NN	70
1983	NN	43
1984	AN	155
1985	NN	107
1986	BN	82
1987	AN	64
1988	BN	127
1989	NN	70
1990	BN	49

LEGEND

Inflow - Observation

Tercile limits calculated using 1950-2011

- Dry trimester
- Normal trimester
- Wet trimester

Dam Reserve - Observation

Thresholds from the Drought Plan of 2007, based on the % of filling of the dam compared to average values (period 1973-2010)

- Reserve > 50% (Normal Situation)
- 50% ≥ Reserve > 30% (Prealert situation)
- 30%≥ Reserve > 10% (Alert situation)
- 10% ≥ Reserve (Emergency)

Figure 23 - Scenario of perfect forecast for La Cuerda del Pozo

(NN = Near Normal, BN = Below Normal or dry, AN = Above Normal or wet)

As an example, the rules of management corresponding to drought situation (Table 4) could be delayed or anticipated thanks to the forecasts (Table 3):

- When in Alert situation, the actions to be implemented could be made stricter (if low flow forecasted) or more relaxed (if high flow forecasted);
- When in Normal situation, the actions to be implemented could be made stricter (if low flow forecasted) or an adjustment could be done to use more water for hydroelectricity or other uses (if high flow forecasted).

Table 11 - Base scenario for La Cuerda del Pozo decision-making process

Seasonal inflow forecast (DJF)	Reserve in the Dam (1st of December)				
	Extremely Low (Emergency)	Very Low (Alert)	Low (Prealert)	Normal	Wet
Low (dry or BN)	Drought emergency	Drought emergency	Drought pre-alert	Normal	Flood control
Normal (NN)	Drought emergency	Drought alert	Drought pre-alert	Normal	Flood control
High (wet or AN)	Drought alert	Drought pre-alert	Drought pre-alert	Normal	Flood control

Table 12 - Possible change in decision making for La Cuerda del Pozo decision-making process

Seasonal inflow forecast (DJF)	Reserve in the Dam (1st of December)				
	Extremely Low (Emergency)	Very Low (Alert)	Low (Prealert)	Normal	Wet
Low (dry or BN)	Drought emergency	Drought emergency	Drought alert	Drought pre-alert	Normal
Normal (NN)	Drought emergency	Drought alert	Drought pre-alert	Normal	Increase industrial use
High (wet or AN)	Drought alert	Drought pre-alert	Normal	Increase industrial use	Flood control

In our case study, six decisions have been defined and evaluated in a workshop conducted in October 2015:

1. Commission October Minimum discharge from October to April
2. Commission October Maximum discharge from October to April (in normal state)
3. Commission October: Minimum safeguards in December, January, February, March and April
4. Commission March: Allocation of reserve in the next months
5. Commission March: Minimum volume in dam by the end of September
6. Commission March: Irrigation period beyond September

For each of these decisions the potential integration of the forecast have been commented.

Table 13 - Possible change in decision making for La Cuerda del Pozo

Decision	Potential integration
1	Necessary to extent forecast to the drought indicators used (precipitation and river discharge) and already pre-defined in the legal document (drought management plan). Need to get approval of Ministry.
2	Not a priority
3	Some small changes could be done. Decision depends on the Dam Commission
4	Might need forecast at an early stage for the seeding plan (September/October) then other organisms should be involved to predict irrigation water demand (such as the National irrigation association and corresponding administration)
5	Not identified as priority – not discussed further
6	Not identified as priority – not discussed further

As shown in the table, the decision making processes are complex and involved many actors beyond the dam commission. The modification of minimum safeguards in December, January, February, March and April are the only decision that is directly governed by on the commission.

Simulations: comparison of risk using forecast and climatology

This step consists in discussing the results of two sets of simulations (these simulations are done with the software SIMRISK based on a simple representation of the water system – this is explained in details in the deliverable of WP23 and D41.2 of WP41. As a result, it is possible to get the potential risks that could be forecasted at 1st of December considering either climatology or forecast.

As an example, for the year 1976, the reserve are low at 1st of December (71hm3) but since the seasonal forecast indicates a wet winter (48%probability being in the wet tercile) the resulting risk is low (e.g. only a 13% probability of having less than 70hm3 in reserve at 1st of October). By using the climatology, the risk calculated is much higher (e.g. probability of 39% of having less than 70hm3 at 1st of October). Due to this perception of a high risk is it very likely that the decisions on the dam management have not been optimum: we can see from the historic time series that the dam outflows at the beginning of winter (December and January) have been zero (very likely impacting on the environment) and that a very high release have been necessary in March (very likely to avoid flooding).

FORECAST

Using each TS probability (complete forecast)

Year	Inflow				Dam reserve				Demand deficit
	Seasonal Forecast (Dic-Jan-Feb)			Observed DJF	Observed	Forecasted 1st Octuber		Forecasted. 1st March	Forecasted 1st Octuber
	% BN (Dry)	% NN	% AN (Wet)	Category	1st Dicember	Proba < 30Hm3	Proba < 70 hm3	>98% Vol max	Fallo>5%
1976	9	43	[illegible]	AN	71	3%	13%	42%	3%
1980	41	37	22	BN	105	7%	25%	8%	7%
2007	41	39	20	BN	132	0%	12%	18%	0%
2009	20	37	[illegible]	AN	147	0%	0%	59%	0%

Using climatology

Year	Inflow				Dam reserve				Demand deficit
	Climatology			Observed DJF	Observed	Forecasted 1st Octuber		Forecasted. 1st March	Forecasted 1st Octuber
	% BN (Dry)	% NN	% AN (Wet)	Category	1st Dicember	Proba < 30Hm3	Proba < 70 hm3	>98% Vol max	Fallo>5%
1976	33	33	33	AN	71	13%	[illegible]	18%	13%
1980	33	33	33	BN	105	5%	18%	20%	5%
2007	33	33	33	BN	132	0%	8%	33%	0%
2009	33	33	33	AN	147	0%	0%	41%	0%

OBSERVATION

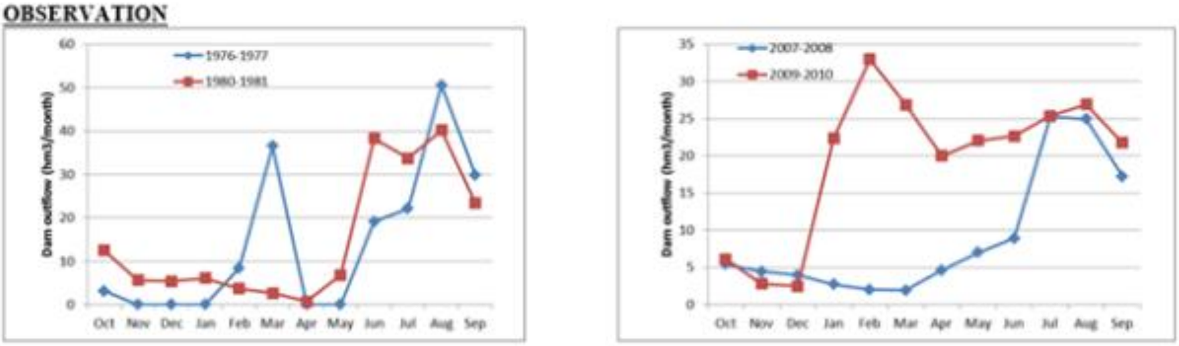

Figure 24 - Comparison of simulations with climatology and forecast

Simulations: update of decision-making processes

The next step consists in realizing the same simulations as above but considering updated decision rules. Accordingly, the level of risk simulated with the forecast should be reduce significantly and the level of risk simulated with the climatology should be either reduce (then we have a win-win update of decision) or increase (in this case, if the forecast is wrong, the update could have negative impacts).

As explained above, and for the Cuerda del Pozo, the only DMP of the Dam Commission that could be impacted by the inflow forecast is the modification of minimum safeguards in December, January, February, March and April. In the examples shown above, the change could have benefit in the management of the high flows that have occurred in 2009: Still the current model used (Water management model based on SIMRISK) is not adapted to simulate flood management option. Other potential benefits of the forecast would be the better management of the water scarcity events (but the changes in the DMP would require additional information and authorization).

Calculating the benefits

In the context of the Cuerda del Pozo, the avoided cost methodology is suitable to estimate the benefits of applying the S-Climaware. Still, an exhaustive application was not possible since the impact of modified DMP according to the forecast could not be simulated.

Avoided costs methodology is a socio-economic benefits valuation commonly used. It consists of assessing the avoided costs of weather or climate events due to improved forecasts. Benefits can be expressed as reductions of expenditures; reduction of evacuation costs; lives saved; avoided morbidity impacts, etc.

Some examples of studies that have calculated the avoided costs associated with the use of met/hydro services:

Considine et al. (2004) assessed the value of hurricane forecast information for oil and gas producers in the Gulf of Mexico. The authors found a benefit of 8.1 US$ annually in terms of avoided costs.

Frei et al. (2014) evaluated the avoided costs in the transport sector in Switzerland due to improved weather services, and they obtained 56.1 million US$ to 60.1 million US$ in avoided governmental spending.

5.5.4. Stakeholders' engagement

The stakeholders of the S-Climaware were very involved in the project development through regular meetings (involving Ministry, AEMET and all the River basin agencies involved as well as the Polytechnic University of Valencia) and workshops (on line workshop beginning of 2016 and workshop in October 2015).

5.5.5. Results and discussion

Climate impacts costs

Cuerda del Pozo reservoir has been affected by several droughts and floods which have caused substantial damages to its users. In the following sub-sections, several examples of drought and flood economic costs are provided. These numbers give a first idea on the potential benefits that the application of seasonal forecast could have in the river basin (avoided cost would be a % of the impact costs presented below). Still, an exhaustive application was not possible since the impact of modified DMP according to the forecast could not be simulated.

Drought Costs

During the last years, several droughts have affected the Douro Hydrographic Confederation, being the most remarkable ones, the 2001-2002; 2004-2005; 2005-2006; and 2012 drought episodes.

Unfortunately, no information was found about drought costs directly related with Cuerda del Pozo reservoir. However, some information related with drought costs and investments done for coping with the 2004-2005 drought episode was found for the Douro river basin.

During the summer 2005, some **problems of water supply** emerged:

- In the area irrigated by canal San José, **600 hectares of corn** were lost.
- In Salamanca and Zamora, serious problems of urban water supply emerged, where nearly **4,000 inhabitants** had to get water from water tankers.
- Additionally, certain problems about water quality also arisen. For example, in Sanchonuño (Segovia) faced problems of **arsenic in water**.

Some of the **measures taken** are summarised next:

- The Governing Council of Castile-Leon and the Council of Zamora planned to invest **300,000 €** during 2005-2006 for granting the urban water supply.
- The Ministry of the Environment invested **150,000 €** in boreholes in groundwater.
- Agricultural insurance policies increased. For example, the region of Cerrato lost more than **40% of its cereal crop**.
- The Governing Council invested **920,000 €** in boreholes in groundwater, so the Valdivia irrigation association and the inhabitants from Revilla, Pomar, Villarén and Porquera had enough water.

Finally, the drought caused the **hydropower production** to be **halved** in comparison with the previous year, and of the order of **55%** in relation to the average production of the last 10 years (Figure 25).

PRODUCCIÓN HIDROELÉCTRICA POR CUENCAS HIDROGRÁFICAS. GWH. 2003-2008

Cuenca	2003	2004	2005	2006	2007	2008	Total GWH	2003-2008 (%)
Norte	10.564	8.038	5.824	9.526	8.672	7.042	49.666	31,0
Duero	11.094	7.569	3.958	5.979	7.965	4.951	41.516	25,9
Ebro-Pirineo	8.559	7.616	5.301	5.054	5.218	5.847	37.595	23,5
Tajo-Júcar-Segura	7.258	5.112	2.086	3.850	3.853	2.870	25.029	15,6
Guadalquivir-Sur	1.259	1.278	1.123	825	565	612	5.662	3,5
Guadiana	139	164	158	97	78	106	742	0,5
Total	38.873	29.777	18.450	25.331	26.351	21.428	160.210	100

Fuente: Red Eléctrica de España.

Figure 25 – Hydroelectric production per hydrographic basins between 2003-2008

Flood Costs

No information has been found on flooding costs link to Cuerda del Pozo. In 2009, flood event is reported upstream the dam but not downstream. On the 13th and 14th

February 2016, heavy rains caused a rise in the Cuerda del Pozo reservoir level, and Douro Hydrographic Confederation decided to release more than 100 cubic meters per second (being the average daily release lower than 10 cubic meters). As a consequence, the Douro River overflowed during its passage through Soria and caused several damages along the river banks.

According to the Mayor of Soria, the direct damages caused by the river overflow counted for **117,000 €**.

5.5.6. Lessons learned

The case study of the S-Climaware brings information on the potential added-value of forecast, but also on the limitations and barriers in the update of decision making according to seasonal forecast. The methodology developed has been applied and the first three steps completed, namely the 1/ Potential added-value of the forecast: evaluation of the skill score, 2/Potential benefits of using Seasonal Forecast and 3/ Simulations: comparison of risks using forecast and climatology. Still, it was not possible to complete the two last steps of the methodology (4/ Simulations: update of DMP and 5/ Calculation of the benefits) for the following reasons: 1) The update of the decision making process would require more information than the one provided by the S-Climaware (e.g. forecast of all the drought indicators, forecast of water demand). 2) The update of the decision making process would require legal modification and approval at a upper level (e.g. ecological flow). 3) The simulation of potential impact of change in decision making process will require another modelling approach (e.g. flood modeling). 4) Based on these results, the stakeholders and the project partners involved in the S-Climaware have decided to apply the methodology developed in another case study more suitable (where both decision making process and physical processes can be simulated).

5.6. Impact analysis and the CMTool case study

Climate change is a growing concern to public health due to increasing global effects such as extreme weather events, food security, and change in pattern of vector diseases (Wolf et al. 2014; Matthies et al. 2008). However, excessive climate-driven vector-borne mortality and morbidity can be reduced with appropriate adaptation measures. For this study, we focused on climate-driven mortality attributable to heat-waves.

The World Health Organization (WHO) defines a heat-wave as "a prolonged period when maximum apparent temperature (T_{max}) and minimum temperature (T_{min}) are over the 90th percentile of the monthly distribution for at least two days" (Matthies et al. 2008). To prevent the temperature-related mortality, the WHO Regional Office for Europe has urged its Member States to develop and implement heat–health action plans (HHAPs) (Matthies et al. 2008).

A previous study (Bittner et al. 2013) found that only 18 out of 53 WHO European Member States had developed HHAPs; even among those with HHAPs, most of them were not prepared with evaluation methodology to assess the effectiveness of implementation of the plans. Another study presented a climate model for mortality prediction for sub-seasonal-to-seasonal climate forecasts, illustrating a potential climate service that could be incorporated into HHAPs, as well as the possibility of other entry points into the plans (Lowe et al. 2015; Lowe et al. 2016).

5.6.1. The survey methodology

As a part of the EUPORIAS project, this study assessed the evaluation process and the entry points of meteorological information from climate services feeding into HHAPs. We assessed the possible entry points of seasonal-to-decadal (S2D) climate forecasts into decision-making processes of HHAPs. The Global Framework for Climate Services (GFCS) defines that "climate services provide climate information to assist decision-making by individuals and organizations". Such services involve high-quality meteorological data, as well as long-term projections and scenarios. Depending on the user's needs, data and information products may be combined with non-meteorological data. On top of the GFCS definition of climate services, the scope of S2D timescale in the context of the EUPORIAS project is "from a month up to 10 years into the future" (Dessai & Soares 2015).

For the purpose of this study, we are assessing the impact of a health-related climate service on a decision-making process. The climate service under study is a temperature-related multi-lead time climate-mortality prediction tool (CMTool) and the relevant decision-making process is defined as being a national or regional heat–health action plan (HHAP). For the purpose of this investigation, we assume a seasonal climate forecast (SCF) with a three-month lead time.

The purpose of this study is to (a) study the potential impact that climate services could have on decision-making processes for health, for the EUPORIAS project (Dessai & Soares 2015), (b) undertake a follow-up to the 2013 study (Bittner et al. 2013) on HHAPs in Europe, and (c) collect data to review development of HHAPs in the Member States for WHO European Region.

For this study, three research questions were formulated.

1. How could this climate service influence the core elements of preparation of the heat–health action plan decision-making process;
    1. If 3-month (seasonal) lead information were available on intensity/duration/frequency of heat-waves, how would it affect the preparatory elements of HHAP?
    2. Are there any pre-season meetings or formal discussion, and if so, who is involved? Could a climate service provide input to those meetings?
2. How could this climate service influence the monitoring and evaluation core element of the HHAP, and thus influence a review process of the plan;

   a. Are there any post-season meetings or formal discussion, and if so, who is involved? How could the climate service provide input to those meetings?

3. What other entry points are there for other possible health-related climate services;

   a. With subseasonal to seasonal prediction on intensity/duration/frequency of heat-waves up to 3 months: what can be done for shorter-term measures?
   b. With regional climate modelling up to 10 years, how can this influence medium-term measures such as reduction in indoor heat exposure, and have advisory roles to health sectors for longer-term measures such as long-term urban planning?

A 20-question survey was developed to undertake the review of heat–health action plans (HHAPs) in the European Region.

Some questions were to support a WHO review of implementation status of HHAPs in the European Region and to have an internal record. They allow for a follow-up of the topic with a better evidence-base.

The total estimated time to complete the survey was 10–20 minutes. The participants were the representatives of organizations and Member States who were participants of the European Working Group on Health in Climate Change (HIC) meeting of the European Environment and Health Task Force (EHTF).

Prior to sending out the questionnaire, it was tested by experts external to the project, who were asked to provide feedback on the questionnaire for validation. The questionnaire was sent via email in English to all nominated HIC members in June 2016. An explanation and a link to the survey were emailed to participants, a reminder was given at the HIC meeting, and an additional reminder was sent via email. The deadline for responses was 9 July, 2016. Some representatives were also followed up personally for additional responses.

5.6.2. The CMTool case study

Climate change is a growing concern to public health due to increasing global effects such as extreme weather events, food security, and change in pattern of vector diseases (Wolf et al. 2014; Matthies et al. 2008). However, excessive climate-driven vector-borne mortality and morbidity can be reduced with appropriate adaptation measures. For this study, we focused on climate-driven mortality attributable to heat-waves.

The World Health Organization (WHO) defines a heat-wave as "a prolonged period when maximum apparent temperature (T_{max}) and minimum temperature (T_{min}) are over the 90th percentile of the monthly distribution for at least two days" (Matthies et al. 2008). To prevent the temperature-related mortality, the WHO Regional Office for Europe has urged its Member States to develop and implement heat–health action plans (HHAPs) (Matthies et al. 2008).

The CMTool is a prototype case study of a climate-driven mortality model to provide probabilistic predictions of exceeding emergency mortality thresholds for heat-wave and cold spell scenarios. The predictions are based on temperature forecasts (1–3 months ahead) to support decision making for the preparedness of health services and protection of vulnerable communities ahead of future extreme temperature events.

Within the broader perspective of the Global Framework for Climate Services (GFCS), WHO and the World Meteorological Organization (WMO) have been working together to foster the development of climate services to protect health, one of the five priority areas of the GFCS. This WHO–WMO collaboration, together with engagement of their Member States shares the common with EUPORIAS aim to bridge the gap between available climate information and public health concerns. The CMTOOL prototype case study illustrates such a potential for climate service application in Europe.

To formulate the model, daily mortality data corresponding to 187 regions across 16 countries in Europe were obtained from 1998–2003. Data were aggregated to 54 larger regions in Europe, defined according to similarities in population structure and climate. Location-specific average mortality rates, at given temperature intervals over the time period, were modelled to account for the increased mortality observed during both high and low temperature extremes and differing comfort temperatures between regions. Model parameters are estimated in a Bayesian framework, in order to generate probabilistic simulations of mortality across Europe for time periods of interest.

By replacing observed temperature data in the model with forecast temperature from state-of-the-art European forecasting systems, which are being developed in the EUPORIAS project, probabilistic mortality predictions could potentially be made several months ahead of imminent heat waves and cold spells.

The decision-making context

The relevant decision-making context is defined as being a national or regional heat–health action plan (HHAP). For the purpose of this investigation, we assume a seasonal climate forecast (SCF) with a three-month lead time. Another potential decision-making context could be national or regional cold weather plans (CWPs), but these were not included in this study.

Heat–health action plans can be evaluated based on inclusion of nine core elements (Bittner et al., 2014, McGregor et al., 2015, Matthies et al., 2008).

1. Agreement on a lead body and clear definition of actors' responsibilities
2. Accurate and timely alert systems, heat–health warning systems
3. Health information plan
4. Reduction in indoor heat exposure
5. Particular care for vulnerable groups
6. Preparedness of the health/social care system
7. Long-term urban planning
8. Real-time surveillance
9. Monitoring and evaluation

The value of SCF in the decision-making

Defining a potential economic and/or non-economic benefit of using seasonal forecasts is very difficult and is ultimately beyond the scope of this study. Potential non-economic benefits, and thus the value of a SCF could be measured in lives saved, that is the decrease in mortality resulting from using a SCF as opposed to not using such a forecast.

From the perspective of the health system, an increase in demand for primary health care induced by a heat wave is only one of many factors stressing the system. The extent of the heat wave impact on the health system is strongly related to its basic capacity (resilience) to handle variabilities in demand (e.g. hospital admissions) and can additionally be stressed or challenged due to limitations of the basic infrastructure or the occurrence of multiple stressors at once. Another critical situation arises when health service facilities fail or capacities and resources get exhausted due to intense or long-lasting heat waves. Thus, more efficient health system planning and resource management, and longer-term climate-resilient investments could present an economic value of SCF in heat–health decision-making.

Furthermore, a successful and effective heat–health action plan or cold weather plan has the potential to reduce temperature-related morbidity, which would have a knock on economic value in decreased health care costs, and potentially increased productivity of the workforce.

The impact of SCF in the decision-making

Better information on future extreme temperature related mortality will support public health agencies in making better decisions on health care provisions and therefore help to justify the additional resources involved (medical staff, beds) and avoid unnecessary loss of human life.

The decision making process begins several months ahead of the target season. Seasonal forecasts from the climate information provider are collated. These forecasts are then processed and used within the mortality model to generate excess mortality forecasts. These probabilistic mortality forecasts are then transferred to the users.

Although there is a large amount of uncertainty in long-lead seasonal climate forecasts for Europe, these preliminary mortality forecasts can be used to take initial decisions. For example, allocating the necessary resources to prepare for any anticipated heat waves or cold spells while considering other contextual information. Just before the target season, additional, shorter range, sub-seasonal forecasts are used to refine the mortality forecasts and considered with updated contextual information. Finally, localised action plans are implemented ahead and during the heat-wave/cold spell events, to protect vulnerable sectors of society.

As such, a HHAP can be divided into four major phases: preparation, activation, implementation and evaluation. Theoretical entry points of climate services in the HHAP can be medium-term (seasonal) climate projections at the preparatory phase, shorter-term forecasts on the duration and intensity information of heat-waves at the activation and implementation phases, and longer-term climate projections to be incorporated into the evaluation phase. As we are focusing on possible parts where seasonal climate services can be incorporated into HHAPs, this is more applicable to the preparatory phase, rather than activation and implementation, which is triggered by short-term weather forecasts or warnings. Also, another purpose of this study is to assess any existing monitoring and evaluation mechanism, which could potentially be used to review and revise the HHAPs based on longer-term climate information.

5.6.3. Applying the methodology

Questionnaires were administered and collected through focal points in each Member State. Each focal point had the opportunity to consult and share the questionnaire with the various responsible departments or ministries or with the responsible federal ministries in countries that have federal systems.

Questions 1 and 2 asked which country each participant represented and which sector best represented their area of work. Questions 3–5 collect general information on HHAPs and whether the Member States of participants had an action plan at a national, regional, and/or local level. Questions 6–8 were devised to enable us to assess these plans and to find out if core elements of a HHAP are present and where the activation signal or alert for the HHAPs comes from.

Questions 9–13 regard the pre-season and answer research question 1, while questions 14–17 related to the post-season evaluation to answer research question 2. Question 17 was specifically asked in order to assess the impact of climate services on the revision process. Questions 18 and 19 were asked in order to answer research question 3, to provide insight into possible entry points for other possible health-related climate services and to determine how different lead times for climate services would influence decision-making. The final question asked for additional comments. To formulate potential health-related climate variables for question 18, health impacts of climatic variability and change were drawn out from the Health Exemplar to the User Interface Platform of the Global Framework for Climate Services (World Meteorological Organization 2014).

5.6.4. Stakeholders' engagement

The participants were the representatives of organizations and Member States who were participants of the European Working Group on Health in Climate Change (HIC) of the European Environment and Health Task Force (EHTF). The Working Group on Climate Change and Health operates within the EHTF, the body leading the implementation and monitoring of the European Environment and Health Process (EHP).

Membership of the HIC is open to nominations from all 53 Member States in the WHO European Region and all organizations and institutions that are members of EHTF.

A total of 19 participants responded to the questionnaire. Some participants did not answer all questions; therefore, the response rate is different for each question.

Although in some cases there are multiple participants from the same country, however they represent different HHAPs at a subnational level.

The participants were from Azerbaijan, Belarus, Belgium, Croatia, Denmark, France, Germany, Kyrgyzstan, Lithuania, Malta, Montenegro, Serbia, and Switzerland. This is a good representative geographical sample of the broad WHO European Region, which includes central Asia. Of 18 participants, 4 were in the environmental sector and the remaining 14 participants represented the health sector.

5.6.5. Results and discussion

For the use of climate services in relation to the prevention of adverse health outcomes of temperature, 17 participants were aware of climate services used to prevent temperature-related health impacts. Six participants from 5 countries (Kyrgyzstan, Belarus, Azerbaijan, Serbia, and Montenegro) did not have a HHAP. Most countries had regional plans, with some having national or local plans as well.

Six participants confirmed that their HHAPs consider climate change projections. National plans tend to have more core elements of HHAPs, as stated in the Heat–Health Action Plans guidance (Matthies et al. 2008), than lower-level plans. Among the core elements, 'reduction in indoor heat exposure', 'long-term urban planning', and 'real-time surveillance' appear to be lacking in most of the HHAPs. All the activation signals or alerts for the HHAPs studied come from national weather services of participants' countries. For the pre-season preparation, meetings of lead bodies with electronic circulars accounted for a three-quarters of the responses, with only a quarter holding workshops involving stakeholders. One respondent held their pre-season preparation in January, but for all others it was held in the period March–May. All participants noted that local health authorities are involved as partners in preparation, as well as ministries of health and national institutes of public health, which play key roles. Four participants additionally noted that their HHAPs also included national meteorological services.

The participants considered a seasonal climate forecast influential for all the sub-elements in the preparatory discussion and considered 'particular care for vulnerable groups' and 'communication and dissemination of public health information' particularly influential. It was noted that seasonal projections are usually used in the pre-season preparation to raise the awareness and interest of decision-makers, health care providers, and stakeholders and to build and strengthen public health capacity. In the case of France, the action plan is revised and published every year, and activated before and beyond summer if needed, regardless of the seasonal forecast. Northern regions or countries (e.g. Denmark, northern Germany) did not find seasonal projections very influential or important for pre-season preparation.

Only five participants conduct post-season evaluation. They are mainly completed in September and October through meetings of lead actors and are complemented with additional methods of information dissemination such as electronic circulars. However, one respondent noted that an evaluation is done only when heat-waves occur. The main partners of post-season evaluation are ministries of health, national institutes of public health, and local health authorities, along with ministries of environment and national meteorological services. In addition to these, partners who are involved in pre-season preparation, science, education, sport, and civil protection government sectors are involved in post-season evaluation. Only two responses confirmed that this evaluation fits into an annual process of revising the HHAP.

The participants found that the suggested climate services are useful, particularly 'impact on mortality of thermal stress from heat events', 'temperature effects on food- and water-borne diseases', and 'direct injury/drowning and bites during flooding and storm events'. In terms of lead times on seasonal-to-decadal climate projections, the participants found 3–6 months (seasonal) lead times to be the most useful.

5.6.6. Lessons learned

Participants who had a seasonal climate forecast on health-related mortality available during the preparatory phase of their heat–health action plans all considered a seasonal climate forecast to be influential on all sub-elements of preparation, and thus the SCF having a significant potential *impact* on decision-making. This was strongly the case for 'particular care for vulnerable groups', who are by definition more susceptible to temperature-related mortality and morbidity and who thereby place a greater burden on health systems, thus making a case for the *value* of a SCF. Another highly influential sub-element was ‘communication and dissemination of public health information’, which could potentially be the most effective measure to improve personal practice of prevention and induce behavioural changes that would further reduce the health impacts of heat-waves.

It is unsurprising that shorter lead time climate forecasts would be considered more favourable for the health sector and would have a greater effect on decision-making regarding preparation. This is largely due to the fact that currently no mechanisms exist to take longer lead time into consideration for long-term adaptation measures. This is also highlighted by the need to strengthen monitoring and evaluation as a core element of heat–health action plans, to feed into a multi-annual iterative review of HHAP performance, and thus present and opportunity for incorporating SCFs into preparation and planning for the health sector.

The main limitations of this investigation are small sample size and low response rate. Not all participants of the HIC Working Group contacted were able to participate in the survey due to various reasons. Moreover, there were fewer responses to questions related to existing HHAPs as some countries surveyed did not have them. Therefore, the results may be biased towards those who have, or are aware of, HHAPs.

These limitations call for further study to increase sample size by raising the interests that are more applicable to their countries or geo-climatic contexts. There is a need to tailor the survey more specifically to countries and regions with existing heat-health action plans. Furthermore, further validation of European heat–health action plans is necessary as very limited studies on the *value* of heat-health action plans exist.

6. Lessons Learnt

- **BSC:** Skill scores require a longer training period for those users that are not familiar with probabilistic scores, instead, translating this scores to economic concepts widely used has a potential to improve the understanding of the value of seasonal predictions over climatology. However, there is a gap between the technical analysts that foresee a future potential for seasonal predictions and the actual decision-makers in the energy companies. To observe a real impact of SCF on DMPs in the energy sector an internal process with a long period of testing of the operational seasonal predictions is needed so that companies can make their internal benchmarking of the two methods (SCF vs. climatology) and present the results to the actual decision-makers.

  However, there is a gap between the technical analysts that foresee a future potential for seasonal predictions and the actual decision-makers in the energy companies. There are multiple types of energy companies such as O&M, wind farm operators, grid operators or energy trading companies. Moreover, within those companies, there are different user profiles ranging from climate analysts, technical engineers to financial teams. Even in those companies that have already stated an open interest in the RESILIENCE prototype (e.g. EnBW, EDPR or Iberdrola), all the contact points have remarked: i) the need for an internal process to adopt changes in decision-making, and ii) the need of operational predictions for a long period, so that they can make their internal benchmarking of the two methods and present the results to the actual decision-makers.

- **University of Leeds:** In the context of this study, the complexity of the land management decisions including the influence of weather, climate and other socio-economic factors as well as the existence (or not) of options available for taking different decision paths required an in depth qualitative analysis in order to allow us to understand the mental models of decision-making used by the farmers involved in the Land Management Tool prototype and the potential value/benefit that SCF can have in supporting those decisions. The potential of SCF to influence and inform DMP regarding farming activities was recognized. However, given the novelty of the forecasts and the complexity and volatility of the decisions that farmers face further research is required to fully understand for example the common entry points for using SCF in those DMP as well as allow farmers more time to get used to the probabilistic nature of SCF and allow them to learn how to fine tune and translate that information in terms of what happens in their land and how it can be applied to support their farming activities. Another lesson learned was the need for further research for developing methodologies capable of addressing the complexity of real decision-making in the farming sector as currently there is a clear gap in this regard.

The farmers involved in the analysis were interested in continuing the study including expanding the provision of SCF to other seasons (although this would raise the issue of the SCF skill in that region outside winter months). A follow-up from this analysis would allow a better understanding of the barriers and enablers to the use of SCF in farming DMP in other farming enterprises and/or other seasons as well as allow the farmers to continuing learning more about SCF and how it could be use in their DMP. Only by continuing this work would be possible to determine the value that SCF can have in farming decisions.

- **Metéo-France**: The estimation of the CS value onto DMP is an essential step for adapting stakeholders' practices by taking account CI that relies both on strong DMP knowledge of end users and on listening ability of scientists for tailoring specific products. The decision redo of numerous past situations by stakeholders is essential to correctly evaluate probabilistic forecasts but necessitate to be able to spend significant time to do it. The RIFF evaluation by Placebo concept (2 scenarios plus current practice) with 29 years replayed and two different dates of SF initialisation has necessitated several end users work days for the simulation of only one dam.

The user feedbacks from the Placebo experiment have shown the interest of such approach to a better understanding of the operational performance of the prototype but also to identify the weaknesses of the current practices.

- **WFP:** By carrying out the Cost Benefit Analysis for the LEAP prototype it has become evident that a similar research on the value/benefits that a SCF could have in a specific sector/system is seminal to motivate stakeholder towards its practical application and introduction. Despite the fact that the LEAP SCF has still not been officially accepted by the Government of Ethiopia as part of the national early warning system, the existence of a clear economic case for its introduction will play a key role in the future discussions on this topic in the coming months.

- **CETAQUA:** The case study of S-Climaware brings information on the potential added-value of forecast, but also on the limitations and barriers in the update of decision making according to seasonal forecast. The methodology developed to determine the impact and the value of the S-Climaware consists in different steps, namely the evaluation of the skill score, an overview analysis to identify the potential benefits of using the forecast, a more detailed analysis using simulation results and comparing potential risks using forecast and climatology and finally an implementation of the avoided cost methodology. It was not possible to fully complete the last two steps of the methodology since the update of the decision making process would require some significant changes and more information than the one provided by the S-Climaware only. Accordingly, the potential of the S-Climaware to avoid impacts (e.g. drought and flood impacts) and associated costs cannot be determined in the site tested (but other sites might be more adapted to perform all the steps of the methodology).

- **WHO:** One of the main challenges in assessing the impact of a SCF on a health-related decision-making is the unfamiliarity of the health sector. This study focused on the hypothetical example of a heat-related seasonal mortality forecast, for which there is currently no entry point for such information to feed into an existing heat–health action plan. Furthermore, it is virtually impossible to assess the potential *value* of a SCF on a HHAP without further studies into the effectiveness of HHAPs and their interventions.

7. Links Built

- Close interaction with all deliverables of **WP41** by using a common structure for describing evaluation methods and results of each partner.
- Close interactions with **WP42** (and D42.2 outputs) for common user feedback on prototype performance assessments; **WP21** (CETAQUA and MF in particular) aiming to develop a modelling framework for seasonal prediction (calibration and downscaling) as input of water management model; and finally, with **WP45** and the analysis of the potential business opportunities in different sectors.
- The two experiments carried out in the water sector of dam management in Spain (**S-CLIMWARE case study**) and France (**RIFF prototype**) have arisen an interest to compare and analyse common impacts of CI on DMP and differences in CS implementation.
- Météo-France was also involved during the last years in a French national program called **PREMHYCE** aiming to benchmark hydrological models for

low-flow simulation and forecasting on French catchments (Nicolle et al, 2014). Five hydrological models (four lumped storage type models – Gardenia, GR6J, Mordor and Presages – and one distributed physically oriented model – SIM, used in EUPORIAS) were applied within a common evaluation framework and assessed using a common set of criteria in simulation and in forecasting modes.

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